Oculoplastic Surgery

A Practical Guide to Common Disorders

Essam A. El Toukhy
Editor

Springer

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ISBN 978-3-030-36933-0 ISBN 978-3-030-36934-7 (eBook)
https://doi.org/10.1007/978-3-030-36934-7

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

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Basics of Oculoplastic Procedures

Ahmed G. El Sharkawy, Rania A. Ahmed and Ali Odadi

Introduction

Oculoplastic surgery is the subspecialty that combines the art and principles of plastic and reconstructive surgery with the delicacy and precision of ophthalmic surgery. An oculoplastic surgeon should be aware of the principles of both worlds as well as surgical skills to get optimum cosmetic and functional results while protecting the globe and the patient's vision. This chapter will focus on these basic surgical principles.

Wound Healing

Wound healing is a natural response to tissue injury. A complex cascade of cellular and vascular events is involved to restore the tissue structure, ensure resurfacing and restoration of tensile strength of the injured skin. This process comprises mainly 3 phases that usually overlap.

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The inflammatory phase is the first response to injury where hemostasis occurs through blood vessels constriction and formation of platelets clot. Once homeostasis is achieved, the blood vessels dilate allowing inflammatory cells, antibodies and enzymes to debride the injured site, promote wound healing and fight infection. At this stage, the patient experiences the signs of inflammation such as pain, swelling, redness and hotness.

The proliferation phase is the stage where a new healthy granulation tissue appears to restore the tissue defect. This requires a good blood supply in order to provide oxygen and nutrients. Mesenchymal cells in the injured area change into fibroblasts that secrete collagen and growth factors that induce angiogenesis. Both form the granulation tissue which is the base for the scar tissue development. The granulation tissue is soft, fragile and bleeds easily. It is pinkish-red if the wound is healthy and dark or yellow in cases of poor vascular supply or infection. At this stage, epithelial cells at the wound edge proliferate, differentiate and migrate to cover the surface area.

The remodeling stage starts after 3 weeks and continues for 6–12 months. This is the stage where the final scar tissue is formed, and the wound gets mature. During this phase, the dermal tissues are overgrown to enhance their tensile strength and non-functional fibroblasts are replaced by functional ones. Cellular activity

E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_1

declines with time and the number of blood vessels in the affected area decreases.

During healing, the tensile strength of the wound gradually increases. Sutures support the wound and take some of the strain over it till the time of their removal. The presence of marked wound tension causes bad wound stretch and unsightly scar.

Scar behavior varies with age, site, skin type and the wound direction. Scars in children tend to be red for a longer period of time and they can become hypertrophic. With aging, the scar settles rapidly, and they tend to be hidden within the existing wrinkles. Suture marks are more prominent in coarse oily skin.

These factors are unavoidable and may jeopardize the outcome. However, proper surgical technique, combating infection and hematoma as well as improving the patient's general condition with special stress on avoiding smoking could provide the best possible results.

Skin incision placement

In order to gain a cosmetically accepted scar, incisions should be placed in natural lines, natural junctional lines or in areas where the scar will not be visible.

The natural creases or wrinkle lines provide a good camouflage for the placed scar. These creases occur perpendicular to the direction of muscles creating them. The upper lid crease incision and the lateral canthal crow's feet are good examples for such placements in the periocular region.

Skin incisions placed near anatomic structures such as eye lashes (in subciliary incision) and eye brow are usually less visible. However, it should be noted that in cases of the latter, the skin incision should be made parallel to the hair follicles to avoid their destruction with the result of an unsightly scar.

Wound closure

A surgical wound closure is usually preplanned to achieve the best cosmetic outcome. In presence of tension on wound edges, subdermal tissue undermining can be done to create small advancing flaps to relieve the tension. The wound edges should be everted to avoid a depressed scar after healing. Hence, sutures should be taken perpendicular to the wound line, equally distanced from the edges with equal bite depth.

However, in cases of trauma with irregular wounds, time should be invested to identify the wound main landmarks and fit the fresh parts of the tissue jigsaw. Although Z-plasty can improve the appearance of scars, its use should be deferred for subsequent scar revisions after proper evaluation.

In cases of suspected tissue defects, the viable tissues should be replaced in their correct places so that the actual defect can be properly assessed. According to the level of expertise of the surgeon, it can be primarily managed or deferred.

Suture material

Sutures' main role is to support the tissues throughout the critical period of wound healing. In oculoplastic procedures, there are used for deep closure or fixation as well as skin closure. Other skin closure techniques such as staples and tissue adhesives have no or limited role in closing wounds in the periocular region due to its thin mobile skin. The choice of the suture material depends on the surgeon's preference and experience as well as the wound condition.

Suture materials are now routinely swaged into the surgical needles and they are mainly classified into;

Absorbable or non-absorbable
Monofilament or multifilament
Natural, synthetic or metal wires.

Absorbable Sutures

They degrade naturally overtime from 5 days to 40 days. They can be left in situ yet the surgeon should consider the extent of tissue reaction induced by them. Gut (collagen), chromic gut, polyglycolic acid (Vicryl) and polycaprolate (Dexon) are common absorbable sutures used in oculoplastic surgery.

Natural absorbable sutures like collagen and chromic gut are absorbed through enzymatic degradation which is unpredictable and can affect the process of wound healing. Synthetic sutures like Polyglactin are degraded by hydrolysis which is more predictable and takes a longer period.

Non-absorbable Sutures

They are permanent sutures that need to be removed if used to close the skin. Examples include Prolene, nylon and polyester.

Monofilament Versus Polyfilament

Monofilament sutures are formed of a single strand making it easier to pass through tissues and are less organism inviting. However, they have a memory making it a bit of a challenge to handle and they can be crushed rendering them weaker. Polyprolene (Prolene) is an example of monofilament suture.

Polyfilament sutures, as the name implies, are formed of multiple filaments that are either braided or twisted. They show higher tensile strength and are easier to handle due to their pliability. They could also be coated to enhance suture knotting and reduce reactions in the tissues. These sutures may invite infection due to their increased capillarity, however, antimicrobial coated sutures are available. Silk and polyglactin are examples of polyfilament sutures.

Natural Versus Synthetic

Natural suture materials include silk, gut and chromic gut while synthetic include prolene, polyester, polyglycolic acid and polytetrafluoroethylene (Gore-Tex). Metal sutures are usually used for repair of telecanthus and certain types of fractures.

The common suture materials used in oculoplastic surgeries and their characteristics are summarized in Table 1.

Needles

Needle penetration and the subsequent suture passage induce an additional injury to the existing wound, hence affecting its healing course. Subsequently, proper needle selection is critical. The surgical needle is formed of a point, a body and a swaged end where the suture is attached. Needles vary in shape, tip and size.

Table 1 Common suture materials and their characteristics

Suture	Nature	Characteristics	Degradation	Color	Uses
Silk	Natural	Multifilament	2 years	Black	Skin closure Lid margin repair
Plain gut	Natural	Monofilament	7–10 days	Straw colored	Skin and conjunctiva closure
Chromic gut	Natural	Monofilament	2–3 weeks	Brown	Deep wound closure, tarsus closure
Nylon	Synthetic	Monofilament	Non absorbable	Black	Skin closure
Prolene	Synthetic	Monofilament	Non absorbable	Blue	Skin closure Permanent deep suturing Used in cases of potential infection
Polyglactin	Synthetic	Multifilament	3–4 weeks	Violet	Deep wounds closure, anchoring sutures, tarsus sutures
Polydioxanone (PDS)	Synthetic	Monofilament	4–6 weeks	White or violet	Deep suspension sutures
Gore-Tex	Synthetic	Monofilament	Non absorbable	White	Frontalis suspension, brow pexy
Polyester	Synthetic	Multifilament	Non absorbable	White or green	Deep permanent sutures

The body forms most of the needle length. It is the part interacting with the needle holder and is responsible for transmitting the penetrating force to the needle point. It can be either straight, curved, half curved or compound curved.

Needles used for oculoplastic surgeries are curved as they have a predictable path through the tissues and require less space for maneuvering. The curve is described as a proportion of a full circle (Fig. 1) and is available in different sizes. The 3/8 circle needles are used for general suturing purposes while the 1/2 circle needles are used for suturing in deep confined spaces such as attaching the lateral tarsal strip to the periosteum and closure of posterior flaps in external dacryocystorhinostomy.

The point is the part that extends from the tip of the needle till the maximum cross section of the body and it determines how easily sutures pass through the tissue. Cutting and taper point (round) needles (Fig. 2) can be used by the ophthalmic and oculoplastic surgeons.

Taper point or rounded needles cut only at the tip and pass through tissues by stretching without cutting thus minimizing potential tissue tearing. They are used for easily penetrated tissues and their use is limited in oculoplastic surgery but can be used to close mucosa and for temporary tarsorrhaphy.

The majority of needles used in practice are cutting needles (Fig. 2). They have at least 2 opposing cutting edges and pass through tissues by cutting. Three types are available;

(a) Conventional cutting: They have triangular cross-section that changes to a flattened body. The third cutting edge is on the inner, concave curvature (surface-seeking) and it cuts at the tip and edges. The suture pass is superficial to the needle path. However, this type of needles may pull out tissues during its passage enlarging the needle pass.

(b) Reverse cutting: They are the most commonly used. They also have a triangular cross section yet the third cutting edge is on the outer convex curvature of the needle (depth-seeking) and it also cuts at the edges and tip. The suture pass is beneath the needle path. It has less cutting out of the tissues and is usually used in oculoplastic surgery. Nevertheless, accidental perforation may occur with partial thickness suture such as rectus scleral fixation.

(c) Side cutting/spatulated: Their cross section is flattened and designed to pass in a lamellar

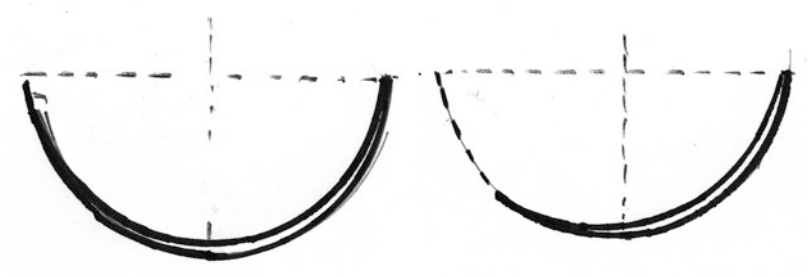

Fig. 1 ½ circle needle (Rt), 3/8 circle needle (Lt)

Fig. 2 Cut section of the needle tips. From left to right; taper (round), cutting, reverse cutting, spatulated

fashion as they cut at the tip and the sides parallel to the tissue plane. They provide easy penetration and better control while avoiding accidental perforation. They are designed for ophthalmic procedures but can be used for attaching the levator aponeurosis to the tarsal plate.

The size of the needle corresponds to the suture size and the choice depends on the type of the tissues to be sutured. For example, thick tissues with greater tension require larger sutures and needles.

Stitch craft

Skin sutures can be interrupted or continuous. Interrupted sutures allow precise wound alignment, eversion of the edges and selective suture removal when required. They are preferred in areas outside the skin lines and in irregular wounds. They can be either simple sutures, horizontal or vertical mattress.

The simple interrupted sutures (Fig. 3) are the commonly used. The wound is better divided into halves and each half is further divided into halves and so on so that the sutures are distributed over the wound. The needle should take an equal bite on each side and should include at least the entire thickness of the dermis. To achieve edge eversion, the base of the sutures should be slightly wider than the surface.

Vertical mattress sutures (Fig. 4) are used when more eversion is needed, e.g. in lid marginal wound repair. The vertical mattress suture is like a U-shaped loop with the outer limits placed deep and inner limits placed more superficial.

Horizontal mattress sutures (Fig. 5) are used for levator muscle attachment to the tarsus during ptosis surgery or if sutures are taken near the lid margin so that the knot is away from the cornea.

Fig. 3 Interrupted sutures

Fig. 4 Vertical mattress suture

Fig. 5 Horizontal mattress suture

Fig. 6 Continuous locked suture (Left), continuous non locked sutures (Right)

If there is no tension on the wound, interrupted sutures are usually enough. However, if there is tension, the use of buried absorbable sutures or continuous intradermal (subcuticular) sutures is suggested thus allowing early removal of skin sutures without fear of wound disruption.

Deep or buried sutures are also used to close any dead space to prevent hematoma, stabilize the wound and anchor muscle flaps or skin.

Subcuticular sutures can be done using a monofilament suture material to reduce wound tension and minimize leaving suture marks. Although they can be used on their own, it was found that additional interrupted sutures make the wound edge opposition more accurate.

Continuous or running sutures (Fig. 6) whether locked or not are faster to place and easier to remove. They are used to close linear wounds especially those placed in crease lines.

Management of Dog ears

They are usually created by redundant tissue at the end of the incision. They can be due to unequal incision length or incisions that are joined at an acute angle. If not removed, they tend to remain prominent and affect the overall appearance of the scar.

A proper wound design minimizes their occurrence. However, to remove a dog ear, the wound should be sutured till the elevation becomes prominent. The extent of the dog ear is then identified by raising it above the wound level. An incision is then placed at the base of

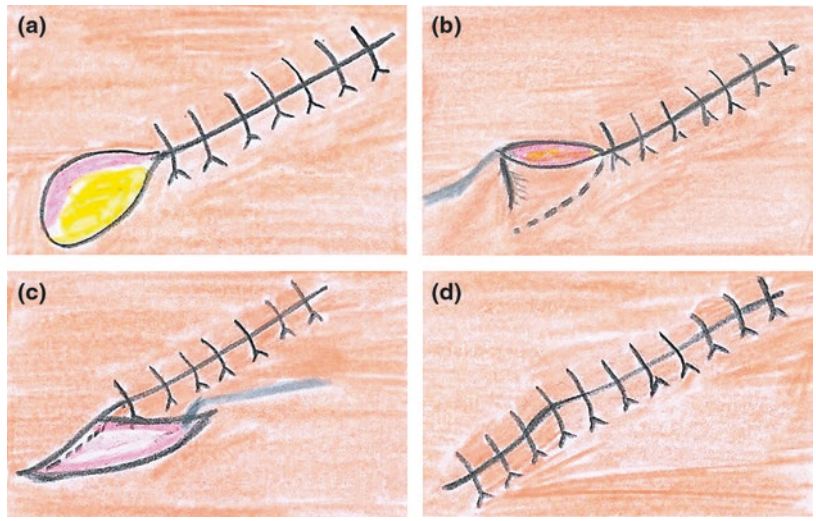

Fig. 7 Removal of dog ear. **a** The wound is closed until the dog ear is apparent. **b** A hook is used to define the dog ear and an incision is made at the base at one side. **c** The excess triangle of skin is removed. **d** The wound is closed at the dog ear area

one side finishing at the wound line to create a flap. The flap is then brought across the wound and the excess skin is removed (Fig. 7).

Basics of flaps and grafts

Skin grafts and flaps are very useful tools in many situations dealing with skin defects such as trauma with tissue loss, after tumor excision, congenital defects and managing scars.

Grafts are usually avoided in conditions with deep spaces as well as exposed bones or cartilage where flaps are preferred.

Basics of grafts

Free skin grafts are either:

- Full thickness graft; that consists of the epidermis and the whole thickness of the dermis and shows less contracture upon healing. It requires a good vascular bed and a longer time to be taken. It is usually harvested using a scalpel and the donor side should be closed. This type is commonly used in the face and neck area and its use is restricted to relatively small defects.
- Split thickness graft; that consists of the epidermis and variable proportion of the dermis. It is usually harvested by a special instrument. It is less vascular with easier take yet more likelihood of contracture. It is not used in the periocular area.

When the graft is applied to its recipient bed, it initially adheres by fibrin that breaks down within 48 hours. This usually coincides with revascularization that encompasses outgrowth of capillary buds from the recipient to unite with those on the deep surface of the graft. This becomes well established by the 3rd day where the graft appears pink in color. Fibroblasts of the bed proliferate and lay collagen to replace the fibrin and the graft is usually anchored to its bed by the 4th day. Lymphatics and nerve supply will be reestablished afterwards.

From the above mentioned, the success of the graft take depends primarily on the extent and speed of vascularization. This is determined by the characteristics of the bed, the character of the graft itself and the conditions under which the graft was applied to its bed.

A well perfused bed is necessary for graft take. The face areas are good recipients and even its fat is highly vascular. Bare bone or cartilage as well as areas exposed to previous irradiation

are poor graft beds. The patient's general condition as well as smoking may also affect the bed microcirculation.

A graft harvested from a highly vascular donor area will likely be easier to take which is better for thin grafts compared to thick grafts. The head and neck areas are highly vascular allowing good take of full thickness grafts.

Provided the bed is vascular and free from pathogens, it is of utmost importance that the graft should be in the closest possible contact with its bed (no hematoma or seroma) and immobile.

Harvesting the Graft

Common donor sites for full-thickness skin grafts of the periocular region include the post auricular region, the eyelids, the supraclavicular region and the upper arm. The first two sites provide a good skin matching characters like texture and color, besides, the scar at the donor site is cosmetically accepted.

The free graft should be accurately fitting in its recipient area with normal skin tension. The size and pattern can be determined by a template using cardboard, paper or aluminum foil. The defect should be displayed to the full before making the pattern to avoid post-operative shortage or ectropion. The template is then applied on the donner area and the skin is marked.

On harvesting the graft, it should be cleared from any fat on its deep surface, either primarily during harvesting or after the graft is cut out using scissors. The donor site is then closed primarily.

The recipient bed should be dry before applying the graft so that no hematoma could collect beneath the graft. Excessive cauterization in the bed should be avoided and simple pressure for enough time is preferred. The graft is sutured to its bed margins. Small grafts could be left exposed.

If the applied graft is large, the surgeon should avoid presence of dead space and collection of hematoma beneath the graft. Few stabs in the graft can provide a possible exit for any blood to be collected. A nonadherent dressing is usually applied with gentle pressure (<30 mmHg) before the final dressing. A "Tie-over dressing" is useful, because it minimizes the risk of hematoma or seroma formation without exerting high pressure on the graft and it also prevents shearing forces from outside.

Basics of flaps

A flap is a unit of tissue that is transferred from a donor to recipient area while keeping its own blood supply. Flaps can be classified according to their composition, location or blood supply and there is usually an overlap between these classifications. Flaps range from simple advancements of skin and subcutaneous tissue to composite flaps that may contain any combination of skin, muscle, bone, fat or fascia. Flaps can either be local or distant that use donor tissue from sites not adjacent to the recipient bed. Flaps that have no specific blood supply are known as random flaps while those having a specific vascular supply in the long axis are known as axial flaps.

Local skin flaps

They are the commonest type used in reconstructing the periocular region. The skin is borrowed from areas of relative excess and transposed to close an adjacent defect. The choice of the flap depends on the site and size of the defect, and the availability of the surrounding tissue. The donor site is closed, and the scar is better planned to be in a natural skin line.

Based on their method of movement, local flaps are classified into sliding flaps, advancing flaps and pivotal flaps.

Sliding flaps

This is one of the most helpful techniques to facilitate wound closure. They are simply achieved by generous undermining of the wound margins. The dissection is carried out until the surgeon is able to draw the wound edges together without tension (Fig. 8). Closure under tension may cause wound dehiscence, wide scars with atrophic or hypertrophic appearance.

Fig. 8 Closure of an elliptical wound (Lt) using undermining at the edges and sliding the skin to achieve closure without tension

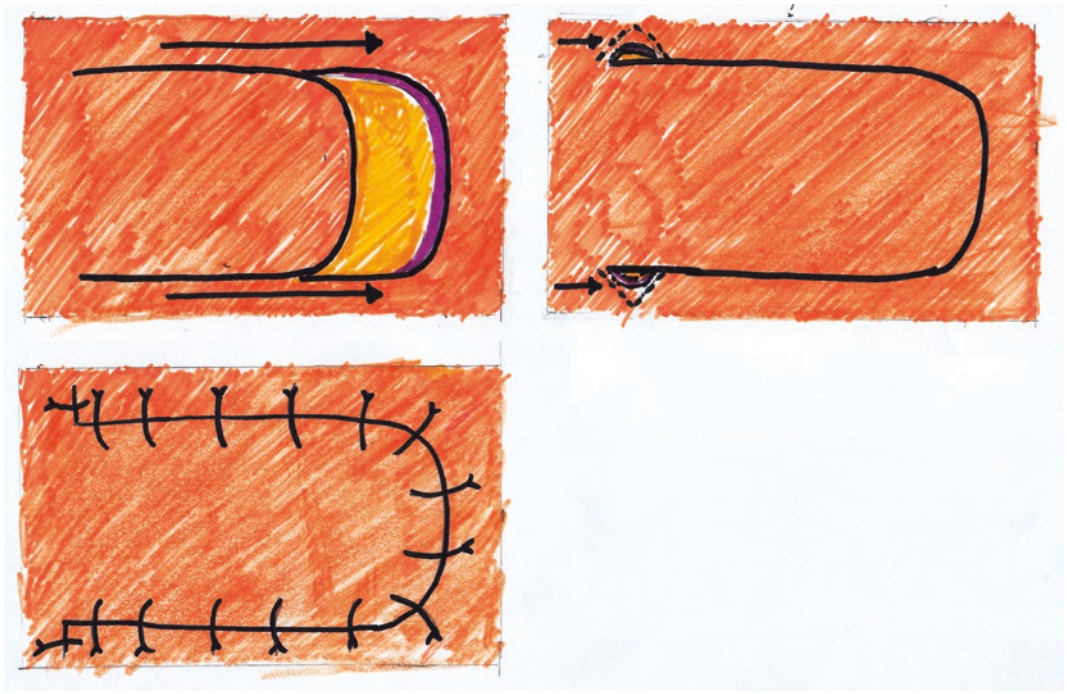

Fig. 9 Unipedicle advancing flap moving towards the defect's direction, small Burrow's triangle (small arrows) are removed at the flap base to achieve good closure without tension

Advancement flaps

They are designed to slide towards an adjacent defect in a single vector without rotation or lateral movement. They are useful in square or rectangular defects.

The flap is usually designed in a way that the length to be 2.5–3 times the width to avoid sloughing. This complication is rare in the lids due to high vascularity.

The flap should be completely dissected until it can be mobilized into the defect with no or minimal tension. An area of stress may appear along the edges of the advancing flap that may hinder its advancement. Excision of

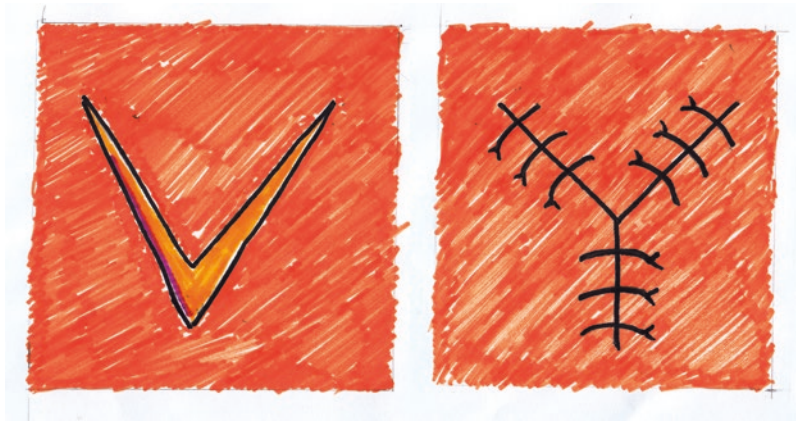

Fig. 10 V–Y plasty

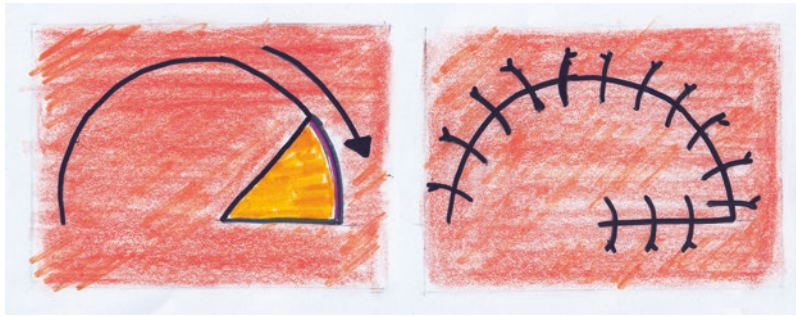

Fig. 11 Closure of a triangular defect using a rotational flap. The greatest tension is at the recipient site

small triangles called Burow's triangles at these areas will facilitate the flap movement (Fig. 9).

Bilateral/ bipedicle flap provide more coverage compared to single/unipedicle flap. V–Y and Y–V repairs are also considered advancement flaps.

V–Y plasty (Fig. 10) is widely used in the face and is very helpful in canthus reconstruction. It can be used to close a defect and to release tension. A V shaped incision is placed along its tension meridian while bisecting the V. The flap is then advanced, and the donor site is closed in a Y fashion. Although in this flap, the skin is not dissected from the underlying tissue, the area lateral to the V is undermined to release the flap. Closure of the lower limb of the Y first will further help advancing the flap into the defect. It is possible to turn Y to V in a reverse manner.

Pivotal flaps

These flaps pivot on a point or a shared base to cover the defect. The greater the pivot, the shorter the effective length of the flap. They include rotational, transposition and interpolation flaps

a. Rotational flaps:

They have a curvilinear or semicircular configuration and they are best used to close a triangular defect. They are designed immediately adjacent to the defect with one border of the flap is the border of the defect (Fig. 11). Ideally, the ratio between the flap length and the width of the defect base should be 4:1 and the ideal defect for repair has a height twice the width in size. Excision of a Burrow's triangle at the base usually facilitate the flap rotation. The greatest

tension is present at the recipient site. The donor site is either closed directly or using a skin graft. Tenzel's semicircular flap and cheek rotation flap are examples of such flaps.

The rhomboid (Limberg) flap:

This is a rotational flap variation that provides minimal tension at wound closure and preserves the natural distances at the site of its use. The tissue to be removed should have a rhomboid shape and the orientation of the excision site is an important key for successfully creating this flap.

The surgeon should identify the direction in which the skin is most extensible. This line becomes the lateral aspect of the flap. In cases of the eyelid reconstruction, perpendicular lines to lid margin should be avoided as they induce excess tension and lid margin malposition. This technique is commonly used in reconstructing the areas lying between the eyebrow and the anterior hairline.

A rhomboid is designed with its short diagonal equals the length of each side and the angles are 120° and 60° as shown in (Fig. 12). The short diagonal is then extended for a distance equal to its length, bisecting the 120° angle. A lateral incision is placed at the end of the extended diagonal at 60° angle, parallel to the top or bottom sides according to the direction in which the flap will be rotated and of the same length as the rhomboid side. The flap is dissected from its site and rotated into the defect, then sutures are taken to secure it in place (Figs. 12 and 13a–c).

b. Transposition flaps:
They have a linear configuration that is laterally rotated about a pivot point into an immediately adjacent defect. The flap shares the base with defect site with the greatest tension is at the donor's site (Fig. 14). The flap must be designed to be longer than the defect as the effective length of the flap becomes shorter the farther the flap is rotated. A cut back incision may be of

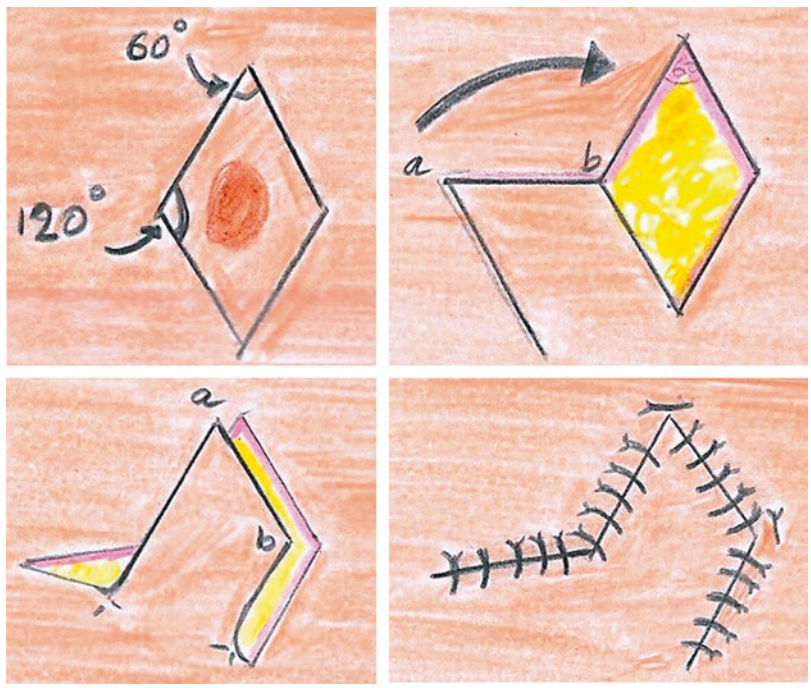

Fig. 12 Creation of the rhomboid flap: tissue excision, design, rotation and closure of rhomboid flap

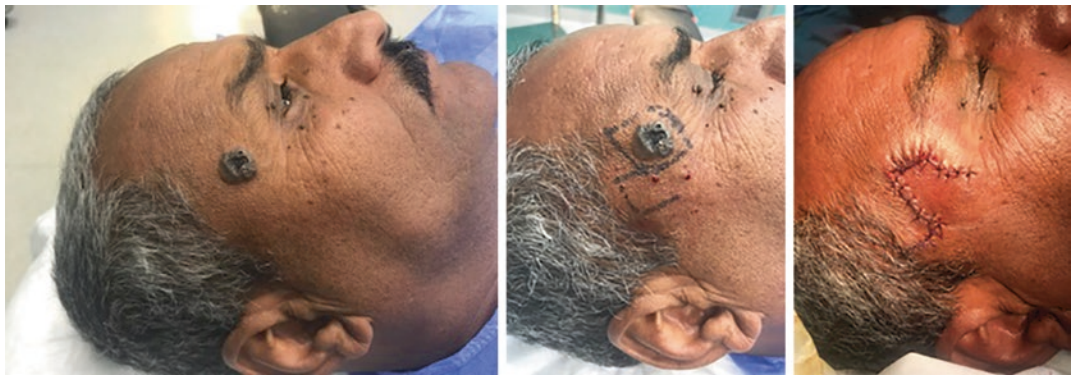

Fig. 13 **a** Basal cell carcinoma affecting the temporal region lateral to orbit. **b** Design of excision with safety margin and a rhomboid flap. **c** Excision of the lesion and closure of the defect

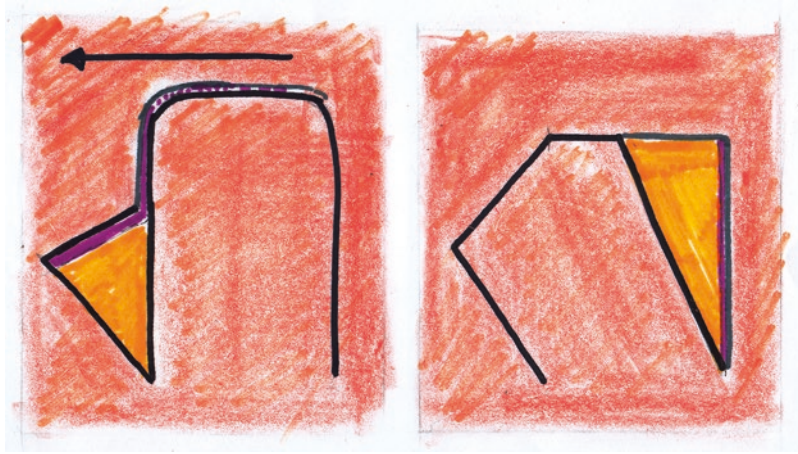

Fig. 14 A transpositional flap that is laterally rotated (Lt), the donor site is either closed directly or with graft (Rt). The greatest tension is at the donor's site

help. Transposition skin flap from the upper to the lower lid is an example.

c. Interpolated flaps:
They are like transposition flaps but the base is not contiguous with the defect. The pedicle either crosses over or under an intervening tissue and it needs a second stage to release its connection. Forehead and Cutler Beard flaps are examples of this type.

Z-plasty:
Z-plasty is an important surgical technique in revising a scar or releasing a scar contraction as it elongates the tissues and changes the scar axis with a more cosmetic appearance.

It is a transpositional flap in which two triangular flaps are reversed and rotated 90°. The central limb is placed along the scar to be excised and the three limbs of the Z must be of equal length to facilitate closure. The lateral limb to central limb angles should be equivalent and the gained length is related to this angle. The 60° Z-plasty is most effective because it lengthens the central limb without placing too much tension laterally (Fig. 15).

In designing the Z-plasty, the surgeon should consider that the final position of the scar will be

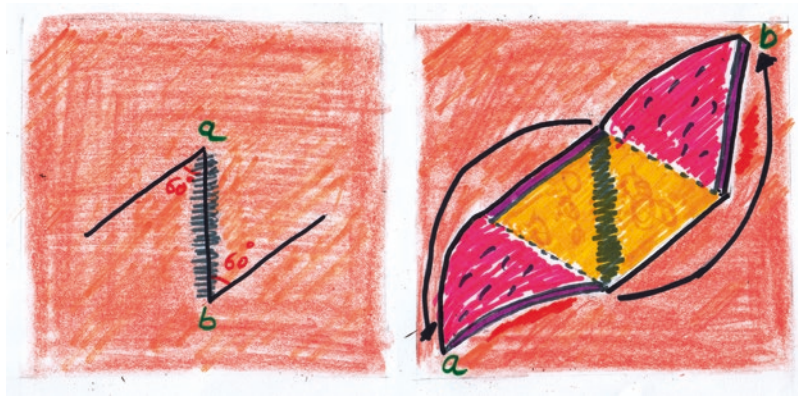

Fig. 15 Creating the flaps by placing the central limb along the scar line, the two other limbs are of equal length at 60°. The arrows show the direction of **a** and **b** upon flap creation

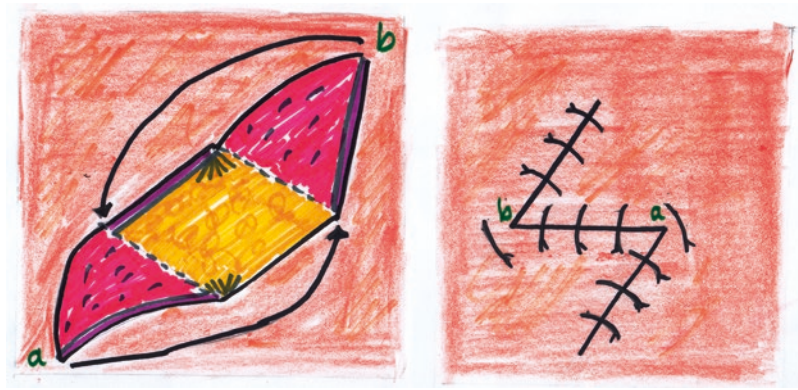

Fig. 16 The subcutaneous scar is removed. The arrows show the direction of flap movement. The flaps are then closed

perpendicular to the original central limb, hence it should be planned to be parallel to the skin lines. Consecutive Z-plasties can obliterate skin straight line scars yet result in transverse shortening and lateral tension on the wound.

After the flaps are created, it is essential to release and excise the subcutaneous bands to make the flaps freely mobile. They are then transposed, and their bases anchored first (Fig. 16). The tension along the flap is evenly distributed using interrupted sutures. Inequality of flaps may cause stress on the wound with poor outcome. If making flaps with equal angles is not feasible, the difference between them should not exceed 20°.

Forehead Flap

Tissues from the forehead could be elevated to replace lower or upper eye lid defects. To minimize unsightly scar at the donor area the flap is raised either above the eye brow or just in front of scalp hair line. The incision at the site of hair line is slanted away to avoid injuring hair follicles with possible resulting alopecia. If a long flap is needed it could be delayed as a bipedicle flap for two week before harvesting.

After insetting the flap the inner surface is covered by mucous membrane graft and in the lower eye lid a cartilage support may be needed at a later stage (Fig. 17a, b).

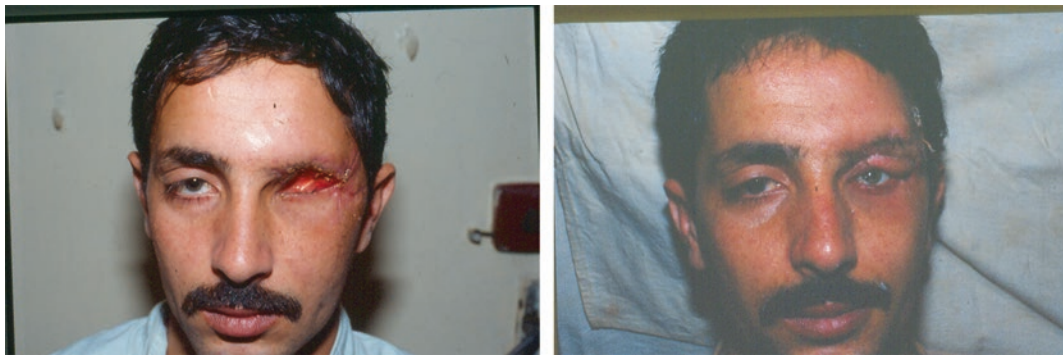

Fig. 17 **a** Upper eye lid defect in a case of subtotal excentation. **b** Reconstruction of the upper eye lid with a forehead flap

Fig. 18 **a** Basal cell carcinoma affecting most of the lower lid. **b** Excision of the lesion with safety margin and reconstructing the lower lid with Mustarde flap

Mustarde Flap

This flap is very useful for a major defect of the lower eye lid. It is a major facial flap in which the whole cheek is mobilized. The incision starts at the lateral end of the defect and goes at a higher level than the outer canthus until it reaches the front of the auricle then is directed downwards in front of auricle like a face lift incision. The whole flap is mobilized at the subcutaneous level and moved medially at its upper end to reconstruct the lower eye lid. The donor site is usually closed primarily and very easily especially in the older age group (Fig. 18a, b).

Inner Canthal Defects

Inner canthal defects present a challenge especially when deep as it is usually associated with disturbance of the canalicular anatomy. In addition repair of the medial canthal tendon or applying a tendon graft that is sutured to the posterior lacrimal crest should be done.

The skin defect itself is usually covered by a skin graft (Fig. 19a–c). An alternative is a transposition flap from nose, glabella or forehead, but the main disadvantage of these flaps is its bulkiness which may need thinning in a second stage (Fig. 20a, b).

Some authors suggest leaving medial canthal defects to granulate and heal by secondary intention. This takes long healing time and can lead to ectropion of the medial aspect of the lower lid. This method may be useful only for small defects.

Eye Brow Injuries and Defects

Wounds of the eye brow should be meticulously sutured with proper alignment of the upper and lower border of the brows. If the wound is deep it

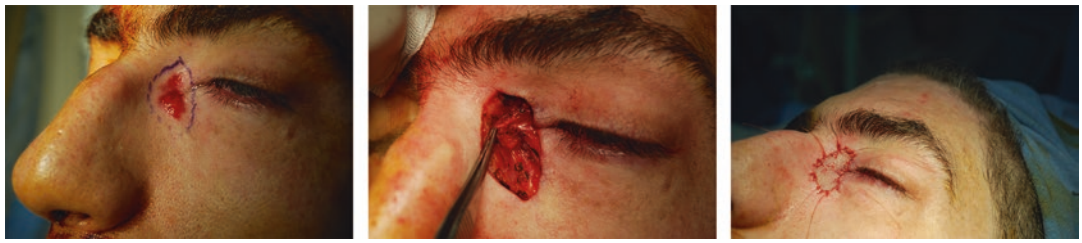

Fig. 19 **a** Basal cell carcinoma at inner canthus. **b** Excision with safety margin. **c** Closure of the defect with split thickness skin graft

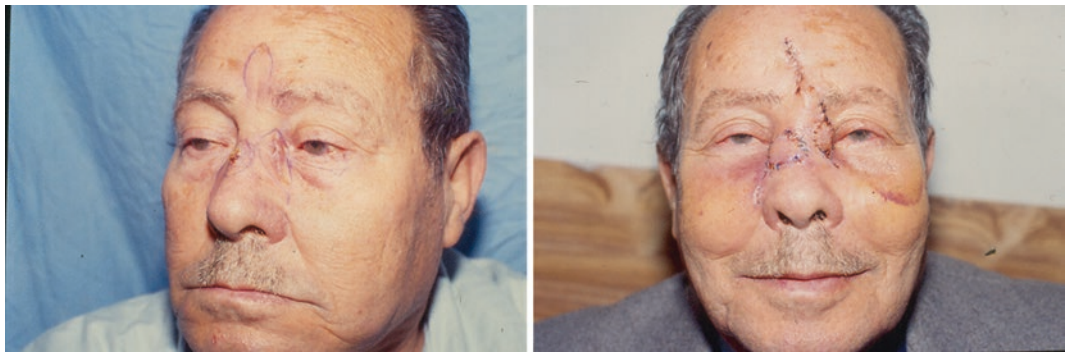

Fig. 20 **a** Basal cell carcinoma affecting inner canthus. **b** Excision and closure of the defect with a glabellar flap with noticeable bulkiness

should be closed in layers to minimize scar stretching. However in spite of the best efforts many wounds of the eye brow will show few weeks after healing as a hairless scar. This could be managed by scar revision and follicular hair transplantation from the opposite or the same brow.

In many occasions brow injury is associated with injury to upper eye lid and forehead. It is advisable to correct the brow first and guarantee its proper alignment then consider forehead and lid injury and if there is a forehead skin defect it should be managed without compromising. The brow alignment is by using properly designed flaps or skin grafts. Deformities of the brow resulting from closing forehead defects without respect to brow alignment are more difficult to correct at a second stage.

If the brow is obviously shorter than the opposite brow follicular hair transplant from opposite brow can correct the shortening. In females tattooing can camouflage this starting.

In large or total brow loss a superficial temporal island flap from scalp could be harvested to reconstruct the brow but the hair is usually denser than the normal brow and needs to be regularly cut or shortened. Tattooing especially in females is an alternative.

Complications of Flap Reconstruction

Variable complications following flaps reconstruction may occur, yet most of them are preventable and can be treated.

Early complications include infection, hematoma, seroma, and wound dehiscence. Flap necrosis is a serious complication and can be due to improper design or execution. It can be avoided by precise flap design and avoiding violation of the flap blood supply as well as closure under tension. If distal necrosis occurs, treatment is conservative and the area could be left to

heal by secondary intention or subsequent surgical revision based on the situation.

Late complications such as unfavorable scars that can be avoided by proper planning. When they are mature, they can be revised or corrected using Z-plasty.

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Anaesthesia in Oculoplasty

Oya Yalcin Cok and Ezzat Sami Aziz

Introduction

Anaesthesia is an indispensable component of every surgery. However, every surgical specialty and subspecialty has its own needs and requirements regarding anaesthesia management. The oculoplastic procedures also need tailored approaches of local, regional and general anaesthesia techniques. This chapter will cover the main anaesthetica techniques used during oculoplastic surgeries, related anaesthetic drugs and some practical advices for anaesthesia management.

Local Anaesthesia

Local anaesthesia techniques sufficiently cover the requirements of most of the oculoplastic surgeries. These techniques include topical anaesthesia with local anaesthetics (LAs) and intradermal or subcutaneous LA administration as infiltrations. They can be used both alone and in combination with each other.

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Topical Anaesthesia

Topical anaesthesia, mostly reserved for ocular surgeries, still can be used for brief and superficial procedures of the globe, conjunctiva, and the lids or prior to infiltration anaesthesia to ease the injection pain. It has an advantage of less distortion of the surgical site. Especially, cornea and conjunctiva are very susceptible to topical local anaesthetic effect in where nerve endings are very superficial under a tear film and a thin epithelium. The local anaesthetics for topical anaesthesia are used in the form of eye drops, gels, creams, ointments, sprays and patches. Furthermore, local anaesthetic soaked cotton tip applicators may be used for topical anaesthesia of the conjunctiva. These drugs have higher concentrations of local anaesthetics and may be readily absorbed to the systemic circulation in high amounts.

Local Infiltration Anaesthesia

Local anaesthetic infiltration is an easy technique to provide a pain-free surgical area for many of the oculoplastic procedures. It is also suitable in some selected paediatric cases. In this technique, local anaesthetics (LAs) are injected into the soft tissue of the operative site. It may be accompanied with or without sedation.

E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_2

Some technical issues should always be considered during local anaesthesia as follows. Local infiltration should always be utilized after cleaning the skin with appropriate material. The needle used should be sufficiently long to avoid multiple insertions, by long passes beneath the skin. This may help decrease the severity of pain and bruising. The syringe should be tightly secured to the needle with the bevel up; a Luer-Lok syringe should be used if possible to prevent needle expulsion which may cause inadvertent penetration of the globe or surrounding tissue. Eyelids are thin structures and they are not resistant to inadvertent full-thickness penetration. Penetration to the globe or corneal puncture should be suspected if the ballooning following LA infiltration ceases immediately.

Concerns During the Local Infiltration Anaesthesia for Oculoplastic Surgery

The local anaesthetic injection causes mild to moderate pain, burning, stinging sensation due to the needle insertion and acidity of LAs. Local anaesthetic injection rate affects injection pain in oculoplastic procedures as slower injection enables less painful infiltration. A smaller gauge needle may also alleviate the pain of injection. Because overall pain sensation and satisfaction during the surgery highly correlates with the initial pain during local anaesthetic infiltration, this is an important matter, especially at the office setting where a higher patient satisfaction and perception of good care are desired. Needle-free jet injections are not recommended for oculoplastic procedures. However, there are still ongoing and promising studies for new needleless alternatives such as nano enabled (nanoparticle) local anaesthetic delivery systems for oculoplastic surgery.

Periocular anaesthetic injections may trigger a forceful reflex sneezing (sternutatory reflex), even under sedation. This possibility should be anticipated and the needle should be drawn quickly to prevent deeper penetration.

A technical concern about local anaesthetic infiltration is its potential to distort the original anatomy of the patient that may be especially important in correction surgeries. This may be due to mass effect or haematoma formation. Therefore meticulous planning of the surgery should be made and drawn on the skin prior to local anaesthetic administration. Especially during ptosis surgery, the use of epinephrine may also result in upper eyelid retraction due to sympathetic activation of Müller muscle. On the other hand, LA diffusion to levator muscle may cause paralysis and make height adjustments difficult. This can be avoided by limiting the LA volume to less than 1 mL in the upper lid.

There are some complications that can be encountered due to periocular injections. First of all it is wise to check if the patient is on anticoagulant drugs and to cease them under the control of prescribing physician to avoid bleeding-related complications such as retrobulbar haematoma. Allergic reactions to LAs are rare, but, they may be observed against the preservatives or the antioxidants in the formula of the local anaesthetics. Systemic local anaesthetic toxicity is less expected since the use of large volumes and high concentrations of local anaesthetics during oculoplastic surgery isn't expected. But it may be of concern during tumescent anaesthesia or with large infiltration areas during full facial reconstruction. The initial symptoms of local anaesthetic systemic toxicity include central nervous system symptoms and signs such as anxiety, dizziness, tinnitus, restlessness, and tremor, and, sometimes, convulsions. Respiratory and cardiac alterations may co-exist or follow central nervous system disturbances. The management includes supportive therapy such as prevention of hypoxia, cardiopulmonary resuscitation and lipid emulsion therapy.

Blocks

The blocks used for oculoplastic surgery includes ocular blocks such as retrobulbar, peribulbar and sub-Tenon blocks and periorbital blocks of separate nerves. They can be used alone or in combination with each other to cover the surgery site. They cause minimal discomfort, lower cost, and lower perioperative morbidity in comparison to general anaesthesia. They also provide the advantages of less local anaesthetic

use and minimal tissue distortion when compared with infiltration anaesthesia. These blocks may be utilized with a blind technique or with the use of ultrasound guidance.

Ocular Blocks

Ocular blocks include retrobulbar, peribulbar and sub-Tenon blocks. They provide the anaesthesia of the globe. The local anaesthetic is injected into intraconal space, extraconal space by a needle and into sub-Tenon's space by a cannula during retrobulbar, peribulbar and sub-Tenon blocks respectively. However, they have very limited use for oculoplastic surgery. They have been reported to have beneficial effects such as longer optic nerve transection, less pain, less postoperative nausea and vomiting following eye amputation procedures.

Periorbital Nerve Blocks

Periorbital sensorial nerve blocks include supraorbital, supratrochlear, infratrochlear, zygomaticotemporal, zygomaticofacial, infraorbital, maxillary nerve blocks. The facial nerve must be blocked for motor blockade of the relevant muscles in the area. Here, the blocks will be described starting from the peripheral and the superficial to the main branches and the deeper ones.

Supraorbital Nerve and Supratrochlear Nerve Blocks

The supraorbital nerve and the supratrochlear nerve are two of the terminal branches of the frontal nerve which is the largest branch of ophthalmic division (V1) of the trigeminal nerve. Both nerves exit the orbit anteriorly and

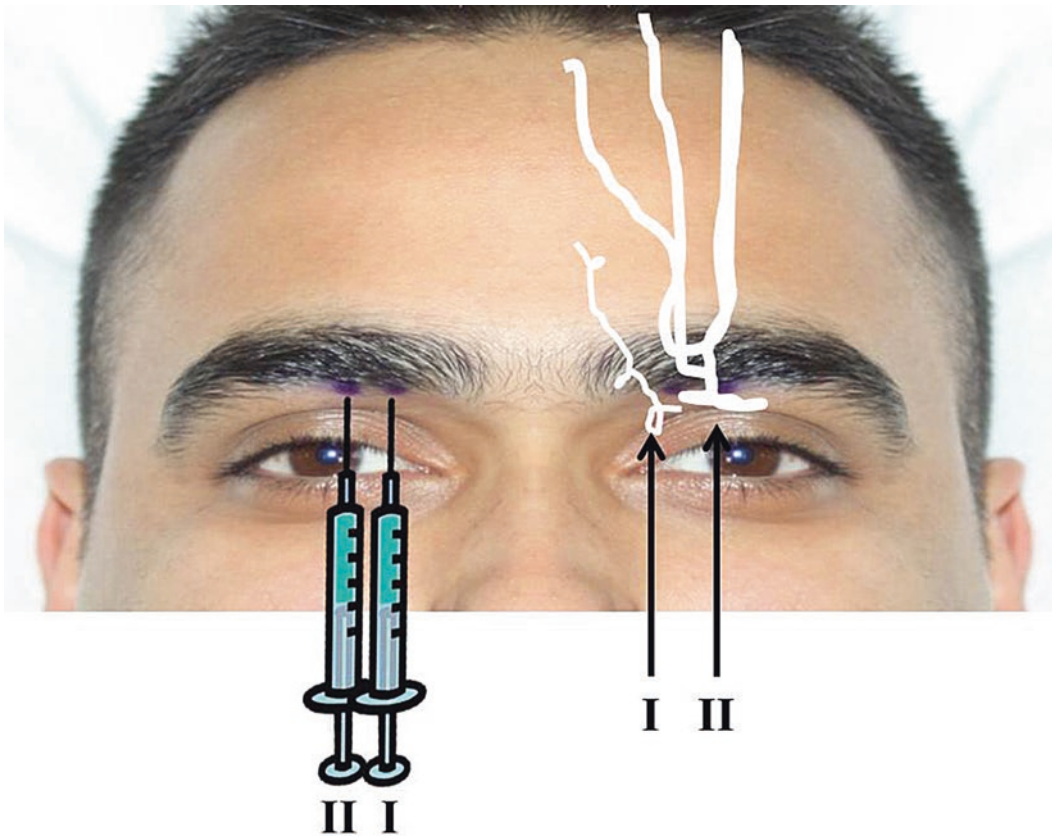

Fig. 1 The supratrochlear and the supraorbital nerves and the respective block sites. I: The supratrochlear nerve, II: The supraorbital nerve

superiorly. The supratrochlear nerve and the supraorbital nerve are located approximately 1 cm and 2 cm lateral from the midline of the forehead on the supraorbital ridge, respectively (Fig. 1). The supraorbital nerve exits from the supraorbital notch or foramen at 0.5–0.7 cm above the supraorbital margin which are usually palpable and visible under ultrasound guidance.

The blockade of supratrochlear and supraorbital nerves provides anaesthesia for procedures such as repair of lacerations, debridement, removal of foreign bodies, oncologic interventions of the forehead and upper eyelid without compromising levator function and specific neuralgias of the related nerves.

The supraorbital nerve can be blocked by a 23–30 G needle inserted perpendicular to the skin by palpating the foramen or the notch by a blind technique and 1–2 mL of LA should be injected. Direct injection the foramen should be avoided to prevent the nerve injury. The supratrochlear nerve can be blocked at 1 cm medial to supraorbital notch/foramen on the upper orbital margin. A practical technique to block both nerves at once is to infiltrate the medial two-thirds of the eyebrow with one long pass of a sufficiently lengthy needle beneath the eyebrow and inject 4–5 mL LA along while withdrawing the injector.

A high-frequency ultrasound transducer transversely placed on the eyebrow should be moved slowly from lateral to medial while dynamically searching for a break in the hyperechoic edge of the bone indicating the supraorbital notch or foramen (Fig. 2). The foramen or the notch should be checked by colour or Doppler mode to visualise vascular structures. The supraorbital nerve can't be visualised in long axis by this approach, however in-plane needle advancement, sectional view of supraorbital nerve, LA spread around the foramina can be observed during the block (Fig. 3). The supratrochlear nerve may also be visualized medial to the supraorbital nerve on the supraorbital ridge with the use of a high-frequency ultrasound transducer (Fig. 4).

Infratrochlear Nerve Block

The infratrochlear nerve is one of the terminal branches of the nasociliary nerve, which is a branch of the ophthalmic division (V1) of the trigeminal nerve. It travels along the medial wall of the orbit before leaving over the medial canthus. The branches of the infratrochlear nerve are distributed throughout the medial area of the upper eyelid and 1/5 of the medial part

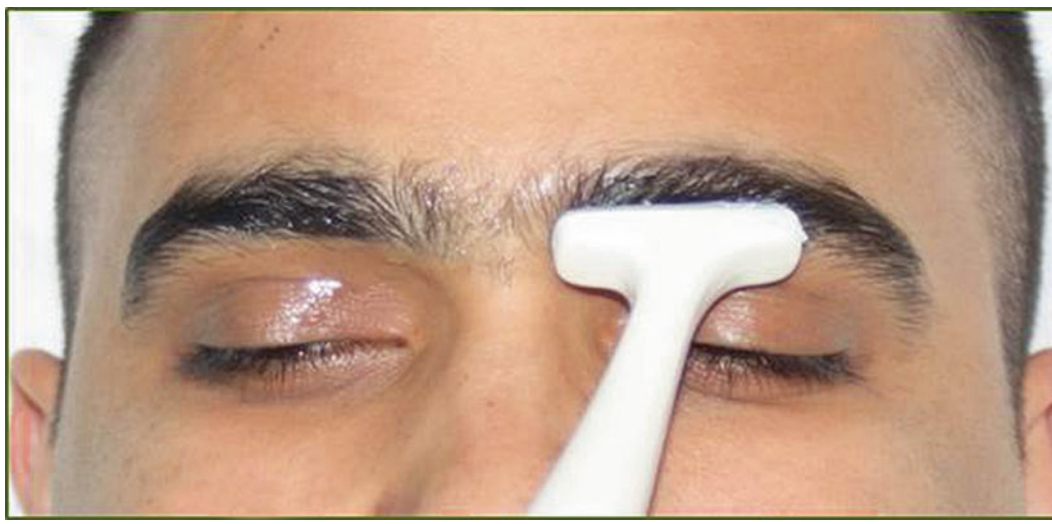

Fig. 2 A high-frequency ultrasound transducer transversely placed on the eyebrow for supraorbital nerve block

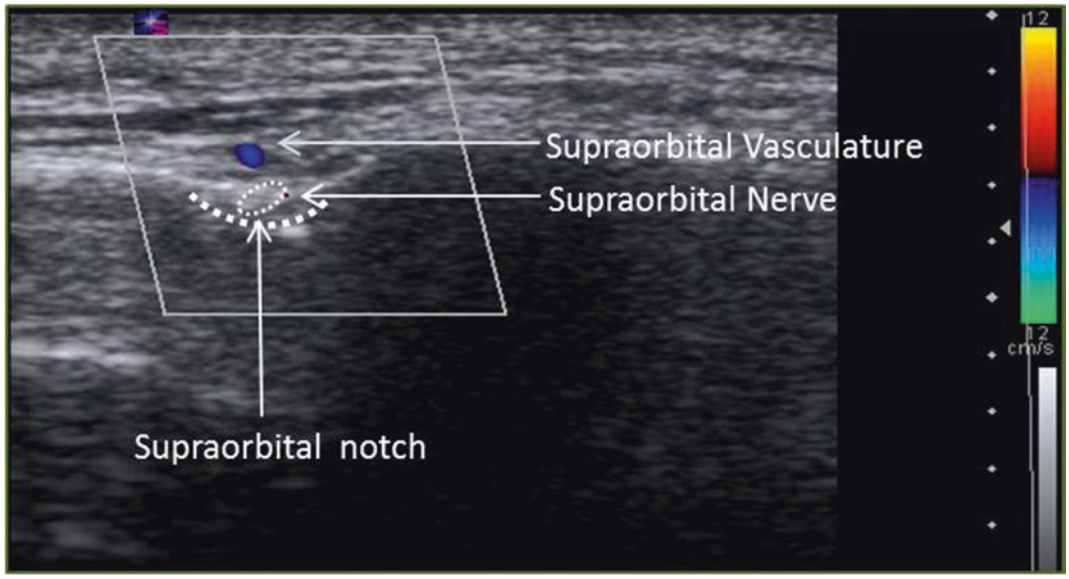

Fig. 3 Ultrasound image for supraorbital nerve block

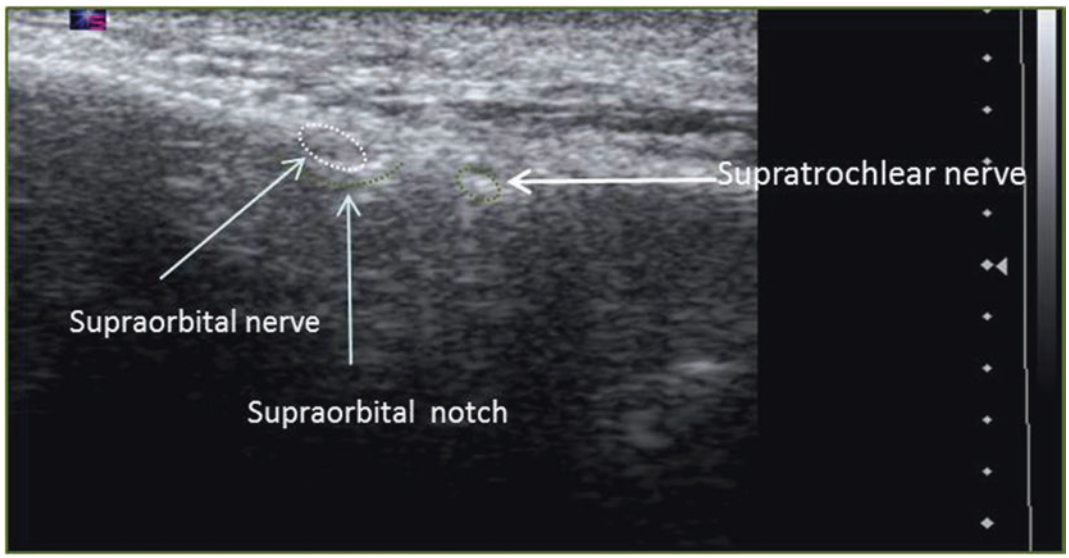

Fig. 4 Ultrasound image for supratrochlear nerve block

of eyebrow height. This nerve innervates the internal angle of the orbit and the medial upper eyelid, the upper bridge of the nose and/or the lacrimal caruncle.

The infratrochlear block is performed by administering 0.5–1 mL of LA with the needle inserted 0.5–1 cm above the medial canthus at the intersection of the nasal base and the orbit (Fig. 5). The blockade of the supraorbital, the supratrochlear and the infratrochlear nerves all at once is possible by 2–3 mL LA injection starting from the midline of the eyebrow to the glabella, however, this technique is more painful than separate blocks of these nerves.

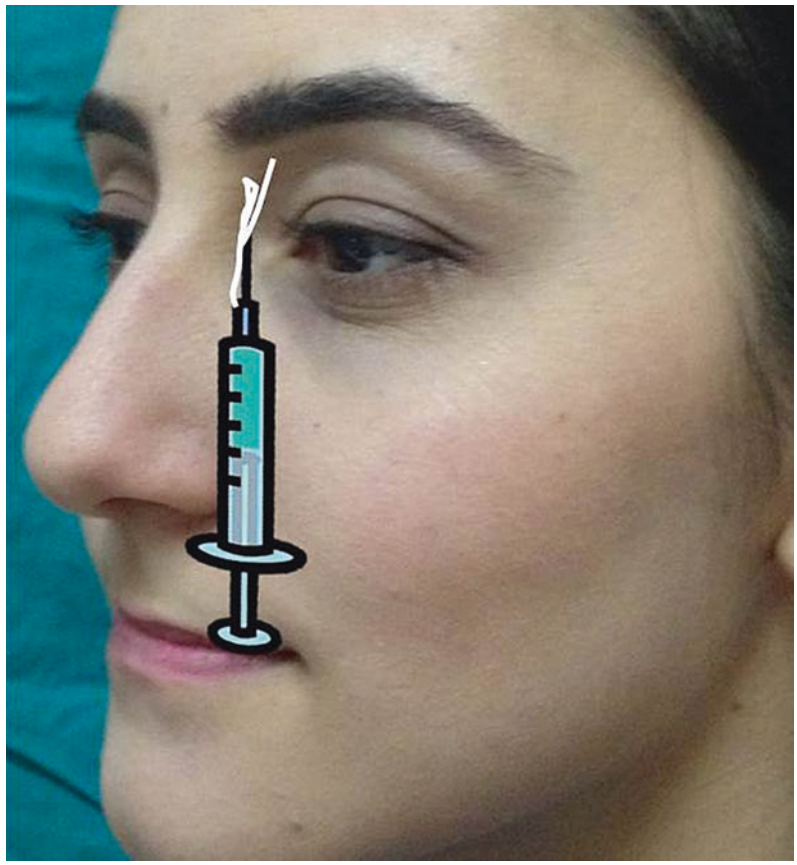

Fig. 5 Infratrochlear nerve and the block site

Zygomaticotemporal Nerve and Zygomaticofacial Nerve Blocks

The zygomaticotemporal nerve and the zygomaticofacial nerve are the peripheral branches of the maxillary division of the trigeminal nerve. The zygomaticotemporal nerve ran along the lateral wall of the orbit and reaches to the temporal fossa between the deep layer and the superficial layer of the deep temporal fascia after passing through the zygomaticotemporal foramen. It has communicating anastomoses with the temporal branch of the facial nerve, which is assumed to be myelinated fibers of proprioceptive or motor function. The zygomaticotemporal nerve innervates an area which is 3 cm lateral to lateral canthus and of 3 cm diameter in adult patients. The zygomaticofacial nerve passes through the lateral wall of the orbit anterolaterally and traverses the zygomaticofacial foramen and it innervates the skin over the zygomatic bone, the inferior region of the temple and the lateral aspect of the lower eyelid.

The blockade of these nerves is indicated when the surgery involves the lateral part of the orbit, separation of temporal muscle from the cranium, lateral part of the lower eyelid, lateral region on the zygoma.

To block the zygomaticotemporal nerve blindly, one should palpate the lateral edge of the orbit at the level of lateral canthus and follow the edge until the superior of the lateral orbital wall at the level of the frontozygomatic suture. The nerve can be blocked at this area (Fig. 6). However, the frontozygomatic suture cannot be palpated in every patient. In this case,

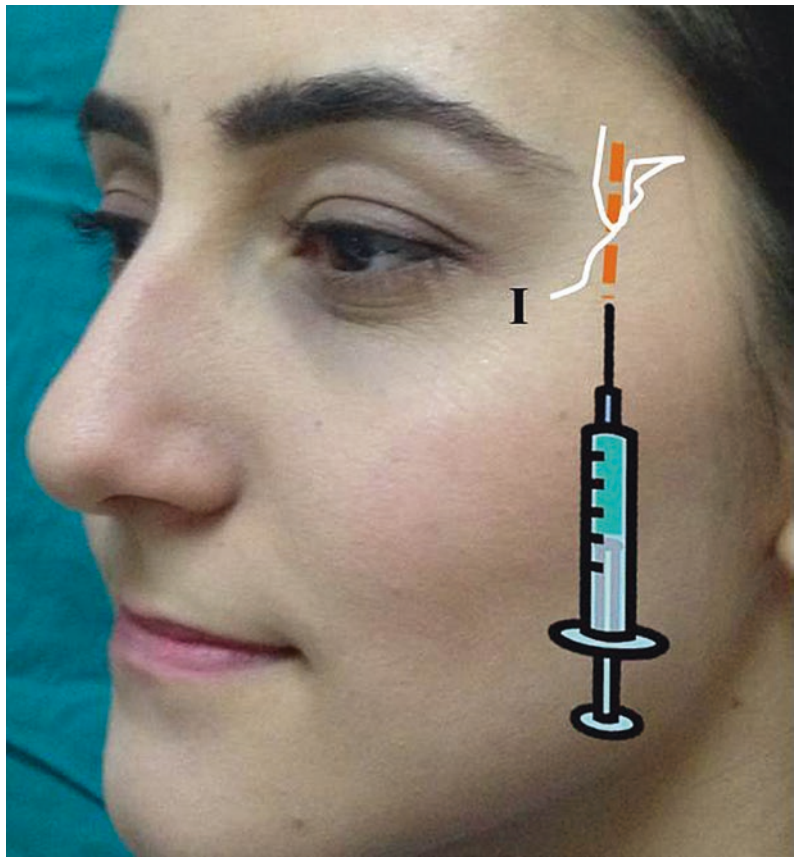

Fig. 6 The zygomaticotemporal nerve and the block site. I: The zygomaticotemporal nerve

the lateral orbital edge must be palpated 1 cm superiorly and then the palpating finger should be moved to into a groove 0.5–1 cm posteriorly. The zygomaticofacial nerve can be blocked at this area which is 1–1.5 cm posterior to frontozygomatic suture and 2 cm superior to zygomatic arch. Due to numerous variations of the zygomaticotemporal nerve location, the block must be performed by superficial and deep injections of 5 mL LA to block both the temporalis and temporoparietalis muscles.

The zygomaticofacial nerve can be blocked blindly by subcutaneous injection of 1–2 mL LA to the area 2 cm lateral and 2 cm inferior to the lateral canthus in the proximity of the zygomaticofacial foramen. It may be also blocked by injecting LA at the lateral edge of the orbit at the level of the frontozygomatic suture in the direction of zygoma. It is frequently blocked together with the zygomaticotemporal nerve. The finer the needle used, the less haematoma or bruising at this delicate area. The use of ultrasound guidance for identifying bony and vascular landmarks eases the block of these nerves, especially in obese patients (Fig. 7).

Infraorbital Nerve Block

Infraorbital nerve is a terminal branch of the maxillary division (V2) of the trigeminal nerve. An infraorbital nerve block is indicated for lower eyelid, lateral side of the nose and upper lip anaesthesia.

This nerve is blocked at the site where it emerges from infraorbital nerve. Infraorbital foramen is located at 2 cm below the midline of orbit. Practically, it is on the same virtual

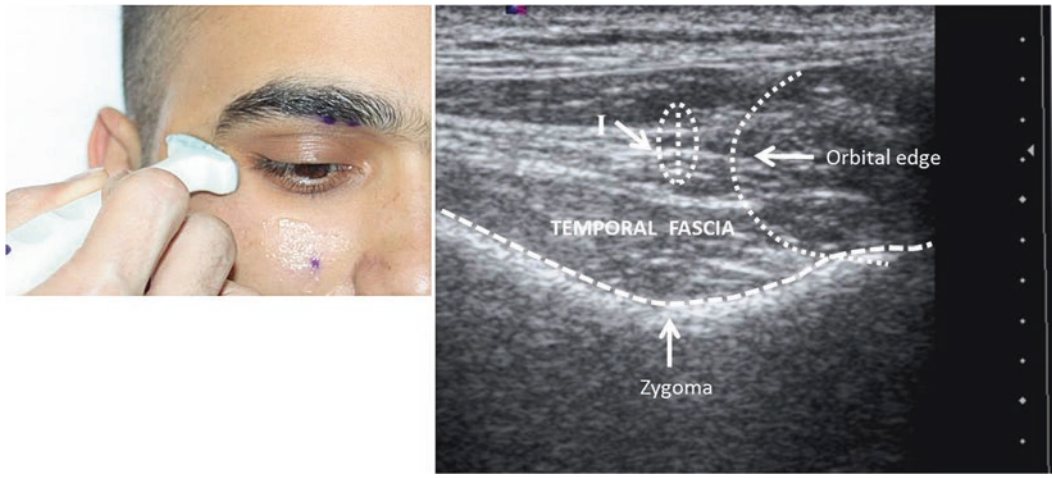

Fig. 7 Ultrasound image for zygomaticotemporal nerve block. I: The zygomaticotemporal nerve block LA injection site

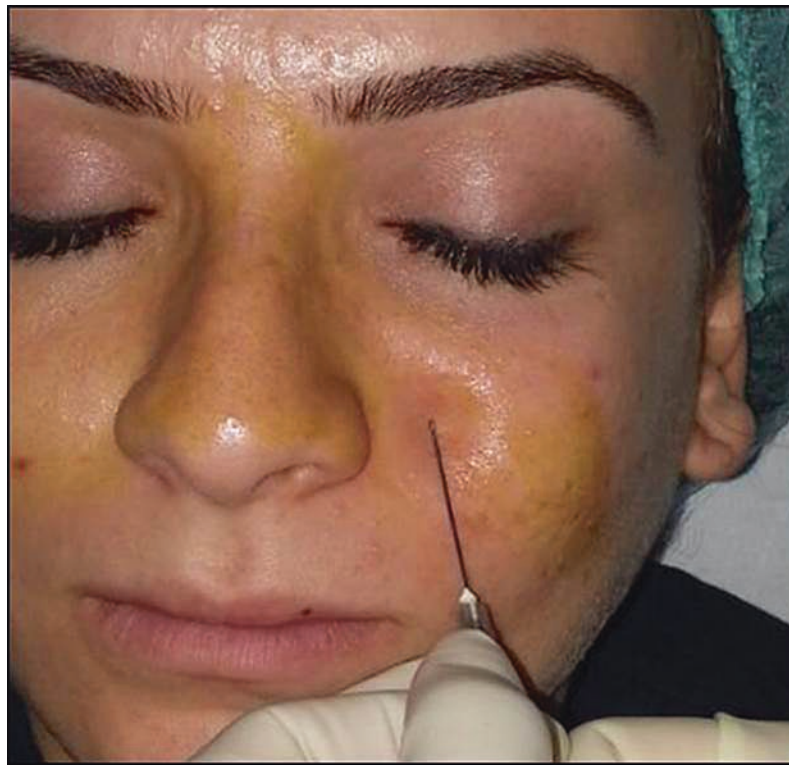

Fig. 8 Infraorbital nerve block site with percutaneous extraoral approach

line drawn from supraorbital notch and pupil at neutral gaze. This block can be performed percutaneous extra-oral or intraoral approaches and blindly or by ultrasound guidance. During the ***percutaneous extraoral approach***, the infraorbital foramen is palpated according to anatomical landmarks such as the infraorbital ridge and the 1–2 mL LA is deposited subcutaneously by a needle perpendicular the skin (Fig. 8). A deeper injection beneath the muscle

is recommended in patients with prominent quadratus labii superioris muscle. The needle should not be introduced into the infraorbital foramen since this may cause globe injury and nerve damage due to direct needle contact, toxicity or local pressure of LA.

During the ***intraoral approach***, the needle is aligned between the roots of the first and the second maxillary premolar teeth and introduced towards the ipsilateral pupil. Palpating the foramen simultaneously provides control of the LA injection and spread. LA spread can be facilitated by 10–15 second massage after LA injection. Theoretically, blind intraoral approach increases the risk of orbital penetration and globe perforation since the needle trajectory, infraorbital foramen and the canal lies on the same plane. If the needle enters the orbit, a swelling in the lower lid is observed during LA injection.

Infraorbital foramen's location rapidly moves to the more inferotemporal site during the first 3 years and between 10 and 12 years of life and this is finalized around the age of twenty. It is more inferotemporal in male patients in comparison to female patients. In paediatric patients, its distance from the midline can be calculated according to the formula as follows: Distance = 21 mm + 0.5 × age (years).

A high-frequency ultrasound transducer should be placed at the inferior orbital rim and transverse sono-scan is performed until a hypoechoic break in the bone indicating the infraorbital foramen is observed (Fig. 9). The foramen should be checked by colour or Doppler mode to visualise vascular structures. The needle is introduced with the in-plane approach and the block is performed while observing the spread of local anaesthetic at the opening of the foramen. However, sagittal scanning parallel to the nose may also be performed and the same imaging principles apply since the foramen can be found in the same way. In-plane needle advancement and LA spread around the foramina can be observed during the block.

Maxillary Nerve Block

Maxillary nerve (V2) is one of the three divisions of the trigeminal nerve. The maxillary nerve exits the cranium through the foramen rotundum and enters the pterygopalatine fossa. Then it starts to give its peripheral branches such as zygomatic nerve (the main branch giving off zygomaticotemporal and zygomaticofacial nerves) and infraorbital nerves which innervate the inferior and lateral periocular region. The blockade of this nerve in the pterygopalatine fossa enables to anaesthetise the area innervated by all terminal branches of this nerve at once.

After defining the midline of the zygomatic process, the sulcus beneath the bone should be

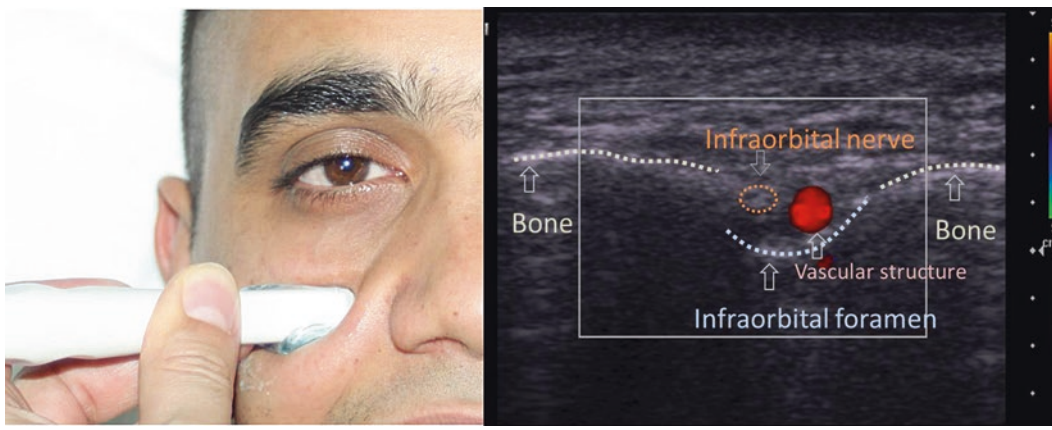

Fig. 9 Ultrasound image for infraorbital nerve block

marked to block the maxillary nerve blindly. A 22G needle should be inserted perpendicularly at this point until it touches the lateral pterygoid plate at around 4 cm depth. Then the needle is retracted and directed upwards for 4.5 cm (not more than 4.5 cm) and 3–4 mL LA is sufficient for the nerve blockade.

During the ultrasound-guided maxillary nerve block, the transducer is placed distal and parallel to the zygomatic arch to bridge the coronoid and condylar processes. The aim of the imaging is to visualize the lateral pterygoid plate and the sphenoid palatine artery, which is a branch of the maxillary artery, flowing to the pterygoid palatine fossa. The needle is introduced to the area anterior to the lateral pterygoid plate which is the pterygopalatine fossa and LA is injected. This block may also be performed with several different approaches.

Facial Nerve Block

The facial nerve block provides motor blockade of the muscles of the face. It doesn't offer sensorial anaesthesia around the eye although it has some communicating branches with the peripheral branches of the trigeminal nerve. Akinesia of the muscles around the eye may benefit some particular surgeries. However, current improvements in oculoplastic techniques minimized the need for this block. The proximal and distal approaches of the facial nerve are Nadbath-Rehman, O'Brien, Atkinson, van Lint techniques and their modifications. In the proximal site, the facial nerve can be blocked by delivering 3 mL LA 1.5 cm deep into the area where facial nerve emerges from stylomastoid foramen, between anterosuperior part of the mastoid and the ramus of the mandible. In the original O'Brien technique, LA is injected directly beneath the condyloid process at the level of the neck of the mandible just anterior to the tragus of the ear. In the modified O'Brien technique, the injection site is at more posterior and inferior of the original approach and approximately 5 mL of LA is injected at the dorsal rim of the mandible near the tragus of the ear at a maximal depth of 1 7 cm. The Atkinson block is performed by subcutaneous injection of 2–5 mL LA at the midpoint of a line between the lower edge of the zygoma and the jaw joint. The modified van Lint block is the most distal of the facial nerve blocks particularly reserved for eye surgeries and practically, 2–5 mL LA is injected below the orbicularis oculi muscle. The more distal the block site gets, the less akinesia is provided. Nadbath-Rehman technique has a higher risk of complications due to its proximity to vagus and glossopharyngeal nerves and these complications include dysphagia, respiratory distress and pulmonary oedema. Van Lint approach causes swelling and distortion of the lids and ocular adnexa and O'Brien technique produces postoperative pain at the site of anaesthesia.

Contraindications of the Periocular Blocks

Infection at the block site, congenital or acquired coagulopathies and the refusal of the patient are a contraindication to block performance. Bone defect or tumours may change the normal anatomy of the block site and may cause an increased risk of complications as well as block failure.

Complications of the Periocular Blocks

Pain during the block performance, bruising and local infection are the common complications during the periocular blocks. Vascular structures accompanying the nerves and the dense vasculature on the face increase the risk of the subcutaneous bleeding. Haematoma formation may be observed in patients who are on anticoagulant and some herbal drugs. However, adding epinephrine to LA is not a recommended practice in these blocks. Pressure due to LAs or direct needle contact may cause nerve injury since most of the nerves of the region are located in a narrow foramen or notch or very superficially. Inadvertent injury to the surrounding structures

via the foramina has also been reported, especially during the infraorbital nerve block.

Essential Knowledge for Ultrasound Guidance During Periorbital Nerve Blocks

Ultrasound guidance helps visualizing the supraorbital foramen or notch and vasculature near the block site and efficient spread of LA to minimize the LA volume used. Since periorbital nerves are very superficial and thin structures to visualize, high frequency linear or hockey stick transducer use (>13 MHz) is advocated for these nerve blocks. Higher frequency ultrasound transducers allow better differentiation of the structures at the depth of 0–3 cm. Use of colour or Doppler mode may help distinguish vasculature, especially arteries which are rarely compressible. It is practical to search for the anatomical landmarks such as foramina, notches, and vascular structures during the ultrasonographic scan. Bony structures present as hyperechoic (bright) lines with an anechoic (dark) shadow beneath. A gap in the hyperechoic line may indicate a notch or foramen. Block performance during real-time visualization should be done very cautiously since the distance to be advanced by the needle is very short or superficial for periorbital nerve blocks. Furthermore, needle tip location and the spread of the LA should be observed during the block to prevent direct nerve injury by the needle or the LA volume itself. The sterile technique should be preserved throughout the ultrasound-guided block performance.

Local Anaesthetic Agents and Adjuvants

Local anaesthetics (LAs) are essential components for topical, local and block anaesthesia. LAs had been first introduced to clinical practice for ophthalmic anaesthesia. Topical administration of cocaine as the first LA agent by Karl Koller opened a new era in surgical anaesthesia.

LAs act on the cell membrane to prevent the generation and the conduction of nerve impulses. Their main action site is voltage-gated Na^+ channels. The open and inactivated states of voltage-gated Na^+ channels have higher affinity to LA drugs than the resting state. In ophthalmic practice, reversibly blocking Na^+ channels inhibits painful nerve impulses from the cornea, conjunctiva, sclera, and orbital tissues.

Local anaesthetics are poorly water-soluble and weak base molecules. However, commercially available LAs are generally water-soluble salts to increase the stability of the LA, but LAs become more charged in these mildly acidic solutions. Higher concentrations ensure rapid onset, whereas lipid solubility allows a greater potency. However, the onset of action of LA also depends on the route of administration and dose of the drug, while the longer duration of effect depends on the higher protein binding. All LAs contain an aromatic ring (hydrophobic part), an intermediate ester or amide bond and an amino group (hydrophilic part). LAs may be classified into two groups according to their chemical formulation as ester type and amide type LAs. Ester type LAs are metabolised by plasma esterase, such as plasma cholinesterase, whereas amide type LAs are degraded by the hepatic cytochrome P450.

In clinical practice, LAs can be grouped into three groups according to their duration of action: short (approximately 20–45 minutes) such as procaine, intermediate (approximately 60–120 minutes) such as lidocaine, mepivacaine and long (more than 2 hours) including bupivacaine, ropivacaine, and tetracaine. The chemical and clinical features of commonly used LAs in oculoplastic procedures are as follows:

Ester Type LAs

Cocaine has a historical significance and is known to the first non-synthetic local anaesthetic used in ophthalmic practice. It has an intense vasoconstrictor feature different than other LAs. Its use as an LA is nearly abandoned

due to its many undesirable effects during anaesthesia as well as substance abuse potential.

Tetracaine (amethocaine) is a highly potent, intermediate-acting local anaesthetic which is mostly used topically at 1% concentration in an aqueous form. It has a higher toxicity potential and repeated administration may also cause corneal epithelial impairment. It causes a burning sensation and pain during administration, which can be alleviated by cooling the solution.

Proparacaine hydrochloride is a short-acting LA, commonly used for topical administration. It is formulated in 0.5% aqueous solution. Its effect onsets within seconds and continues for approximately 15 minutes. Its burning sensation is reported to be less than tetracaine. Due to a rare, but severe and hypersensitivity reaction, it may cause large areas of necrotic epithelium, ground-glass appearance, and erosion of the cornea.

Oxybuprocaine is an ester-type local anaesthetic which is used extensively for topical anaesthesia in 0.4% concentration.

Amide Type LAs

Lidocaine is the most commonly used LA for oculoplastic procedures with its predictable and rapid onset (approximately 60 seconds), duration of action up to an hour and unexpected risk of toxicity. Its maximum dose is 4 mg/kg when administered alone and 7 mg/kg with epinephrine. It provides 30–60 minutes of action without epinephrine. This duration may be prolonged up to 2–4 hours with the addition of epinephrine. Its concentration is 4% during topical administration and total dose may be as high as 5 mg/kg during tumescent anaesthesia. Therefore, the patient should be monitored attentively for the possible risk of systemic toxicity since systemic absorption of the topically and tumescent applied drugs is relatively very high. Lidocaine in gel form is also efficient in providing anaesthesia in a dose-dependent manner. Lidocaine is also effectively used for subconjunctival, transconjunctival and intracameral application.

Prilocaine is an intermediate-acting LA very similar to lidocaine. It is administered at 2–4% concentrations for infiltration and topical anaesthesia, respectively. It is also available in a eutectic mixture of local anaesthetics with lidocaine, which is commonly used to alleviate the pain before LA injections to eyelids and periocular botulinum toxin injection. High doses of prilocaine exceeding 7 mg/kg or a total dose of 500 mg lead to methemoglobinemia as a sign of systemic toxicity which should be treated with methylene blue in a dose of 1–2 mg/kg (except in patients with known G6PD deficiency) and ascorbic acid (vitamin C).

Bupivacaine is a highly lipid-soluble and potent agent with slow onset (10–25 minutes) and prolonged duration of action (up to 6–8 hours) with a narrow therapeutic index. It has a severe cardiotoxicity potential above its maximum dose of 2–3 mg/kg.

Levobupivacaine is the pure S (-) isomer of bupivacaine. Its clinical features are very similar to bupivacaine, however, with less potential cardio- and neurotoxicity.

Ropivacaine is an LA similar to bupivacaine with slow onset and long duration of action; however, its cardiac toxicity and potency are less than bupivacaine. It is used in 0.75–1% concentrations for topical, local and block anaesthesia.

Etidocaine is used in 0.5–1.5% concentration enabling rapid-onset, prolonged duration, and intense motor blockage during ophthalmic regional anaesthesia.

Mepivacaine used at 2–3% concentrations in ophthalmic practice, is similar to lidocaine with longer duration of action.

Adjuvants have been added to LAs to provide an early onset, longer duration, less pain during injection, less bleeding and less systemic effects.

LAs are frequently accompanied with ***epinephrine*** (1:100.000–400.000) to slow down the systemic absorption and decrease bleeding during oculoplastic procedures. Duration of action may be prolonged by 50% when epinephrine is added to intermediate-acting and natural

vasodilator LAs. However, adding epinephrine to long-acting LAs usually do not provide the advantage of longer duration but only less bleeding and less systemic absorption. Addition of epinephrine to the local anaesthetics before infiltration enables less bleeding during the surgery and this practice reaches maximal haemostatic effect in 7 minutes and waiting longer doesn't offer a further decrease in bleeding. Periocular injections with epinephrine are a relatively contraindicated in patients with untreated narrow angles because of pupillary dilation. It should also be kept in mind that the use of vasoconstrictors with LA during ophthalmic surgery may also reduce retinal artery blood flow and lead to vision loss and this should be avoided during retrobulbar, peribulbar, sub-Tenon blocks and during regional administrations close to vascular structures. Lower concentrations of epinephrine may help avoid such complications.

Sodium bicarbonate is another adjuvant used with LAs to increase the pH of them to accelerate the onset of action slightly and alleviate injection pain. It is reported to be used in a ratio of 1: 10–31 (sodium bicarbonate: LA). However, it may cause precipitation of the solution.

General Anaesthesia

Sedation and general anaesthesia management are not very detailed for oculoplastic surgeries. Sedoanalgesia with short-acting benzodiazepines such as midazolam and opioids such as alfentanil and remifentanil for oculoplastic surgery under local anaesthesia enables low pain scores and high patient satisfaction as well as maintaining the requirements of outpatient setting. Ketamine is an NMDA receptor antagonist and provides a dissociative state when administered. The main advantages of ketamine are its good analgesic potency and minimal effect of respiration; however, it may cause agitation and hallucinations when it is not accompanied by a benzodiazepine. Propofol may also be used at sedative doses while periocular LA injections. Monitored anaesthesia care has been reported to provide effective anaesthetic conditions even for enucleations and eviscerations.

General anaesthesia techniques must meet a few particular needs of oculoplastic surgery. In terms of hypnotics, any intravenous and inhalation anaesthetics can be used to provide induction and maintenance of the general anaesthesia. Total intravenous anaesthesia may provide the advantage of rapid recovery and discharge from the hospital. Laryngeal mask airway insertion or intubation may secure the airway effectively and can be used according to the operation site if there is no emergency case with a full stomach. The use of neuromuscular blocking agents is frequently limited to non-depolarizing ones. Patients undergoing oculoplastic surgery under general anaesthesia experience postoperative pain and discomfort by 32.1% and 28.3% respectively. Anxiety, prior surgery in the eye and smoking are the predictors of postoperative pain and discomfort following general anaesthesia in this patient population. Management of preoperative anxiety, postoperative pain, and prevention of postoperative nausea and vomiting should be an essential part of the anaesthetic plan. The main recommendation for sedation and general anaesthesia is the existence of a physician, preferably an anaesthesiologist, monitoring and managing the patient.

Challenges of Anaesthetic Management During Oculoplastic Surgery

Specific anaesthetic challenges during lacrimal, orbital and oculoplastic surgery must also be highlighted. These issues include challenging patients and challenging procedures.

Challenging Patients

The patients' anaesthetic needs have been expected to be low for many oculoplastic surgeries which are performed at an office setting. However, the patients undergoing surgery due to oculoplastic disorders may be too young, too old, or may have serious co-morbidities. These

patients may have increased malignant hyperthermia risk due to neuromuscular disorders, considerable hormonal alterations, or metabolic disorders, systemic manifestations of malignancies which may affect anaesthetic management.

The patients with ptosis and strabismus who may have oculoplastic surgery are specifically at risk of ***malignant hyperthermia*** (MH). MH is an autosomal dominant disorder of skeletal muscle, mostly caused by a defect in the ryanodine receptor. It is a hypermetabolic response triggered by inhalational anaesthetics and succinylcholine, a depolarizing muscle relaxant. The incidence has been reported to range from 4 to 100 in one million cases. The clinical signs of MH include hyperthermia, tachycardia, tachypnea, increased end-tidal carbon dioxide, acidosis, hyperkalemia and muscle rigidity. Increased oxygen consumption and rhabdomyolysis also co-exist. The risk of malignant hyperthermia may jeopardize or alter general anaesthesia plans. Detailed family history regarding general anaesthesia and related mortality is essential during the preoperative assessment of these patients. Early suspicion and recognition of the MH is the key for immediate treatment. General anaesthesia may be acceptable when precautions are in place with close follow-up. However, regional anaesthesia techniques should be preferred if possible especially in patients with concomitant neuromuscular or metabolic diseases such as Kearn-Sayre Syndrome. When MH is initiated, the management plan includes cessation and removal of the inhalational anaesthetics, external cooling, and supportive therapy and, mainly, the administration of dantrolene sodium. Increased understanding of the pathophysiology and better intraoperative monitoring systems enabled a considerable decrease in mortality the last few decades.

The patients with ***thyroid eye disease*** may also represent a challenge for anaesthetic management. These patients usually undergo orbital decompression surgery. They may present to the operating room with considerable hormonal alterations since both hypo- and hyperthyroidism has ophthalmic manifestations. Both disorders may affect the eye and surrounding tissues via auto-immunity by antibodies to eye muscles and fat tissue. These patients should have thyroid function tests preoperatively to check euthyroidism which is the preferred state. Elective surgery should be deferred until the patient has been rendered euthyroid and appropriate medication has started to control cardiovascular response due to disease. During anaesthetic management of hyperthyroid patients, the agents that can stimulate the sympathetic nervous system, such as pancuronium, ketamine, direct and indirect adrenergic agonists, should be avoided. Exaggerated hypotensive response during induction may be observed, however exaggerated hypertensive response is also possible due to inadequate anaesthetic depth before laryngoscopy or any surgical stimulation. Epinephrine should not be added to local anaesthetics. In patients with hypothyroidism, increased sensitivity to anaesthetic agents, delayed recovery, hypothermia, poor tolerance to blood loss are expected. Inhalational anaesthetics may exaggerate cardiac depression in very symptomatic hypothyroid patients. Neuromuscular monitoring is also recommended for titrating neuromuscular blocking agents and timing of tracheal extubation in these patients. Opioids should be used attentively. Another concern in thyroid eye disease patient is difficult airway management due to tracheal compression or deviation by overgrown thyroid gland or tumour. Patients should be evaluated for difficult ventilation and/or intubation preoperatively and difficult airway management measures should be readily available in the setting.

Patients with orbital tumours with systemic malignancies or systemic tumours with orbital metastasis may also need ophthalmic surgery. Especially, melanoma has cardiac involvement which is usually in the right chambers of the heart. On the other hand, renal cell carcinoma, breast cancer, angiosarcoma, lymphoepithelioma, and hepatocellular carcinoma have been reported to have orbital metastasis. Here, the primary disease and its systemic effects are the major concerns during anaesthesia. These patients should be evaluated individually and the anaesthetic management should be tailored accordingly.

Challenging Procedures

One of the brief but challenging procedures is ***probing and nasolacrimal intubation***. It is the most frequent lacrimal operation in children. Tracheal intubation, laryngeal mask airway, and mask ventilation are possible ways to secure ventilation. Although this a very brief intervention in experienced hands, the main concern during this procedure are sharing the airway with the surgeon and the possible risk of aspiration of blood or saliva when the airway protective devices aren't used during a sedation technique. General anaesthesia with inhalational or intravenous anaesthetics is both feasible. However, only sedation is mostly the frequent anaesthetic technique at an office-based setting, which is practical as well as highly satisfying according to the parents. Probing and nasolacrimal intubation is also one of the rare ophthalmic surgeries possibly indicating infection prophylaxis for endocarditis in patients at high risk, however the results of the studies about the issue are still controversial.

Another procedure that needs more attentive anaesthetic management is ***orbital fracture surgery***. Orbital surgeries often present as an emergency due to trauma which occurs frequently with the problem of full stomach and underevaluation of the patient. A difficulty in airway management such as insufficient mask ventilation or unsuccessful intubation as well as a need for fast induction and smooth intubation may co-exist. The patients with orbital fractures may also have concomitant intracranial pathologies or dural tears. The anaesthesia measures during these surgeries must also meet the needs of neuroprotection.

Enucleation, ***evisceration, exenteration and socket reconstruction*** may also represent a challenge for anaesthesia and ophthalmology teams since patients may experience severe postoperative nausea and vomiting and pain. These adverse events prevent early discharge from the hospital. Postoperative acute pain is usually localized to the remaining orbit and responds well to paracetamol, NSAIDs, and opioids. Perioperative regional techniques may also provide efficient pain relief. In the late postoperative period, phantom eye syndrome may be present as any sensation as originating in the eye despite it was amputated. These sensations include painful sensation such as cutting, penetrating, shooting or superficial burning pain, itching, feeling of non-existent eyelids and visual hallucinations. The medical therapy frequently consists of tricyclic antidepressants, anticonvulsants, ß-blockers, IV calcitonin, NMDA antagonists and rarely opioids.

Summary

Anaesthetic management for oculoplastic surgeries mainly requires a thorough knowledge of anatomy, local anaesthetic pharmacology, and particular adjustments according to the specific needs of the surgery. Periocular blocks usually provide intraoperative anaesthesia and postoperative analgesia effectively; however, general anaesthesia is still a custom practice for a specific patient population such as children and specific surgeries such as dacryocystorhinostomy.

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Part II
EyeLid Disorders

Benign Lid Lesions

Rania A. Ahmed

Background

Various lesions can be detected in the eyelid due its diverse composition. The skin epidermis is keratinized stratified squamous epithelium while its dermis contains cilia in addition to modified sweat and sebaceous glands. The tarsus also contains Meibomian glands which are modified sebaceous glands while the lining conjunctiva contains accessory lacrimal glands and goblet cells. The majority of the lid lesions are benign, but their identification is important for proper treatment and ruling out malignancy.

Benign lesions are usually uniform with regular borders and show slow growth. They usually don't show induration, ulceration or lid margin destruction and can be classified according to:

- Structure of origin to epidermal, dermal or adnexal
- Clinical appearance either solid or cystic
- Location whither related to the lid margin, pretarsal area or supra/infra tarsal region.

Generally, the clinical appearance is highly suggestive of the lesion nature yet, when in doubt, a biopsy is required to confirm the diagnosis. Biopsies are either incisional which entails removal of a part of the lesion or excisional in which the lesion is totally removed thus, additionally provides a cure.

Treatment options in general include total excision of the lesion, with special attention to removal of the walls in case of cysts, marsupialization i.e. removal of the top of the cyst if excision is not feasible and surface ablation in superficial lesions.

Some of the common benign lid lesions are described below.

Seborrheic Keratosis (Basal Cell Papilloma)

This is extremely common asymptomatic benign proliferation of the epithelium basal cells that shows slow increase in size and number with age.

The lesions are superficial, usually present on the face, trunk and extremities of the elderly patients. They are either single or multiple; typically with a well defined edge, rough surface and classically described to have a greasy, ***stuck on*** appearance. According to the degree of skin pigmentation, the lesion's color varies from flesh color to dark brown (Fig. 1). Large and flat lesions may show pits filled with keratin. In the eyelid area, the lesions appear wrinkled. Seborrhoeic keratosis should be differentiated from pigmented basal cell carcinoma, neavus and malignant melanoma

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_3

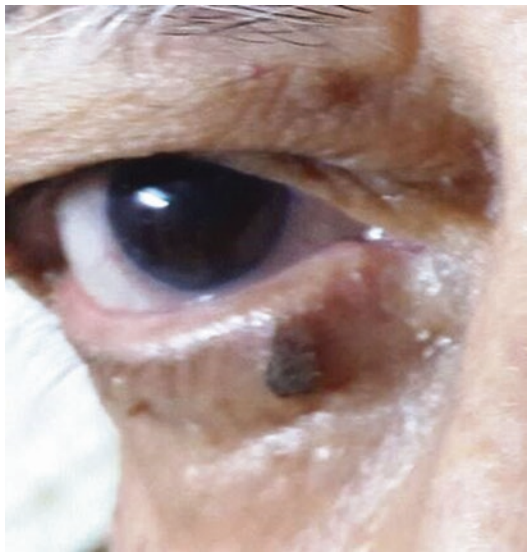

Fig. 1 Upper and lower seborrheic keratosis. The one in the lower lid is more pigmented

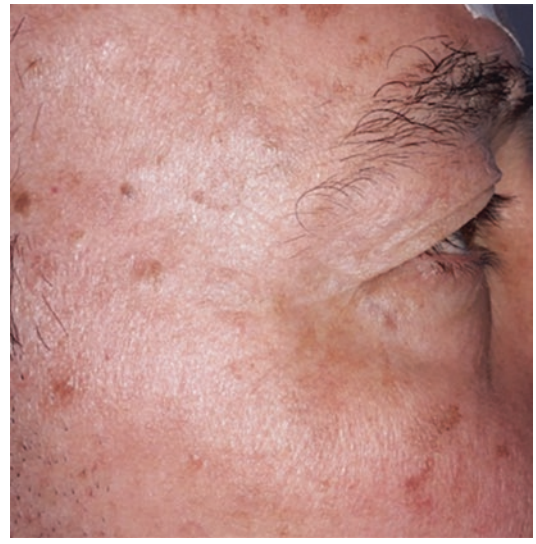

Fig. 2 Multiple actinic keratosis lesions

Sudden onset of multiple seborrheic keratoses is associated with systemic malignancy, classically gastrointestinal adenocarcinoma. This is known as Leser-Trélat sign.

Pathologically, there is proliferation of basal cells of the epidermis, acanthosis and hyperkeratosis with variable pigmentations. It may contain pseudohorn cysts that are formed by infoldings of the epidermis and appear as cysts in cross section filled with keratin.

Treatment

Total surgical excision, however, shave excision at the epidermal-dermal junction could also be done. Laser ablation, cryotherapy and chemical peeling are available options.

Actinic (Solar/Senile) Keratosis = Sun Damaged Skin Lesions

The ultraviolet rays are largely responsible for face aging and this damage is common and more profound in fair skinned individuals. The sun damaged skin is thin with deep wrinkles, variable pigmentations and visible blood vessels. The presence of such signs suggest that the patient is at risk of developing skin cancers.

Actinic keratois is a common slowly growing skin lesion that is rarely seen in the eyelid. The lesions appear as part of solar skin damage and they may turn to squamous cell carcinoma.

They appear as flesh colored, yellow or brown plaques with distinct borders and a rough dry scaly surface (Fig. 2). Pathologically, there is epithelial dysplasia with hyperkeratosis and parakeratosis.

Treatment

Surgical excision, cryotherapy or topical 5FU in selected cases. Patients should be closely monitored by a dermatologist for the development of squamous cell carcinoma.

Cutaneous Horn (Fig. 3)

These are non specific hyperkeratotic lesions that may be associated with variable lesions whether benign or malignant. They need surgical excision

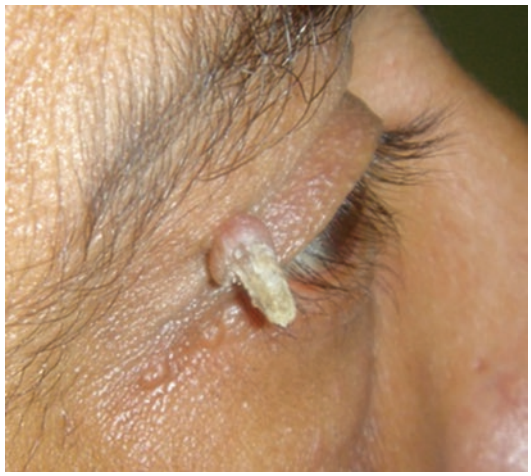

Fig. 3 Cutaneous horn

Epidermal Inclusion Cyst/Epidermoid Cyst

An epidermal inclusion cyst (EIC) is a dermal implantation cyst of epidermis. It can be congenital occurring along the closure lines (**epidermoid cyst**) or acquired following trauma or surgery.

It is a small, slow-growing, round, smooth, white lesion that could be either superficial or subcutaneous (Fig. 4). It is usually firm and opaque on transillumination due to its ***keratin*** content. It may get infected or ruptured with an associated inflammatory reaction.

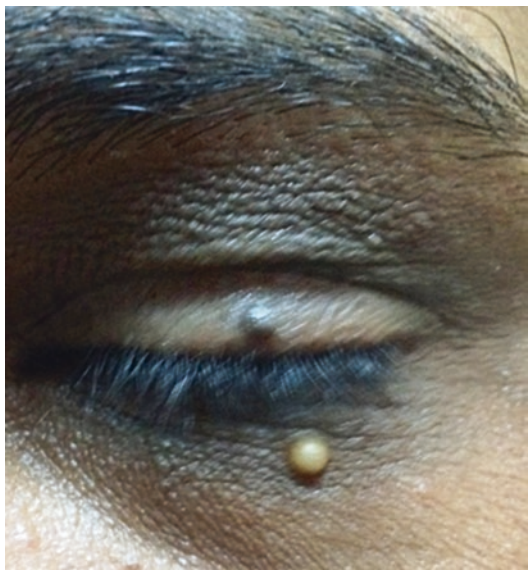

Fig. 4 Upper and lower lid epithelial inclusion cysts

Treatment

Excision or marsupialization.

Adnexal Lesions

Skin adnexa including sebaceous and sweat glands as well as hair follicles are placed in the dermis and can give an origin to a wide variety of, usually, benign lesions.

The sebaceous glands of the eye lid include; the Meibomian gland of the tarsus, glands of Zeis that are related to the eye lashes and the sebaceous glands related to hair of the eyelid skin as well as the hair of the eye brow.

The sweat glands of the eye lid are either eccrine glands (that have a true secretory duct) that are present everywhere in the body skin including the eyelid or apocrine glands (that have no duct and secrete by cellular decapitation) that are present in relation to eyelashes and known as glands of Moll. They are discussed in chapter "**Periorbital Dermatology and Oculoplasty**".

Chalazion/Hordeolum

A chalazion is a chronic lipogranulomatous inflammatory process that occurs in the eyelid. It results from obstruction of the meibomian glands (deep chalazion) or sometimes Zeis glands (superficial chalazion) orifices with retention of sebaceous secretions that may leak to the surrounding tissues inducing a granulomatous inflammatory reaction.

Pathologically, there is lipogranulomatous inflammation surrounding a clear space (previously occupied by lipids that dissolve on processing). It contains neutrophils, plasma cells, lymphocytes, epithelioid cells and multinucleated giant cells (touton giant cells) that have a

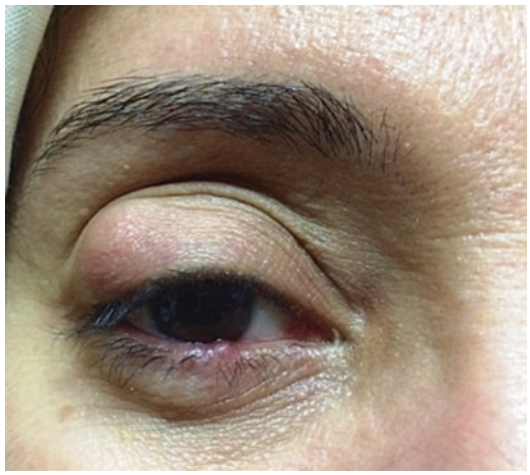

Fig. 5 Upper lid large chalazion inducing mechanical ptosis while the lower lid shows marginal chalazion

central foamy cytoplasm corresponding to the ingested lipids.

The lesion is a slowly growing painless hard nodule that may start de novo or follow an attack of acute inflammation (hordeolum). It is commonly associated with blepharitis and rosacea both of which usually present with recurrent multiple chalazia.

The deep chalazion bulges towards the conjunctival side and is usually associated with mild inflammatory reaction or a conjunctival granuloma. It is better felt than seen and the orifice of the affected gland may show inspissated sebum (Fig. 5).

A marginal chalazion (Fig. 7) is located at the lid margin either is connected to a deep chalazion or due to blocked Zeis gland. Vision is usually preserved yet may be temporary affected with large chalazia either due to mechanical ptosis or induced corneal astigmatism. Carcinoma should be ruled out in cases of recurrent lesion within the same place especially in the elderly.

If any of these glands become infected with pyogenic bacteria, a ***hordeolum*** is formed which is usually painful, red, tender and can be associated with preseptal cellulitis. It is called ***hordeolum internum*** (Fig. 6) if the Meibomian gland is affected and ***hordeolum externum or stye*** if Zeis gland is affected.

Treatment

- Conservative treatment:
  This includes warm compresses 15 minutes 2–4 times per day, lid massage and expression of inspissated sebum at the Meibomian gland orifices especially in recent chalazia. These measures are effective in at least a third of cases.
- Treatment of risk factors:
  - Blepharitis: via lid hygiene
  - Systemic tetracycline such as oral doxycycline 100 twice per day or minocycline 50 mg once per day, can be used in cases associated with rosacea and in recurrent cases.
- Antibiotic (topical and oral):
  They are reserved to cases with significant bacterial infection as chalazia are inflammatory, not infective lesions.
- Intralesional steroids:
  Injection of 0.1–0.2 ml of triamcinolone 40 mg/ml into or around the non infected lesion is reported to have a similar outcome to surgical removal. It is usually used in cases of multiple or marginal chalazia or those related to the upper lacrimal system. Injection can be repeated after 1–2 weeks especially with large lesions.
  However, it may result in localized skin atrophy and depigmentation, though uncommon, it can be avoided by injecting through the conjunctival side. Few reports of retinal vascular occlusion are present due to inadvertent intravascular injection with distant embolization.
- Surgical excision:
  It is reserved for persistent lesions. It is usually an outpatient procedure unless general anesthesia is required, or an operating microscope is needed for juxta punctal chalazia.

Technique

After local anesthesia is infiltrated and topical anesthetic instilled, a chalazion clamp is applied and the lid is everted.

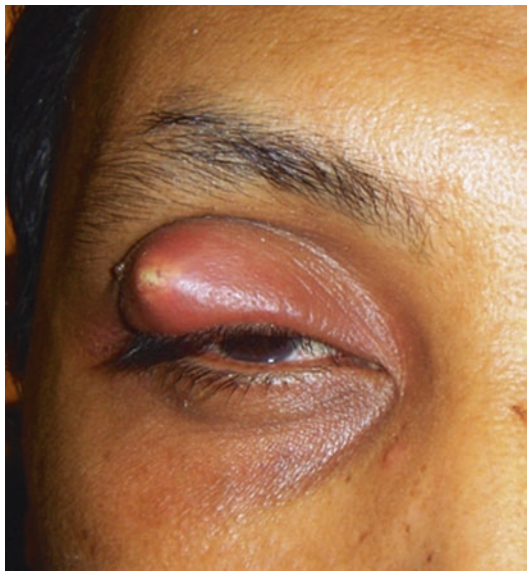

Fig. 6 Hordeolum internum of the upper lid

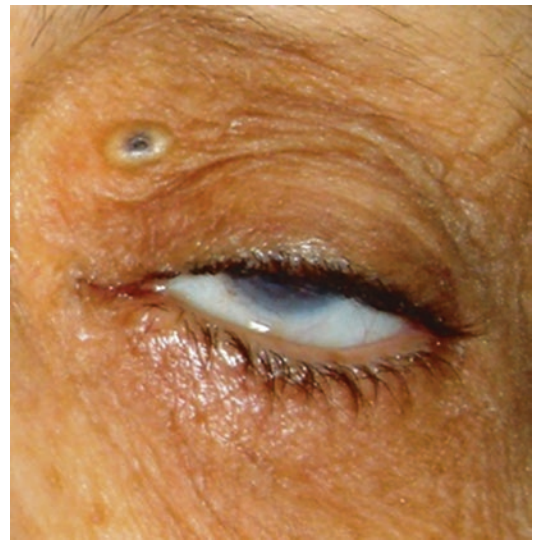

Fig. 7 Sebaceous cyst of the upper lid with comedo head

A vertical incision is done through the tarsus using a no 11 blade and the cyst contents are curetted. If the content was solid or in cases of recurrence, an incisional biopsy is taken for histopathological correlation.

The wall of the cyst is removed as much as possible. Temporary gentle compression is then applied to the lid to ensure hemostasis. Topical antibiotic ointment is instilled by the end of the surgery and the eye is patched for a couple of hours.

Surgical removal of marginal chalazion can be done in a similar way by placing a the incision across it, better from the conjunctival side without cutting down to the lid margin. The contents are also scraped.

Sebaceous/Pilar Cyst

It occurs due to blockage of a sebaceous gland related to pilosebaceous unit. It is not common in the eyelid yet may occur near the medial canthus and eye brow (Fig. 7).

Sebaceous Hyperplasia

A common lesion that occurs due to proliferation of the sebaceous gland elements. It is usually found on the cheek, nose and forehead. It appears as a yellow papule with raised irregular margins and central umbilication that shows slow growth.

Benign Pigment Cell Lesions

Any type of skin lesion could contain melanin and be pigmented. It is important to differentiate between pigment cell lesions (that originate from melanocytes) and pigmented lesions.

Freckles (Ephelides)

Multiple, small, well circumscribed red brown macules (Fig. 8) that occur in the sun exposed areas and get darker upon sun exposure. They

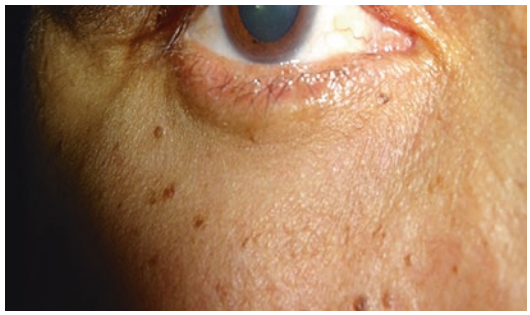

Fig. 8 Multiple freckles on the cheek and lower lid

result from hyperpigmentation at the basal cell layer of the epidermis due to increased melanin content without change of the melanocytes number.

Treatment

Using sun screens as well as covering with cosmetics can improve the appearance.

Melanocytic Nevus (Mole) = Acquired Melanocytic Nevus

It is a collection of melanocytes in the skin either congenital or acquired. Acquired nevi are not present at birth yet they start to appear in childhood as junctional nevus where they appear flat and get deeper in color towards puberty. The nevus becomes raised and acquire dome shaped appearance by the middle age as it turns into a compound nevus. As the nevus gets older, it becomes intradermal, remains elevated while its color fades. The clinical appearance and the potential for malignant changes is determined by the location of the nevus

a Junctional: (Fig. 9): it lies at the junction between the dermis and epidermis. It is usually dark brown flat lesion with uniform color. Malignant transformation is low.

Fig. 9 Upper lid junctional naevus lid

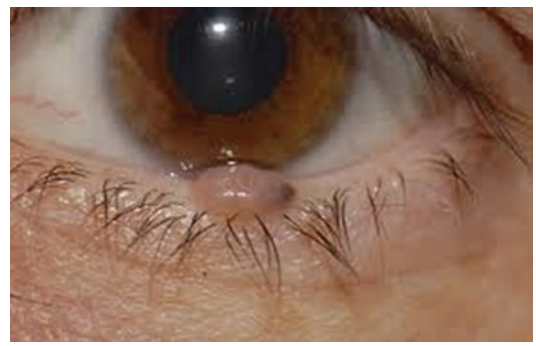

Fig. 10 Compound nevus of the lower

b Compound: (Fig. 10): it extends from the epidermis to dermis. The potential to turn malignant is low and related to its junctional component.
c Intradermal: it lies entirely in the dermis. There is no potential of malignant transformation.

Nevi are frequently found on the periocular skin, eyelids and eyelid margin. Atypical or dysplastic moles can occur. In atypical mole syndrome (AMS) multiple dysplastic moles are present and are associated with increased risk of developing conjunctival and iris nevi as well as skin and, conjunctival and uveal melanomas.

Treatment

Treatment is indicated for cosmetic reasons or if malignant changes are suspected. Surgical excision should be complete in most cases. If the lesion is on the lid margin, wedge resection is required. In some elderly intradermal nevi, shave excision may be useful.

Congenital Melanocytic Nevus

This is a nevus that appears at birth. It varies in size from a small lesion to a large one that covers an entire area. It is usually dark, uniform in color and may be hairy. Kissing nevi are form of congenital nevus that develop on the eyelid while still fused in utero so the nevi will be located opposite each other in the upper and lower eyelids. It has a high potential for malignant transformation and if indicated, total surgical excision is the treatment of choice.

Vascular Lesions

These include vascular benign tumors such as **Capillary hemangioma and port wine stain.** **(see chapter "Periorbital Dermatology and Oculoplasty")**

Suggested Readings

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Malignant Lid Lesions

Kareem B. Elessawy and Aliaa A. Farag

Introduction

Lid and periocular skin lesions are common finding that encounter most of the ophthalmologists. The main goal of the general ophthalmologist is to exclude malignancy. Certain points in history taking and clinical examination help to rule out malignant lesions.

Features suspicious of malignancy:

- Recent onset
- Increasing in size
- Change in color or multiple colors
- Ulceration
- Telangiectasia
- Pearly borders
- Ill-defined margins
- Distorted anatomy e.g. loss of lashes, distorted lid margin
- Recurrent lesion e.g. recurrent chalazion
- Pain disproportional to the lesion i.e. peineural spread
- History of irradiation e.g. for acne, retinoblastoma
- History of other malignancies
- Immunosuppression

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Biopsy, either incisional or excisional is required in suspicious cases for definite tissue diagnosis. Histological examination is essential for both definite diagnosis and differentiation between different malignant lid tumors.

Basal Cell Carcinoma (BCC)

BCC is a common, slowly growing, locally malignant epidermal skin tumor that has a higher prevalence in Caucasians.

BCC is the commonest human malignancy (about 80% of non-melanoma skin cancers). BCCs usually occur between 5th and 8th decades of life.

It is more common in the lower eyelid or medial canthus. It may be associated with other BCC located elsewhere on the face in 60% of these patients. The eyelids and nose are the commonest sites of BCC in young adults.

The most important risk factor for BCC is exposure to ultraviolet radiation. However, the exact relation between risk of basal cell carcinoma and the amount, duration and pattern of exposure to ultraviolet radiation is not fully understood.

People with skin type 1 (skin always burns, never tans on exposure to sun light), fair hair, and light colored eyes have been shown to be risk factors for the development of basal cell carcinoma.

E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_4

A positive family history of skin cancer is also a risk factor for development of basal cell carcinoma.

Other environmental factors that have been associated with increased risk of basal cell carcinoma include; ionizing radiation, high fat diet, low vitamins intake, many chemicals as arsenic and dust.

Previous irradiation to head and neck and immunosuppression also increase the risk of basal cell carcinoma.

Smoking and fluorescent lighting does not seem to increase risk of basal cell carcinoma.

Several precancerous conditions are associated with the risk of developing basal cell carcinoma as albinism, xeroderma pigmentosa, Bazex's syndrome, and the naevoid basal cell carcinoma syndrome (Gorlin's syndrome).

These syndromes either decrease pigments level in the epidermis with increased risk of UV light-induced oncogenic transformation or develop epidermal genotypic instability.

Desmoplastic trichilemmoma is a condition associated with different atypical basaloid changes as acantholytic processes of diverse type, warts, porokeratosis, neurofibromata, nevi sebaceus and epidermal nevi, condylomata accuminata, hemangiomas, cysts of hair follicle derivation, pilomatricomas and a variety of common skin neoplasms such as seborrheic keratoses and melanocytic nevi. BCC can occur also in up to 19% of the cases. Basal cell carcinoma have also been reported in association with a common dermal fibrosis reaction to trauma (i.e. dermatofibroma)

Typically, basal cell carcinoma is indolent and slowly growing. It usually spreads by infiltrating the surrounding tissues in finger-like outgrowths. It is mostly not associated with metastasis to regional lymph nodes or distant organs. The morbidity associated with BCC is related to local tissue invasion and destruction, especially on the head and neck. However, metastasis may occur in large, locally aggressive, neglected and recurrent lesions.

Clinical Picture

BCC vary widely clinically, presenting as; nodular, cystic, ulcerated ('rodent ulcer'), superficial, morphoeic or sclerosing, keratotic and pigmented variants as shown in Fig. 1.

Early the lesion is small nodule, may be translucent, with pearly margins, with surface telangiectasia as shown in Fig. 2.

The classic picture is the rodent ulcer, with indurated base, rolled in edge and ulcerated center as shown in Fig. 3.

Although this tumor is slowly growing but, if left untreated, it may spread deeply to the surrounding tissues, especially around the eye, nose, or ear even into the periorbital tissues and bone.

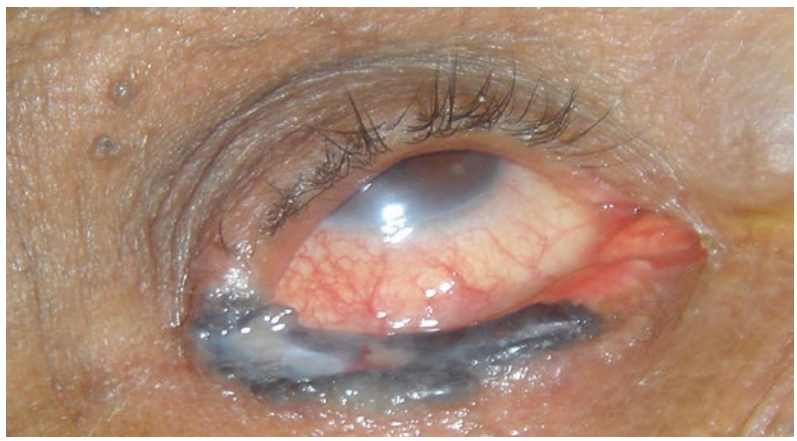

Fig. 1 Pigmented basal cell carcinoma of the lower lid (Courtesy Rania A Ahmed, M.D.)

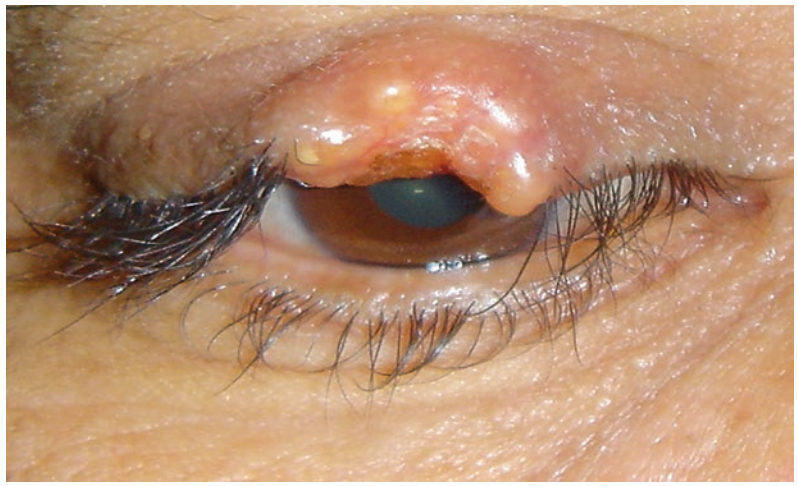

Fig. 2 Nodular basal cell carcinoma of the lower lid (Courtesy Rania A Ahmed, M.D.)

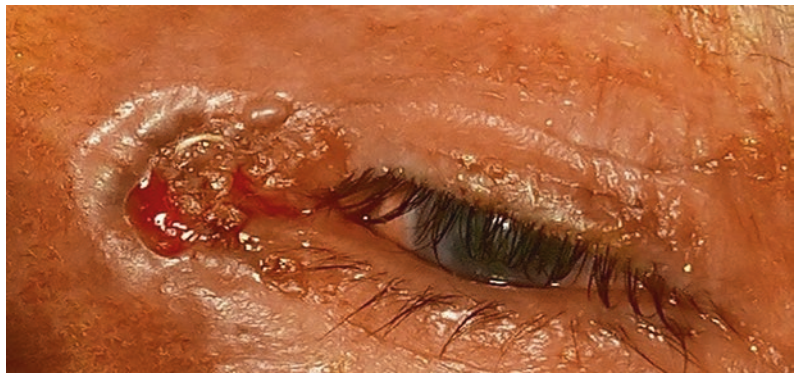

Fig. 3 Basal cell carcinoma (rodent ulcer)

Superficial basal cell carcinoma is flat well demarcated erythematous plaque, that usually occurs on the trunk. Psoriasis, discoid eczema, and Bowen's disease may produce a similar picture and should be included in the differential diagnosis. Superficial variant is particularly slow growing when compared to other types.

Nodulocystic basal cell carcinoma appears as a solitary red nodule with surface telangiectasia, it usually develops on the face.

The most important clinical subtype is the morphoeic basal cell carcinoma. It is the most aggressive type with ill-defined borders, making complete excision difficult. This type of basal cell carcinoma is difficult to be diagnosed clinically and is usually detected in late stage. Some of these tumors reach a very large size that require lengthy surgical reconstructions and is usually associated with significant cosmetic disfigurement. It represents 5% of all BCC variants.

Differential Diagnosis

Differential diagnosis includes squamous cell carcinoma, malignant melanoma (pigmented), melanocytic naevi (pigmented), Bowen's disease (especially superficial), psoriasis and eczema (superficial), molluscum contagiosum.

Prognosis

Prognosis depends on several factors as tumor size, tumor site, clinical type and margins definition, growth pattern and histological subtype. Poor prognostic factors include recurrent tumors and immunocompromised patients.

A BCC greater than 5 cm in diameter is called a "giant BCC" and is associated with a higher risk of morbidity and mortality. Also, BCC arising in a young person than 35 years of age may show more aggressive course.

Recurrent BCC

Recurrence can occur in about 10% of BCCs treated by conventional management, either surgical excision or curettage followed by fulguration of the lesion base. The recurrence rate is related to the margin positivity after attempted surgical excision, at least 4 mm free safety margins are required after surgical excision. Incidence of recurrence varies according to the histological type, being highest for the aggressive variants (for example 26.5% for morhoeic infiltrative BCCs) and lowest in the indolent variants (e.g. 6.4 and 3.6% for nodular and superficial BCC, respectively).

After the introduction of Mohs micrographic surgery, the recurrence rate is lessened to be about 1%. The recurrence rates may also vary according to the anatomic site.

Most of recurrences occur within the first 3 years following the original surgery; however, 20% of recurrences may occur later between 6 and 10 years after the original operative procedure. The risk of further recurrence after management of a recurrent lesion is said to be higher, in the range of 40%.

Recurrent BCC presents clinically by areas of induration, erythema, ulceration or bleeding at the surgical site for known BCC. The histopathology of recurrent BCC is usually more aggressive growth than indolent growth variant. The presence of scar tissue of the previous surgery usually disrupts the pre-existing original anatomy. It also shows no connection to the overlying epidermis or to pre-existing follicular structures. A strong positive correlation is found between the surgical margins clearance and the recurrence rate.

Nevoid BCC (Basal Cell Nevus) Syndrome

The nevoid BCC syndrome (Gorlin–Goltz syndrome) is an autosomal dominant trait with some sporadic mutations in about 30–50% of case. Although the syndrome is typically expressed in young adulthood, it may appear in children as young as 2 years of age.

The clinical manifestations of nevoid BCC syndrome include the presence of multiple BCCs, mainly nodular, superficial, and nodular cystic variants. Patients may also develop pitting of the palms and the soles of the feet, jaw cysts, bone anomalies in spine and rib, and calcification of the falx cerebri.

Differential diagnosis includes tumor syndromes that can form basaloid adnexal neoplasms as Muir–Torre syndrome and Cowden's syndrome but these form neoplasms with sebaceous and trichilemmal differentiation.

Squamous Cell Carcinoma (SCC)

Squamous cell carcinoma is an invasive malignant tumor that arises from the squamous cell layer of the skin epithelium.

It is the second most common malignant eyelid tumor after BCC.

It may occur in different locations, such as: esophagus, anus, lungs, head, neck, prostate, urinary bladder, vagina, and cervix.

In the eyes, it affects specially the lid, the conjunctiva and the cornea.

It may develop de novo but often it may arise on top of preexisting lesions such as actinic keratosis, xeroderma pigmentosum, carcinoma in situ (Bowen's disease), or after radiotherapy.

About 5–10% of all skin cancers occur in the eyelid, SCC represents about 5–10% of all types of skin cancer in the eyelids. It also may occur

in the palpebral conjunctiva representing around 5% of its malignancies.

SCC is more common in males. It usually occurs in elderly (the 7th and 8th decade of life, however may occur in younger age). It shows a higher prevalence in the lower lid more than the upper lid, in the inner canthus more than the outer canthus.

Important risk factors include: chronic exposure to Ultra Violet (UV), arsenic and exposure to oil derivate, active or even passive smoking, viral infections as Human Papilloma Virus (HPV) and Human Immunodeficiency Virus (HIV), precancerous lesions as xeroderma pigmentosa, skin lesions as albinism, on top of old burns, chronic ulcers and scars, previous irradiation and immunosuppression.

UVB exposure can induce mutations that disturb multiple cellular pathways which lead to the formation of SCC.

SCC exhibits defective genomic maintenance with the evolution of new mutations. The mechanism of genomic instability in keratinocytes is likely due to inactivation of p53 induced by UVB exposure.

Clinical Picture

The clinical types of carcinoma are variable and there are no pathognomonic features.

Sometimes, the tumor may be difficult to be differentiated from a basal cell carcinoma (BCC), but usually it does not have telangiectasia or superficial vascularization, it grows faster with more frequent hyperkeratosis.

The nodular SCC is shows a hyperkeratotic nodule with crusts and fissures as shown in Fig. 4.

The ulcerating SCC has a hyperemic base with well defined, hard and raised everted edges, but not pearly margins. Superficial vascularization and telangiectasia are not present as in BCC as shown in Fig. 5.

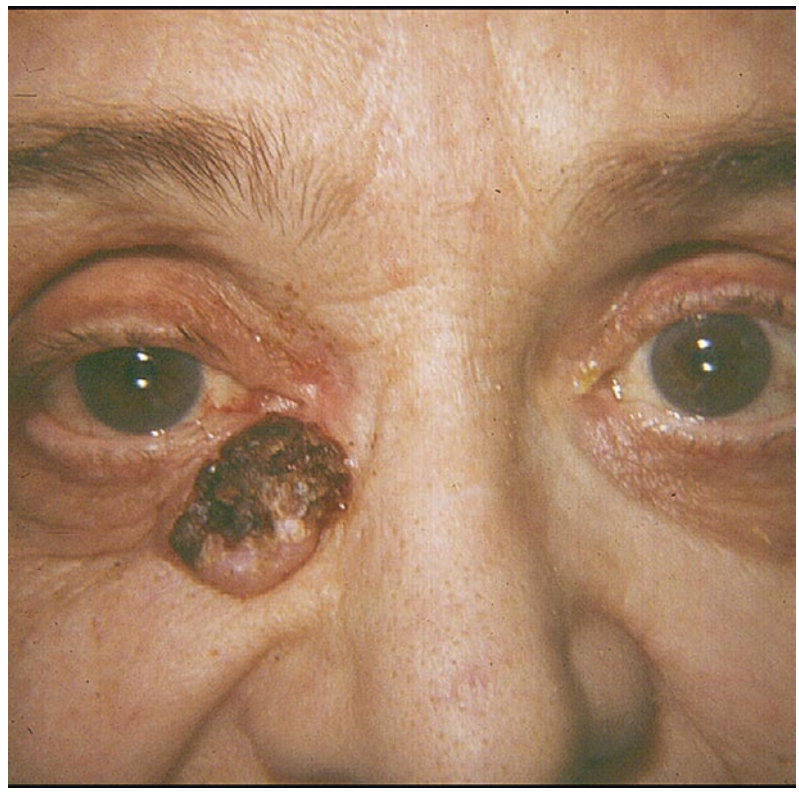

Fig. 4 Nodular squamous cell carcinoma of the lower lid (Courtesy: Essam Eltoukhy, M.D.)

Fig. 5 Ulcerative squamous cell carcinoma of the lower lid (Courtesy Rania A Ahmed, M.D.)

The histopathologic feature of SCC differs according to the degree of differentiation of the tumor. In well-differentiated tumors, the cells are polygonal with hyperchromatic nuclei and acidophilic abundant cytoplasm with, dyskeratosis and intercellular bridges. Poorly differentiated SCC shows evidence of anaplasia with pleomorphism, multiple abnormal mitotic figures, no or little keratinization and loss of intercellular bridges. Variants of SCC include spindle SCC and adenoid SCC.

The tumor may show metastasis to the regional lymph nodes or to distant organs. Perineural spread can occur in about 14%.

Perineural spread is characteristic for squamous cell carcinoma; it has the tendency to extend in the nerve sheaths, surrounding the nerve just beneath the perineurium. The perineural space acts as conduit with low resistance for malignant cell invasion. Malignant cells invade the perineural space with no significant invasion of the nerve itself. Imaging may be required for detection of the tumor invasion. Perineural invasion makes complete surgical excision more difficult and should be taken into consideration during histopathological examination. Unfortunately, perineural spread is associated with poorer outcome.

In Situ Carcinoma

It shows cytological abnormalities characteristics of malignancy as hyperchromatism, pleomorphism, frequent mitoses and loss of the architecture only in the epithelium, but with no evidence of invasion either locally or to distant metastases.

The squamous cell carcinoma in skin is known as Bowen's disease.

It appears as a brown spot, resistant to treatment that may be mistaken for psoriasis or eczema.

There is a strong association of Bowen's disease with HPV (human papilloma virus) infection, type 16.

Cutaneous Horn

A cutaneous horn is a formed of a base and a cap, the base is usually papule or nodule while the cap is a keratotic cap of different lengths and shapes, and it resembles an animal horn.

Clinically, it varies in size, color and shape; size varies from few millimeters to several centimeters, its color may be white, black or yellowish, it may be straight, curved, or spiral.

Histologically, it is also variable; it usually shows hypertrophic actinic keratosis, however it may show SCC in situ, or invasive SCC at its base. Because of the possibility of invasive SCC, any cutaneous horn should always be excised.

Actinic Keratosis

Actinic keratosis is the commonest precancerous skin lesions, it affects people in 4–7th decade of life, it occur in about 60% of fair-skinned population over the 4th decade of life.

Actinic keratosis appears as round or oval hyperkeratotic lesions with or without erythematous base, commonly seen in sunlight exposed areas.

Actinic keratosis is a direct precursor of invasive SCC and also it is considered a risk factor for other skin cancers. Although the incidence of progression to invasive SCC is rare, actinic keratosis is considered as a SCC in situ.

The main histological feature of actinic keratosis is keratinocytes dysplasia or maturation disorder.

Keratoacanthoma

Recently, it is considered as a variant of SCC, the lesion is typically a cup-shaped nodule with a central crater of keratin with elevated and rolled edges.

It usually develops within a short period (weeks to a few months) and may show spontaneous regression.

Histologically, these cup shaped nodules is formed of thickened epidermis containing areas of well-differentiated squamous epithelium surrounding a central mass of keratin. These epithelial islands may be infiltrated by neutrophils. The base of the lesion can be easily differentiated from the adjacent dermis by inflammatory reaction.

Cancer Stage Grouping

The stage of an eyelid SCC is given by combining the T, N, M, and G classifications: as shown below in Table 1.

Table 1 Squamous cell carcinoma cancer stage grouping

Stage	TNM	Local tumor	Lymph node	Distant metastasis
Stage 0	Tis N0 M0	Carcinoma in situ	No	No
Stage IA	T1, N0, M0	The tumor is 5 mm or smaller in diameter or has not invaded the tarsal plate	No	No
Stage IB	T2a, N0, M0	The tumor is larger than 5 mm but not more than 10 mm in greatest diameter, or it has invaded the tarsal plate	No	No
Stage IC	T2b, N0, M0	The tumor is between 10 and 20 mm in greatest diameter or has spread into the full thickness of the eyelid	No	No
Stage II	T3a, N0, M0	The tumor is larger than 20 mm in greatest diameter or has spread to nearby parts of the eye	No	No
Stage IIIA	T3b, N0, M0	The tumor is large enough or has spread enough so that the surgeon will need to remove the eye and nearby structures to get rid of the tumor	No	No
Stage IIIB	any T, N1, M0	The tumor is of any size	Yes	No
Stage IIIC	T4, any N, M0	The tumor has spread outside of the eye,, and cannot be surgically removed due to extensive invasion in structures near the eye	Yes or No	No
Stage IV	Any T, any N, M1	A tumor of any size	Yes or No	Yes

Recurrent: Recurrent lesions after treatment. Recurrence may occur in the eye or another part of the body especially sun exposed parts.

Follow Up and Prognosis

SCC is more aggressive than BCC and may spread to the orbit, regional lymph nodes or other distant organs.

The prognosis is good in lid if it is detected early and completely removed.

If malignant orbital invasion occurs, multidisciplinary team should share in the management including ophthalmology, oncology, maxillofacial, plastic surgery and radiology according to the extent and direction of tumor invasion.

In general, sun exposure should be reduced as much as possible with use of sunscreen. Alcohol and tobacco smoking should be discouraged.

Any recurrence should be treated aggressively.

Malignant Melanoma (MM)

Malignant melanoma of the skin of the eyelid is a rare, highly malignant tumor; it represents 1% of all eyelid tumors and less than 3% of all skin melanomas.

This tumor can arise from the eye lid skin or the conjunctiva with possibility of growth into the both directions. If eyelid melanoma is associated with conjunctival involvement, it becomes more aggressively than if it is confined to the eyelid skin only.

Malignant melanoma has a relatively poor prognosis: two thirds of all mortality from skin cancer results from malignant melanoma. Survival rates in patients with malignant melanomas depend on the depth of skin invasion. Histopathologically, 5-year survival rate is 100% if the tumor measures 0.76 mm or less, whereas 5-year survival rate is only 50–60% in patients with tumors that had invaded more than 1.5 mm.

Risk factors for developing malignant melanoma of the skin involves: ultraviolet light exposure, fair skin, light hair, personal history of melanoma or other skin cancers, family history of melanoma or other skin cancers, previous irradiation, immunosuppression, old age, precancerous lesions as xeroderma pigmentosa and eyelid nevi.

A nevus is considered hamartoma (benign neoplasm in the tissue of origin) tumor of incompletely differentiated melanocytes (nevus cells). The incidence of malignant transformation from the eyelid nevi into melanomas is rare.

The clinical presentation of a nevus is variable. Nevus usually presents at birth and typically manifests throughout a person's life. A benign nevus is usually a brown or black spot on the skin. It may be flat or raised. It may be round or oval. Nevus is generally less than 6 mm. Some nevi present at birth, but mostly nevi appear during childhood or young adulthood. Any new nevi that appear later in life may be suspicious and should by investigated.

Nevi usually keep the same size, shape, and color for long duration. Eventually, some nevi may show spontaneous resolution.

Junctional nevus: it presents as a flat pigmented macule. Histopathologically, the nevus cells are located in the basal epithelial layer at the epidermal-dermal junction. It usually occurs during childhood. During puberty pigmentation often increases and then extends beyond the second decade; it may turn into an elevated, pigmented papule.

Compound nevus: As the patient grows older, the nevus may transform into a compound nevus when the nevus cells extend from the junctional zone down into the dermis.

Intradermal nevus: in older age, the nevus loses its epidermal pigmentation and remains as an elevated, minimally pigmented or even amelanotic lesion. Histopathologically, there is involution of the epidermal component and all of the nevus cells are within the dermis.

Nevi are common finding on the periocular skin, eyelids and eyelid margins. Nevi that present on the lid margin may extend to the underlying ocular surface if they contact the globe. In nevi, lashes are still present and seen protruding from them.

Histopathology

Nevus cells contain bland nuclei, may be multinucleated, with no evidence of malignancy (no/rare atypia, no/few mitotic figures).

Signs of Malignant Transformation

There are specific clinical signs to exclude malignant transformation of nevus into malignant melanoma:

- Asymmetrical: One half of a nevus or birthmark does not match the other.
- Irregular or ill-defined borders.
- Size is larger than 6 mm, although melanomas can start by smaller size than this.
- Different colors: shades of brown or black, or with patches of pink, red, white, or blue.
- Change in size, shape or color.
- Persistent ulcer that doesn't heal.
- Spread of pigment into surrounding skin.
- Redness or a new extension beyond the previous border of the nevus.
- Change in sensation as pain, tenderness or itching.
- Change on the surface as oozing, bleeding, lump formation, or scaling as shown in Fig. 6.

Atypical Nevi (Dysplastic Nevi)

This nevus shows some features of normal nevi but also has some features of melanoma. It usually varies in size, shape and color; it is usually larger than other nevi and has a different shape and color. It may appear on sun exposed areas of skin as well as skin that usually covered, as on the back, buttocks or scalp.

Dysplastic nevus is usually familial. Malignant transformation into melanoma is usually rare.

Dysplastic nevus syndrome (familial atypical multiple mole melanoma syndrome or FAMMM) is inherited condition that presents with many dysplastic nevi and at least one close relative who has had melanoma.

People with this syndrome have a very high risk of melanoma, so regular thorough skin examination is a must.

Congenital Melanocytic Nevi

Congenital melanocytic nevus is the nevus that present at birth. The risk of melanoma developing in congenital melanocytic nevi is rare (0–10%), it mainly depends on the size of the nevus. People with very large congenital nevi as those on back and buttocks (bathing trunk nevi) have a higher risk, while the risk is lower for those with small ones.

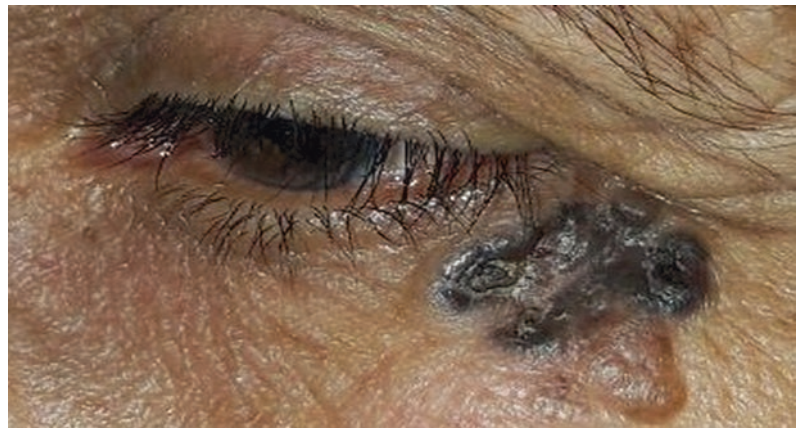

Fig. 6 Malignant melanoma of the lower lid

Histopathology of Malignant Melanoma of the Skin

Histopathologically, malignant melanoma is divided into three types of:

1. Superficial spreading malignant melanoma: Diagnosed by intraepidermal invasion by cells with abundant cytoplasm containing a light dusting with melanin, not confined to the basal layer with variable degree of stromal invasion. The thickness of the tumor here ranges from 0.1 to 2.2 mm.
2. Nodular malignant melanoma: Diagnosed by extensive invasion of the subepithelial stroma with no or little junctional activity or lateral intraepidermal spread. The tumor usually starts at the lid margin at the junction between the epidermis and conjunctival epithelium. The thickness of the tumors in this type varies from 1.2 to 3.9 mm. It shows pleomorphism, frequent mitotic figures with variation in nuclear size, shape, and staining properties. The melanin content is usually variable, and even may be amelanotic.
3. Lentigo maligna: Lentigo maligna usually occurs on the head and neck, in elderly patients (7th–9th decades of life). It usually starts as a brown macule or patch, it may show variable degree of pigmentation and may even be amelanotic. It is slowly growing and usually progresses radially before vertically. Lentigo maligna can develop de novo or on the top of solar lentigo. Patients usually present with recent onset of asymptomatic pigmented macule or patch on the head or neck region with change in size, shape, or color.

Lentigo maligna is now considered the in situ phase of lentigo maligna melanoma, however it carries a better prognosis than other types of melanoma, it is now staged in the same way as other types of melanoma using the American Joint Committee on Cancer (AJCC) guidelines, and its prognosis is directly related to the depth of invasion.

If left untreated, lentigo maligna may turn into an invasive melanoma in 30–50% of cases. Risk depends on time of presentation; patient with a new diagnosis of lentigo maligna at the age of 45 has a 3.3% risk of developing melanoma by the age of 75, but the risk is reduced to 1.2% if the new diagnosis was made at the age of 65.

Histopathological findings of lentigo maligna include: atypical melanocytic proliferation at the dermoepidermal junction, replacement of the basal layer with atypical melanocytes and possible pagetoid spread. It is associated with cytoplasmic retraction and adnexal involvement of atypical melanocytes. Sometimes, it shows ridge effacement and epidermal atrophy, but these features are not essential for diagnosis of lentigo maligna.

All patients are at risk of metastasis to regional lymph nodes. The risk of metastasis to lymph nodes is directly related to Breslow thickness. Distant spread can also occur to distant organs as liver, lung.

Staging

TNM staging as shown below in Table 2.

Clark Scale

As shown below in Table 3.

Breslow Scale

The Breslow scale depends on the thickness which is the total vertical length of the melanoma, from the superficial layer (called the "granular layer") to the area of deepest penetration of the lesion in the skin.

The prognosis and risk of spread depends on the Breslow thickness, the worse the prognosis and the higher risk of spread is suspected in thicker melanoma. The 5-year survival rates based on a certain Breslow thickness is shown below in Table 4:

Table 2 TNM staging of malignant melanoma

Tumor (T)	Node (N)	Metastasis (M)
Tis means the melanoma cells are only in the very top layer of the skin surface	N0 means that the nearby lymph nodes don't contain melanoma cells	M0 means the cancer hasn't spread to another part of the body
T1 means the melanoma is less than 1 mm thick	N1 means there are melanoma cells in one lymph	M1 means the cancer has spread to another part of the body
T2 means the melanoma is between 1 and 2 mm thick	N2 means there are melanoma cells in 2 or 3 lymph nodes	
T3 means the melanoma is between 2 and 4 mm thick	N3 means there are melanoma cells in 4 or more lymph nodes	
T4 means the melanoma is more than 4 mm thick		
Ta melanomas are not ulcerated Tb melanomas are ulcerated	Na means the cancer in the lymph node can only be seen by microscope (micrometastasis) Nb means there are obvious signs of cancer in the lymph node (macrometastasis) Nc means that there are melanoma cells in small areas of skin very close to the primary melanoma (satellite metastases) or in the skin lymph channels (in transit metastases)	M1a means there are melanoma cells in the skin in other parts of the body or in lymph nodes far away from where the melanoma started growing M1b means there are melanoma cells in the lung M1c means there are melanoma cells in other organs, or the melanoma causes a high level of a chemical made by the liver (lactate dehydrogenase)

Table 3 Clark scale of malignant melanoma

Level	Description
Level 1	melanoma in situ—the melanoma cells are only in the outer layer of the skin (the epidermis)
Level 2	there are melanoma cells in the layer directly under the epidermis (the papillary dermis)
Level 3	the melanoma cells are throughout the papillary dermis and touching on the next layer down (the reticular dermis)
Level 4	the melanoma has spread into the reticular or deep dermis
Level 5	the melanoma has grown into the layer of fat under the skin (subcutaneous fat)

Table 4 Breslow scale of malignant melanoma

Thickness	5 year survival rate (%)
Less than 1 mm	92–97
1.01–2 mm	81–92
2.01–4 mm	70–81
Greater than 4 mm	53–70

Due to its high accuracy in predicting the spread and prognosis, the Breslow thickness is incorporated into the standard TNM staging system for melanoma.

Sebaceous Gland Carcinoma (SGC)

Sebaceous carcinoma is a rare, invasive malignant tumor, it most commonly occurs in the eyelid. It is associated with high mortality rate.

The neoplasm arises from sebaceous glands, as the meibomian glands in the tarsus, the Zeiss glands of the eyelashes, the sebaceous glands in the caruncle, and the sebaceous glands of the eyebrow.

Unlike most of the lid malignancy, it usually occurs in the upper eyelid, most likely due to the presence of a greater number of meibomian glands in the upper lid compared to the lower one.

In 25% of cases, sebaceous gland carcinoma of the lid may be associated with similar malignancy in other body areas as other areas of the head and neck and other areas of skin with hair, even genitalia.

Muir-Torre Syndrome (MTS)

MTS is an autosomal dominant condition; it includes sebaceous tumors associated with gastrointestinal, endometrial, urologic tumors (without any predisposing factors). The sebaceous tumors in this syndrome include: sebaceous adenoma, basal epithelioma with variable sebaceous differentiation and sebaceous carcinoma. Fortunately, the sebaceous carcinomas in MTS are less invasive with less incidence of metastasis than solitary sebaceous carcinoma.

The condition occurs more commonly in females. The upper eyelid accounts for most of the cases. Older age is risk factor, it usually occurs between 6th and 8th decades of life. However, tumors may occur in younger age when treated with periocular irradiation. The tumor has a higher incidence in Asian population.

Clinical Picture

A high index of clinical suspicion is essential for the diagnosis of sebaceous carcinoma. Caution should be taken in patients with atypical presentation of a typical diagnosis. For example: atypical or recurrent chalazia, especially in the upper lid as shown in Fig. 7, yellowish thickening of the eyelid, persistent blepharitis or keratoconjunctivitis resistant to treatment.

Sebaceous carcinoma is yellowish in color (from the lipid inside the malignant cells). It arises at the sebaceous glands, it usually starts at the lid margin, but it can extend to the palpebral conjunctiva as shown in Fig. 8. Therefore, eversion of the lid is an essential step.

The clinical diagnosis of sebaceous carcinoma is usually difficult and late. It is considered one of the great masqueraders, as it can mimic other lesions, either benign or malignant. It can mimic chalazia, chronic blepharitis, superior limbic keratoconjunctivits, basal cell carcinoma, squamous cell carcinoma and ocular cicatricial pemphigoid.

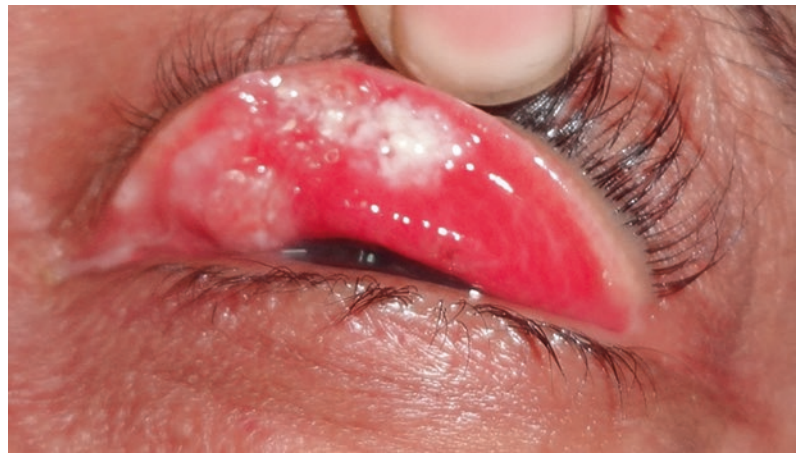

Fig. 7 Sebaceous gland carcinoma resembling chalazion (Courtesy Rania A Ahmed, MD)

Fig. 8 Sebaceous gland carcinoma extending to the conjunctiva (Courtesy Rania A Ahmed, MD)

Spread

Similar to SCC, sebaceous carcinoma is characterized by pagetoid spread; spreading of malignant cells to epithelium that appears to be separate from main tumor. Therefore, a wide excisional biopsy of the primary lesion and map biopsies of the conjunctiva (including the palpebral conjunctiva in both upper and lower lids and 4 quadrants of the bulbar conjunctiva; superior, inferior, nasal and temporal) is a must. It is important to mark the specimen margins before sending it for pathology.

Histopathology

The histopathological appearance varies depending on the degree of tumor differentiation. In well differentiated lesions, it shows a lobular arrangement and vacuolization of the cytoplasm cells centrally.

Cells present include both sebaceous and undifferentiated cells. Nucleus shape and size varies with the mitotic activity indicated by the prevalence of mitotic figures. Special stains can be used to detect sebaceous carcinoma as: oil red-O, Sudan IV, epithelial membrane antigen, Leu-m1 immunostains.

Prognosis

Sebaceous carcinoma is associated with high rate of recurrence (33% of the cases).

According to the American Joint Committee on Cancer, stage T2b or worse is associated with regional lymph node metastasis. T category of T3a or worse is associated with distant metastasis and death. No distant metastasis or death is suspected if the tumors <12 mm in size.

Kaposi Sarcoma (KS)

Kaposi's sarcoma is a rare, malignant tumor that may occur in the skin, lymph nodes, or other organs.

It was first described by Moritz Kaposi in 1872.

The skin lesions are typically purple in color. They may occur separately, as a cluster in a one area, or widespread. It may progress either gradually or quickly. Lesions may be flat or raised. Human herpesvirus 8 (HHV8) is found in all the lesions.

The main risk factor is immunosuppression, either as a result of disease or specific medications. Patients with HIV/AIDS and following organ transplant are most commonly affected, it occurs in 35% of people with AIDS

Four sub-types are described:

1. Classic KS: tends to affect older men, slow growing, and mainly occurs in the legs.
2. Endemic KS: occurs in young adult, males, in Africa and usually more aggressive.
3. Immunosuppression therapy-related KS: generally occurs in people following organ transplantation and mostly occurs in the skin.
4. Epidemic KS: occurs in people with AIDS and many parts of the body can be affected.

Histopathology

Despite its name, in it is not considered a true sarcoma, which is a tumor arising from mesenchymal tissue. The origin of KS remains controversial. KS arise from lymphatic endothelium and forms vascular channels that fill with blood cells, giving the tumor its characteristic bruise-like appearance. KSHV proteins are detected in all KS cancer cells.

KS lesions contain spindle cells with a characteristic abnormal elongated shape. The most typical feature of Kaposi sarcoma is the presence of spindle cells forming slits containing red blood cells. Mitotic activity is usually moderate with no pleomorphism. The tumor is highly vascular, containing irregular abnormally dense blood vessels, which leak red blood cells into the surrounding tissue and give the tumor its dark color. Inflammation around the tumor may be associated with swelling and pain. PAS positive hyaline bodies of variable sizes are usually seen both in the cytoplasm and extracellularly.

In Kaposi sarcoma, the spindle cells are usually differentiated into endothelial cells, probably of lymph vessel rather than blood vessel nature.

Definite diagnosis can be made only by biopsy and histopathological examination with detection of the KSHV protein in tumor cells.

Merkel Cell Carcinoma (MCC)

Merkel cell carcinoma is rare, invasive malignant skin tumor. It shows a higher prevalence in the periorbital region.

Merkel cell carcinoma mostly occurs in old age, in sun exposed area of skin. Risk factors include chronic sun exposure, immunosuppression, other skin cancer and fair skin.

Merkel cell carcinoma tends is characterized by rapid growth with metastasis to other parts of your body.

Clinical Picture

It usually starts as a painless nodule on the skin. The nodule may be skin-colored or may show different color as red, blue or purple. It usually develop on the face, head or neck, but it may develop anywhere on the body, even on areas not exposed to sunlight.

Due to lack of clinically distinctive features, the diagnosis is late and not suspected; the clinical differential diagnosis includes more common lesions, such as basal cell carcinoma, squamous cell carcinoma, epidermoid cyst, or even amelanotic melanoma.

Histopathology

Merkel cell carcinoma starts in the Merkel cells, found at the base of the epidermis. Merkel cells are connected to the nerve endings that are responsible for the sense of touch. More recently, it has been suggested that MCCs may derive from proliferations of dermal pluripotent stem cells.

Histopathology shows small uniform cells, blue in color, rounded in shape, arranged in the form of interlacing cords, anastomosing bands and clusters. The cells have ill-defined borders, little cytoplasm, and round vesicular nuclei with "salt and pepper" chromatin and frequent mitotic figures. MCCs exhibit pagetoid intraepidermal spread in 10% of cases.

MCCs may show areas of squamous differentiation. It can also occur with other epithelial tumors. It is associated with adjacent or overlying Bowen's disease or squamous cell carcinoma in 40% of cases. Less commonly, it is found in association with BCC or eccrine tumors.

Merkel cell polyoma virus lives on the skin surface and is not associated with any manifestations; it is thought to play a role in the development of this skin malignancy.

Spread

Merkel cell carcinoma is highly malignant tumor; it commonly spreads beyond the skin, even with treatment, Merkel cell carcinoma spread first to regional lymph nodes. Then, it may spread to distant organs as brain, bones, liver or lungs.

Treatment of Malignant Lid Tumors

The successful management of malignant lid tumors should entail complete surgical excision with free surgical margins as shown in Fig. 9.

Incisional biopsy is only required in doubtful cases and aggressive intervention is delayed after definite tissue diagnosis.

The goals of therapy for periocular lid malignancy are threefold: to completely excise the tumor; to maintain the integrity and the function of the eye; and to achieve a good cosmetic result.

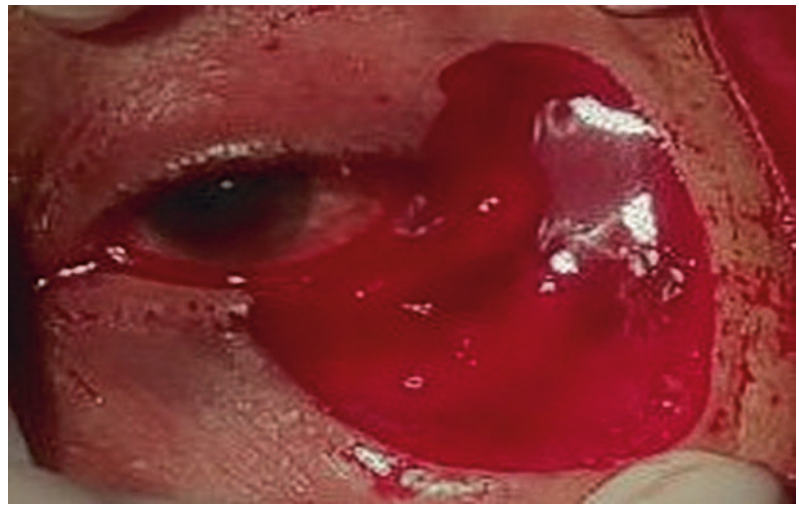

Fig. 9 Surgical excision with wide safety margins

It may be difficult to accomplish all of these objectives in every patient or by one surgery. The dilemma of removal of the tumor while preserving normal tissue is more challenging in the periocular area than it is on other areas on the skin.

The main advantage of surgical excision is that excision margins can be examined histologically to check for tumor clearance. An excision margin of 4 mm around the tumor at least is recommended as possible.

Sometimes it is even necessary to go with an extensive surgical approach to ensure complete removal of the lesion. Orbital exenteration may be indicated for large, deeply invasive lesions, or significant bulbar conjunctival involvement.

Adequate removal should ensure shows tumor-free margins of excision, in techniques such as Mohs' micrographic surgery or excision with frozen-section control.

Mohs' micrographic surgery is a specialized technique that offers high cure rates for malignant lid tumors, with maximal preservation of normal tissues. Serial sections are taken and examined histologically until all margins are clear. The overall five year cure rate with Mohs' micrographic surgery has been estimated at 99% for primary tumors and up to 95% for recurrent ones.

Lid reconstruction should aim at restoration of normal lid anatomy with replacement of defect in the anterior and/or posterior lamella using the appropriate reconstructive surgical technique, individualized for each case.

Radiotherapy is generally used for elderly patients with extensive lesions when major surgery may not be appropriate. It is not recommended for young patients, as the late cosmetic results are inferior to those of surgery.

Also, radiation therapy can be used as an adjunct therapy for patients post-surgery who have a disease which has spread to nerves/lymph nodes or cancer with ill-defined margins.

The side effects of radiotherapy include localized hyperemia, erosions, alopecia, localized pain, skin atrophy, pigmentation changes and telangiectasia in the radiation site.

In photodynamic therapy, a photosensitizing drug, light, and oxygen are used to induce targeted cell death though apoptosis of cancerous or abnormal tissue.

Topical photodynamic treatment may be effective for superficial basal cell carcinoma and gives good healing. It is also suitable for SCC in situ and actinic keratosis.

But, there is a higher rate of recurrence with this method as compared with surgical excision.

Supplemental cryotherapy can be used if the tumor margin is unclear or if there is residual involvement of bulbar conjunctiva.

Cryotherapy uses liquid nitrogen in low temperatures to eradicate the SCC tissue structure. It is only suitable for those with in situ squamous cell carcinomas and actinic keratosis, but it is not suitable for invasive cancers.

It is a safe and cheap procedure that can be useful in patients with bleeding disorders, those who refuse surgery/poor surgical candidates, or in patients whereby surgery is contraindicated.

The side effects of cryotherapy include transient localized pain, swelling, pigmentation changes, loss of hair over hair-bearing areas and blistering.

Interferon alpha: A meta analysis of all currently available data from trials of adjuvant interferon versus control has shown that there is a statistically significant benefit from interferon, but no good evidence of any difference in the size of the benefit with respect to dose.

Topical Imiquimod is an imidazoquinoline, a local immune response modifier that stimulates cytokines, activates skin Langerhans cells, and inhibits T helper 2 productions, which can be overexpressed in skin cancer. It can be used to treat genital warts, actinic keratosis, Bowen disease, superficial SCC, primary malignant skin melanoma and cutaneous melanoma metastases. It should be applied 3 times per week for 4–6 weeks. Localized side effects include increased redness, swelling, and erosions or ulcerations. If applied over large areas, it may cause flu-like symptoms. Given the ocular effects of keratitis and chemosis with temporary decreased visual acuity, it is recommended to be

used with caution. Further studies on the safety of imiquimod on the periocular tissue are still required.

Topical chemotherapy agent like 5-fluorouracil can be used for the treatment of actinic keratosis and SCC in situ. It should be applied daily for about a month. It may cause skin irritation and hyperemia over the application area.

Systemic chemotherapy is used for advanced cases that have metastasized to other sites of the body as in SCC and SGC.

In kaposi sarcoma, in patients with HIV/AIDS, highly active antiretroviral therapy (HAART) prevents and often treats KS. In certain cases the addition of chemotherapy may be needed.

Lymph node management

It has been debated strongly whether prophylactic lymph node dissection at the time of melanoma excision is associated with better survival rate or no. Selective nodal dissection, alone or in conjunction with radical neck dissection or modified radical neck dissection, depending on the site and the size of the primary lesion, may allow accurate pathologic staging and better control of local disease with minimal morbidity.

Also in SGC, according to the American Joint Cancer Committee, sentinel lymph node biopsy or at least strict regional lymph node surveillance is recommended for patients with sebaceous carcinoma of the eyelid who have T category of T2b or worse or tumors of 10 mm or more in greatest dimension (T2b: tumor > 10 mm, but not > 20 mm in greatest dimension; or, involves full thickness eyelid).

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Common Eyelid Malpositions

Riad Ma'luf and Sari Yordi

The eyelids are the primary defense of the eye against dryness, exposure, and trauma. Therefore, proper lid positioning is important to ocular health. Entropion and ectropion are among the most common eyelid malpositions encountered by the ophthalmologist. Entropion is defined as inward rotation of the lid margin and should be distinguished from trichiasis, in which the lashes are misdirected towards the globe and the lid margin is in a normal position. Ectropion refers to outward rotation of the lid margin. Visual loss may occur in either condition due to keratopathy secondary to exposure or lashes rubbing on the ocular surface.

A thorough understanding of the anatomy, pathophysiology, appropriate evaluation, and treatment options of these lid malpositions is essential for the practicing ophthalmologist.

The classification of entropion and ectropion is divided according to their respective etiologies. While ectropion much more commonly affects the lower eyelid, entropion occurs with significant prevalence in both upper and lower eyelids. Moreover, some types of ectropion and entropion could occur with, and even exacerbate, other types. The following highlights the classification and etiology of both eyelid problems as well as the recommended preoperative evaluations that maximize relevance and efficacy of treatment.

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Ectropion

There are five main types of ectropion: involutional, paralytic, mechanical, cicatricial, and congenital. Due to the relative infrequency of upper lid ectropion, the lower lid will be the main focus.

Involutional

Involutional ectropion is the most common form. It results from the laxity of medial and lateral canthal tendons (horizontal laxity) or atrophy of the lower lid retractors. This instability allows gravity and the weight of midfacial structures to pull down on the lid structures, leading to ectropion (Fig. 1). The frequency of involutional ectropion increases with age due to increased structural changes of facial skin and muscles over time. Lateral canthal tendons are affected more commonly by involutional changes, however, the medial canthal tendons can be affected independently and result in punctal ectropion and secondary epiphora (Fig. 2).

E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_5

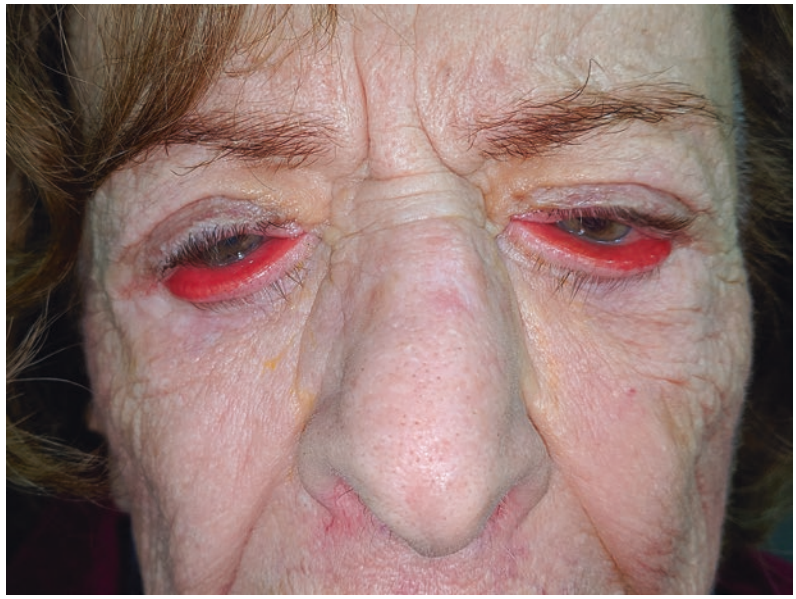


Fig. 1 Bilateral involutional ectropion

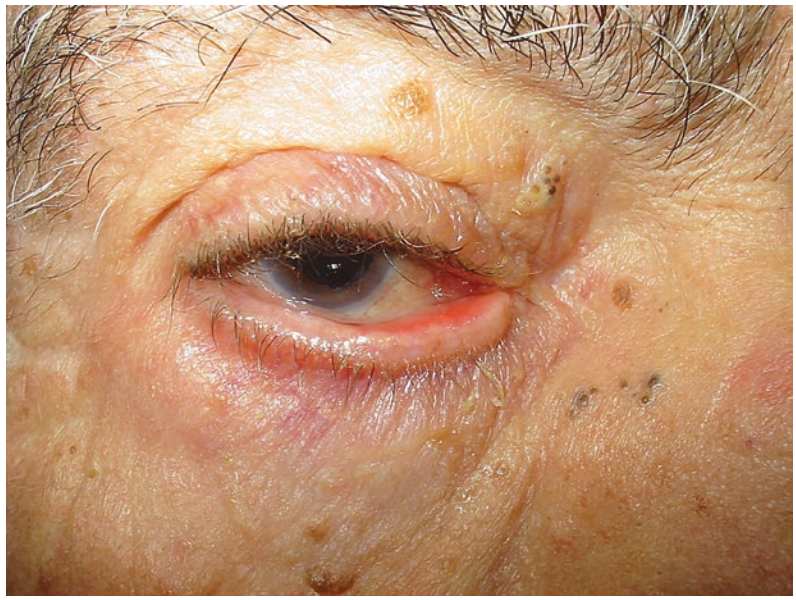


Fig. 2 Medial ectropion

Due to the fact that the upper eyelid is not affected by the weight of midfacial structures, upper lid ectropion does not occur except in cases of spontaneous eversion, such as in floppy eyelid syndrome (Fig. 3).

Paralytic

Paralytic ectropion results from seventh cranial nerve palsy of any etiology, most commonly Bell's palsy. Since the action of the orbicularis

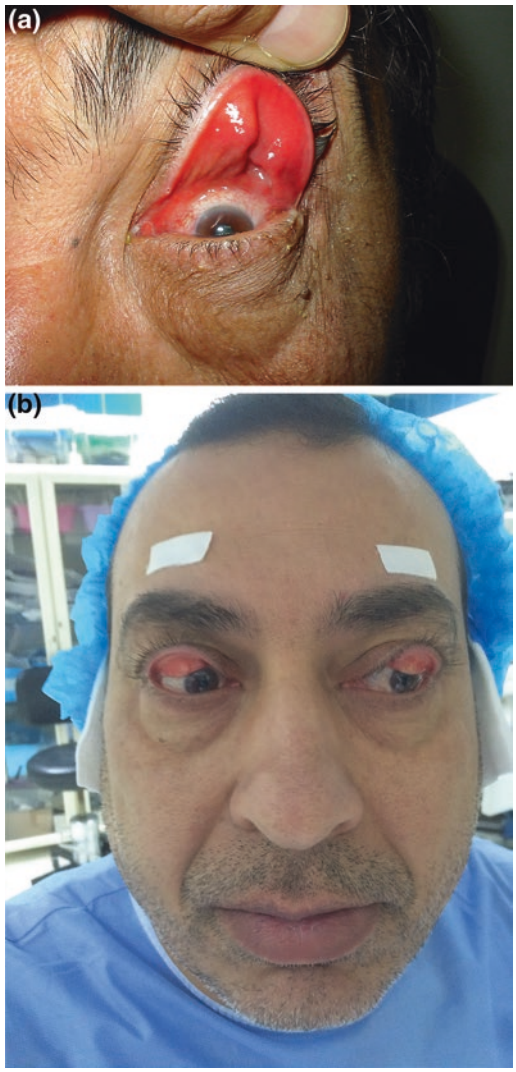


Fig. 3 Floppy eyelid

oculi is absent or reduced, gravity is unimpeded and the weight of midfacial structures and skin pulls the lower eyelid downwards.

Mechanical

Mechanical ectropion is associated with a growth on, or adjacent to the lower eyelid as the mass pulls downward and disrupts the normal anatomy. Any growth on the superficial tissues of the lower lid can result in ectropion especially with coexistent horizontal laxity. Cutaneous T-cell lymphoma has been implicated in ectropion formation due to mechanical and cicatricial factors.

Cicatricial

Cicatricial ectropion results from an imbalance between the anterior and posterior lamellae. The anterior lid structures are relatively shorter in this case. Both upper and lower lids can exhibit cicatricial changes as a result of lacerations, burns, infections, and skin disease. Herpes zoster ophthalmicus has also been linked with upper eyelid cicatricial ectropion. Other notable causes include:

- Actinic skin changes
- Resection of skin lesions
- Topical eye medications, mostly Dorzolamide, followed by Brimonidine can result in significant dermatitis and ectropion. The ectropion may improve after discontinuing the medication and using topical steroid ointment to the affected skin.
- Oral medications including Epidermal Growth Factor (EGF) inhibitors such as Cetuximab and Erlotinib. The systemic use of fluorouracil has also been associated with cicatricial ectropion. These medications have cutaneous toxicity which include the periocular skin. Their effect could be explained by the abundance of EGF receptors in sebaceous glands, and hair follicles in the eyelids.
- Radiation, prior eyelid surgery, or Laser resurfacing of the lower eyelid and the mid-face.
- Rare dermatologic disorders such as pityriasis and lamellar ichthyosis (Fig. 4).

Congenital

Congenital ectropion is very rare. Down Syndrome patients may present with congenital eversion of the upper lids. On the other

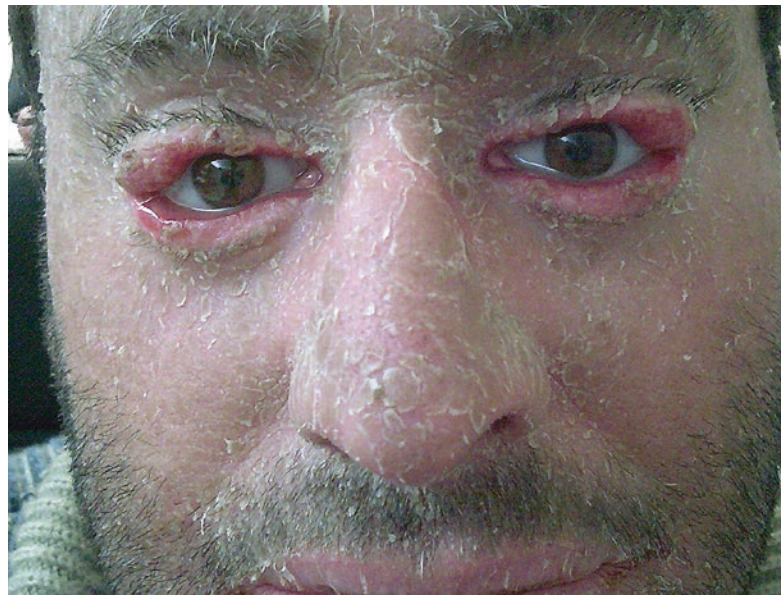


Fig. 4 Lamellar ichthyosis and 4-lid ectropion

hand, lower lid ectropion is associated with Blepharophimosis Syndrome: a triad of congenital ptosis, telecanthus, and epicanthus inversus. Lamellar Ichthyosis is also implicated in congenital lower lid ectropion.

Entropion

Entropion is subdivided into 4 categories: involutional, acute spastic, cicatricial, and congenital.

Involutional

As with ectropion, involutional entropion is the most common form and usually affects the lower eyelid (Fig. 5). It is caused by a similar mechanism: Horizontal eyelid laxity and vertical instability, both play a role. The horizontal laxity results from stretched canthal tendons and atrophic tarsus. The vertical instability results from dehisced lower lid retractors and overriding of the preseptal orbicularis. The combination of horizontal and vertical lid laxity can result in either entropion or ectropion. Larger tarsal plate size is associated with ectropion and smaller tarsal plates tend to result in entropion. Interestingly, gender-related correlates have also been shown: Involutional ectropion more often occurs in men, while involutional entropion tends to occur more in women. This could be explained by differences in tarsal plate size.

Acute Spastic

Acute Spastic entropion is often a result of ocular inflammation or irritation (such as trichiasis) leading to orbicularis oculi spasm. It may follow any ocular surgery, including cataract surgery. Trichiasis should be treated immediately if present. Management includes lubrication and taping of the eyelids as a temporary measure. Injections of Botulinum toxin can be very helpful in idiopathic cases. Surgery is indicated whenever significant horizontal or vertical lid laxity is present. Even when resolved, most patients will proceed later to develop involutional entropion due to the lid laxity and overriding orbicularis. The condition is even seen by many as a precursor or an early stage of involutional entropion.

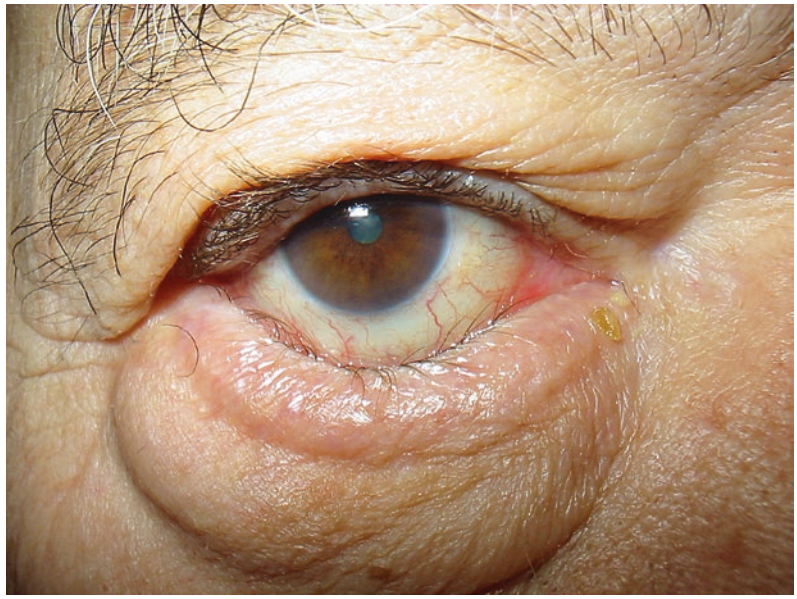


Fig. 5 Involutional entropion

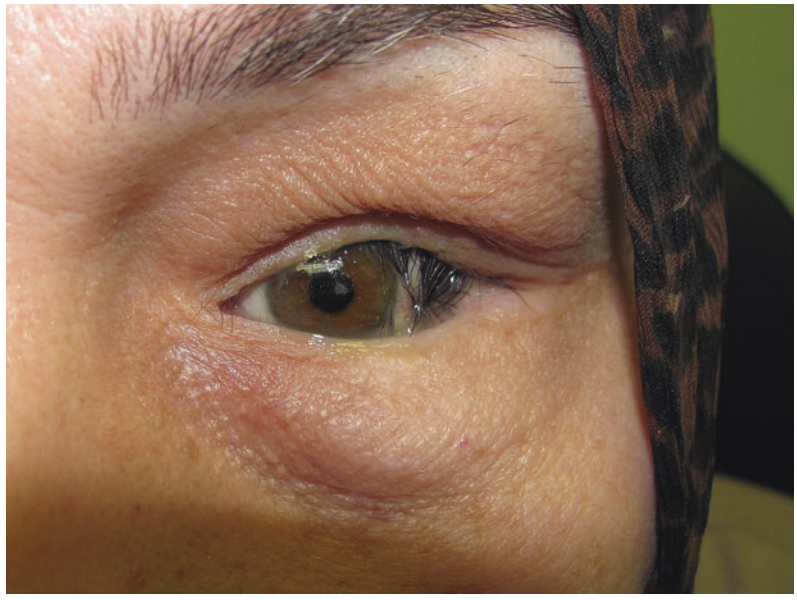


Fig. 6 Cicatricial entropion

Cicatricial

Cicatricial entropion results from contracture of the posterior lamellae, leading to rotation of the lid margin (Fig. 6). Both the upper and lower eyelids can be affected, and multiple causes have been implicated. These include, but are not limited to, trachoma, adenoviral keratoconjunctivitis, Steven Johnson Syndrome, advanced meibomitis or blepharitis, ocular cicatricial pemphigoid,

and chemical or thermal burns. Certain medications have also been shown to lead to entropion, specifically via a Type IV Hypersensitivity reaction causing inflammation of the conjunctival substantia propria, such as Dipivefrin and Apraclonidine hydrochloride 1%. Trachoma and its sequalae on the lids and conjunctiva is discussed in chapter "Trichiasis and Trachoma".

Congenital

Congenital entropion is rare, can involve both lids, and usually does not have systemic associations. With regards to upper lid, retractor dysgenesis and congenitally shortened posterior lamellae have been implicated, and could lead to corneal ulceration in infants. Lower lid entropion has been associated with congenital disinsertion of lower lid retractors, as well as an overriding preseptal orbicularis oculi (similar to involutional entropion).

Pre-operative Assessment

Distinguishing between the types of ectropion and entropion is crucial to determine the preferred surgical approach. A thorough history, eye examination, and a more specific eyelid examination is crucial. The presenting symptoms are usually nonspecific, including red, irritated eyes with epiphora or chronic infections.

History

Inquiry about prior medical and surgical history, medications, infections and inflammatory disorders is essential.

Examination

Patients must be assessed for meibomitis and blepharitis, trichiasis, distichiasis, cicatrix, and corneal integrity. If the lid malposition is intermittent, then forceful lid closure may elicit involutional changes. Signs of retractor disinsertion include poor retraction with downgaze (less than 3 mm), visualization of the dehisced retractors' white edge in the inferior fornix, and a deep inferior cul-de-sac.

The medial canthal tendons are assessed by pulling the lid laterally. The severity of medial canthal tendon laxity is graded according to the degree of punctal displacement:

- Grade = 0 → Punctum in normal position
- Grade = 2 → Punctum at medial limbus
- Grade = 4 → Punctum at mid-pupil
- Grade = 6 → Punctum at lateral limbus

Horizontal laxity is established by the distraction test. If the lid margin can be pulled more than 8 mm away from the globe, then significant canthal tendon laxity is present (Fig. 7). A positive snap-back test, in which the lid does not return to its normal position after distraction without a blink, is a sign of poor orbicularis tone (Fig. 8a–c). The strength of the orbicularis

Fig. 7 Distraction test: Positive if lid margin can be pulled more than 8 mm away from globe

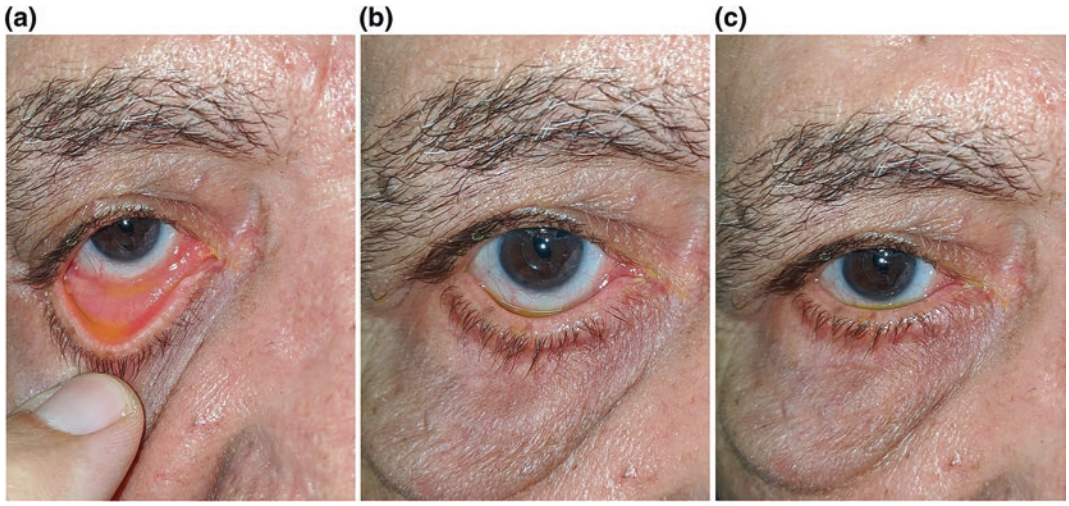


Fig. 8 Snap-back test: Poor orbicularis tone if the lid does not return (**b**) to its normal position after distraction (**a**), until the next blink (**c**)

is tested in forced closure of the eyes and should be compared with the opposite eye.

Eyelid Retraction

Eyelid retraction often produces a look that is described as a stare with an accompanying illusion of exophthalmos. In adults, the normal upper lid transects the cornea approximately 2 mm below the limbus in primary gaze. The lower eyelid margin is usually positioned at the level of the limbus at the 6-o'clock position with the eye in primary position. Although there are many normal variations, especially in myopes and infants, any visible sclera between the edges of the cornea and eyelid margins is usually indicative of some degree of lid retraction. In addition, the average palpebral fissure is approximately 10 mm in height.

Upper Eyelid Retraction

Graves' ophthalmopathy is often the first diagnosis explored in a differential diagnosis for eyelid retraction (Fig. 9). This common feature of Graves' ophthalmopathy is certainly deserving of a workup for thyroid disease. Once thyroid disease has been ruled out, the differential diagnosis becomes much more diverse. A classification scheme proposed by Bartley separates eyelid retraction into neurogenic, myogenic, mechanistic, and miscellaneous causes.

Neurogenic eyelid retraction, although usually acquired, can be present at birth. Normal infants from 14 to 18 weeks of age may also have an "eye-popping" reflex when ambient lighting levels are suddenly reduced. Other important causes of neurogenic eyelid retraction include dorsal midbrain syndrome and pseudoretraction from Herring's law in patients with contralateral ptosis.

Myogenic eyelid retraction is commonly caused by Graves' ophthalmopathy, one of the more common causes of eyelid retraction. Eyelid retraction is the most frequent eye finding in patients with Graves' disease and may be seen in up to 90% of such patients at some time during their clinical course.

Several hypotheses have been offered regarding the eyelid retraction seen in patients with Graves' disease. Histology examinations have demonstrated enlargement of individual muscle fibers of the levator palpebrae superioris and expansion of the extracellular space. In addition, studies have demonstrated an association between lid retraction and levator muscle

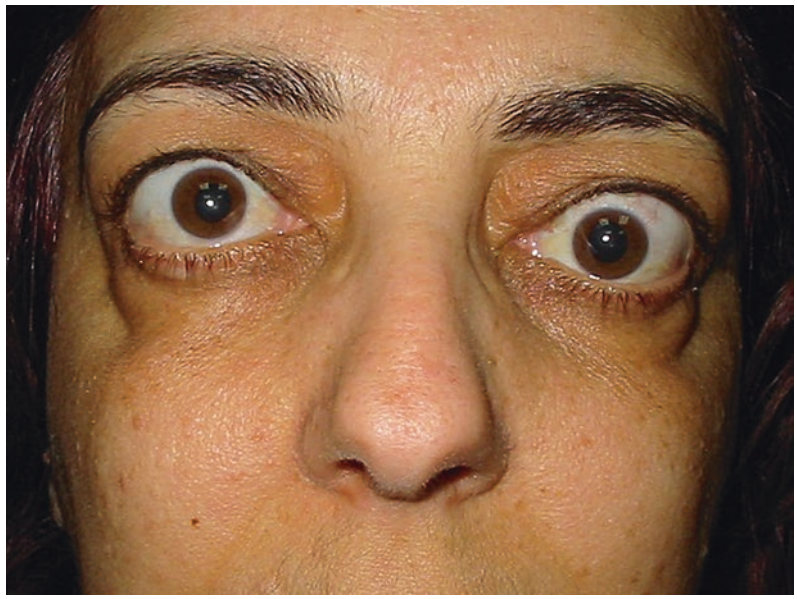


Fig. 9 Eyelid retraction in the setting of Graves' disease

volume. Overstimulation of the sympathetically innervated Müller's muscle has also been implicated in the development of lid retraction in association with Graves' disease. Simple proptosis of the globe may also result in eyelid retraction with significant lateral flare as the lids are unable to lengthen to accommodate increased amounts of globe displacement.

Prominence of the globe from a number of causes, including high myopia, proptosis, or buphthalmos, can result in mechanical upper lid retraction. Also included under the mechanical causes of retraction would be scarring of the lids from previous surgery, neoplasm, burns, and anterior lamellar shortening.

Lower Eyelid Retraction

Because the lower lid lacks a muscle devoted to retracting the lid (like the levator palpebrae of the upper lid), many neurogenic causes of upper lid retraction may not cause retraction of the lower lid. Retraction of the lower lid is more likely to be caused by myogenic, mechanistic, and miscellaneous causes.

Like that of the upper lid, lower eyelid position varies with the prominence of the globe. Possibly, the lower lid is unable to lengthen to accommodate a more prominent globe, resulting in significant scleral show in cases of proptosis. As in the upper lid, the most common cause of lower lid retraction is Graves' disease. Although lower lid retraction may exist in Graves' disease without proptosis, retraction of the lower lid usually implies some degree of proptosis in affected patients.

A second cause of lower lid retraction of the lower lid, which may not have been seen in the upper lid, is flaccidity of the lower eyelid. Because retraction of the lower lid is affected by gravity, weakening of the orbicularis, dragging of the sub–orbicularis oculi fat pad inferiorly or relaxation of the tarsus of the lower lid may result in retraction of the lower lids. Similarly, contraction of the lower lid from burn, neoplasm, or dermatoses can affect lower lid position in the same manner in which the upper lids are affected.

Finally, lower eyelid retraction may be induced iatrogenically by a number of surgeries. Recession of the inferior rectus muscle may

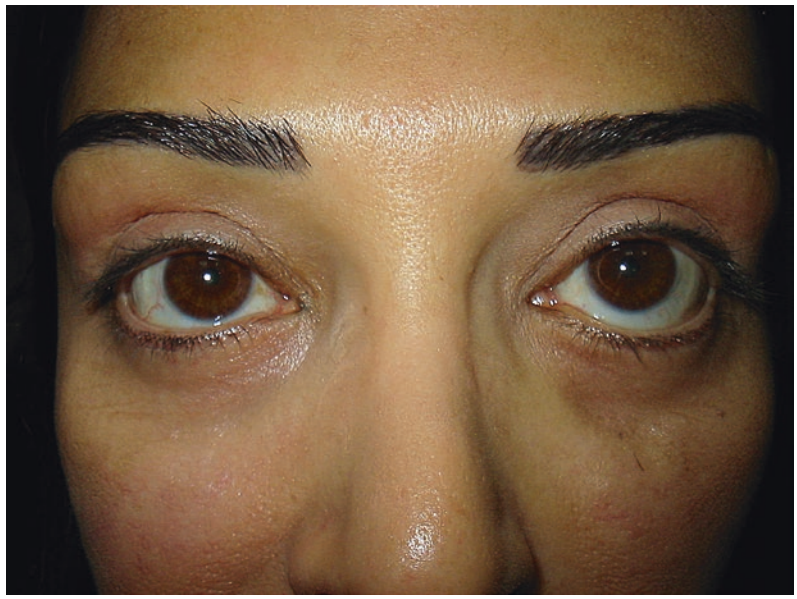


Fig. 10 Lower eyelid retraction from aggressive blepharoplasty

cause lower lid retraction. Aggressive lower eyelid blepharoplasty with significant skin removal from the lower lids is also a fairly common cause of retraction (Fig. 10).

Sequelae of Eyelid Retraction

The most severe consequences of lid retraction are derived from exposure of the cornea and the ocular surface due to lagophthalmos. The severity of symptoms is related to the extent of corneal exposure, the ability of reflex tearing to keep the cornea well lubricated, and the level of the patient's Bell's reflex. Temporary treatment should be directed at aggressively lubricating the cornea with drops or lubricating ointments. Primary lateral tarsorrhaphies to prevent exposure keratopathy are cosmetically unsightly and should be avoided. If temporary eyelid closure is required to reduce keratopathy or to treat corneal ulceration, suture tarsorrhaphies with foam bolsters may be used until appropriate permanent surgery may be rendered.

Globe subluxation can occur in cases in which lid retraction and proptosis are combined (e.g., cases of Graves' disease). Forward displacement of the globe occurs as the muscle and connective tissue volume behind the eye increase, elevating the pressure within the confines of the bony orbit. A temporary suture tarsorrhaphy may be placed to prevent such occurrences while waiting for definitive surgical correction of the underlying problem.

Eyelid retraction can be very disfiguring cosmetically. Retraction of the eyelids gives the eye a more prominent look, promoting a staring appearance. Overly aggressive lower lid or even upper lid blepharoplasty may result in eyelid retraction with concurrent functional problems. These types of problems are particularly prevalent in patients with significant horizontal laxity prior to surgery.

Treatment

Frequent lubrication with artificial tears and lubricating ointments are used if the malposition is mild and no ocular irritation is present. Taping the eyelids at night can also be employed. However, a surgical repair is usually necessary.

Involutional Ectropion

Horizontal laxity and/or dehiscence of retractors from the tarsus are similarly treated in cases of involutional ectropion or entropion. The **lateral tarsal strip**, described by Anderson et al. in 1979, effectively addresses the horizontal laxity. The steps of the procedure include:

- Canthotomy and cantholysis.
- Exposure of the periosteum of the lateral orbital rim using cotton applicators.
- Prolapsing fat can be cauterized.
- The eyelid is split laterally into anterior and posterior lamella and the extent of this split depends on the amount of lid shortening needed (Fig. 11a).
- The inferior edge of the separated tarsus is freed from attached retractors and conjunctiva, thereby creating a 4–5 mm wide tarsal strip.
- The mucosal lining at the superior margin of the tarsal strip is then trimmed off and a blade is then used to denude the tarsus of palpebral conjunctiva (to avoid epithelial inclusion cyst formation).
- The length of the tarsal strip is determined by stretching the lid laterally to the periosteum and excess tarsus is then excised.
- The tarsal strip is sutured to the periosteum of the inner aspect of the lateral orbital wall with 4-0 double-armed vicryl suture (Fig. 11b). A slight overcorrection in tightness and elevation is desired to allow for slight stretching in the early postoperative period.
- A wedge of anterior lamella, including the eyelash follicles, is excised.
- The lateral canthotomy incision is closed with interrupted 6-0 nylon sutures.

Often a mild medial ectropion persists and this is due to disinsertion of the lower eyelid

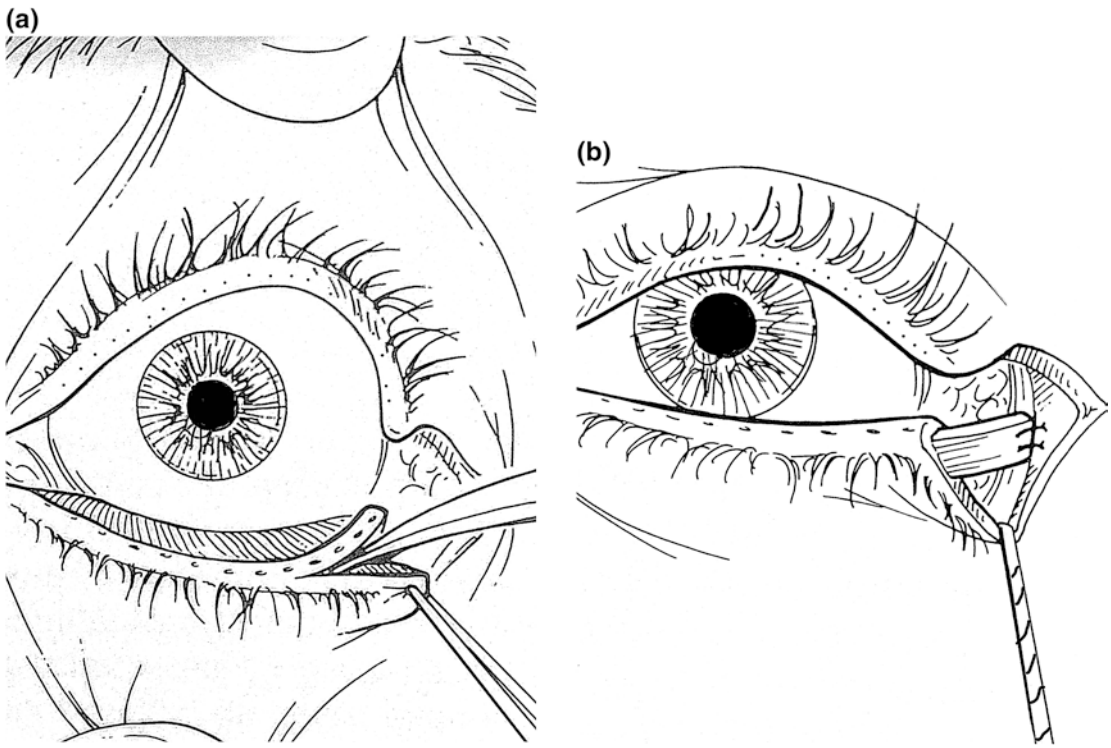


Fig. 11 The lateral tarsal strip procedure; **a** Splitting the eyelid laterally into an anterior and a posterior lamella. **b** The tarsal strip is sutured to the periosteum of the inner aspect of the lateral orbital wall with 4-0 double-armed vicryl suture

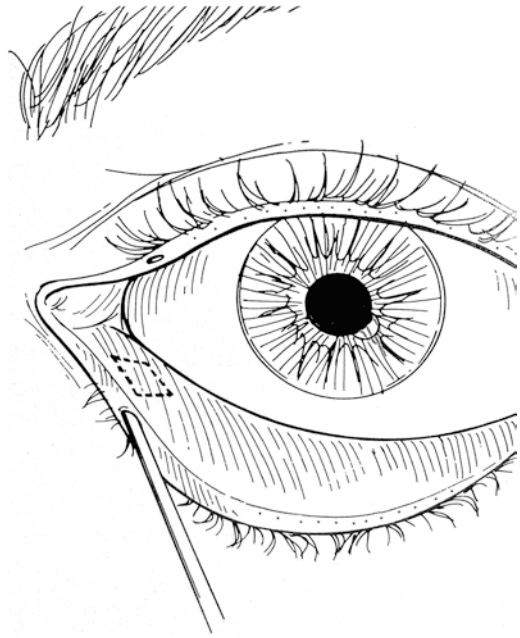


Fig. 12 The medial spindle procedure: a diamond-shaped piece of conjunctiva and underlying capsulopalpebral fascia is excised below the inferior punctum, and the edges are repaired with buried 6-0 vicryl suture

retractors. A medial spindle procedure is needed to add to the effect of the lateral tightening. This should be performed before the lateral tightening. A diamond-shaped piece of conjunctiva and underlying capsulopalpebral fascia is excised below the inferior punctum, and the edges are repaired with buried 6-0 vicryl suture (Fig. 12).

Cicatricial Ectropion

Vertical skin shortage is quite common in the lower lids and may worsen the involutional component. Mild degrees of cicatricial changes can be treated by steroid ointments applied to the skin for a few weeks, and avoiding spillage of topical medications (especially antiglaucoma) over the eyelid. More severe cicatricial changes require release of the scar, horizontal tightening, and supplementation with a full-thickness skin graft. An upper to lower eyelid myocutaneous flap based laterally is a better alternative and has more chance of graft survival (Fig. 13).

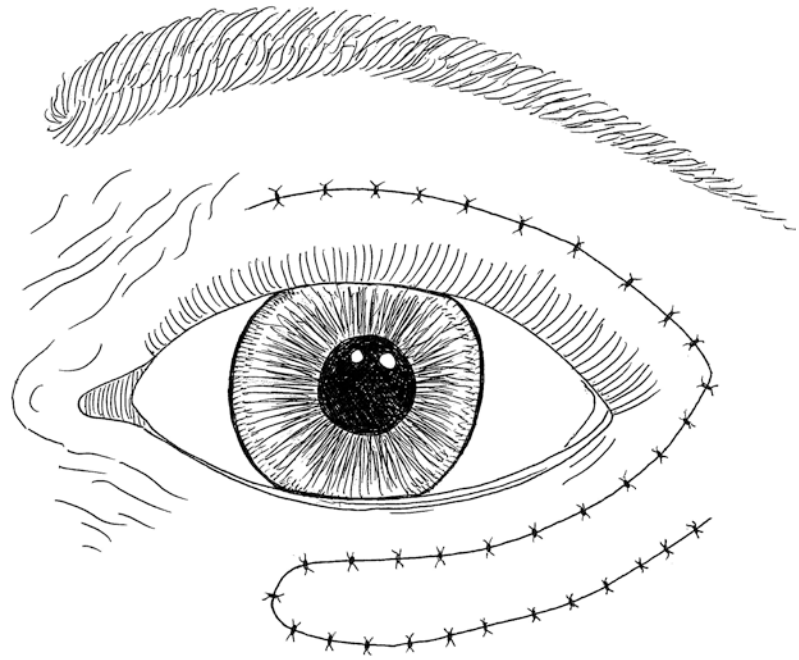


Fig. 13 For cicatricial ectropion, an upper to lower eyelid myocutaneous flap based laterally offers a good option and has more chance of survival than a free graft

Involutional Entropion

Correction of involutional entropion should address the aforementioned structural factors: horizontal lid laxity, disinsertion of the lower lid retractors from the tarsus, or pretarsal override of the orbicularis. The Quickert-Rathbun full-thickness rotation sutures are effective for mild cases but do not give a long-lasting effect. The sutures repair the retractor dehiscence and prevent override of the preseptal orbicularis. Double-armed 5-0 chromic or vicryl sutures are inserted in the conjunctival fornix and then directed in an anterior and superior direction to exit the skin 2 to 3 mm below the eyelid margin (Fig. 14). The sutures are tied tightly with tension titrated to yield optimal rotation. two to three sutures that are equally spaced are usually needed. In case of significant horizontal laxity, a full-thickness eyelid resection is done.

Both internal and external surgical approaches to repair involutional entropion are described in the literature. The transconjunctival method has the advantage of of avoiding visible scar, but may be associated with a higher rate of recurrence. The external approach may predispose to postoperative lid eversion. Treatment should be individualized and in those where there is no significant horizontal laxity, then surgery should aim at retractor correction and orbicularis override only. The procedure described below addresses all three factors and is the most commonly used by the author (R.M.)

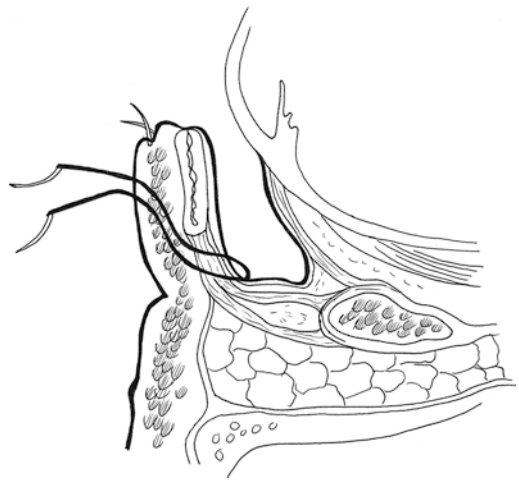


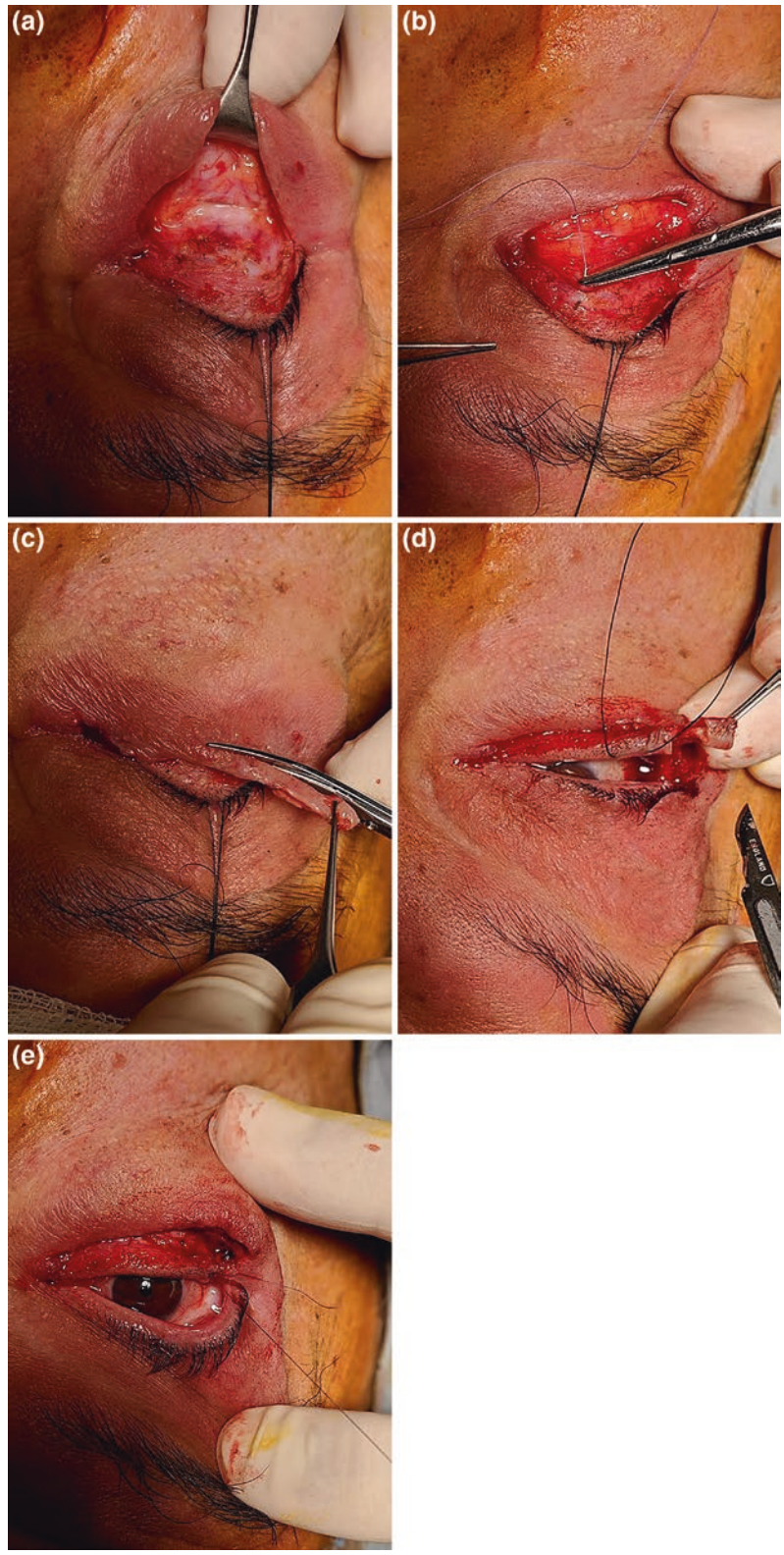
Fig. 14 The Quickert-Rathbun full-thickness rotation sutures for involutional entropion

Fig. 15 Correction of involutional entropion: **a** A subciliary incision is made and Dissection is then carried in the post-orbicular fascial plane. The septum is then opened below its fusion with the lid retractors. **b** The disinserted edge of the retractors is reattached to the inferior margin of the tarsus with two 5-0 vicryl sutures. **c** A small amount of excess skin is removed from the inferior edge of the incision. **d** The redundant lid is excised in a block. **f** The lid margin and tarsus are then repaired

Subcutaneous infiltration of the lower lid with 2% lidocaine with epinephrine. A 4-0 silk traction suture is placed. A subciliary incision is made through the skin and orbicularis with a 15 Bard-Parker blade. Dissection is then carried in the avascular post-orbicular fascial plane. The septum is then opened below its fusion with the lid retractors (Fig. 15a). The fat pads are gently dissected from the anterior surface of the retractors and can be excised if desired. The disinserted edge of the retractors is then reattached to the inferior margin of the tarsus with two 5-0 vicryl sutures (Fig. 15b). A small amount of excess skin can be removed from the inferior edge of the incision (Fig. 15c). A conservative preseptal orbiculectomy is made. Then a lateral tarsal strip procedure is done as described above to correct the horizontal laxity. Or, less commonly, a wedge resection of the lower lid is done as follows. A full-thickness vertical eyelid incision through the tarsus, positioned lateral to the lateral limbus is made. The tarsal segments are then overlapped to determine the degree of horizontal redundancy. The redundant lid is excised in a block (Fig. 15d), and the lid margin and tarsus are then repaired (Fig. 15e). The lower lid incision is closed with a running 6-0 Nylon suture.

Cicatricial Entropion

The principles of cicatricial entropion repair involve either recessing the anterior lamella, lengthening the posterior lamella with a graft,


(a)
(b)
(c)
(d)
(e)

or both. In the author's experience (R.M.), the use of grafts can be avoided most of the times. A simple and easy procedure to correct cicatricial entropion is to separate the anterior lamella from the posterior lamella at the gray line using a sharp blade and then excise a 2–3 mm of anterior lamella across the whole length of the eyelid (Fig. 16a). By this, the hair follicles are completely ablated and recurrence, which is common in cicatricial entropion, is not anymore a problem. This procedure is suitable for elderly patients whose eyelashes are not very prominent and cosmesis is not an issue, and especially in those patients who have already lost a significant number of eyelashes secondary to previous cryotherapy procedures or electrical hyfrecation.

Good long-term results have been reported using superior advancement of the upper eyelid margin, with or without a tarsal rotation flap. In the latter, the anterior and posterior lamellae are split starting at the gray line and all the way across the height of the tarsus. The anterior lamella is then sutured to tarsus recessed by 2–3 mm (Fig. 16b). In the case of a tarsal rotation flap, the lid is everted over a Desmarres retractor with a lid margin 4-0 Silk traction suture. A horizontal incision 3 mm above the lid margin is made through the posterior lamella (conjunctiva and tarsus) with a scalpel. Westcott scissors are then used to dissect between the anterior lamella and tarsus superiorly. Relaxing vertical incisions are then made at the medial and lateral extent of the tarsal incision. The anterior lamella, including the now fully everted lid margin, is recessed 2–3 mm above the cut edge of the tarsus and secured in this position using 6-0 vicryl mattress sutures both above and below the lashes (Fig. 16c). This same technique can be used without recessing the anterior lamella (Fig. 16d).

Upper Eyelid Retraction

Treatment of eyelid retraction is usually aimed at correction of the underlying cause. Surgical intervention may range from temporary suture tarsorrhaphy for ocular surface protection to eyelid-lengthening procedures to correct eyelid retraction and to decrease scleral show.

Tarsorrhaphy largely serves a protective role in the management of eyes with corneal exposure and lagophthalmos. Tarsorrhaphy may be performed either as a temporary or permanent procedure, depending on patient needs. Temporary suture tarsorrhaphies may be placed using one or more double-armed 5-0 nylon sutures placed in a mattress fashion with foam bolsters to protect the skin of the lids. In the acute phase of a patient's disease, in which the patient may require definitive surgery later, suture tarsorrhaphy is an excellent option for protecting the globe. Large permanent tarsorrhaphies can be cosmetically unappealing and should be used only in cases of last resort. Occasionally, a small permanent lateral tarsorrhaphy can effectively mask small degrees of proptosis (<3 mm) and provide select patients with greater symmetry of the horizontal palpebral fissure.

In cases requiring lengthening of the eyelids, upper lid retraction may be treated by weakening of Müller's muscle or the levator palpebrae superioris (or both). Numerous approaches to this kind of surgery have been advocated. The choice of the procedure is usually determined by a surgeon's experience. The two types of approaches to the upper lid are the internal approach through the conjunctiva and the external approach through a skin incision. Spacers, such as banked sclera and fascia lata, have been used to keep recessed Müller's muscle and levator aponeurosis from reattaching to the tarsus. The authors generally have not found these spacers to be necessary. These surgical techniques require extensive dissections that may contribute to unpredictable outcomes of postoperative ptosis, contour abnormalities, eyelid thickening, lid crease recession, and undercorrection.

The transconjunctival graded Muller's muscle recession under local anesthesia is a simple and highly effective technique in mild and moderate cases. Dissection of the muscle from the tarsal edge is carried out using radiofrequency or diathermy while local anesthesia

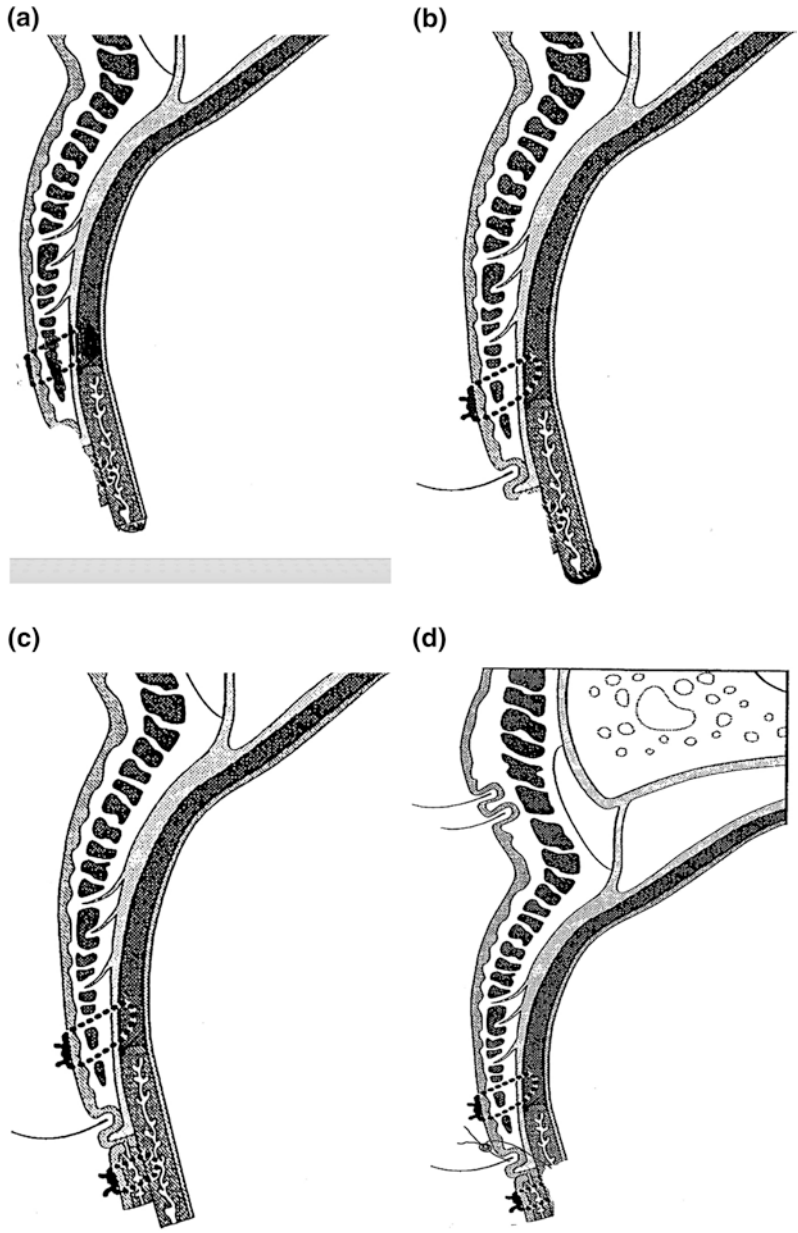


Fig. 16 Techniques for repair of cicatricial entropion: **a** Separate the anterior lamella from the posterior lamella at the gray line and then excise a 2–3 mm of anterior lamella across the whole length of the eyelid. **b** Separate the anterior lamella from the posterior lamella at the gray line and all the way across the height of the tarsus. The anterior lamella is then sutured to tarsus recessed by 2–3 mm. **c** Recession of anterior lamella and a tarsal rotation flap. **d** Tarsal rotation flap

allows for intraoperative adjustment. Sitting the patient up allows for accurate adjustment of the lid level and symmetry between both eyes. Lateral flare can be corrected by recessing more muscle laterally to achieve a better contour. The recessed edge of Muller's muscle is lightly sutured to the undelying levator muscle using 7-0 vicryl suture.

The **graded blepharotomy** technique originally described by Leo Koornneef in the 1990s is an effective and simple procedure that yields predictable results, even in patients with severe eyelid retraction. A lid crease incision is made and dissection through the orbicularis oculi muscle for the length of the incision. Dissection is then carried superiorly between the septum and orbicularis. The levator aponeurosis, Muller's muscle, and conjunctiva are then incised in the area of greatest retraction, creating a full-thickness blepharotomy. The full-thickness blepharotomy is then extended medially and laterally in a graded fashion based on lid height and contour (Fig. 17a–d). When extensive medial dissection resulted in flattening of the upper lid contour, a single 6-0 vicryl mattress suture is placed between the levator aponeurosis and tarsal plate in the flattened area to restore a desirable upper lid contour. Alternatively, a 1–2 mm wide conjunctival bridge can be left centrally to avoid flattening of the eyelid contour.

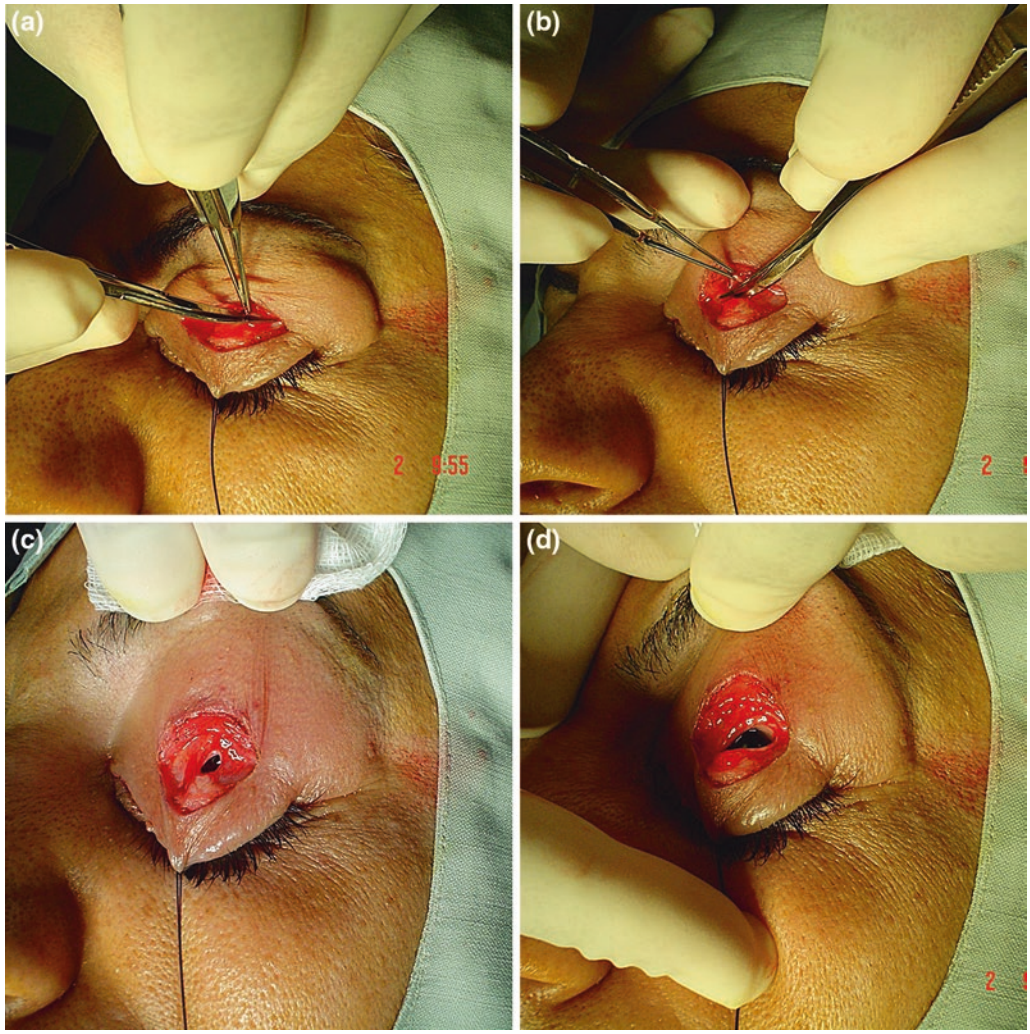


Fig. 17 The graded blepharotomy technique: **a–d** A lid crease incision is made. The levator aponeurosis, Muller's muscle, and conjunctiva are then incised in the area of greatest retraction, creating a full-thickness blepharotomy. The full-thickness blepharotomy is then extended medially and laterally in a graded fashion based on lid height and contour

Lower Eyelid Retraction

The lower eyelid is affected by a number of factors not found in the upper lid, rendering the correction of lower lid retraction particularly challenging. Gravity and the position of the globe relative to the lower rim are two important considerations that do not contribute as much to retraction in the upper lid. When there is horizontal laxity in the lower lid, gravity can have a significant effect, drawing the lid margin inferiorly. In addition, because the lower lid does not have the excursion capability of the upper lid, globe prominence in relation to the orbital rim inferiorly will cause a more noticeable increase in retraction than that seen in the upper lid.

If horizontal eyelid laxity is present, it should be addressed by a tightening procedure. The lower lid can be lengthened through an anterior or posterior approach. Unlike the upper lids, the lower lid is more easily approached through the transconjunctival approach. The lower lid can be everted over a Desmarres retractor with a silk traction suture placed through the lid margin. Dissection of the conjunctiva and the lower lid retractors from the lower border of the tarsus is then performed with a fine-toothed forceps and a scissors. Blunt dissection with a scissors can then be carried out in this preseptal plane down to the level of the orbital rim. The capsulopalpebral fascia can then be excised from the underlying conjunctiva. A spacer graft of various materials can then be placed to maintain the recession (Fig. 18). These include donor sclera, auricular cartilage, upper lid tarsus, hard palate mucosa, porous polyethylene (Medpor), and acellular dermis (Alloderm). Once the spacer graft has been placed, a Frost suture may be used to place the lower lid on stretch in a raised vertical position to allow healing of the graft site in a recessed position.

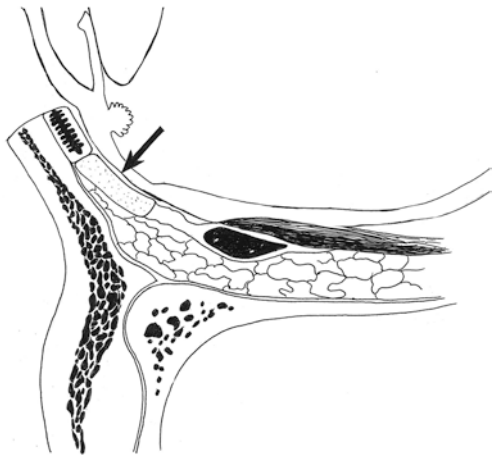


Fig. 18 Correction of lower eyelid retraction: Dissection of the conjunctiva and the lower lid retractors from the lower border of the tarsus is performed and a spacer graft of various materials can then be placed to maintain the recession

Repair of lower eyelid retraction following aggressive lower eyelid blepharoplasty with significant skin removal from the lower lids is best achieved by a skin muscle transposition flap from the upper eyelid to the lower eyelid (see chapter "Eyelid Reconstruction"). If there is little skin in the upper eyelid, then a full thickness skin graft is needed.

Conclusion

Ectropion, entropion and retraction are common eyelid abnormalities that pose challenges to the ophthalmologist. The goal of a successful surgical repair includes a good apposition of the lid margin to the globe, corneal irritation symptoms relief, good cosmetic outcome with lasting results. This chapter also emphasizes the importance of addressing the underlying pathophysiology.

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Centurion Syndrome

Can Öztürker and Pelin Kaynak

Introduction

Centurion syndrome is a medial canthal tendon insertion anomaly that causes functional epiphora in children and young adults. Epiphora is mostly bilateral (85%) and manifests in puberty with the growth of the midface leading to the anterior displacement of the lacrimal puncta. Prominent nasal bridges and enophthalmos are other features of this uncommon entity (Fig. 1a–c). Centurion syndrome was first described by Sullivan et al. in 1993. They preferred to use the name "Centurion" for this syndrome due to the similarity in nasal structure between these patients and portrayal of Roman Centurions.

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Anatomy of the Medial Canthal Tendon in Relation to the Lacrimal Pump Mechanism

In healthy individuals, the eyelids and punctum are normally in touch with the globe. The lower puncti are slightly everted inwards to the lacrimal lake that accumulates tears near the inner canthus. The tears enter the lacrimal canaliculi through the puncti by negative pressure formed in the lacrimal canaliculi during the eyelids' opening and is directed into the lacrimal duct by the lacrimal sac and eventually into the nasal cavity by the inferior meatus, by positive pressure on the sac exerted by contraction of orbicularis oculi muscle fibers and their tendons as the eyelids are closed. Conditions that impede contact between the lacrimal lake in the inner canthus and the puncti are some of the causes of functional epiphora.

The medial canthal tendon is a delicate and complex anatomical structure. The integrity of this structure is crucial for the function of the eyelids and the lacrimal pump. The anatomy of the tendon can be imagined as an X-shaped structure with its medial and lateral limbs being rotated through 90° lying on different planes. While the lateral limbs of the X, formed by the palpebral extensions of the tendon, are in a vertical plane; the medial limbs, consisting of the anterior and posterior limbs of the medial canthal tendon, are in a horizontal plane (Fig. 2).

E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_6

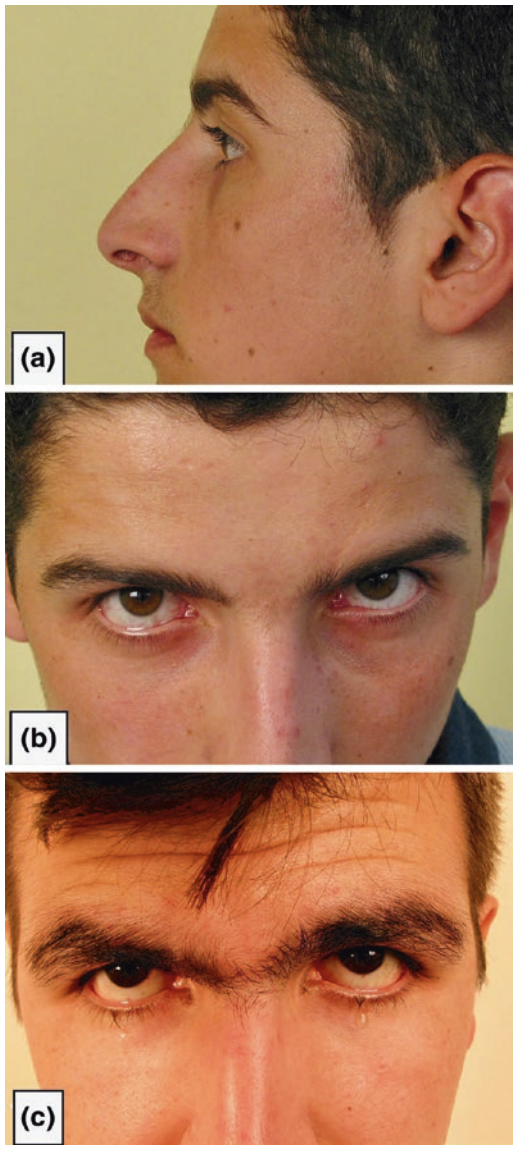

Fig. 1 **a** High and prominent nasal bridge and deep-set eyes in Centurion syndrome (Hertel exophthalmometric measurements: 7 mm OU). **b** Medial and lateral eyelid–globe malposition and epiphora. **c** Inferiorly angulated medial canthus named as the "beak" sign by Murthy et al.

The lacrimal canaliculi are encircled by the palpebral extensions of the medial canthal tendon. They merge medially to form the common canaliculus and the medial canthal angle. The anterior limb extends from the anterior lacrimal crest to the suture between the frontal process

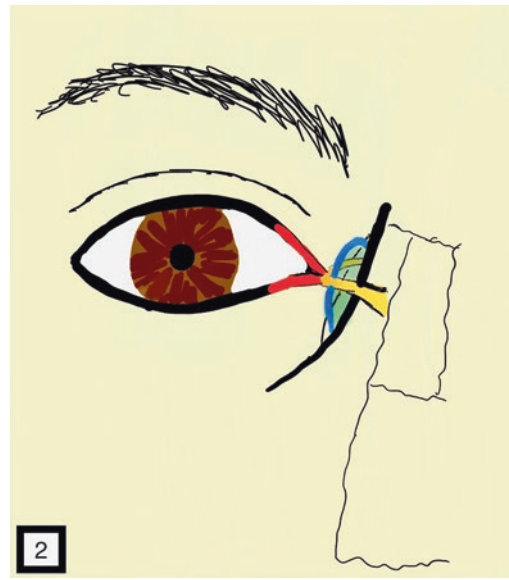

Fig. 2 The "X shaped" anatomy of the medial canthal tendon, red: palpebral extensions, yellow: anterior and post limbs of the medial canthal tendon

of the maxilla and the nasal bone. The posterior limb, positioned anterior to the Horner's muscle, proceeds posteriorly passing through the lacrimal fascia and diaphragm and attaches to the posterior lacrimal crest. The common canaliculus, which is behind the anterior limb of the medial canthal tendon gets through the posterior limb and the lacrimal fascia to enter the lacrimal sac. Any imbalance or disturbance of this fine configuration may lead to functional epiphora.

In Centurion syndrome, the reason for the anterior displacement of the lower punctum away from the lacrimal lake is considered to be secondary to an abnormal anterior insertion of the anterior limb of the medial canthal tendon, which pulls the punctum anteriorly and disrupts the eyelid–globe apposition. Murthy et al. named the shape of the inferiorly angulated medial canthus in this syndrome as the "beak" sign (Fig. 1c). A prominent nasal bridge is another pathognomonic feature and probably plays a role in the development of the canthal anomaly (Fig. 1b). A relative weakness of the posterior limb by diminishing the posterior pull or a relative retro-displacement of the globe may contribute to the impairment as well. In the

meantime, a lateral impediment of the eyelid-globe apposition may coexist and require additional surgery.

The mean referral age is the second decade of life in concordance with the growth of the midface during puberty, though the onset of epiphora is in the first decade of life.

The diagnosis of the syndrome is based on the recognition of anterior displacement of the medial canthal tendon and the punctum (Fig. 1b). The prominence of the nasal bridge is another important sign of the syndrome. The exact incidence of Centurion syndrome is unknown and the number of published cases in the literature is very scarce. One of the reasons for this rarity may be that the canthal anomaly can easily be overlooked. Therefore, it should always be suspected in young patients with unexplained epiphora. Once the diagnosis of Centurion syndrome has been clarified, it is important to notice concomitant features like exophthalmos or lateral eyelid laxity.

Hertel exophthalmometer readings below 15 mm have been reported and acknowledged deep-set eyes as one criterion for the Centurion syndrome (Fig. 1a).

Lacrimal syringing is patent, but fluorescein dye disappearance test and dacryoscintigraphy reveal a delay of the lacrimal passages like other types of functional epiphora.

Surgical Management

The correction of the malposition mainly involves disinsertion of the anterior limb of the medial canthal tendon. The release of the anterior limb alone does not cause any problem if the posterior limb is uniform. However, there is no consensus about the efficacy of the present medial canthal tendon surgeries in obtaining eyelid–globe apposition for a long-term period in patients with Centurion syndrome and frequently adjunct procedures may be required for improvement.

Sullivan et al. performed various techniques in a series of 13 patients with Centurion Syndrome with variable outcome followed by adjunct surgeries to resolve epiphora. They released medial canthal tendon alone in 7 patients with tendon stump plication and suturing to the periosteum posterior to the anterior lacrimal crests. Four patients underwent medial canthal tendon release combined with dacryocystorhinostomy due to additional lacrimal outflow obstruction. One of these 4 patients required an additional medial tarsoconjunctival diamond excision. Another patient with anterior displacement of the lateral canthal tendon underwent bilateral lateral tarsal strip procedure and medial canthal tendon surgery was not required.

Sujatha et al. reported total resolution of epiphora by restoring normal apposition between the lower eyelid and globe in all 40 patients by releasing the anterior limb of the medial canthal tendon without resuturing of the cut tendon. However, medial canthal tendon release, solely was found to be insufficient for adequate lower punctum apposition in the treatment of Centurion syndrome by some of the authors.

Murthy et al. performed medial canthal tendon release alone and in combination with punctoplasty and/or with conjunctivoplasty, with success in resolving epiphora in primary and failed cases.

Lower eyelid retractor plication added to medial canthal tendon release in these patients was also reported to achieve a good results, with or without lateral tarsal strip procedure.

Kaynak et al. reported two patients with Hertel exophthalmometry readings 7 and 10 mm bilaterally and Centurion syndrome whom they performed medial canthal tendon release and posterior plication with partial relief of epiphora (Fig. 3a, b). An additional lateral tarsal strip procedure with posterior refixation of the tendon had to be performed in both cases to improve the eyelid-globe apposition (Fig. 4) suggesting that tendon release alone may not be efficient to solve the epiphora in patients with Centurion syndrome who have significant accompanying enophthalmos.

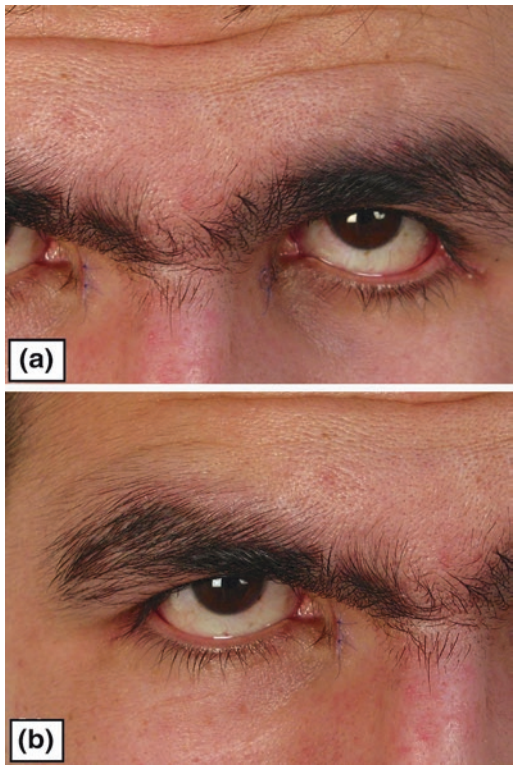

Fig. 3 **a** Inadequate eyelid–globe apposition after medial canthal tendon surgery alone in the left eye; medial region: 0.5 mm, lateral region: 1.5 mm. **b** Inadequate eyelid–globe apposition after medial canthal tendon surgery alone in the right eye; medial region: 0.5 mm, lateral region: 1.3 mm

Fig. 4 Eyelid–globe apposition after medial canthal tendon surgery alone in the left eye and medial canthal tendon surgery combined with lateral canthal tendon surgery in the right eye. Eyelid–globe apposition is better in the right eye compared to the left eye

Conclusion

Centurion syndrome is rare medial canthal tendon insertion anomaly that causes functional epiphora in children and young adults. Epiphora is mostly bilateral and manifests in puberty with the growth of the midface leading to the anterior displacement of the lacrimal puncta. Prominent nasal bridges and enophthalmos are other features of this uncommon entity.

Medial canthal tendon release combined with its posterior refixation may not be adequate in every patient and different surgical interventions for the absolute apposition of the punctum and lacrimal lake should be chosen according to the individual patient's characteristics. Sometimes the patients may need to be operated more than once to achieve relief of epiphora.

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Floppy Eyelid Syndrome

Can Öztürker and Pelin Kaynak

Introduction

Floppy Eyelid Syndrome (FES) is one of the rare and underdiagnosed disorders of the eyelids. It is characterized by easily everted, floppy and rubbery upper eyelids and associated papillary conjunctivitis. Depending on the patient's preferred sleeping side, one or both of the lax upper eyelids get everted spontaneously during sleep. As a consequence; the constant friction and rubbing lead to conjunctival irritation, inflammation, and keratinization ending up with a general thickening of the upper eyelid.

This syndrome was first reported in middle-aged, overweight men having the typical symptoms of FES. With continuous reports of FES, females and different age groups are being affected as well.

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Pathogenesis

The pathogenesis of FES is still unclear, but it has been associated with many systemic and ophthalmologic comorbidities like obesity, obstructive sleep apnea (OSA), keratoconus and glaucoma. These co-occurrences give rise to the thought that local and systemic mechanisms may act together in the pathogenesis of FES.

Loss of tarsal elasticity leading to spontaneous eversion of upper eyelids during sleep may be one of the causes. Resultant exposure and constant rubbing to pillow were assumed to be the reason for the mechanical irritation and inflammatory changes in the conjunctiva and tarsus. The observations of the severely affected eyelid corresponding to the side that the patient slept on provided the basis for this mechanical theory. The association of FES with keratoconus, another disease known to be related to eyelid rubbing support this mechanical theory as well. Moreover, the ocular symptoms of FES typically improve with eyelid taping or wearing an eye shield.

Pressure-induced ischemia related to sleep posture and following oxidative reperfusion injury might be another mechanism leading to the changes in tarsal structure. Because of frequently co-existing OSA, patients with FES may experience low arterial O_2 levels while asleep and rapid reoxygenation on awakening. This mechanism is known to induce stroke, myocardial infarction, and arrhythmias. When the

E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_7

patient moves during sleep, local pressure on the eyelids due to face down sleep posture may lead to repeating cycles of temporary ischemia and reperfusion.

Specific histopathologic changes underlying the changes in FES are a marked decrease in the number of elastin fibers in the tarsal plate and the pretarsal orbicularis muscle of patients with FES. An increased matrix metalloproteinase (MMP) activity, especially MMP-7 and MMP-9, has been found in the eyelids with FES. The increased MMP activity may lead to elastin fiber degradation and may evoke eyelid laxity and instability.

Similarly, disorganization of elastin fibers has been demonstrated in the uvular tissue samples of OSA patients who underwent uvulopalatopharyngoplasty. This finding can be evidence of a common pathophysiological mechanism underlying both disorders, the FES and OSA. This common mechanism can be a combination of local pressure-induced ischemia and systemic nocturnal hypoxia. Elevated serum levels of Leptin in patients with FES and sleep apnea have been detected. Leptin is a hormone that gives the feeling of satiety and is usually increased in obese people due to resistance to it. Leptin may have a role in the upregulation of MMP's causing degradation of elastin. This theory can be another hint for the association of FES with obesity and OSA.

Clinical Features

The most commonly affected group remains obese men aged 40–69 presenting mostly with ocular irritation. The hallmark of FES is an easily everted upper eyelid and associated papillary conjunctivitis. On palpation, the tarsal plate feels rubbery and soft combined with a horizontal laxity of the eyelid. A gentle lifting of the upper eyelid can evert the eyelid very easily. Sometimes a laxity of the lower eyelids can be observed as well (Fig. 1a–c showing a patient with both upper and lower lids affection).

On eversion, the lids can stay everted for up to few minutes (Fig. 2). On attempted lid closure, the upper lids can become everted with exposure of the upper palpebral conjunctiva (Fig. 3). Although the eyelids are the primarily

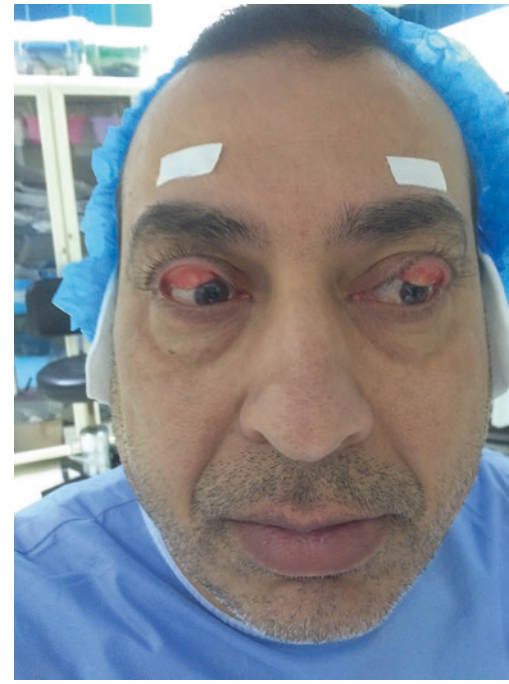

Fig. 2 The lids can stay everted for up to few minutes

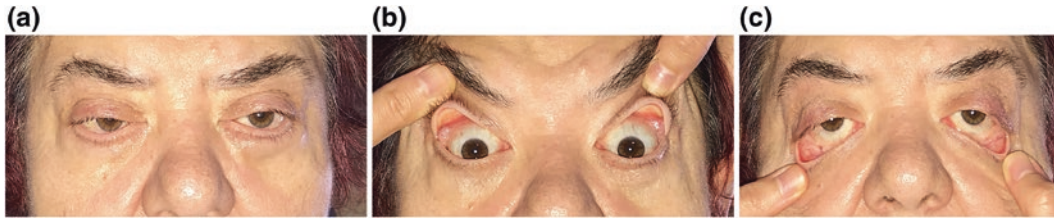

Fig. 1 **a** A 56 years old woman referred for bilateral blepharoptosis. **b** The upper eyelids get everted very easily just by gently lifting the upper eyelids revealing the diagnosis for floppy eyelid syndrome. **c** Concurrently the patient also has severe lower eyelid laxity

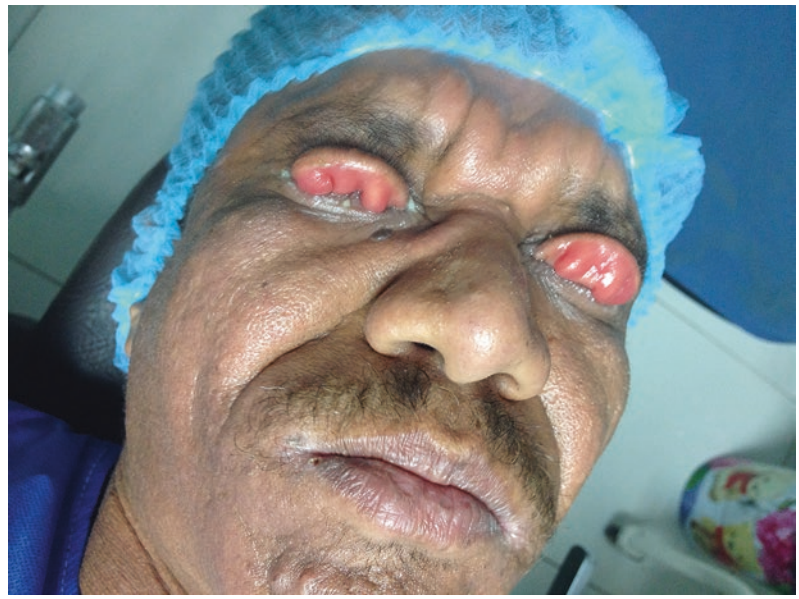

Fig. 3 Spontaneous eversion with conjunctival exposure on attempted lid closure

affected organs in FES, pathological changes can be observed in other ocular structures as well. Cornea is the second most common ophthalmic structure involved in FES. Besides punctate epitheliopathy being the most common corneal problem seen in FES (45%), an association between keratoconus and FES (10%) has also been revealed, followed by corneal scarring and neovascularization, thinning, microbial keratitis and corneal perforation. This can be related to the fact that mechanical trauma is one of the key factors in the pathogenesis of both entities. Other ocular problems related to FES include chronic conjunctivitis, dermatochalasis, blepharochalasis, blepharoptosis, eyelash ptosis, blepharitis, tear dysfunction, lower eyelid laxity, ectropion, and globe luxation. Moreover, OSA has also been found to be associated with glaucoma, nonarteritic ischemic optic neuropathy (NAION) and central serous chorioretinopathy (CSR).

As a consequence of sharing similar mechanisms in pathogenesis, a strong association between OSA and FES exists as well. While only a minority patients with OSA do have FES (2.3–32.6%), a majority of patients with FES do suffer from OSA (at least 50%). Together with OSA, FES has also been reported to appear in conjunction with numerous systemic conditions like obesity, hypertension, diabetes, hyperlipidemia, ischemic heart disease, skin pathologies, mental retardation, hyperglycinemia, and Hashimoto's thyroiditis.

Management

Treatment options for FES are mainly surgical, but some patients may benefit from conservative treatments like lubricating drops and ointments, eye patching, and placement of a nightly eye shield to avoid the mechanical trauma during sleep. There have also been a few reported cases, where weight loss and treatment of OSA has been beneficial for the relief of FES symptoms.

The surgery in FES is to correct the poor globe apposition, horizontal laxity, and lagophthalmos. All the different surgical techniques used for the treatment of FES are aiming the correction of horizontal eyelid laxity. The results of the surgery are satisfactory and can relieve the ocular symptoms by correcting the impaired anatomy. These include pentagonal upper eyelid wedge resection, lateral tarsal strip procedure

with or without a periosteal flap for lateral canthal fixation, medial canthal procedures or different combinations of these procedures. In order to avoid recurrence of FES, it has been recommended to start treatment for OSA before the surgery.

Lateral tarsal strip procedures remain the mainstay of treatment, being small incisional surgeries healing with minimal scaring. On the contrary, full thickness pentagonal resections do have the disadvantage of the incisions being perpendicular to the relaxed skin tension lines, which may cause a risk for visible scarring.

Conclusion

Floppy eyelid syndrome may cause significant morbidity and vision loss. Early diagnosis of OSA may save the patient from related serious ocular and systemic complications and avoid recurrence of FES after eyelid surgery.

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Congenital Ptosis

Mark R. Levine

Congenital ptosis is a localized dystrophy of the levator muscle. There is fibrous tissue where striated muscle would be expected. This correlates well with the severity of the ptosis. Mueller's muscle is normal. Congenital ptosis may be unilateral or bilateral. It maybe classified as simple or complicated by ophthalmoplegia (superior rectus weakness), blepharophimosis syndrome, and Marcus Gunn jawing winking ptosis.

Patients may have amblyopia resulting from anisometropia, strabismus, pupil occlusion, or meridional amblyopia.

In the preoperative evaluation the amount of ptosis is measured as the distance between the upper and lower eyelid margins with the brow held in a normal position and the lower lid at the inferior limbus. The amount of ptosis can be determined in unilateral cases between the difference in the palpebral fissure, or the marginal light reflex, that is the difference between the corneal light reflex to the upper eyelid. In bilateral cases the marginal light reflex is the only way to measure the amount of ptosis.

The amount of ptosis may be mild (2 mm), moderate (3 mm) or severe (4 mm). Levator muscle function is the measurement of the upper eyelid excursion from far downgaze to far upgaze with the eyebrow held in a fixed position to eliminate frontalis muscle action. Excellent levator function is 13–15 mm, very good function 10–13 mm, good function 8–10 mm, fair function 5–7 mm, and poor function 4 mm or less. Although the amount of ptosis is important, the amount of levator function is critical for determining a good outcome. The better the muscle function the better the result. The worse the muscle function the more resection you need to do. As this chapter is a surgical approach it must be remembered that a complete preoperative exam is mandatory as described in Chap. 11.

What are the surgical choices in congenital ptosis surgery? In the case of levator function of greater than 13 mm with a good response to phenylephrine a posterior approach such as the conjunctival Mueller's muscle resection can have an effective result. This is not generally the case however.

When levator function is 5–15 mm levator aponeurosis and muscle resection is the most appropriate technique (Table 1).

The real problem arises in cases of unilateral ptosis with less than 4 mm of levator function. The obvious questions that are constantly debated is: maximum levator resection with or without cutting the horns vs a unilateral frontalis sling. Cutting the horns mobilizes more levator muscle, while not cutting the horns effectively allows suture placement through the superior

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_8

Table 1 Levator resection table

Amount of ptosis (mm)	Amount of levator resection (mm)
Levator function 12–15 mm	
2	10
3	12
4	14
Levator function 9–11 mm	
2	12
3	14
4	16
Levator function 5–8 mm	
2	14
3	16
4	18

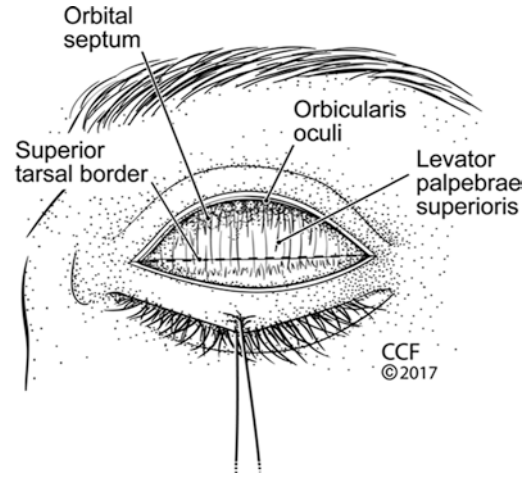

Fig. 1 Anterior approach showing the barred tarsal plate, orbital septum and levator aponeurosis

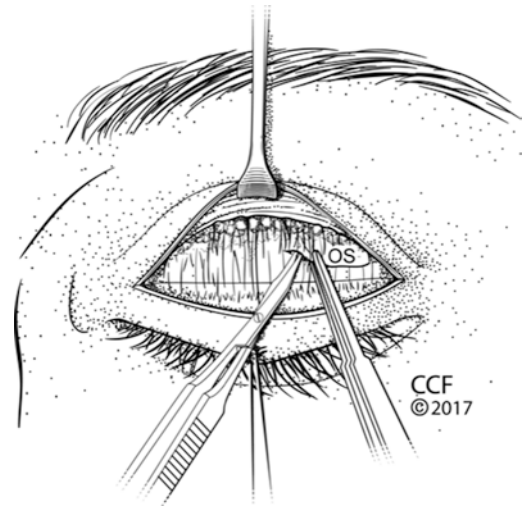

Fig. 2 Opening of orbital septum to expose preaponeurotic fat

transverse ligament of Whitnall acting much like an internal sling. However if an 18 mm resection does not bring the eyelid up to the limbus or one mm below the limbus, cutting the horns will allow more levator muscle mobilization and resection. If a maximum levator resection is suboptimal, a frontalis sling can always be performed. It is important that these options are discussed with the family.

The indication for doing ptosis surgery is a patient who has an eyelid obstructing the visual axis, amblyopia, abnormal head position or unsatisfactory facial appearance. The best time for surgery is around 4 years of age when accurate measurements can be taken unless the risk of amblyopia and poor visual development is high. Most cases of ptosis correction are done under general anesthesia. However older children around 16–17 years of age may be performed under monitored anesthesia to allow for the best eyelid height and contour.

In the case of moderate ptosis with levator function greater than 4 mm the procedure is as follows. Under general anesthesia the upper eyelid crease is marked out with methylene blue marking pen to correspond with the opposite upper eyelid crease. A small amount of skin is marked out now or removed at the end of the procedure. The eyelid is injected with 2% lidocaine with 1:100,000 epinephrine and equal parts of 0.75% bupivacaine for hemostasis and postoperative pain control.

The skin is incised along the length of the eyelid crease. A scissors is used to remove the skin and orbicularis muscle to expose the superior tarsal border. The middle two thirds of the tarsal plate is barred with orbicularis muscle removal and hemostasis maintained (Fig. 1). Dissection is carried up superiorly under orbicularis muscle to

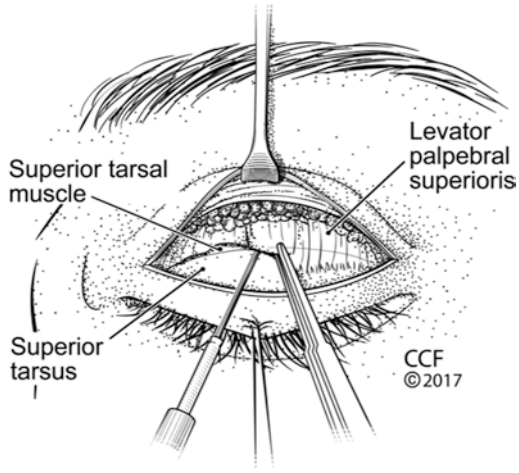

Fig. 3 Dissection of levator aponeurosis off Muller's muscle with cautery

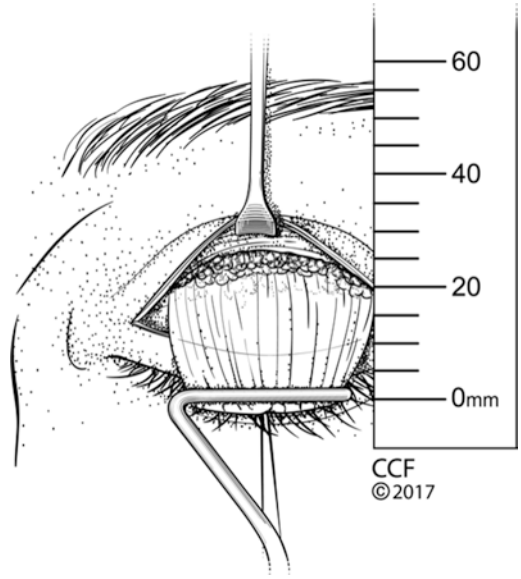

Fig. 4 Measuring the amount of levator resection

expose the orbital septum and the levator aponeurosis. Gentle pressure on the globe will prolapse the preaponeurotic fat. The orbital septum is opened completely exposing the preaponeurotic fat underneath being the levator aponeurosis and muscle (Fig. 2). It maybe necessary to remove some preaponeurotic fat depending on the amount of levator muscle resection.

With inferior traction on the pretarsal skin muscle flap, a hand held double battery cautery is used to dissect the levator aponeurosis off the tarsal plate. The dissection continues superiorly off Muller's muscle and conjunctiva to the desired predetermined position. The superior transverse ligament of Whitnall is not cut, as well as the medial and lateral horns (Fig. 3).

The amount of the levator resection is measured from the inferior edge of the cut aponeurosis (Fig. 4). A double armed 6-0 silk is placed partial thickness through the mid tarsal plate and back through the levator at the desired predetermined level and tied over a 4-0 silk. The contour and height are then determined and readily adjusted if necessary by pulling on both ends of the 4-0 silk. Two additional sutures are placed nasal and temporally for reinforcement and contour adjustment. The 4-0 sutures are removed and the 6-0 silk sutures tied down firmly (Fig. 5). The excess levator is excised with a hand held cautery (Fig. 6).

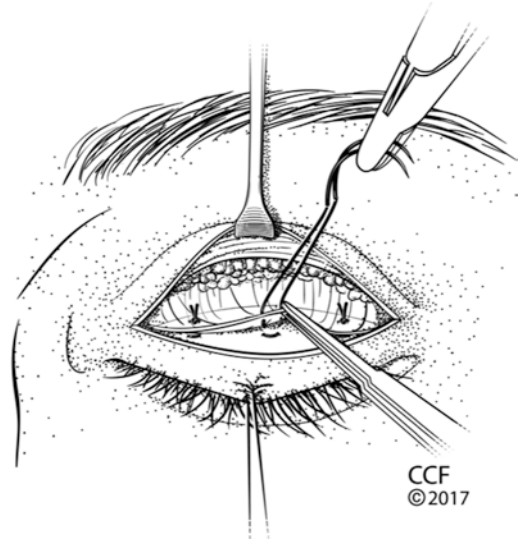

Fig. 5 Levator sutured to mid tarsal plate

Skin may be excised superior to the incision if not excised initially. The lid crease is then formed by placing three to four 6-0 plain sutures placed through the skin orbicularis muscle inferiorly, then through the edge of the levator, and out through the orbicularis muscle and skin superiorly. The remainder of the eyelid is closed with a 6-0 fast absorbing

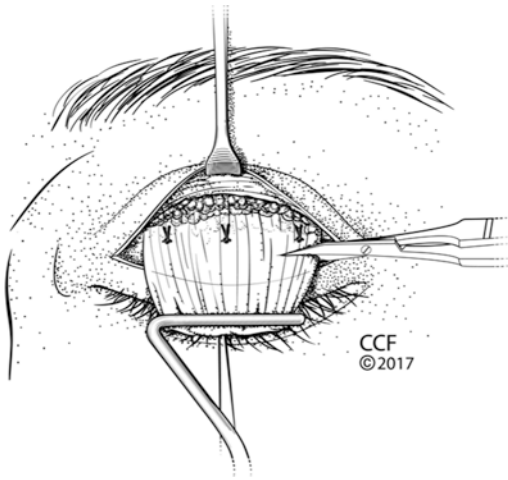

Fig. 6 Excess levator muscle excised

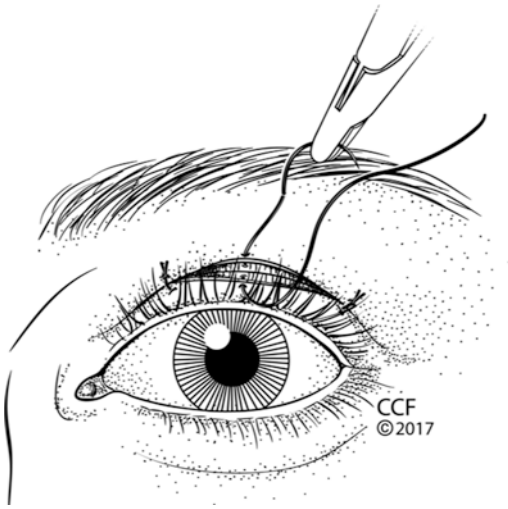

Fig. 7 Closure of the eyelid crease incision

suture (Fig. 7). A 4-0 silk suture is placed in the lower lid margin and taped to the forehead for ocular protection and the eye patched. The patch and suture are removed the next day, the lid position checked and the eye lubricated with artificial tears during the day and ointment at night. A plastic bubble may also be helpful at night. Remember the more levator resection performed, the more lid lag and lagophthalmos so aggressive lubrication is essential.

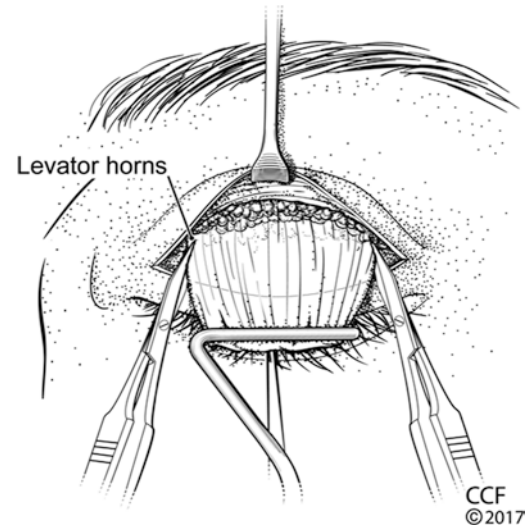

Fig. 8 Cutting of the lateral and medial horns in supramaximal resection

In the case of maximum levator resection with levator function of less than 4 mm and 4 mm of ptosis a resection of 25 mm may need to be performed. This can only be accomplished only by cutting the medial and lateral horns of the levator muscle. The dissection plane is carried between levator and Muller's muscle conjunctival complex or between levator-Muller's muscle complex and conjunctiva. The dissection is best carried out with a double battery hand held cautery allowing for easy dissection and minimal bleeding (Fig. 8). The goal here is to set the eyelid at the superior limbus. When in doubt, overcorrection is better than undercorrection. Once again 3 double armed 6-0 silks are placed intratarsally centrally first, then through the levator-Muller's complex and are tied over a 4-0 silk suture. The eyelid position is adjusted for height and contour, and repositioned if necessary with 4-0 silk adjustment. When the height is satisfactory, nasal and temporal sutures are placed to reinforce levator muscle on the tarsal plate and adjust the contour. The excess levator muscle flap is excised with a hand held cautery and the eyelid crease formed and closed as described. A 4-0 silk traction suture is place through the lower lid and taped to the brow. The eye is patched. The patch and traction suture

are removed the next day. Intense lubrication is started to avoid postoperative keratopathy.

Complications are undercorrection, overcorrection, conjunctival prolapse, and severe keratopathy. Overcorrection can be corrected with a small levator recession. Under correction with additional levator resection or frontalis sling. A conjunctival prolapse, if it doesn't spontaneously resolve within few days, is best treated with full thickness sutures to fixate the conjunctiva to the upper fornix. Keratopathy is best treated with aggressive lubrication.

Frontalis Sling

The frontalis sling operation is the preferred procedure to correct severe ptosis with poor levator function (less than 4 mm of function), or after a failed maximum levator resection. The goal of the operation is to suspend the upper eyelid to the frontalis muscle above the brow. A variety of materials have been used for sling material, but the procedure remains the same. The gold standard is autogenous fascia lata but it is difficult to harvest in sufficient length under 5 years of age. Preserved fascia lata use to be readily available and has a significant absorption rate. In recent years silicone rods have become a preferred choice as it is easily adjustable, very elastic with a low recurrence rate (see Chap. 11). In general a single pentagon sling is very effective for a child's lid. The decision to suture the sling material directly to the tarsal plate through an eyelid crease incision, or small stab wounds behind the upper eyelid lashes is surgeons choice. Both effectively work.

It is important to discuss complications before surgery such overcorrection, undercorrection asymmetry, lagophthalmos, corneal exposure, graft rejection, abnormal blink reflex, donor site incisional scars and muscle herniation.

The technic for retrieving autogenous fascia is as follows. Under general anesthesia and same day surgery, the child is placed on the operating table with the donor leg flexed and elevated on a small pillow. This puts the tensor fascia lata on stretch and makes the graft easier to obtain. The entire leg is prepped and draped. The fascia lata is palpated and a 3 cm methylene blue longitudinal mark beginning two fingerbreadths above the lateral condyle of the femur to the anterior iliac spine is made (Fig. 9). The area is injected

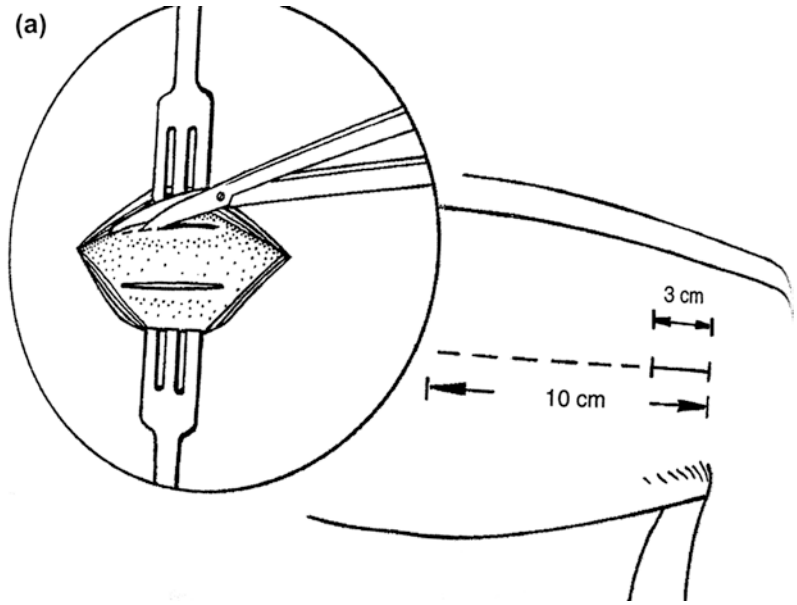

Fig. 9 Placement of incisions on lateral aspect of leg

with 2% xylocaine with 1:100,000 epinephrine with equal parts of 0.75% bupivacaine for hemostasis and pain control. A 3 cm incision is made through skin and fat to expose the white glistening fascia lata. A long curved Metzenbaum scissors is placed in the wound and dissection is carried up 10 cm extending up the thigh separating all the attachments of the subcutaneous tissue to the fascia. Short 8 mm fascial incisions parallel to each other are made into the fascia lata. Metzenbaum scissors are inserted beneath the fascia and run up 10 cm making sure all attachments are released between fascia lata and the vastus lateralis muscle. This is critical to facilitate fascia removal with the fascial stripper. The short fascia incisions are then elongated superiorly (Fig. 9).

The distal fascia strip is cut and made long enough to fit into the Masson or Crawford stripper. The fascial strip is clamped with a hemostat and the stripper is run superiorly for 10 cm. The fascial trip is then severed and removed (Fig. 10). No attempt should be made to close the fascial defect to avoid an ischemic compartment syndrome. The dermal layer is closed with 5-0 colorless nylon suture layered closure, the skin with a 4-0 or 5-0 suture of choice and a pressure dressing applied to the donor site to avoid a hematoma. Do not use a circumferential pressure dressing that may restrict circulation. The dressing stays on for three days while the patient is carefully ambulatory.

The fascia lata is placed on a cutting board and fat and connective tissue are remove from the fascial strip. The fascia is cut into two pieces each measuring 3–4 mm in width. Even if only one eyelid is being operated on, an 8 mm strip must be harvested because it is difficult to remove a narrow 4 mm strip of fascia from the leg.

Fig. 11 Placement of proposed brow and eyelid incisions

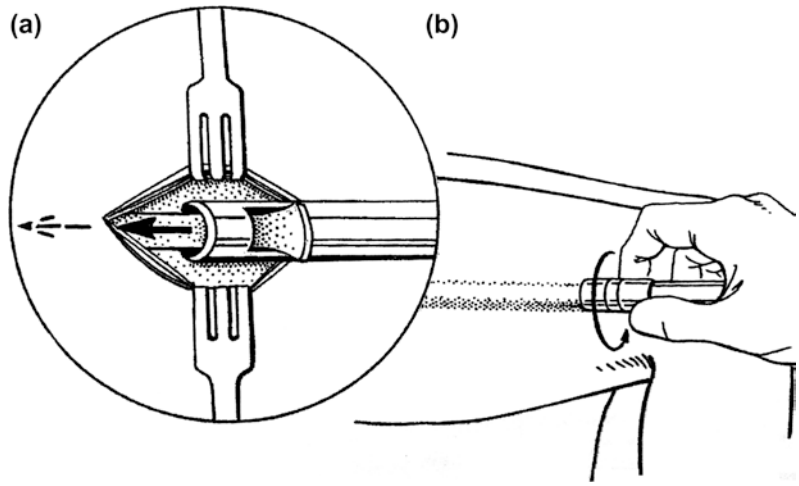

Fig. 10 Use of fascial stripper

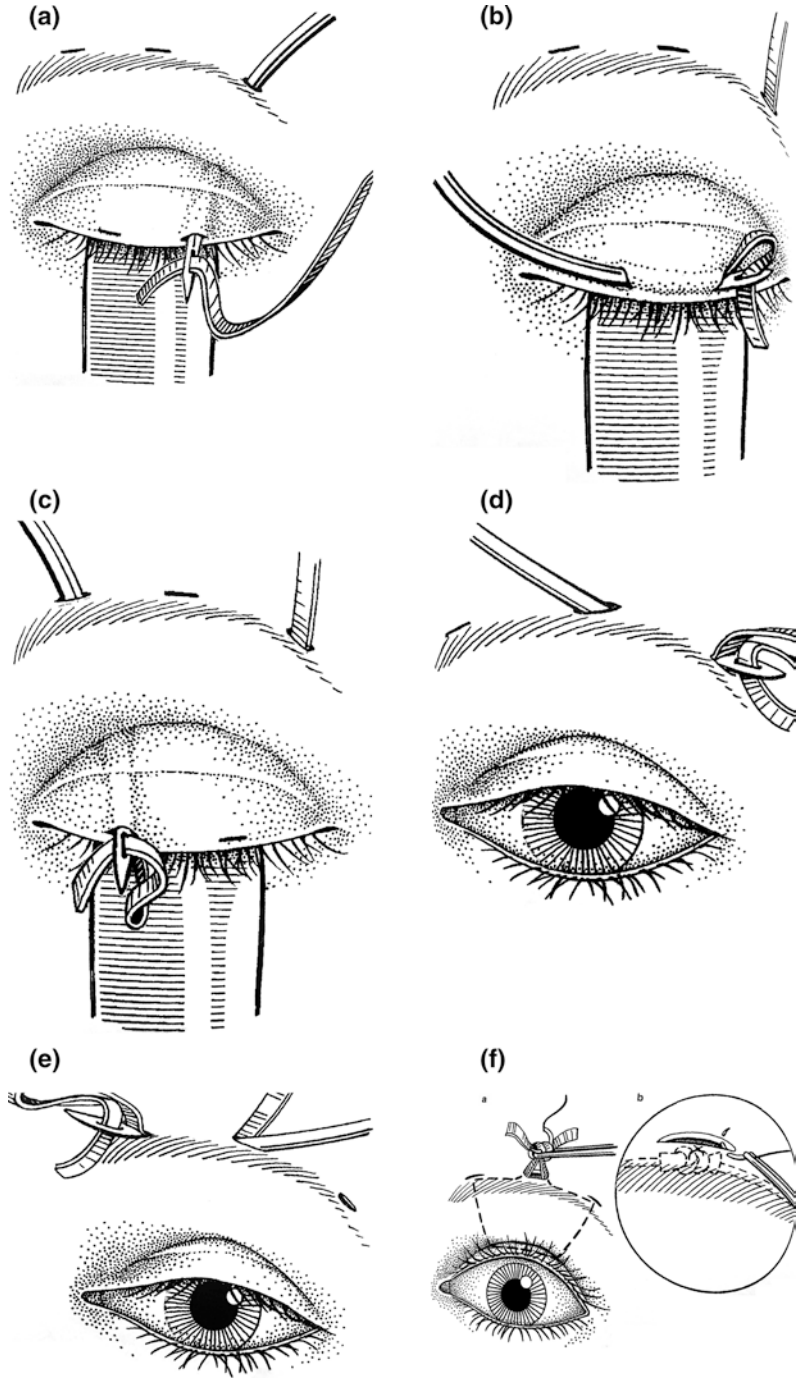

Fig. 12 **a–f** Autogenous fascia lata graft placement and lid positioning

Attention is directed to the eyelid to be elevated. Five 3 mm horizontal incisions are then made in the shape of a pentagon. Three incisions are made just above the brow the and two just above the edge of the upper lid. The upper eyelid incisions are placed where the corneal limbus intersects the eyelid with the eye in the primary position Figs. 18 to 11b. Two forceps are used to pull up the upper lid at the proposed incision site and observe the lid contour. If the eyelid incisions are to close the lid will be peaked. If they are too far apart the lid contour will be flat centrally. All five incisions must be placed accurately so that when the fascial strips are tied down, a pleasing eyelid crease and contour results. In older children with a large lid six incisions may need to be made in a double rhomboid configuration to pick up each half of the upper lid (Fig. 11).

Incisions are made through each brow incision to the frontal bone with a 15 blade. Firm pressure is applied to compress transient bleeding. Eyelid incisions are then place through skin and orbicularis muscle to the tarsal plate. Scissors are used to connect both incisions to facilitate passage of the Wright fascial needle. A Jaeger plate is placed underneath the lid to protect the globe during the passage of the Wright fascial needle. The needle is passed from the temporal brow incision to the temporal lid incision deep to the skin and orbicularis muscle and anterior to the orbital septum (Fig. 12a). Too superficial placement will result in bowing of the skin. The fascia is placed through the needle eye with a tooth forceps and pulled up into the brow incision. The fascial needle is placed through the nasal eyelid incision underneath the skin and orbicularis to the temporal incision, the fascia inserted and brought through the nasal lid incision and the fascia brought nasally (Fig. 12b). The Wright needle is then inserted in the nasal brow incision underneath skin and orbicularis to the nasal eyelid incision, fascia inserted and brought up to the nasal brow incision (Fig. 12c). Both pieces of fascia are brought through the central incision (Fig. 12d, e). The eyelid fascia is pulled up as high as possible

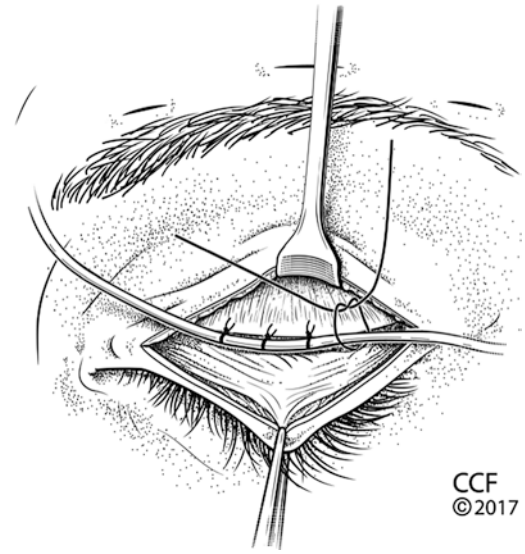

Fig. 13 Placement of silicone rod on tarsal plate

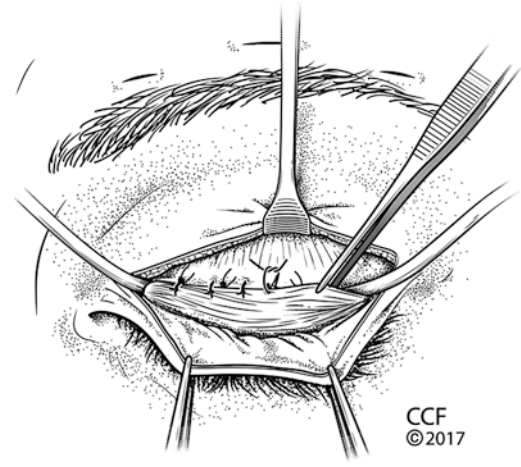

Fig. 14 Covering the rod with orbicularis muscle

(Fig. 12f). The fascia is tied with a single square knot and reinforced with a 5-0 braided polyester suture. The knot is placed deep and above the central brow incision. Each of the brow incisions is closed with a 6-0 mild chromic catgut suture. No suture closure is necessary in the eyelid if the incisions are small.

If the surgeon chooses to fix the fascia lata or silicone rod to the tarsal plate, this is performed

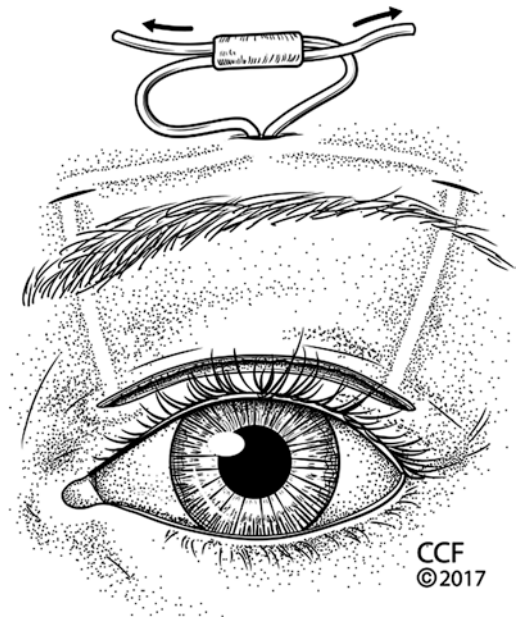

Fig. 15 Placement of silicone rod through silicone sleeve

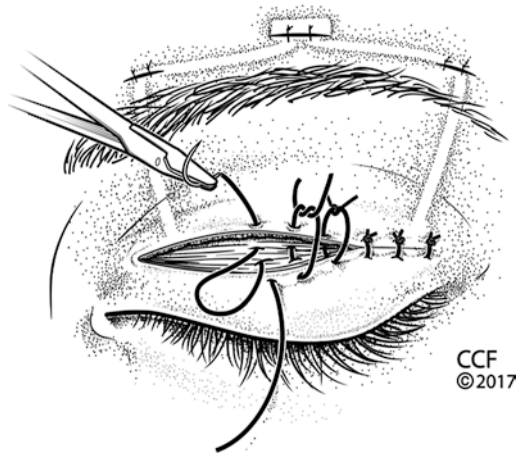

Fig. 16 Closure of eyelid crease incision

by making an eyelid crease incision removing some skin and orbicularis muscle down to tarsal plate. The superior half of the tarsal plate is barred with removal of some orbicularis muscle. The orbital septum is open to expose the levator aponeurosis. The fascia lata or silicone is fixed

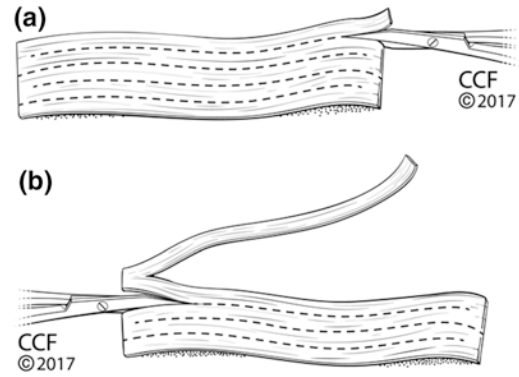

Fig. 17 Elongation of short fascial strip

to the tarsal plate with a 5-0 Vicryl or 5-0 nylon suture going partial thickness through the tarsal plate and securing the fascia or silicone in a position so that the eyelid may be brought up to a satisfactory position (Fig. 13) The remaining orbicularis muscle is brought over the silicone rod and secured with 5-0 Vicryl suture Fig. 14. The fascia lata or silicone rod is brought superiorly with the Wright fascia needle as described before. The silicone rod is place through the silicone sleeve and the lid fixed in the desired position (Fig. 15). The sleeve is placed in a deep position. The lid crease is formed by placing a 6-0 plain suture through the skin at the inferior margin of the lid crease incision, taking a bite of the levator muscle and back through the skin of the superior skin margin and tied down. All incisions are closed as described (Fig. 16).

At the end of the procedure no patch is applied however the eye heavily lubricated. Complications include overcorrection, undercorrection, asymmetry, lagophthalmos, herniated leg muscle and scar. In the cases of silicone sling adjustment, it may be made by exposing the silicone sleeve and the silicone adjusted. It is harder to do with fascia lata. Another unique problem is too short of fascia lata. This piece can be elongated by making fascial cuts the length of the fascia with the ends being reinforced with 5-0 Vicryl (Fig. 17).

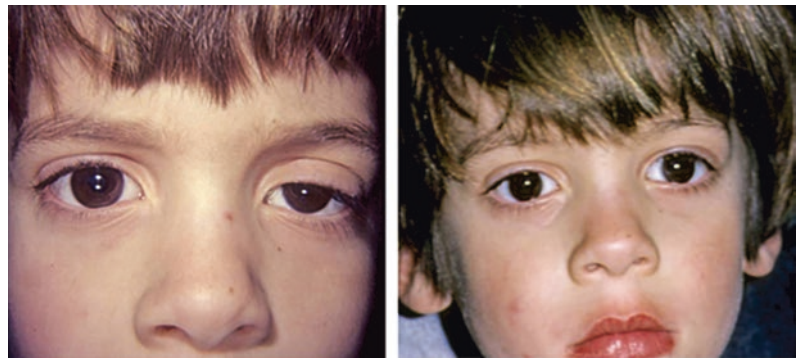

Fig. 18 Pre and postoperative Levator resection

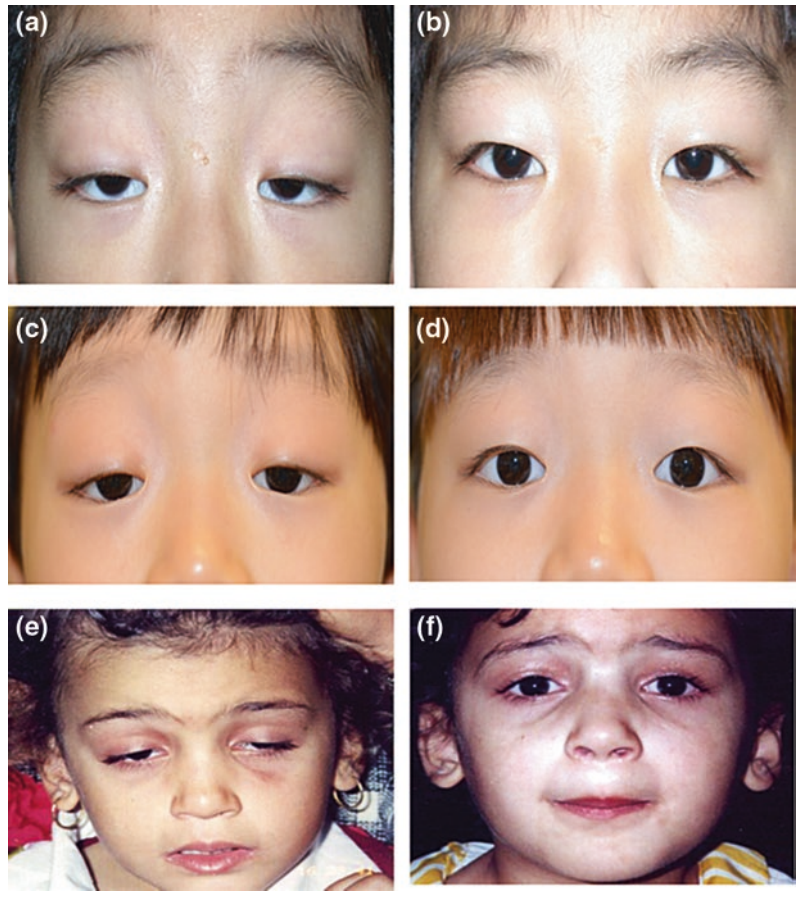

Fig. 19 Pre and postoperative frontalis sling surgery. Five-year-old boy with bilateral congenital ptosis (**a**), who underwent bilateral frontalis suspension with autogenous fascia lata (**b**). Four-year-old boy with bilateral congenital ptosis (**c**) with improved lid height and contour 3 years post frontalis suspension with preserved fascia lata (**d**) A 5 years old girl with bilateral congenital ptosis (**e**), who underwent bilateral frontalis suspension with autogenous fascia lata (**f**)

Figures 18 and 19 shows pre and postoperative photos of levator resection and frontalis sling surgeries respectively.

Suggested Reading

1. Chen Y, Weber AC, Marx DP, Allen RC, Levine MR. Frontalis sling frontalis sling in manual of oculoplastic surgery, 5th ed. Switzerland: Springer; 2018. p. 183–95.

Blepharophimosis And Marcus Gunn Ptosis as Special Types of Pediatric Ptosis

A. K. Grover, Shaloo Bageja, Amrita Sawhney and Anurag Mittal

Ptosis refers to drooping of the upper eyelid. It can be congenital which is due to dystrophy of levator muscle or acquired. Congenital ptosis can be further classified as—**Simple congenital ptosis** and **complicated congenital ptosis**.

Complicated Congenital ptosis can be of the following types-

1. Congenital Ptosis with Marcus Gunn phenomenon
2. Blepharophimosis syndrome
3. Congenital Ptosis with Ocular motility abnormalities

Marcus Gunn Ptosis is the most common form of congenital synkinetic ptosis. It constitutes about 2–13% of all the cases of congenital ptosis. It can present in a wide range of age groups with no sex predilection. Majority of the cases of Marcus Gunn Jaw Winking Ptosis are sporadic but a few familial cases show an autosomal dominant inheritance. Unilateral presentation was reported in most of the cases, however, bilateral cases, initially considered a rare entity, were found more common than previously thought. The condition occurs due to cross innervation between oculomotor and mandibular branch of trigeminal nerve.

The presence of jaw winking is assessed by moving the jaw from side to side (chewing movements) or opening and closing the mouth and observing the lid movements (Fig. 1a, b). The associated ocular abnormalities include amblyopia, double elevator palsy, superior rectus muscle palsy and congenital fibrosis of the extraocular muscles. Systemic anomalies which can occur with Marcus Gunn Jaw Winking ptosis include cleft lip, cleft palate and CHARGE syndrome. An Inverse Marcus Gunn phenomenon is also known, which is characterised by occurrence of ptosis with mouth opening due to inhibition of the levator palpebrae superiorus muscle on contraction of the lateral pterygoid muscle.

Marcus Gunn grading is based on the amount of excursion of jaw winking:

- Mild: Less than or equal to 2 mm
- Moderate: 3–6 mm
- Severe: More than or equal to 7 mm.

Management of the condition is based on assessing three factors; the severity of ptosis, the excursion of jaw winking and the associated ocular motility problems.

However, one needs to tackle ocular motility problems, when present, before ptosis surgery

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_9

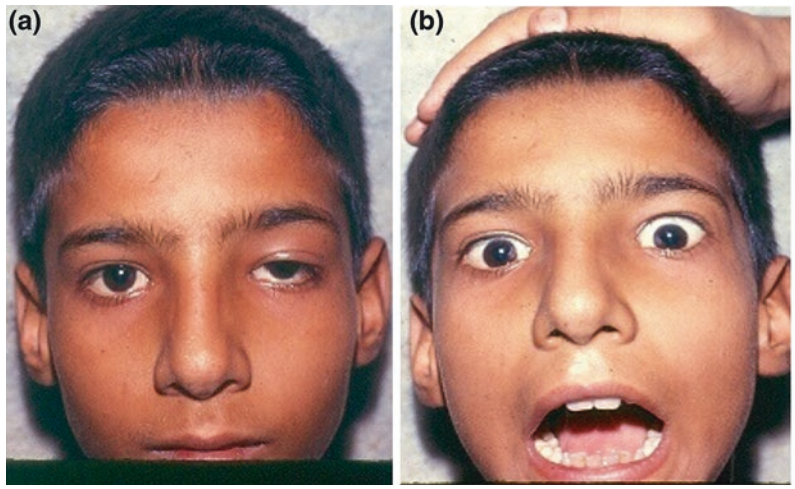


Fig. 1 **a**, **b** A 10 year old boy with severe ptosis with Marcus Gunn phenomenon in left eye

as it allows for elimination of pseudoptosis and improves Bell's phenomenon. The frequency of association of vertical ocular motility disorders is approximately 50–60%.

The two main objectives of surgery in a case of Marcus Gunn ptosis are to correct ptosis and to eliminate Jaw winking (where significant). It is also important to ensure maximum possible symmetry.

In mild Jaw winking, where jaw winking is not severe the choice of procedure is dictated by the amount of ptosis and the levator action, as in any other case of congenital simple ptosis by procedures like Fasanella Servat surgery and levator resection. Larger resections may be needed in levator surgery as undercorrections are more commoner.

In significant jaw winking, where the excursion of jaw winking is 3 mm or more and cosmetically significant it is important to disable the levator to eliminate jaw winking and to correct the drooping with a frontalis sling procedure. The options are:

- Unilateral levator excision with frontalis sling
- Unilateral levator excision with bilateral frontalis sling
- Bilateral levator excision with bilateral frontalis sling surgery

A sling procedure done unilaterally results in lagophthalmos and lid lag, giving rise to an asymmetry between the both eyes in downward gaze. Unilateral levator excision with bilateral sling removes asymmetry but may commonly result in apparent undercorrection of the involved eye, due to inadequate use of Frontalis. Bilateral levator excision with bilateral frontalis sling removes the asymmetry in down gaze and sleep. It is the authors' procedure of choice.

Material of Choice for Frontalis Sling

Autologous Fascia lata is the first choice in all cases where a bilateral sling is performed.

Where patient opts for a unilateral procedure, the choice of material is usually silicone rod or PTFE, though a number of material, like prolene, have been used for this purpose.

Harvesting of the Fascia Lata is Shown in Fig. 2a–f, See also chapter "Congenital Ptosis"

See Fig. 2.

Fascia Lata Sling Suspension (Fig. 3a–h)

The eyebrow incisions are done as shown (in Fig. 3a, b), see also chapter "Congenital Ptosis".

Eyebrow and forehead.

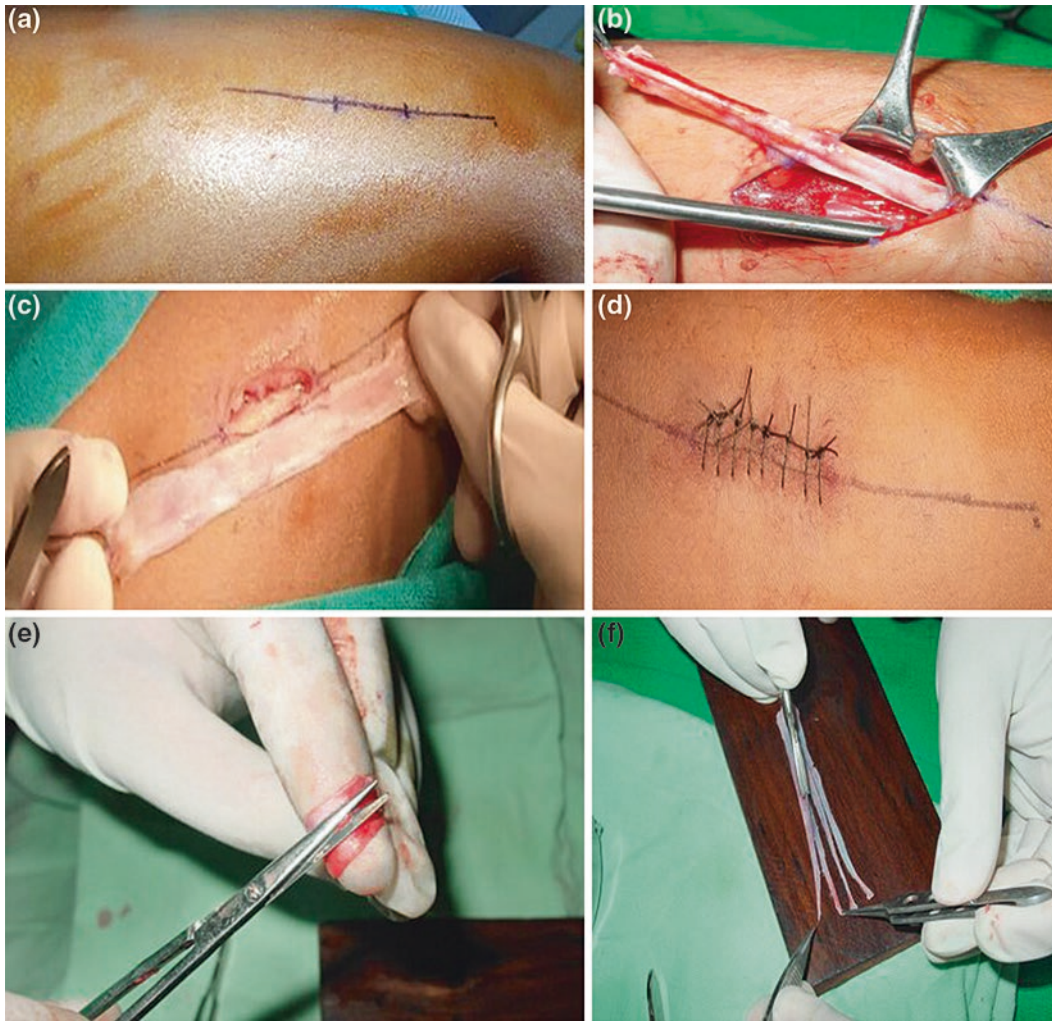
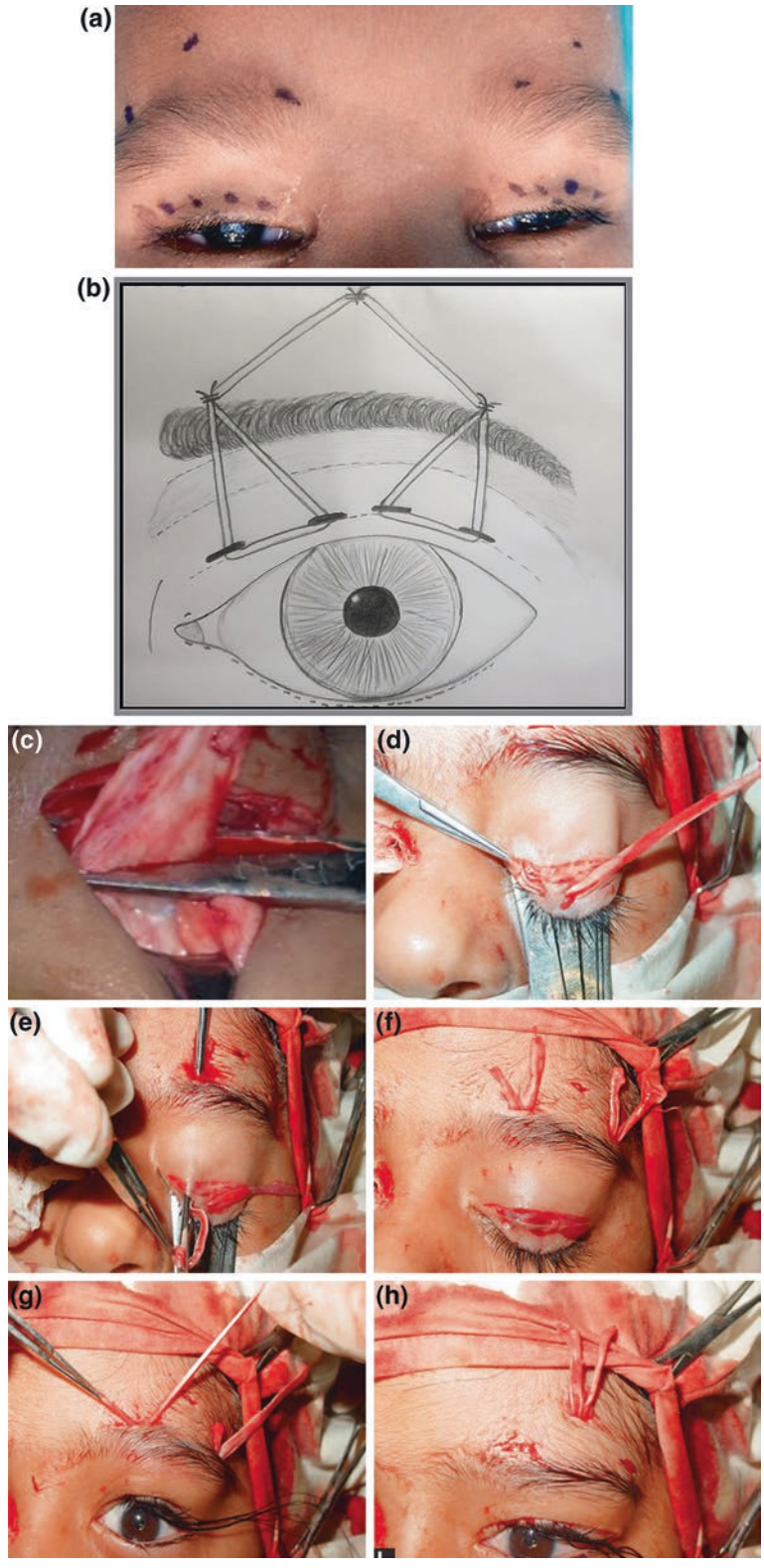


Fig. 2 Fascia lata sling surgery with levator excision: Harvesting of fascia lata **a** An incision is marked along line joining the lateral condyle of femur to the anterior superior iliac spine. The marking is begun 2 inches above the lateral condyle of femur and extended up to 4 inches. The incision is given in the center 1 inch of the area that has been marked; **b** The skin incision is deepened through the fat till the glistening fascia is visible. The fascia is then cleared of the overlying tissue and underlying vastus lateralis muscle along the whole length. Two linear incisions are given 12 mm apart on the fascia along the 4 inches length of dissection using a long scissors. The superior end of the fascia is made free by making horizontal cut using a long bladed scissors while the assistants retract the skin and the subcutaneous tissue; **c** The harvested fascia lata (12 mm × 100 mm); **d** The subcutaneous tissue is closed using 4-0 polyglactin and the skin is closed using 4-0 non-absorbable sutures; **e** The fat is trimmed from the fascia lata strip; **f** The fascia lata strip is kept on a wooden board, stretched and fixed. It is divided into four pieces each of about 3 mm width by a scalpel blade

Levator excision: an eyelid crease incision is given through skin and orbicularis. The skin and the orbicularis are dissected from the underlying orbital septum. Any dissection on the surface of the tarsal plate is scrupulously avoided. The orbital septum is cut completely across exposing the preaponeurotic fat. Fat is retracted posteriorly to reveal the underlying tendinous aponeurosis. The levator is dissected from the adjoining structures. The lateral and the medial horn are cut. Excision of a large segment of levator aponeurosis is carried out (Fig. 3c).


(a)
(b)
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◀**Fig. 3** Fascia lata sling suspension with levator excision **a** Incisions marked according to Modified Crawford technique; **b** Diagrammatic representation of modified Crawford technique; **c** Excision of levator aponeurosis. **d** Fascial strip is passed from the medial lid incision to central incision; **e** The two ends of a strip are then passed from the inner eyelid incisions to the inner eyebrow incision using a Wright's fascia lata needle. The needle is passed in the submuscular plain from the medial brow incision to emerge from the medial incision in the lid. The procedure is repeated on the lateral side; **f** The fascial strips are pulled up and a single tie is made so as to place the eyelid margins about 2 mm above the desired position as the lids will fall down when the knots are buried; **g** After a single tie the position and contour of the eyelid is assessed. Required adjustments are made. Presence of good lid crease is ensured at this stage. A second tie is made and secured with 5'0 polyglactin; **h** One end of fascial strip from each brow incision is pulled through the central brow incision. Knots are tied and secured

Then the fascia lata strip is then inserted as described in chapter "Congenital Ptosis" (Fig. 3d–g). Knots are tied and secured (Fig. 3h). An excess strip of skin is removed along the eyelid crease incision. Eyelid incisions require no closure. The brow incisions and the eyelid crease incision are closed with 6-O nylon.

On Retrospective analysis of 191 patients with significant (2 mm or more) jaw winking ptosis. Seventy three patients had undergone unilateral levator excision with bilateral fascia lata sling while in 118 patients bilateral levator excision with bilateral fascia lata sling was carried out. Elimination of jaw winking was achieved in 98.5% of all cases. Good results was defined as asymmetry of habitual MRD of two upper eyelid of 1 mm or less and fair results was defined as asymmetry of habitual MRD between 1.5 and 2 mm between the two upper eyelid.

Good results were achieved in

- Unilateral excision group—15/73 (20.6%)
- Bilateral excision group—91/118 (77.1%)

Good or fair results were achieved in

- Unilateral excision group—48/73 (65.7%)
- Bilateral excision group—115/118 (97.5%)

Bilateral levator excision with bilateral fascia lata sling provides the most consistent elimination of jaw winking and improvement in ptosis (Fig. 4).

Khwarg et al. in 1999 *and* Demirci et al. in 2010 reported similar results.

Blepharophimosis Syndrome

Blepharophimosis and epicanthus inversus syndrome (BPES) is a rare genetic condition with a global prevalence of 1 in 50,000. It generally displays an autosomal dominant inheritance pattern.

BPES is caused by mutations in the FOXL2 gene, the expression of which is associated with fatal eyelids' development and adult ovarian granuloma cells.

The condition is characterized by narrowed horizontal palpebral aperture, ptosis, epicanthus inversus and telecanthus. Ptosis is usually bilateral and severe with poor levator action. Blepharophimosis denotes reduction in horizontal fissure from 25–30 to 18–22 mm. Epicanthus inversus means a fold originating in the lower lid and traversing superiorly and medially the inner canthi. Telecanthus is defined as increased distance between the inner canthi. Normal distance between medial canthi is half the interpupillary distance. This distance is increased in telecanthus. There is increased length of medial canthal tendon (MCT) in cases of BPES (Fig. 5a).

Other associated ophthalmic features can be high arched eyebrows, abnormalities of eyelid margin, microphthalmos and optic disc colobomas, the non-ocular associations being broad flat nasal bridge, high arched palata, female infertility and cardiac defects.

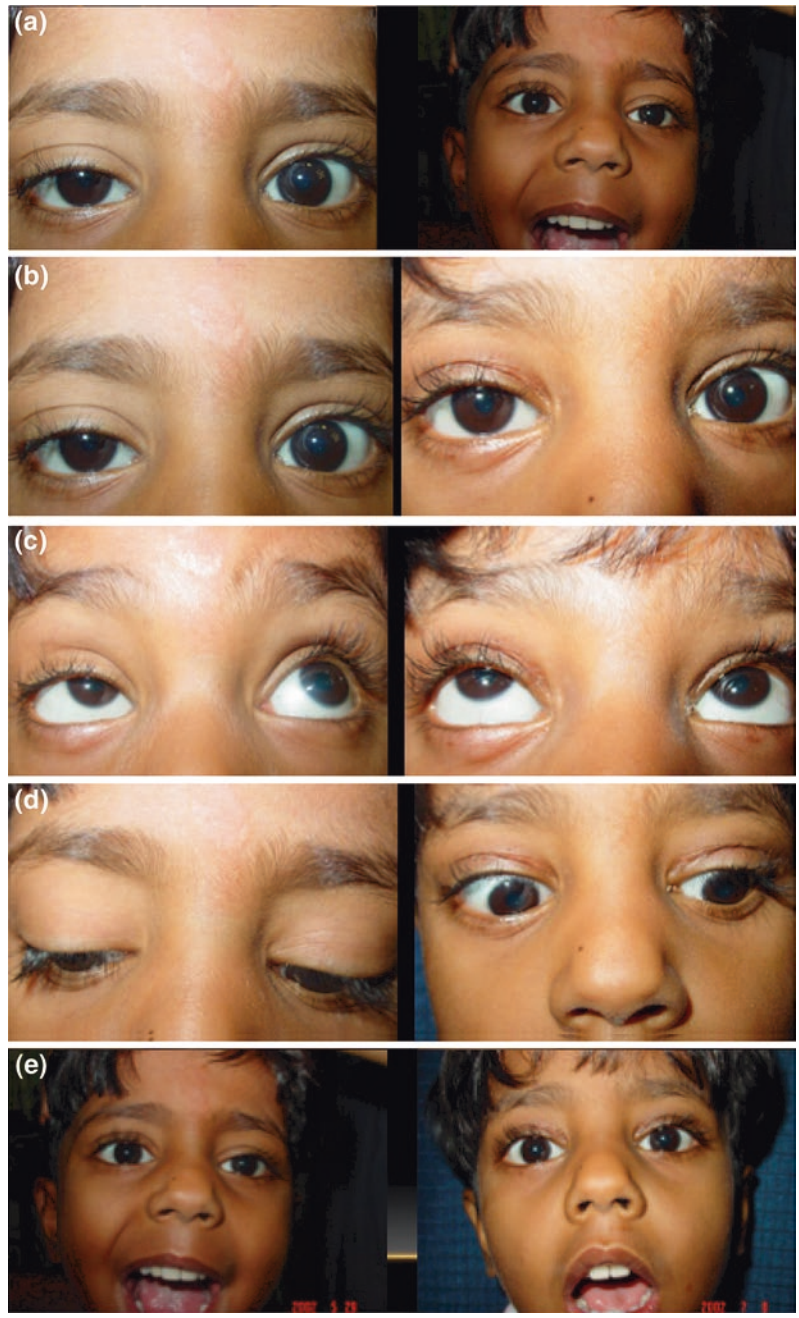


Fig. 4 **a** Preop clinical picture showing right eye Marcus gunn Ptosis. **b** Preop and postop images in primary gaze. **c** Preop and postop images in upgaze. **d** Preop and postop images in downgaze. **e** Preop and postop images showing abolition of jaw winking

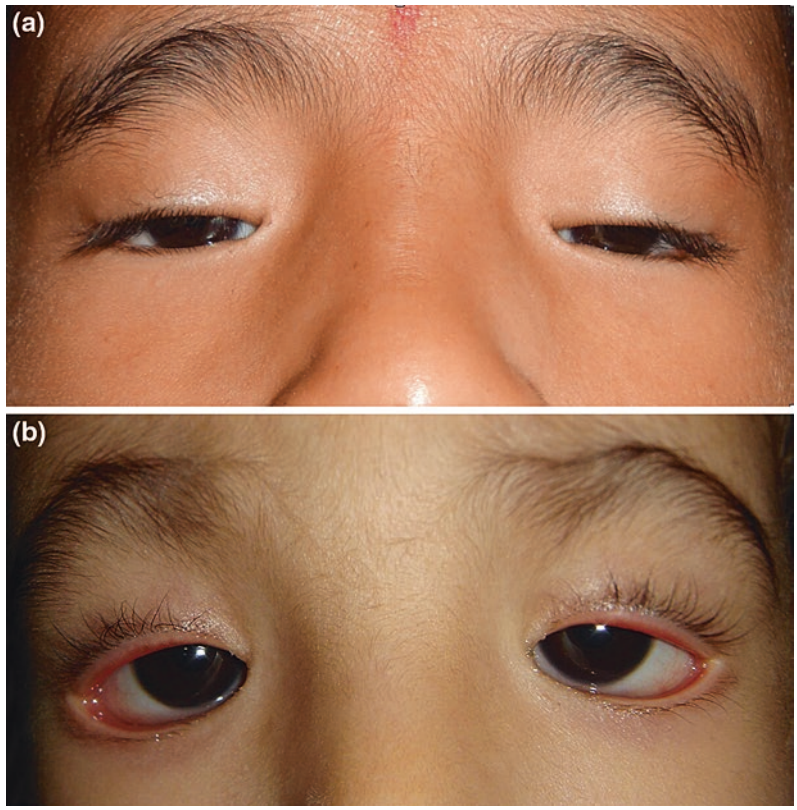


Fig. 5 **a** A 6 year old boy with classical tetrad of BPES (ptosis, epicanthus inversus, telecanthus and horizontal palpebral aperture narrowing). **b** A 5 year old boy with telecanthus, lateral ectropion and skin shortening with ptosis suggestive of type 2 BPES. There is also an associated high arched brow

Classification of BPES

Type 1 BPES (classic BPES)—It is characterised by ptosis, telecanthus and epicanthus inversus with premature ovarian failure. It has autosomal dominant inheritance with male to male transmission.

Type 2 BPES—In this case only eyelid defects are present including ptosis, telecanthus and lateral ectropion with equal inheritance through both the sexes in an autosomal dominant pattern (Fig. 5b).

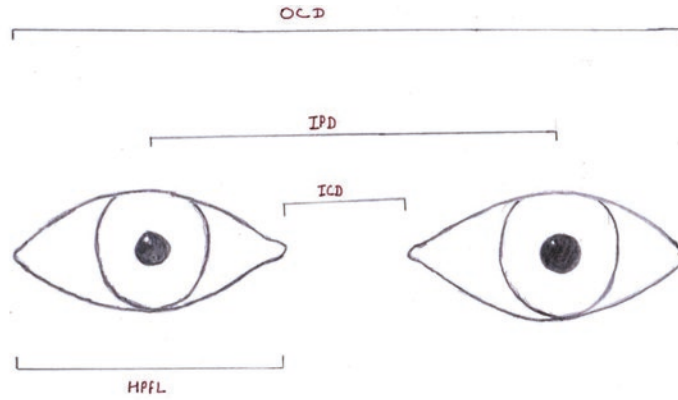
Type 3 BPES—It is similar to type 2 with associated hypertelorism.

Grading of BPES and Normal Anatomical Landmarks (Fig. 6)

The evaluation of interocular distances can be done by measurement of the following landmarks: Inter pupillary distance (IPD), Inner canthal distance (ICD), Outer inter canthal distances (OCD), and Horizontal palpebral fissure length (HPFL). It is considered that ICD is equivalent to HPFL and half of IPD.

The normal ICD/HPFL ratio is 1–1.2. Based on this ratio, the BPES can be graded into:

- Mild – 1.3–1.5
- Moderate – 1.5–1.8
- Severe – >1.8



ICD - Inner intercanthal distance

IPD - Interpupillary distance

OCD -Outer intercanthal distance

HPFL- Horizontal palpebral fissure length

Fig. 6 Diagrammatic representation of normal anatomical landmarks of the orbit. ICD—Inner intercanthal distance, IPD—Interpupillary distance, OCD—Outer intercanthal distance, HPFL—Horizontal palpebral fissure length

Farkas canthal canthal index can be calculated by ICD/OCD X10. In hypertelorism it is more than 42.

Management

Management involves correction of both horizontal and vertical palpebral aperture depending on the severity of the condition. Milder cases may be carried out as a single stage procedure where epicanthus, telecanthus and smaller horizontal size of palpebral fissure are corrected in the same sitting with correction of ptosis.

Surgery for most the cases is often performed in two stages:

1. Stage 1 is usually done at about 3 years of age, it aims at correcting the epicanthal fold, telecanthus and horizontal palpebral aperture (by lateral canthoplasty) where indicated.
2. Stage 2 is done at about 6 months after the first stage to correct ptosis.

However, it should be noted that if the ptosis is severe and the risk of amblyopia is high, a temporary frontalis sling procedure can be done in the first year of life. Then the telecanthus is repaired later, followed by removal of the temporary sling and permenant correction of ptosis.

Fort he telecanthus, Mustarde's double 'Z' plasty or 'Y to V' plasty with Medial canthal tendon plication or transnasal wiring is done as a primary procedure. This gives good surgical results both in terms of correction of epicanthus and telecanthus as well as deep placement of the medial canthus. The results are long-lasting.

Double Z plasty: The markings are made as shown (in Fig. 7). The first mark is made just medial to the medial canthus (X). The proposed canthal site (Y) is marked such that intermedial canthal distance is half that of interpupillary distance. The two marks are joined. All the other lines drawn are 2 mm smaller than the line XY.

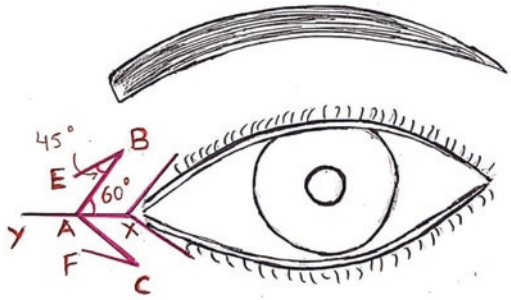


Fig. 7 Diagrammatic representation of the markings of Z plasty

Two lines are drawn from X parallel to upper and lower lid margins. From the center point of XY (A), lines are drawn medially at 60° both above and below (AB, AC). Another set of lines are drawn outward at an angle of 45° from the point of B (BE) and from the point C (CF).

Y–V plasty: The markings are made at the medial canthus so that the horizontal limb of the Y marks the present location and the proposed location of the medial canthus while the two oblique limbs of size roughly equal to the horizontal limbs are made on the two eyelids (Fig. 8a–d)

Lateral canthoplasty: Lateral canthotomy and canthoplasty, where it is planned, is carried out before the skin incisions for epicanthus and telecanthus correction are made. It helps in lengthening the horizontal palpebral aperture. The lateral canthus is crushed by a straight hemostat for a few seconds. A lateral canthotomy is performed. The bulbar conjunctiva at the lateral canthus is undermined. The apex of the conjunctiva is sutured to the proposed new position of the canthus which is short of the end of the skin incision. The skin edges distal to the new lateral canthus are apposed with 6-0 non-absorbable sutures. A similar procedure is repeated on the other side.

Technique of Y–V plasty with transnasal wiring(Fig. 9a–h)—The incisions are marked and made through the skin down to the orbicularis. The flaps are undermind (Fig. 9a). The site of proposed canthus is cleared of all tissues up to the periosteum and the medial palpebral

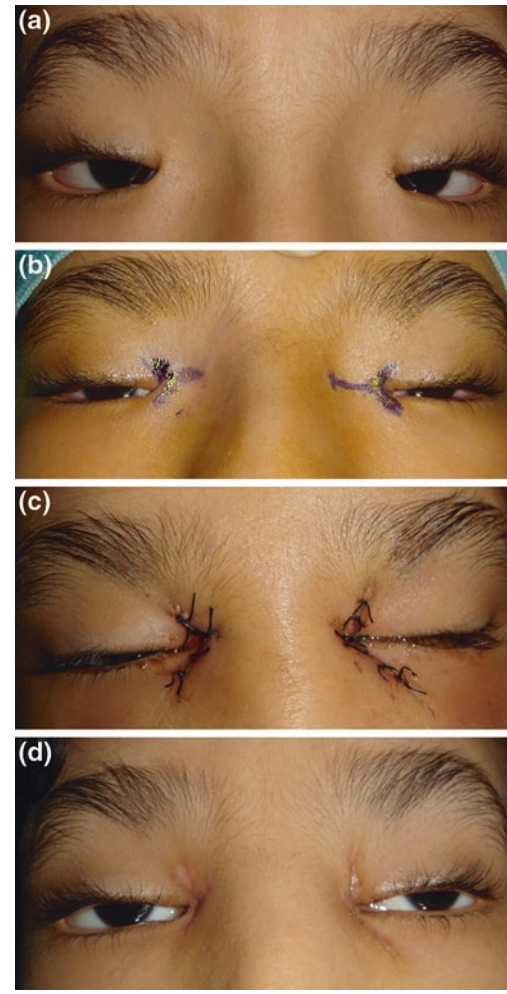


Fig. 8 **a** Preop image of a 8 year old female with Blepharophimosis syndrome. **b** Intraop image showing marking done at the medial canthus, such that the horizontal limb of the Y marks the present location and the proposed location of the medial canthus. **c** Intraop image showing V-shaped closure of the incision. **d** Postop image showing epicanthus inversus has been corrected

ligament is exposed. The periosteum is incised medial to the insertion of medial palpebral ligament (MPL) and is reflected along with the lacrimal sac.

A large bony opening 12–15 mm high and 10–12 mm wide is made as for dacryocystorhinostomy but located more posterior and superior in line with medial palpebral ligament. The edges of the bony opening are smoothened

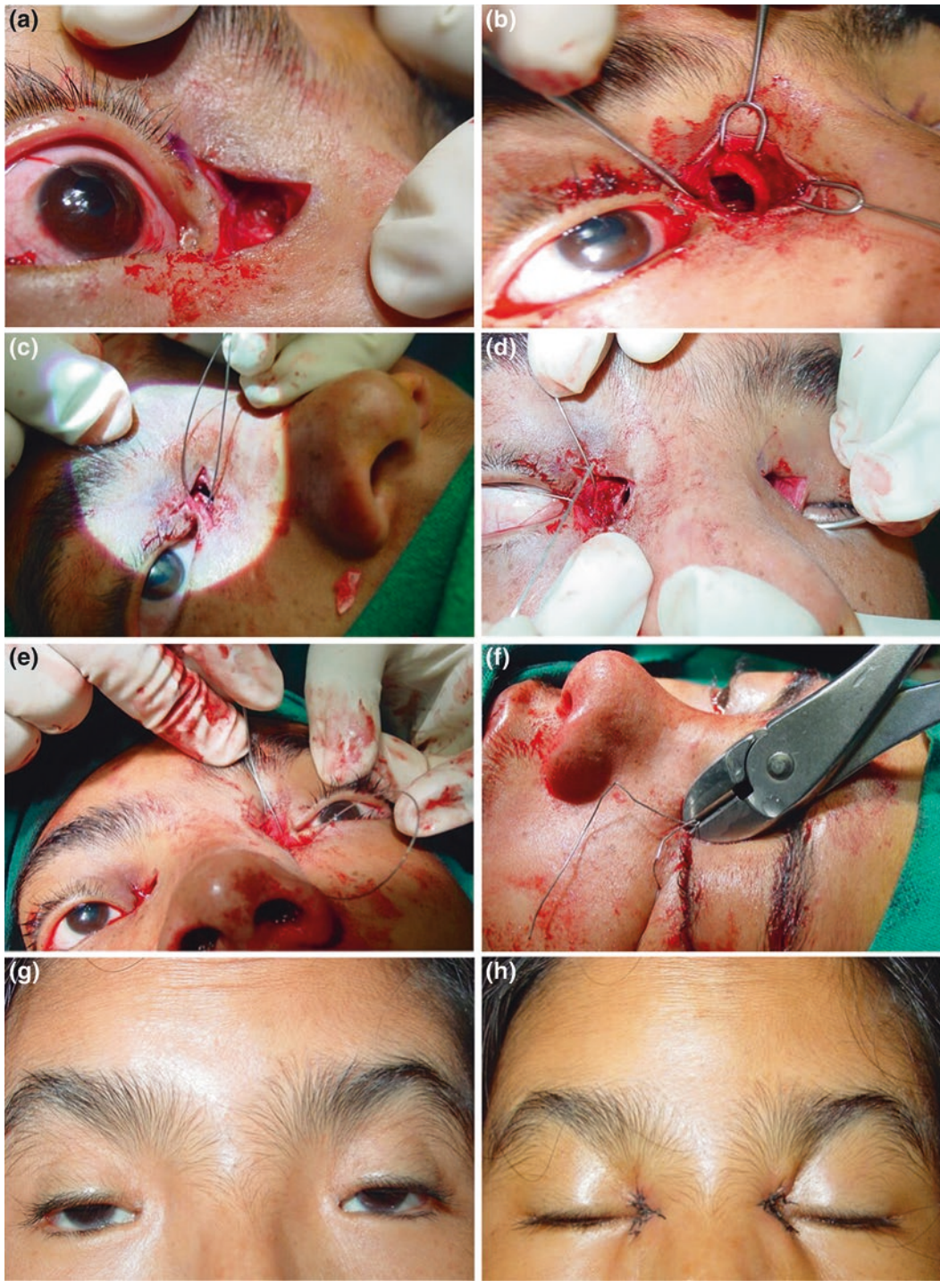


Fig. 9 Technique of Y–V plasty with transnasal wiring **a** Undermining of skin flaps. **b** Bony ostium mode. **c** MPL is wired with 28G stainless steel wire. **d** The wire is passed through bony opening using Wright's fascia lata needle, and threaded into the MPL of opposite side. **e** The positions medial canthi are assessed. **f** The wire is twisted and cut. **g** Preop image, **h** Postop image

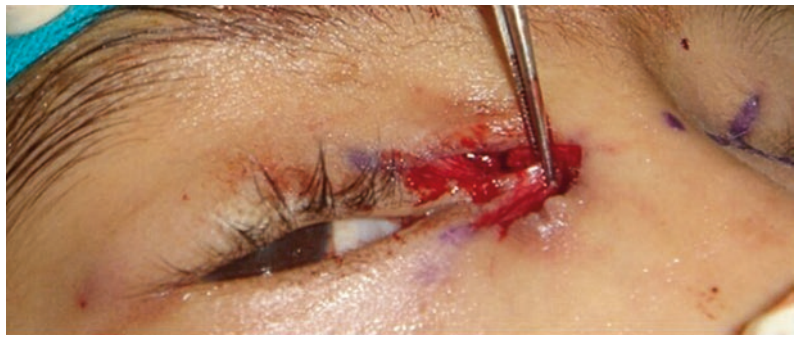


Fig. 10 Medial palpebral ligament tucking

(Fig. 9b). A similar procedure is performed on the opposite side.

Medial palpebral ligament of one side is wired with 28/30 G stainless steel wire close to its attachment to the tarsus and the two ends of the wire are passed to the opposite sides through the bony opening with the aid of an aneurysm needle or a Wright's fascia lata needle (Fig. 9c). The wire is threaded into other MPL with similar double bite (Fig. 9d). The two ends are tightened and a single twist given to the wires. The position of the medial canthus is assessed from the front, above, and the sides (Fig. 9e). Once the desired position is obtained, the wire is twisted several times and cut (Fig. 9f). The ends of the wire are pushed into the bony opening. After achieving the hemostasis the incision is closed in several layers. The skin flaps may need to be trimmed before they are transposed and sutured with 6-0 non-absorbable sutures.

Medial palpebral ligament tucking may also be carried out in mild cases (Fig. 10).

The bandage is removed after 24 h and sutures are removed in 5–7 days.

Stage II: The second stage is performed after 6 months. A bilateral fascia lata sling surgery is performed using modified Crawford technique (Fig. 11).

Correction of Ptosis by Fascia lata sling surgery is moderately good, however—the correction achieved is limited by anatomical abnormalities of the blepharophimosis syndrome

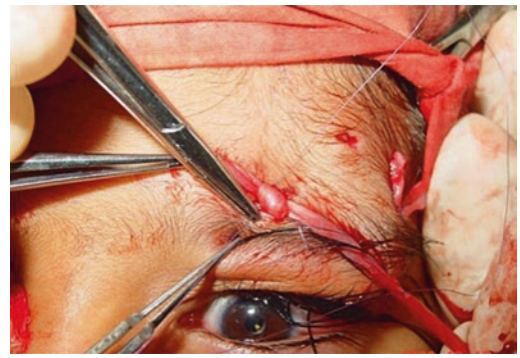


Fig. 11 Fascia Lata Sling surgery using modified Crawford technique

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Correction of Congenital Ptosis with Poor Levator Function with the Frontalis Flap Procedure

Essam A. El Toukhy, Ibrahim Mosad and Lobna Khazbak

Ptosis is the most common lid malposition encountered in clinical practice in both adults and children population and is the most surgically correctable lid disorder.

The upper lid position is a function of the delicate balance between the lid retractors including levator muscle, Muller's muscle, and frontalis muscle, and the lid protractors including the orbital pat and palpebral part of the orbicularis oculi muscle.

Normally the upper lid covers the upper 1–2 mm of the cornea in the primary position, providing no obstacle to image formation on the retina. It follows the globe on looking down with no lag. It provides complete coverage of the eye on lid closure. Finally, it rises up for up to 20 mm in extreme up-gaze.

Changing the activity of the levator, Muller's muscles, bring all of these movements about. The frontalis muscles are called into action only in extreme up-gaze. The orbicularis muscle in mainly used in forceful lid closure although its palpebral part shares in the blinking mechanisms.

Both upper eyelids are symmetrical. The brain considers both lid retractor as yoke muscle. They receive equal innervations form single subdivision of the oculomotor nucleus in the midbrain. Changes in the position of one lid will lead to affection of the position of the other in a similar fashion to the secondary changes occurring in an extraocular muscle when its yoke muscle is weak, paralyzed or overacting.

A successful ptosis surgery provide a lid that is at or just below the limbus in the primary position and moves freely with the globe in up and down gaze. This result can be obtained only in mild to moderate degrees of ptosis when levator muscle can be strengthened successfully.

However, when the levator function is poor (less than 4 mm), frontalis muscle surgery has long been accepted as the best technique for managing the blepharoptosis. In these cases if levator muscle surgery is attempted, then In order to position the lid at an acceptable level, at least 25 mm or more of the levator muscle should be resected. This would entail cutting of both levator horns as well as the advancement of Whitnall's ligament and its suturing to the anterior surface of the tarsus.

The results are usually less than acceptable with a lid that is so shortened to be practically immobile or frozen. Lagophthalmos is inevitable and corneal exposure is considered the major

Electronic supplementary material The online version of this chapter (https://doi.org/10.1007/978-3-030-36934-7_10) contains supplementary material, which is available to authorized users.

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_10

post—operative complication and occurres in over 75% of patients. In unilateral cases, marked asymmetry between both lids is noted. Most surgeons conclude that good results are seldom achieved with this procedure in poor levator function cases and recommend frontalis muscle surgery instead.

For any technique of frontalis surgery to be successful, the patient should be stimulated to use the frontalis muscle to lift the ptotic lid. Therefore, severe unilateral ptosis corrected only with a unilateral frontalis surgery causes "a functional undercorrection" of the ptosis. The reason for this undercorrection is that the normal lid level on the contralateral side allows the patient to see well, and therefore, the patient is not stimulated to use the frontalis muscle. This is similar to the patient with jaw—winking phenomenon who learned to see well with either the contralateral eye in unilateral jaw—winking or with jaw movements in bilateral cases. This signifies the importance of documenting the trial to lift the lid preoperatively by the patient with frontalis contraction. The full correction of ptosis in the primary position can be noticed when the patient contractes the frontalis voluntarily especially in unilateral cases. A trial of occlusion of the sound eye can documents the functional undercorrection and differentiates it from true anatomical undercorrection. Occlusion therapy (as in amblyopia cases) and excercises to develop and maintain binocular vision can help reducing this phenomenon.

The Mechanism of Lid Elevation After Brow Suspension

The upper eyelid is suspended from the brow so the patient opens the eye by the brow and closes the eye by orbicularis contraction. The transmission of frontalis muscle activity to upper lid is achieved by the insertion of a biologically acceptable non-stretchable rod- shaped connection between the two. The mechanism of lid elevation after brow suspension is totally different from the mechanism when the levator muscle is lifting the lid. Normally, the elevating force vector of the levator muscle on the upper lid is superio-posterior. This is due to the pulley effect of Whitnall's ligament, which diverts the antero-posterior contractile fore of the levator muscle to a more superio-posterior direction.

In frontalis muscle suspension where the sling material is passed at a more superficial level from he brow to the anterior eyelid layers, the brow transmits a superior, and frequently, an antero-superior elevating force to the upper eyelid. This superior vector tends to pull the upper lid away from the globe and presents an even greater problem in patients with prominent brows or deep set eyes. The line of pull also tends to obliterate, rather than form, a lid crease.

This antero-superior elevating force could be directed posteriorly by placing the suspensory material behind the septum. Several problems arise from posterior placing of the sling. Depending on its nature, it might adhere to the septum and leave the upper lid at a frozen level. There is increase in the incidence of lagophthalmos and exposure keratopathy. If infection occurs it may result in an orbital space infection.

The ideal material used in frontalis sling should be chemically inert, non carcinogenic capable of resisting mechanical stress, sterilizable, yet not physically modified by tissue fluids, dose not excite an inflammatory of foreign body reaction, not induces a state of allergy or hypersensitivity.

Several sling materials have been used; as fascia lata (autogenous or preserved); synthetic materials as silicone rods, sutures and meshes.

Frontalis Muscle Flap Advancement

The frontalis muscle flap advancement is a technique of direct transfer of the force of the frontalis muscle to the eyelid without the insertion of fascia, suture or a graft between the muscle and the tarsus. Frontalis suspension by frontalis muscle flap is a well-accepted method of treating severe bleharoptosis. Being

from the same patient, there is no risk of rejection or severe body reaction as may occur with homogenous or alloplastic materials. There is no risk of disease transmission. A Frontalis flap grows with the child's growth and does not lead to cheese-wiring as synthetic materials. The frontalis muscle is well developed before fascia lata maturation. Therefore, this procedure can be performed earlier, if indicated, in cases of infantile ptosis. Additional advantages of this technique include its technical simplicity, lack of remote scar as the donor site is in the primary surgical field, minimal ptosis on upgaze, less lid lag on downgaze, preservation of eyelid contour and less tendency for the lid to pull away from the eye. In contrast to traditional frontalis slings, only one 2 cm brow incision is required. This direct linkage of the frontalis muscle to the eyelid has been documented by postoperative magnetic resonance imaging scan.

This procedure can be conducted on patients with ptosis and eyelid excursion measured as poor or less than 4 mm. The aetiology of ptosis can be congenital or acquired. The procedure can be done on primary cases as well as cases with recurrent ptosis following previous levator muscle surgery or frontalis sling procedures. The forehead must be examined to detect any abnormality. This surgery has an effect similar to a brow lift in that it affects forehead wrinkles and therefore is best indicated for patients with bilateral ptosis or unilateral ptosis with a smooth forehead preoperatively.

Anatomy of the Occipitofrontalis

Occipitofrontalis covers the dome of the skull from the highest nuchal lines to the eyebrows. It is a broad musculofibrous layer consisting of four thin, quadrilateral parts –two occipital and two frontal connected by the epicranial aponeurosis. Each occipital part (occiptalis) arises by tendinous fibres from the lateral two-third of the highest nuchal line of the occipital bone and the mastoid part of the temporal bone, and ends in the aponeurosis. Each frontal part (frontalis) is adherent to the superficial fascia, particularly of the eyebrows. It is broader than the occipital part and has fibers that are longer and paler. Although frontalis has no bony attachments of its own, the medial fibres are continuos with those of procerus muscle, the intermediate fibres blend with corrugator supercilii and orbicularis oculi muscles. And the lateral fibres also blend with orbicularis over the zygomatic process of the frontal bone. The frontalis muscle is closely adherent to the skin and subcutaneous tissues at the eyebrow region but is mobile on the underlying periosteum due to loose areolar connections between the frontalis and the periosteum of the supraorbital rim. From theses attachment the fibres ascend to join aponeurosis in front of the coronal suture. The medial margins of the frontal bellies are joined together for some distance above the root of the nose. Contraction of the frontalis muscle elevates the eyebrows strongly and the eyelids weakly.

The blood supply of the frontalis muscle is via the supraorbital, the supratrochlear and the superficial temporal arteries. Sensory branches of the supraorbital nerve course upwards over the frontalis muscle. The frontal or temporal branch of the facial nerve passes approximately 1.5 cm at the lateral brow to enter the undersurface of the frontalis muscle no higher than 2 cm above the eyebrow.

Surgical technique

The frontalis muscle is exposed through a horizontal brow incision that begins 5 mm lateral to the supraorbital notch and extends laterally 2 cm on the upper border of the eyebrow parallel to the hair line. It is necessary to limit the lateral extent of the incision so the frontal branch of the facial nerve is not injured. A subcutaneous plane is then dissected downwards bluntly to free the frontalis from the brow till the orbicularis is seen, providing adequate length to be used in the flap formation. The anterior surface of the frontalis muscle is exposed by blunt dissection superiorly so that a superiorly based frontalis muscle flap can be designed. The frontalis muscle is incised along its attachment to the brow. Care is take to avoid injury to supra orbital nerve and vessels as they emerge from the notch (Fig. 1 a).

Blunt dissection releases the under surface of the frontalis from the periosteum of the frontal bone, creating a flap 1–2 cm in length. Two vertical incision are made through the frontalis muscle parallel to the muscle fibres at the extremes of the eye brow incision to form a tongue of the frontalis muscle 7–12 mm in width to be advanced onto the tarsus. The dissection is performed so that the vertical height of the frontalis flap is 1–2 cm depending of the degree of ptosis and the power of the frontalis muscle.

An eyelid crease incision is made deep to the plane beneath the orbicularis oculi muscle to expose the tarsus downward. The dissection is continued superiorly to form a tunnel underneath the orbicularis muscle and then turns superficially to the subcutaneous plane by cutting the muscle layer transversely at the level of the inferior eyebrow margin. The inferior portion of the frontalis flap is then brought down through the tunnel above the septum and below the orbicularis and advanced onto the anterior surface of the tarsus (Fig. 1b)

The isolated flap is then fixated to the upper third of the tarsus with two—interrupted mattress sutures of 6-0 polypropylene (Fig. 1c).

In cases of bilateral ptosis the eyelid margin position is set at or 1 mm above the limbus on both sides, because the lid will lower approximately 2 mm when orbicularis function returns and gravity forces the eyebrow down in the upright position (Fig. 1d) (Video-1).

In unilateral cases, the lid should be set 1–2 mm above the level of the non-ptotic lid. Because of a tendency to undercorrection, we recommend suturing the side of the flap to the original frontalis muscle helping to maintain the level of the lid higher as needed. This

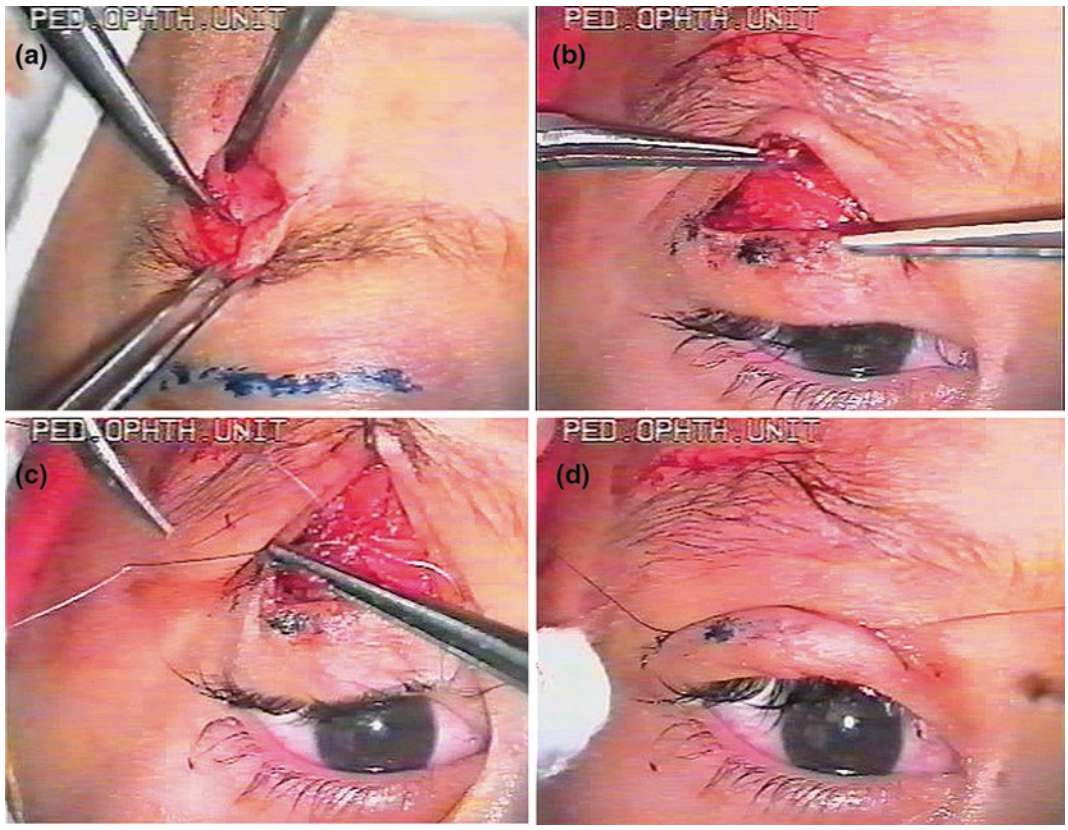

Fig. 1 **a** Exposure and creation of the flap. **b** Flap dissected and passed downwards through the tunnel. **c** Flap sutured to the tarsus. **d** Lid level at the end of surgery

modification reduces the incidence of late under-correction that is reported with this technique, suspected to be due to gradual stretching of the flap.

The lid crease incision and eyebrow incision are sutured by 6-0 polypropylene in older children and adults, or 6-0 chromic cat gut in younger children. Polypropylene skin sutures are removed after 5 days, and ophthalmic antibiotic ointment is applied at bedtime for 2 weeks or until lagophthalmos resolve.

This described technique for frontalis muscle advancement differs from previously described technique, which likely explains our successful use of this procedure. Part of the frontalis muscle insertion is transferred directly to the eyelid in our surgical technique. We make the frontalis flap rectangular and base it superiorly, in contrast to the earlier reports of a superolaterally placed L-shaped flap. This distributes the pull of the frontalis muscle on the tarsal plate.

Our experience suggests that a flap width of 7 mm in younger children and 12 mm in older ones provides adequate elevation if properly centered over the tarsus. Also, the tenting deformity described earlier, was not seen, likely because we make the flap in a rectangular fashion and undermine the flap as high as necessary to prevent overcorrection by a tight flap.

It should be emphasized that the length of the flap is adjusted according to the degree of ptosis and the power of the muscle. The more pronounced the ptosis, the shorter the flap must be to elevate the lid adequately. In this aspect the flap acts like a harness, the shorter it is, the closer the insertion (tarsus) is to the origin (brow) i.e. the higher and taughter is the lid. Accordingly, based on this experience, we believe that adjustment of the lid height can be done using recession or resection of the flap in cases of under or over correction post-operatively. The advanced flap can be shortened directly in cases of residual ptosis. Also, it is not necessary to advance a thick, bulky flap, a thin flap will cause less eyelid fullness and still elevates the lid well.

Complications

Residual ptosis of +2.00 mm or less occurs in about 10% of cases. This can be corrected as explained earlier.

Entropion can occur due to lower insertion of the flap in the middle third of the tarsus. It should be immediately repaired by reinsertion of the flap in the upper part of the tarsus.

Lagophthalmos is usually temporary in the first few weeks till edema resolves. It disappears with the full recovery of orbicularis function and the patient can close his eyes by orbicularis contraction. Lubricants are prescribed until the lagophthalmos resolves.

Lid lag on down gaze and corneal exposure during sleep are potential complications of the procedure. In our cases, lid lag on down gaze occurred in almost all cases. It is an inherent side effect of all frontalis muscle surgery and should be well explained to the patients or their parents. However, it is usually accepted as the price for correction of the ptotic lid in primary position and in upgaze.

Asymmetry between the lids of more than 1 mm can occur in patients with unilateral surgery.

Cases of over-correction rarely occurs. The post operative lid height attained at 6 weeks visit is usually stable and maintained thereafter.

Electronic Supplementary Material

Below is the link to the electronic supplementary material.Supplementary material 1 (MP4 13632 kb)

Suggested Readings

1. Iliff WJ, Pacheco EM. Ptosis surgery. In: Tasman, Jaeger EA, editors. Duane's clinical ophthalmology. J.B. Lippincott W and Philadilphia; 1992. p. 1118.

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7. Hintschich CR, Zurcher M, Collin JRO: Mersilene mesh brow suspension, efficiency and complication. Br J Ophthalmol. 1995;79(4):358.
8. Wagner RS, Mauriello JA, Nelson LB, et al. Treatment of congential ptosis with frontalis suspension: a comparison of suspensory materials. Ophthalmology. 91:245.

Adult Ptosis

Yoon-Duck Kim and Stephanie Ming Young

Introduction

Blepharoptosis refers to drooping of the upper eyelid and is one of the most common surgical eyelid disorders. It can occur in both children and adults, and can be classified based on the aetiology of the ptosis: neurogenic, myogenic, aponeurotic, mechanical and pseudoptosis.

Evaluation of the ptotic patient should include an attempt to determine the precise aetiology of the ptosis. In adults, the most common cause of ptosis is aponeurotic (also known as *senile* ptosis). In this condition, the levator muscle is normal, but the levator aponeurosis is either attenuated or has undergone dehiscence from its normal insertions on the tarsal plate and in the orbicularis muscle. This may be a naturally occurring involutional change, or it may be precipitated by intraocular surgery, long-term daily contact lens wear, steroid use or trauma.

Many surgical procedures have been described to correct ptosis, each with its own indications and advantages. The individual success of any of these procedures depends on its ability to adjust the eyelid position relative to the amount of levator function present. This chapter will cover the most common types of adult ptosis surgery—Müller's muscle conjunctival resection (MMCR) and its variations, external approach levator advancement and resection, and frontalis suspension.

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Preoperative Evaluation

History

A thorough history is imperative in optimizing surgical outcomes in any ptosis surgery. The onset or duration of the ptosis should be sought to determine if the ptosis is likely congenital or acquired. Past photographs can also help in determining the time period of the ptosis. Variability and fatigability of the ptosis should also be asked as the presence of both can point towards ocular myasthenia rather than simple aponeurotic ptosis.

Any history of trauma or prior ocular surgery (cataract, glaucoma, LASIK and other refractive surgery) should be elicited as these may contribute to aponeurotic ptosis (Fig. 1). Mechanisms of ocular surgery-related blepharoptosis include eyelid speculum use, eyelid oedema, and mechanical stretching of attachments between levator aponeurosis and tarsal plate.

E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_11

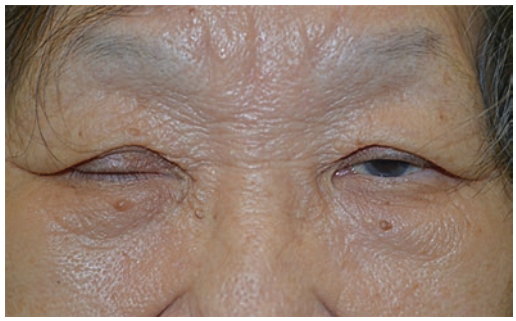

Fig. 1 Patient with multiple glaucoma surgeries in both eyes with resultant bilateral aponeurotic ptosis, right more severe than left

These mechanisms may be reversible (as with other forms of traumatic ptosis) and it may be worthwhile to allow at least a few months for spontaneous improvement before performing surgery on these patients.

Prolonged soft and hard contact lens wear is known to be a risk factor of acquired, aponeurotic blepharoptosis. The mechanism for the development of contact lens-induced blepharoptosis is likely recurrent manipulation and subsequent stretching of upper eyelid structures during contact lens insertion and removal, and increased rubbing of the upper eyelid over the ocular surface. Giant papillary conjunctivitis secondary to contact lens wear may also contribute to ptosis mechanically.

Any dry eye syndrome and other ocular surface problems are best identified and treated preoperatively as they are likely to become more symptomatic following surgery. Patients with ptosis may present with dry eye symptoms due to the decreased rate of blinking. Medications such as anticoagulants (e.g. warfarin, heparin), platelet inhibitors (e.g. aspirin, NSAIDs, clopidogrel, ticlopidine) should also be checked as these increase the risk of excessive bleeding during and after surgery, and the patient should be advised to stop prior to surgery as necessary.

It is also useful to document how the ptosis affects the patient's vision or daily activities. Patients with ptosis often complain of decreased peripheral vision during daily activities. The ptotic eyelid blocks peripheral vision and, if severe enough, can also affect central vision. Many patients report difficulty with reading, as the ptosis may worsen in downgaze. Complaints of difficulty driving at night are also common. Most patients with ptosis will report that the ptosis is worse at the end of the day, perhaps because the compensatory frontalis lifting of the brows becomes fatigued.

Physical Examination

There are several clinical parameters that are routinely documented in evaluation of a patient with ptosis, of which levator function is the most important criterion in selecting a successful surgical procedure.

- Levator function is measured as maximum eyelid margin excursion from extreme down gaze to extreme up gaze positions (Fig. 2). The frontalis muscle must be immobilized, usually with the examiner's finger at the brow to eliminate its contribution to elevation. By convention, more than 13 mm of function is considered excellent, 10–13 is very good, 8–10 mm is good, 5–7 mm is fair, and 4 mm or less is poor.
- Margin-reflex distance 1 (MRD1) is the distance between the upper eyelid margin and corneal light reflex in primary position (Fig. 3). It is important to note that there is a relatively wide variation in eyelid position in the general population with ethnic and racial differences, with mean MRD1 in whites being approximately 5 mm, and in Asians 2–4 mm depending on the ethnicity.
- Vertical interpalpebral fissure height, or palpebral aperture (Fig. 3), is the widest point between the lower and upper eyelid.
- Upper eyelid crease position is the distance from the upper eyelid crease to the eyelid margin and is formed by insertion of levator fibers to the orbicularis intermuscular septa and skin. It is absent or low in the East Asian eyelid due to more distal insertion of the orbital septum

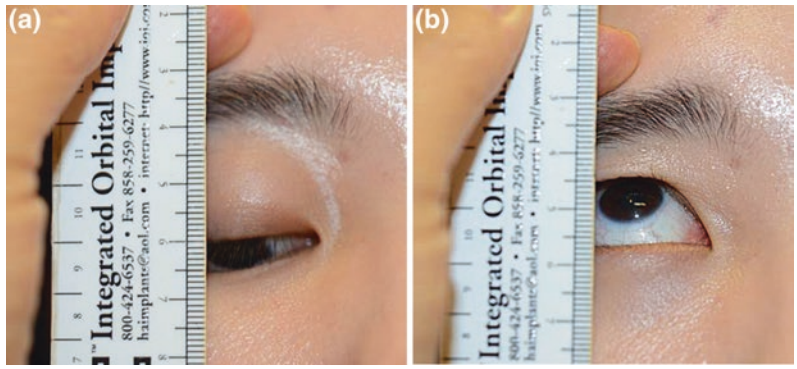

Fig. 2 Levator function is measured as maximum eyelid margin excursion from extreme downward gaze (**a**) to extreme upward gaze positions (**b**). The frontalis muscle must be immobilized, usually with the examiner's finger at the brow to eliminate its contribution to elevation (**b**). In this case, the levator function measures as 15 mm

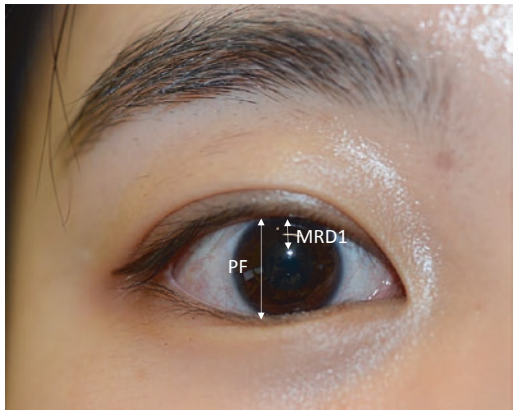

Fig. 3 Margin-reflex distance 1 (MRD1) is the distance between the upper eyelid margin and corneal light reflex in primary position. Palpebral fissure (PF) is the widest point between the lower and upper eyelid

and more inferior extension of extraconal orbital fat (Fig. 4a). In patients with acquired aponeurotic ptosis, the eyelid crease may be elevated due to dehiscence of the levator from the pretarsal orbicularis fibres (Fig. 4b).

In senile aponeurotic ptosis, which is the most common form of ptosis encountered in the adult population, certain physical examination findings are characteristic, such as preservation of fair to good levator function, an upper lid skin crease that is higher than normal, visibility of the cornea through the thinned upper eyelid in severe cases, and lid drop on downgaze.

Other things to look out for in the physical examination include the presence or absence of abnormal head posture (head-up posture, chin elevation), frontalis overaction, coexisting brow ptosis, lower lid position, lagophthalmos, and Bell's reflex. In unilateral or asymmetric ptosis, it is important to take into account the presence of the Hering effect. The Hering law of equal innervation postulates that the upper eyelid muscles are innervated simultaneously and equally. Thus, if one eyelid is ptotic, the other eyelid will reflexively attempt to elevate it, leading to an equal elevation of the non-involved lid. Similarly, lifting the ptotic eyelid results in decreased innervation to bilateral levator palpebrae muscles, which are equally innervated. This may result in drooping of the contralateral eyelid.

Surgical Approaches

Posterior Approach

Müller's Muscle-Conjunctival Resection (MMCR)

Müller's muscle-conjunctival resection (MMCR), or conjunctivomüllerectomy originally described by Putterman and Urist in 1975, is a good option for correction of mild to moderate upper eyelid ptosis with good levator muscle

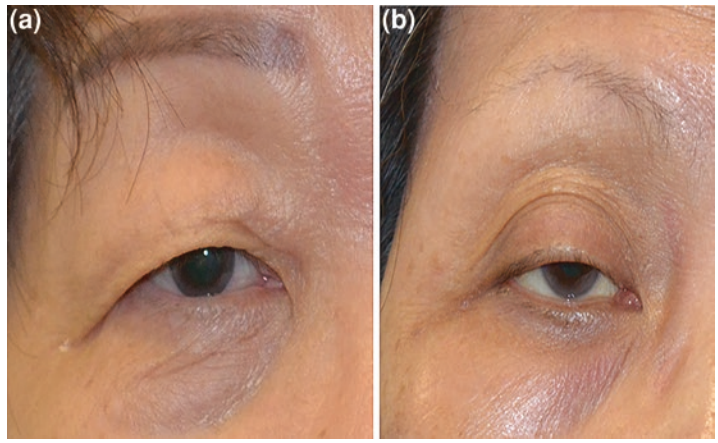

Fig. 4 **a** An absent or low crease in the East Asian eyelid due to more distal insertion of the orbital septum and more inferior extension of extraconal orbital fat, giving a "puffy" appearance to the upper lid. **b** An elevated eyelid crease in patients with acquired aponeurotic ptosis due to dehiscence of the levator aponeurosis from the pretarsal orbicularis fibres

function and positive response to phenylephrine preoperatively. Unlike the Fasanella–Servat procedure, MMCR preserves the tarsus and accessory glands and has several advantages: predictable, relatively simple to perform, lack of an external scar, and ability to maintain a natural upper eyelid contour (Fig. 5). While most surgeons do not perform MMCR in patients with severe ptosis or in patients with no response to phenylephrine eyedrops, there have been studies which show that MMCR may work even in patients with severe ptosis or with negative phenylephrine test.

There have been several attempts to elucidate the mechanism of action for the Fasanella–Servat and Müller's muscle conjunctival resection procedures, but the exact mechanism has remained elusive. Although originally thought to work by shortening the Müller's muscle, clinicopathologic assessments in which Müller's muscle resection area did not correlate with change in eyelid position tend not to support this claim. Levator plication as a potential alternative mechanism has become a pervasive theory supported by intraoperative and histologic evidence.

Technique

Conjunctivomüllerectomy can be performed under local or general anesthesia. Under local anesthesia, 2% lidocaine with 1:200,000 epinephrine is infiltrated into the upper eyelid. A Desmarres retractor is then used to evert the upper eyelid and local anesthesia is infiltrated along the supratarsal palpebral conjunctiva. Many surgeons prefer to administer a frontal nerve block, using local anesthesia without epinephrine to avoid stimulation and distortion of Müller's muscle.

The classic algorithm for resection of conjunctiva and Müller's muscle is represented by a 4:1 ratio of resection length to eyelid elevation: 4 mm of resection for 1 mm of ptosis, 6 mm of resection for 1.5 mm of ptosis, 8 mm of resection for 2 mm of ptosis, and 9–10 mm of resection for 3 mm of ptosis. This technique is generally not recommended for patients with more than 3 mm of ptosis. Resection of tissue of more than 10 mm should be avoided as this may cause shortening of the fornix.

Once the amount of ptosis to be corrected is determined, the amount of tissue to be resected is divided in half. For example, 2 mm of

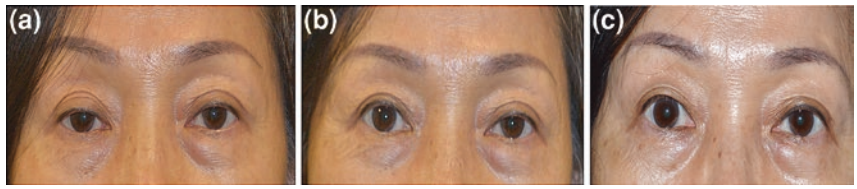

Fig. 5 **a** Patient presenting with right sided ptosis. **b** Phenylephrine 2.5% revealed improvement in right sided ptosis but a resultant left sided ptosis from Hering's law. **c** Patient underwent bilateral MMCR with 8 mm resection on the right and 4 mm on the left. At postoperative month 1, she is happy with the improvement in lid height and absence of external scar

ptosis would require 8 mm of resection. 4 mm is marked superior to the superior tarsal border at three points: nasally, centrally and temporally.

With toothed forceps, the conjunctiva and part of the Müller's muscle that is adherent to its undersurface is grasped and pulled from side to side and up and down to separate its loose areolar connections from the levator aponeurosis. This is repeated at several positions across the lid (Fig. 6a). Placement of 6/0 silk traction suture through conjunctiva and Müller's muscle is performed at several points (Fig. 6b).

Traction is then applied to the silk suture. A Putterman clamp (Fig. 6c) or hemostat (Fig. 6d) is then placed on the conjunctiva-Müller's muscle flap, avoiding the tarsal plate.

Suturing of the flap can be performed with 6/0 prolene or a suture of the surgeon's choice. The suture is placed from the lateral aspect of the eyelid crease and this is placed high in the fornix to minimize irritation to the cornea. The conjunctiva-Müller's muscle flap is secured in a horizontal mattress fashion across the entire length of the clamp (Fig. 6e). At the medial aspect of the clamp, the suture is then directed high into the fornix and externalized on to the skin at the lid crease.

Excision of the conjunctiva-Müller's muscle flap is performed with a blade or scissors (Fig. 6f, g). Utmost care should be taken to avoid cutting the suture, and this can be ensured by feeling metal-on-metal contact between the blade and the clamp. The suture should then be tied with minimal tension and removed at the 1 week postoperative visit. Some surgeons like to run the suture back from the medial to lateral aspect across the wound and bring two arms of the suture through the lid temporally.

Müller's Muscle-Conjunctival Resection (MMCR) with Tarsectomy

The concept of adding a tarsectomy to the MMCR procedure was introduced in 2002. The modified algorithm by Perry et al. was as follows: 9 mm of conjunctiva and Müller muscle + x mm of tarsus, in which x = distance of undercorrection after phenylephrine testing. Additional elevation was achieved by the resection of the tarsus at a 1:1 ratio. This algorithm granted surgeons a powerful tool, allowing for the correction of moderate to severe ptosis greater than 3–4 mm as long as the candidates possessed good levator muscle function and a fair phenylephrine response.

Since then, there have been various modifications to the nomogram for MMCR with tarsectomy, one of which is Liao's modification of the nomogram for combined MMCR and tarsectomy with no reference to the phenylephrine response. For each case, 8 mm MMCR and 1–3 mm tarsectomy was performed. Specifically, if MRD1 was negative, 8 mm MMCR and 3 mm tarsectomy were the chosen amounts of resection. If MRD1 was 0–1 mm, 8 mm MMCR and 2 mm tarsectomy were done. When MRD1 was 2–3 mm, 8 mm MMCR and 1 mm tarsectomy were performed. For patients with fair levator muscle function (5–7 mm), an additional 1 mm of the tarsal plate was resected for better results. The results of the phenylephrine test alter the nomogram by 1 mm of tarsectomy.

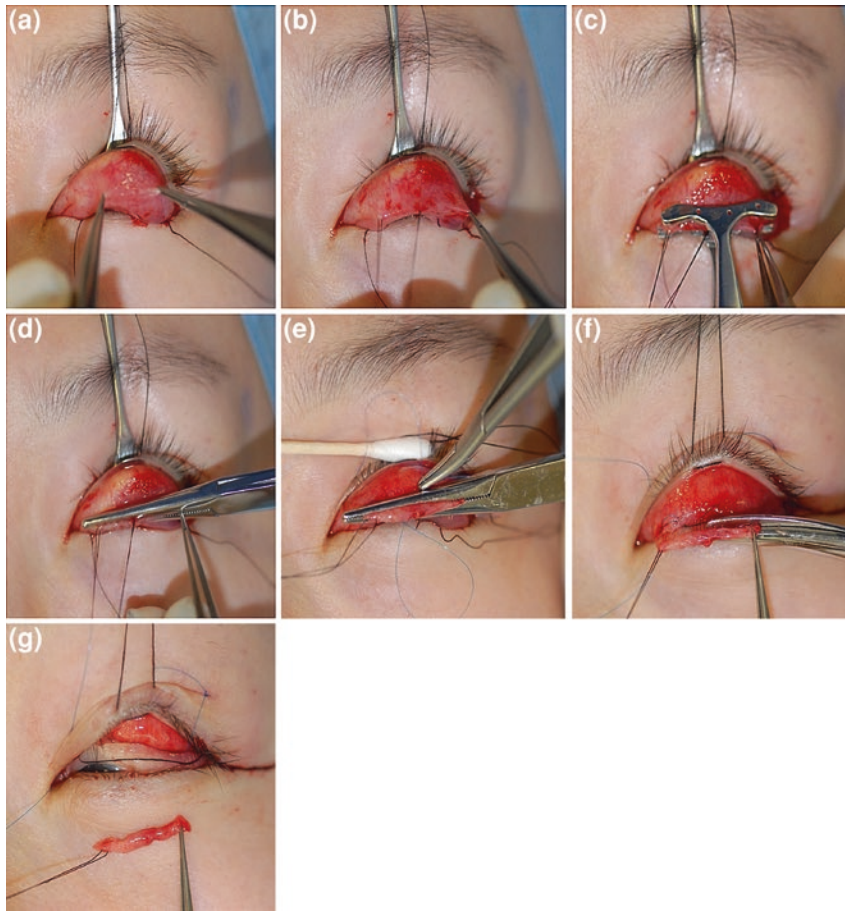

Fig. 6 **a** With two toothed forceps, the conjunctiva and part of the Müller's muscle that is adherent to its undersurface is grasped and pulled from side to side and up and down to separate its loose areolar connections from the levator aponeurosis. **b** 4 mm is marked superior to the superior tarsal border at three points: nasally, centrally and temporally. Placement of 6/0 silk traction suture through conjunctiva and Müller's muscle is performed at these points. **c** A Putterman clamp is then placed on the conjunctiva-Müller's muscle flap, avoiding the tarsal plate. **d** Alternatively, a hemostat can be placed over the conjunctiva-Müller's muscle flap. **e** A 6/0 prolene suture is placed in a horizontal mattress fashion across the entire length of the clamp. **f** Excision of the conjunctiva-Müller's muscle flap is performed with a scissors. Care is taken to avoid cutting the sutures. **g** A strip of excised conjunctiva-Müller's muscle flap is excised

Posterior Tarsoconjunctival Resection (Fasanella–Servat)

Similar to MMCR, the Fasanella–Servat procedure is classically reserved for mild to moderate ptosis with good levator function. The tarsoconjunctival resection procedure is relatively simple to perform and predictable in terms of results. Another advantage is that it may be performed for the phenylephrine-negative patient. However, it sacrifices the upper portion of the tarsus and accessory lacrimal glands.

The procedure is similar to MMCR. If it is determined that a 3 mm tarsal resection and a 3 mm conjunctival and mullers muscle resection will be performed, these marks are made with a monopolar cautery corresponding to the central third of the eyelid. Tooth forceps are then used to grasp the superior border of the tarsus. A 4-0 silk traction suture is then placed at the superior boarder of the tarsus in a locking running fashion.

The traction suture then holds the eyelid in position and two curved hemostats are used to

clamp at the previous markings on the tarsus. Alternatively, a Putterman clamp can be used. The hemostats are placed across the upper tarsus 3 mm from its superior border so that tarsus and conjunctiva are included in the bite. A 6-0 chromic suture is then placed in a running mattress fashion on the other side of the curved hemostats. This suture is placed across the eyelid and then turned around to complete the passes. There is significant discussion around the most appropriate suture to use as well as whether to place these sutures transcutaneous.

A #15 blade is then used to make metal on metal contact with the curved hemostats to excise the tissue. The tissue is removed and the suture is tied. If the knot is on the inside of the eyelid, a contact lens should be placed. The traction sutures are removed at the end of surgery.

Potential Complications

Complications of the MMCR and Fasanella–Servat procedures includes duplicate eyelid creases, suture allergies, hematomas, undercorrections and overcorrections, wound dehiscence, pyogenic granulomas, and dry eye syndrome. Undercorrection is more common than overcorrection in MMCR. This results from failure to resect enough tissue or from poor patient selection.

Corneal abrasions may occur from the chromic sutures placed across the conjunctival edges. Ophthalmic ointment should be used liberally until the sutures dissolve.

Contour abnormalities in Fasanella–Servat may be caused by uneven placement of the clamps, resection of too wide a segment of the tarsus, or failure to leave the central tarsus longer that the sides.

Anterior Approach

The "Age of aponeurotic awareness" in 1985 directed the trend of ptosis surgery toward the anterior approach. The proponents of levator aponeurosis surgery argued that since the defect of involutional ptosis was found to be in the aponeurosis instead of in the Müller's muscle or tarsus, it was improper to violate tissues not directly responsible for the disease as per posterior approach ptosis surgery.

External Levator Advancement

In most cases with fair to good levator muscle function, levator advancement or repair is a good option for correction of ptosis, with reported success rates of 70% to more than 95%. Compared to MMCR and Fasanella–Servat, it has a clear pathophysiologic-anatomical basis of repair: reapproximation of the attenuated/dehisced levator aponeurosis back to its former anatomical position (Fig. 7).

Levator advancement or resection surgery remains the standard of adult ptosis surgery especially in patients with moderate to severe ptosis with fair to normal levator function, who require simultaneous blepharoplasty, do not respond to phenylephrine or want lid crease formation.

Although most appropriate for acquired aponeurotic ptosis, this surgery also works well for neurogenic, myogenic and congenital ptosis. It allows for accurate adjustment of eyelid height and contour, especially when performed under local anaesthesia.

Technique

The upper eyelid crease incision is the ideal approach for external levator advancement especially since many of the adult ptosis patients have coexistent upper eyelid dermatochalasis. Accurate skin marking of upper eyelids is an essential step for successful upper eyelid blepharoplasty or ptosis surgery. The native eyelid crease is usually used. In non-Asians, the central eyelid crease height is approximately 6–9 mm in males and 8–11 mm in females. In Asians, the eyelid crease is often much closer to the lid margin, approximately 4–6 mm in males and 6–8 mm in females. It is important to note that levator dehiscence-related blepharoptosis may result in an upper eyelid crease that is unusually high or asymmetric and the crease should be marked at the lower native crease position and

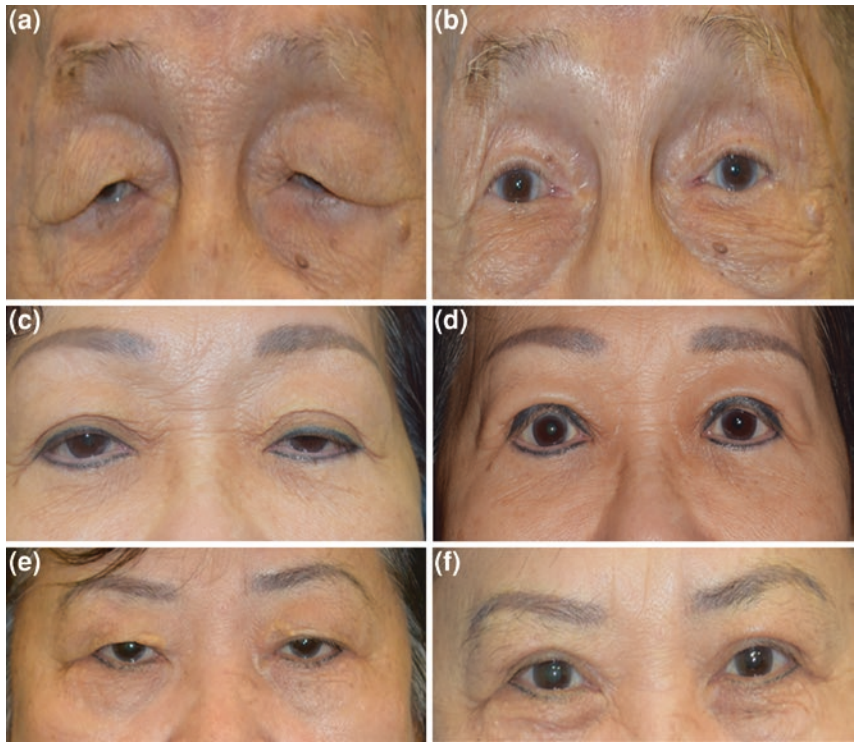

Fig. 7 **a** and **b** Patient with significant dermatochalasis and ptosis (**a**) underwent bilateral blepharoplasty and levator resection with significant improvement in visual fields (**b**). **c** and **d** Patient with bilateral asymmetrical ptosis and upper eyelid creases (**c**) underwent bilateral levator advancement with improved symmetry postoperatively (**d**). **e** and **f** Patient with heavy upper lids and mild ptosis (**e**) underwent bilateral blepharoplasty with removal of her xanthelesmata and improvement in her lid height (**f**)

not at the crease position resulting from levator dehiscence.

The nasal aspect of the upper eyelid crease marking should not extend past the punctum to avoid medial upper eyelid webbing. Laterally, the marking can be extended beyond the lateral canthus if hooding is present, but care should be taken not to extend too far out into the thicker skin beyond the lateral canthal area to avoid unappealing scarring. Non-toothed forceps can be used to pinch redundant skin for excision. Alternatively, marking of 10–15 mm between the upper eyelid margin and lower border of eyebrow can be made bilaterally to ensure symmetrical and sufficient residual anterior lamella on both upper lids.

Wherever possible, ptosis surgery should be performed under local anesthesia to allow more precise adjustment of the eyelid height and contour. Prior to incision, local anesthesia of 2% lidocaine with 1:200,000 epinephrine is infiltrated into the upper eyelid skin, with care taken to give not more than 1.5 ml to each eyelid and avoid injecting too deep into the orbit to avoid a motor block to the levator (Fig. 8a). The epinephrine in the local anesthesia induces hemostasis and facilitates surgical dissection. Throughout the surgery, the surgeon should be vigilant about hemostasis as bleeding and oozing may create a hematoma and obscure surgical planes.

Retraction of the upper and lower skin incisions give good exposure of the upper lid structures. Note the status of the aponeurosis, which may be dehisced, disinserted or still attached to the tarsus. If dehisced or disinserted, the Müller's muscle may be visible inferior to the edge of the aponeurosis. The underlying cornea

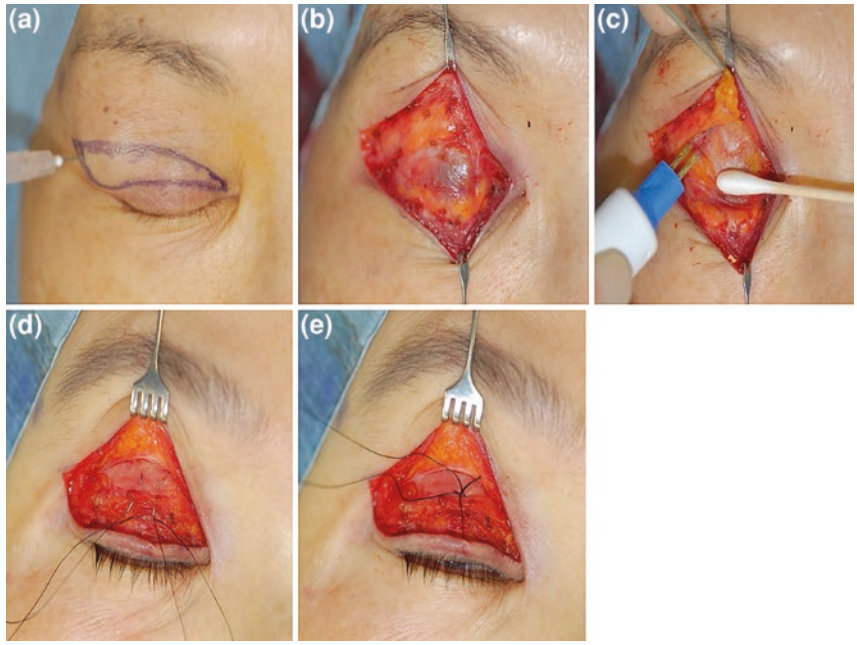

Fig. 8 **a** After marking, local infiltration is performed. **b** The underlying cornea may also be visible as greyish structure beneath the dehisced levator aponeurosis (white arrows represent disinserted white line of levator aponeurosis). **c** After the septum is opened, dissection is performed between the levator and preaponeurotic fat. **d** After a partial thickness bite through the tarsus, both ends of the 6/0 silk suture are passed through the edge of the levator aponeurosis such that it is advanced and plicated to the tarsus in a horizontal mattress fashion. **e** A temporary knot is placed over a free silk tie

may also be visible as greyish structure beneath the thinned-out levator aponeurosis (Fig. 8b, white arrows represent disinserted white line of levator aponeurosis). The orbicularis and orbital septum are then opened, with either Wescott scissors or cutting cautery, across the entire length of the incision. The preaponeurotic fat pockets are usually visible beneath the orbital septum and are important surgical landmarks as the levator aponeurosis lies directly beneath it. The levator is then dissected free from the overlying preaponeurotic fat pads, and any fine fascial attachments between the fat capsules and aponeurosis can be divided with scissors, cautery or even cotton tipped applicators (Fig. 8c).

The pretarsal orbicularis is then dissected free from the superior half of the tarsus. Some of the pretarsal orbicularis can be debulked but should be done so conservatively, to avoid problems with eyelid closure after surgery.

A 6/0 silk suture (or a suture of the surgeon's choice) is then passed partial thickness through the superior one-third of the tarsal plate. The tarsal plate should be everted to ensure the suture has not passed full thickness through the tarsus to avoid any keratopathy postoperatively. One end of the suture is then passed through the edge of the levator aponeurosis to advance it. The other end of the suture is similarly passed through the edge of the levator aponeurosis such that the levator aponeurosis is plicated to the tarsus in a horizontal mattress fashion (Fig. 8d). If a double armed suture is not used, the other end of the suture can be passed on a free needle. A temporary knot is then placed, or a free silk tie can be used (Fig. 8e).

The patient is then asked to open his or her eyelids. Eyelid contour, height and symmetry are noted. If necessary, the patient can be placed in a sitting position to determine the eyelid position. Once satisfactory, the temporary knot is

made permanent. Some surgeons put just one central suture. Other prefer to place additional medial or/and lateral sutures to better adjust the lid contour. All sutures can be adjusted and replaced upward or downward in the levator aponeurosis as necessary until the correct lid height and contour is achieved. Excess levator aponeurosis can be resected.

Lid crease formation sutures can be placed to create a deeper, more defined crease. 7/0 Nylon is passed through a small bite of tarsus, levator aponeurois stump and to the orbicularis beneath the lower skin incision in a buried fashion. Three such knots can be placed across the eyelid length—nasally, centrally and laterally. The skin is then closed with continuous 7/0 Nylon or prolene, taking small bites of the skin edge along the way. The sutures can be removed at the 1-week postoperative visit.

Potential Complications

Like most eyelid surgical procedures, potential complications of ptosis include bleeding, hematoma, infection, suture granuloma and scarring.

Dry eye problems may increase after the surgery, but this is usually transient and improves with time and is relieved with lubrication. Some degree of lagophthalmos may also be present postoperatively. This almost always resolves with time. Significant and persistent lagophthalmos may result from inadvertent shortening of the orbital septum by failure to separate it from the aponeurosis or by including it in the skin sutures. This will require opening of the wound with lysis of the septal attachments. Lagophthalmos combined with poor Bell's reflex may result in exposure keratopathy.

Undercorrection or overcorrection may occur in ptosis surgery. Within the first two weeks postoperatively, this can be revised in the outpatient clinic by opening the wound and adjusting the sutures on the aponeurosis as necessary. Poor eyelid contour may also occur and is caused by uneven advancement of the aponeurosis. It is prevented by careful attention to the contour intraoperatively. If necessary, it can also be corrected within the first two weeks by opening the wound and segmental advancement or recession of the aponeurosis.

Levator Muscle Resection

Patients with myogenic (adult or congenital) or neurogenic ptosis with fair to poor levator function may respond to maximum aponeurosis advancement up to Whitnalls ligament or a levator muscle resection procedure. Some patients with aponeurotic ptosis who do not respond sufficiently to a levator advancement may also benefit from levator muscle resection.

The amount of muscle to be removed can be adjusted intraoperatively according to the Berke method, which is based on the degree of expected postoperative fall or elevation in the lid position. With fair to good levator function, the lid is placed 2–3 mm below the limbus and no postoperative fall is expected; with poor to fair levator function, the lid is placed at the superior corneal limbus as a postoperative fall of several millimetres is expected. Some surgeons prefer to adjust the lid height in all cases to within 1 mm of or exactly at the superior corneal limbus.

Procedure

The steps of levator resection surgery are similar to that of levator advancement from the skin marking to incision to exposure of the superior tarsus and the levator aponeurosis. An additional step that is then taken is the dissection of levator and Müller's muscle from the underlying conjunctiva. It is helpful to have your assistant place counter traction on the conjunctiva during dissection so the planes between Müller's muscle and conjunctiva open up nicely. A corneal shield should also be placed to avoid inadvertent injury to the cornea in case of a button-hole of the conjunctiva. Dissection is carried out superiorly to as far as the level of Whitnall's ligament.

Similar to levator advancement, a partial thickness bite is taken on the tarsus and passed in a double-armed horizontal mattress fashion through the levator—Müller's muscle flap. Note the position of the upper eyelid. The lid margin should rest at or near the superior corneal limbus. If it does not, further dissection of the levator—Müller's muscle flap may be necessary and the suture needs to be repositioned.

Medial and lateral sutures are additionally placed through the levator—Müller's muscle flap and adjusted to achieve adequate eyelid contour. The excess levator muscle is then excised distal to the sutures with a cutting cautery.

Reformation of the lid crease is necessary with small bites through skin-tarsus or levator-skin using a permanent suture (e.g. 7/0 Nylon) in adults or an absorbable suture (e.g. 7/0 Chromic) in children. This helps to prevent entropion especially if the posterior lamella has been significantly shortened compared to the anterior lamella. Skin is then closed with a running 7/0 Nylon in adults or a fast absorbing suture (e.g. 7/0 fast absorbing gut or Vicryl Rapide™) in children.

Potential Complications

Lagophthalmos during eye closure or sleep is usually present in cases with poor levator function. Significant lagophthalmos can lead to exposure keratopathy especially in patients with poor Bell's phenomenon. Care must be taken to protect the cornea by regular instillation of lubricant eyedrops. If necessary, a frost suture may be placed.

Conjunctival prolapse may result from the lack of suspensory attachments in the fornix during supramaximal levator resection. It may recede spontaneously in a few weeks if small; but if large, it will have to be replaced or excised. Fornix deepending sutures can be placed to create adhesions between the levator and conjunctiva by passing double armed sutures from the apex of the prolapsed conjunctiva and exiting high in the fornix onto the skin above the eyelid crease.

Similar to levator advancement, under- or overcorrection may occur. In particular, undercorrection may occur in patients with poorer levator function if the levator has not been sufficiently dissected and resected. Overcorrection may also occur although massage and time usually resolves small overcorrections. If persistent or large, revision surgery with levator muscle recession may be required. Poor eyelid contour can also occur if there is inadequate adjustment of sutures intraoperatively.

Frontalis Suspension

In patients with no or very poor levator function, the operation that will achieve adequate eyelid elevation is frontalis suspension. In adult ptosis surgery, this is reserved for patients with pre-existing congenital ptosis, myogenic or neurogenic ptosis which cannot be corrected with conventional ptosis surgery on the levator muscle. In this procedure, the frontalis is used as a supplemental eyelid retractor as the eyelid is fixed to the frontalis muscle at the brow. The patient opens the eye by elevating the brow and closes the eye by contracting the orbicularis.

Frontalis suspension surgery may use several surgical techniques and different sling materials. Materials include autogenous or banked fascia lata and alloplastic materials that include chromic gut, collagen, polypropylene, silicone, stainless steel, silk, nylon monofilament, polyester and polytetrafluoroethylene (PTFE). Autogenous fascia lata has proven to give good results with comparably low rates of recurrent ptosis and infections but requires secondary surgery on the leg for harvesting of the fascia. Silicone rod has the advantage of not scarring into position, so that it can be adjusted indefinitely. However, it has a higher rate of ptosis recurrence and pyogenic granuloma formation. Nylon and PTFE have reported higher rates of complications such as early postoperative exposure keratopathy, inflammation or pyogenic granuloma, suture infection with preseptal cellulitis, and suture exposure.

Frontalis Suspension with Silicone Rod

Procedure

The upper eyelid crease is marked using the fellow eyelid crease as a guide in unilateral surgery, or according to preoperative discussion with the patient on the position of the lid crease in bilateral surgery. Two horizontal 3-mm lid incisions are marked 2–3 mm above the lid margin, one medial and one lateral. Two more 3 mm skin marks are made above on the eyebrow, one slightly laterally and the other slightly medially from the eyelid marks created before. The final

central suprabrow marking is slightly higher than the nasal and temporal brow markings such that the five incisions form a pentagonal configuration, which maximizes the vector pull of the upper eyelid by the frontalis muscle. Local infiltration of anesthesia in the form of 2% lidocaine with 1:200,000 epinephrine is injected into the skin incision markings on the upper lid and brow.

Stab incisions are then made over the 3 mm markings on the eyelid and suprabrow region. The eyelid incisions should be made deep through skin and pretarsal orbicularis to the tarsus. The brow incisions should be deep to the frontalis muscle to the periosteum. The stab incisions along the suprabrow are then widened to create subcutaneous pockets.

The needle is passed from the medial lid incision to the lateral lid incision. A gentle curve is placed on the needle that is supplied with the silicone rod. With a lid guard or corneal shield in place, the needle is placed form the medial lid incision at a level deep to the orbital septum. It is then directed towards the superior orbital rim and passes in a pre-periosteal plane towards the medial brow incision. The lateral end of the silicone rod with the needle attached is similarly passed deep to the orbital septum and retrieved in the lateral brow incision. Palpation should be performed over the course of the sling to verify the depth of placement. If the sling is palpable, it should be adjusted in a deeper plane as deeper placement of the sling may yield better cosmetic and functional results. A 6/0 silk or prolene suture is then used to take a partial thickness bite of the tarsus. The suture then secures the silicone rod onto the tarsus.

The two ends of the rods are then united in the central incision. The pass should be deep to the subcutaneous layer and the frontalis muscle. A Wright fascia needle may also be used as an alternative to the attached needle to the silicone rod. The sleeve that is included in the set can be trimmed to a shorter length. The nasal and temporal ends of the rods are then passed into the sleeve in a correct orientation to avoid excessive torqueing of the sleeve. The sleeve tension is adjusted, following which the silicone rods are tightened over the sleeve and then reposited in the subcutaneous tissues. 6/0 prolene or silk sutures are then used to secure each end of the sleeve. Excess silicone rod is then trimmed to approximately 3 mm on each side. The sleeve is then reposited back into the subcutaneous incision and buried in the subcutaneous pocket to avoid extrusion postoperatively. Subcutaneous closure is performed with a 6/0 Vicryl suture.

Frontalis Suspension with Autogenous Fascia Lata: See Chap. 8

Procedure

Among materials used for frontalis suspension, autogenous fascia has been considered to result in lower ptosis recurrence and lower complication rates and therefore has been considered the material of choice. It is contraindicated in children under 3 years old where the fascia lata is thin and poorly developed.

A line is drawn in the approximate direction of fibres in the iliotibial tract from the lateral knee to the anterior iliac crest. A 2 cm segment of this line 2 fingerbreadths above the lateral condyle of the femur is further marked. Local anaesthesia of 1:100,000 epinephrine is injected.

An incision is made along the 2 cm line segment where one can palpate the inferior aspect of the muscle. Dissection is then performed through the subcutaneous fat with scissors to the fascia. The fascia is easily identified by its glistening white appearance. Metzenbaum scissors are then used to bluntly dissect along the surface of the fascia. A #15 blade is then used to make a horizontal incision through the fascia. A tongue of fascia is then developed which is parallel to the strands of the fascia. The Metzenbaum scissors are used to further develop the tongue. A 4-0 Vicryl suture is then used to engage the tongue in order to introduce the tongue into the Crawford fascia stripper. The Crawford fascia stripper is then introduced and advanced with gentle pressure. It is passed along the line that was previously drawn and should slide relatively easily parallel to the fascia strands. The stripper has a guillotine mechanism on the end of it so that when you pull back it cuts the fascia. The stripper and fascia are then removed from the

incision. The incision is then closed with deep interrupted 4-0 Monocryl sutures and then 5-0 prolene sutures through the skin in a vertical mattress fashion. It is not necessary to close the fascial defect. At the conclusion of the procedure the leg is checked for hematoma formation and the wound is dressed with antibiotic ointment and Tegaderm. The patient returns in one week for suture removal.

Once the fascia lata is harvested, the remainder of the frontalis suspension procedure is similar to that for silicone rods described above (Fig. 9a). A Wright fascia lata needle is used to retrieve the fascia lata from the incisions (Fig. 9b). The fascia lata is secured to the tarsal plate through the lid crease incision as described above. To bring the fascia lata out from the upper lid to the suprabrow incisions, a Jaeger lid plate is placed under the eyelid, in contact with the orbital rim to protect the globe during the passage of the Wright needle. The Wright needle is then passed through the temporal brow incision deep in the tissues of the lid with the point of the needle constantly palpated and directed by the surgeon's index finder so that the needle exists at a lid incision. The fascia lata is then loaded into the Wright needle and the Wright needle is pulled back to draw the fascia lata into the temporal brow incision. The above is repeated with the medial brow incision. Once both ends of the fascia lata have been brought out in the temporal and medial suprabrow

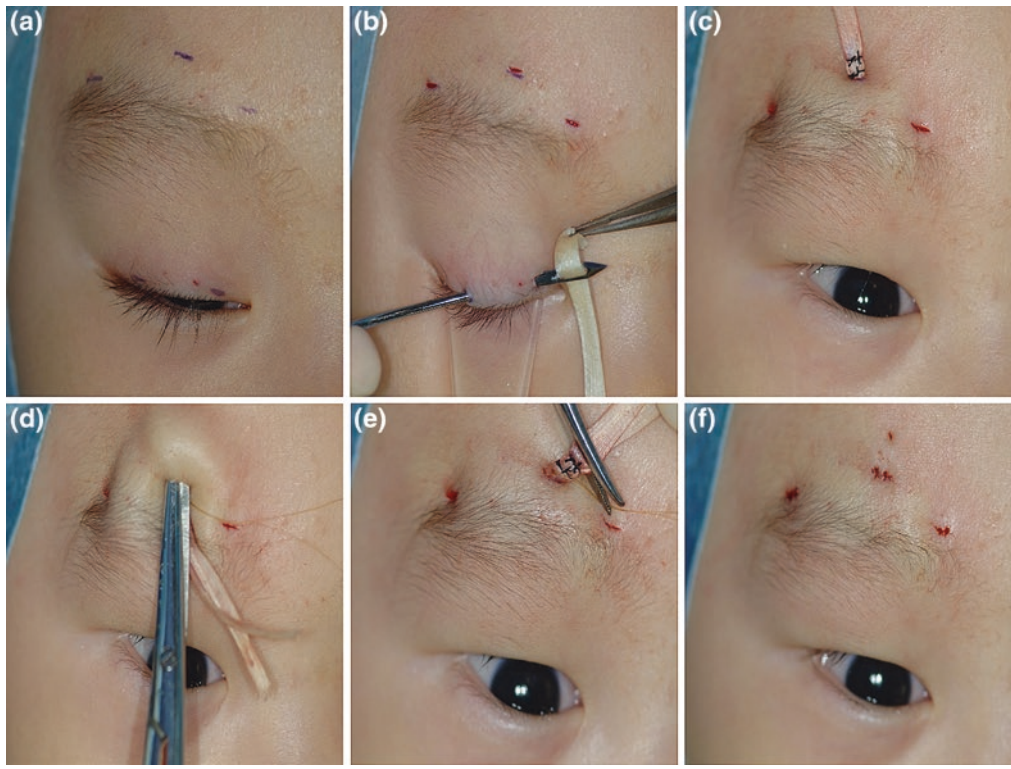

Fig. 9 **a** Five 3 mm incisions are drawn—two on the upper lid, three above the brow—such that the five incisions form a pentagonal configuration. **b** A Wright fascia lata needle is used to retrieve the fascia lata from the incisions. **c** Finally, both ends of the fascia lata are brought out to the central suprabrow incision to complete the pentagon. The lid height is adjusted and the fascia lata ends are tied with silk sutures. **d** The central suprabrow pocket is deepened to allow the fascia lata to be buried deep to the subcutaneous layer. **e** The fascia lata ends are then cut. **f** Both ends of the absorbable suture that were previously passed through the fascia lata ends are then brought out through the skin just superior to the incision, burying the fascia ends deep in the subcutaneous pocket

incisions, the Wright needle is passed deep in the central brow incision and out into the temporal and medial brow incisions separately, bringing out each end of the fascial strip to complete the pentagon (Fig. 9c). The lid height is adjusted and the fascia lata ends are tied with 6/0 silk sutures. A double-armed absorbable suture such as 6/0 Catgut is then passed through the fascia lata ends. The central suprabrow pocket is deepened to allow the fascia lata to be buried deep to the subcutaneous layer (Fig. 9d). The fascia lata ends are then cut (Fig. 9e) and both ends of the absorbable suture are passed just superior to the incision, burying the fascia ends deep in the subcutaneous pocket (Fig. 9f).

Potential Complications

Common complications that are associated with frontalis suspension include lagophthalmos and early postoperative exposure keratopathy. Lagophthalmos is common after frontalis suspension. Sufficient lubrication is necessary to prevent the condition until the lagophthalmos improves or the cornea adapts to chronic exposure.

Inflammation or pyogenic granuloma, suture infection with preseptal cellulitis, and suture exposure are also relatively common complications after frontalis sling surgery particularly with the use of alloplastic materials. Rates of each complication vary with different sling material with higher rates of complications are associated with nylon monofilament and PTFE. In cases of extrusion or chronic infection, surgical excision of sling suture is required.

Undercorrection may result due to failure to position the lid at the superior limbus when the knot is tied. If recognized within the first week, the fascia can be retrieved at the brow wounds and retied. For late recurrences, a new sling will be needed. Overcorrection is less common than undercorrection. Vigorous massage may loosen the sling. Recession or cautious cutting of the fascial strip may allow some recession of the lid.

Ectropion may occur if the sling is placed too close to the lid margin. Entropion may occur if the posterior lamella is shortened too much in comparison to the anterior lamella. This can be prevented by placing eyelid crease formation sutures from skin, orbicularis, tarsus, orbicularis to skin or Pang's suture technique using 4-0 chromic sutures.

For the fascia donor site, hematoma formation is an occasional complication. It is best for the patient to be on limited activity for at least 1 week after surgery. Discomfort along the site of fascia removal may also be common, especially with ambulation, although this should resolve within a couple of weeks.

Infection and poor scar formation may occur over the leg wound as the wound is more difficult to keep clean because of its location, and because the skin over the lateral thigh is thick. This can be prevented by careful postoperative wound care, and by careful closure of the underlying fat and dermal layers intraoperatively, followed by vertical mattress sutures on the skin to evert and slightly pucker the wound to avoid later depression.

Conclusion

Blepharoptosis will continue to be a commonly presented condition to the ophthalmologist and oculoplastic surgeon, given its interference with the patients' visual field and quality of life. Numerous surgical techniques have been described in the management of blepharoptosis. The choice of treatment is dependent upon the severity of the patient's ptosis, the levator function, the response to phenylephrine, and the surgeon's preference. Levator advancement or resection surgery remains the standard of adult ptosis surgery especially in patients with moderate to severe ptosis with fair to normal levator function, who require simultaneous blepharoplasty, do not respond to phenylephrine or want lid crease formation. Patients who demonstrate mild-to-moderate ptosis (<3 mm) with sufficient levator function (>8 mm) may benefit from the posterior lamellar approach, mainly involving Müller's muscle-conjunctival resection (MMCR) with or without tarsectomy. The frontalis suspension is less frequently used in adult ptosis surgery but is useful in cases with very

poor or absent levator function such as pre-existing congenital ptosis, neurogenic or myogenic ptosis.

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Blepharospasm, Hemifacial Spasm and Functional Applications of Neurotoxins in the Periocular Area:

Pelin Kaynak and Nadeen El Toukhy

BTX injections, frequently applied in treating spastic facial dystonias are still the most preferable treatment methods today due to undesired effects of alternative treatment methods.

BTX is successfully used in temporary treatment of idiopathic and thyroid dysfunction induced upper eyelid retraction, lacrimal gland blockage and temporary induction of ptosis in facial paralysis, as well as in other areas including extremity hyperhidrosis, bruxism, migraine, tension-type headaches, and paralytic spasticity. BTX injections to minimize scar formation have been recently reported.

Botulinum toxin is the exotoxin of anaerobic Clostridium species. Type A, B and E botulinum toxins are colorless, odorless, and tasteless. Only these three types of toxins affect humans and can cause systemic botulism.

Type A is the most potent toxin, followed by types B, and F. Each botulinum toxin is synthesized as a single chain protein, which is inactive until it is cleaved by bacterial proteases into its active form. The active botulinum toxins are composed of two chains: one heavy chain joined to one light chain by a relatively weak disulfide bond, which is shown to be highly responsible for the unstability of the molecule. The toxin is inactivated by heat, 85 °C (185 °F) or greater in 5 minutes.

Botulinum toxin prevents muscular contraction by inhibiting the release of acetylcholine from vesicles at the presynaptic nerve terminal at the neuromuscular junction. It also inhibits release of acetylcholine at the autonomic gangliae, postganglionic parasympathetic and sympathetic nerve endings. The different serotypes bind to different sites on the motor neuron terminal and within the motor neuron. The heavy chain functions both as a channel and a companion to bring the light chain across the endosomal membrane and then into the cytosol in the presynaptic region. The light chain acts inside the cell on synaptosomal associated protein receptor proteins (SNARE) to block the release of the vesicle-bound neurotransmitter acetylcholine from nicotinic and muscarinic nerve endings. Muscle weakness becomes evident in 2–4 days due to the continued release of acetylcholine from vesicles that have not been blocked by the toxin. Recovery of muscle activity typically begins 3–4 months after injection and is thought to occur due to the regeneration of new end plate units.

Doses of all commercially available forms of botulinum toxins are expressed in terms of units (= mouse units). The standard measurement of the potency of the toxin is one international unit (IU), which is the amount of toxin that kills 50% of a group of 18–20 female Swiss-Webster

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_12

mice (LD50) when injected intraperitonally. The LD50 in humans is estimated to be approximately 2,730 IU.

Commercial Preparations

BOTOX® (Allergan Corporation, Irvine, CA, USA) is a dry, protein crystalline complex of botulinum toxin A and it contains 100 units (MU = U) per bottle. One unit of BOTOX® COSMETIC equals to the calculated median intraperitoneal lethal dose (LD50) in mice. The product is unstable so it must be kept frozen before constitution. This is diluted with 1–4 cm^3 of non-preserved saline to yield a concentration of 10.0 U/0.1 mL, 5.0 U/0.1 mL or 2.5 U/0.1 mL, as needed. The onset of paralysis takes 24–48 h and reaches maximum at 7–10 days. The effect usually lasts 4–6 months. Repeated injections may delay the onset of paralysis but sometimes a more protracted paralysis will occur.

Dysport (Ipsen, Slough, UK) which is another trademark of botulinum toxin type A. Four units of Dysport is approximately equivalent to one unit of BOTOX®.

Myobloc® (Neurobloc) (Elan Pharmaceuticals, San Diego, CA, USA) contains a liquid formulation of purified botulinum toxin type B. When reconstituted, Myobloc® has a shelf life of more than 12 months which is longer than BOTOX®. It has a faster onset of action and better diffusion to tissues however the injections are more painful due to the acidity of the product. Botulinum toxin A is 50–100 times more potent than botulinum toxin B.

Reconstitution and Storage

Botulinum toxin A is recommended to be reconstituted with sterile nonpreserved 0.9% NaCl solution before injection and must be kept at 4 °C until injection. It has to be injected in 4 hours after reconstitution for maximum activity. The weak disulfide bonds between the two chains of the toxin renders it fragile under mechanical stress such as frothing when diluting and agitating the liquid inside the vial. Tuberculin syringes with 30 or 32 gauge needle are preferred which allow more painless and accurate injections at intended sites, and less bleeding. When botulinum toxin is injected in the periocular area both ice packs and EMLA® cream can be applied for topical anesthesia. EMLA® cream for periocular anesthesia works slightly better than ice pack skin cooling when botulinum toxin A is injected.

Blepharospasm (BEB)

Benign essential blepharospasm is the involuntary, repetitive contractions of orbicularis oculi muscle. Depressor muscles of eyebrows as corrugator superciliaris, procerus are also involved. The condition usually starts with periods of increased blinking that gradually increase in duration. The eyelids are relaxed between spasms, but the condition is invariably progressive, with periods of relaxation becoming shorter. In some patients there is difficulty or failure to open the eyelids between the spasms (apraxia of eyelid opening). It is worsened by stress, fatigue, and bright light and is improved by rest and sleep. Meige Syndrome is a cranial dystonia with bilateral blepharospasm accompanied by dystonia in the lower face. Involountary contractions of orbicularis oris, buccinator and masseter muscles are prominent.

BEB occurs in middle age and old age, and women are more commonly affected. Blepharospasm may lead to significant vision impairment, ocular irritation, and social embarrassment.

The forceful contractions of the orbicularis oculi and forced attempts to open the eyelid often lead to brow ptosis, levator aponeurotic disinsertion and blepharoptosis, dermatochalasis, and laxity of the canthal tendons and ectropion. Dry eye syndrome is frequently present. Conditions that should be considered in the differential diagnosis include psychogenic blepharospasm, habitual spasms, tardive dyskinesia, Parkinson disease, and the use of antipsychotic drugs. A complete ophthalmologic and neurologic examination is required to establish the diagnosis.

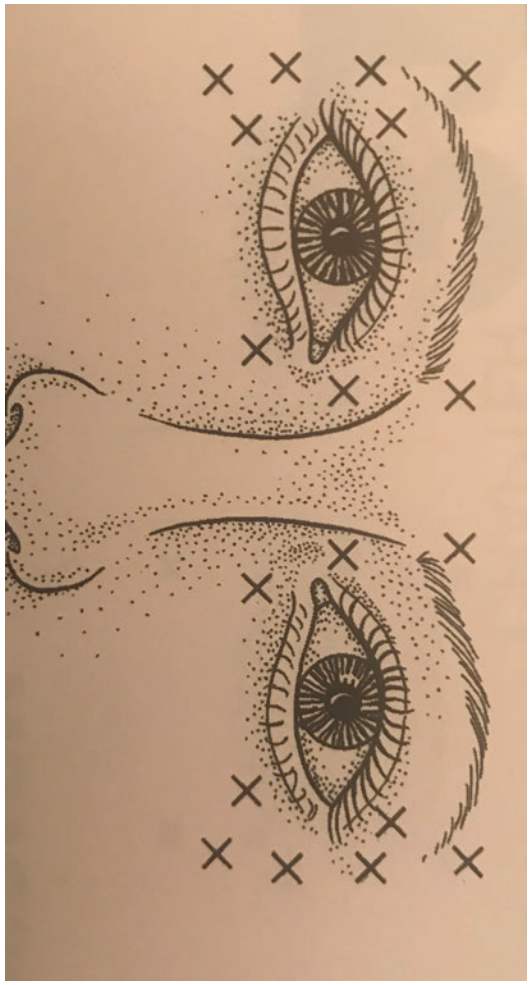

Fig. 1 Sites of injection in blepharospasm (Printed with permission. Cleveland Clinic Center for Medical Art & Photography. 2017)

The usual dose and muscles injected for blepharospasm treatment is about 5 U in each of the 3 points laterally in orbicularis oculi muscle 1 cm lateral to the lateral orbital rim. The orbicularis muscle extends 1.4 cm above the rim, 1.2 cm below the rim, and 2.5 cm laterally. Therefore, we have extended injections father laterally in BEB and hemifacial spasm treatments. Also, treatments farther from the orbital rim likely decrease chances of ptosis and diplopia (Fig. 1).

Subcutaneous injections of 2.5 U botulinum toxin A to the upper and lower eyelids in the orbicularis oculi perceptual fibers are then given, the injection sites must be at least 5 mm far from lacrimal punctate to avoid lacrimal pump failure. This is followed by injections of 1–3 units into frontalis muscles centrally and 5–10 U in the corrugator supercilia muscles and 1–2 U in procerus muscles. The injections within the orbicularis muscle are quite superficial, whereas those in the corrugator and procerus are deeper. This generally stops contractions for 4–6 months (Fig. 2). Touch-up reinjections may be done at the 10–15 day visit. Dose vary individually, so dose and modifications for the future injections may be noted. Meige syndrome is treated with higher doses. Orbicularis myokymia treatment requires lower dose injections of the toxin.

Response to the treatments with botulinum toxin continues after repeated injections in majority of the cases followed up for more than 10 years. For patients who are not responding to botulinum toxin A botulinum toxin B may be effective in treating the spasms. Injecting higher

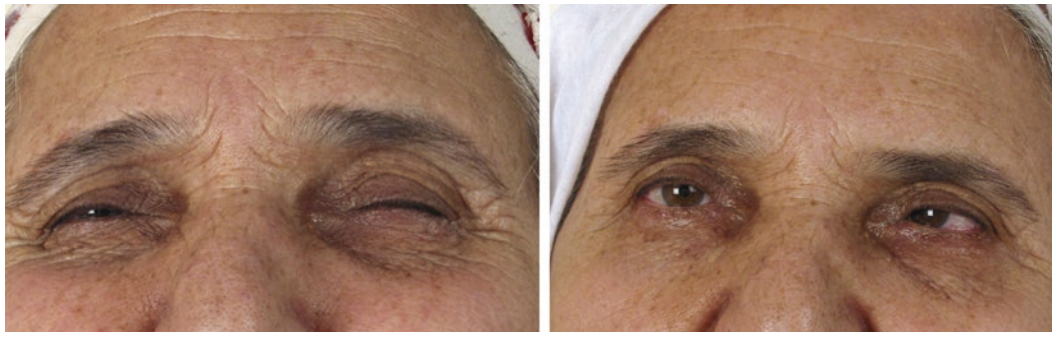

Fig. 2 Photographs of a patient with blepharospasm before and after botulinum toxin A injection (Courtesy of Dr. Kaynak)

doses of toxin may also stop involuntary contractions, that do not respond to lower doses. Complications are usually a result of paralysis of the periocular musculature. Mild ptosis, diplopia, lagophthalmos and ectropion may occur in less than 10% of patients and is usually transient (two to four weeks). It can be avoided to a great extent by making sure the injections are superficial, outside the orbital rim, and avoiding injections in the central part of the upper and lower lid.

Surgical management of blepharospasm by orbital myectomy is usually reserved for cases in which botulinum toxin is ineffective, injections are required too frequently, or in which it is part of another procedure (e.g., with blepharoptosis repair). The procedure involves complete removal of the orbicularis oculi, corrugator superciliaris, and procerus muscles. Not infrequently, botulinum toxin injections are still used after the procedure. Selective facial nerve avulsion is no longer recommended due to a higher rate of complications.

Hemifacial Spasm

Hemifacial spasm (HFS) is a progressive disorder of intermittent, irregular contraction of the muscles of one side of the face. It usually begins with unilateral fasciculation of the periocular orbicularis oculi and surrounding muscles and gradually spreads to involve the muscles of facial expression and the platysma.

HFS is typically unilateral, involves the whole side of the face, and may continue during sleep. Mild facial weakness is usually present. HFS is usually caused by irritation of the facial nerve near its origin in the brain stem, usually a kink in the anterior inferior or posterior inferior cerebellar artery, although other vessels may be involved. Magnetic resonance imaging (MRI) is usually recommended in the work-up of these patients to rule out posterior fossa lesions that should be treated surgically.

HFS must be differentiated from myokymia and facial tics. Myokymia is a continuous unilateral localized fasciculation within the orbicularis oculi of the eyelid that occurs in normal individuals under conditions of stress and fatigue. It is usually transient and non-progressive. Facial tics are habitual and usually begin in childhood and can be suppressed voluntarily.

In cases in which vascular compression of the facial nerve is confirmed by magnetic resonance imaging and magnetic resonance angiography, microvascular decompression of the facial nerve (Janetta procedure) can be used with a success rate of greater than 80%. However, serious complications such as hearing loss, otitis media can occur.

Botulinum toxin type-A has become the first line of treatment for HFS. It blocks the release of acetylcholine at the nerve terminal in the neuromuscular junction. It is simple, effective, and has a success rate of more than 90%.

Injections are first started in a manner similar to blepharospasm. Injections are then given into the nasolabial fold, upper lid, chin, and other musculature of the face. However, the retractor

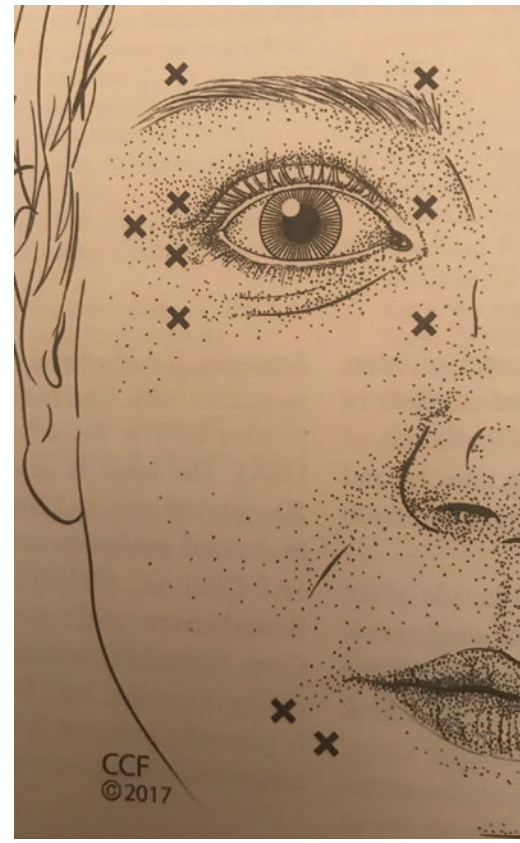

Fig. 3 Sites of injection in Hemifacial spasm (Printed with permission. Cleveland Clinic Center for Medical Art & Photography. 2017)

muscles at the corner of the mouth should be avoided to prevent drooping of the mouth. Due to the associated facial palsy, a dose lower than that needed for blepharospasm is usually sufficient (Fig. 3). Approximately 25–30 U of Botox® are usually necessary to treat the side of the face effected by HFS. Patients are given artificial tears to guard against dry eye syndrome due to a change in eyelid dynamics, which is a common side effect.

Botulinum Toxin Use in Apraxia of Eyelid Opening

Apraxia of eyelid opening is the inability to initiate to open the eyelids. It may be noted in patients with blepharospasm due to pretarsal fibers of orbicularis oculi muscle activity.

Injections of 1–2 U of toxin A at 2 sides medially and laterally 5 mm. away from the lid margin are recommended. If the frontalis muscle is functioning patients may also benefit from frontalis suspension surgery.

Botulinum Toxin Use for Dysthyroid and Upper Eyelid Retraction Management

BTX is administered for temporary correction, particularly in the inflammatory ascending stage of the disease's Rundle's curve and during the period when stabilization is expected, to prevent or delay surgical management till a more accurate outcome can be achieved. Two Injections of 1–10 U of BTX A subconjunctivally at the upper border of tarsus, medially and laterally are given

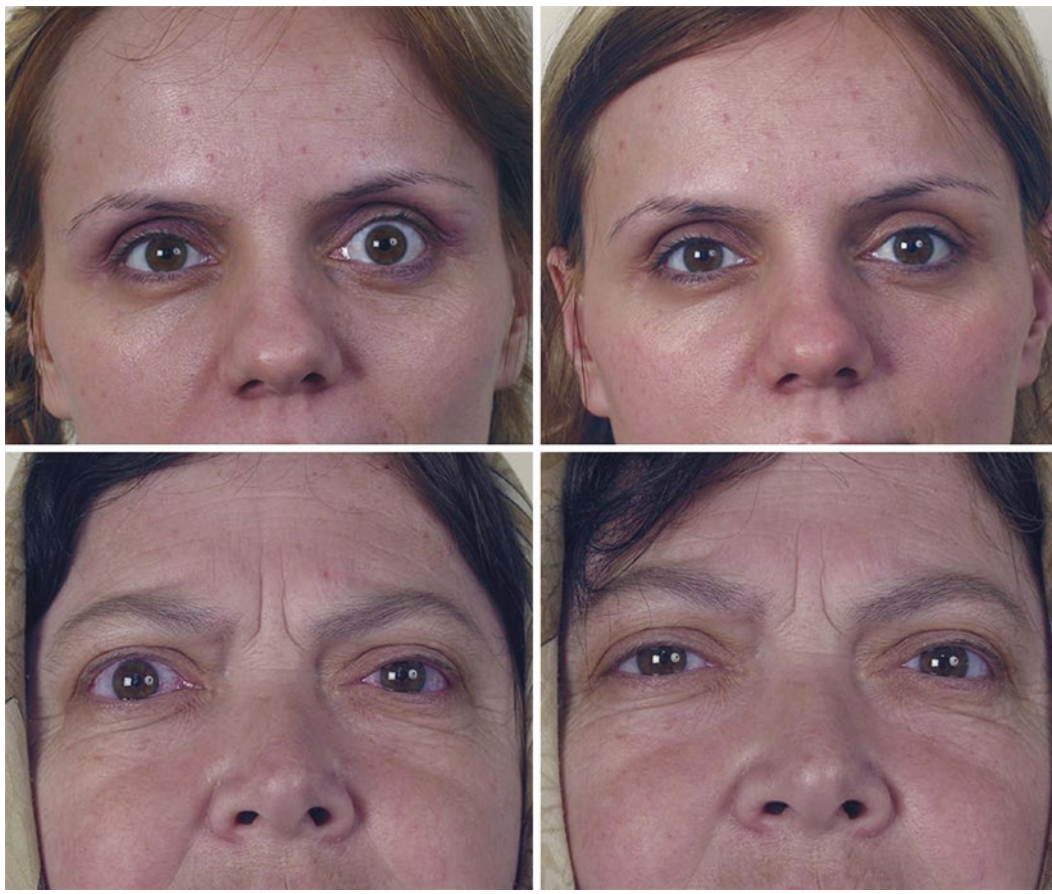

Fig. 4 Photographs of two patients with upper eyelid retraction before and after botulinum toxin A injection (Courtesy of Dr. Kaynak)

to minimize ptosis occurence. Despite multiple administrations of BTX A the effect is temporary and if the upper eyelid retraction stabilizes, definitive surgery is performed. Similar results were obtained by injecting botulinum toxin A through the skin into levator muscle. Similarly decreasing the activity of corrugator supercilia muscles in cases with dysthyroid ophtalmopathy by injecting botulinum toxin in these muscles were reported (Fig. 4).

Botulinum Toxin Use for Entropion Treatment

BTX injection decreases the tone of lower pretarsal and preseptal fibers of orbicularis oculi overriding, therefore correcting entropion temporarily. 2–5 U injections to the central portion of the subciliary orbicularis muscle 3–5 mm inferior to the eyelid margin in lower eyelid treats the spastic component of entropion for 4–5 months.

Botulinium Toxin Use to Decrease Lacrimal Gland Secretion

Gustatory lacrimal gland function (crocodile tear syndrome) can be controlled by 2.5–10 U botulinum toxin A injection administered directly in the gland. It is also used as an alternative to CDCR and Jones tube placement to treat proximal lacrimal system obstructions with excellent results (see this chapter).

Botulinum Toxin Use for Corneal Protection in Facial Paralysis

For cases with facial paralysis, particularly for patients for whom a surgical procedure seems to be difficult, lagophtalmus can be decreased by achieving eyelid ptosis with 2–10 U botulinum toxin A injection in the levator palpebrae superioris muscle instead of tarsorrhaphy and/or gold weight implantation, so that corneal ulcers can be prevented.

Patients receiving radiation therapy near the face are also good candidates for this application of botulinum toxin because the atrophied eyelid skin would not tolerate an eyelid implant for a long time. 5–15 U of botulinum toxin A are injected in the levator muscle subconjunctivally 5–6 mm above the tarsus to prevent diffusion into orbicularis oculi muscle fibers and worsen the lagophthalmus in these patients.

Control of synkinetic eyelid movements

Synkinetic movements of eyelid retractor and protractors as well as extraocular muscles can be seen after aberrant regeneration of 3rd or 7th cranial nerve palsies. The muscle contraction can be seized by customized doses of botulinum toxin injections in these muscles.

Modulation of Wound Healing

After closure, 2–5 units of botulinum toxin can be injected on either side of facial incisions or wounds to reduce muscle contraction and better stabilize the wound edges producing a form of chemical splinting. This results in a much better healing and reduce scar formation e.g. following blepharoplasty or ptosis incisions

Tension Headache

A rapidly growing indication is injection of toxin in the forehead and scalp as a measure to prevent occurrence of headache. Relaxation of the smooth muscles surrounding the blood vessels is supposed to produce such an effect.

Complications of Botulinum Toxin in Periocular Procedures

General complications include ecchymosis, rash, hematoma, headache, flu-like symptoms, nausea and dizziness. Most common ocular complications are undercorrection, asymmetrical features, change in and/or loss of facial expression (overcorrection, frozen face), lower eyelid laxity, dermatochalasis, ectropion, epiphora, brow and eyelid ptosis, lagophthalmus due to orbicularis

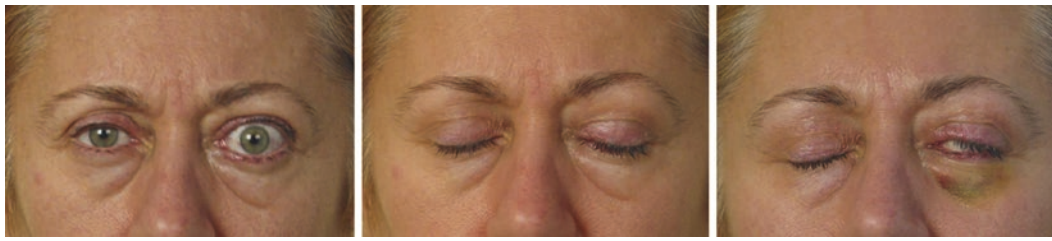

Fig. 5 Patient with lid retraction and good eyelid closure developed lagophthalmos with incomplete eyelid closure after botulinum toxin injections, due to diffusion of the toxin into orbicularis oculi muscle (Courtesy of Dr. Kaynak)

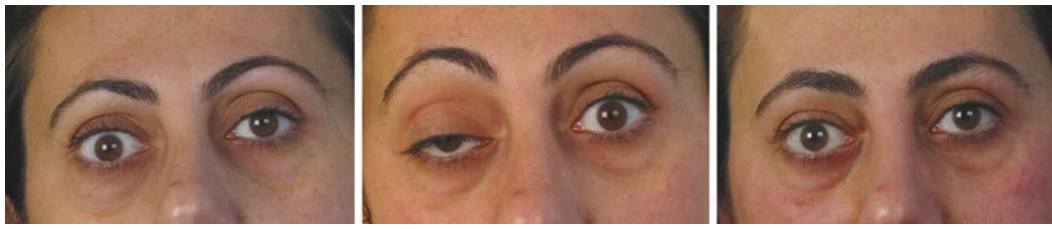

Fig. 6 Patient with lid retraction developed ptosis after botulinum toxin injections and returned to normal 4 weeks later (Courtesy of Dr. Kaynak)

muscle weakness (Fig. 5), keratitis sicca, diplopia, and photophobia. Alpha agonists as Apraclonidine can partially reverse the induced ptosis by contraction of Muller's muscle.

Perilabial ptosis, related to weakening of zygomaticus major muscle can occur when botulinum toxin is injected for crow's feet treatment (Fig. 6). Festoon formation developing in recovered cases after blepharoplasty is another reported botulinum toxin complication. The reason is decreased lymphatic drainage due to hypotony of orbicularis muscles of the patients involved, loss of "pumping action" of the muscle and fluid accumulation in loose soft tissue over the zygoma. Lower concentration use and adding adrenaline in the injection may decrease the frequency of complications.

Brow ptosis and dermatochalasis are frequently seen complications of periocular injections of botulinum toxin. Injections in the upper temporal part of the orbicularis oculi muscle can lift the lateral end of the eye brow and decrease the dermatochalasis at this area.

Injecting botulinum toxin A in the subciliary pretarsal fibers of orbicularis oculi muscles must be done cautiously, because paralysis of the tarsal orbicularis associated with higher doses may lead to lower scleral show and occasional epiphora.

Contraindications

Pregnancy and lactation, neuromuscular junction disorders (Myasthenia gravis), peripheral motor neuropathies, presence of active infections, hypersensitivity to any of the contents are the contraindications of botulinum toxin applications.

Botulinum Toxin, Botulismus and Antibody Development, and Non-responder Cases

As the doses are low and intervals are relatively long in periocular functional and cosmetic procedures, there is only one reported case in the literature of botulisms development after injection. One of the most important issues to be faced in relation with increasing number of cosmetic procedures in the future is antibody development against botulinum toxin, and the

concern for not receiving proper response after the treatment. For cases refractory to botulinum toxin A injections, other botulinum toxin subtypes might receive responses. However, pharmacological effects and duration of activity of such various subtypes are different from botulinum toxin A, and Botox and Dysport are still considered as the most effective and reliable preparations.

Cross tolerance may occur between various subtypes of the toxin.

Questionable Issues About Dilution and Storage?

According to recommendations of manufacturers, botulinum toxin loses its activity significantly within a certain period after reconstitution, and breaks into pieces due to fracture of the protein chains, whose molecular structure is connected with weakened disulphide bonds, as a result of heat and agitation. Therefore, the toxin should be transported in a cold chain and without vibration. However, Trinidade et al. reported in their controlled and double blinded studies that molecular structure of botulinum toxin A was resistant to foaming and cosmetic effect lasted for the same period. Similarly other studies by various authors showed that reconstitution of botulinum toxin 1 week and 2 weeks prior to injection did not decrease the efficacy of botulinum toxin, even after 6 weeks post-constitution.

The botulinum toxin manufacturers recommend, reconstitution of botulinum toxin type A using nonpreserved saline. However, less painful injections were noted with the use of the preserved saline compared the nonpreserved preparation. The preserved reconstitution appeared to have no effect on clinical outcome.

Also, since injections of botulinum toxin A reconstituted in lidocaine are associated with significantly reduced pain, lidocaine-reconstituted botulinum toxin A may be preferable for use by many surgeons.

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Eyelid Reconstruction

Mark A. Prendes and Bryan R. Costin

Pre-operative Consultation

The pre-operative consultation for eyelid reconstruction is central to surgical success and centers around managing patient expectations. The discussion should be open and address potential functional and cosmetic outcomes as well as potential for additional surgical interventions. Being informative and honest will increase the patients' satisfaction. Use of the 'tip of the iceberg' phenomenon prepares patients for unexpectedly large defects. Large defects are often psychologically traumatizing to patients who are already frightened by a diagnosis of malignancy. It is important to reassure them of the excellent healing over 6–12 months in the vast majority of cases while balancing realism with optimism. Procedures of the nasolacrimal system should be discussed including silicone intubation or the possibility of future conjunctivo-dacryocystorhinostomy if sacrifice of the canaliculi is required. Globe prominence, hypoplasticity of the inferior orbital rim, eyelid laxity, and actinic damage should all be inventoried.

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Assessment of patient comorbidities, medications and allergies is an important portion of the preoperative evaluation. While many new anticoagulants have been brought to the market in recent years, it is important to be familiar with these medications to ensure it is not missed preoperatively. Anticoagulation should be stopped in the perioperative period whenever reasonable with respect to the patients' systemic risks and with the permission of the prescribing physician.

Forthrightness with the patient and assessment of their support system are crucial to success particularly because the size of the final defect may be surprisingly large. The goals of tumor excision and reconstruction should be outlined in order of importance: Removal of the malignancy; restoration of function; cosmesis.

Reconstruction of Isolated Anterior Lamellar Defects

Defects of the anterior lamella of the eyelid can be repaired by direct closure, rotational flaps, grafts, or a combination of these methods. While the general principles of facial reconstruction suggest closing defects parallel to the relaxed skin tension lines (RSTLs), this rule is often violated in the periocular region to prevent cicatricial eyelid malposition. Defects near the lid margin should be closed vertically (perpendicular to the RSTLs), which decreases the risk of

E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_13

postoperative eyelid malposition by aligning the tension horizontally.

The simplest closure is done by creating an ellipse which should be closed perpendicular to the lid margin. Additional options of particular utility in the periocular region include unipedicle advancement flaps, rhombic flaps, bilobed flaps and glabellar flaps. Bilobed and glabellar flaps are discussed further in the section on reconstruction of defects of the medial canthus. Rhomboid flaps are discussed in chapter "Basics of Oculoplastic Procedures". Advancement flaps can be performed along lid crease or subciliary lines to advance skin horizontally to fill a defect. These can be performed on one or both sides of the defect depending on the amount of tissue laxity and size of the defect. Frequently a burrows triangle will need to be removed after advancement from the base of the flap. These flaps allow tension to be directed horizontally which decreases the likelihood of post-operative complications. When utilizing these flaps to cover a defect of the lower eyelid, consideration should be given to advancing the flap from a slightly superior position to provide additional vertical support to the lower eyelid (Fig. 1).

Fig. 1 Unipedicle advancement flap for repair of anterior lamellar defect of the lower eyelid. (Reproduced with permission from Biswas A. (2014) Flaps in Eyelid Reconstruction. In: Eyelid Tumors Springer, New Delhi.)

Repair of lower eyelid retraction following aggressive lower eyelid blepharoplasty with significant skin removal from the lower lids is best achieved by a skin muscle transposition flap from the upper eyelid to the lower eyelid (Fig. 2). If there is little skin in the upper eyelid, then a full thickness skin graft is needed.

Reconstruction of Full-Thickness Eyelid Defects

To achieve acceptable eyelid reconstruction, mastery of the repair of full-thickness, margin-involving eyelid defects is a necessity. Full-thickness eyelid laceration repair is described in detail in chapter "Eyelid Injuries". The targeted repair of the posterior and anterior lamellae with careful attention on the amount of tension results in improved post-operative function and cosmesis. This reconstruction serves as the backbone for many of the repairs described herein. Many of the more complex procedures are designed to provide an appropriate amount of temporal laxity to allow a central reconstruction of the full-thickness lid margin. Anytime an eyelid defect can be closed primarily, that is the procedure of choice. Due to the elasticity of the eyelid tissues, many full-thickness defects can be repaired with direct closure despite their gaping appearance. In young patients, defects of up to 25% of the horizontal width of the eyelid can be directly closed. In elderly patients with increased laxity, direct closure may be possible for defects involving up to 33% of the eyelid. It is important to ensure that the cut edges of the tarsus are parallel before proceeding with repair. While it is important to preserve as much eyelid tissue (particularly tarsus) as possible, the edges of the defect may need to be excised to create parallel edges and achieve the optimal repair. Appropriate anatomic knowledge and strict

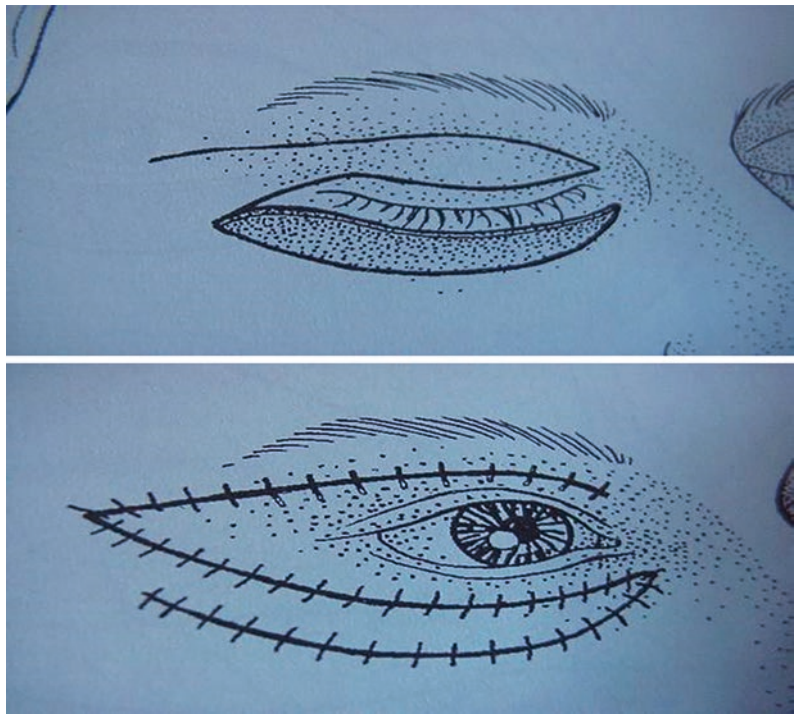

Fig. 2 skin muscle transposition flap from the upper eyelid to the lower eyelid. (courtesy of Dr Essam ElToukhy)

attention to detail can result in excellent functional and cosmetic results in the majority of cases.

Patients with excessive tension on direct closure or with a negative vector (shallow orbit) may require additional modifications to minimize tension on the eyelid as tight closure can often result in the lower eyelid retracting below the globe. The first option to consider is a lateral cantholysis to allow the lid to be medialized and achieve a primary closure on less tension. We prefer to incise the skin of the lateral canthus with a #15 blade and then use Westcott scissors to expose the lateral orbital rim periosteum and release the desired crus of the lateral canthal tendon to achieve the required amount of relaxation.

When full-thickness eyelid defects involve greater than 33% of the margin, direct closure is typically not possible and flaps and grafts must be considered. The available techniques for the upper and lower eyelid will be discussed separately. While the techniques differ, the basic principles of eyelid reconstruction are constant and should be addressed with each repair.

Principles of Full-Thickness Eyelid Reconstruction

- Reconstruction of both the anterior and posterior lamellae are required
- Either the anterior or posterior lamella must have a blood supply
  A graft on top of a graft will result in failure of both grafts
  A pedicle flap is required for one of the lamellae
- Minimize vertical tension on the eyelid during closure
  Horizontal tension will typically improve with healing, vertical tension will not and will cause eyelid malposition
- Aim to match tissue color, texture, and quality as best possible
- Limit cautery to the minimal required amount

Arterial bleeding and brisk venous bleeding should be controlled, but excessive cautery will lead to tissue ischemia of flaps and grafts.

- Anatomic re-creation of the canthi is paramount to achieve a stable lid
- Consider use of a frost suture to prevent early post-operative retraction and to protect the globe during healing.

Upper Eyelid Reconstruction

Full-thickness upper eyelid defects involving greater than 33% of the eyelid margin present a complex problem due to the need to recreate corneal coverage with a stable and dynamic structure. The most commonly utilized techniques for large defects include semicircle flaps and Cutler-Beard flaps.

Semicircle Rotational Flap

Upper eyelid defects involving 33–50% of the margin can be repaired via a semicircular flap as described by Tenzel in 1978 When the eyelid defect is central or medial, this flap will allow the lateral portion of the lid margin defect to be advanced medially and closed via a standard fashion. This flap is performed as follows (Fig. 3):

- An incision is extended from the lateral canthus inferiorly and temporally in a semicircular fashion and a skin-muscle flap is elevated.

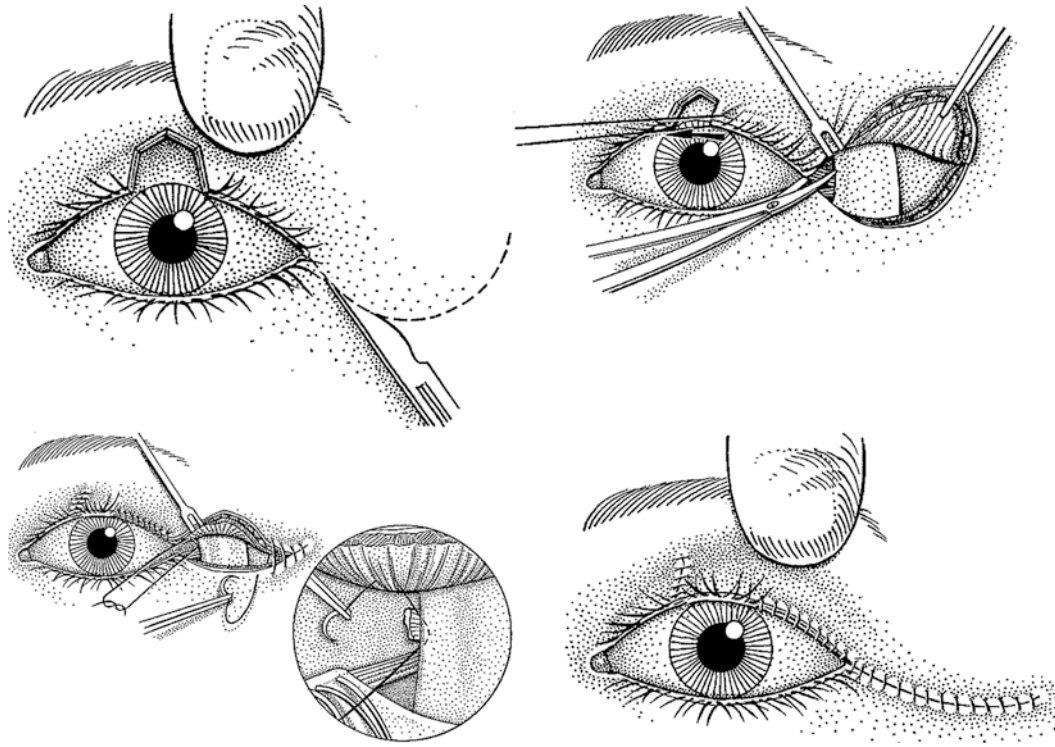

Fig. 3 The steps of the Tenzel semicircle flap are demonstrated for repair of an upper eyelid defect. Note the superior cantholysis followed by reconstruction of the lateral canthus with a buried suture. Reproduced with permission from Buerger D.G., Buerger D.E., Buerger G.F. (2018) Repair of Lid Defects Using a Semicircular Flap. In: Levine M., Allen R. (eds) Manual of Oculoplastic Surgery. Springer, Cham

The typical lateral extent of the incision should stop at the lateral edge of the brow with vertical and horizontal extents roughly around 20 mm each.

- The superior crus of the lateral canthal tendon is released internally.
- The lateral portion of the lid margin defect should be advanced medially to assess the amount of tension on closure.
- If tension is acceptable, a full-thickness margin repair is performed as described elsewhere in this text.
- The skin-muscle flap position is noted and when the appropriate tension is achieved, the lateral canthus is re-created at the desired position.
- A 5-0 dissolvable suture such as polyglactin is used in a buried fashion to reform the lateral canthus by attaching the flap to the lateral orbital rim periosteum.
- Skin closure is performed with 6-0 nonabsorbable monofilament suture.

Cutler-Beard Procedure and Modifications

Defects greater than 50% of the horizontal width of the eyelid may require a lid-sharing procedure. An upper eyelid defect may be repaired with a Cutler-Beard flap. This provides a vascularized skin-muscle-conjunctiva flap from the lower eyelid which is left in place for 4–6 weeks and then taken down in a second-stage surgery.

- The procedure starts by performing a horizontal skin incision 3–5 mm inferior to the lower lid margin, with care to avoid damaging the marginal arcade of the lower eyelid.
  This incision is made full-thickness with a lid plate in position to protect the globe.
- Vertical incisions are then made full-thickness starting on the conjunctival surface to create a pedicle flap.
  The above steps leave a bridge of lower eyelid margin intact.
- The suborbicularis plane of the flap is dissected inferiorly to achieve the desired laxity, as is the subconjunctival plane.
- The skin-muscle-conjunctiva flap is then advanced superiorly, underneath the bridge of lower eyelid.
- The flap is sewn into the upper eyelid defect in two layers: the conjunctival layer and the skin-muscle layer.
- Approximately 4–6 weeks later, the second-stage of the procedure involves dividing the pedicle flap, repairing the new upper eyelid margin by suturing the conjunctiva of the upper lid to the anterior lamella, and repairing the lower lid in two layers.

The lack of tarsus or tarsal substitute with the traditional procedure has led to complications such as entropion from eyelid instability. This has led to many options for modification of this procedure. Some surgeons advocate placement of a tarsal substitute such as sclera or auricular cartilage between the conjunctiva and muscle layers of the flap during the first stage of the procedure. Others recommend a free tarsoconjunctival graft from the contralateral upper eyelid or a hard palate or nasal septal chondromucosal graft. This may be grafted during the second stage of the procedure after a traditional first-stage Cutler-Beard. Alternatively, it can be done in stage one with some additional alterations in technique. In these procedures the posterior lamella is repaired first by placement of the graft of choice with reattachment to the remaining tarsus or medial or lateral canthal tendons. The inferior edge of the levator aponeurosis is connected to the superior edge of the graft. The lower eyelid skin-muscle flap is then advanced superiorly and sutured to the remaining anterior lamella. The conjunctiva from the lower lid should be dissected off of the skin-muscle flap in this situation and the flap can be taken anteriorly over the bridge of remaining lower eyelid. This has the benefit of leaving the lower lid retractors and conjunctiva in place.

Lower Eyelid Reconstruction

Reconstruction of the lower eyelid has many correlates to repair of the upper eyelid but is facilitated by the improved ability to borrow tarsus from the upper eyelid and the less dynamic nature of the lower eyelid. Defects up to 50% of the eyelid margin can be repaired with a semicircular flap similar to the upper eyelid as described above. When additional lateral support is needed, some authors advocate use of a periosteal flap which is attached to the lateral border of tarsus. This is also a useful technique for lateral lower eyelid defects without a lateral tarsal remnant. This procedure is done by elevating a periosteal flap over the external portion of the lateral orbital rim, superior to the lateral canthal tendon insertion. This flap is then rotated medially and the free end is attached to the lateral aspect of the tarsus. This provides a firm attachment for the lid laterally, and when fashioned appropriately provides a superior vector to prevent sagging of the lateral lower lid.

Modified Hughes Tarsoconjunctival Flap

Repair of defects of the lower eyelid involving greater than 50% of the margin is commonly performed via a modified Hughes tarsoconjunctival flap. This flap replaces the posterior lamella with a tarsoconjunctival flap from the upper eyelid. The anterior lamella is repaired with a rotational flap or full-thickness skin graft. The procedure is performed as follows (Fig. 4):

- The upper eyelid is everted over a Desmarres' retractor with aid of a traction suture through the lid margin
- The defect of the lower eyelid is measured with calipers and the measurement is superimposed to the upper eyelid tarsus
- A horizontal marking is made on the upper eyelid tarsus a minimum of 4 mm from the upper lid margin. Leaving less than 4 mm of tarsus in the upper eyelid can lead to postoperative instability of the upper eyelid.

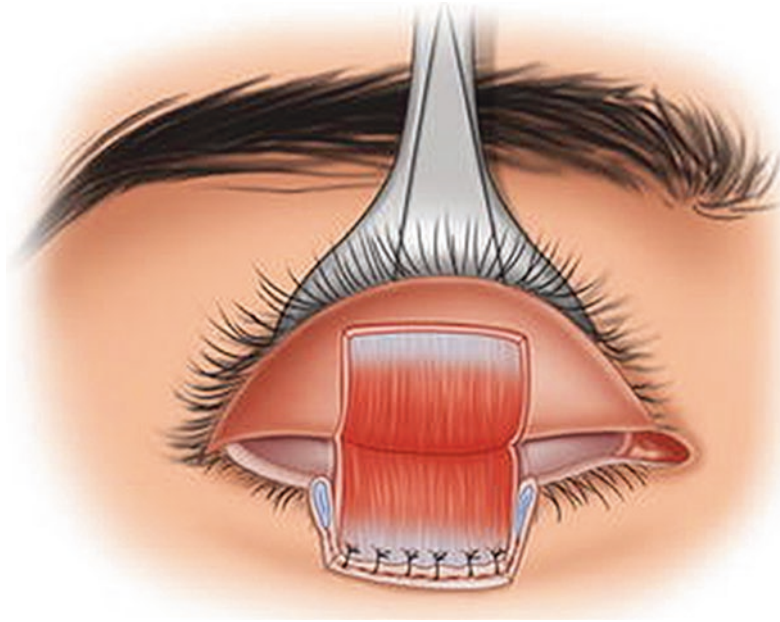

Fig. 4 Tarsoconjunctival flap from the upper eyelid has been created and sutured into position in the lower eyelid. A rotational flap or full-thickness skin graft would then be planned to reconstruct the anterior lamella. Reproduced with permission from Gladstone G.J., Nesi F.A. (2018) Eyelid Reconstruction. In: Gladstone G., Nesi F., Black E. (eds) Oculoplastic Surgery Atlas. Springer, Cham

- A #15 blade is used to incise along the horizontal marking and to create vertical relaxing incisions to the superior border of tarsus.
- Dissection is then carried out superiorly between Muller's muscle and levator aponeurosis or in the subconjunctival plane.
  If leaving Muller's muscle in place, the flap will have better vascular supply, but will be more difficult to divide during the second stage of the procedure.
- The flap is advanced inferiorly and sutured to the remaining lower eyelid tarsus and inferior fornix conjunctiva
- The anterior lamella is then repaired, typically with a full-thickness skin graft or rotational flap.
- A second-stage procedure is classically performed 4–6 weeks later, though some authors recommend even earlier performance of the second-stage. The second stage is performed as follows:

  The upper lid is retracted superiorly and a malleable retractor is placed between the flap and the ocular surface.
  Scissors are used to divide the flap with a few millimeters of excess conjunctiva to re-drape over the new lower lid margin.
  Consider recession of the upper lid retractors transconjunctivally to prevent retraction

Alternatives to the Hughes Flap

Occasionally, patient situation such as performing surgery on the seeing eye of a monocular patient, will necessitate avoidance of a lid-sharing procedure due to the inability to have the eye closed for an extended period of time. In this situation, there are alternatives to the tarsoconjunctival flap, but most will require a vascularized anterior lamella. Depending on the degree

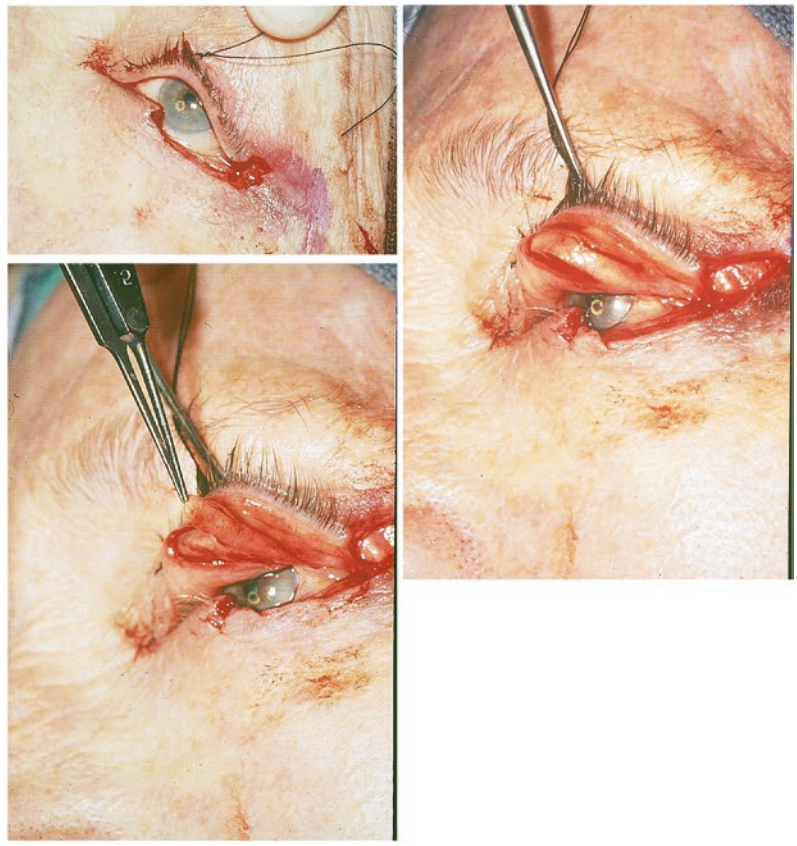

Fig. 5 Single stage tarso-conjunctival flap from the upper lid to the lower lid. (courtesy of Dr Essam ElToukhy)

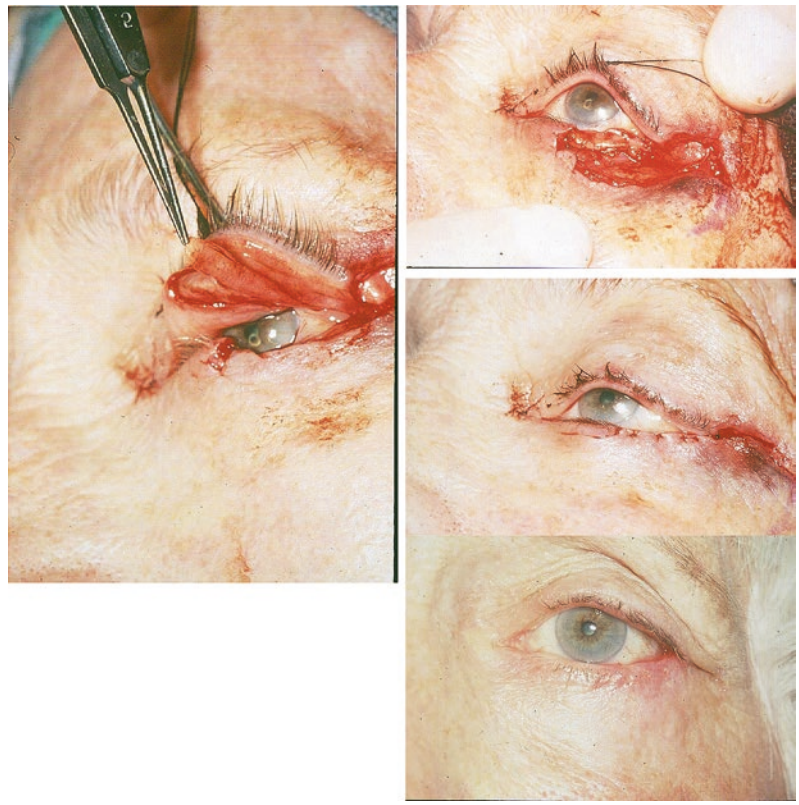

Fig. 5 (continued)

of anterior lamellar loss, it can be replaced with a variety of options including a lateral advancement flap (Tenzel semicircular, switch flap, or unipedicle advancement flap) or a Mustarde flap.

The posterior lamella can be replaced with a free tarsoconjunctival graft from the upper eyelid, a hard palate mucosal graft, a nasal septal chondromucosal graft, auricular cartilage, or commercially available tissue substitutes. The free trasoconjunctival graft has the best tissue match and is most familiar to ophthalmic surgeons.

If the posterior lamellar defect is in the lateral 40–70% of the lid, lid sharing can be achieved by replacing the defect with a tarso-conjunctival transposition flap from the upper lid. This is then covered by anterior lamella. This is a lid sharing single stage procedure that alleviates the need for a second stage (Fig. 5).

Graft Harvesting

Full-Thickness Skin Graft

Full-thickness skin grafts should be selected based on finding the best possible match of color, thickness and texture. Available sites include excess skin from the upper eyelid via a blepharoplasty-type skin resection, pre-auricular, post-auricular and supraclavicular locations. These areas should be examined preoperatively for lesions, degree of solar damage, color and texture to determine the best possible match to the eyelid. The patient can then be appropriately counseled on post-operative expectations and care. The graft should be slightly oversized to account for contraction during healing. Complications include donor site morbidity,

graft necrosis, hematoma, dehiscence, ectropion from contracture, and poor skin match. Graft sites should be kept small enough to close primarily in the majority of cases. The graft itself should be thinned free of any subcutaneous tissue to the level of the dermis. Frost sutures are useful to prevent early graft contracture during the early post-operative period and are typically left in place for up to one week.

Tarsoconjunctival Graft

The free tarsoconjunctival graft can be harvested as described above for a Hughes flap but with transection of the conjunctival pedicle. The surgeon should recall that the harvesting of the graft should not leave the upper eyelid unstable. For this reason, many advocate for leaving a minimum of 4 mm of tarsus in the upper eyelid. After the tarsus is elevated and dissected free of muller's muscle and the levator aponeurosis, a cuff of conjunctiva should be kept so that it can be re-draped over the new lower eyelid margin. When sizing a free tarsoconjunctival graft, it is common to intentionally undersize the graft by 2 mm less than the measured defect to ensure that there is enough tension on the closure to prevent post-operative lid malposition.

Medial Canthal Defects

Cutaneous defects of the medial canthus are often the result of malignancy excision. This region is prone to particularly deep extension of tumors, which may damage underlying structures. Repair depends largely on wound depth, size and involved structures. If the nasolacrimal system is involved, this should be discussed with the patient prior to surgery, along with a discussion of possible future interventions to address potential epiphora.

Options for repair of medial canthal defects include primary closure, allowing the wound to granulate, full-thickness skin grafting, and rotational or advancement flaps. Of these, granulation is the least common and least recommended as it can take several months to complete and may lead to secondary eyelid malposition requiring revision surgery. Primary closure is possible only when tension on the closure is absent. Often, a portion of the wound can be closed primarily, while the remainder must be addressed with a rotational flap.

Rotational flaps offer recruitment of tissue with its own blood supply and transfer tension to adjacent anatomical subunits. Many flaps are available, but those most helpful to the medial canthus are the bilobed flap and the glabellar flap.

Bilobe Flap

The bilobe flap is an excellent choice for repair of defects of the medial canthus and lateral nasal sidewall because it transfers tension away from the eyelid toward the nasal bridge. When planning the flap, it should be crafted from tissue superior to the defect so that any traction is upwards to avoid ectropion. Once the flap is marked, an incision is made with a #15 blade and the scalpel is then used with forceps to dissect out the flap taking care to preserve underlying muscle particularly at the flap's base. Cautery is used for arterial and heavy venous bleeding, but extensive cautery is not necessary and may in fact decrease the vascularity of the wound bed. With the flap fully constructed it is then mobilized and rotated to simulate filling the defect. Once the flap fits comfortably into the wound, it is secured with buried, dissolving sutures (e.g., 4-0 polyglactin). This deep suture is of particular importance to achieve appropriate flap position, good revascularization and avoidance of medial canthal webbing. Once the buried sutures have secured the tissue transfer, a running 6-0 non-dissolving suture such as polypropylene is used to close the wound (Fig. 6).

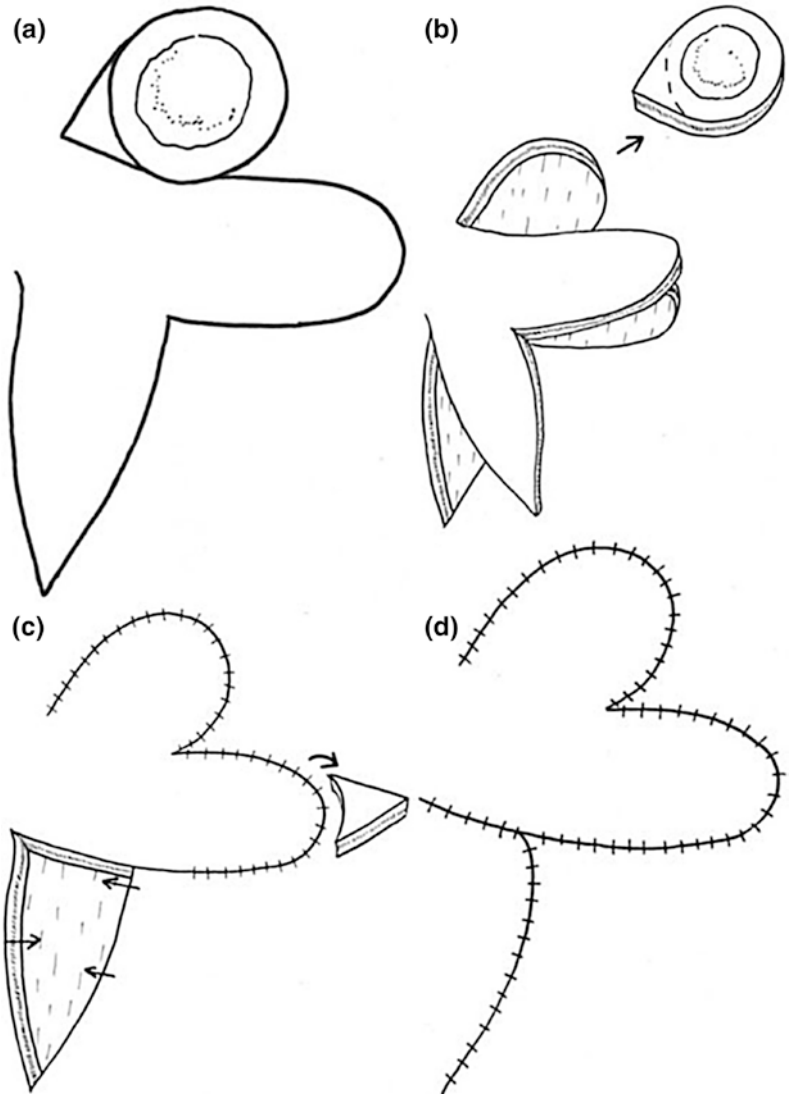

Fig. 6 Bilobe flap **a** The flap is marked to plot a double transposition flap which shares a common base. **b** The lesion is excised and incisions are made along the previous markings. Surrounding tissue should be undermined sufficiently to allow tension-free rotation. **c** + **d** The flaps are sutured into position and a standing cone deformity can be removed. Reproduced with permission from Ilankovan V., Ethunandan M., Seah T.E. (2015) Basic Flaps. In: Local Flaps in Facial Reconstruction. Springer, Cham

Glabellar Flap

This flap allows transmission of tension away from the medial canthus to the glabella however at the cost of blending distinct aesthetic units. Larger defects may require forehead tissue which can be accomplished through extension of the glabellar flap. The flap is created as an inverted "V" incision through the central glabella. Forceps are used to grasp the incision and the flap is dissected using a #15 blade. Once the flap is crafted, it is rotated across the nasal bridge and into the defect. The flap is sutured to the nasal bridge and to the upper or lower eyelids or both depending on the defect with 5-0 polyglactin suture. The brow defect is

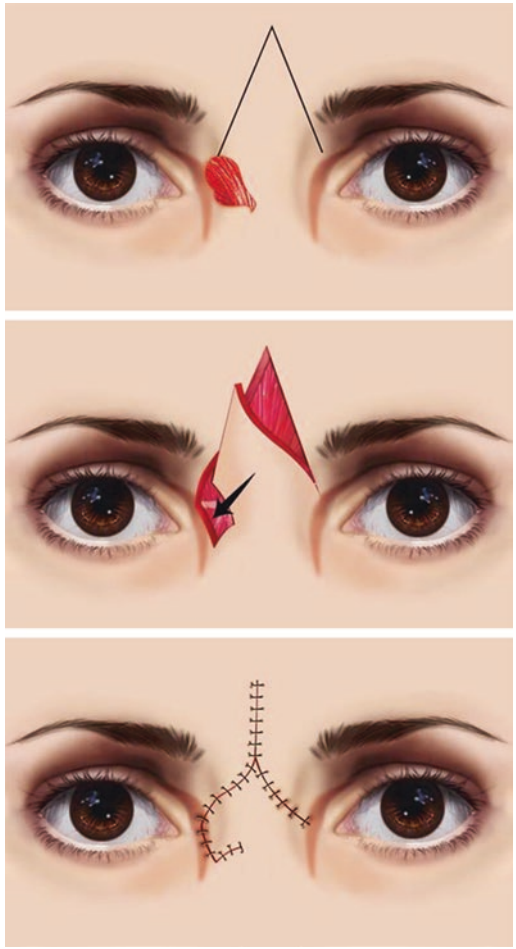

Fig. 7 Glabellar flap for repair of medial canthal defect. The inverted V formation of the glabellar flap allows rotation of the glabellar tissue into the medial canthal defect and resultant V-to-Y type closure of the glabellar region. Reproduced with permission from Biswas A. (2014) Medial Canthal Reconstruction. In: Eyelid Tumors. Springer, New Delhi

then closed with dissolving 4-0 suture deep and all wounds are closed with 6-0 polypropylene suture superficially. The superior tip of the flap may need to be trimmed for ideal fit into the tissue bed. A Burrow's triangle at the pivot point may also require excision (Fig. 7).

Post-operative Care

Typical post-operative care involves the use of ice and antibacterial ointment for 1–2 weeks. In cases where the wound is under any degree of tension inferiorly and there is concern for ectropion, a Frost suture with a pressure patch is used and removed at one week. The patient is then examined 6–10 weeks later.

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Trichiasis and Trachoma

Essam A. El Toukhy and Nadeen El Toukhy

Trachoma is an infection caused by *Chlamydia trachomatis* types A, B, Ba, and C. The infection usually occurs in childhood in the form of conjunctivitis with follicles and papillae. Healing results in scarring and fibrosis that affects the palpebral conjunctiva and the lids. Repeated infection can lead to destruction of the conjunctival epithelium, meibomian glands and accessory lacrimal glands, tarsal deformation, trichiasis, and corneal scarring. Superior tarsal conjunctival scarring takes the form of Arlt's line, diffuse scarring and fibrosis, localized focal scarring or tarsal deformation. Corneal scarring can be in the form of superior pannus, Herbert's pits at the upper cornea, peripheral or central scars or generalized scarring.

It is estimated that 144 million people are affected with trachoma, with about 2.5 million having trichiasis and/or cicatricial entropion. It is the most common infectious cause of blindness worldwide. The World Health Organization (WHO) adopted the "SAFE" strategy to prevent and treat trachoma. **S** is the use of surgery for entropion and trichiasis. **A** is for antibiotics to treat active cases and reduce the burden of *Chlamydia trachomatis* in the population. **F**acial cleanliness and **E**nvironmental improvements are promoted to reduce transmission of the disease.

Trachoma has five main clinical signs:

1. **TF** = Trachomatous inflammation-follicular.
2. **TI** = Trachomatous inflammation-intense.
3. **TS** = Trachomatous conjunctival scarring.
4. **TT** = Trachomatous trichiasis.
5. **CO** = Corneal opacities.

Clinical forms of misdirected lashes:

Normally, the lashes arise from hair follicles just anterior to the tarsus, approximately 2 mm from the lid margin, and emerge through the skin at the level of the anterior eyelid margin. Although the lashes are among the shortest and finest hairs in the body, they potentially pose the most hazards. In case of chronic misdirection, the resulting ocular surface injury can lead to blindness. Several forms of abnormal lash position are identified. These include: Distichiasis, Trichiasis, Entropion (see chapter "Common Eyelid Malpositions") and Epiblepharon (see chapter Pediatric Ophthalmology and Oculoplasty").

Distichiasis

Is defined as aberrant cilia emerging through the meibomian orifices, in addition to a normal row of lashes anteriorly. Distichiasis may be congenital or acquired.

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_14

Congenital Distichiasis can be autosomal dominant or sporadic. It usually involves all 4 lids and, though congenital, it usually symptomatize later in life in the preschool age. Lashes vary in color and shape being small and depigmented in most cases. It results from arrested differentiation. Acquired Distichiasis, on the other hand, is a reaction to noxious stimuli that results in Metaplasia of the meibomian glands and usually coexists with trichiasis (Fig. 1).

Management of congenital distichiasis must be surgically treated early in life. The aim is to destroy the aberrant lash follicles without sacrificing the normal lashes. Surgical options include lid splitting at the grey line with cryotherapy applied to the aberrant lash follicles using a retinal probe. This technique is simple, but usually results in residual scattered few lashes. Direct excision of the aberrant lash follicles under microscope is a more difficult and tedious technique which results in a better outcome. The trap-door technique where excision of the follicles is done under a tarsal flap is more difficult and is rarely used.

Trichiasis

Trichiasis is a misdirection of otherwise normally positioned eyelashes in the anterior lamellae of the eyelid while the lid margin is in a normal position. The pathogenesis of trichiasis involve fibrosis in the area of the follicles. The follicles are distorted and the lashes become misdirected due to scarring. Trachoma is by far the most common disease that cause trichiasis, but other diseases include ocular pemphigoid, Steven-Johnson syndrome, chronic MGD and blepharitis, recurrent herpetic infections and chemical burns. All these diseases may also cause keratinization of the lid margin mucosa, and abnormalities of tear production, further aggravating the ocular surface problem.

In trachoma cicatricial Entropion is caused by scarring of tarsus and conjunctiva. The clinical findings include rounding of posterior lid border, posterior migration of keratinized epithelium, secondary trichiasis, shallow inferior fornix, and dry eyes. With trachomatous trichiasis, lashes can vary in location, thickness and length.

Management of trichiasis

Controlling inflammation is essential, especially in OCP and Stevens–Johnson syndrome to prevent further damage and fibrosis. In trachoma, azithromycin in the acute phase and in endemic areas is part of the SAFE strategy. Frequent lubrication is essential, but definite treatment is surgical. After analyzing the anterior and

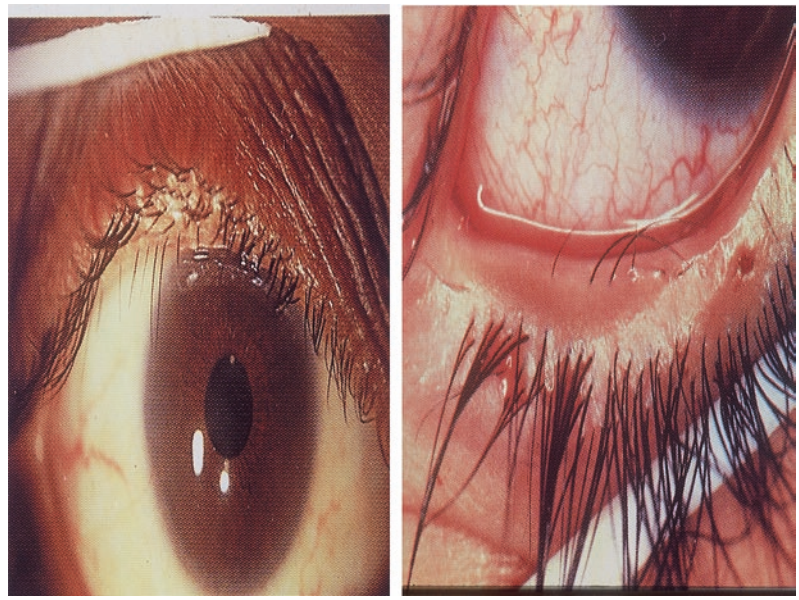

Fig. 1 Distichiasis of the upper and lower lids

posterior lid lamellae, the number of the misdirected lashes and their position, several options are available including.

Epilation

Is a simple, usually effective and inexpensive technique performed by the patient or relative. It can be used as a temporary method, in cases with 1 or 2 peripheral lashes with a normal lid margin, or in cases of postoperative trichiasis with residual 1 or 2 lashes. There is no evidence to support the belief that lashes will grow to be more stiff and damaging after epilation or that epilation will promote regrowth of larger number of lashes. Repeated epilation can sometimes lead to destruction of the lash follicle in 25% of cases.

Electrolysis

It destroys one lash follicle at a time by passing a current through a fine needle placed at the base of the follicle. The lash is then epilated. It has a low success rate and results in additional fibrosis of the lid margin. It is reserved for a few isolated lashes to avoid a lid notch. It is not advised in cases with severe inflammation as OCP or Stevens-Johnson. It is rarely used nowadays.

Cryotherapy

It is based on differential sensitivity of cells to cold injury. A rapid freeze of the lid margin between −20 to −30 °C followed by a slow thaw, irreversibly damages 80–90% of the lash follicles, as well as surrounding glandular structures. The technique is performed under local infiltration anesthesia with epinephrine, better with a thermocouple. A retinal cryotip is applied to the lid margin. A rapid freeze, followed by a slow thaw. This is then repeated after 5 minutes. The lashes are epilated. Cryotherapy can be applied to the posterior lamella after lid splitting as in distichiasis.

Cryotherapy complications include a marked inflammatory response for 2–3 days, lid depigmentation, possibility of lid notching, symblepharon formation, induction of adjacent trichiasis, acceleration of conjunctival shrinkage in OCP and Steven-Johnson, a recurrence rate of 10–20%, and rarely, necrosis and sloughing of the lid margin (Fig. 2a, b).

Argon laser ablation

To avoid the non-localizing nature of cryotherapy and extensive tissue destruction, argon laser ablation of the lash follicles can be used. It is the preferred in patients with OCP and Steven-Johnson syndrome when the stimulation of inflammation is undesirable. It is usually used in few scattered lashes without entropion or in post operative trichiasis. Lashes must be pigmented to absorb the laser energy. The technique is performed under topical and local infiltration anesthesia with epinephrine. A slit lamp mounted argon laser is used with a co-axial beam, 100 spot size, 1000 W power, 0.5–1 second duration. The aim to produce a very high localized power aimed at the desired follicle. The eyelash is vaporized to a depth of 2 mm in the pretarsal plate. Up to 20 applications per lash maybe needed. Argon laser has a success rate of about

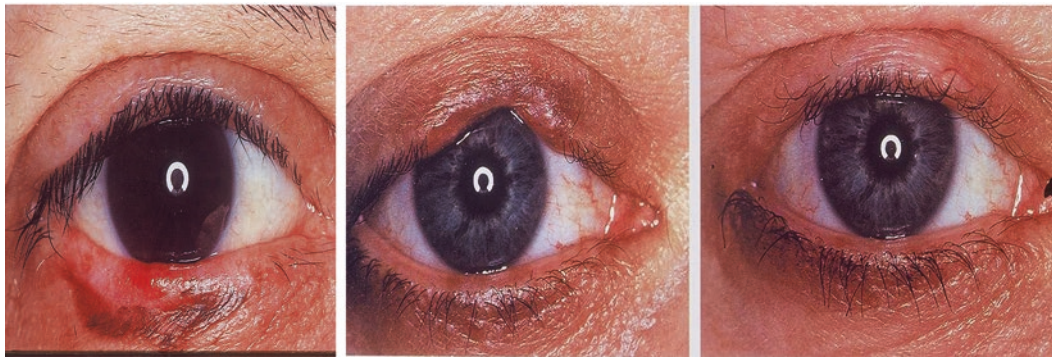

Fig. 2 Lid pigmentation and notching following cryotherapy for trichiasis

80%, and can be repeated. Though it induces less inflammatory reaction, still mild dimpling, induction of adjacent trichiasis can occur.

Surgical resection

Surgical resection of the abnormal lash follicles can be sometimes used in localized trichiasis, either in the form of full thickness excision of the lid margin and reconstruction in a manner similar to a tumor or by excision of anterior lamella bearing the lash follicles and leaving a bare tarsus to granulate.

Despite the above options, most commonly, definitive surgery will be needed to correct trichiasis especially trachomatous trichiasis and when cicatricial entropion is present. The choice will be either to recess the anterior lamella with or without applying a graft (see chapter "Common Eyelid Malpositions"), to lengthen the posterior lamella with amniotic membrane graft, tarsal graft or a hard palate graft (see chapter "Common Eyelid Malpositions") or more commonly to evert the lid margin using a tarsal rotation procedure.

Tarsal rotation procedures share a common principle; the tarsus is divided into a large 4–5 mm part which will be sutured to the skin and orbicularis muscle in a way to rotate the small proximal 2–3 mm part carrying the misdirected lashes outwards away from the corneal surface. The Bilamellar Tarsal Rotation procedure (BLTR, Weiss procedure) is performed using a transcutaneous approach with a skin incision. The Posterior Lamellar Tarsal Rotation procedure (PLTR, Trabut procedure) is done using a transconjunctival approach without a skin incision. Both procedures are simple, effective in about 80% of cases, and in endemic areas can be done by properly trained health workers. A recent study from Ethiopia have suggested that PLTR may be superior to BLTR. Both are recommended by the WHO for trachoma endemic areas.

Transconjunctival Tarsal Rotation (PLTR, Trabut Procedure)

This procedure uses the same principle as the Weiss procedure; i.e., tarsal fracture and marginal rotation. It differs from the Weiss procedure in being done transconjunctivally without the need of a skin incision. It is primarily used for the upper lid, but can be used for the lower lid as well. Transmarginal lid slough is unlikely because of preservation of the skin and orbicularis muscle, which is heavily vascularized.

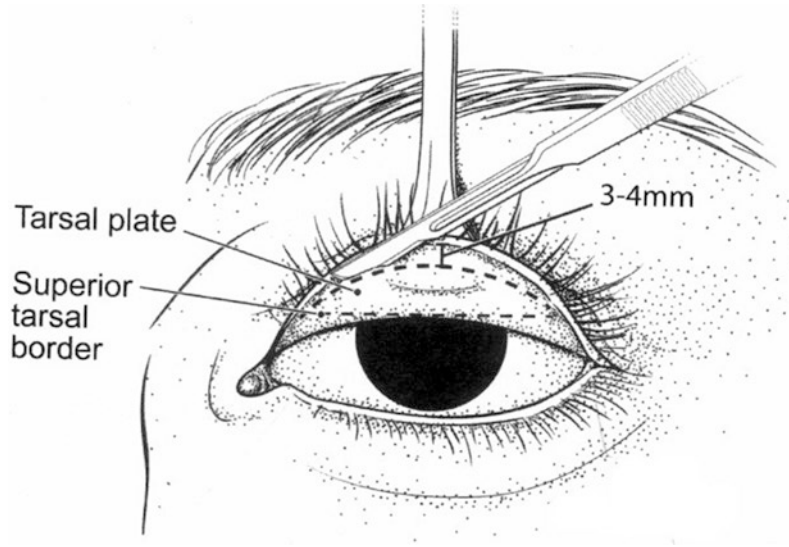

Fig. 3 Transconjunctival tarsal incision 3 mm from the lid margin

Surgical procedure

Local infiltration with 1% lidocaine with epinephrine a few minutes before the procedure is used in the affected lid. Usually 2–3 ml of the mixture is enough. Topical anesthetic drops are applied to the cornea. The upper lid is everted over a large Desmarres' retractor to expose the tarsal conjunctiva. Alternatively, a Trabut plate is applied and used to fix the eyelid in the everted position. Advantages of using the plate include better fixation of the lid as well as providing an extra hand without the need for an assistant. However, using the clamp may incur some difficulty in applying the lateral suture to the lid. The clamp is available in different sizes depending on the size of the lid. With a #15 blade, an incision is made in the conjunctiva and tarsus 3 mm from the lid margin, down to the orbicularis muscle (Fig. 3). The incision extends across the whole lid and can be extended with scissors medially and laterally if needed. With a blunt scissor, dissect between the tarsal plate and the pretarsal orbicularis muscle to create a pocket 2–3 mm deep in both directions. Using 6/0 silk or Vicryl sutures mounted on spatulated needles, 3 double-armed sutures are passed from the distal larger tarsal fragment, through the created pocket, to emerge on the skin side about 1 mm above the lashes (Fig. 4). The 3 sutures are evenly spaced along the lid margin. The amount of rotation can be increased by emerging closer to the eyelashes if needed. In this way, the weight of the larger distal tarsal fragment will exert pressure on the smaller proximal tarsal fragment carrying the lid margin and induce its rotation outwards (Fig. 5). The entropion will be corrected and the lashes turned away from the globe. The sutures are tied firmly to provide a slight overcorrection. Antibiotic-steroid ointment is applied and then used twice daily for 2 weeks. Eye pads are not applied as they may counteract the eversion

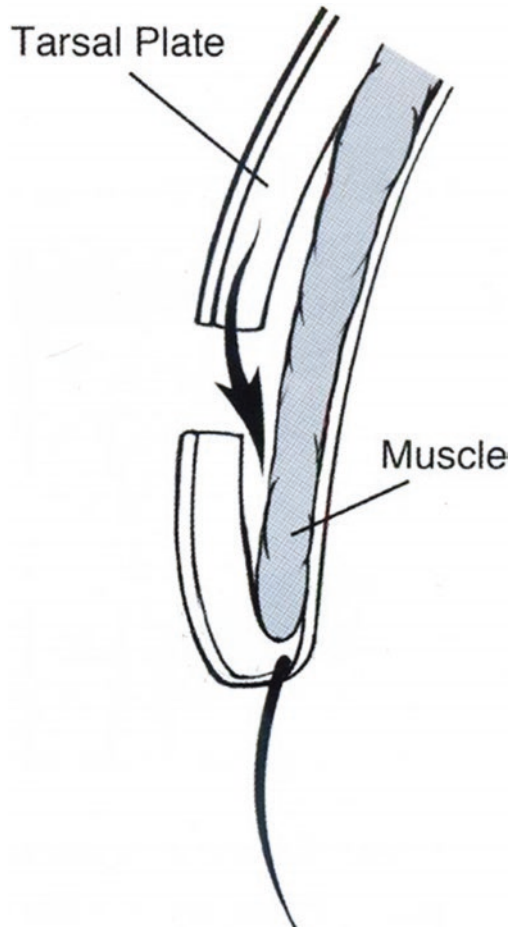

Fig. 4 3 sutures from the distal tarsal fragment, through the pocket, to emerge at the lid margin

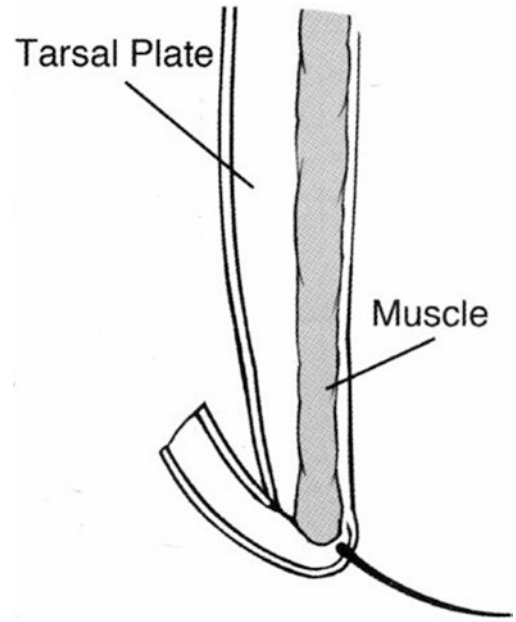

Fig. 5 Pressure of the distal tarsal fragment to rotate the proximal tarsal fragment

produced by the procedure.Sutures are usually removed 7–10 days postoperatively.

Bilamellar Tarsal Rotation (BLTR, Weiss Procedure)

Surgical procedure

A 2–3 mm mark from the lid margin is made across the whole lid before injecting the anesthetic. Local infiltration with 1% lidocaine with epinephrine a few minutes before the procedure is used in the affected lid. Usually 2–3 ml of the mixture is enough. Topical anesthetic drops are applied to the cornea. An eye lid spatula is used to protect the globe and decrease bleeding. Alternatively, a special clamp is applied and used to fix the eyelid. Advantages of using the clamp include better fixation of the lid as well as providing an extra hand without the need for an assistant. However, using the clamp may incur some difficulty in applying the lateral suture to the lid. The clamp is available in different sizes depending on the size of the lid. With a #15 blade, an incision is made full thickness through the skin, muscle and tarsus 3 mm from the lid margin (Fig. 6). The incision extends across the whole lid and can be extended with scissors medially and laterally if needed. With a blunt scissor, dissect between the tarsal plate and the pretarsal orbicularis muscle to create a pocket 2–3 mm deep at the lid margin. Using 6/0 silk or Vicryl sutures mounted on spatulated needles, 3 double-armed sutures are passed from the distal larger tarsal fragment, through the created pocket, to emerge on the skin side about 1 mm above the lashes (Fig. 7). The 3 sutures are evenly spaced along the lid margin. The amount of rotation can be increased by emerging closer to the eyelashes if needed. In this way, the weight of the larger distal tarsal fragment will exert pressure on the smaller proximal tarsal fragment carrying the lid margin and induce its rotation outwards (Fig. 8a, b). The entropion will be corrected and the lashes turned away from the globe. The sutures are tied firmly to provide a slight overcorrection. The skin is then closed with the same suture in a running fashion. Antibiotic-steroid ointment is applied and then used twice daily for 2 weeks. Eye pads are not applied as they may counteract the eversion produced by the procedure. Sutures are usually removed 7–10 days postoperatively.

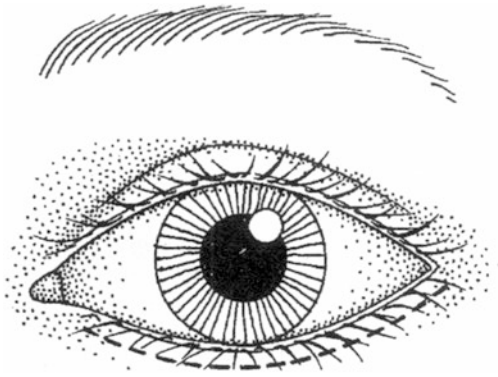

Fig. 6 Full thickness incision 3 mm from the lid margin

Complications

Intraoperatively, bleeding can occur. Mild bleeding can be stopped by compression unless the marginal artery is injured. This usually happens on the medial part of the incision. It can be stopped by gentle cautery or diathermy, or

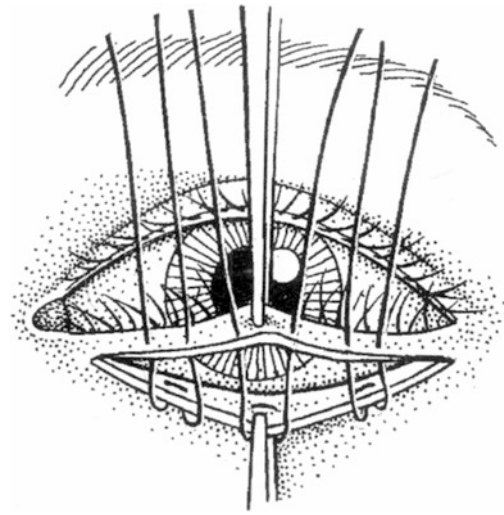

Fig. 7 3 double armed sutures from the distal tarsal fragment, through the pocket, to emerge at the lid margin

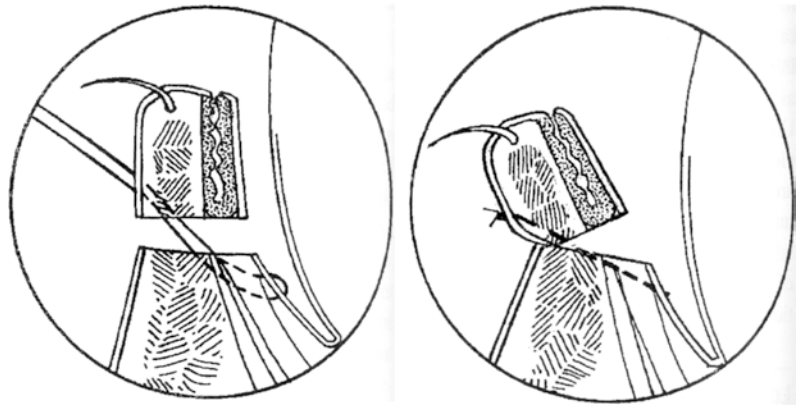

Fig. 8 The weight of the larger distal tarsal fragment exerting pressure on the smaller proximal tarsal fragment inducing its rotation outwards

by applying a hemostat for a minute to close it. Overcorrection and undercorrection can be avoided by adjusting the placement and tension of the sutures at the end of the procedure to produce a mild overcorrection. This mild overcorrection will resolve spontaneously in few weeks with healing.

Post operative recurrence have been observed with the use of cutting needles or more than 3–4 sutures. Cutting needles cause vertical splitting of the tarsus and this damage results in a weaker tarsus that is unable to generate a sufficient turning force on the eyelid margin. This can be avoided by the use of spatulated needles and the use of only 3 sutures across the whole lid.

Lid contour abnormalities can occur if the sutures were not placed evenly across the lid. Again this should be noticed intraoperatively and corrected immediately by proper positioning of the sutures.

Lid granulomas can sometimes occur and are better prevented by proper suturing techniques and the removal of sutures in all cases.

Management of postoperative trichiasis

Postoperative trachomatous trichiasis can occur due to inadequate surgery or can be due to disease progression. There is no consensus on the proper management, but few scattered lashes are usually epilated or can destroyed with electrolysis or laser if available. More lashes, particularly if central and touching the cornea will need an additional surgical procedure.

Trachoma as a public health problem and the role of the ophthalmologist

In many trachoma endemic countries the most trained eye care personnel are general ophthalmologists. In these settings, the general ophthalmologist will be expected to perform the roles of the oculoplastic surgeon in managing trachoma and its complications. To be able to carry out these functions, the general ophthalmologists will be expected to:

1. Clearly understand the indications for trachoma lid surgery and other management modalities for trichiasis
2. Understand the various surgical procedures available for trachomatous trichiasis and the principle behind lid rotation procedures for trachoma.
3. Understand the complications that could arise from TT surgery, the factors that make these complications likely and how to prevent and/or manage them.
4. Know the basic set of instruments that are required for TT surgery so as to provide guidance to trachoma programs on procurement and replacements.
5. Undertake surgical audit of trichiasis surgeons and provide remedial training or stop

those perceived to cause harm from continuing with surgery.

6. Guide trachoma programs as the when to carry out outreach based trichiasis surgery and when to completely provide TT surgery as part of routine clinical care.

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Facial Nerve Palsy and Oculoplasty

Khaled Abuhaleeqa and Essam A. El Toukhy

Introduction

The facial nerve arises from the pons and travels through the internal auditory canal and the petrous portion of the temporal bone and the parotid gland before innervating the muscles of facial expression.

Innervation of the upper facial muscles originates from bilateral corticobulbar projections to the upper part of the ipsilateral facial nucleus. The lower facial muscles receive innervation from contralateral corticobulbar projections to the lower part of the ipsilateral facial nucleus. Thus, a lesion to the upper motor neuron would result in paralysis of only the contralateral lower facial muscles. A lower motor neuron lesion would result in ipsilateral paralysis of both the upper and lower facial muscles and is the most common form of facial paralysis.

Although trauma, infection, and inflammation of CNVII may occur, by far the most common cause of peripheral facial nerve paresis is idiopathic or Bell's palsy. Bell's palsy is a unilateral, acute onset (<72 hour), and idiopathic facial paralysis affecting around 23 people per 100,000 per year or about 1 in 60–70 people in a lifetime. It occurs equally between men and women and peaks between the ages of 10 and 40.

Peripheral facial weakness results in decreased closure of the eyelid and a larger palpebral fissure. The primary ophthalmic concern in facial nerve palsy is corneal exposure and lagophthalmos, and these patients need to be evaluated by an ophthalmologist. Facial nerve disorders are a good example where a multi-disciplinary team approach is needed for patient care.

Management

Patients with facial weakness frequently present to ophthalmologists with symptoms of corneal exposure. The role of the ophthalmologist is protecting the eye from complications such as corneal ulceration, while maintaining good vision and cosmoses, with medical treatment or surgical rehabilitation.

When medical management by itself does not prevent corneal complications or when recovery from the facial paralysis is not expected, surgical rehabilitation should be considered. The patient's symptoms should dictate the choice of surgical method for managing problems caused by the facial nerve paralysis. The oculoplastic surgeon is concerned with maintenance of lid position, lid closure, protection of the cornea from exposure

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_15

and control of symptoms such as epiphora and ocular discomfort. A stepwise regimen of management consists of ocular lubricants which are the mainstay of treatment, drops are given by day as frequently as required to keep the eye comfortable with the more viscous s drops providing better corneal epithelial protection during sleep.

Botulinum Toxin Induced Ptosis

Botulinum toxin-A (Botox) can be injected into the levator muscle to induce ptosis to protect the cornea if lubricants are inadequate. This is an alternate to taping the eye and can be repeated as needed. An injection of 0.1 mL (5 U) of botulinum toxin-A is given subconjunctivally with the lid everted and just above the tarsus. Maximum effect is seen in 2–7 days, and the ptosis may last for 6–8 weeks. Diplopia may occur if the superior rectus is involved.

Tarsorraphy

Tarsorrhaphy gives suboptimal cosmoses, limitation of the visual field, and may obscure the visual axis, but can be useful in protecting the cornea if the patient is unable or unwilling to have other surgery. A 5-mm lateral tarsorrhaphy reduces lagophthalmos by 70–80%.

Temporary tarsorrhaphy is indicated if the cornea is decompensating, recovery of function is expected and the patient is unable to have other procedures performed. It can be a suture tarsorraphy or by tissue glue. The glue is better reserved to cases of anophthalmia or ICU patients with exposure keratopathy who need to be closed for 1–2 weeks. Permanent tarsorrhaphy is indicated if the cornea is decompensating, there is no prospect for recovery of function, and the patient is unwilling to have other procedures performed.

Lower Eyelid Ectropion Repair

The most common eyelid malposition seen with facial nerve paralysis is ectropion. Lower lid ectropion causes discomfort because of conjunctival exposure, contributes to lagophthalmos, causes epiphora by punctual eversion, and is not cosmetically appealing. Lateral canthoplasty is the mainstay of surgical rehabilitation. It is the most efficient and anatomic approach to lower eyelid shortening. Shortening the lower eyelid at the lateral canthus avoids vertical blepharotomy or wedge resection. See chapter "Common Eyelid Malpositions" (Fig. 1).

Medial Canthoplasty

Medial canthoplasty is a useful adjunct to lateral canthoplasty in patients with facial nerve paralysis. The addition of a medial canthoplasty will improve closure and minimize lagophthalmos.

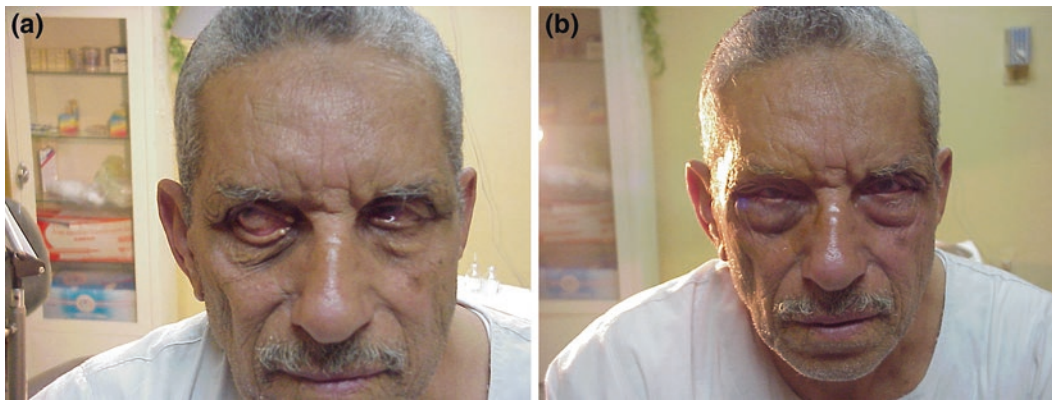

Fig. 1 **a** and **b** Paralytic ectropion: pre and post operative

Under local anesthesia, the upper and lower puncta are dilated and a double zero Bowman probe is passed into the upper and lower canaliculi. A v-shaped incision is made medial to the punctum and anteriorly in both upper and lower eyelid skin, the anterior and posterior lamellae are separated by making a small incision and a muscle flap. The posterior lamella from the lower eyelid is sewn to the posterior lamella of the upper eyelid with a series of 6-0 vicryl sutures. Care must be taken to avoid injury to the canaliculi. The anterior lamella is sewn together with vertical mattress sutures of 6-0 plain.

Lower Lid Retraction

Most patients with facial nerve paralysis have some degree of lower eyelid retraction and mid facial descent that lateral and medial canthoplasty would not completely address. These patients can be helped with grafts of either hard palate or ear cartilage to the posterior lamella with lateral canthoplasties. Hard palate grafts are preferable in most cases because they are stiff but pliable, and give the best cosmetic results. Ear cartilage grafts, however, can be used when very large grafts are desirable and the patient refuses hard palate surgery.

The hard palate is harvested from the lateral aspect of the palate 3–4 mm from the adjacent molars and Incisors. The submucosal tissues are infiltrated with local anesthetic and epinephrine. The graft is harvested free hand with a no. 15 blade, Absorbent gelatin sponge (Gelfoam) can be placed in the palatal defect and a hard palate stent can be fabricated by a dentist. If the patient wears dentures, these will serve as a stent. The lateral canthoplasty begins with a canthal incision using a no. 15 blade. The canthoplasty is completed with a Stevens scissors. A 4-0 silk traction with the needle suture is placed through the lid margin point of the cautery, an incision is made through the conjunctiva and the lower lid retractors along the lower tarsal border. A pocket is developed in which to place the graft, which recesses the lower eyelid retractors and helps support the lid at a higher position. Usually a 2:1 graft to retraction ratio is desired thus, 2 mm of lower eyelid retraction requires a 4-mm graft. The graft is cut into a pendant shape and the upper border sewn into the lower edge of the tarsal plate with 6-0 plain suture, and the lower portion to the retractors. Another useful adjunct in patients with significant mid facial descent is to perform a subperiosteal cheek lift in conjunction with a posterior lamellar graft and canthoplasty. This procedure elevates the cheek and mid face and may prevent recurrent lid retraction and/or ectropion.

The use of palmaris tendon sling to support and mildly elevate the lower lid has also been used.

Upper Lid Retraction

Patients with lagophthalmos may benefit from gold weight implantation. Patients with upper eyelid retraction should be considered for levator aponeurosis recession with or without a gold weight. Gold is used because it is inert, has a high weight-to volume ratio and is a good color match for the skin. Gold weights are available in sizes ranging from 0.6 to 1.6 g in 0.2-g increments, and the gold is 99.9% pure 24 K.

These implants are placed in the upper eyelids to correct retraction and to assist in closure. The size of the weight is determined preoperatively in the office with the patient seated. Fitting weights can be purchased or a few weights can be kept in stock and tried in the office. A trial weight is applied to the upper pretarsal eyelid with double stick tape or benzoin, and the patient is examined. The gold weight can be autoclaved. The advantages of gold weight implantation include the simplicity of insertion and a lower extrusion rate; the disadvantages include its occasional visibility through the dermis and the need for gravity assistance in its effectiveness. The weight is contoured to match the tarsus and has fixation holes. The gold weight can be used as early as several days after the onset of facial palsy because it is easily reversible if orbicularis function returns and can greatly reduce the need for supportive care.

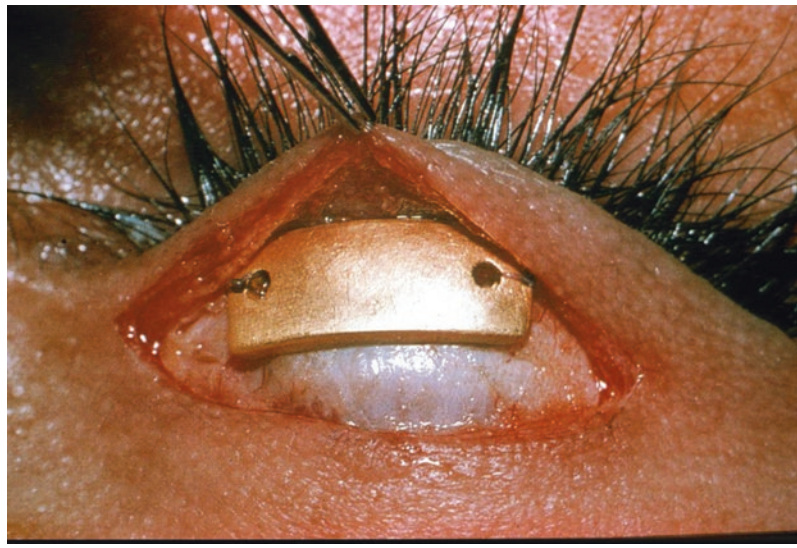

Fig. 2 Gold weight insertion and fixation

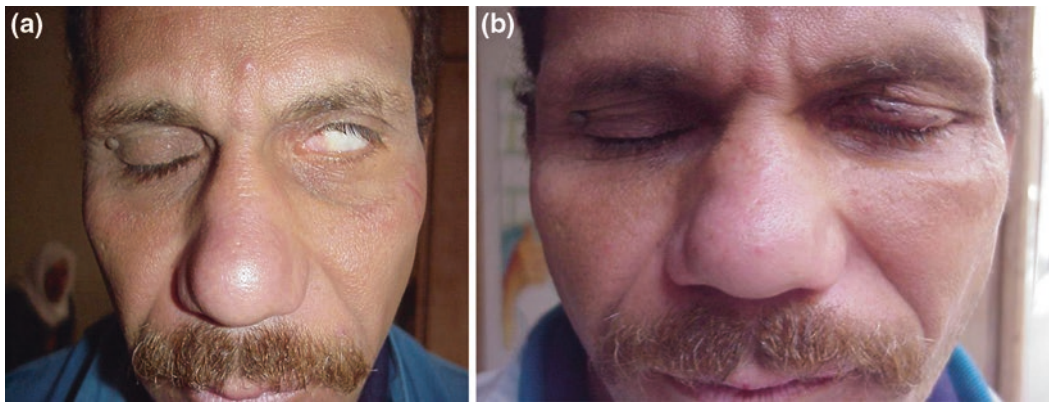

Fig. 3 **a** and **b** Gold weight insertion: pre and post operative

The indications for gold weight insertion are exposure keratopathy or marked irritation despite intensive medical therapy in short- or long-term facial palsy. The correct weight places the lid 2-mm below the limbus with the eye open and causes complete closure in the erect position. Usually 1.2–1.4 g is adequate for implantation. The patient may need to sleep with his head slightly elevated to get the required effect of gravity at night.

Under local anesthesia, an incision is made in the eyelid crease through the skin, orbicularis, and levator aponeurosis down to the tarsal plate, the dissection is continued inferiorly in the pretarsal space so that the anterior tarsus is bared at the site for implantation. The gold weight is placed into this space with the top edge of the weight level with the top edge of the tarsus and fixed to the tarsus with 7-0 nylon suture (Fig. 2). To prevent ptosis, the levator aponeurosis can be closed however, it is often desirable to perform a small recession so as to decrease exposure.

The orbicularis is carefully closed with 7-0 polyglactin to prevent exposure of the gold weight, then the skin is closed with 7-0 polyglactin (Fig. 3a, b).

Complications of Gold Weight Implantation

The most common complication following a gold weight insertion is implant migration which can be prevented by good fixation to the tarsus and closure of the orbicularis muscle as a seoarate layer over the weight. The second common complication is persistent inflammation in response to the gold weight or fixation sutures that may necessitate removal. Extrusion may occur if the gold weight is placed anterior to the orbicularis or if poor wound closure and delayed healing occur.

The use of a stainless steel spring to help reanimate the upper eyelid presents another alternative. The thinness of the spring wire makes it relatively invisible in the upper eyelid, and it does not need gravity assistance. Its major disadvantages include the technical difficulty of the operation, the need for postoperative adjustment, and a fairly high extrusion rate anteriorly and posteriorly. However, it is useful in patients with profound facial nerve paralysis after tumor surgery when no return of function is expected Successful. Implantation of springs requires a surgeon experienced in this technique.

Aberrant Facial Nerve Regeneration

Aberrant facial nerve regeneration can be a result of severe injury to the facial nerve. aberrant innervation which occur most commonly in longstanding or recovering Bells palsy.

Aberrant regeneration of the facial nerve can occur in three forms:

(1) Hypertonicity occurs as the affected side appears contracted at rest. This finding have been successfully treated with local injection of small amount of botulinum toxin.
(2) Synkinesis which involves reinnervation of different muscles than those originally served by a particular branch. In the case of facial nerve this results in narrowing of the palpebral fissure due to lower orbicularis contraction (upsidedown ptosis) on attempted lower facial movements as smiling. This can be treated with small doses of botulinum toxin in the lower orbicularis and upper cheek, sometimes combined with muller muscle resection (see below).
(3) Similarly, a crocodile tears syndrome occurs as nerve fibers destined to the salivary glands reinnervate the lacrimal gland and cause tearing during chewing. This can be managed with direct injection of 5 units of botulinum toxin into the lacrimal gland.

The Muller Muscle Conjunctival Resection Procedure

Is an excellent operation in the setting of post–Bell's palsy with aberrant regeneration to elevate the ptotic eyelid and yet avoid lagophthalmos with corneal exposure. The Müller's muscle conjunctival resection procedure can correct from 1 to 3 mm of ptosis in patients with a positive phenylephrine test. This technique plicates Müller's muscle via an internal approach (see chapter "Adult Ptosis") Because no skin incision is required, the protractors are not weakened further in a condition in which they are already compromised. The extent of increase in ptosis induced from facial animation remains undiminished, but the procedure does allow the lid fissure to be better normalized and it lessens the tendency for the lid to encompass the pupillary axis with facial movements especially smiling and while being photographed.

Facial Reanimation

There are several principles that can guides dynamics facial reanimation; first we need to have a functioning nerve and muscles for facial movements, second facial muscles can respond to nerve grafting if denervation was less than one year, else other muscles need to be transferred as a substitute of nonfunctioning facial muscles.

A contralateral facial nerve offers the best chance for spontaneous coordinated facial movements. This is typically obtained through cross-facial nerve grafting which usually requires 8–12 months to become functional, meanwhile, a nearby functioning nerve can babysit the facial muscles or transferred muscles to prevent denervation.

The sources of muscles and nerves for dynamic restoration of facial muscles and nerves include both from regional and distant sites. The muscle sites include temporalis muscles and gracilis muscle as a free flap. The nerves include we can use the masseteric nerve and hypoglossal nerve, and the sural nerve.

The temporalis muscle can be used to reanimate the face in long-standing facial paralysis when the fifth cranial nerve is intact. The temporalis muscle can function as a motor activator to the cheeks, upper lip, and nasolabial fold. Although strips from the temporalis muscle with attached fascia can also be placed in the upper and lower eyelid as slings, this method is much less satisfactory than mid- and lower facial reanimation. Through an extended facelift incision, the temporalis muscle and deep temporalis fascia can be harvested, the central portion of the muscle is mobilized from the bony temporalis fossa, reflected over the zygomatic arch, and then sewn to the nasolabial folds and the corner of the mouth. Fascial extensions are used if necessary.

Overcorrection at the time of surgery is necessary to better establish facial tone. The defect in the temple can be replaced by a temporalis fossa implant if desired. The postoperative patient can initiate smiling or movement of the face by chewing or biting the teeth together. Mid- and lower facial reanimation in conjunction with eyelid resuspension with either gold weight or eyelid spring can give very gratifying results.

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Part III
Cosmetic Blepharoplasty

Upper Blepharoplasty and Browplasty

Christopher R. Dermarkarian and Richard C. Allen

The distinction between functional and cosmetic oculoplastic surgery can be subtle. In this chapter, cosmetic blepharoplasty and browplasty will be addressed, but many of the principles are also applicable to functional blepharoplasty and browplasty. A functional defect implies that the process has some effect on the activities of daily living of the patient. This effect has subjective and objective components. For upper blepharoplasty and browplasty, the objective functional defect can be quantitated with visual field testing. The subjective functional complaints, however, may not be as straight-forward. These include difficulty seeing, headaches, and effects on the patient's activities of daily living such as driving and reading. Some patients may complain bitterly of the subjective component of their disease, while the objective effect may be virtually non-existent. This places the surgeon in an uncomfortable situation in determining whether the indication is cosmetic or functional, as this has implications particularly with regards to expectations.

Cosmetic complaints are subjective, with no objective criteria. These complaints are based on appearance. As the complaints have little objective criteria, so will the results. Judging of the results by the patient is the principle outcome after cosmetic surgery, as the opinion of the surgeon has little bearing on the patient's satisfaction. The implications of this are that the patient must be counselled carefully with a full-understanding of the expected result. When the patient's expectations are not met by the outcome of the procedure, the result will be patient unhappiness. Therefore, it is wise to under-promise and over-deliver.

Evaluation

Evaluation of the patient presenting for cosmetic blepharoplasty and/or browplasty is similar to other oculoplastic surgeries. History includes history of present illness, previous medical history, previous surgical history, social history and family history.

History of present illness should contain the exact words of the patient's complaints. For cosmetic patients, this usually involves the appearance of the eyelids and/or eyebrows. These complaints should outline the exact dissatisfaction the patient has with the current

Electronic supplementary material

The online version of this chapter (https://doi.org/10.1007/978-3-030-36934-7_16) contains supplementary material, which is available to authorized users.

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_16

configuration of the face. It is useful to have the patient bring previous photos so that an idea of the previous configuration of the face can be assessed. Using a mirror to have the patient point out exactly what areas are bothersome is mandatory.

Previous medical history is obtained to determine if there are any illnesses which may affect the outcome of the procedure or the type of anesthesia that can be used. Healing of the incisions will be affected by diabetes and autoimmune disease. The use of medications that may affect the surgery should also be elicited. This includes anticoagulants and also any herbal supplements. Anticoagulants should be discontinued if possible, prior to the surgery depending on the type of anticoagulant. Permission to discontinue the anticoagulant should be obtained from the physician that placed the patient on the medication. Herbal supplements should be discontinued 2 weeks prior to surgery. Any medications that may affect healing should be noted. This includes medications such as prednisone and immune modulators such as methotrexate. Patients that are on immunosuppressive medications may need to be placed on oral antibiotics after the procedure due to the possible risk of infection. Patients with hypertension should have this controlled prior to the surgery due to the risk of bleeding during and immediately after the surgery.

Previous surgical history is centered on any previous procedures on the face. This includes incisional surgeries but also any previous botulinum toxin, dermal fillers, or skin resurfacing. Patients should be asked specifically if any of these procedures have been previously performed. It is not uncommon for the physician to perform eyelid surgery and then encounter a previous surgeon's sutures of which the patient did not think was important to inform the surgeon.

Patients with a history or multiple previous cosmetic surgeries should be approached carefully. Dissatisfaction by the patient with previous surgeons should be a "red flag". These patients may have unrealistic expectations or underlying psychiatric illness. Body dysmorphic disorder (BDD) has been noted to occur with increased incidence in patients who have undergone multiple previous cosmetic surgeries. This is discussed in detail in Chap. "Body Dysmorphic Disorder ".

Social history should include drug, alcohol, and tobacco use. Patients who use opioids may require more potent pain medications after the surgery or may have some tolerance to the anesthetic agents used. Alcohol use may result in liver disease which could predispose the patient towards difficult to control bleeding. Tobacco use may predispose the patient to poor wound healing. In addition, the patient's social situation at home should be assessed to ensure that there will be a capable care-giver that will help the patient post-operatively.

Cosmetic Upper Blepharoplasty

Cosmetic upper blepharoplasty involves the removal or skin, orbicularis muscle, and/or fat of the upper lid. Patient complaints usually involve an extra fold of skin or puffiness of the upper eyelid. In general, the onset of this appearance should be slow. Patients may also have coexisting blepharoptosis and this should be addressed if present. If there is a recent change, the patient should be evaluated for the etiologies of periorbital edema. If the patient notes recent onset, then signs of thyroid eye disease should be investigated and likely serum thyroid function tests and autoantibodies should be sent. Previous medical and surgical history specific to upper lid blepharoplasty is centered mostly on previous upper eyelid surgeries and dry eye. It is important to evaluate the strength of closure of the upper lids. Any previous surgery often compromises the closure which may result in frank lagophthalmos. Schirmer testing and fluorescein staining for dry eye should be evaluated. Ocular irritation and/or dry eye will, by definition, be worsened by an upper lid blepharoplasty. Medical treatment of the dry eye should be maximized prior to the surgery and the patient should be counselled to expect to need to use ocular lubrication more often after the surgery and potentially long-term. Placement of punctal plugs can be helpful in managing the dry eye. In

those patients with significant dry eye, surgery should not be performed prior to optimizing the ocular surface and may need to be delayed indefinitely.

Examination of the patient centers on extra skin and prolapsed fat pads. The closure of the eyelids should be carefully examined. Any concomitant brow ptosis should be noted and if significant, may need to be addressed. In general, surgical planning takes into account the amount of skin, orbicularis muscle, and fat that should be removed. The extra skin can be marked using a number of methods, depending on surgeon preference. The determination of orbicularis muscle removal is usually based on the presence of any ocular surface disease. Any predisposition to dryness should probably lead to a decision to spare orbicularis resection. For fat removal, the medial fat pad is often removed; however, the preaponeurotic fat should be spared in most cases unless robust, as seen in patients with a history of thyroid eye disease. Lateral lacrimal gland prolapse should be noted, and if present, should be addressed during the surgery with repositioning of the gland.

Surgery for cosmetic upper blepharoplasty alone is usually performed under local sedation anesthesia. The patient should be placed in a seated position to examine the effect of gravity on the upper eyelids. The eyelid crease should then be marked. In general, a female's lid crease will measure 8–10 mm in height while a male's will measure 6–8 mm. With the patient's eyes in primary gaze, the upper eyelid skin should be inspected to determine the excess. There are many different ways to assess this. The author prefers to mark the skin just above the fold of the eyelid skin across the eyelid. This is then connected medially and laterally. Medially, the lid crease marking should not extend medial to the punctum. Laterally, the marking should flare superior temporally just medial to the lateral canthus. The marking should not extend beyond the lateral orbital rim. The expected amount of skin retained post-operatively should measure approximately 18–20 mm between the inferior brow cilia and eyelashes, and this should be equal on both sides. Excessive skin removal may result in descent of the brow and/or lagophthalmos. The medial fat pad and preaponeurotic fat should be noted. It is typical to debulk the medial fat pad, but the preaponeurotic fat should only be debulked when truly in excess, as in disease states such as thyroid eye disease.

The area is then infiltrated with local anesthetic with epinephrine. The patient is prepped and draped in the normal sterile fashion. The cutting instrument of the surgeon's choice can then be used to make an incision along the markings of the eyelid. This can be performed with a scalpel blade or cutting cautery, as each has been shown to result in equivalent scars. Other cutting instruments such as a carbon dioxide laser can also be used. The decision to retain or resect orbicularis muscle has been made preoperatively. If the medial fat pad is to be debulked, the orbital septum is opened medially and the medial fat pad is identified and mobilized. The fat pad is then infiltrated with local anesthesia and the fat pad can then be debulked. If the preaponeurotic fat is to be debulked, the septum is opened centrally and the fat pad is addressed. Hemostasis is assured, and the incision is then closed with the suture of the surgeon's choice. The author prefers a running 6-0 polypropylene suture (Video 1).

Lacrimal gland prolapse can be addressed if present. The orbital septum is opened laterally, and the lacrimal gland is identified. The anterior surface of the lacrimal gland is then engaged with a double-armed suture. Each arm then engages the periosteum just posterior to the superior orbital rim in the area of the lacrimal gland fossa. Tying the suture results in repositioning of the gland posterior to the orbital rim. If there is any evidence or history of a lacrimal gland process (inflammation or mass), a biopsy can be performed concurrently (Video 2).

Post-operative instructions are designed to decrease the chance of infection and decrease the edema and bruising. Antibiotic ointment is applied to the incision three times per day for one week. The patient is to keep their head elevated above their heart for two days and ice packs should be applied to the eyes for two days. Oral antibiotic is usually not necessary.

A tapering course of oral corticosteroids can be helpful in decreasing inflammation. Patients are evaluated at one week and sutures are removed.

Potential complications of upper blepharoplasty include bleeding, infection, pain, over-correction, under-correction, asymmetry, dry eye, and scarring. Bleeding risks can be decreased with discontinuation of agents with anti-coagulant properties and also control of hypertension. A retrobulbar hemorrhage is potentially blinding. Patients should be given the warning signs and symptoms of a retrobulbar hemorrhage. Although infection is uncommon due to the vascularity of the eyelids, worsening erythema, edema, and pain after the first two days are warning signs. Appropriate preoperative preparation with povidone-iodine and postoperative hygiene and use of antibiotic ointment is recommended. Over-correction, under-correction, and asymmetry can be avoided with careful preoperative measurement of the amount of tissue that needs to be resected. Although lid crease incisions usually heal well, any signs of exuberant scar can be treated with topical or intralesional corticosteroids.

Fig. 1 Ideal brow position

Brow Ptosis

The brow and upper lid constitute a continuum which must be evaluated in any patient undergoing an upper lid blepharoplasty. The mere performance of an upper lid blepharoplasty will have an effect on brow position. True ptosis of the brow must be determined through the inspection of the patient's previous photos. Although there is the concept of ideal brow position, in reality, ideal brow position is individualized based on the position of the patient's brow when they were younger. (The ideal brow should lie completely above the superior orbital rim, with the medial end on the same vertical line with the ala of the nose, the lateral end at the extension of a line from the ala to the lateral canthus, and the apex on a vertical line directly above the lateral limbus) (Fig. 1).

The etiology of involutional brow descent is multi-factorial. The effect of gravity results in descent through the loosening of attachments of the brow to the supraorbital rim. In addition, the frontalis muscle does not extend lateral to the temporal fusion line, resulting in more significant brow ptosis laterally. Volume loss through fat deflation also results in brow descent. Reinflation of the brow with dermal fillers or autogenous fat is effective in those cases of volume loss.

Evaluation of the brow position should center on the height and contour of the brow. There are distinct differences in position between men and women, with a male's brow being flatter and lower and a female's brow being arched and higher. In choosing the appropriate procedure for the patient, respecting the gender specific characteristics of the brow should be taken into account.

There are multiple procedures to consider when elevating or stabilizing the brow. A direct browplasty is a straight-forward, strong procedure which gives the greatest amount of lift per

millimeter of tissue resected. It works well for temporal brow ptosis; however, it is difficult to extend the incision medially without giving a noticeable scar. The brow is assessed, and the amount of lift determined. A supraciliary marking is made, and the desired lift and contour is outlined with an incision superior to the supraciliary incision. The tissue is resected, and the incision closed (Video 3). The main disadvantage of the procedure is the potential of giving the patient a noticeable scar. Most surgeons would consider a direct browplasty to be more of a functional procedure rather than a cosmetic procedure, although when used for temporal brow ptosis, a well-healed scar can give an excellent cosmetic result.

A mid-forehead lift should be avoided in a cosmetic patient. Although it is also a powerful lift and has the advantage of providing medial elevation of the brows, the scar can be objectionable. An incision is made in the forehead, preferably in a deep furrow. The amount of tissue to be resected is removed and the defect is closed (Video 4). In general, this procedure should only be considered for males with significant furrows in the forehead for a functional procedure.

The gold standard cosmetic lift is a coronal browplasty. In this procedure, an incision is extended across the top of the head. Dissection is then carried out inferiorly in a subperiosteal plane to release the attachments of the brow to the superior orbital rim. A strip of scalp is removed to elevate the forehead. The incision is hidden in the scalp. The main advantages of the procedure are its strength, long-lasting effect, and the ability to hide the scar above the hairline. However, the scar may be noticeable in some situations, and the procedure will elevate the hairline, which may be objectionable especially in patients who have a pre-existing high hairline.

An option for patients with a high hairline is a pretrichial browplasty, where an incision is made at the hairline. Dissection proceeds as noted for the coronal lift and a strip of forehead tissue is excised to give the desired lift (Video 5). The main advantage of this lift is the ability to not raise the hairline. However, the scar at the hairline may be objectionable, and the patient may have some hypoesthesia above the incision due to transection of branches of the supraorbital nerve. This brow lift is best used in female patients that wear bangs or Hijab so that the scar is hidden.

A less invasive procedure that will elevate the forehead is an endoscopic browplasty. In this procedure, smaller incisions are made in the scalp and a subperiosteal dissection with or without the aid of an endoscope is performed inferiorly to the superior orbital rims to free the brows from their attachments at the superior orbital rim. The endoscope can be used to identify the exit of the supraorbital nerve at the medial superior orbital rim so that it is not damaged. Alternatively, the supraorbital nerve can be identified from the blepharoplasty incision by dissecting along the surface of the orbital septum and incising the periosteum of the superior orbital rim. Additional incisions are made in the scalp over the temporalis muscle and dissection is carried out inferiorly along the surface of the deep temporalis fascia. The temporal fusion line is then transected with or without the aid of the endoscope so that the entire forehead is mobile. The forehead is then elevated and fixated into position with a number of different fixation devices available to the surgeon (Video 6). This is a very nice cosmetic lift; however, the durability of the lift has been questioned and the procedure will elevate the hairline.

Recently, there has been renewed interest in browpexy procedures. As noted, a blepharoplasty will often result in some brow descent. In patients who need brow stabilization, but do not need a significant lift, a browpexy is a viable option. There are multiple browpexy procedures available, using external or internal approaches. The main advantage of the browpexy procedure is the lack of a significant external incision. An external browpexy will use an incision at the supraciliary position measuring 1–2 cm. For an internal browpexy, no additional external incision is used as the procedure is performed through the blepharoplasty incision (Video 7). However, the elevation obtained from a browpexy is modest at best. Most surgeons perform

this procedure in conjunction with an upper blepharoplasty to stabilize the brow and prevent post-operative descent.

Post-operative instructions are similar to that given for upper blepharoplasty. Complications include bleeding, infection, pain, reoperation, over-correction, under-correction, asymmetry, dry eye, scaring, and nerve damage. The temporal branch of the facial nerve that innervates the frontalis muscle may be damaged during endoscopic, coronal, or pretrichial procedures.

Electronic Supplementary Material

Below is the link to the electronic supplementary material.Supplementary material 1 (zip 1384947 KB)

Suggested Readings

1. Joseph AW, Ishii L, Joseph SS, et al. Prevalence of body dysmorphic disorder and surgeon diagnostic accuracy in facial plastic and oculoplastic surgery clinics. JAMA Facial Plast Surg. 2017;19(4):269–74.
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Lower Blepharoplasty

Yoon-Duck Kim, Kyung In Woo, Jill Foster and Lance Bodily

Surgical Anatomy

The anatomy of the lower eyelid features structures analogous to those found in the upper eyelid, however, they are often less robust and sometimes surgically less apparent. As in the upper eyelid, the skin is the thinnest in the body and is devoid of subcutaneous fat. The orbicularis oculi underlies the skin with pretarsal, preseptal, and preorbital components. Both laterally and medially the orbicularis oculi condenses into a lateral and medial canthal tendon. The lateral canthal tendon inserts onto the Whitnalls tubercle in the lateral orbit, while the medial canthal tendon splits into anterior and posterior arms, which insert onto the anterior and posterior lacrimal crests.

The orbital septum is located deep to the orbicularis oculi, and is generally less robust than that seen in the upper eyelid and in an older patient may be very thin. The tarsus of the lower eyelid is reduced in vertical height compared to the upper eyelid, generally less than 5 mm and tends to be more thin and less firm. The lower eyelid features 3 fat pads, nasal, central, and lateral. Of great surgical importance is the position of the inferior oblique muscle, which arises just inferolateral to the lacrimal sac fossa and sits between the nasal and central fat pads as it courses through the orbit to insert onto the posterior globe. The lateral and central fat pads are separated by strands of fibrous tissue from the lower eyelid retractors.

The lower eyelid retractors, or capsulopalpebral fascia, is located deep to the lower eyelid fat pads and originates from the fascia surrounding the inferior rectus muscle. The retractors wrap around the inferior oblique muscle, and insert into the inferior tarsus. The conjunctiva is located deep to the retractors.

As the lower eyelid transitions to the cheek inferiorly, the suborbicularis oculi fat pad (SOOF) is deep to the orbital orbicularis oculi over the inferior orbital rim. Inferior to the rim, the superficial musculoaponeurotic system (SMAS) overlies the SOOF. Superficial to the SMAS lies an additional malar fat pad. The correct position of both the

Electronic supplementary material

The online version of this chapter (https://doi.org/10.1007/978-3-030-36934-7_17) contains supplementary material, which is available to authorized users.

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_17

SOOF and the malar fat pad lead to a high, smooth cheek characteristic of the youthful midface.

While planning a lower blepharoplasty, it is essential to understand the aging changes in the eyelid and the midface based on anatomic knowledge. The aging process may leave various structural changes in the soft tissue and the bone in the periorbital region. As lower eyelid blepharoplasty is generally considered cosmetic rather than functional surgery, the evaluation generally starts with listening to the patient to understand specific concerns and goals for their lower eyelids. The surgical approaches should be tailored to each patient to achieve a satisfactory surgical outcome.

Functionally, the lower eyelid plays an important role in maintaining the tear film and protecting the eyeball. The position of the lower eyelid is critical in preventing dry eye, and the tone of the orbicularis oculi muscle and the eyelid is important for the proper eyelid function of closing and blinking. Hence lower blepharoplasty should be performed in a way that preserves the lower eyelid's function.

1. **Preoperative clinical evaluations**
   Several aging changes need to be evaluated for successful lower eyelid blepharoplasty. Each defective feature should be noted and the surgical plan should be made on the base of the evaluation (Fig. 1a–d).
   Facial photographs should be taken to record the preoperative feature of the patients, for postoperative discussion or legal purposes.
   a. **Skin laxity and wrinkles**
      Lack of elasticity from aging results in the thinning and wrinkling of the lower eyelid skin. The orbicularis oculi muscle, prolapsed fat, and the depressed region are more visible through thinned skin. With blepharoplasty, excessive skin can be resected; however, the decreased elasticity in the skin cannot be restored. Therefore, correction of fine wrinkles or thinned skin cannot be the target of blepharoplasty. For fine skin wrinkles, chemical peeling or laser resurfacing can be performed.
   b. **Fat prolapse**
      Fat may be protruded from three pockets (medial, central, and lateral), and each protruded fat pocket should be evaluated. In the lying position in the operating room, fat protrusion is much less visible. So, fat prolapse should be checked in the sitting position. Sometimes, prolapsed lateral fat pockets are missed during the preoperative examination and the surgery may result in undercorrection of this pocket.
   c. **Tear trough deformity**
      One should also consider hollows of the lower eyelid and the position of the SOOF and malar fat pads as part of the continuum of the lower eyelids. With descent of the

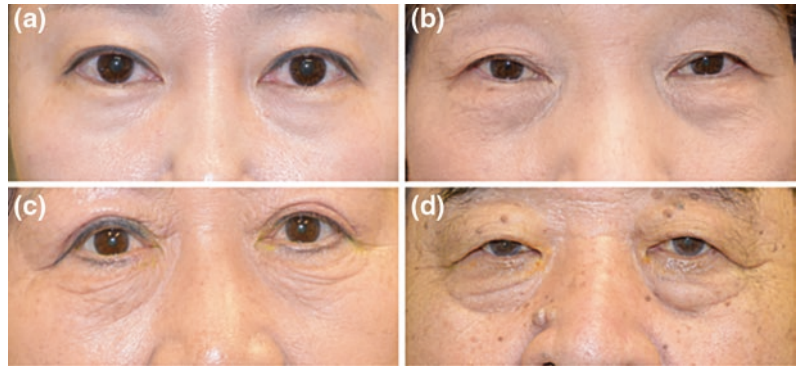

Fig. 1 Patient evaluation. **a** This patient presents with fat prolapse with good skin and eyelid tone. Transconjunctival fat removal can be indicated. **b** This patient shows fine skin wrinkles, fat prolapse, and tear trough deformity. Fat reposition procedure is needed for tear trough deformity. Small amount of skin resection is also necessary for redundant skin. **c** This patient has prominent skin and orbicularis oculi muscle laxity with mild fat prolapse. Transcutaneous blepharoplasty with fat removal, anterior lamellar shortening with or without horizontal eyelid strengthening procedure can be applied. **d** This patient shows skin and orbicularis muscle laxity, fat prolapse, and tear trough deformity. Transcutaneous blepharoplasty with fat repositioning, anterior lamellar shortening with or without horizontal eyelid strengthening procedure can be applied

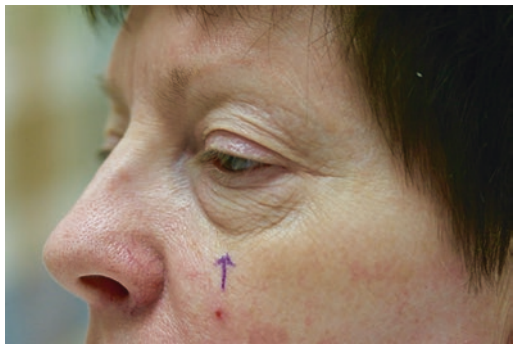

Fig. 2 Preoperative photos of lower eyelid blepharoplasty patient. Prominent steatoblepharon is present. She does have mild to moderate descent of her malar fat pad and SOOF, resulting in lower eyelid and tear trough hollows. She has mild lower eyelid laxity and mild excess skin. She was deemed to be a most suitable candidate for transconjunctival fat transposition with lower eyelid tightening

SOOF and malar fat pads, hollows can form along the lower orbital rim and medially, contributing to a prominent tear trough. These can result in a characteristic "double convexity" seen in the aged face (Fig. 2). The reason for tear trough deformity formation is considered to be the thinning of subcutaneous tissue and skin at the top of midface descent.

If a patient only has a fat prolapse without a tear trough deformity, a fat resection procedure will address the fat bulging. If a patient has a prominent tear trough deformity, volume should be added to the tear trough region through such means as filler injection or blepharoplasty with the fat reposition technique. In addition to placing volume into the tear trough, fat pad redraping may provide some mild lift to the SOOF and malar fat pads. For significant midface descent, one may also select approaches that specifically help lift the SOOF, SMAS, or malar fat pad at the time of lower blepharoplastly.

d. **Eyelid position**
Lower eyelid position should be noted, measuring MRD2 (margin-to-reflex distance 2) and lower scleral show in millimeters to prevent the complications of eyelid retraction or ectropion. Anterior lamella of the lower eyelid may be shortened with previous trauma or blepharoplasty surgery. The degree of lagophthalmos also needs to be described. One must also carefully assess the position of the margin, noting any retraction or reverse ptosis. Preoperative retraction may require a lower eyelid retraction repair with placement of a spacer graft.

e. **Eyelid laxity**
Lower eyelid laxity is assessed with the snap-back test or the eyelid distraction test.
Snap-back test: Retract the lower eyelid inferiorly and let it go back, and evaluate the degree of eyelid repositioning. If the eyelid is repositioned instantly, there is no eyelid laxity. If the eyelid is repositioned with blinking, there is a mild eyelid laxity. If the eyelid is not repositioned even with blinking, there is a significant laxity (Fig. 3a).

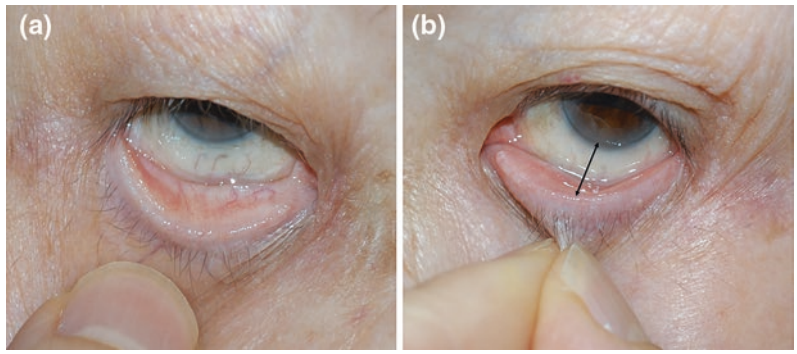

Fig. 3 Tests for lower eyelid laxity. **a** Snap-back test showing retracting the lower eyelid inferiorly. After that, release the eyelid and see the degree of repositioning. **b** Distraction test showing pulling the lower eyelid away from the eyeball. Measure a distance from the eyeball to the lower eyelid margin in mm (arrow)

Distraction test: Measure the distance from the lower eyelid to the eyeball in mm after the lower eyelid is pulled away from the eyeball. More than 6 mm in the distraction test indicates the presence of laxity of the lower eyelid (Fig. 3b).

Laxity of the lateral canthal or medial canthal tendons should be noted and generally addressed at the time of lower eyelid blepharoplasty. Failure to do so increases the risk for post-operative lower eyelid malposition, even if the laxity is not sufficient to cause an ectropion or entropion before the procedure.

2. **Surgical planning**

The main surgical considerations in performing a lower lid blepharoplasty are the approach (transcutaneous vs. transconjunctival), the need for lateral canthal fixation, and how the fat pads should be addressed (resection vs. repositioning).

a. A case with prominent fat prolapse without tear trough deformity

If there is no skin laxity, fat resection with the transconjunctival approach is a good choice (Fig. 1a). If there is concomitant skin laxity, the same approach can be performed with skin resection with the pinch technique.

b. A case with prominent fat prolapse with tear trough deformity

A fat repositioning procedure is needed to address tear trough deformity by adding a volume to the region, through either transcutaneous or transconjunctival approaches (Fig. 1b).

c. A case with prominent skin and orbicularis oculi muscle laxity

Transcutaneous blepharoplasty can address the anterior lamellar laxity (Fig. 1c, d).

d. A case with significant eyelid laxity

If there is a significant eyelid laxity, horizontal eyelid tightening procedure should be added to the blepharoplasty technique to prevent complications of eyelid retraction or ectropion.

e. Additional steps to augment lifting of the SMAS and SOOF can be performed laterally with orbicularis sling techniques and SOOF elevation procedures.

3. **Anesthesia**

Lower eyelid blepharoplasty is often performed under straight local anesthetic or monitored anesthesia care, although general anesthesia is also appropriate and may be better in an anxious patient. Patient participation in the surgery is not necessary. Locally injected anesthetic is applied to the lower eyelid both transconjunctivally and through the anterior lamellae. When appropriate, the lateral canthus is also blocked for tightening procedures. Generally a combination of lidocaine with epinephrine, marcaine, and hyaluronidase is used. Two ml of local injected transconjunctivally in each eye, 2 ml per side as an infraorbital nerve block and two ml per side for the lateral canthal block is a reasonable initial block to be augmented for comfort during the surgery. When a subciliary incision is used for a skin muscle flap, an additional ml injected below the lashes is helpful for hemostasis.

4. **Transcutaneous lower blepharoplasty**

This is the classical approach to lower eyelid blepharoplasty. It can correct anterior lamella laxity and fat prolapse using subciliary skin incision.

Surgical procedure

Evaluate the amount and extent of fat prolapse by gently compressing the eyeball. Draw a subciliary incision line from the punctum to the lateral canthus. The incision line can be extended from the lateral canthus temporally in a wrinkle line in the extent of less than 1 cm (Fig. 4a). A 4-0 silk suture is also placed through the grey line and left loose until the incision is made. A transcutaneous incision is marked about 1–2 mm below the cilia. There is a natural lid crease that may be followed with the incision. A 15 blade is used to make incision through skin. Depending on the surgical plan, a skin muscle flap or skin flap is elevated over the orbital septum. Dissection is carried out to the inferior

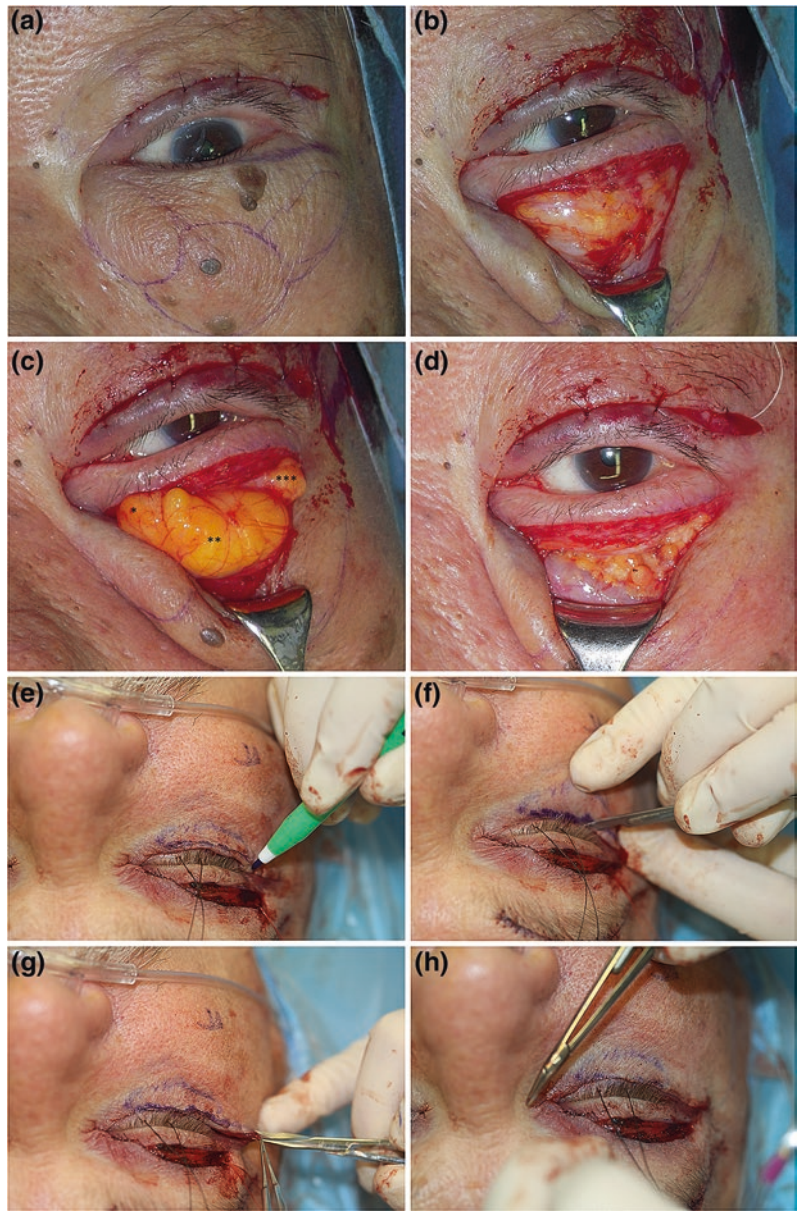

Fig. 4 Transcutaneous blepharoplasty. **a** Each prolapsed fat pocket is marked. Subciliary incision line is designed. **b** Preseptal dissection is carried out inferiorly. **c** After septal incision, fat pockets are protruded. (*nasal fat, **central fat, ***lateral fat). **d** Resect each fat pocket at the level of the inferior orbital rim. **e** Conservative amount of lower eyelid skin is marked for incision. **f** The skin marking is incised with a 15 bade and then. **g** Removed with Wescott scissors. **h** The incision is closed with a subcuticular 6-0 prolene suture

orbital rim (Fig. 4b). Incise the orbital septum with scissors and identify three fat pockets (Fig. 4c). Resect each fat pocket with proper hemostasis using bipolar or monopolar cautery. The fat pocket can be resected with the clamp-cut-cautery technique. Care should be taken not to injure the inferior oblique which separates medial fat from the central fat pocket. If the protruded part is noted with gentle eyeball

compression, resect more from the protruded portion. The fat resection plane should be at the level of the lower orbital rim (Fig. 4d). Try not to resect deeper orbital fat. Make sure proper amount of fat is removed by comparing the volume of resected fatty tissue from both sides. The sitting position can also help in checking the degree of fat resection. A lateral tarsal strip or other lower eyelid tightening should usually be performed with a transcutaneous approach, as the risk of lower eyelid retraction without proper tightening is high. If one is planning on transposing the fat pedicles, the tightening is often done after exposing and preparing the fat pedicles but before placement of the transposing sutures with bolsters. After lower eyelid tightening and management of the lower eyelid fat pads, one then directs attention to the lower eyelid skin. A draping and pinch technique is used to assess the amount of skin that will be subtracted from the inferior aspect of the transcutaneous incision. There should not be traction or movement of the eyelid margin or cilia with the desired amount of tissue that is removed. Have the patient open his/her mouth and look up, then mark and resect overlapped skin. This technique may prevent over-resection of the skin. It is preferable to have residual tissue redundancy than to have posteroperative retraction. It should be noted that a transcutaneous approach, even without removing any skin, will result in up to 2 mm of skin tightening because of the healing process.

Once the amount of desired skin to be removed is determined, this is then incised with a 15 balde Bard Parker and then trimmed from the lower aspect of the incision with a Wescott scissor. The skin incision is then closed with a 6-0 plain gut or 6-0 prolene suture in a running fashion (Fig. 4e–h).

5. **Lateral tarsal strip, lateral SMAS lifting**
The lateral tarsal strip is an essential step in many lower eyelid blepharoplasties. There may be some transconjunctival procedures in younger patients where it is found to be unnecessary. It is almost always a feature of a transcutaneous approach.

When a lateral tarsal strip is planned, liberal anesthetic should be injected at the lateral canthus at the beginning of the case. After fat removal for a subtractive blepharoplasty or before fat pedicle transposition, a canthotomy and cantholysis is performed. The lower eyelid edge and the tarsus are imbricated with a 5.0 or 6.0 suture. That canthal suspension suture is then passed just inside the orbital rim, starting inferiorly at about the level of the desired lateral canthus (about 2 mm above the medial canthus) and is then passed upward and through the periosteum. This may be done as a single throw or as a mattess suture. The ends of the sutures are pulled tight to assess the position of the lateral canthus. If the desired position has been obtained, a commissure suture is then placed with a 6-0 plain gut suture or 6.0 vicryl suture going from the lateral upper grey line to lateral lower grey line and is then tied. The canthal suspension suture is then tied firmly. The skin overlying the lateral canthus can then be closed with 6-0 plain gut suture.

One may also consider tightening of the SMAS and/or SOOF or the orbicularis along with the lateral tarsal strip (Fig. 5a–c). Undermining of the SOOF may be performed as needed to achieve the desired elevation. One may use a 4-0 vicryl to grasp SMAS and SOOF through the lateral incision. This can then be secured to periosteum or the deep temporal fascia superiorly. Should one be performing a simultaneous upper eyelid blepharoplasty, the SMAS and SOOF can be pulled superiorly through the upper lid incision and secured to periosteum at the lateral orbit.

6. **Transconjunctival lower blepharoplasty**
This technique does not leave a scar between the orbital septum and orbicularis oculi muscle, and therefore it does not result in complications such as ectropion or retraction. This technique is good for cases with fat prolapse without significant skin laxity.

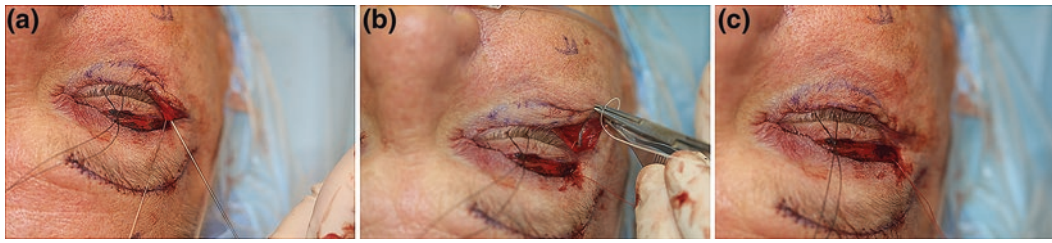

Fig. 5 **a** 4-0 vicryl suture is used to grasp the lateral orbicularis sling. **b** The sling is then passed across the periosteum of the lateral orbital rim. **c** The needle is then externalized through the upper eyelid blepharoplasty, where it is tied

Transconjunctival approach, subtractive blepharoplasty

In an upright position, preoperative markings are made over the skin identifying the areas corresponding to the lower lid steatoblepharon. These areas will be targeted with tissue subtraction during the procedure. The patient is then prepped and draped in a sterile fashion, leaving the full face exposed for the procedure.

A 4-0 silk suture is placed through the grey line of the lower eyelid. The eyelid is then everted. One may use a Desmarres retractor or cotton swab to help with the eversion, as well as an assistant putting light downward traction on the cheek throughout the case. Incision is then made 1–2 mm below the tarsus along the full width of the lower eyelid. Light cautery can be made before using sharp Wescott scissors to dissect through the conjunctiva and into the preseptal plane (Fig. 6a). Once the preseptal plane is reached a 6-0 silk or vicryl suture can then be used to place a traction suture through the conjunctiva and lower eyelid retractors. This traction suture is then secured superiorly to the drapes with a hemostat to assist with exposure (Fig. 6b).

The preseptal dissection is then carried down to the orbital rim. Once at the orbital rim the orbital septum can be opened just above the arcus marginalis. The fat pads are carefully dissected away from the overlying fibrous septal tissue. Care is made not to damage the inferior oblique as it sits between the nasal and central fat pads. Careful attention to hemostasis is maintained, as the fat pads are quite vascular. Conservative removal of the fat pads is then made with a Wescott scissor or cutting cautery, assessing the contour of the lower eyelid and taking more fat as necessary (Fig. 6c) The lateral fat pocket tends to be undercorrected especially in the transconjunctival approach. Proper amount of fat resection from the lateral fat pocket should be performed in patients with prominent lateral fat pocket. One should be cautious not to be too aggressive with fat removal as this will result in a deflated, hollowed appearance. There may be a slightly redundant appearance to the overlying skin after fat removal. If this was not present before fat subtraction, one should be hesitant to perform skin removal intraoperatively as the redundancy often improves with healing and aggressive skin subtraction could result in lower eyelid retraction. It should be noted that a transconjunctival approach will result in up to 2 mm of skin tightening because of the healing process.

One should have evaluated the need for suspension of the eyelid and the lateral canthus preoperatively and determined if the lateral tarsal strip should be performed at this time. Tests of lower eyelid snap back and lower eyelid lateral distraction are methods to challenge the eyelid suspension to watch for laxity. When canthal tendon tightening is planned or if the lateral canthus appears more lax than was thought preoperatively, one should proceed with lower eyelid tightening at this time as well. When the lid resuspension

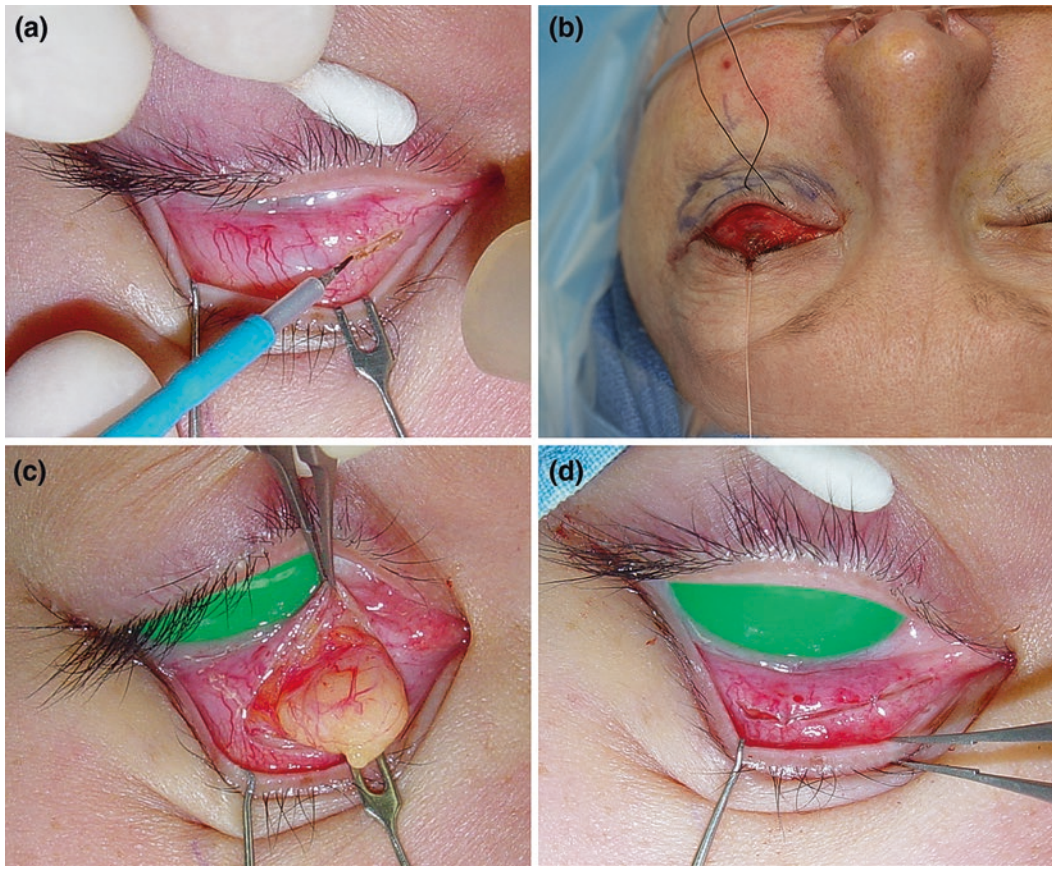

Fig. 6 Transconjunctival blepharoplasty: subtractive technique. **a** Make a conjunctival incision with monopolar cautery at 4 mm inferior to lower border of the tarsal plate. **b** 6-0 vicryl suture is attached to the surgical drape for traction to aid in preseptal dissection down to the orbital rim. **c** When dissection proceeds inferiorly, orbital fat is prolapsed through the incision site. **d** After fat resection, the conjunctival wound is closed with 7-0 vicryl suture

technique includes a lateral canthotomy and cantholysis, it is useful to open the lateral canthal angle prior to the fat manipulations as this provides for wider access.

If needed, One or 2 (6-0) vicryl sutures are placed in a buried fashion through the conjunctival incision, one at about the line of the medial limbus and one at the lateral limbus (Fig. 6d).

Transconjunctival approach, tissue redraping (fat repositioning) procedure (Fig. 7a–d)

Tissue redraping is also generally accompanied by some fat pad subtraction as well. The areas of the steatoblepharon should be marked and the hollow areas for filling with fat pad transposition should also be marked. The procedure then is carried out as described above for the subtractive transconjunctival blepharoplasty, with an incision made transconjunctivally into the preseptal plane and carried down to the orbital rim. Once at the orbital rim, light cautery is made onto the rim to aid in adhesions with the transposed fat pedicles. The orbital septum is then opened at the rim and the 3 fat pads are carefully dissected out, taking care to free them from overlying fibrous tissue and avoiding damage to the inferior oblique.

Once the fat pads have been dissected out, their size is evaluated. The surgeon may

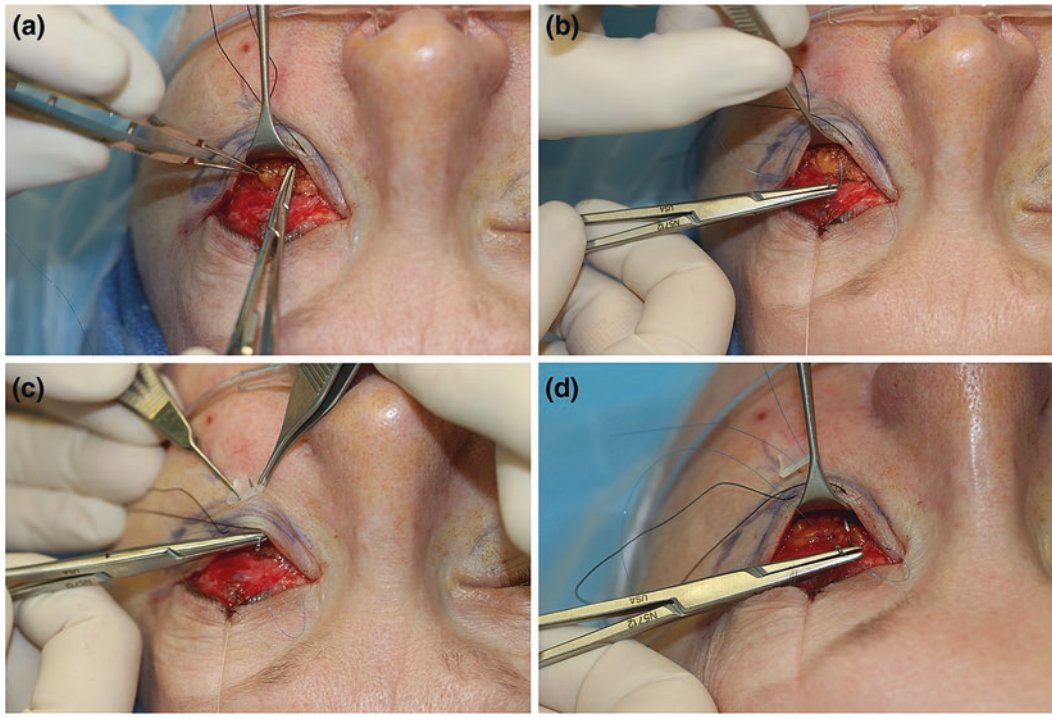

Fig. 7 Transconjunctival blepharoplasty: Fat repositioning. **a** A 6-0 prolene suture is passed through the edge of the central fat pedicle, which has already been shortened with electrocautery. **b** A free needle is used to pass the prolene suture into the dissected pre-periosteal space. **c** The free needle is passed through the skin and into silicone bolsters. **d** The same technique is performed with the nasal fat pad to fill in the more nasal tear trough. Nasally one generally passes slightly inferior and medial to the tear trough

elect to perform some subtraction of the fat before transposition. A periosteal elevator is then used to bluntly dissect down onto the cheek in the pre-periosteal space. One may also choose to dissect down into the subperiosteal space for transposition (Fig. 8). Once the pre-periosteal space has been dissected and the fat pedicles are prepared, a 6-0 prolene suture is then used with a silicone bolster. The suture is passed in a weaving fashion through the inferior edge of the fat pedicle, then out through the skin. A free needle facilitates the passage of the prolene through the skin and also through the silicone bolster placed on the surface of the skin. The second end of prolene goes through the bolster in a mattress fashion again using the free needle to pass throught the eyelid/cheek skin. Nasally one generally passes slightly inferior and medial to the tear trough. While the prolene is being passed, the transconjunctival incision is held open with a Desmarres retractor for good visualization. Some of the SMAS is generally grabbed with this more inferior

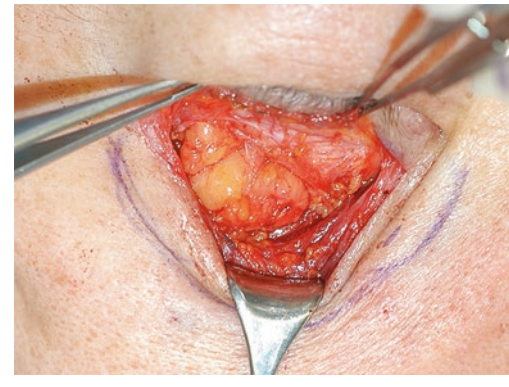

Fig. 8 Subperiosteal dissection

bite of the needle. The needle is then passed through the silicone bolster a few millimeters away from the original suture and left untied until all of the fat redraping sutures have been placed. The placement of the pedicles are then assessed. The surgeon may remove the suture and replace the bolster if the position is not desirable. A similar 6-0 prolene suture with silicone bolster is then passed in a similar fashion to drape the central fat pad. The needle is passed inferior to the orbit rim, also grasping SMAS in the pass in and out. One should again carefully assess the placement of the pedicle once again and remove the suture and replace the pedicle. Once both the nasal and central

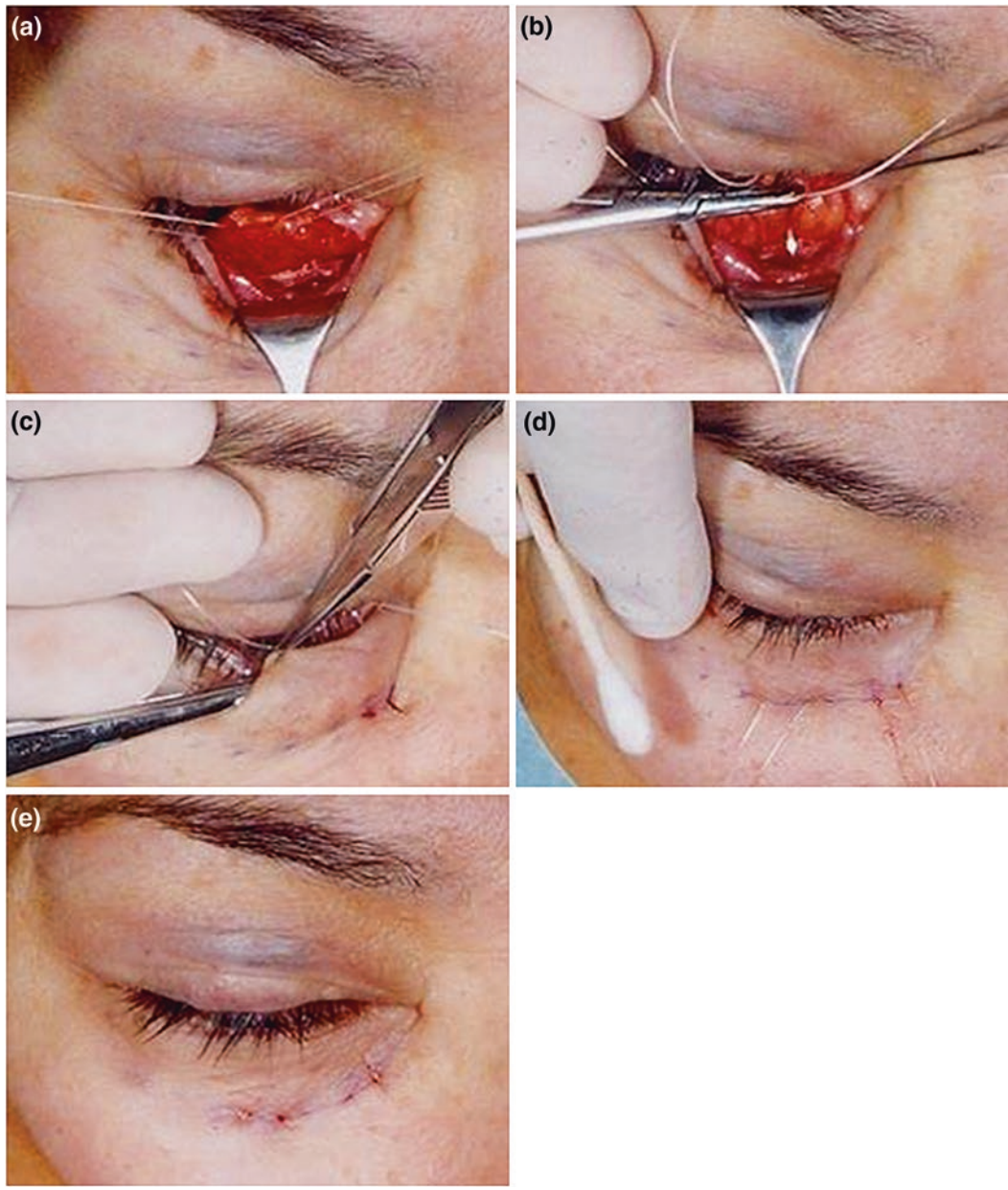

Fig. 9 **a–e** Fat repositioning: Direct fixation to the skin using 4-0 vicryl suture

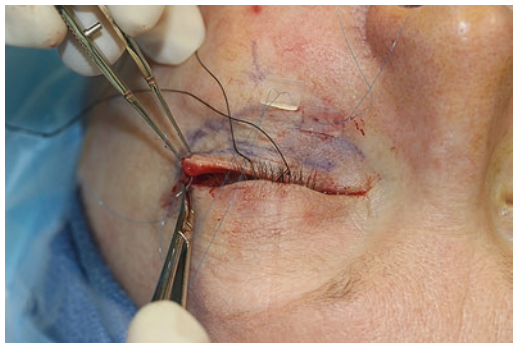

Fig. 10 A prolene suture is passed through the lateral tarsus for lateral canthal tightening. Note that the prolene sutures holding the transposed fat pedicles are left untied

fat pads have been transposed, the prolene sutures are lightly tied down over the bolsters. The fat pedicles can also be fixated directly to the skin without the bolsters (Fig. 9a–e).

If a lateral canthal tightening procedures is to be performed with fat transposition, one should place the sutures without securing them for the lateral tarsal strip before tying down the prolene sutures on the transposed fat pedicles so as not to limit surgical access to the lateral canthus. Likewise, the conjunctival closure sutures should be placed and tied down prior to the lateral canthal closure (Fig. 10).

Pinch technique skin excision

For those who had skin redundancy after transconjunctival fat resection, skin resection can be added through the pinch technique. This procedure does not leave a scar between the orbital septum and the

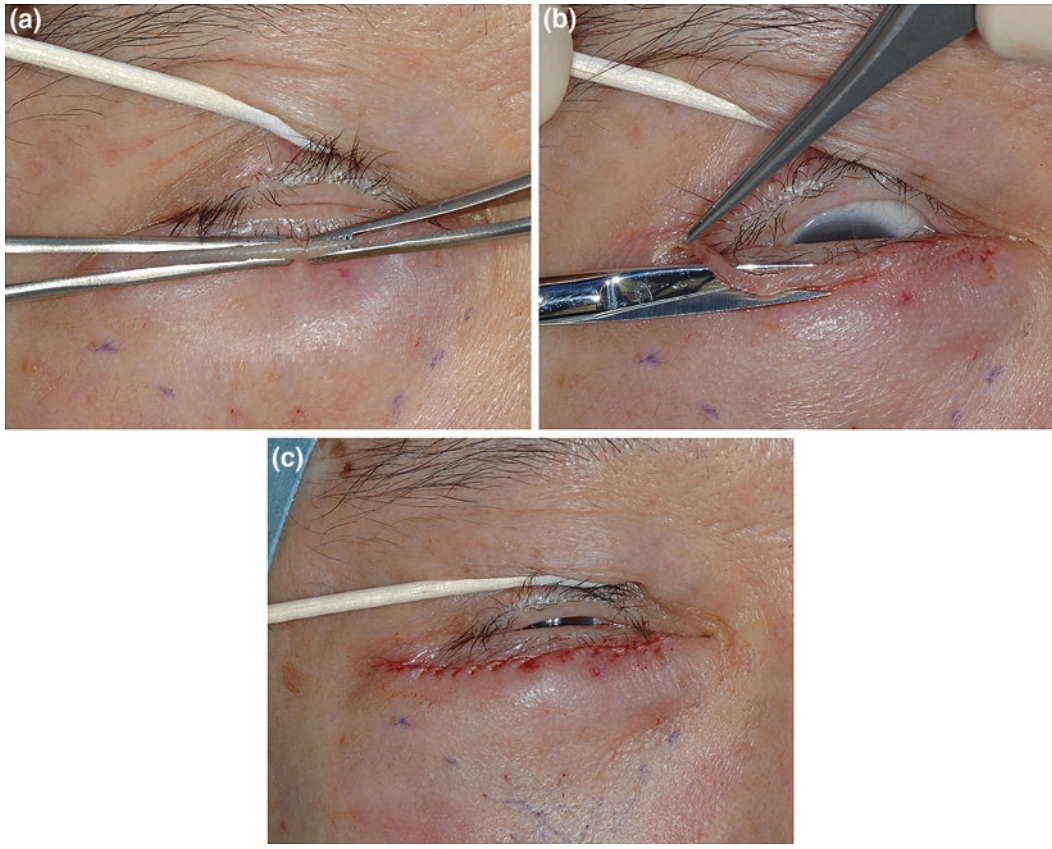

Fig. 11 The Pinch technique. **a** To remove the redundant skin, pinch the skin with two Adson-Brown forceps. **b** The formed skin mound is excised with sharp scissors. **c** Skin is closed with 6-0 fast absorbing suture after hemostasis

orbicularis oculi muscle and preserves the pretarsal orbicularis muscle, so that complications related to skin resection in transcutaneous blepharoplasty can be avoided.

i. Pinch the redundant skin at 1–2-mm below the ciliary line at the lateral canthal area with two toothed forceps. Extend the pinching medially to the punctum area and laterally at the extent of less than 1 cm, forming a fixed horizontal skin mound (Fig. 11a).
ii. If the lower eyelid margin is about to rotate outward with pinching, reduce the pinching amount to restore the eyelid margin to normal position.
iii. Resect the base of the skin mound with straight scissors, from the lateral to the medial side (Fig. 11b).
iv. After hemostasis, close the skin with 6-0 fast absorbing gut or 7-0 nylon suture (Fig. 11c).

Postoperative measures

Apply eye drops of antibiotics and steroids for a week postoperatively. Apply antibiotic ointment for a week in cases with pinch technique skin excision. Apply a cold pack on the eyelid for 2 days.

7. **Complications**

a. **Orbital hemorrhage**

The most serious complication related with blepharoplasty is visual loss from orbital hemorrhage and its occurrence rate is reported as 1 in 40,000 cases. Before surgery, anticoagulants and antiplatelet should be stopped for a sufficient period as per each drug's recommendation. To prevent this complication, meticulous hemostasis and gentle manipulation of the fat is critical.

b. **Lower eyelid retraction** (Fig. 12a)

This complication is caused by scarring in the middle lamella of the eyelid and over-resecting the skin, which is aggravated with eyelid laxity. To prevent eyelid retraction, excessive cauterization to the orbital septum or orbicularis layer and over-resection of the skin should be avoided, and the horizontal

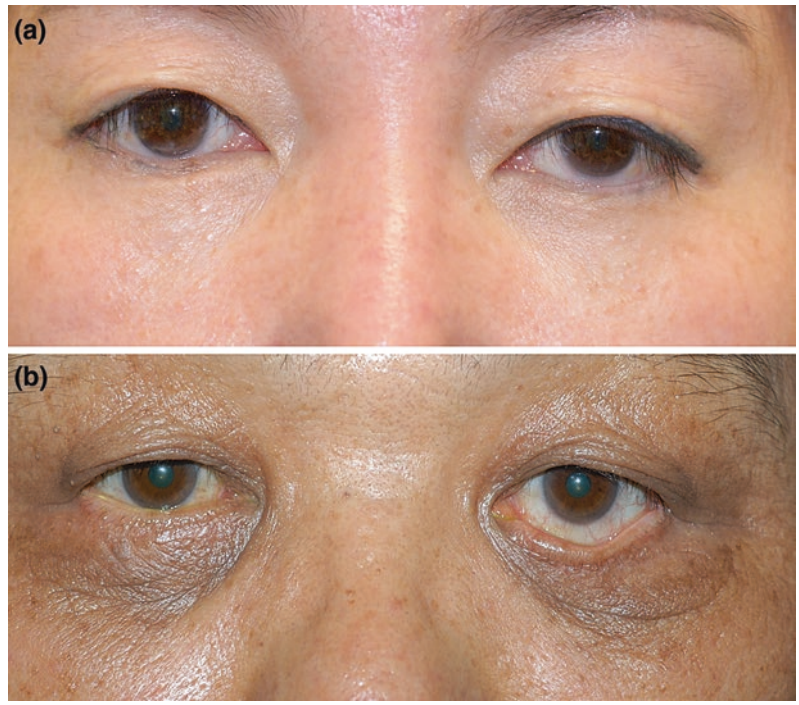

Fig. 12 Complicated cases. **a** Lower eyelid retraction is noticeable in the left eye after lower eyelid blepharoplasty. **b** Ectropion and retraction occurred in the left eye with eyelid laxity. Fat was over-excised in both eyes from the previous surgery

eyelid strengthening procedure should be performed in cases with eyelid laxity.

In case of eyelid laxity, a horizontal eyelid strengthening procedure such as the lateral tarsal strip procedure or pentagonal eyelid resection can be done. For anterior lamellar shortening, SOOF (Sub-orbicularis oculi fat) lift or skin graft can be performed after middle lamellar scar revision.

c. **Lower eyelid ectropion** (Fig. 12b)

Transient ectropion can occur in the case of postoperative swelling and eyelid laxity. If the anterior lamella is over-excised, permanent ectropion can result. To prevent ectropion, judicious skin excision is needed. For anterior lamellar shortening, a SOOF lift or skin graft can be done with or without horizontal eyelid strengthening procedures.

If there is any evidence of ectropion or retraction, some surgeons consider early postoperative injection of 5-FU or corticosteroid to the area with aggressive upward massage of the eyelid.

d. **Over or under-corrected fat prolapse**

Undercorrection for a specific fat pocket may leave an uneven appearance on the lower eyelid. To prevent this outcome, try cutting fat pockets at the level of the orbital rim. Close care should be taken not to undercorrect the lateral fat pocket.

e. **Conjunctival chemosis**

Chemosis is known to be caused by postoperative increased permeability in vessels and obstructed venous and lymphatic channels. In the early postoperative period, steroid eye .drops, lubricants, and pressure patches can help relieve the condition. If it persists, surgical intervention is needed.

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Electronic Supplementary Material

Below is the link to the electronic supplementary material.Supplementary material 1 (zip 546737 KB)

The Cosmetic Use of Injectables in Oculoplasty

Kasturi Bhattacharjee, Shubhra Goel, Sripurna Ghosh and Essam A. El Toukhy

Introduction

With ever evolving standards and demands for beauty, the knowledge of aesthetics remains indispensable. Facial rejuvenation encompasses correction of facial rhytides and volume attrition by cosmetic surgical or non-surgical procedures. Facial ageing is an ongoing natural process which is influenced by intrinsic and extrinsic factors. The synergistic effects of reduction of tissue elasticity, collagen loss, soft tissue atrophy, persistent use of facial muscles and the effects of gravity are the main factors for the intrinsic tissue changes. Photo degradation of tissues, smoking, lifestyle habits are some of the extrinsic contributors. The fundamental principle of facial rejuvenation is to reverse or halt these changes with surgical or non surgical methods to improve the tissue descent, restore the lost volume, and improve the quality of the skin thereby retaining the "V shape" of facial contour (Fig. 1).

In the present days there are myriad of treatment modalities available to correct facial aging. Among which, botulinum toxin and soft tissue fillers are one of the most common and favorite tools for non-surgical rejuvenation.

Botulinum Toxin Preparation, Dilution and Storage (See Chapter "Blepharospasm, Hemifacial Spasm and Functional Applications of Neurotoxins in the Periocular Area")

Indications of Botulinum toxin

Botulinum toxin A injection has been use for various cosmetic and non-cosmetic indications. Some of the common aesthetic indications are listed. It is FDA approved for the treatment of Blepharospasm, hemifacial spasm, strabismus, glabellar lines and periocular rhytides. Wrinkles can be (caused by aging, loss of volume, actinic damage, scars, …) or dynamic (caused by repeated contractions of muscles of facial expressions) or both. Botulinium toxin exerts its effect by relaxing those muscles resulting in improvement of dynamic wrinkles i.e. in animation. Patients presenting with static wrinkles would achieve little improvement form BTX therapy (Fig. 2). Its effect on wrinkles has an

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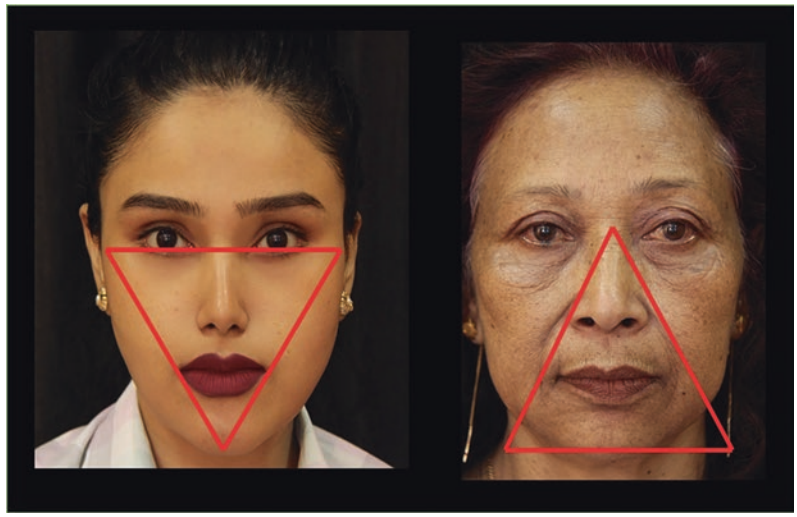

Fig. 1 Shows the facial difference in a young and aged patient characterized by typical reversal of V pattern of facial contour

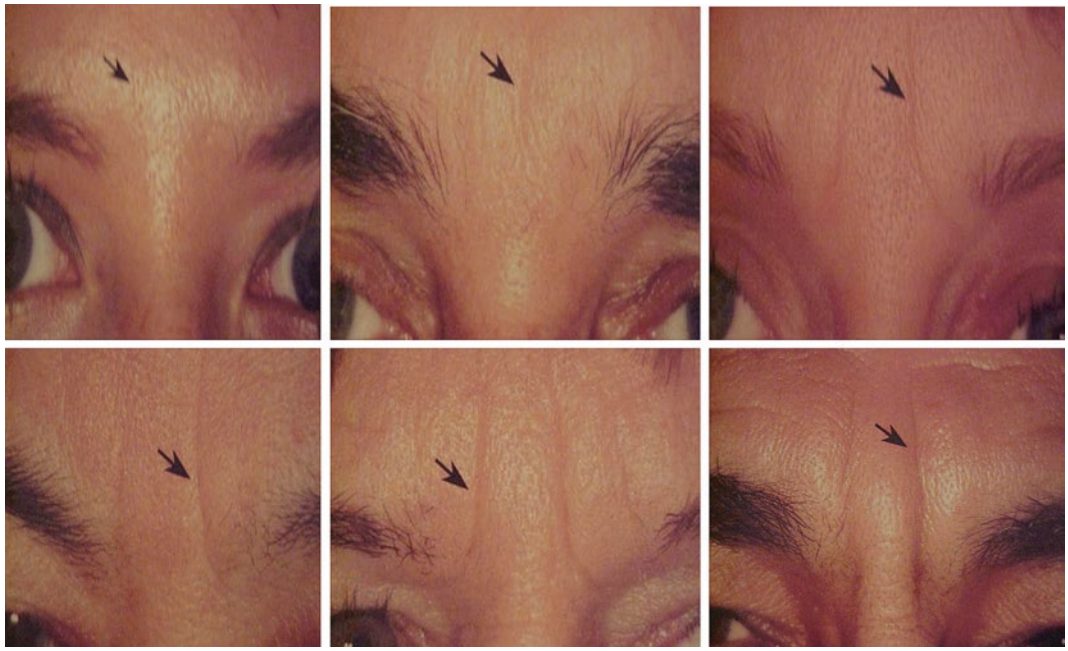

Fig. 2 Wrinkle grading from 1 (faint line) to 6 (deep furrow)

early temporary reversible phase with relaxation of the muscle tone and decreased force of contraction giving a better appearance during animation. With repeated injections, the late permanent stable phase results in remodeling of the dermis and skin to achieve a lasting improvement. So, in addition to decreasing wrinkles that are present, ultimately, prolonged use of BTX prevents further deepening of the crease and truly prevents signs of aging. Best response is seen in ages between 30 and 50 years. The effects of Botox are cumulative, and results improve on repeated treatment.

Understanding the anatomy of the facial muscles is essential. Injection is done in the muscles whose contraction results in appearance of the wrinkle and not in the wrinkle itself (Fig. 3).

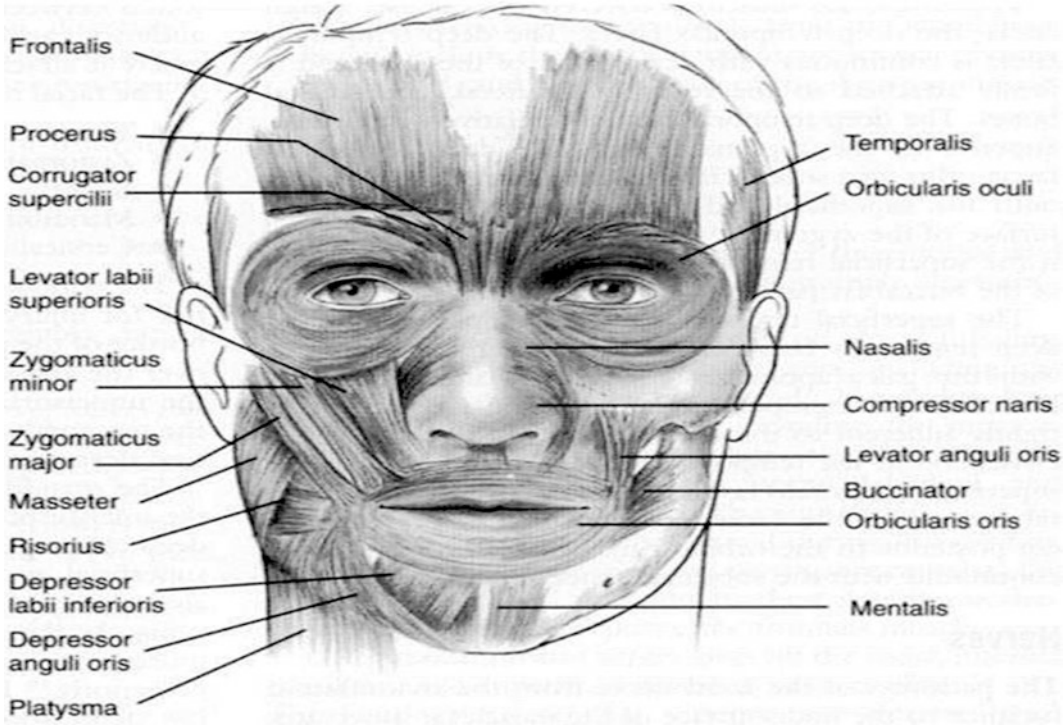

Fig. 3 Facial muscles of expression

Before injection, the injected sites must be marked. The patient should be asked to remove all makeup and the area is gently cleaned with non-alcoholic wipes. The use of a topical anesthetic like EMLA and ice compresses for at least ten minutes prior to injection reduces patients' discomfort. Some surgeons advise against this, particularly with repeated injections and the use of 32 gauge needles. There is some evidence of reduced duration of effect in patients treated with topical anesthetic and skin cooling. Pinching the injected spot and stretching and rubbing the adjacent skin can minimize patient discomfort.

Following primary injection, BTX effect starts after 2–3 days with maximal effect at 7–10 days. A repeat visit is usually scheduled at that time, when a touch up injection can be given if needed. It is better to slightly undercorrect on new patients until optimum dosing is achieved. It is mandatory to keep preinjection photos, injection sites and dosage in the patients' records to help with subsequent injections. It should be noted that men and older patients generally require higher doses than women and younger patients.

To avoid undesired spread of the toxin to other muscles, it is advisable to aim the needle to a direction opposite to the undesired muscle, i.e. upwards while injecting the forehead to avoid the levator muscle, and towards the ear while injecting the crow's feet to avoid the lateral rectus muscle.

Upper face indications

Forehead wrinkles:
Frontalis muscle injection is useful in treating horizontal forehead wrinkles. Injection sites should avoid the area directly above eyebrows to avoid a ptotic or an expressionless eyebrow. Injection is performed symmetrically on both sides across the medial and lateral parts of frontalis muscle, taking into consideration the eyebrow position and shape to avoid segmental

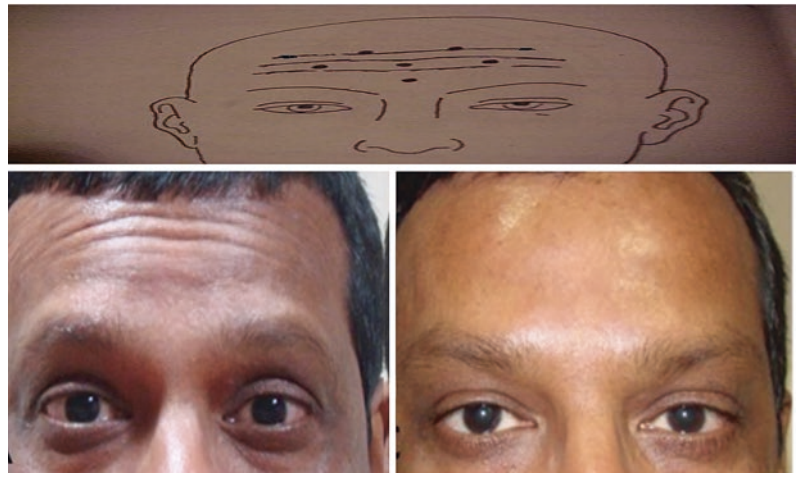

Fig. 4 Injections for the forehead

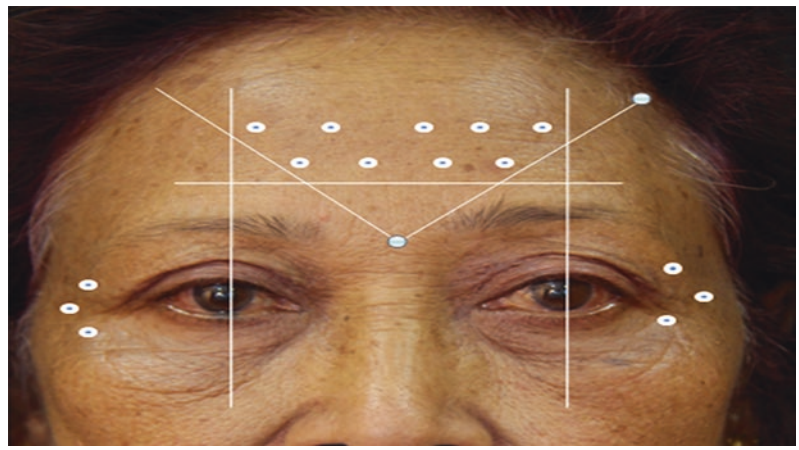

Fig. 5 Showing the multiple forehead points for females as well as points for crow's feet

eyebrow elevation. Usually 6–10 injection sites are needed. As noted, men tend to have active frontalis muscles that require larger doses (20–25 units) compared to women (15–20 units) (Figs. 4 and 5).

The frontalis muscle is the only elevator of the forehead and brow, injection of the frontalis without treatment of the depressors (orbicularis oculi, corrugator, and procerus) may lead to brow descent. Forehead injection and the resulting eyebrow depression may worsen an underlying eyelid ptosis in such patients Also, there is no need to inject the vertical midline of the forehead were the frontalis is either nonexistent or extremely attenuated.

Injecting the BTX upward rather than downward prevents against any spreading of the toxin over the orbital rim and onto the upper lid and levator muscle. Injections should not be deep to the level of the periosteum.

Glabellar folds (Frown lines)

The corrugators are the principal muscle to be injected, but the procures should always be treated as well. In cases with bunny lines, the nasalis muscle should be included and injection

must extend down both sides of the nose. Injection is usually in the form of an inverted triangle with the apex at the root of the nose. Usually 5 sites are injected with a total amount of 10–15 units (Fig. 6).

Crow's feet:
Injection in the orbicularis oculi works well for crow's feet and both active and static wrinkles. As stated earlier, It also delay the onset and progression of such wrinkles, and is a good adjuvant to transconjunctival lower blepharoplasty procedures or skin laser resurfacing. At least three injections on a vertical line are performed outside the lateral orbital margin. A dose of 5–10 units are usually needed (Fig. 7).

Lower lid Wrinkles
Fine small lower lids wrinkles can improve with BTX injections, however a combination of BTX

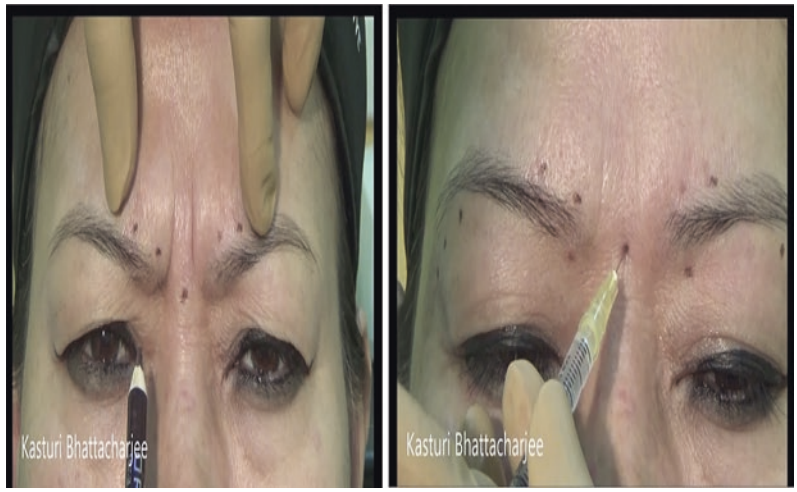

Fig. 6 Shows the classic inverted triangle injection site for the glabella

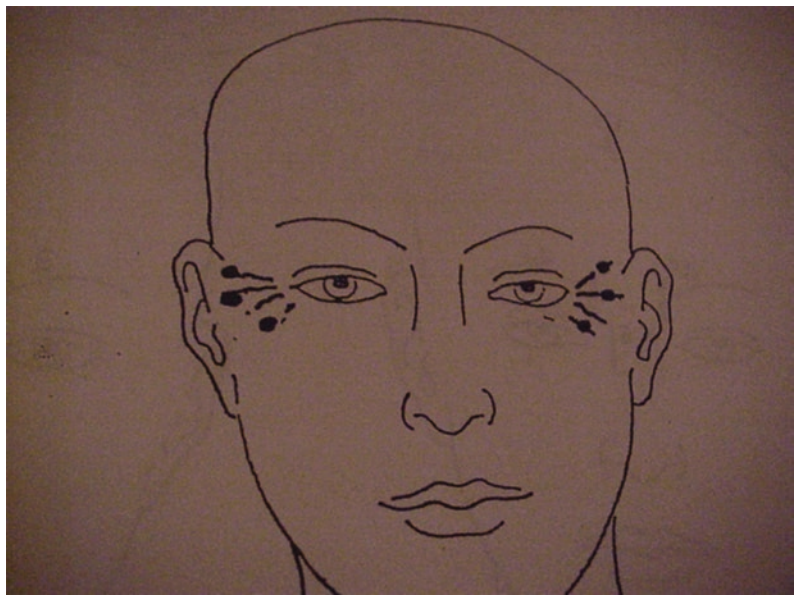

Fig. 7 Crow's feet injection

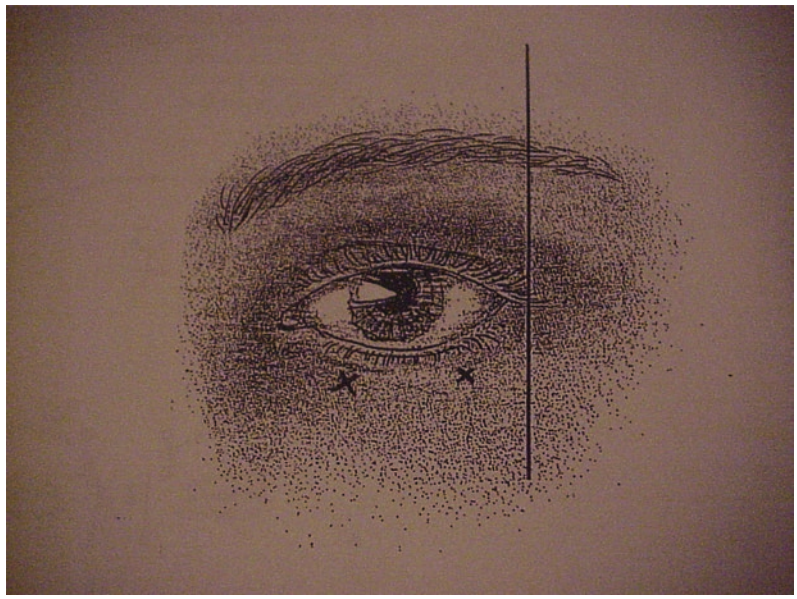

Fig. 8 Botox injection for orbicularis hypertrophy

and fillers or a blepharoplasty procedure is better performed for lower lids wrinkles or festoons in this area.

Orbicularis hypertrophy (Sausage roll orbicularis)

An orbicularis roll immediately below the lid margin (sausage shaped orbicularis) can be constantly present or more commonly appear on smiling. An injection of 2.5–5 units avoiding the medial part of the lid improves the condition (Fig. 8).

Brow lift and repositioning

By differential injections in the brow depressors and/or elevators, the position and shape of the eye brow can be altered to correct intrinsic or iatrogenic asymmetry of the eyebrows (chemical browplasty or brow lift).

Muscles acting on the brow are functionally divided into the elevator (the frontalis), the medial depressors (the medial portion of the orbicularis oculi, the corrugator supercilia, and the procerus), and the lateral depressors (the lateral portion of the orbicularis oculi). The rationale of treating brow asymmetry is to selectively target and reduce relevant muscle activity. For example, an eyebrow that is too high or too arched may be lowered by focally weakening the frontalis muscle that lies superior to it. To avoid overcorrection and ptosis, it essential to start with small doses. Reassessment after 10–14 days, with supplemental injections as needed, will minimize the risk of brow

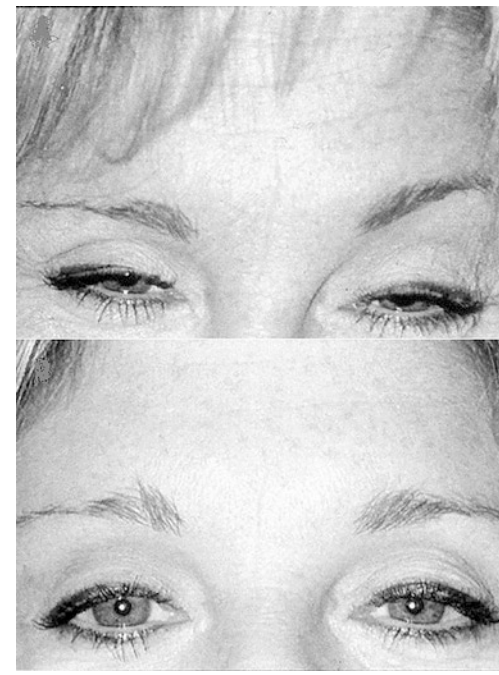

Fig. 9 Brow repositioning

ptosis. Alternatively, a "Jack Nicholson" brow is treated or prevented by injecting a small amount of BTX into the lateral frontalis muscles.

Avoiding the frontalis fibres directly above the central brow reduces the risk of brow ptosis, and if only the medial and lateral aspects of the frontalis are treated as described above, an aesthetically desirable arching of the central portion of the eyebrow can be achieved (Fig. 9).

Midface indications:

Upper gum show (gummy smile)

Show of the upper gum on smiling can be corrected by injection of the levator labii muscle on either side of the nares with 2.5 units (Fig. 10).

Vertical lip lines (Smoking lines)

Botulinum toxin may be used to reduce the perioral rhytids and to improve the lateral angle of the mouth. Injection in this area is less predictable than the rest of the face because the involved muscles are in constant action. A slightly larger dose can result in interference with eating, drinking, speaking and smiling resulting in temporary drooling or inability to pronounce certain letters properly. A very cautious approach to this area is recommended (Fig. 11).

Mental crease and notch

Injection into the mentalis muscle is used relax a peau d'orange chin and correct a mental crease.

Masseter Injection (Texas jaw line)

Injection of 20–40 units directly into the masseter muscle on either side helps slim the muscle and better define the jawline. This is also beneficial in patients with TMJ or those who clinches their teeth.

Cervical indications:

Vertical platysmal bands

These can be improved and flattened by injections of BTX on either side of the midline. Usually 3 injections on each side using 10–15 units

Post-treatment instructions

Patients are instructed to avoid hot showers, saunas, or other exposure to heat for 12 hours after injection. Exercise and facial massage or creams are avoided for 24 hours.

There is a strong evidence that the muscles injected needs to be moved repetitively immediately following an injection to improve the results and help spread the injected BTX.

Botuliunm toxin injection to high dynamic areas, such as the crow's feet and lips, may last 3 months, whereas less dynamic areas, such as the forehead or glabella, may last up to 6 months.

Complications such as diplopia, dry eyes, exposure keratitis, and lagophthalmos are unusual with cosmetic injections. If ptosis occurs due to diffusion to the levator muscle, alpha agonists

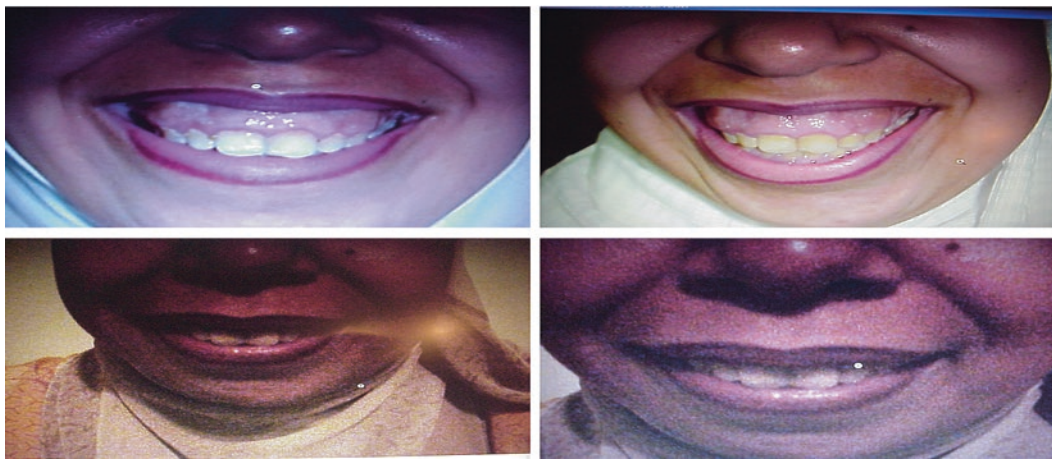

Fig. 10 Botox injection for gummy smile

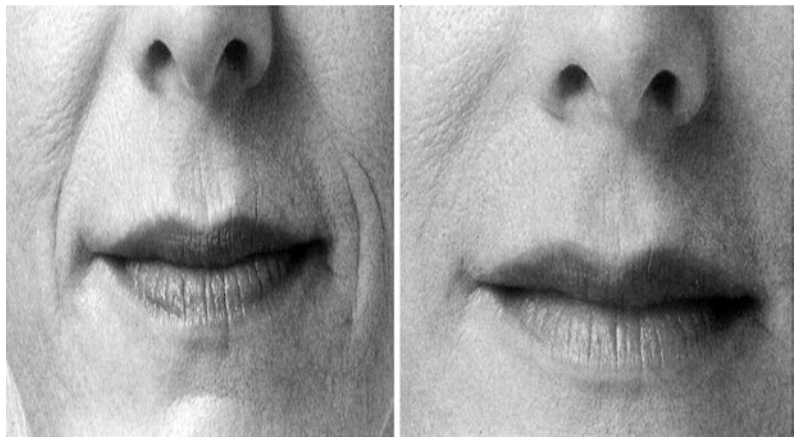

Fig. 11 Injections for the lips

as Apraclonidine can partially reverse the induced ptosis by contraction of Muller's muscle.

Patients are instructed to come for a touch up visit 7–10 days after the injection. Botox can be injected simultaneously with fillers at the same settings. It can be also injected in conjunction with other cosmetic procedures as surgery or laser.

The advantages of BTX are clear, it is a medical drug with dosages that can be calculated and adjusted. It is easy to perform, has a rapid action and requires few minutes to be performed (lunch-time procedure). When constantly used, it truly prevents signs of aging. Above all, it is a reversible procedure with no permanent side effect. The disadvantages include the fact that it needs to be repeated and the cost of the repeated injections.

Mesobotox Technique

This is a technique of multiple intradermal injections of botulinum toxin in diluted doses in a large surface including the face, neck and chest. This technique improves skin texture as well as facial contour in the injected area.

Baby Botox Technique

With the classic botox injections Patients are advised to return after 3–6 months when the effects have disappeared and return of muscle activity has occurred. The cycle is then repeated. With "Baby Botox technique" a much smaller dose is given in the same areas, then repeated at shorter duration (usually monthly). This results in a more stable effect with less variability as well as an overall reduced cost. It is also more effective in fine wrinkles and in younger patients and practically eliminates the possibility of a frozen look that could occur with the usual doses.

Soft Tissue Fillers

Fillers are substances used for augmentation of soft tissues or fill up the volume attrition due to subcutaneous fat loss associated with aging. With increasing age, the body's natural potential to produce hyaluronic acid as well as its inherent hygroscopy decreases thereby playing an important role in facial soft tissue atrophy. Fillers are primarily indicated for volume augmentation

and correction of static rhytides. They restore symmetry and the volume loss on the face. Soft tissue fillers help in re-augmentation of the depleting collagen, and support and lift the fat pads and ligaments.

Many substances like paraffin, mineral oil, lanolin, beeswax, vegetable oil, rubber and purified latex were used for cosmetic purpose but were found to have many undesirable side effects. Off label use of liquid silicone for facial augmentation was in vogue during the 1960s. It was not until 1980s that bovine collagen became the first FDA approved dermal filler for use in facial rejuvenation. The role of dermal fillers for facial aesthetics has revolutionised with the introduction of Hyaluronic acid (HA) fillers. The newer Hyaluronic Acid (HA) based agents has restored the interest in dermal fillers as they promise better outcomes with a lesser side effect The first HA filler approved by FDA was Restylane in 2003. Since then, HA fillers have been the crux for volume augmentation and facial rejuvenation.

Classification

Fillers can be classified depending on the material of origin, duration of effect, and reversibility. The different types of reversible and non-reversible fillers used in facial aesthetics have been elaborated by Kevin C. Smith (Table 1). Depending on the duration of effect they may be classified as short (less than 3 months), medium (3–12 months), long (12–24 months), or very long acting (more than 24 months).

Thorough knowledge of the anatomy of facial planes and its vascular supply is a must before attempting to inject the soft tissue fillers. The most severe complication apprehended with dermal fillers is vascular occlusion, leading to ischemia and necrosis of the skin and in

Table 1 Shows the classification of fillers. Adapted from Smith (2008)

Source	Example
Autologous	Fat
Biological	Collagen, Hyaluronic acid
Synthetic	Hydroxyapatite, silicone oil, polymethamethylacrylate microspheres, polyacrylamide hydrogel, hydroxyethyl methylacrylate/ethyl methacrylate, poly-L-lactic acid
Duration of cosmetic benefit	
Temporary short duration	Saline
Short duration	Bovine collagen
Reversible(medium to long duration)	HA
Nonreversible long duration	Hydroxyapatite, polyacrylamide hydrogel, porcine collagen
Nonreversible very long duration	Silicon oil, PMMA microspheres, hydroxyethylmethacrylate, ethylmethacrylate, poly-L-Lactic acid, Fat
Nonreversible variable duration	Fat
Risk profile	
Low	Saline, HA
Medium	Collagen, hydroxylapatite, PMMA microspheres, poly-L-Lactic acid, fat
High	Hydroxylapatite, polymethylmethacrylate microspheres, poly-L-lactic acid, fat, silicone, polyacrylamide hydrogel, hydroxyethyl methacrylate/ethyl methacrylate
Level of physician skill, training, experience, and judgment	
Low	Saline
Medium	HA, collagen
High	Hydroxylapatite, polymethylmethacrylate microspheres, poly-Llactic acid, fat, silicone, polyacrylamide hydrogel, hydroxyethyl methacrylate/ethyl methacrylate

worst case scenarios loss of vision. These situations call for a medical emergency and prompt management must be advocated. The main end artery for the face is the facial artery and hence it becomes important to understand its course and anastomoses with other vascular systems on the face. Higher risks of complications are entailed in regions of superficial location of the artery. Thus understanding of the facial blood vessels along with their course in different facial plane in the cheeks, glabella, nasal ala and temples regions are essential to be a safe injector (Fig. 12).

Hyaluronic Acid Derivatives (Ha)

Hyaluronic acid is a polysaccharide naturally occurring compound, which forms a part of the normal extracellular matrix of the dermis and connective tissue. Thus it is biocompatible with no immunogenicity. Its hydrophilic property and the ability to imbibe water, makes it a natural filler. HA is naturally unstable in its non-cross-linked form, and is rapidly degraded in the body. For commercial use it is cross-linked, which makes it more stabilized and resilient to degradation.

Various commercial preparations of HA differ according to the source, concentration, particulate size, cross-linking, type of crosslinking agent being used, and whether the HA is monophasic or biphasic, and if an anesthetic has been added. Each HA filler product has different manufacturing process resulting in different particle size, cohesively and crosslinking. Based on the amount of crosslinking, size and the concentration of HA molecule, HA fillers can be injected at different layers of the facial tissue. The injection technique as well the filler type needs to

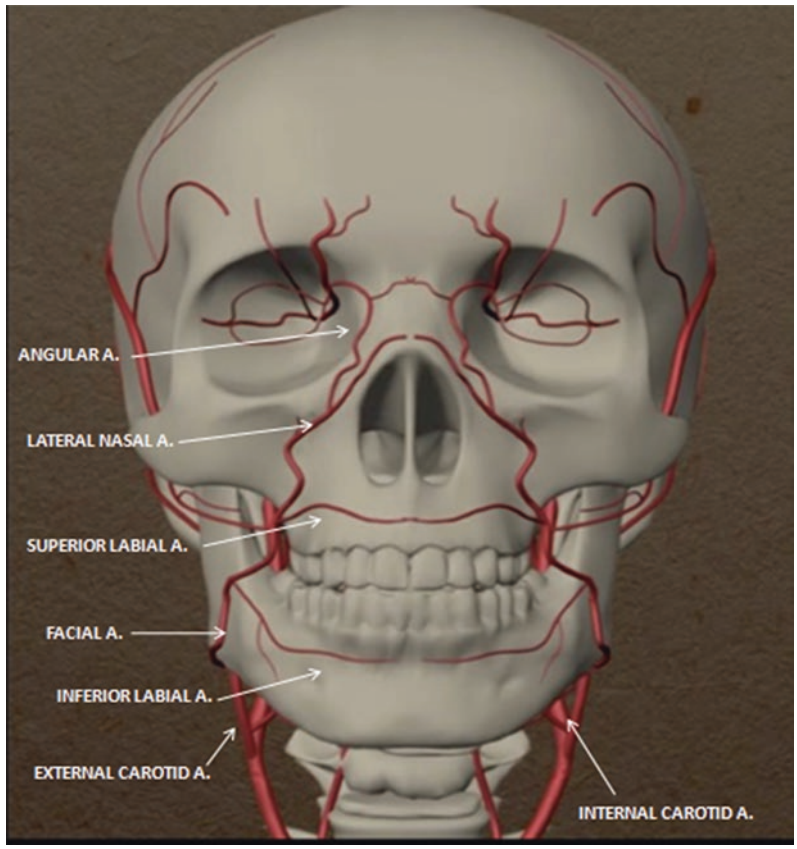

Fig. 12 Shows the facial blood vessels

be customized to the area is to be treated. For example for treatment of superficial fine wrinkles, less viscous HA is to be given, while for volume augmentation of the malar area or naso-labial fold, more viscous agents are preferred. Also lighter, more temporary materials are generally preferred in regions with thinner skin, such as the eyelids. HA may be associated with excessive local water sequestration. Thus, areas at risk for unacceptable visible edema such as the lower lids and lips should be treated conservatively.

It is always better to undertreat, as HA fillers tend to expand as they imbibe water overnight.

Advantages of HA fillers are include non-immunogenicity, non-requirement of skin testing, reversibility and a long lasting effect. A major advantage of hyaluronic acid filler rejuvenation is that its effect can be reversed or modified with diluted hyaluronidase injection.

Fillers are an excellent adjunct to botulinum toxin and in many cases, the combination is superior to surgery. An ideal combination is the administration of the neurotoxin to relax the muscles of facial expression and maximally reduce the dynamic lines, and subsequently, a filler is injected to further reduce any remaining static lines. Glabellar lines is a good example for such a combination.

Adverse effects include pain, bruising, edema, nodule formation, accidental intravascular injection, granuloma or even scarring. The use of blunt microcannula has minimized the risk of ecchymosis and virtually eliminated the risk of intravascular injection.

A bluish hue to the overlying skin (Tyndall effect) can occur if the injection is given too superficial and the skin is very thin. Modern fillers do not produce such an effect.

Although some degree of palpability is common immediately after injection, nodules arising or persisting after a few days should be addressed. They can be managed conservatively with dispersive massage, however for refractory nodules that use of diluted hyaluronidase injection.

Some of the common indications for its use are:

1. **Upper face**: Correction of glabellar lines, superior sulcus deformity, temporal fossa hollowing and forehead contouring
2. **Mid-face**: midface lift, correction of tear trough deformity, cheek augmentation, nose augmentation and contouring
3. **Lower face**: Lip augmentation, marionette lines, perioral rhytides, downturned oral commissures, and irregular chin lines, prejowl sulcus, redefining of jaw line and chin augmentation.

The **tear trough** is of particular interest to the oculoplastic surgeon. Tear trough deformities results from a combination of orbital fat herniation in the lower lid and skin tethering to the orbitomalar ligament. Adding volume, combined

Fig. 13 Injection of the tear trough courtesy of Dr. Jerry Popham, Denver, USA

with horizontal cutting (subcision) of the orbitomalar ligament skin adhesions with the injecting needle is performed. Injection is typically in a pre-periosteal plane and results in reversal of the double convexity deformity of the tear trough (Fig. 13).

Superficial, **fine lower lid lines** can also be treated by first performing parallel subcision with a sharp injection needle (e.g., 27 gauge) along the length of the lines, followed by injection of a thin hyaluronic acid through a finer needle, enabling filling of the fine superficial lines while avoiding lumps.

Fillers are also used in **periorbital hyperpigmentation** (black circles or halos).

Technique of filler injection

1% Lignocaine topical cream (Prilox, Elma, etc.) is applied 30 minutes prior to the filler injection. Cold compress and inferior alveolar nerve block have also been used for anaesthesia. The desired areas are then cleaned with isopropyl alcohol or chlorhexidine. Different techniques of injection have been elaborated-serial puncture, linear, crosshatching and fanning techniques (Fig. 14). In the serial puncture technique, multiple punctures are made and small boluses are injected in close proximity to each other. This is particularly useful for acne scars. The threading or linear threading technique achieves a similar effect by tunneling the needle beneath the defect and injecting while withdrawing. These techniques are useful for linear rhytides and nasolabial folds. Cross hatching again involves two perpendicularly placed injections in a linear fashion, while fanning technique utilises a single injection with multiple linear threads emanating from that point.

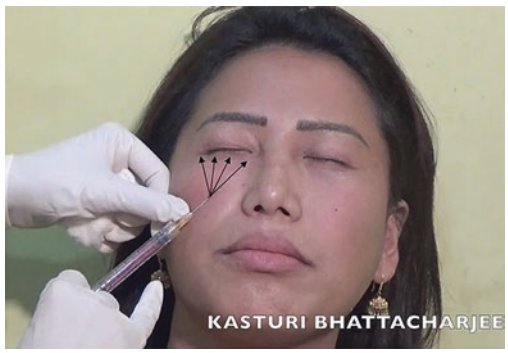

Fig. 14 Fanning technique of dermal filler injection. The use of a microcannula is recommended

Platelet-rich plasma

This has been used in treating dark circles. Platelet-rich plasma has the potential to act as a stimulant for fibroblast proliferation and collagen release. It can improve color homogeneity, tear trough deformity and wrinkles. It is also injected around the lacrimal gland to stimulate tear secretion in cases of dry eyes.

Lipodissolvants

Deoxycholic acid (bile acid derivative) has been FDA approved for use in the management of chin fat for several years with excellent efficacy and safety. It is being used off label to as a non-surgical treatment of lower eye lid fat pads, particularly in young patients with no overlying wrinkles. Patients usually receive 2–4 ml of 10 mg/ml deoxycholic acid injection within the infra orbital fat pads. Two to three injected, one month apart are usually needed. Because of its propensity to provoke an inflammatory response, it is combined with triamcinolone and lidocaine.

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Body Dysmorphic Disorder

Noha El Toukhy

The number of patients with body dysmorphic disorder (BDD), a mental disorder where patients spend the majority of their time worrying about slight or un-noticeable flaws in their appearances, has greatly increased over the past decades, according to cosmetic surgeons. While cosmetic surgeries have become more popular than ever over the past decades, physicians in this field have reported their frequent encounter of body dysmorphic patients. It is important to understand that patients struggling with BDD are in need of psychological assistance, not surgical help. These patients do not need surgeries, but instead, should be referred to psychologists, who would work on the patients' sense of self perception and self-esteem. A deeper understanding of BDD will allow physicians to make the correct medical calls and refer BDD patients to psychological facilities, instead of operating on them.

Identifying patients with this disorder is the first step to combatting this problem. This is achieved by diagnosing BDD patients according to the following diagnostic criteria: (1) obsessive thoughts surrounding a perceived flaw in one's appearances that others can hardly identify, most commonly of facial features; eyes, eyelids, nose or lips (2) repetition of behaviors related to self-checking/looking at flaws in the mirror, or constant comparing to others, and lastly, (3) preoccupations with the previously mentioned behaviors in a way that conflicts with one's ability to live his or her normal lives. A red flag is the history of the number of a patient's cosmetic surgeries, for these patients have often undergone numerous surgeries within short periods of time (Fig. 1).

Additionally, these patients often have unrealistic expectations about their desired cosmetic procedures and are insistent on getting the surgeries, refusing to compromise, or refusing to allow their physicians to convince them otherwise. Ultimately, reports have proven that the level of distress in the patient around his or her flaw is the most reliable measure of body dysmorphic disorder. Screening these patients if any of these signs are evident is beneficial, for there are numerous tests and assessments that can guide physicians to refer these patients to mental health institutions e.g. BDD questionnaire and Dysmorphic Concern Questionnaire (DCQ) assessments. A special dermatology version of the former called BDDQ-DV is a brief screening tool that a patient can complete in less than 3 minutes while in the waiting room.

While the disorder mainly affects young or middle aged, type A, high intellectual, competitive, or self-conscious individuals, it equally effects women as it does men. In terms of the frequencies of occurrence, while this disorder is

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_19

Fig. 1 Reprinted with permission from Project LSTS, Westbury, New York

often times underreported and underdiagnosed, it is believed that about 14% of patients who are classified as aesthetic procedure seekers suffer from BDD.

Because these patients' treatment is heavily dependent on psychotherapy and psychological support, cosmetic surgeons have been more wary and cautious of their response to these patients, as a means of avoiding legal or safety issues. While patients believe that their desired surgery will magically fix their appearance and their perceived "flaw", physicians' approval of the surgeries, when there is evidently no flaw that requires fixing, will only further reinforce the disorder within patients, for they will immediately start demanding more procedures. Studies have shown the 84% of plastic surgeons have operated in BDD patients. It is vital for the physicians to distinguish between the patient's disordered thoughts and the cosmetic preferences that the patients are desiring, especially because if the patient is dissatisfied with the outcome, he or she might become aggressive and threaten the physician. Since physicians will continue to encounter more BDD patients and the number of BDD patients will only increase, a high level of suspicion is needed and even BDD screen tools and assessments should be severely considered, before operating on such patients. Unwanted legal complications can be avoided if physicians read more about this disorder and are more aware of the increasing number of BDD patients.

Since BDD is a psychological disorder, its treatment can be achieved through Cognitive Behavior Therapy (CBT), prescription drugs such as Selective Serotonin Reuptake Inhibitors (SSRI), or group therapy sessions, not plastic surgeries.

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Part IV
Lacrimal Disorders

Dry Eye Disease

Rashmi Deshmukh and Essam A. El Toukhy

Dry eye disease (DED) is one of the common disorders of the eye with an estimated prevalence of 5.5–33.7% worldwide. The Dry Eye Workshop (DEWS II) in 2017, defined dry eye syndrome (DES) as:

> A multifactorial disease of the ocular surface characterized by a loss of homeostasis of the tear film, and accompanied by ocular symptoms, in which tear film instability and hyperosmolarity, ocular surface inflammation and damage, and neurosensory abnormalities play etiological roles.

Tear Film

The tear film is a simple fluid that coats the eye and protects the ocular surface. A healthy tear film is essential for normal functioning and health of the eye. Normal tear film consists of aqueous, mucin and lipid layers. Various epithelial and glandular tissues (cornea, bulbar and palpebral conjunctiva, and lacrimal and accessory eyelid glands) of the ocular surface, contribute in the secretion of tear film.

Dry eye disease can occur due to the following mechanisms:

1. Reduced tear production
2. Increased tear film evaporation
3. Mixed mechanism

The dry eye disease spectrum can be classified as:

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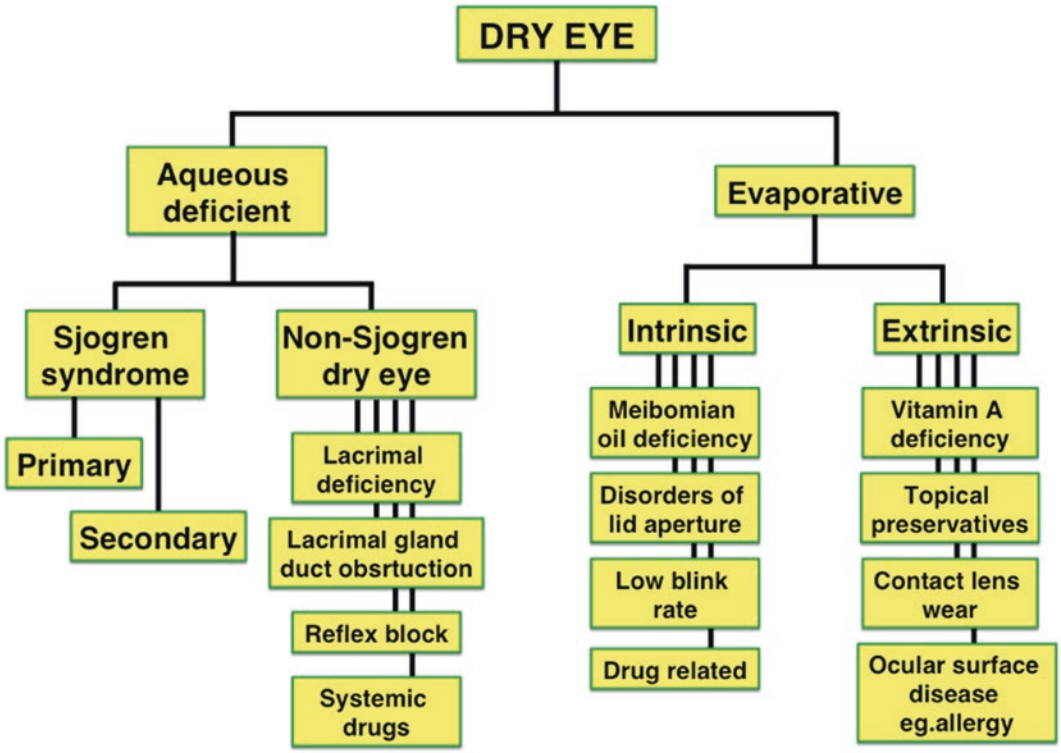

Aqueous Deficiency Dry Eye Disease

(a) Sjogren Syndrome: It is an auto-immune exocrinopathy affecting lacrimal and salivary glands.

(b) Non-Sjogren Dry Eye: It is a lacrimal dysfunction where the systemic autoimmune features have been excluded.

(i) **Sjogren Syndrome**:

Sjogren syndrome (SS) is the second most common autoimmune rheumatologic disease. It is characterised by lymphocytic infiltration of the lacrimal and salivary glands resulting in the "classic sicca complex" of dry eye (keratoconjunctivitis sicca) and dry mouth (xerostomia).

Types of Sjogren syndrome:

(a) Primary Sjogren Syndrome: Features of SS without any associated systemic connective tissue disease.

(b) Secondary Sjogren Syndrome: Features of primary SS along with features of systemic autoimmune diseases like rheumatoid arthritis (RA), systemic lupus erythematosus (SLE), PAN etc.

(ii) **Non-Sjogren Dry Eye Disease**:

There are various causes for Non-Sjogren Dry Eye Disease.

(A) Lacrimal gland deficiency:

It is characterised by a lacrimal glad dysfunction. It can be divided into:

(a) *Primary Lacrimal Gland Dysfunction*: Caused by age related dry eye resulting from periductal fibrosis, acinar cell loss; use of hormone replacement therapy, congenital alacrimia (Riley-Day syndrome).

(b) *Secondary Lacrimal Gland Dysfunction*: Caused by lacrimal gland infiltration secondary to sarcoidosis, lymphoma, amyloidosis, hemochromatosis.

(B) Lacrimal gland obstruction: This is characterized by obstruction of lacrimal gland ducts such as in cases of cicatrizing conjunctivitis caused by trachoma, mucus membrane pemphigoid, chemical and thermal burns.

(C) Reflex Block: A reflex sensory block is seen in cases with impaired neurosensory pathways such as diabetes mellitus, neurotrophic keratitis. This contributes to dry eye in two ways. A reduced reflex-induced lacrimal secretion, and an increased evaporative loss caused by reduced blink rate.

(D) Drug-induced: Long term use of certain drugs has been shown to cause dry eye disease. These include beta-blockers, selective serotonin reuptake inhibitors (SSRIs) and anti-histamines.

Evaporative Dry Eye Disease

Evaporative dry eye disease is characterised by a normal tear film production and secretion, but an increased tear film evaporation from the surface. This could be caused by intrinsic and extrinsic factors.

(A) Intrinsic factors

(a) Meibomian gland dysfunction (MGD): It is defined as a chronic, diffuse abnormality of the meibomian glands, commonly characterized by terminal duct obstruction and/or qualitative/quantitative changes in the glandular secretion.

Types of MGD:

1. *Low-delivery type or Obstructive type*: Keratinized plugs at the gland orifices secondary to squamous metaplasia of the epithelium causes inspissation of lipids and cell debris within dilated ducts. Consequently, there is absence/hyposecretion of meibum and gland atrophy.
2. *High-delivery type or Seborrheic type*: In this type of MGD, hypersecretion of meibum causes inflammation of the ocular surface. There are no morphological changes seen in the meibomian glands.

(b) Disorders of the lid aperture: Increased tear film evaporation is seen in cases of lagophthalmos, proptosis and craniosynostosis where there is increased lid aperture or incomplete closure of the lids.

(c) Low Blink rate: A low blink rate is a physiological phenomenon that occurs during performing certain tasks like working on a computer (computer vision syndrome). Neurological diseases like Parkinson's disease also cause blink rate to reduce.

(B) Extrinsic factors

Extrinsic factors causing ocular surface damage and subsequent dryness and keratinization are known:

(a) Chronic ocular surface disease like allergic conjunctivitis, vernal catarrh, contact lens wear etc.

(b) Nutritional deficiencies: Nutritional imbalance has been shown to increase the oxidative stress affecting the ocular surface, and supplementation of these nutrients has promising results in the treatment of DES.

1. **Vitamin A deficiency**: Vitamin A deficiency is a leading cause of childhood blindness all over the world. It is most prevalent in developing countries where most children suffer from malnourishment and infectious disorders. Among adults, it is known to occur as a result of intestinal malabsorption, liver diseases and poor dietary intake. The spectrum of ocular disease arising from vitamin A deficiency is known as *xerophthalmia.* Ocular changes include conjunctival and corneal drying (xerosis), corneal ulceration and melting (kerotomalacia), night blindness (nyctalopia) and retinopathy. Vitamin A deficiency is associated with a high degree of morbidity and mortality, mainly because affected children are more susceptible to respiratory and intestinal infections.

Pathophysiology

Vitamin A is a fat-soluble vitamin that is ingested as carotene from plant sources (green leafy vegetables, red palm oil, yellow fruits) and as retinol from animal sources (fish, eggs, milk, meat, liver). It is absorbed from the small intestine. Within the intestinal mucosal cells,

carotene is converted to retinol. Along with already absorbed retinol, it is esterified to palmitic acid. Retinyl palmitate is then transported via lymphatics to the liver, where it is stored. When metabolic requirement of vitamin A arises, retinyl palmitate is hydrolysed and reconstituted to retinol. This retinol is attached to retinol-binding protein (RBP) and transported via bloodstream to the target tissue.

Vitamin A has two roles in ocular metabolism. First, in the retina, vitamin A serves as a precursor to the photosensitive visual pigments that participate in the initiation of neural impulses from the photoreceptors. Second, it is necessary for conjunctival epithelial cell RNA and glycoprotein synthesis, which help to maintain the conjunctival mucosa and corneal stroma.

Vitamin A is essential for maintaining the visual pigments in both rods and cones. In rod cells, retinal combines with the protein opsin to form the photosensitive pigment called rhodopsin. When light hits the rod cells, there is isomerization of the retinal to initiate the visual signal. The pigment is broken down to opsin and all-trans retinal. The correct geometrical form of retinal has to be reconstituted to combine with opsin to reform the pigment. However, in this process, some of the retinal always is lost, so a constant source of vitamin A must be available for adequate levels of rhodopsin and optimal rod function.

Vitamin A is also needed to maintain mucosal and epithelial surfaces. Lack of vitamin A causes loss of goblet cells and inappropriate keratinization of epithelium. Also, the colliquative necrosis of the substantia propria of the cornea results in keratomalacia.

Ocular Manifestations

Table.
World Health Organization Reclassification of Xerophthalmia Signs

Classification	Ocular Signs
XN Night blindness	
X1 Conjunctival xerosis	• X1A Conjunctival xerosis • X1B Bitot's spots
X2 Corneal xerosis	
X3 Corneal ulceration-keratomalacia	• X3A Corneal ulceration-keratomalacia involving one-third or less of the cornea • X3B Corneal ulceration-keratomalacia involving one-half or more of the cornea
XS Corneal scar	
XF Xerophthalmic fundus	

Night Blindness

Night blindness is the earliest sign of Vitamin A deficiency. Subclinical deficiency can be diagnosed by using electroretinography and dark adaptation study, which shows impaired retinal function. Night blindness usually responds within 24–48 hours of Vitamin A administration.

Conjunctival manifestations

Vitamin A deficiency leads to loss of mucosal goblet cells and keratinization of the conjunctival epithelium. The term "xerosis" is used to describe this dryness. Conjunctival xerosis (X1A) is found typically in the temporal, interpalpebral, bulbar conjunctiva. It appears as a dry, granular patch with loss of transparency, thickening and wrinkling. It stains with Rose Bengal.

Bitot's spots (X1B) are triangular, gray plaques of keratinized conjunctival debris overlying areas of conjunctival xerosis. They are occasionally found in individuals with normal vitamin A levels too. When these are associated with vitamin A deficiency, they tend to disappear with treatment.

Corneal Manifestations

The earliest corneal manifestation is a loss of the corneal sheen and a resultant dull appearance of the cornea with superficial punctate keratopathy.

This occurs due to an unstable tear film and if left untreated, the keratopathy progresses to epithelial defects, stromal edema, and keratinization in the interpalpebral fissure. Corneal epithelial defects can progress to ulcers. These ulcers are characteristically small, with sharp borders and located nasally in the peripheral cornea. They may progress to involve the visual axis and may get secondarily infected. A full-thickness liquefactive necrosis may occur and is termed as "keratomalacia". Clinically, it appears as a grayish-yellow, opaque, sharply demarcated lesion. Vitamin A supplementation speeds healing and often, it is associated with a preceding systemic stressor, such as measles, diarrhea, or respiratory infection, or with concurrent severe protein-energy malnutrition.

Xerophthalmic Fundus

Appearance of yellow and white dots in the periphery indicating structural damage to the retina, although rare, is known to occur in xerophthalmia. These dots indicate retinal pigment epithelium defects. Rarely, patients can present with scotomas corresponding to the area of retinal involvement. These changes can respond to vitamin A therapy, with scotomata disappearing in 1–2 weeks and retinal lesions fading in 1–4 months.

Vitamin D

Vitamin D and its role in the etiopathogenesis of dry eye disease has been the subject of a many recent reseach publications. Studies have demonstrated the association of vitamin D deficiency with DED. Vitamin D exhibits anti-inflammatory and immunoregulatory properties and its deficiency results in inflammatory or immune mediated dryness of the eyes. It can influence the severity of symptoms by modulating nociception by regulating nerve homeostatis and inflammatory responses. The exact mechanism linking Vitamin D to pain remains elusive however several theories have been put forward. Serotonin which can perpetuate chroin pain response was found to be high in patients with DED and vitamin D is known to affect serotonin synthesis indicating a role of vitamin D in nociception. Studies have shown that Vitamin D decreases nitric oxide, a nociceptive neurotransmitter production and resulting hyperinnervation there by modulating pain. Vitamin D and its agonists have been found to inhibit maturation and induce tolerance in dendritic cells resulting in the arrest of inflammatory processes. Lower vitamin D levels were associated with an increase in DCs with dendritic processes (mature phenotype) in our cohort which supports the current understanding regarding the immunomodulatory role of vitamin D on DCs. Vitamin D also modulates the expression of various inflammatory cytokines in various cells, including corneal epithelial cells substantiating the anti-inflammatory/immunomodulatory functions of vitamin D.

Essential Fatty Acids

The Dry Eye Workshop demonstrated that the pathophysiology of DES was associated with an inflammatory mechanism. MGD is associated with altered lipid composition, dietary supplementation with antioxidants like omega-3 fatty acids has been recommended in both the International Dry Eye Workshop and International Workshop on Meibomian Gland Dysfunction as primary therapy.

Essential fatty acids, including the omega-3 fatty acids docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), perform numerous roles in the human body and are considered essential nutrients.

Clinical studies have shown the beneficial role of omega-3 FAs in tear function parameters, such as the Schirmer test, tear film break-up time, and fluorophotometry, indicating that omega-3 FAs increase tear secretion and decrease the rate of tear evaporation.

O3FA and O6FA are the precursors of eicosanoids that function as lipid-based inflammation regulators.

Eicosanoids derived from O3FA are anti-inflammatory, decreasing inflammation and apoptosis of the acini and secretory epithelial cells of the lacrimal glands, resulting in increased secretory function of the lacrimal glands and tear production. They also retard evaporation of the tear film through restoration of the lipid layer, by clearing meibomitis, and resulting in secretion of a better quality, more fluid lipid.

Eicosanoids derived from O6FA are pro-inflammatory.

Combined use of O3FA and O6FA could achieve better protective effects against DES. Also the balance between O3FA and O6FA in the supplement is important because they function synergistically

O3FAs in a dose of 2,400 mg/day for 45 days does improve dry eye symptoms and tear film stability.

However, the role of Omega 3 fatty acids has been challenged currently and is becoming controversial with a large number of studies indicating that it does not have a beneficial effect in evaporative dry eye.

Other nutrients

Vitamin C helps to regenerate other anti-oxidants like vitamin E. These help in maintaining the blood vessels and connective tissues and helps in free-radical scavenging. Free radicals are responsible for damage of conjunctival and corneal epithelium and tear-secreting tissues.

(c) Chronic Anterior Blepharitis

It affects the area surrounding the base of eyelashes. It could be staphylococcal or seborrheic. Staphylococcal blepharitis is known to be caused by coagulase negative staph or *S. aureus*. It is characterised by scaling, crusting, erythema of the eyelid margin with collaret formation at the base of the cilia. Seborrhoeic variety is marked by greasy scaling of eyelid and is associated with seborrheic dermatitis of eyebrows and scalp.

Diagnosis

History and symptoms:

(a) Abnormalities in tear film cause symptoms like dryness, grittiness, soreness, redness, photophobia and ocular fatigue. These symptoms may or may not correlate with the severity of the disease with regard to tear film metrics. Increasing age and long-term contact lens wear decreases corneal sensations and may result in symptoms that are disproportionate to the severity of the disease.

(b) Examination of the lids is mandatory in all cases. Abnormalities in the eyelid position and blink rate, punctal ectropion or stenosis, the presence of any blepharitis with scaling or lash inflammation should be noted. meibomian glands should be expressed by gentle pressure and its secretions should be clear or slightly yellow and express easily. In a patient with gross epiphora, it is mandatory to irrigate the lacrimal passages

Subjective tests:

Validated questionnaires allow quantification and scoring of symptoms and consist of a series of questions with numerical values attributed to the answers. This ensures consistency in recording systematic information. Furthermore, the scores can be correlated with various imaging and tear film metrics to determine changes that are strongly associated with ocular symptomatology. Few of these validated questionnaires are:

1. Ocular surface disease index (OSDI)
2. Impact of Dry Eye on Everyday Life questionnaire (IDEEL)
3. Standard Patient Evaluation of Eye Dryness (SPEED)
4. Dry Eye Questionnaire
5. McMonnies Questionnaire.

OSDI and SPEED are two questionnaires which are frequently used.

Have you experienced any of the following *during the last week*?	All of the time	Most of the time	Half of the time	Some of the time	None of the time
1. Eyes that are sensitive to light? . .	4	3	2	1	0
2. Eyes that feel gritty?	4	3	2	1	0
3. Painful or sore eyes?	4	3	2	1	0
4. Blurred vision?	4	3	2	1	0
5. Poor vision?	4	3	2	1	0

Subtotal score for answers 1 to 5 (A)

Have problems with your eyes limited you in performing any of the following *during the last week*?	All of the time	Most of the time	Half of the time	Some of the time	None of the time	N/A
6. Reading?.	4	3	2	1	0	N/A
7. Driving at night?	4	3	2	1	0	N/A
8. Working with a computer or bank machine (ATM)?.	4	3	2	1	0	N/A
9. Watching TV?	4	3	2	1	0	N/A

Subtotal score for answers 6 to 9 (B)

Have your eyes felt uncomfortable in any of the following situations *during the last week*?	All of the time	Most of the time	Half of the time	Some of the time	None of the time	N/A
10. Windy conditions?.	4	3	2	1	0	N/A
11. Places or areas with low humidity (very dry)?	4	3	2	1	0	N/A
12. Areas that are air conditioned?. . .	4	3	2	1	0	N/A

Subtotal score for answers 10 to 12 (C)

Fig. 1 Ocular surface disease index questionnaire

The OSDI is a 12-item questionnaire that assesses both dry eye symptoms and their effects on vision (Fig. 1).

It has a Likert design and assesses frequency of ocular symptoms (soreness, blurred vision), difficulty with vision-related function (television, visual display unit, driving, reading) and discomfort due to environmental triggers (low humidity, high wind). Patients are asked about the frequency of occurrence of various symptoms and difficulty encountered with vision-related activities and for their response on a 0–4 scale that ranges from "none of the time" to "all of the time." The final score is calculated by multiplying the sum of all the scores by 25 and then dividing the total by the number of questions answered. Scores range from 0 to 100 with 0 to 12 representing normal, 13–22 mild dry eye

disease (DED), 23–32 moderate DED, and more than 33 severe DED.

Limitations of the OSDI include variation of difficulty between categories of questions, no linear relationship of the results to symptom severity, and analysis issues from the use of ordinal ranking. The final percentage score may also be artificially high when difficult questions are not answered or deemed not applicable by the patient.

The SPEED (Standard patient evaluation of eye dryness) questionnaire is a frequently used questionnaire. It is quick and easy to perform and detects severity of disease as well.

- **Objective tests**

I. **Quantitative tests**:

a. **Schirmer's test**: It is done to assess the aqueous tear production. It is an invasive test in which a strip of filter paper (5 × 35 mm Whatman filter paper) is placed in lower conjunctival cul-de-sac and measurement of wetting length is done over a certain period of time, usually 5 min. There are two commonly used variants of Schirmer's test.

Schirmer's I: measures the total tear production including both basal and reflex tears. Jones modification of this test can measure only basal secretion with the aid of an anaesthetic agent.

Schirmer's II: Schirmer II test is performed by irritating the nasal mucosa with a cotton-tipped applicator prior to measuring tear production, which is mainly used for measuring the reflex tear secretion of main lacrimal gland.

A value of less than 5 mm wetting in 5 minutes is considered abnormal for both tests. A 1-minute (with anesthesia) and 2-minute Schirmer test has been suggested, with cut-offs of 6 mm and 10 mm respectively (99% confidence interval). It has been found to lack accuracy and reproducibility.

b. **Phenol Red test**: The phenol red thread is less invasive than the Schirmer's test (although more difficult to perform) and has been described as an index of tear volume. A cotton thread impregnated with phenol red dye is used. The thread is inserted for 15 seconds and the dye, which is pH sensitive, turns color from yellow to red when wetted by tears. The crimped end of a 70 mm thread is placed in the lower fornix. After 15 seconds wetting length is measured which normally is between 9 and 20 mm. A value of less than 9 mm indicates dry eye. Several studies have found the phenol red test to be more repeatable than the Schirmer test (with and without anesthestic) as well as more reliable in diagnosing dry eye (Fig. 2).

c. **Meniscometry**: Tear meniscus height and radius are amongst the best indicators of dry eye. This can be measured using slit-lamp, micrometer, keratograph or Fourier domain ocular coherence tomography (FD-OCT). The average tear meniscus height measured with the keratograph and FD-OCT is 0.232 ± 0.074 mm and 0.308 ± 0.129 mm, respectively. Heights of less than 0.2 mm indicate reduced tear fluid quantity.

d. **Tear turn over**: It is defined as the rate at which newly secreted tears reside within the tear film before they are lost either to evaporation or drainage through the lacrimal puncta and the nasolacrimal ducts. Tear volume and turnover are most accurately measured by dye dilution studies.

In this method, a small amount of fluorescein dye is instilled into the tear film and the

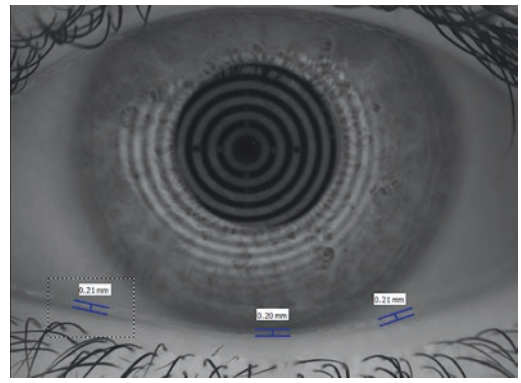

Fig. 2 Tear meniscus height on Oculus Keratograph

concentration of the dye is measured over time. Gamma scintigraphy and fluorophotometry use the electromagnetic spectrum to monitor a tracer molecule in the tear film.

An alternative, inexpensive method of semi-quantitatively grading fluorescein dilution can be done by instilling 5 μL of 1% fluorescein dye into the tear film. The patient is asked to blink to distribute the dye and serial 1-minute Schirmer's tests are performed every 10 min. Initially, the staining of the paper strip with the dye will be intense. Persistent staining (beyond 10 minutes) indicates delayed tear clearance (DTC).

II. **Qualitative tests**:

a. **Tear break-up time**: The tear break-up time (TBUT) is defined as the time interval between a complete blink and the first appearance of a dry spot in the tear film after preservative free fluorescein administration. A TBUT of less than 10 seconds suggests tear film instability, and less than 5 seconds suggests definite dry eye.

Factors, which reduce the reliability/reproducibility of this test, include:

- Volume of fluorescein administered
- Preservatives, such as benzalkonium chloride, shorten the BUT.
- Superficial punctate keratopathy.

There are nonfluorescein (noninvasive) measurements of BUT that employ reflective devices with a grid projected onto the corneal surface. These values are slightly higher that the invasive technique. Instruments such as a Keratometer, hand-held Keratoscope or Tearscope are required to measure NIBUT. A pre-rupture phase that precedes actual break up of the tear film can also be observed with some techniques. This pre-rupture phase is termed Tear Thinning Time (TTT). Measurement is achieved by observing the distortion (TTT) and/or break up (NIBUT) of a keratometer mire (the reflected image of keratometer grid). The clinician focuses and views the crisp mires, and then records the time taken for the mire image to distort (TTT) and/or break up (NIBUT). NIBUT measurements are longer than fluorescein break up time. NIBUT values of less than 15 seconds are consistent with dry eyes (Fig. 3).

b. **Tear film interferometry**:

When white light is projected over the cornea, a color interference pattern is produced due to specular reflection at the lipid-aqueous interface. An appropriately thick lipid layer spans the tear surface in a continuous manner whereas a thin lipid layer degenerates into discontinuous patchy regions denoting an unstable tear film.

The technology of interferometry has also been applied in a kinetic fashion in evaluating

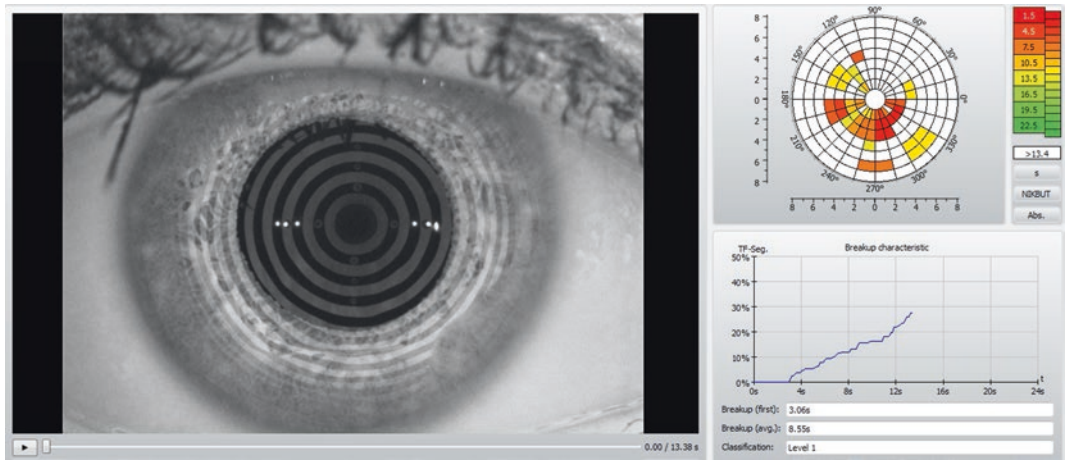

Fig. 3 Non-invasive keratograph break-up time (NIKBUT) measured on Oculus Keratograph

the spread of lipids through the tear film with blinking. LipiView (TearScience Inc., Morrisville, NC) is a commercially available interferometer that provides quantitative values of the tear-film lipid layer thickness (LLT), and this automated assessment of the LLT might be a suitable screening test for detecting meibomian gland dysfunction (MGD). LipiView uses interferometry to measure the lipid layer's thickness between blinks, and gives a quantitative assessment in interferometric color units, which are close to, nanometers. Studies of lipid layer thickness have found a connection between a patient's lipid layer thickness and his dry-eye symptoms. Patients with severe dry-eye symptoms have a LLT of 60 nm or less. On the other end of the spectrum, patients with no symptoms have a LLT of 75 nm or thicker. Several other commercial devices have been available as well.

Blink rate and number of partial blinks can also be studied using the LipiView device. This can be used to counsel patients with evaporative dry eye to maintain better blink patterns to prevent rapid evaporation of the tear film (Fig. 4).

c. **Tear Osmolarity**: An increase in tear osmolarity is seen in patients with dry eyes. Osmolarity values greater than 308 mOsm/L are a sensitive indicator of mild dry eye and values greater than 312 mOsm/L are indicative of moderate to severe dry eye (sensitivity 73%; specificity 92%). Tear film osmolarity can be measured in three ways: freezing point depression (FPD), (considered to be the gold standard); vapor pressure and electrical conductivity or impedance. Since the electrical impedance of tear samples requires a small sample size (0.05 μl) and short test duration (30 seconds), it is considered more suitable for clinical use.

The TearLab osmolarity system, based on electrical impedance, collects a 50-nL tear sample and provides instant assessment of tear osmolarity using a test card. The test card serves two purposes. First, it can be used to collect tears through a microfluidic channel so that evaporation of fluid is eliminated. Second, it presents tear osmolarities as numerical values. The TearLab osmolarity system has proven to be an accurate and reliable laboratory tool for the detection of dry eye syndrome (Fig. 5).

d. **Meibography**: Meibography is the only clinically in vivo technique to visualize the morphology of the meibomian glands (Fig. 6).

Tapie used a diaphanoscope with a red-light filter to transilluminate the lids and a slit lamp microscope to observe the Meibomian glands. Mathers et al. were the first to refer to Infra-red

Fig. 4 Interferometric pattern showing a healthy and poor lipid layer in the tear film

Fig. 5 Tear lab osmometer (courtesy of Tearlab Inc., Escondido, California)

photography of meibomian glands as ''meibography''. Noncontact meibography with infra-red transmitting device was first used by Arita et al. in 2008. Various type of Meibography techniques currently available are:

1. ***Infra-red meibography***
   Infrared meibography is the technology most commonly utilized in contact and noncontact techniques. Phoenix (Version 2.5) by Costruzione Strumenti Oftalmici (CSO, Florence, Italy)), Oculus Optikgeräte GmbH (Wetzlar, Germany), Bosch infrared camera, Topcon SLM system mounted on slit lamp are some of the most widely used devices for meibography. Even an autorefractometer can be used to evaluate the Meibomian glands.
2. ***Laser Confocal Meibography***
   It has the ability to resolve and characterize the microenvironment and microscopic structures of the meibomian glands. However, it is more invasive than infrared meibography. Periglandular inflammatory cell infiltrates and periglandular fibrosis were observed in obstructive type of MGD
3. ***OCT based meibography***
   OCT based meibography (OCTM) is a noninvasive method capable of obtaining 2-D and 3-D tomograms of the meibomian glands in vivo. The distinguishing feature of OCTM from other forms of meibography is the capability to quantify meibomian gland morphology volumetrically.

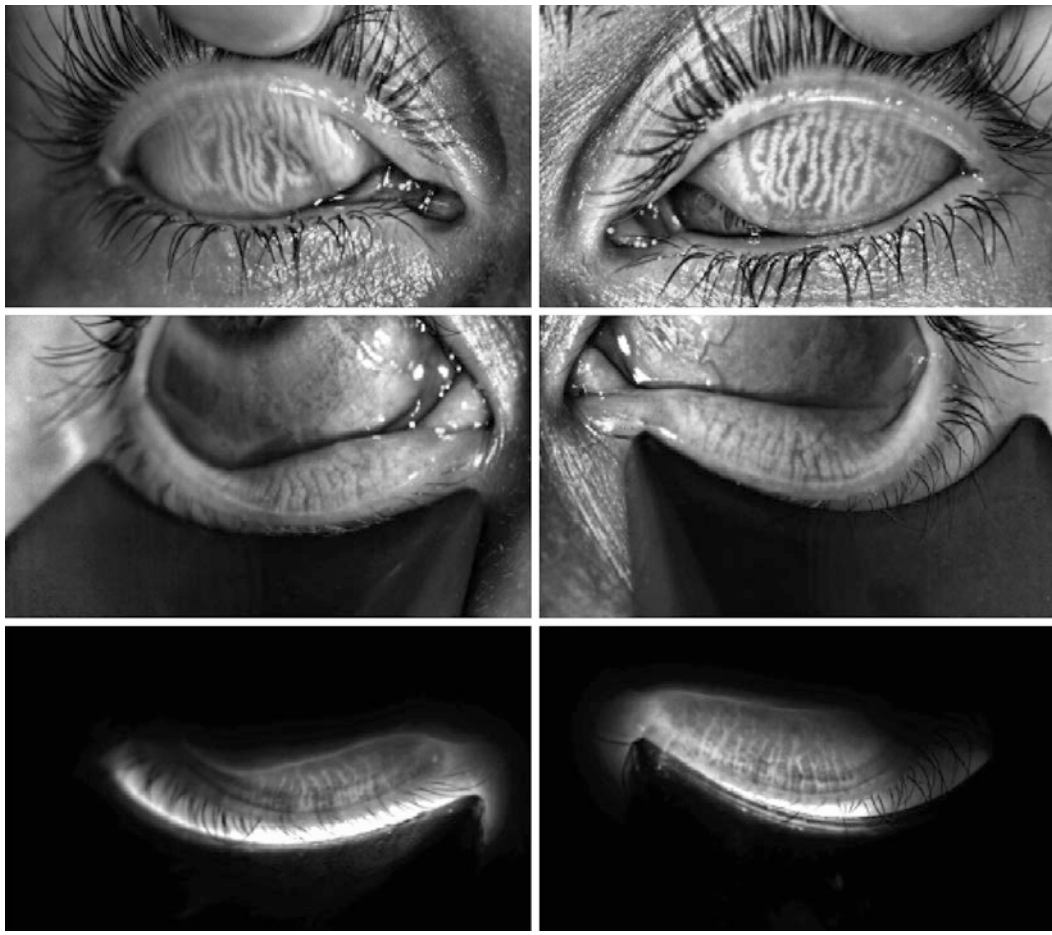

Fig. 6 Image of Meibomian Glands Meibomian gland on Lipiview II

Meiboscore

It was first proposed by Arita et al. in 2008. Graded based on the presence of gland drop outs.

(0): lid has no partial or missing glands
(1): involved lid area is <33%
(2): involved lid area is 33–66%
(3): involved lid area is >66%.

Meiboscores for the upper and lower lid are summed to derive a total meiboscore from 0 to 6 for each eye.

Meiboscore has been shown to correlate with lid margin abnormality score and meibum scores indicating that it validates the other scores. However, it does not take into account the morphologic changes that precede gland drop out.

Meibograde

Considers gland distortion, gland shortening, gland dropout. A score of 0 through 3 is given to each of the three categories and then sums the categories to obtain a meibograde from 0 through 9 for each eyelid.

It helps us identify subtle pathologic changes in the Meibomian glands before irreversible changes like gland drop-outs occur (Figs. 7 and 8).

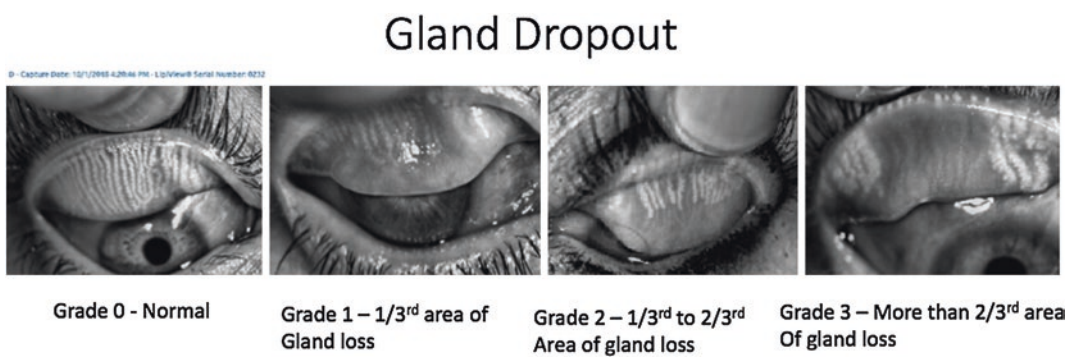

Fig. 7 Images denoting different grades of gland dropout

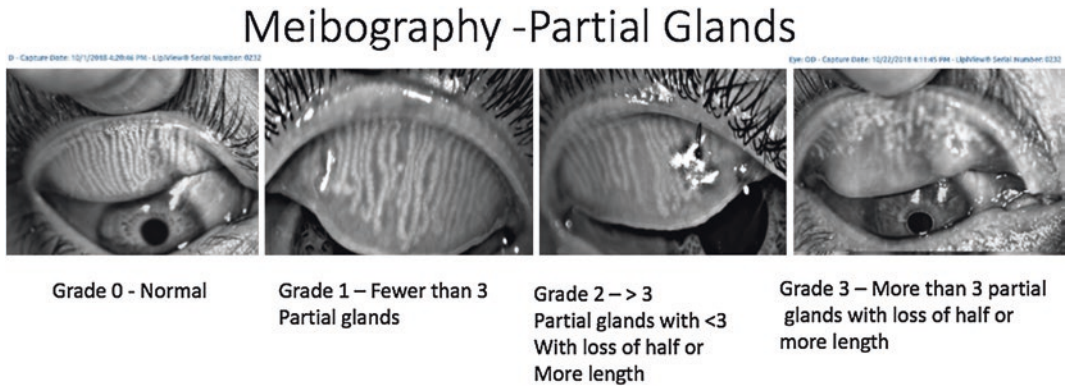

Fig. 8 Images denoting different grades of partial gland loss

III. **Tests for ocular surface**

a. **Corneal and conjunctival staining**: The following dyes have been used to evaluate epitheliopathy:

1. **Fluorescein**: Penetrates poorly into the lipid layer of the corneal epithelium, and therefore, it does not stain normal cornea. Instead, the surface is stained whenever there is disruption of the cell-to-cell junctions. Fluorescein pools in epithelial erosions and stains exposed basement membrane; generally, it stains the cornea more than the conjunctiva. The conjunctival staining by the fluorescein is not clearly seen due to the poor contrast because of the sclera. However, this staining can be more readily viewed if a yellow (blue-free) filter is used.
2. **Rose Bengal**: It was originally thought to stain dead or devitalized cells. However rose bengal is currently believed to stain any part of the ocular surface that is not adequately protected by the tear film. It is an excellent diagnostic tool. It has been shown to be toxic to epithelial cells and causes stinging. It has been shown to have anti-viral activity.
3. **Van Bijsterveld** developed a scoring system for rose bengal that evaluates the intensity of staining on a scale of 0–3 in 3 areas: (1) nasal conjunctiva, (2) temporal conjunctiva, and (3) cornea. With this system, the maximum possible score is 9, and a score of 3.5 or higher is considered positive for dry eye syndrome.

4. **Lissamine green**: It is a synthetic organic acid dye that stains in a similar fashion to rose bengal, but without causing stinging and without affecting the viability of the cells. It stains healthy epithelial cells that are not protected by a mucin layer like rose bengal and stains degenerating or dead cells like fluorescein. However, staining with lissamine green is dose-dependent and an inadequate volume results in weak staining that is transient and thus can be overlooked on slit-lamp examination. A minimal dosage of 10–20 μL is recommended for accurate diagnosis.

A linear pattern of inferior conjunctiva and corneal staining by rose bengal or lissamine is characteristic of meibomian gland dysfunction.

b. **Fluorophotometry**: Fluorophotometry has also been used as "a sensitive measure of epithelial integrity". To detect changes in fluorescence emitted from the ocular surface following the instillation of fluorescein, measurements are taken 10 minutes after washing out the dye with saline, then again every 10 minutes up to an hour. The fluorescein uptake at the center of the cornea is assessed, and patients with dry eye demonstrate an increased corneal permeability and a slower rate of fluorescein elimination compared to patients with normal eyes. Residual fluorescein in the tear film can give a false reading with this technique.

c. **Lid Wiper Epitheliopathy Evaluation (LWE)**: The diagnosis of LWE involves sequential staining with a mixture of 2% fluorescein and 1% lissamine green. The lid is then everted and the fluorescein is graded from 0 to 3 depending on the linear area and severity of the staining, followed by the same grading system for lissamine green. The highest final score is taken to be the LWE severity grade. The classification is no LWE, grade 1 LWE (mild, 0.25–1.0), grade 2 LWE (moderate, 1.25–2.0), or grade 3 LWE (severe, 2.25–3.0).

d. **Lid Parallel Conjunctival Folds (LIPCOF)**: Lid parallel conjunctival folds (LIPCOF) may be observed in the temporal and nasal areas bordering the posterior lid margin in primary gaze. Pult et al. suggested an optimized grading scale where 0 indicated no conjunctival folds; 1 indicated one permanent and clear parallel fold; 2 indicated two permanent and clear parallel folds (normally <0.2 mm); 3 indicated more than two permanent folds (normally >0.2 mm).

IV. **Laboratory tests**:

1. **Tear ferning**: Tear samples dried on a slide and examined under a microscope display a crystalline pattern of tear mucin. In aqueous tear deficiency, this pattern resembles ferns. This test has been reported to have greater specificity and sensitivity than the Schirmer's test, particularly for more severe forms of dry eye disease.
2. **Tear protein analysis**: Lactoferrin, lysozyme, lipocalin, cytokines and MMP-9 are the few proteins analysed in tear films.

A commercially available point-of-care test, RPS InflammaDry Detector (RPS, Inc, Sarasota, FL, USA) offers an easy-to-administer and rapid turn-around test (10 minutes) for measuring MMP-9 levels in the tear film. MMP-9 is considered to be a reliable marker for the presence of inflammation, commonly associated with dry eye. It utilizes Direct Sampling Micro-Filtration technology. MMP-9, if present in the tear sample, is captured between MMP-9 specific monoclonal and polyclonal antibodies at concentration greater than 40 ng/ml (Fig. 9).

V. **Histological tests**:

1. **Impression cytology**: This minimally invasive procedure involves applying nitrocellulose filter paper to the area of interest on the ocular surface to remove the superficial 2–3 layers of cells. Cells are air dried and stained with periodic acid—Schiff and hematoxylin. The cells are then subjected to histological, immunohistochemical, and molecular testing.

Fig. 9 RPS InflammaDry Detector (Manufactured by Quidel Corporation, San Diego, California, USA.)

2. **Conjunctival brush cytology**: Under topical anaesthesia, a soft brush is used to obtain both superficial and basal cells. The sample can then be assessed for the presence of squamous metaplasia, inflammatory cells, and the expression of surface markers on the ocular surface epithelium. This is often combined with flow cytology, which gives a highly sensitive and specific analysis of epithelial cell markers, inflammatory cells and goblet cells.

VI. **Systemic Evaluation**:

Serum Vitamin A levels

The biochemical definition of vitamin A deficiency is plasma level of 35 μmol/dl or less. High-pressure liquid chromatography is the most reliable method. Vitamin A levels may be decreased despite adequate intake in cases of protein deficiency.

Total and holo-RBP test

Total and holo-RBP (complex of Vitamin A and RBP) for serum RBP tend to correlate with measures of serum vitamin A. These, too, can be depressed in the presence of protein deficiency.

Conjunctival Impression Cytology

It can help in detecting preclinical xerophthalmia. Squamous metaplasia is evident by the presence of enlarged, irregular, and keratinized epithelial cells and loss of goblet cells.

Antibodies for Sjogren's

Sjögren syndrome (SS) is characterized by the combination of aqueous tear deficiency (ATD) and dry mouth (xerostomia).

At this time, the most comprehensive criteria for a diagnosis of SS include the following:

- Abnormally low Schirmer test result
- Objective evidence of low salivary flow
- Biopsy-proven lymphocytic infiltration of the labial salivary glands
- Dysfunction of the immune system, as manifested by the presence of serum autoantibodies (e.g., antinuclear antibody [ANA], rheumatoid factor [RF], and anti-Ro [SS-A] and anti-La [SS-B] antibodies)

A novel test called Sjo is available from IMMCO Laboratories. It is used to evaluate for proprietary early markers of SS. These early antibodies may enable the clinician to identify SS up to 4 years earlier than the traditional antibody panel.

Treatment

(A) **Tear Supplementation**: Traditionally, tear substitutes usually form the first line of treatment for any type of dry eye. Commonly used lubricants include Hydroxypropyl Methylcellulose (HPMC), Carboxymethyl cellulose (CMC), sodium hyaluroate,

polyethylene glycol (PEG). They are available in a liquid form and a gel and semi-gel forms.

Artificial tears or lubricants have several beneficial effects:

(i) Act as lubricants to the dry ocular surface
(ii) Replace deficient tear constituents
(iii) Dilute pro-inflammatory substances
(iv) Reduce tear osmolarity

It should be noted however that tear substitutes have several disadvantages including:

- The health of the lacrimal gland is not restored
- The underlying inflammation is not fully addressed
- The effect is temporary as rate of drainage through the puncti is always higher
- They do not improve patient's life, and raise the issue of patients' compliance with lifelong treatment

Constituents of Artificial Tears

(i) Hydrogels: Hydrogels have the property of swelling up in water and retaining moisture. They enhance the viscosity and prolong tear retention owing to their mucous adhesive property.
(ii) Preservatives: These are used to increase the shelf life of artificial tears and facilitate the use of multi-dose bottles. Commonly used preservatives include Benzalkonium Chloride (BAK) and Chlorobutanol. BAK is known to be epitheliotoxic. Newer preservatives like purite (sodium chlorite) and sodium perborate are less damaging to the ocular surface. Purite degrades to chloride ions and water and sodium perborate is converted to water and oxygen on contact with the tear film. If tears substitutes are required frequently, non-preserved ones are recommended.
(iii) Inactive ingredients: HP guar promotes the retention on surface, bicarbonate containing artificial tears promote healing in severe dry eyes. Oil containing eyedrops are beneficial in meibomian gland dysfunction. These eyedrops replenish the lipid layer of the tear film and prevent tear evaporation.

(B) **Autologous Serum**: Autologous serum produced from the patient's serum is particularly useful in severe DED. Tears contain Epithelial Growth Factors (EGF), Transforming Growth Factor beta (TGF-b), and vitamin A to maintain a healthy ocular surface. Serum contains EGF, Nerve Growth Factor (NGF), substance P that helps in epithelial healing

In Keratoconjunctivitis sicca, pro-apoptotic cytokines TNF-a and -b and IL-1 are increased. Autologous serum particularly helps in these cases. The blood is first drawn from the recipient and allowed to clot. The supernatant is then centrifuged to separate the serum from other blood components. The serum is then diluted to up to 20% concentration for use as eyedrops. It can be stored at 4 degree Celsius for up to 1 month.

(C) **Treatment of chronic anterior blepharitis**: Apart from maintaining lid hygiene and warm compresses, topical antibiotics must be given to decrease bacterial load from the eyelid margins. Tetracyclines are particularly useful for cases of acne rosacea. A short course of topical steroids is recommended especially if there is associated marginal keratitis or phlyctenules.

Demodecosis should be considered in patients who did not improve with treatments. Weekly 50% tea-tree-oil eyelid scrubs & daily tea-tree-oil shampoo scrubs for at least 6 weeks are given. Oral ivermectin must be given in cases of recalcitrant Demodex blepharitis.

(D) **Anti-inflammatory therapy**: Inflammation as evidenced by the tear hyperosmolarity is caused by several factors like chronic irritative stress (e.g., contact lenses) or systemic inflammatory/autoimmune disease (e.g., rheumatoid arthritis). Topical and oral steroids and cyclosporine are used for anti-inflammatory effects. Cyclosporine 0.05% eye drops and the more specific lifitegrast (Xiidra; Shire US Inc, MA) are used for 3–6 months to reduce lymphocytic infiltration and inflammation of the lacrimal glands. This can result in increased tear production in a large number of patients, particularly when used early in the disease process before atrophy of the acini.

(E) **Tear Secretagogues**: Oral cholinergic agonists are given to patients with severe aqueous deficient DED. Oral pilocarpine is given in a dose of 5 mg BD. Side effects include sweating, flushing, hypersalivation, increased urinary frequency. Cevimeline, which has a high affinity to muscarinic receptors M1 and M3, is given in a dose of 15–30 mg TDS. Adverse effects of Cevimeline include nausea, vomiting and increased sweating. They are rarely used nowadays. Plasma Injection (PRP) in the area of the lacrimal gland is postulated to increase tear production.

(F) **Meibomian glands heat therapy**: A very effective technique in cases of MGD and is regarded by many as the single most important treatment method. It includes application of localized heat and pressure therapy to the meibomian glands and tarsus to facilitate release of lipid from the cystic partially occluded meibomian glands and ducts. This allows removal of old tenacious secretions and reconstituting with new more effective meibom.

Several machines are now available that provide controlled heat and intermittent pressure therapy to eyelids. They deliver heat at a temperature of 42.5 °C to the eyelid, and pressure to the outer eyelid surface simultaneously, that continually pressurize and depressurize, squeezing the meibomian glands against the lid warmer. The duration of each treatment is 12 min. If the ducts are blocked, debridement of the lid margin can be done first with a cotton tip or a burr. Meibomian duct dilatation with specially designed probes has been advocated to ensure duct patency and proper lipid flow before the heat therapy

(G) **Lacrimal Occlusive Devices**: Occluding the nasolacrimal system to conserve the tear film is one of the most common nonpharmacological therapies used in aqueous deficient patients. Types of lacrimal occlusive devices:

a. *Punctal occluders*:
(i) Total punctal occluders
(ii) Partial punctal occluders
b. Canalicular occluders:
I. Horizontal canalicular occluders
II. Vertical canalicualr occluders

Both horizontal and vertical occluders could be temporary or permanent. (32) They are inserted under topical anesthesia in the office and have the following advantages:

- They maintain normal, diurnal and environmental adjustment of tear composition
- Their maximum effect occurs in early cases with decreased but not absent tear secretion
- Being non-patient dependent, they improve life style
- They allow prolonged effect of artificial tears and reduce the amount needed

(H) **Neurostimulation**: Stimulation of the anterior nasal mucosa by micro electric pulses results in increased natural tear production by the lacrimal gland. A portable hand held device;True Tears device (Allergan Inc, USA) was approved in 2017 to be used by patients to stimulate the lacrimal functional unit with increased secretion of aqueous glands, goblet cells and meibomian glands. This returns the ocular surface to a more normal physiologic state without prescribing drops or surgery.

(I) **Tarsorrhaphy**: Partial tarsorrhaphy is reserved for severe or refractory DED. Indications include paralytic lagophthalmos from 7th cranial nerve damage, cicatricial lagophthalmos, poor blink reflexes, and neurotrophic keratopathy. It reduces area of exposed ocular surface thereby benefitting cases of severe epitheliopathy, persistent epithelial defects, or frank stromal ulceration.

(J) **Salivary gland transplant**: This surgical procedure involves transplantation of salivary submandibular gland to replace the deficient mucin and aqueous tear film phase. It is indicated only in end stage disease when there is Schirmer-test wetting of 1 mm or less and persistent severe pain despite punctal occlusion and at least hourly application of unpreserved tear substitutes.

Suggested Readings

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Congenital Nasolacrimal Duct Obstruction

A. K. Grover, Shaloo Bageja, Amrita Sawhney and Anurag Mittal

Congenital nasolacrimal duct obstruction (CNLDO) is the most common cause of epiphora in the pediatric population caused by failure of the lacrimal drainage pathway due to mechanical obstruction at the distal end of the nasolacrimal duct. The prevalence ranges from 5 to 20% in infants with 95% of them being symptomatic at one month of age. It is usually unilateral (80%), however, 20% of cases present with bilateral CNLDO. Approximately 30% of full-term infants have obstruction at birth but only 2–4% become symptomatic. Furthermore, the prevalence of CNLDO reported is higher in prematures compared to full-term infants suggesting the importance of the physiological development of the nasolacrimal drainage system during intrauterine life.

Development of the Lacrimal Drainage System

The development of the lacrimal drainage system can be divided into embryonic (first 8 weeks post ovulation) and fetal (after 8 weeks) developments.

The lacrimal pathway develops along the line of cleft between the maxillary and the lateral nasal process when an epithelial thickening of the lacrimal groove forms the lacrimal lamina at the Carnegie stage 16 (crown rump length, 11 mm). The morphology of the lacrimal system is developed almost completely by the end of the embryonic stage.

Canalization of the lacrimal cord and development of the surrounding tissues begin at around 10 weeks of gestation. The canalicular epithelium comes in contact with the palpebral conjunctival epithelium, and they form a continuous epithelial lamina. The distal extreme of the lacrimal duct and the inferior meatal lamina come into contact, and the meatal lamina begins to cavitate. Central cells undergo apoptosis and degeneration and shed off leaving a clear lumen behind, but this process varies from the sixth-month intrauterine to several weeks or months after the birth. The canalicular lumina become patent by the fourth month of gestation and the lacrimal puncta open onto the eyelid margins during the seventh month once the eyelids separate.

The development of the lacrimal sac and the nasolacrimal duct occurs earlier than the canaliculi, but the caudal end of the nasolacrimal duct is the last to canalize. This is the reason for most of the cases with CNLDO having a pathology at distal end, where the nasolacrimal duct (NLD) normally opens into the inferior meatus.

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_21

Aetiology

Mechanical obstruction in CNLDO can be attributed to either persistence of distal lacrimal duct epithelium, obstruction at the Valve of Hasner or any bony abnormalities. Syndromes and craniofacial abnormalities associated with CNLDO include Down's syndrome, Crouzon syndrome, Treacher Collins syndrome, Klinefelter syndrome, cleft lip/palate, facial cleft, hypertelorism, bifid uvula and hemifacial microsomia.

Types and Variations

In **1976, Jones and Wobig** described a number of variations of obstruction at the lower end of NLD leading to CNLDO (Fig. 1).

Type 1: NLD fails to open through the nasal mucosa and stops at the vault of the anterior end of the inferior nasal meatus (the most common type).

Type 2: NLD extending up to the nasal floor lying lateral to nasal mucosa or a buried probe.

Type 3: NLD obstruction caused by impacted anterior end of inferior turbinate.

Type 4: NLD ending in anterior end of inferior turbinate

Type 5: NLD ending blindly into the maxillary wall

Type 6: Complete absence of NLD

Based on the intraoperative findings during probing, Kushner divided the types of CNLDO into simple and complex.

1. Simple obstruction: It includes cases where there is no resistance felt while passing the probe through the NLD until a point of membranous obstruction at the distal end (which can be perforated) or cases of canalicular valves, where a proximal resistance is

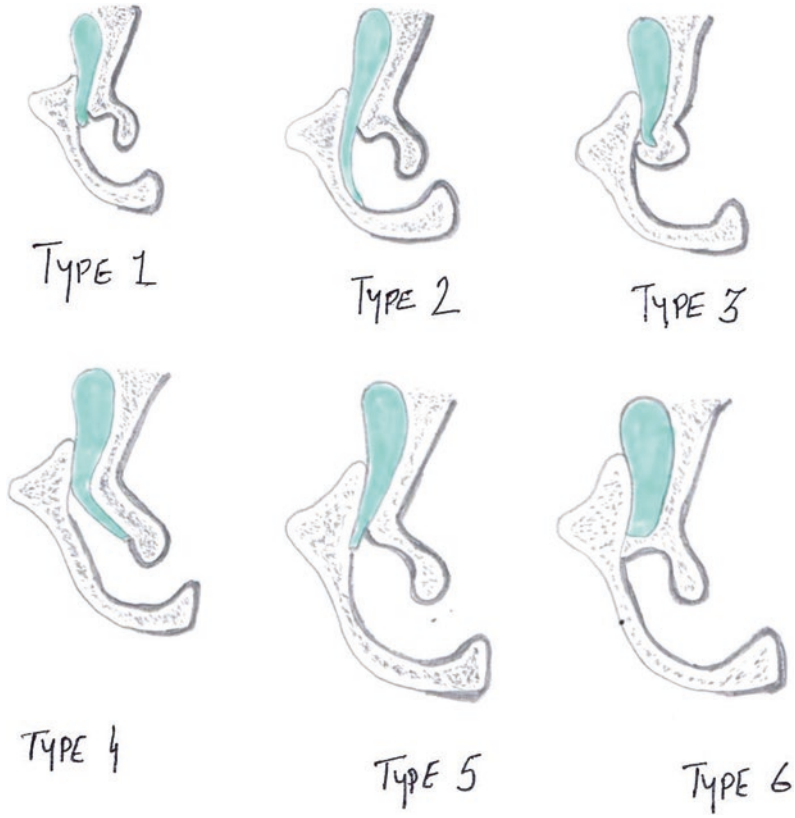

Fig. 1 Diagrammatic representation of variations of CNLDO

encountered but there isn't a true obstruction. This corresponds to type 1

2. Complex Obstruction: It includes cases associated with any of the variations like a buried probe, bony obstruction or non-development of nasolacrimal duct. These corresponds to types 2–6.

Clinical Features (Table 1)

The characteristic clinical presentation includes excessive watering, ocular discharge and matting of eyelashes with or without skin maceration. Upper respiratory tract infections lead to worsening of the symptoms.

The diagnosis of CNLDO can be confirmed by positive regurgitation on pressure over the lacrimal sac, increased tear meniscus height and positive fluorescein dye disappearance test.

Rarely, a child can present with acute dacryocystitis, dacryocele, mucopyocele, preseptal cellulitis, orbital cellulitis, lacrimal fistula and conjunctivitis. Complex cases usually have more severe symptoms, do not respond to conservative treatment and usually requires early intervention. Bilateral cases and cases of positive consanguinity or previous occurrence in a sibling are usually of the complex types.

For the differential diagnosis, it is important to rule out other causes of epiphora, in infants, like ocular surface foreign body, infections or infantile glaucoma.

Treatment (Table 2)

Several studies have reported spontaneous resolution in 32–95% of CNLDO cases by the age of 13 months. It is also believed that spontaneous break in the membrane, present at the distal end of the nasolacrimal duct (NLD), usually occurs by 3–4 weeks of age due to respiratory efforts, crying, and sucking which create negative pressure within the nose.

Hence, a conservative approach consisting of observation and Crigler's lacrimal sac massage is our preference in children up to 1 year of age.

In children with persistent CNLDO beyond the age of 1 year, minimally invasive techniques like probing, intubation, balloon catheter dilation and endoscopic-assisted correction of associated nasal abnormalities have proven to be beneficial.

More advanced surgeries including External or Endonasal Dacryocystorhinostomy are reserved for recalcitrant cases.

Table 1 Showing difference in clinical presentation with different levels of obstruction

Level of obstruction	Type of discharge
Distal obstruction at the Valve of Hasner	Mucopurulent discharge
Obstruction near the lacrimal sac	Watery discharge

Lacrimal sac massage (Fig. 2)

It was introduced by Crigler in 1923 and is a widely used technique to encourage patency of NLD. The goal of Crigler hydrostatic massage

Table 2 Showing preferred treatment modalities

Age of presentation	Preferred treatment
<1 year	Conservative approach - Observation - Crigler massage
>1 year	Minimally invasive technique - Probing - Intubation - Balloon catheter dilation - Endoscopic-assisted inferior turbinate infracture
>3 years and recalcitrant cases	External DCR or Endonasal DCR

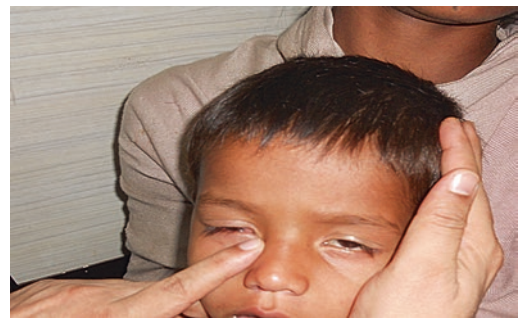

Fig. 2 Technique of Crigler massage

is to occlude and compress the lacrimal sac to transmit the increased hydraulic pressure to the valve of Hasner. In this technique, after supporting the head of the child, direct compression of the lacrimal sac and canaliculus on the base of the nose is performed using the index or little finger. The pressure is then directed downwards through the NLD to mechanically overcome the obstruction. In 1982, Kushner showed statistically significant improvement in resolution rates of NLD obstruction with "hydrostatic massage" as compared to gentle massage or no massage. There is a statistical difference in the resolution rate of CNLDO in infants effectively treated with regular lacrimal sac massage in comparison with observed infants and infants that did not have frequent lacrimal sac massages (96.2% vs. 77.7%, $p = 0.001$). Thus, the importance of lacrimal sac massage should be emphasized to the parents and proper technique must be explained to ensure higher success rates. Usually ten strokes twice or thrice a day must be given to improve the chances of resolution.

Antibiotics

Topical antibiotics should be used only when symptoms of discharge are present or in cases of conjunctivitis complicating CNLDO. More severe complications like orbital cellulitis and preseptal cellulitis require urgent hospitalization and intravenous antibiotic therapy.

Irrational use of antibiotics must be avoided as it can facilitate the growth of resistant bacteria in the lacrimal passages, especially in premature infants who are highly susceptible to secondary infections.

Invasive Treatment in CNLDO

The first-line invasive treatment includes syringing and probing of the lacrimal passages while techniques that are helpful in complex or failed cases include repeat probing, endoscopic guided probing, inferior turbinate infracture, silicon intubation, balloon catheter dilation and dacryocystorhinostomy.

Probing

Probing is recommended through the upper canaliculus. The procedure of probing includes dilating the punctum with a Nettleship's dilator and passing a Bowman's probe of appropriate size, according to the age, into the vertical canaliculus then medially in the horizontal canaliculus. Once a hard stop is felt (about 10 mm) the probe is rotated inferiorly, laterally and slight posteriorly and is passed down the NLD. Resistance may be felt while passing through the intraosseous part or obstruction at valve of Hasner, and excessive force must be avoided as it can create false passages. A probe graduated in mms can be used

It must be noted that up to 1 year of age, the distance from the punctum to the NLD is approximately 12 mm, whereas, to the floor of the nose is 20–25 mm. In adults, punctum to floor of the nose distance is 30–35 mm.

Although there are proponents of early probing, most surgeons prefer to delay their intervention to the age of about one year. Success rates for primary probing are up to 97% during the first year. Good success rates have been reported in older children as well (88% at mean age of 33 months). Probing being a blind procedure can lead to complications like false passages, bleeding, infections and NLD fibrosis. Failed probing is defined as recurrence of symptoms after primary probing, usually occurring within 6 weeks. Incidence ranges from 2.2 to 3.6% in children less than 24 months of age and it increases to 20–57% in 24–60 months old children. Factors implicated in failure of probing include improper technique (false passage created), narrow opening causing recurrence, late age of probing, bilateral NLDO, anatomical variations (complex NLDO), inferior turbinate hypertrophy/impaction, or associated nasal pathology.

Endoscopy-assisted probing has added a new dimension to the procedure and helped in achieving better success rates (94–97%), especially in complex NLDO, failed probing, and in cases with associated nasal pathology. It helps identify and manage variations such as submucosal entry, elastic membrane at the Hasner's valve and a tight inferior turbinate.

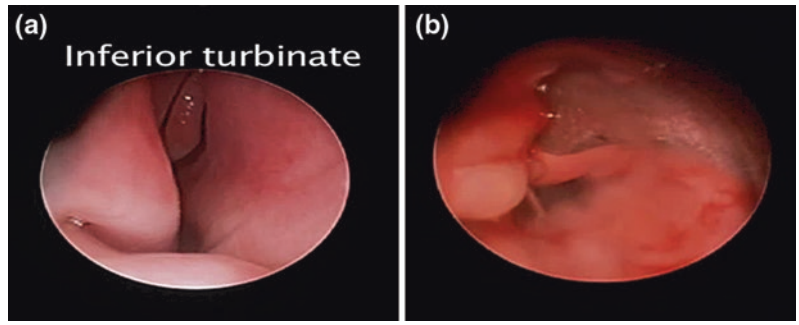

Fig. 3 Technique of Endoscopic guided Inferior turbinate infracture. **a** Impacted Inferior turbinate. **b** Inferior turbinate infracture

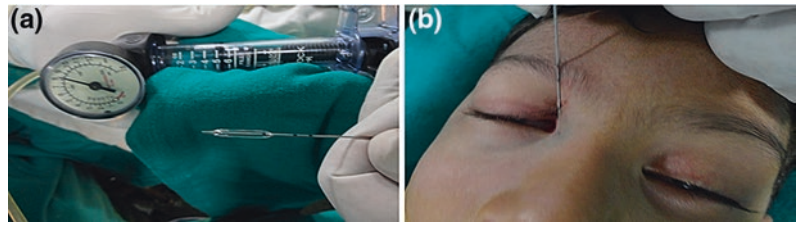

Fig. 4 **a** Showing catheter with 10 and 15 mm black mark and the inflated manometer. **b** Catheter insertion through upper punctum and canaliculus while watching the black lines

Our procedure of choice in cases of failed probing is endoscopic guided Inferior turbinate infracture with syringing and probing which allows for creation of adequate space for canalization of NLDO. Inferior turbinate infracture is indicated in cases of failed probing especially when impacted inferior turbinate is seen endoscopically.

Technique of inferior turbinate infracture (Fig. 3a, b)

Under anaesthesia, a freer elevator is slid along the lateral nasal wall medial to the inferior turbinate. The elevator is then rotated to move the inferior turbinate medially.

Nasal packing is done for 2 hours.

Silicon tube intubation

It is an invasive technique which consists of placement of a bi- or monocanalicular silicon intubation stent which are left in situ for at least 3 months. Success rates for silicon intubation in congenital NLDO at 95% for less than 12 months, 92% for 12–24 months, 84% for 24–45 months, and 84% for failed cases, are encouraging.

The complications of intubation include damage to puncta, tube loss and granuloma formation.

Balloon catheter dilation (Fig. 4a, b)

It works by dilating the NLD through balloon inflation and helps reducing probing related complications. It allows dilatation of the duct in both the vertical and the horizontal meridia.

Balloon catheter dilation allows greater dilation of the duct and is less invasive than intubation. A balloon size of 2 mm is used for patients less than 30 months of age and 3 mm for older ones. Two cycles of balloon inflation and deflation are performed at 15 and 10 mm marking each. The first cycle of 8 atmospheric pressure is given for 90 seconds and the second cycle for 60 seconds.

The limitations of the procedure are a lower success rates (82% in primary cases and 77% in failed cases) and the high cost of the procedure. It is used as a less invasive step before reverting to DCR in selected cases.

Dacryocystorhinostomy

Dacryocystorhinostomy (DCR) for CNLDO in children is reserved for cases which fail to resolve with repeated probing or any of the above procedures. Most surgeons prefer to wait till the child reaches an age of 3 years to avoid compromising on the nasal bony growth.

The procedure may be carried out as an external DCR which is the "gold standard" procedure or as an Endonasal DCR.

The endonasal procedure has been traditionally carried out with an endoscope with high success rates. However, a non-endoscopic endonasal (NEN DCR) approach retains the benefits of the endonasal approach without the disadvantages like high cost and required learning curve.

A study by Bothra et al. (2017) compared the results of non-endoscopic nasal (NEN DCR) approach to DCR with the gold standard technique of EXT DCR. They concluded that NEN DCR technique, though has its advantages of avoidance of an external scar, and has a fair success rate, still falls short of the gold standard external DCR technique in results.

DCR in children poses unique set of challenges due to the anatomical factors. Extra precaution during the surgery is needed owing to the narrow nasal cavities, lower skull base and desired bony osteotomy. It is not as predictable as in adults because of the rapidly changing anatomy and a greater tendency towards scar formation.

Causes of failure of DCR in children are mostly associated with aggressive healing responses causing cicatricial closures of ostia. The large adequately sized osteotomy and full-length sac marsupialization can help reduce the failure rates. Endoscopic DCR can have success rates approaching that of external DCR in children (82–94%)

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Acquired Lacrimal Obstruction

Osama H. Ababneh, İlke Bahçeci Şimşek, Pelin Kaynak and Essam A. El Toukhy

Introduction

The lacrimal drainage system, located in the anterior medial orbit starts with the punctum (0.4–0.8 mm in diameter) at the medial end at the junction of the lash-bearing lateral five-sixths (pars ciliaris) and the medial non-ciliated one-sixth (pars lacrimalis) of each eyelid. The punctae should be open and in firm apposition to the globe facing slightly posteriorly. The punctum is surrounded by a fleshy elevation oriented perpendicular to the eyelid margin and continues for 2 mm of vertical canaliculus (the ampulla) then turns 90 degrees medially and runs as a horizontal canaliculus for 8–10 mm in each eyelid. The canaliculi are lined with non-keratinized, non-mucin-producing stratified squamous epithelium, and in more than 90% of individuals the upper and lower canaliculi combine to form a common canaliculus (1–2 mm long) before opening in the lateral wall of the lacrimal sac (the internal punctum). A mucosal fold (the valve of Rosenmüller), which has been described at the junction with the sac, acts as a one-way valve to prevent tear reflux from the sac into the canaliculi. New studies have suggested that the common canaliculi enter the sac at an acute angle from a posterior to anterior direction behind the medial canthal tendon, which also plays a role in blocking tear reflux. The lacrimal sac, the body of which is 10–12 mm, lies within a lacrimal fossa between the anterior and posterior lacrimal crests that are formed by the thicker frontal process of the maxilla anteriorly and the thin lacrimal bone posteriorly and separate the lacrimal sac from the middle meatus of the nasal cavity. The fundus of the sac extends superiorly for about 3–5 mm above the medial canthal tendon. The lacrimal sac is surrounded by the superficial and deep limbs of the medial canthal tendon and continues inferiorly into the nasolacrimal duct (NLD). The intraosseous NLD is about 12–15 mm long and runs inferiorly, posteriorly, and slightly laterally in the nasolacrimal canal in the medial wall of the maxillary sinus. The duct extends for about 5 mm below the bony portion (meatal part) and opens into the inferior meatus under the inferior turbinate about 2.5 cm

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_22

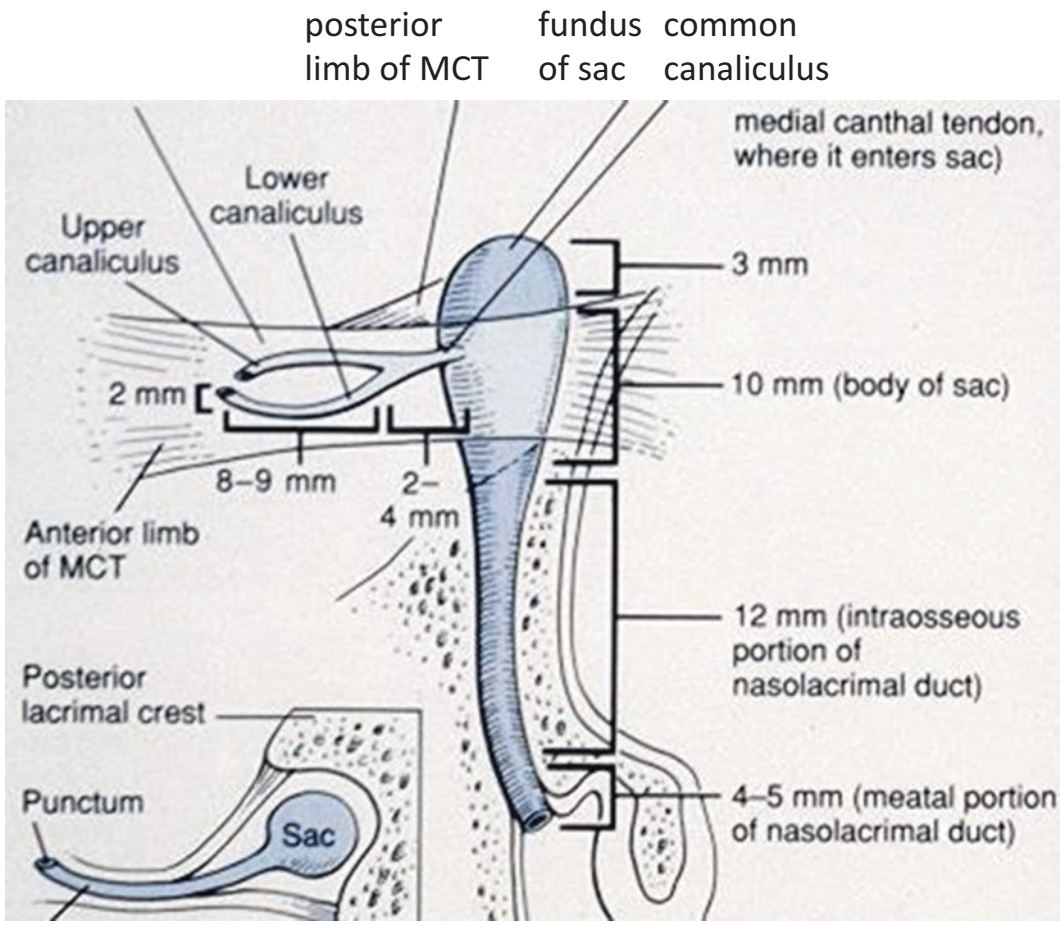

Fig. 1 Anatomy of the lacrimal drainage system

posterior to the naris. A mucosal fold is also present at its opening in the nose (valve of Hasner), which prevents retrograde passage of mucus or air upward. The valve of Hasner is the cause of most congenital NLD obstruction in children when it is closed, because it is the last portion of the lacrimal drainage system to canalize (Fig. 1).

Causes of Watery Eyes

Tearing may occur due to two main mechanisms with different causes.

The first mechanism, tear overproduction (lacrimation or hypersecretion), is watering that occurs secondary to excessive tear production in the presence of a normal excretory system. It usually responds to medical treatment and may result secondary to ocular surface inflammation or anterior segment diseases as in blepharitis, dryness, and uveitis. Cold and windy weather also encourage tearing due to reflex lacrimation caused by corneal stimulation. Tear overproduction also can result from emotional distress and ocular irritation caused by smoke, dust, foreign bodies, pollutants, injury, and surgery. Primary hypersecretion can occur in cases of aberrant facial nerve regeneration (crocodile tears; gustatory epiphora) or rarely due to irritation of the parasympathetic nerve fibres destined to the lacrimal gland while running on the petrous bone in cases of petrous bone fractures.

The second mechanism is obstruction (obstructive epiphora), i.e., watering that occurs secondary to an abnormal excretory system (a compromised lacrimal drainage system) in the

presence of normal tear production. It is usually relieved by surgery and can result from a malposition of the lacrimal punctum (ectropion) or obstruction anywhere along the lacrimal drainage system from the punctum to the NLD, or lacrimal pump failure due to lower lid laxity or weakness of the orbicularis muscle as in facial palsy.

Compromise of the lacrimal drainage system can occur due to a variety of reasons depending on the anatomic area that is defective, such as

(1) punctal stenosis (chapter "Punctal Stenosis".)
(2) canalicular obstruction, which may be congenital, a post-traumatic or herpetic infection, drugs (Taxotere, docetaxel), irradiation, and chronic dacryocystitis; and
(3) NLD obstruction.

There are limited epidemiologic data of lacrimal drainage disorders in the literature; the annual incidence rate of symptomatic acquired lacrimal system obstructions was 30.47 per 100,000, of which nasolacrimal duct obstruction was the most common. Of the 20,102 patients diagnosed with lacrimal drainage disorders, the prevalent disorder was acquired nasolacrimal duct obstruction with 51.56%.

Symptoms and Signs

Symptoms and signs of a defective lacrimal drainage system can be either due to difficulty in tears passing from the lacrimal lake into the nose, i.e., flow-related symptoms, resulting from stenosis or obstruction in the lacrimal drainage system, or volume-related symptoms related to increased tear volume in a dilated lacrimal sac with debris accumulation and reflux back into the lacrimal lake. Patients with a defective lacrimal drainage system may complain of excessive tears, spillover of tears from the lacrimal lake over the cheeks, the presence of a mucocele with its mucous or mucopurulent discharge with or without infective conjunctivitis, recurrent painful attacks of acute dacryocystitis, and interference with vision and daily activities mainly during reading due to the elevated tear meniscus and its prismatic effect or tear-splattered glasses. Patients also may complain of morning stickiness of the eyelids due to reflux of the lacrimal sac mucoid debris into the tear lake or collected dried tears. Chronic tearing can induce sore and irritated lower lids, with secondary anterior lamellar shortening that causes mild cicatricial ectropion, mostly medially, that may be exacerbated by continuous wiping away of tears. Patients also may develop a fistula between the sac and skin after spontaneous or surgical drainage of an acute dacryocystitis abscess and are at increased risk of infection after intraocular surgery.

Acquired NLD obstruction is a relatively benign condition that can result from inflammation of unknown causes and eventually lead to secondary acquired stenosis and occlusive fibrosis of the lumen of the NLD. It is more common in elderly patients and affects women twice as frequently as men. It is most commonly an idiopathic involutional stenosis, or after accidental and iatrogenic trauma to the nose or orbit, or after sinus surgery. Other secondary causes of obstruction or stenosis may result from infiltration by nasopharyngeal tumors, lacrimal sac tumors, or dacryolith, granulomatous diseases (sarcoidosis and Wegener's granulomatosis).

Grading of Epiphora

The severity of tearing varies from mild and occasional to constant tearing. Munk et al. graded tearing as follows: grade 0 no tearing, grade I occasional tearing (<twice/day), grade II 2–4 times/day, grade III 5–10 times/day, grade IV > 10 times/day, and grade V constant tearing.

Evaluation of the Lacrimal Drainage System

The main goals are differentiation of both the causes of watery eye and differentiate lacrimation from obstructive epiphora. Drainage failure tends to be exacerbated by a cold and windy environment and to be least evident in a warm

dry room. Overflow of tears onto the cheeks from the medial, or less commonly the lateral canthal region is more likely to indicate lacrimal drainage failure.

History

The following points should be considered when assessing a patient with tearing: the nature of the tearing, that is, whether it is constant, seasonal, or intermittent in one or both eyes; the severity of the tearing (grading) and interference with daily activities; the presence of a foreign-body sensation, grittiness, or redness; and use of contact lenses or previous corneal refractive surgery. Other considerations include a history of allergies or use of topical medications, especially antiglaucoma medications; lid surgery, probing during childhood, punctal plugs insertion, nasal or sinus trauma or surgery; ocular surface infections or blisters on the eyelids that may cause herpetic canalicular obstruction, recurrent conjunctivitis or ocular pemphigoid that cause punctal and/or canalicular obstruction. Further considerations include a history of Bell's or facial palsy (crocodile tears); lacrimal sac swelling or infection suggesting distal NLD obstruction; systemic diseases such as sarcoidosis or Wegener's granulomatosis; systemic chemotherapy or irradiation to the eyes and orbits, or radioactive iodine treatment for thyroid cancer for which the radiation dose is higher than for treating hyperthyroidism; or tearing associated with bloody tears, nasal obstruction, or epistaxis, which should raise the suspicion of a nasal, sinus or lacrimal sac tumor.

Examination

During the examination, the clinician should be alert to tearing to determine its cause and differentiate lacrimation from obstructive epiphora or pseudoepiphora, i.e., the sensation of too many tears without frank epiphora.

The punctae and eyelids should be examined using the slit lamp to determine the size and site of the punctum and the presence of a membranous punctal obstruction or aplasia or double puncta (Fig. 2) or punctal stenosis, which is extremely common in the general population. If the punctum can be seen without manual eversion of the eyelid, its position is abnormal and may be responsible for the tearing. A pouting punctum with swollen canaliculus is typical of canaliculitis. The increased level of the tear meniscus and the presense of visible mucopurulent discharge are more likely associated with NLD obstruction rather than blockage more proximally. The clinician should evaluate the position of the eyelids and if there is ectropion, entropion, lid laxity as in facial nerve weakness or palsy, or the presence of caruncular hypertrophy or conjunctivochalasis, which are folds of redundant conjunctiva prolapsing over the lower eyelid margin, occluding or everting the punctae away from the globe. Centurion syndrome is a rare cause of tearing in which a prominent nasal bridge causes the medial part of the eyelid margin and punctum to displace anteriorly away from the lacrimal lake. Slit-lamp examination during the blink cycle may help determine if the punctum is positioned properly within the lacrimal lake and that eyelid closure is complete.

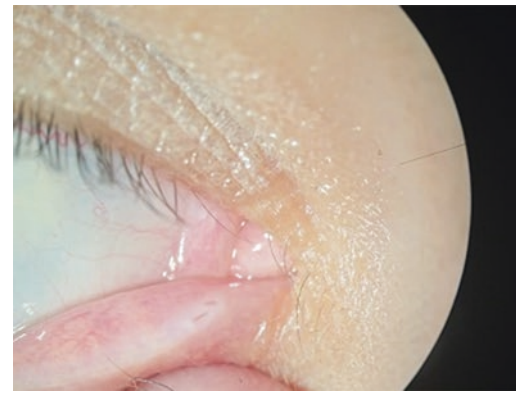

Fig. 2 Double puncta

When examining the eyelashes for blepharitis, clinicians should look for thickened, hyperemic lid margins with scales deposited on the lashes, blocked meibomian gland orifices, and frothy secretions on the lid margins.

Topical rose Bengal (an ocular irritant), lissamine green, and fluorescein can detect subtle

ocular surface diseases and/or dryness. Many patients with tearing do not have obvious tear overflow but merely have an increased tear meniscus of 0.6 mm or more versus 0.2–0.4 mm in normal individuals. Dryness secondary to mucous or meibomian secretion deficiency can cause paradoxical tearing. The diagnosis usually is based on a decreased lower tear meniscus and increased debris in the tear film on slit-lamp examination. A rapid tear break-up time shorter than 10 seconds and reduced Schirmer's strip wetting corroborate the diagnosis. Fluorescein staining in the lower third of the cornea also indicates tear film malfunction or incomplete lid closure (lagophthalmos) during blinking. An unusual cause of tearing is anterior uveitis with which patients complain of tearing associated with photophobia with or without decreased visual acuity.

Palpation of the lacrimal sac with pressure over a distended sac may result in reflux of mucopurulent material back through the punctae into the lacrimal lake, which confirms complete NLD obstruction. No further diagnostic tests are needed. Palpation of the lacrimal sac may sometimes identify masses (tumors) or dacryoliths (stones). In acute cases, because of tenderness, palpation should be avoided.

Nasal endoscopy is helpful to evaluate the nasal anatomy and may uncover unusual causes of tearing such as intranasal tumor, turbinate hypertrophy, or chronic allergic rhinitis. It is also useful to rule out nasal polyps or a deviated septum, which makes future surgery more difficult. Nasal endoscopy can be extremely useful for evaluating dacryocystorhinostomy (DCR) failures and the postoperative care of Jones tubes.

Diagnostic Tests

Fluorescein Dye Disappearance Test (DDT)

This is a quick, simple, safe, painless, and physiologic test to assess the adequate functioning of the lacrimal drainage system, especially in patients affected unilaterally and children. It is associated with a high sensitivity (75–90%) and specificity (71–100%). A drop of 2% fluorescein solution is instilled bilaterally into the lower conjunctival fornices and the tear meniscus is observed with the cobalt blue filter of the slit lamp. The presence of fluorescein in tears after 5 minutes indicates inadequate drainage,

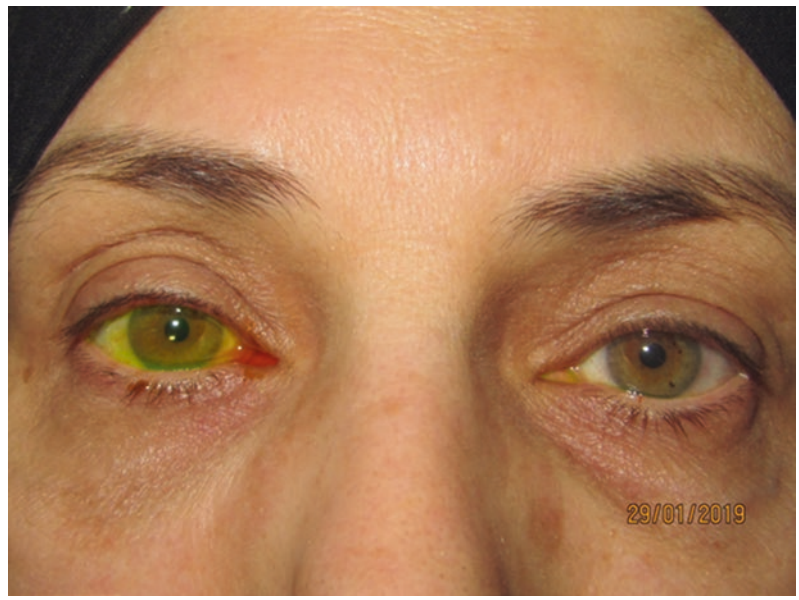

Fig. 3 Asymmetric dye disappearance test (DDT)

especially when the dye clearance is asymmetrical (Fig. 3). If the DDT is normal (no residual dye), the presence of significant lacrimal drainage obstruction is highly unlikely, but if the test is delayed, it cannot distinguish between obstructive tearing and hypersecretion or between upper and lower obstruction, and further testing is needed.

Lacrimal Drainage System Irrigation

Lacrimal drainage system irrigation usually is performed after ascertaining punctal patency, and it is performed for adults in the clinic after DDT to determine the level and type of obstruction. After instilling topical anesthesia, the lower punctum is dilated and any punctal occlusion or stenosis is noted. The editor recommends injecting a small amount of methylcellulose before any canalicular manipulation. This straightens the canaliculus and protects the canalicular mucosa preventing any iatrogenic injury. The tip of the irrigating cannula (gently curved, blunt-tipped 23-gauge lacrimal cannula on a 3-mL syringe) is inserted into the ampulla at a right angle to the lid margin. The tip of the irrigating cannula is then rotated medially and advanced 4 to 5 mm into the horizontal canaliculus while the eyelid is pulled laterally to prevent canalicular kinking and difficulty while advancing the cannula and observing any canalicular obstruction or stenosis (Fig. 4). With the opposite punctum (upper) everted, gentle irrigation with clear saline or distilled water is performed. A patient with a normally functioning lacrimal drainage system, will feel and taste the saline passing into the nasopharynx as it is injected. If the fluid regurgitates along the upper canaliculus, this confirms patency at least as far as the common canaliculus. If the fluid flows back along the same canaliculus, the tip of the cannula is advanced gently to identify the position of the block. If mucus or fluorescein regurgitates through the opposite punctum with lacrimal sac distension, complete blockage of the NLD is implied. If no reflux is seen through either canalicular system and no fluid passes down the nose and the lacrimal sac is distended, complete NLD obstruction with a functioning valve of Rosenmüller that prevents reflux through the canalicular system is implied. A combination of both reflux and passage of fluid into the nose indicates partial NLD obstruction. The regurgitated material may be clear, mucoid, or mucopurulent, depending on the contents of the lacrimal sac. The passage of fluid into the nose with no reflux through the punctae confirms anatomic patency but not functional normality of the tear passages because of the increased hydrostatic pressure of the irrigating fluids (Fig. 5). Presence of acute dacryocystitis and acute canaliculitis are the relative contraindications to irrigation.

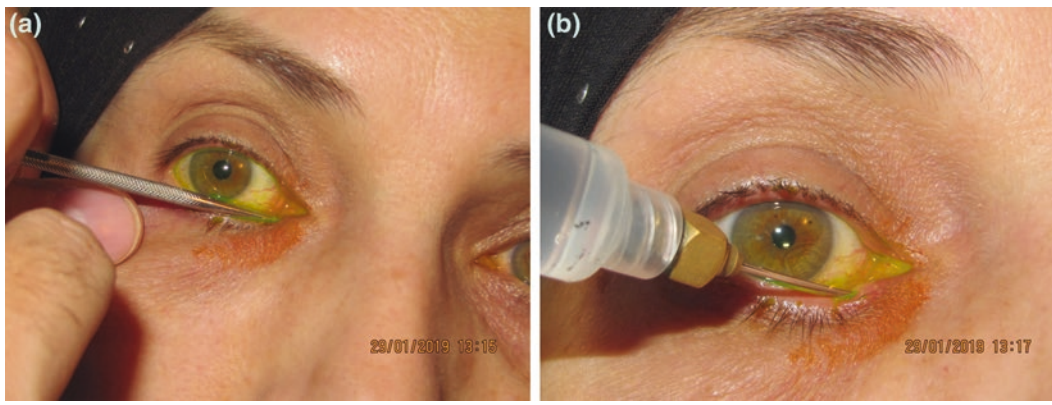

Fig. 4 Punctal dilatation (**a**) and lacrimal system irrigation (**b**)

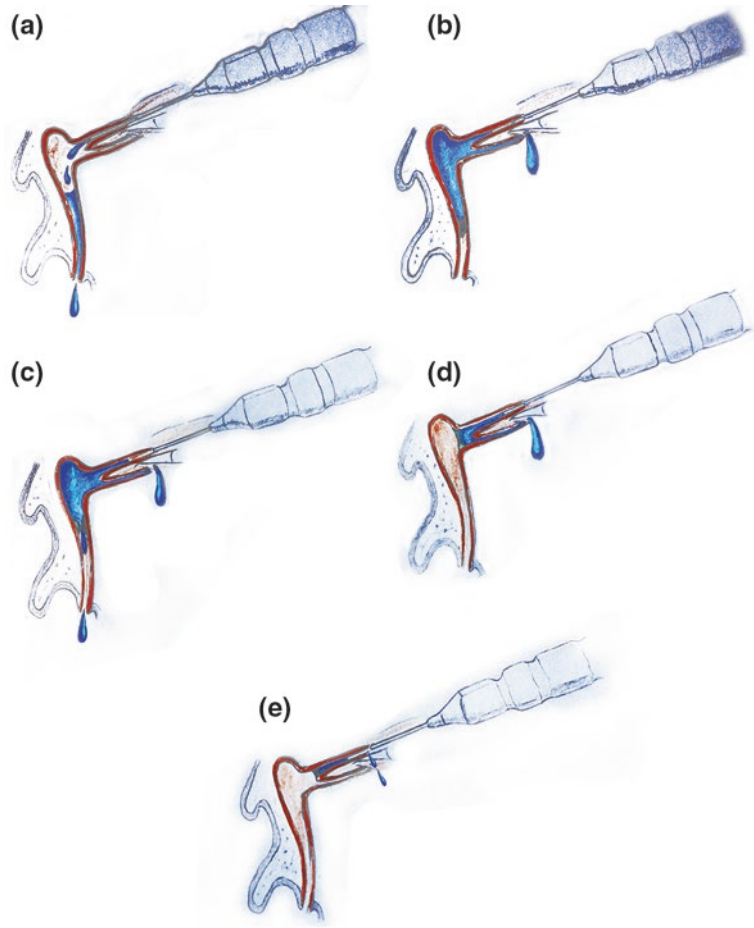

Fig. 5 Lacrimal drainage system irrigation: **a** Patent lacrimal drainage system with no reflux. **b** Complete nasolacrimal duct obstruction with reflux from the opposite punctum. **c** Partial nasolacrimal duct obstruction with reflux from the opposite punctum with passage into the nose. **d** Common canaliculus obstruction with reflux from the opposite punctum. **e** Distal canalicular blockage with reflux from the same punctum

Jones I and Jones II Tests

These tests have been performed historically to evaluate tearing since they were first described in 1961, but they are not performed routinely because they may yield high false-negative results in normal patients if the examiner does not detect dye passing into the nose on the cotton-tipped applicator, and because retrieving dye or fluid from the nose is technically difficult. Jones testing is indicated only in patients with suspected partial obstruction of the drainage system where patient complains of tearing and the irrigated fluid is felt in his throat, and is of no value in the presence of total obstruction. The Jones I test (primary or physiologic dye test) differentiates partial obstruction of the lacrimal passages and lacrimal pump failure from primary hypersecretion of tears and is performed similar to the DDT, in which one drop of 2% fluorescein is instilled into the lower fornix and a cotton-tipped applicator is passed into the inferior nasal meatus after 5 minutes (nose is sprayed with local anesthetic to reduce discomfort). The test is positive if fluorescein is recovered from the nose, which indicates patency of

the lacrimal drainage system, and tearing is due to primary hypersecretion and no further tests are necessary. If the Jones I test is negative and no dye is retrieved on the cotton-tipped applicator, indicating partial obstruction of an unknown site or lacrimal pump failure, then the Jones II (irrigating or nonphysiologic test) is performed to identify the probable site of partial obstruction. The remaining dye is washed away from the conjunctival sac, and the lacrimal drainage system is irrigated using clear fluid or saline; the dye and fluids then are retrieved from the inner aspect of the nose (similar to Jones I). A positive secondary test is characterized by reflux from the punctum while irrigating contains fluorescein and/or fluorescein is retrieved from the nose; this indicates partial NLD obstruction and confirms functional patency of the upper (proximal) drainage system and that the dye entered the sac. A negative secondary test is characterized by only clear fluids, with no fluorescein retrieved after irrigation; this indicates an upper lacrimal drainage system (punctae, canaliculi, and/or common canaliculus) partial obstruction or lacrimal pump failure (Fig. 6).

The results of the Jones tests might be misleading. Because these tests are uncomfortable for the patient, many ophthalmologists have abandoned them and depend mainly on lacrimal system irrigation and the DDT.

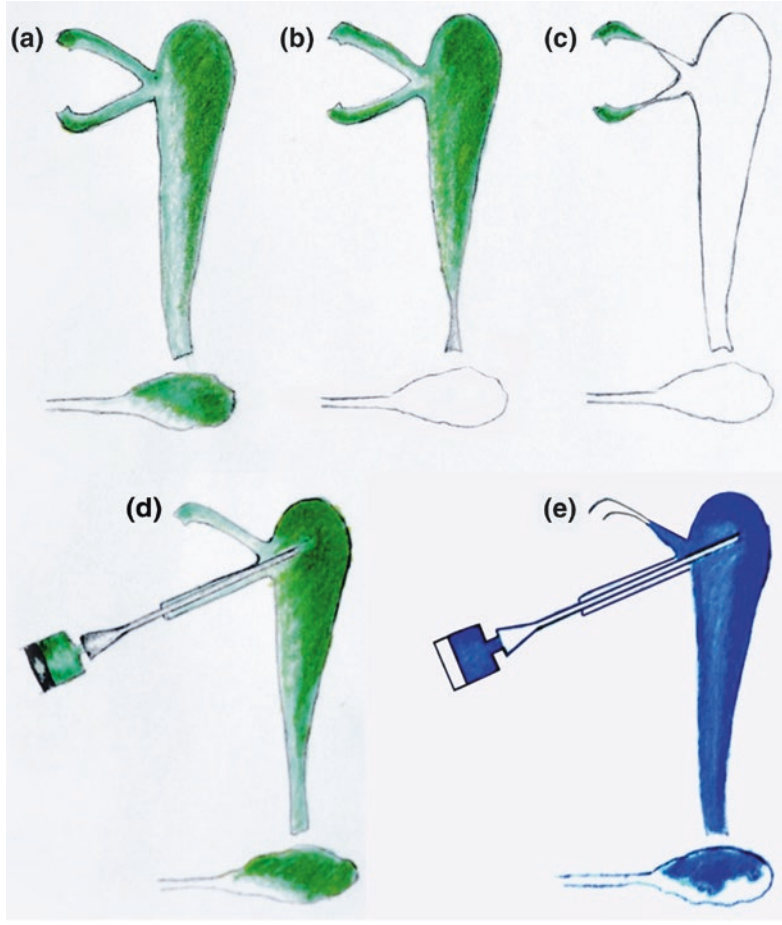

Fig. 6 Jones dye testing. **a** Positive Primary Jones dye test, tearing is mainly due to primary hypersecretion of tears. **b** Negative primary test due to partial obstruction of the lacrimal drainage system (site unknown) or Lacrimal pump failure (**c**). **d** Positive Secondary Jones dye test indicates partial obstruction of the nasolacrimal duct where Negative secondary Jones test **e** implies partial obstruction of the upper drainage system, or Lacrimal pump failure

Diagnostic Probing

Diagnostic probing of the upper lacrimal drainage system (punctae, canaliculus, and lacrimal sac) can be performed in adults under topical or local anesthesia with a small probe (0 or 1 probe) to confirm the level of obstruction. The probe is advanced while lateral traction is applied to the eyelid to straighten the canaliculus and decrease the risk of damaging the canalicular mucosa and creating a false passage. A hard stop occurs if the cannula enters the lacrimal sac and stops at the medial wall of the sac against the rigid lacrimal bone; this excludes complete obstruction of the canalicular system. A soft stop characterized by a spongy feeling occurs if resistance to the probe occurs before entering the lacrimal sac, along with medial movement and wrinkling of the medial canthal skin. A soft stop results more commonly from kinking in the canalicular system; in this case, the probe is withdrawn and the lateral horizontal traction on the eyelid is increased while reinserting the probe. Again, injecting methylcellulose is very helpful in this respect as described earlier. If the probe comes to a hard stop, then the canalicular system is patent, otherwise there is canalicular system obstruction or stenosis. However, probing has no place in diagnosing or treating NLD obstruction in adults and is limited to diagnosing problems in the canalicular system only.

Role of Imaging in the Evaluation of NLD Obstruction

Dacryocystography (DCG) aids in the anatomic evaluation of the lacrimal system, during which dye is injected into the bilateral lacrimal systems and magnified images then are obtained. DCG also helps identify the exact level of obstruction or stenosis and the presence of diverticulum, fistula, stones, or tumors. DCG is not performed routinely to evaluate tearing but is useful in patients with suspected lacrimal sac tumors or those who may have abnormal anatomy due to trauma or congenital abnormal pathologies. Normal DCG results in the presence of subjective and objective epiphora suggest lacrimal pump failure. DCG is also the method of choice to assess the patency

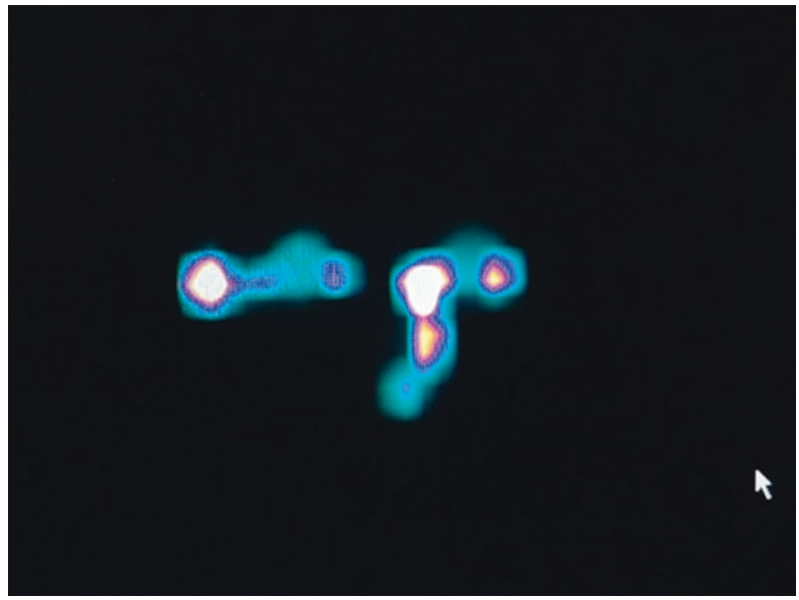

Fig. 7 DSG of the patient in Fig. 3 with right upper nasolacrimal system obstruction (punctal obstruction), while the left system shows passage of the radioactive material into the nose under the inferior turbinate

of a dacryocystorhinostomy. Computed Contrast Dacryocystography (CT-DCG) shows the bony structure around lacrimal system as well.

Dacryoscintigraphy (DSG) is a procedure in which radioactive labeled material (technetium 99) is instilled into the conjunctival sac and a modified gamma camera monitors the physiologic progress of the labeled material through the lacrimal system using a sequence of recorded images over 20 minutes. DSG is a more physiologic and noninvasive test than DCG but does not provide the same anatomic visualization as DCG (Fig. 7). DSG can be performed to identify the location of a partial or functional block, such as conjunctivochalasis or punctal occlusion, or sometimes to confirm the presence of a normal drainage system to avoid surgery.

Computed tomography (CT) and magnetic resonance imaging (MRI) are reserved for patients with atypical signs or symptoms and are useful in congenital craniofacial deformities, after trauma, to assess the position of the cribriform plate or evaluate suspected lacrimal sac or nasal neoplasia, or sinus pathologies that may cause tearing. CT also is useful to evaluate infants with a congenital cystic mass in the medial canthal area and to differentiate amniocoles from meningoceles.

Lacrimal sac biopsy of a mass can be performed during external or endonasal DCR when a systemic or granulomatous disease is suspected, or atypical clinical or intraoperative findings or masses are encountered intraoperatively. The biopsy in these cases permits early diagnosis of potentially life-threatening malignancies and defines the degree of active inflammation to determine further treatment and management.

A review of the clinicopathological results of 162 lacrimal sac biopsy specimens from 150 consecutive patients reported that 147 (98%) patients had histopathological findings consistent with inflammation or fibrosis of the lacrimal sac or both. Other abnormalities included sarcoid granuloma (one patient), oncocytoma (one patient), and lymphoma (one patient, two specimens). Other studies of selective lacrimal sac biopsies obtained from 442 consecutive external DCR surgeries in patients with atypical clinical or intraoperative findings found that only 3.8% were positive for pathologies including non-Hodgkin B-cell lymphoma (two patients), squamous cell carcinoma (two patients), malignant melanoma (one patient), oncocytoma (one patient), pyogenic granuloma (three patients), Wegener's granulomatosis (three patients), and sarcoidosis (two patients). In other series in which routine lacrimal sac biopsies were performed (1,294 specimens), only 0.5% identified a specific pathology that was not suspected clinically, and only one (0.08%) case was malignant (lymphoma). Therefore, lacrimal sac biopsy is not performed routinely during DCR.

Management of the Various Causes of Acquired Lacrimal Obstruction

Conjunctivochalasis is a chronic conjunctival condition characterized by loose, redundant conjunctival folds over the lower eyelid margin. Anatomical obstruction of the punctum by loose conjunctival folds, chronic low grade inflammation and ocular surface irritation contributes to epiphora. It may be observed in a wide range of ages, most commonly affecting elderly patients. It is usually bilateral. It is a common but often overlooked finding in cases of ocular surface. Lubricants and topical steroid or anti-inflammatories are indicated for symptomatic patients. For the cases who fail to respond to the medical therapy, the surgery options are; conjunctival cauterization, conjunctival excision with or without tissue graft, scleral fixation of the conjunctiva with 6-0 Vicyrl sutures.

Punctal Stenosis: See chapter "Punctal Stenosis"

Canalicular stenosis: see also chapter "Canalicular Obstruction" Obstructions may occur either in the proximal or distal parts of the upper or lower canaliculus or in the opening of the common canaliculus to the lacrimal sac. Causes of canalicular stenosis have been linked to trauma, viral infections (herpes simplex, herpes zoster, and adenovirus), external beam radiation,

and toxic effects of topical and/or systemic medications, and ocular surface disorders such as, cicatricial pemphigoid, Stevens-Johnson syndrome, lichen. (Table 1, chapter "Punctal Stenosis".) Histopathologic examination of the material retrieved from canalicular obstructions usually demonstrates fibrosis and chronic inflammation. The inflammatory response ends up with contraction of the diameter of canaliculus. Location and degree of obstruction affects the rate of surgical anatomic success. Success rates are higher for common canalicular blockage, in comparison to lower obstructions. Partial obstruction of the common canaliculus or constriction of either canaliculi may be treated with monocanalicular or bicanalicular silicone intubation. Both microtrephination and balloon canaliculoplasty followed by silicone intubation have been used to recanalize the intracanalicular strictures.

Total obstruction of the common canaliculi and a limited area of the canaliculi may be treated with canaliculodacryocystorhinostomy (CDCR) with bicanalicular silicone intubation. In case of severe bicanalicular obstruction, a CDCR with the placement of a Jones Pyrex glass tube (Gunther Weiss, Portland, OR, U.S.A.) or other variations like the flanged glass Stoploss tube or the PVP coated silicone Materieau tubes is the standard treatment. The surgery is performed as for external approach DCR (see below) and a Pyrex tube is inserted through an opening created at the caruncule to an osteotomy site into the nasal cavity. Anatomic success rates for CDCR with Jones tube are high and range between 83 and 97.7%. However complications including obstruction of the tube with mucus, extrusion or migration of the tube may be troublesome leading to variable rates of patient satisfaction.

Another minimally invasive treatment option for epiphora in lacrimal canalicular obstruction is off-label injection of botulinum toxin-A (BTX) directly in the lacrimal gland. Botulinum toxin-A blocks the presynaptic release of acetylcholine and decreases tear production. Different doses and concentrations (2.5–5 U) are used transconjunctivally or transcutaneously. The transconjunctival approach is associated with fewer complications and requires fewer doses. Side effects are transient; dry eye, ptosis, and diplopia that can be seen with this treatment. For elderly population with multiple comorbidities BTX is an excellent alternative treatment.

Acquired NLD Obstruction

Aetiology of PANDO

NLDO is classified as primary acquired NLDO (PANDO) and secondary acquired NLDO (SANDO). Idiopathic or primary cases are the most common ones. Although the initial factor in PANDO is still uncertain, pathologic studies revealed compression of the duct by inflammatory infiltrates and edema. This inflammatory process proceeds to fibrosis of the nasolacrimal duct and end up with clinical chronic dacryocystitis. However, there are predisposing and associated factors. It occurs more frequently in the middle-aged patients affecting women two to three times more than men. History of infectious conjunctivitis, rhinitis and swimming pool exposure are possible predisposing factors. The small diameter of bony nasolacrimal canal is one of the potential etiologic factors of PANDO.

The current focus is on understanding the lacrimal drainage-associated lymphoid tissue (LDALT) and tear duct-related lymphoid tissue (TALT). TALT appeared to be lost in symptomatic dacryostenosis. The other focus is the reduction or absence of multiple hormonal receptors in the nasolacrimal duct. These studies are controversial but important for further exploration of the etiopathogenesis of PANDO.

Aetiology of SALDO

Secondary acquired nasolacrimal drainage obstruction (SALDO) may result from a wide variety of causes, the treatment is target specific. SALDO is classified into five categories: infectious, inflammatory, neoplastic, traumatic and mechanical.

Infectious causes may be bacterial, viral, fungal, or even parasitic. Most common pathogens are Staphylococcus, Streptococcus, and Actinomyces species. Trachoma, leprosy, tuberculosis, treponema pallidum or rhinosporidiosis are the other unusual agents.

Inflammatory SALDO can be a result of endogenous diseases like, Wegener granulomatosis, sarcoidosis, Stevens-Johnson syndrome, cicatricial pemphigoid, and idiopathic inflammatory pseudotumor. Wegener granulomatosis and sarcoidosis are the most common diseases effecting the nasolacrimal system.

Exogenous etiologies are thermal and chemical burns, allergies, radiotherapy, systemic chemotherapy, bone marrow transplantation. Both endogenous or exogenous inflammatory etiologies end up with nasolacrimal tissue progressive fibrosis and secondary obstruction of nasolacrimal duct.

SALDO due to a primary tumor of the lacrimal system are relatively uncommon; these are papilloma, squamuous cell carsinoma, fibrous histiocytoma, oncocytic adenocarcinoma, melanoma, and fibroma. Secondary infiltrating tumors are more common and include lymphoma, leukemia, basal cell carcinoma, neurofibroma, and maxillary sinus tumors. Metastatic tumors are melanoma, breast and prostate carsinoma.

Traumatic causes of SALDO can be iatrogenic and noniatrogenic. Accidental, noniatrogenic trauma is a frequent cause. Naso-orbito-ethmoid, midfacial fractures usually involve the nasolacrimal canal. At the initial operation or evaluation of the traumatized patient, nasolacrimal canal must be checked and prophylactic silicone intubation should be done to prevent SALDO.

Iatrogenic nasolacrimal obstruction may result after many procedures. The potential procedures are nasolacrimal surgeries, transantral orbital decompression surgery, sinus surgery, rhinoplasty, rhinotomy, and other nasal surgeries and craniofacial procedures.

Mechanical blockage of nasolacrimal canal may result from internal causes; dacryolith, migrated or retained medical device or external causes; mucocele, nasal foreign bodies. Dacryoliths are the most common etiology of all, an eyelesh can be nidus for dacryolithiasis.

Treatment of NLD Obstruction

The appropriateness of a surgical procedure is determined by the etiology and level of the obstruction in the lacrimal drainage system. In patients with acquired NLD obstruction, DCR is the treatment of choice for most patients. During the procedure, a new and direct anastomosis is created between the lacrimal sac and mucosa of the middle nasal meatus by removing the intervening bone. The surgical aim is to create a wide anastomosis of the lacrimal sac into the nose ideally extending vertically from the fundus of the sac to the upper part of the NLD, thus eliminating the action of the lacrimal sac and bypassing the NLD. The indications for DCR include symptomatic epiphora, recurrent dacryocystitis, painful lacrimal sac distension, and frequent mucoid discharge.

DCR can be performed through an external (transcutaneous) or internal (endonasal or endoscopic) approach. The main advantage of the internal approach includes lack of a visible external scar (more troublesome in young and dark-skinned patients) and wound-related complications such as a hematoma, infection, and wound dehiscence. Other advantages are shorter operating and recovery times, minimal blood loss, no disruption of the medial canthal ligaments, and less patient discomfort. Initially, the success rate for external DCR was higher than the internal approach (90% vs. 80%, respectively), although authors have reported recently nearly similar success rates depending on the surgeons' experience (better than 90%). The endonasal approach (endoscopic) DCR can be performed using nasal endoscopes directly through the nose or fiberoptic light through the canaliculi to help locate the lacrimal sac and identify the lacrimal bone. External DCR is however better for the management of unexpected lesions and intraoperative complications, and obtaining biopsies is relatively easier with

external DCR. Further, the scar from the external DCR heals nicely without sequelae if the skin had been quiescent preoperatively even in younger patients. The main advantage of external DCR over endonasal DCR is the clear advantage of the ability to directly suture the sac and nasal flaps together to ensure long term patency.

External DCR is performed either under general anesthesia or local anesthetic infiltration with intravenously monitored sedation. To enhance intraoperative hemostasis, the skin over the lacrimal sac and medial canthal area is infiltrated with 2% lidocaine with adrenaline (1:100,000) and the nose is packed with vasoconstrictive agents such as oxymetazoline hydrochloride, cocaine 4%, or lidocaine with adrenaline.

Classically, a skin incision is made 10 to 11 mm medial to the inner canthus just above the medial canthal tendon and extended downwards and slightly laterally for about 10 mm to avoid the angular blood vessels and wound contracture that lead to epicanthal folds. Another approach for creating the incision to prevent scaring is by pulling the upper and lower eyelids and determining the location of the skin fold and then making the incision anterior (medial) to it. A better cosmetic incision can be done in the form of a half Z; a small horizontal limb about 5 mm along the medial canthal tendon and a longer vertical limb that extends from the medial end of the horizontal limb along the tear trough line. This keeps the whole incision in the thin skin of the lower eyelid, avoiding the thick nasal skin, resulting in a better cosmetic result with virtually no scar. Also, the angular vein lies in the medial flap of the incision and is retracted by the assistant during the procedure with a very low possibility of being injured (Fig. 8).

The edges of the skin are dissected bluntly, with care taken to not damage the angular vein that lies in the orbital part of the orbicularis muscle.

Blunt scissors are used to separate the orbital fibers of the orbicularis muscle just beneath the point at which the medial canthal tendon attaches to the bone and the periosteum is identified overlying the orbital rim.

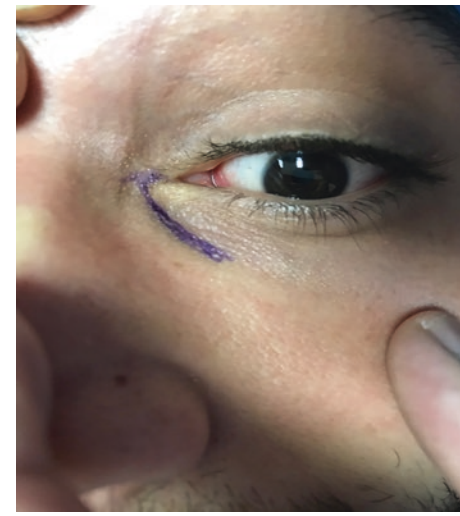

Fig. 8 DCR incision

Dealing with the medial canthal tendon is an important step. In most patients, the anterior part of the tendon can be clearly identified and may even be prominent. Cutting its attachment to the periosteum allows better dissection and enlarges the field. It is also postulated to increase the success rate of the procedure. Some prefer to reattach it back at the end of the surgery; the editor does not feel this is even necessary.

The periosteum is divided just anterior to the orbital margin, 3–5 mm above the anterior lacrimal crest using the freer elevator, and the periosteum is reflected anteriorly for 5–7 mm.

The periosteum is reflected posteriorly over the anterior lacrimal crest, and the sac is separated laterally from the floor of the lacrimal fossa to expose the entire floor of the fossa down to the posterior lacrimal crest (the periosteum is loosely attached to the lacrimal fossa).

The suture between the lacrimal bone and the frontal process of the maxilla is separated using the periosteal or freer elevator, bone trephine, drill, or hammer and chisel.

The nasal mucosa is detached with the freer elevator from the nasal aspect of the floor of the lacrimal fossa and the bony opening (rhinostomy) is enlarged with multiple bone punches; vertical bites are taken to protect the nasal mucosa. When completed, the rhinostomy should extend downward from the top of the

fossa about 5 mm above the opening of the common canaliculus under the medial canthal tendon to include the first 5 mm of the bony NLD. The posterior margin should lie just anterior to the posterior lacrimal crest and extend forward to include the entire floor of the lacrimal fossa. The anterior lacrimal crest is removed 3–4 mm in front of the orbital margin. A good rhinostomy will not have a bony margin closer than 5 mm to the common canaliculus. The ethmoid sinus may extend anteriorly to behind the lacrimal bone. Lacrimal bone removal may result in entry into the anterior ethmoid sinus rather than the nasal cavity.

The lacrimal sac lumen is identified by passing a size 0 or 1 probe into the sac via a canaliculus to make a tent of the medial sac wall.

The medial wall of the sac and the periosteum is incised vertically using a sac knife (crescent knife, Bard-Parker blade number 12 or 66). Using a sharp, curved Stevens or iris scissors, the incision is extended upward to the fundus of the sac and downward into the NLD.

A vertical cut is made into the nasal mucosa and the mucosa is divided into the anterior two-thirds and posterior one-third. Short horizontal relieving incisions are placed at the top and bottom of the anterior flaps of both the lacrimal sac and nasal mucosa to allow it to swing forward.

A silicone tube is inserted from the punctum down the canaliculus into the rhinostomy and retrieved from the nose. The other end of the silicone tube is inserted from the other punctum into the nose. The two parts of the silicone tube are tied after the common canaliculus in the rhinostomy with 6-0 Prolene or other non-absorbable sutures to prevent unwanted prolapse of the silicone tubing into the eye; it must be ascertained that there is no tension on the punctum to prevent cheese wiring. Most studies did not find any increase in the success rate of the procedure when tubes where used. It is recommended to limit the use of tubes to recurrent cases, cases with common canalicular pathology, and cases when there was difficult operative dissection or prolonged manipulations.

An absorbable material (Surgicel or Gelfoam) soaked with Kenacort (triamcinolone acetonide) or mitomycin C (in repeated cases) is inserted into the rhinostomy and between the lacrimal sac and nasal mucosal flaps to reduce fibrosis and scarring and increase the surgical success rate.

The anterior mucosal flaps are approximated with 5-0 Polyglactin 910 sutures (Vicryl) or other absorbable sutures. The subcutaneous tissue is closed with buried interrupted 5-0 Polyglactin 910 sutures. The skin is closed with

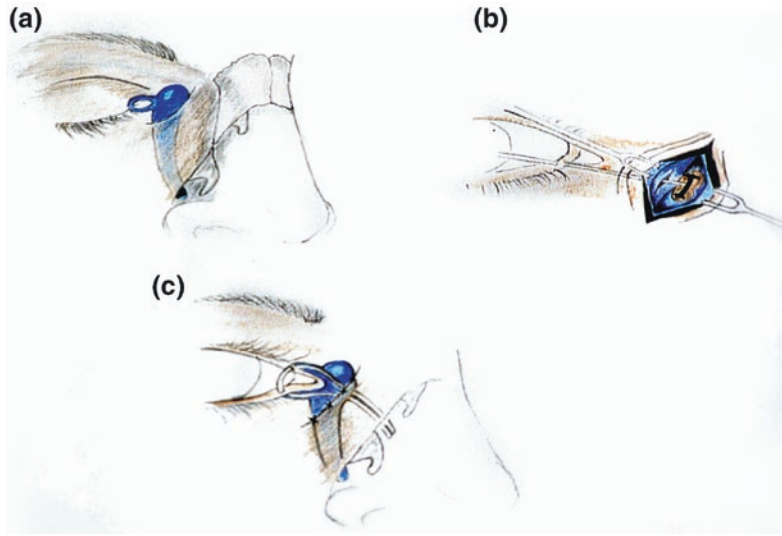

Fig. 9 DCR surgery. A direct anastomosis is created between the lacrimal sac and nasal cavity

interrupted or subcuticular 6-0 Prolene or 5-0 Polyglactin 910 sutures.

An antibiotic ointment is applied to the wound and patient is discharged on oral antibiotics and instructed to not blow his or her nose (Fig. 9).

Endonasal DCR technique: There are several techniques including conventional endomechanical method and the endolaser (endonasal laser assisted or transcanalicular laser assisted) method. The nasal mucosa is decongested for vasoconstriction and hemostasis. The lateral nasal mucosa adjacent to the lacrimal sac is then incised vertically and elevated. A fiberoptic endoilluminator can be passed through the canaliculus into the lacrimal sac to transilluminate the lacrimal bone. The lacrimal bone is next removed with a drill or Kerrison rongeurs. Laser energy may also be utilised to create the osteotomy. The bony ostium should be at least 7–8 mm in height and include adequate clearance of the common canaliculus ostium. After the removal of the bone, the medial side of the lacrimal sac mucosa is removed with the forceps. Adequate lacrimal sac mucosal removal is confirmed by free flow of saline, or direct visualization of the common internal punctum with the endoscope. Bicanalicular silicone intubation may also be performed. Mitomycin-C, an antimetabolite, may be applied to the intranasal ostium to modulate fibrosis.

Advantages of laser-assisted DCR over mechanical DCR are shorter learning curve, shorter surgery and recovery time in addition to the precise removal of tissue by ablation and minimal trauma to adjacent tissues. However, there is a possibility of traumatizing the upper lacrimal system mechanically by laser probe and sleeve. The thermal effect may also cause burns and fibrosis which heal with narrowing or occlusion of upper lacrimal drainage system which may necessitate recanalisation surgery.

DCR Complications

These include intraoperative and postoperative bleeding (epistaxis), stent-related complications such as ocular irritation, prolapse of the stent into the eye, cheese wiring of the canaliculus, and pyogenic granuloma formation. Development of orbital complications are more likely to be associated with the endonasal approach if the periorbita is disrupted and may include injury to the medial rectus muscle, orbital fat herniation into the nasal cavity, orbital hemorrhage, or emphysema. Other complications include cutaneous scarring that may require scar revision by Z-plasty, injury to the medial canthal structures, infection (wound cellulitis), and cerebrospinal fluid rhinorrhea if the subarachnoid space is entered inadvertently after disruption of the cribriform plate.

The DCR success rate is relatively high (about 90%). However, surgical failure and recurrence of epiphora are most common during the first 3 months postoperatively by either approach and may result from many causes, including fibrosis and scarring between the osteotomy and the middle turbinate or the septum; common canalicular obstruction; the sump syndrome, in which the surgical opening in the lacrimal bone is too small and too high; an inadequate (small) opening of the lacrimal sac into the osteotomy, and scar formation over the lacrimal sac. If DCR fails, the patient will still complain of tearing, symptoms of dacryocystitis, sac retention, morning stickiness, or recurrent conjunctivitis. In these cases, the surgery needs to be repeated and any adhesions or scar tissue divided.

Another treatment for lacrimal obstruction is transcanalicular endoscopy, which provides more information about the anatomy, morphology, and causes of lacrimal obstruction. Microendoscopy allows direct visualization of the lacrimal drainage system throughout the system down to the inferior meatus or the point of obstruction, and the examination can define many pathological findings such as the presence of membranes or mucosal folds, canalicular scarring, submucosal scars with shrinkage of the lacrimal sac in chronic inflammation, and foreign bodies such as dacryoliths or remains of tubes from previous intubations. Microendoscopy also makes it possible to biopsy a lacrimal sac mass or polyp. Using a

transcanalicular endoscope with a laser probe or microdrill through the canaliculus to create the bony osteotomy reduced the rate of DCR as a first-step procedure in selected patients and is faster with a shorter recovery time depending on the surgeons' experience. However, these minimally invasive procedures (laser dacryoplasty and microdrill dacryoplasty) require special endoscopic and therapeutic equipment and have a success rate of around 80%, which continues to improve over time. These procedures also replace an external (cutaneous) scar with an internal (mucosal) scar; temporary silicone tubing is necessary to prevent recurrence of stenosis. The costs and paucity of data regarding the long-term results continue to limit the use of transcanalicular surgery.

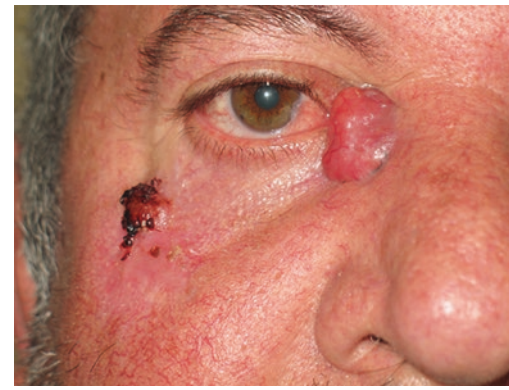

Fig. 10 Nodular basal cell carcinoma (BCC) over the right medial canthus overlying the lacrimal system. Another BCC is present in the lateral lower eyelid

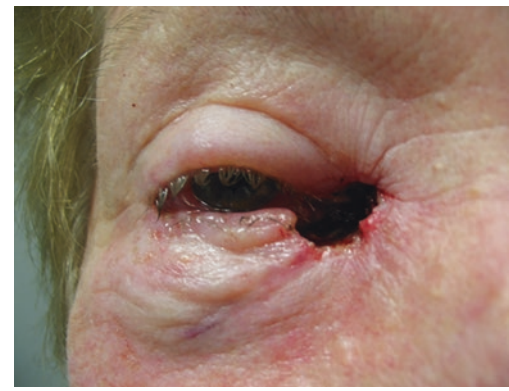

Fig. 11 Patient with a right medial canthal defect after Moh's excision of basal cell carcinoma with loss of the lower and upper canalicular systems

Lacrimal Sac Tumors

Primary lacrimal sac tumors are rare and present as firm masses located above the medial canthal tendon and telangiectasia in the skin overlying the mass; this is in contrast to diffuse erythema and swelling below the medial canthal tendon in cases of dacryocystitis. Primary lacrimal sac tumors usually present with epiphora or chronic dacryocystitis. Irrigation may reveal partial obstruction with bloody reflux from the punctum. Once suspected, CT or MRI can determine the presence and extent of a neoplasm. About 45% of lacrimal sac tumors are benign, and 55% are malignant. Epithelial tumors are the most common (around 73% of cases) and include benign tumors such as squamous cell papillomas, transitional cell papillomas, mixed-cell papillomas, and oncocytomas (oncocytic adenoma). Malignant forms include squamous cell carcinoma, transitional cell carcinoma, adenocarcinoma, mucoepidermoid carcinoma, and oncocytic adenocarcinoma. Mesenchymal tumors are less common and include fibrous histiocytoma, fibroma, hemangioma, hemagiopericytoma, angiosarcoma, or lipoma. Lymphomas and malignant melanomas are rare. Metastatic tumors confined to the lacrimal sac are extremely rare. Other primary tumors of the surrounding tissues that may invade and compromise the lacrimal drainage system include most commonly eyelid skin tumors (basal or squamous cell carcinoma and capillary hemangioma) or nasal tumors invading and destroying the lacrimal drainage system (Figs. 10 and 11).

Treatment of benign lacrimal sac tumors requires dacryocystectomy. Malignant lacrimal sac tumors may require dacryocystectomy with or without lateral rhinotomy, chemotherapy, radiotherapy (lymphomatous lesions or as a palliative measure in extensive epithelial lesions), and/or exenteration depending on the tumor type, anatomic extension, and clinical staging.

The prognosis depends mainly on the histopathological diagnosis and the staging of the disease. However, due to the paucity of reports on long-term follow-up, and the pathologies themselves, the long-term prognosis remains uncertain.

Suggested Readings

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Punctal Stenosis

Erfan El-Gazayerli

Introduction

Definition

Punctal stenosis is a condition in which the external opening of the lacrimal canaliculus, located in the nasal part of the palpebral margin is narrowed. Text book parameters for punctal diameter range from 0.2 to 0.5 mm. Therefore, narrowing of the punctum to less than 0.2 mm can be considered the anatomical definition of punctal stenosis. However, the term punctal stenosis in clinical practice is often used to indicate either narrowing or complete occlusion of the lacrimal punctum coinciding with epiphora symptoms.

Incidence

Punctal stenosis frequency is more common than anticipated. The exact incidence is still unknown, with reported rates ranging from 8 to 54.3% of cases of epiphora depending on setting, demographics, and probably interobserver variability.

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Importance

Punctal stenosis is a condition that should be given more consideration and deserves special attention particularly by general ophthalmologists for all the following reasons:

- It is relatively common,
- frequently missed or undermined,
- its etiology and causative factors are often undiagnosed or neglected,
- it is often mismanaged causing aggravation of the condition
- early rather than late management is easier and yields better outcomes.

Anatomy

Lacrimal puncti are 2 visible openings located each at the top of the lacrimal papilla in the medial aspect of the eyelid margins. The upper and lower puncti sit 5 mm and 6 mm, respectively, lateral to the medial canthal edge. The puncti typically oppose each other when the eyelids are closed. They open into the tear lake near the plica semilunaris and bulbar conjunctiva.

Each lacrimal punctum leads to the vertical canaliculus and both are considered as tarsal components in both upper and lower lids. The 2 mm long vertical canaliculus extends perpendicular from the eyelid margin before widening

E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_23

to form ampulla. At the ampulla, the canaliculus makes a 90 degree turn medially. The canaliculi then continue 8 mm horizontally before they join to form the common canaliculus.

Punctal diameter ranges from 0.2 to 0.5 mm. It is reported to be narrower in the upper lid, in older population and in the Asian race.

Practical methods to measure punctal size include slit lamp assessment using a graduated eyepiece or slit lamp examination coupled with micro ruler standardized photography of the puncti.

Lacrimal punctum and canaliculus are lined by non-keratinized stratified squamous epithelium and surrounded by a ring of fibrous tissue which is an extension of the tarsal plate.

The lacrimal papillae are surrounded by the muscle of Riolan and are pulled medially and posteriorly by the muscle fibers.

Lacrimal canaliculus epithelium stem cells, equivalent to limbal epithelium stem cells, exist and lie deep in the epithelium. They may play a role in the pathophysiology of punctal stenosis.

Pathophysiology

Chronic inflammation and subsequent fibrosis is the basic ultra-structure response to various noxious stimuli and appears to be the current proposed mechanism for acquired punctal stenosis.

Nearly all histopathological findings of punctal stenosis specimens demonstrated changes at the level of the lining epithelium and stroma, consistent with inflammation, fibrosis, or both.

Most of these changes include conjunctival metaplasia, increase number of stromal fibroblasts, macrophages and other inflammatory cells.

Early stage punctal disease may initially present with punctum mucosal oedema (Figs. 1 and 2) with stuffed punctal appearance and narrowing of punctal lumen without actual stricture.

If the noxious stimulus is allowed to continue, fibrotic stricture of the punctum (Fig. 3) or membranous overgrowth supervenes (Fig. 4), giving rise to the most commonly encountered and described stage of actual cicatricial punctal stenosis or occlusion (Fig. 5).

In the late stages of the disease, complete loss of punctal landmarks may develop and is caused

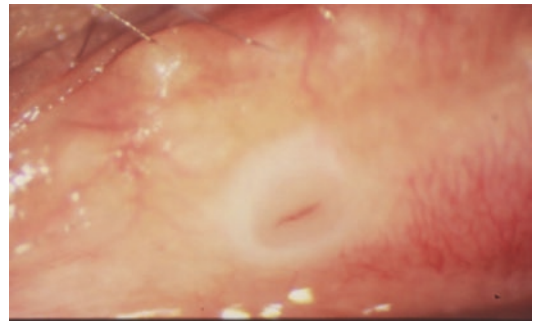

Fig. 1 Edematous punctal stenosis (moderate)

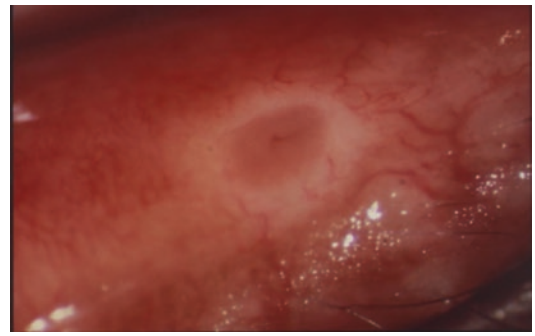

Fig. 2 Edematous punctal stenosis (severe)

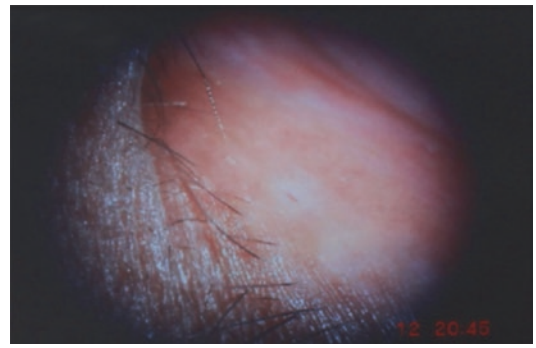

Fig. 3 Cicatricial punctal stenosis

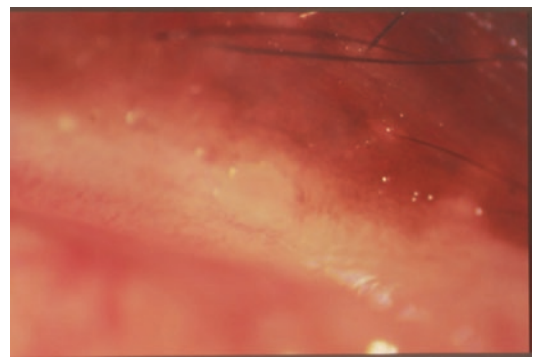

Fig. 4 Membranous punctal occlusion

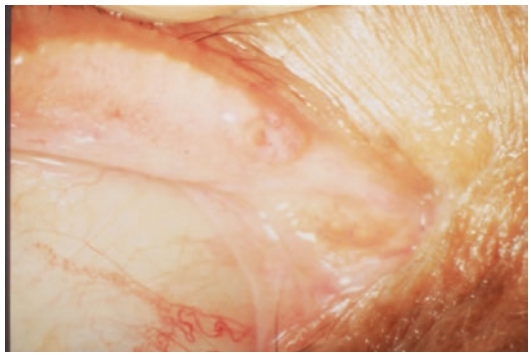

Fig. 5 Cicatricial punctal occlusion

by peripunctal tissue overgrowth totally burying the punctum.

Etiology

It is important to be aware of the many recognizable causes of punctal stenosis as this represents an important key stone in the treatment and even in the prophylaxis.

Etiology of punctal stenosis can generally fall under 3 major groups (Table 1): A-Involutional, B-Noxious Stimuli, & C-Idiopathic.

A-Involutional

Age related changes, and tissue atrophy can cause the dense fibrous structure of the punctum to become less resilient and the surrounding orbicularis fibers to become atonic, resulting in punctal stenosis. This maybe nature's way to balance old age associated dryness.

B-Noxious Stimuli

Exogenous or endogenous harmful factors initiating the inflammatory process leading to punctal stenosis.

1. **Chemical**
   - Longstanding treatment with several topical anti glaucoma agents, such as timolol, latanoprost, betaxolol and pilocarpine have been associated with punctal stenosis. Other topical agents have also been suggested as causes, and are often administered simultaneously. They include prednisolone acetate, dexamethasone, chloramphenicol, tobramycin, adrenaline, naphazoline, tropicamide, indomethacin, and mitomycin C. Punctal affection may be related to the medication themselves, the preservatives in the commercial preparations or the duration of treatment [16]. The term "**Dacryotoxicity**" was introduced by the editor (ElToukhy) in 1999 to describe a possible concurrent effect. The use of these topical medications may result in changes in the chemical and physical properties of the tears drained by the punctum (e.g. ph solutes' concentration, suspensions, …) to which the delicate punctual epithelium reacts by inflammation and later fibrosis.
   - Systemic medications are also associated with acquired punctal stenosis. Chemotherapeutic agents such as docetaxel, paclitaxel, and 5-fluorouracil have been implicated in the literature. Idoxuridine is also suspected to be a causative agent.
2. **Mechanical**
   Mechanical trauma caused by injuries or induced iatrogenically from repeated probing or other maneuvers are well known etiologies for punctal stenosis.
   Repeated or chronic mechanical stress on punctal mucosa caused by continuously wiping tears at the corner of the eye is an undermined cause of punctal stenosis.
3. **Physical**
   Punctal stenosis following local irradiation or photodynamic therapy for macular disease has also been described in the literature.
4. **Inflammatory/Conditional**
   Conditions such as dry eyes which may be associated with chronic blepharitis has been suggested as causative factors.

Table 1 Etiology of acquired punctal stenosis

A-INVOLUTIONAL
B-NOXIOUS STIMULI
1. CHEMICAL
• Topical medications
- Timolol, Latanoprost, Betaxolol, Pilocarpine
- Prednisone acetate, Dexamethasone
- Chloramphenicol, Tobramycin
- Adrenaline, Naphzoline, Tropicamide
- Endomethacin, Mitomycin C
• Systemic Medications
- Taxanes (Docetaxel–Paclitaxel)
- 5-Fluorouracil
- Idoxuridine
2. MECHANICAL
• Trauma (Injuries–Iatrogenic)
• Repeated or chronic mechanical stress on punctal mucosa
3. PHYSICAL
• Local irradiation
• Photodynamic therapy for macular diseases.
4. INFLAMMATORY/CONDITIONAL
• Dry eyes
• Chronic blepharitis
• Ectropion
5. IMMUNE RELATED
• OCP
• Steven Johnson Syndrome
6. PATHOGENIC
• Chlamydia Trachomatis
• Herpes virus, Human papilloma virus
• Actinomyces
7. GENETIC
• Acrodermatitis enteropathica
• Porphyria cutanea tarde
C-IDIOPATHIC

Eyelid malposition, as seen in ectropion, may cause punctal stenosis, possibly due to underuse of a punctum unopposed to the tear meniscus, or perhaps secondary to local inflammation.

5. **Immune Related**
   Ocular cicatricial pemphigoid and Steven's Johnson are immune mediated diseases ending in conjunctival scarring and punctal occlusion.
6. **Pathogenic**
   Infections involving the eyelid and conjunctiva such as herpes simplex can result in stenosis. Other pathogens implicated are chlamydia, actinomyces and human papilloma virus.
7. **Genetic**
   Genetic diseases, such as acrodermatitis enteropathica and phorphyria cutanea tarda, have also been reported in association with punctal stenosis.

C-Idiopathic

Not uncommonly, no specific cause is identified for punctal stenosis, the term idiopathic is used in such a situation.

Clinical Diagnosis

Reaching a diagnosis is achieved by the interpretation of information collected from history, examination and diagnostic tests.

A. **History**
   Detailed history is imperative to establish a correct diagnosis and to identify needs for treatment.
   History should include onset, frequency and severity of epiphora. With longer duration of onset, one should expect severer pathology and more extension of the disease down the canaliculi.
   Frequency and severity enquiry should include variations between outdoors and indoors conditions and are important considerations in the treatment decision.

B. **Examination**
1. External Examination
   Thorough examination is very valuable to rule out causes of watering other than punctal stenosis. Facial nerve palsy, lower lid laxity, lagophthalmos, blepharospasm and abnormal blinking are among the conditions to look for and to exclude.

2. Slit lamp examination
   This will provide a closer look at the punctal pathology and size to determine severity of the disease.
   Other conditions to be ruled out include corneal pathology, conjunctivochalasis, punctal ectropion, blepharitis and centurion syndrome.
   A simplified-management oriented-stenosis severity grading, based on slit lamp findings and inspired from Khaskouli et Al in 2003 with minor adaptation is shown in Table 2.

C. **Diagnostic tests**

1. Fluorescein dye disappearance test is a useful quantitative assessment of delayed tear outflow but can be misleading.
2. Lacrimal probing is important to exclude associated canalicular block and should be done whenever possible.
3. Lacrimal syringing is likewise important as it excludes block in the lower lacrimal pathway which will change treatment strategy.

Management

A. Management philosophy

- Punctal stenosis alone is not an indication for treatment. Punctal stenosis causing persistent bothersome epiphora on the other hand warrants management interference.
- Punctal stenosis is often linked with hyperlacrimation (pseudo epiphora) from associated ocular surface disorders. Accordingly causes of hyperlacrimation should be excluded or treated prior to any management decisions for the stenosis.
- If associated pathologies are additionaly contributing in epiphora with punctal stenosis, the art of management requires determining which process is contributing the most to the epiphora and then direct treatment accordingly. Occasionally, other contributing etiologies for epiphora (such as lower lid laxity and punctal ectropion) are more successfully managed compared to some punctal surgeries rendering them a treatment preference.

B. Management overview and guidelines

- Many treatment procedures have been suggested in the literature with wide variations in results and success rates
  This may be largely attributed to the great disparity in pathology and lack of clinical standardization. However the following knowledge concerning punctal stenosis treatment modalities seems to have achieved reasonable consensus among experts and workers in the field. This info may be of assistance when considering various management options and decisions:

Table 2 Severity grading and correlated management of acquired punctal stenosis

Grades	Grade description	Slit lamp findings	Valid and relevant management
Grade 0 (very severe disease)	Obliterated punctum with loss of landmarks	No traces of punctum detected	Retrograde transcanalicular reconstruction and lacrimal stenting
Grade 1 (severe disease)	Occluded punctum without loss of landmarks	Recognizable but either severely constricted (cicatricial shrinkage) or blocked (membranous coverage)	Punctoplasty with lacrimal stenting
Grade 2 (moderate and mild disease)	Narrowed to less than normal size	Narrowed to less than 0.2 mm by fibrotic stricture or mucosal lining oedema	• Lacrimal stenting or punctoplasty • Topical preservative free steroids for edematous stenosis
Grade 3 (no disease)	Normal punctum	Patent punctum equal or more than 2 mm. (rounded or slit)	No action

- Snip punctoplasty procedures remain the classic main stay treatment procedure for punctal stenosis
  Substantial knowledge and experience with the snip procedures make them always a valid option in the treatment.
- Among various snip procedures described, the 3 snip procedure is the most popular and has been advocated by many as the most successful treatment.
  On the other hand, the one snip procedure is generally believed not to yield long term results.
- Among the 3 snip procedures the modified rectangular 3 snip seems superior to the traditional triangular 3 snip in preserving the lacrimal pump mechanism.
- Punctal stenting procedures are relatively newer options with success rate ranges close to that provided by punctoplasty surgery.
- Punctal stenting are less invasive, easier to perform and less likely to induce punctal cicatrization and damage.
  On the other hand, they are financially demanding and longterm stability remains a concern.

- Since management guidelines in the literature are inconsistent and scattered, a more integrated management approach—summarized in Table 2—will be considered informative and practical. The table underlines the most valid and relevant treatment modality for every grade of the diseased punctum.

C. Basic and valid modalities

1. **Topical preserved free steroids**
   Topical preservative free steroids (0.1% dexamethasone preparation) can prove very beneficial when punctal stenosis is shown to be caused by edematous thickening of the lining mucosa (Figs. 1 and 2). Coinciding with topical treatment, any noxious stimuli should be eliminated. Patients should also be given instructions to abstain from traumatizing the punctal area by continuously wiping tears at the inner corner of the eye.
2. **Snip punctoplasty**
   - <u>One snip punctoplasty</u>
     - Straight vannas scissors is used with one blade of scissors into the vertical canaliculus and the other blade faces the conjunctival side and a snip is made in the vertical canaliculus.
     - Drawback of one snip technique is restenosis and short term solution
   - <u>Triangular (traditional) 3 snip punctoplasty</u>
     - It involves one snip along the vertical canaliculus till ampulla, one snip along the roof of horizontal canaliculus to create a flap and a third snip to join the two ends and remove the base of the flap.
     - Although studies have documented high success rate with the triangular 3 snip, it is believed to cause a permanent damage to the vertical and proximal horizontal canaliculus.
   - <u>Rectangular (modified) 3 snip punctoplasty</u>
     - Two vertical cuts are made on either side of the vertical canaliculus only and one joining cut at the base without any involvement of the horizontal canaliculus.
     - The rectangular 3 snip is a more conservative approach and seems superior than triangular 3 snip mainly in preserving the lacrimal pump mechanism (Figs. 6, 7, and 8).
3. **Lacrimal stenting procedures.**
   - <u>Perforated punctal plugs</u>
     - These are similar to the plugs used for the treatment of dry eyes, but slightly larger and perforated in the center with an orifice of 0.6 mm.
     - Main drawback of these perforated plugs is spontaneous extrusion and suspicious long term success.
   - <u>Mini Monoka stent (FCI Ophthalmics)</u>
     - Mini Monoka is a 40 mm long self-retaining silicon stent. It consists of circular collarette connected to a solid

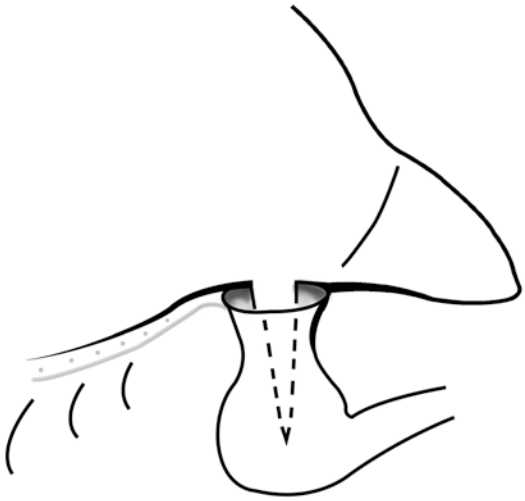

Fig. 6 1snip

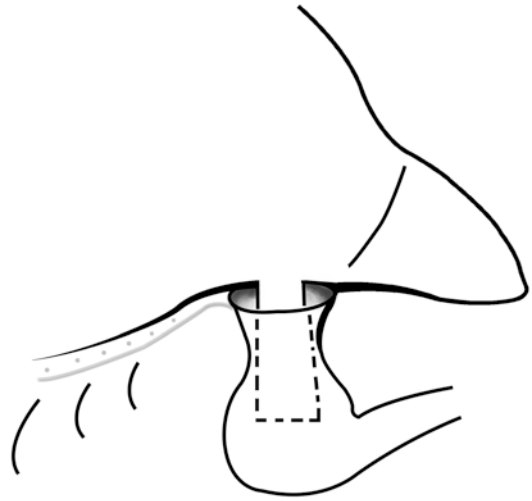

Fig. 8 3snip (rectangular)

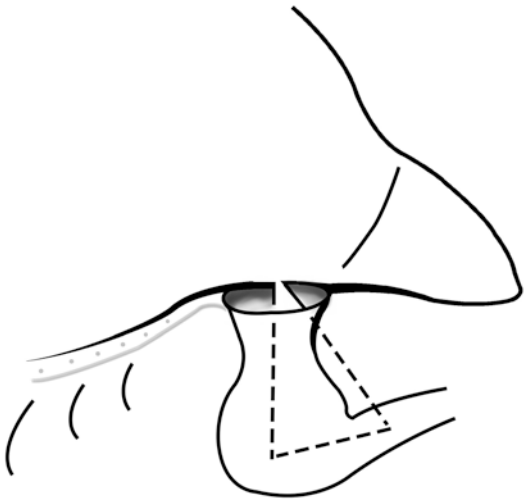

Fig. 7 3snip (triangular)

silicone tube by a neck and a bulbous joint at a vertical angle.

The collaret sits over the punctum and allows stable fixation. The neck and bulb are designed to fit the vertical proximal canaliculus and address punctal stenosis.

The silicon tube fits the horizontal canaliculus and addresses canalicular stenosis.

- The main advantage of Mini Monoka is its capability of addressing both punctal and canalicular stenosis coexisting in 45% of cases.

  Other advantages include a reported high success rate and non-invasive nature requiring only punctal dilatation in a clinic setting. Its main drawback is the occasional premature loss and the associated epiphora while in place.

- Self-retaining Bicanalicular intubation set (FCI Ophthalmics)
  - It consists of a silicone tube, available in three lengths (25 mm, 30 mm, or 35 mm). the tube has an anchor-shaped head on each end, which are preloaded on a small guiding probe provided in the set.
  - Each head has two flexible winglets that fold inwards during insertion through the punctum and spread back at the junction of common canaliculus and lacrimal sac, thus securing stent fixation.
  - Advantages are many:

– Can address punctal, lateral canalicular and common canalicular stenosis simultaneously
– Can address upper and lower puncta and canaliculi simultaneously.

– Provide comfort and allow tear drainage while in place.
– Easy implantation and extubation as an office procedure or under the slit lamp.
– Particularly suitable as an adjunct to the three snip procedure to reduce incidence of punctal restenosis and to improve outcome. Its main drawback is spontaneous extrusion.

4. **Wedge Punctoplasty**
   Wedge punctoplasty involves a punch incision in the posterior wall of the punctum and vertical canaliculus. The procedure is conducted by either Kelly punch or Reiss punch. The resultant tissue excised from the posterior wall is wedge shaped and is supposed to prevent reapproximation of the cut edges. The wedge punctoplasty, compared to the 3 snip procedure, is more standardized, reproducible and requires less surgical competences.
5. **Retrograde transcanalicular punctal reconstruction.**
   - This microsurgical technique is useful when the punctum is absent or lost its landmarks.
   - An exploratory cut down through the posterior lid margin and adjacent conjunctiva medial to the punctum is done, best under the microscope.
   - . The cut edges of the lateral canaliculus are first identified in the depth of the incision. A probe or a pigtail is then introduced through the proximal cut end of the canaliculus in a retrograde fashion to identify and recreate the lost punctum.
   - The sutured edges of the cut canaliculus as well as the recreated punctum are finally secured over a silicone stent of several choices.

Acknowledgements The author wishes to thank Moataz Dabees, fellow oculoplastics at Magrabi eye hospital, Cairo, Egypt for his contribution in research and editing work.

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Canalicular Obstruction

Vikas Menon and Anita Bisht

Introduction

Disorders or obstructions of this part of lacrimal drainage system are far more complex to manage compared to an obstruction that occurs in the distal part of the lacrimal system.

Puncta and canaliculi may be non functional from birth (congenital) or develop a closure subsequently in life (acquired). Agenesis of one or both lacrimal canaliculi is rare, diagnosed in about 4% of the patients attending a lacrimal clinic. Most of the acquired punctal/canalicular obstructions are either idiopathic or result of some sort of allergic process, whether to some topical medications or environmental factors. Common causes of acquired proximal lacrimal system pathway stenosis and obstruction are enumerated in Table 1 chapter "Punctal Stenosis".

Punctal and Canalicular Agenesis

Congenital obstructions of the proximal pathway can be in the form of isolated punctal atresia, but more often it is seen in association with canalicular agenesis as well, which makes this problem more complex to manage. The basic defect lies in failure of outbudding of canaliculi from the upper end of lacrimal cord during embryogenesis. Severity of symptoms depend on whether the dysgenesis involves single punctum or both. Examination reveals an absence of punctal papilla and occasionally presence of eyelashes medial to normal anatomical site of punctum (Fig. 1).

Punctal agenesis has been found to be associated with other ocular abnormalities like lacrimal fistula, absent caruncle, distichiasis, blepharitis, eyelid tags and divergent strabismus.

Management of the agenesis is difficult. Patients with agenesis involving single punctum may not need any intervention unless there is an associated nasolacrimal duct obstruction which can be managed with probing or dacryocystorhinostomy (DCR). Patients with both puncta missing can be kept under observation if the symptoms are minimal, whereas those with significant epiphora need to be managed with conjunctivo-DCR with Lester-Jones tube or Gladstone-Putterman tube.

Other punctal pathologies include punctal membranes, also termed as 'Incomplete Punctal Canalization' by Ali et al. in 2013. This could represent persistence of epithelium over the normally formed canaliculi. Management is simple membranotomy using a punctal dilator.

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_24

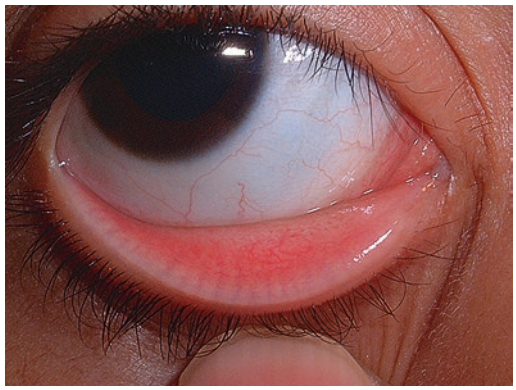

Fig. 1 Absence of punctal papilla and presence of eyelashes medial to normal anatomical site of punctum

Canalicular Obstruction

Canalicular obstruction and stenosis can be either congenital (see above) or more commonly acquired.

Anatomically, the canalicular obstructions can be proximal canalicular (first 2–3 mm of canaliculus), mid canalicular (3–6 mm) or distal canalicular (beyond 6–8 mm of normal canaliculus) (Fig. 2).

Diagnosis can be easily made with syringing and a carefully done gentle probing which shows a typical 'soft' stop as the probe encounters soft tissue obstruction within the canaliculus, compared to a 'hard' stop seen in nasolacrimal duct obstructions. A thin probe, preferably not larger than 00 should be used gently and never forced inside the canaliculus to avoid creating a false passage. The editor recommends injecting a small amount of methylcellulose before any canalicular manipulation. This straightens the canaliculus and protects the canalicular mucosa preventing any iatrogenic injury. Fluorescein dye disappearance test can also be used as an adjunct for evaluation of epiphora.

Management of canalicular obstruction: **Canalicular Trephination**: Sisler and Allarakhia first described a transcanalicular trephine in 1990. Canalicular trephine (Fig. 3) has a sharp metallic end which is advanced carefully through the canaliculus after appropriately dilating the

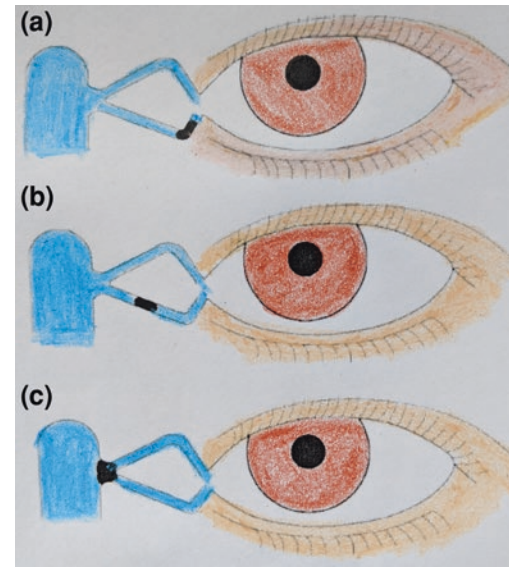

Fig. 2 Proximal canalicular, mid canalicular or distal canalicular obstructions

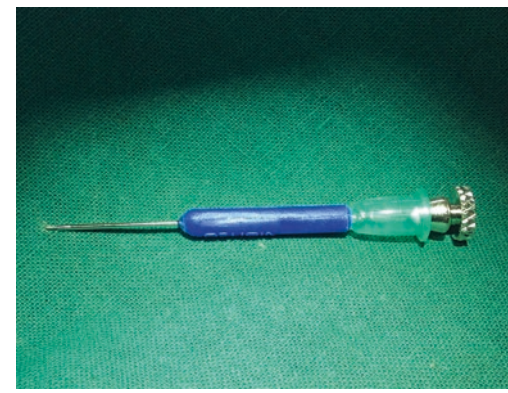

Fig. 3 Sisler's canalicular trephine. (BV International)

punctum. While advancing initially a blunt ended stillet that protrudes beyond the trephine's sharp end is kept inside the lumen of trephine till the soft tissue obstruction is encountered within the canaliculus. Once the obstruction has been reached, then the blunt stillet is withdrawn and the sharp edge of trephine advanced through the obstruction along the anatomical direction of canaliculus till the time obstruction is bypassed. Syringing is then performed and if found patent, a self-retaining mono-canalicular mini monoka

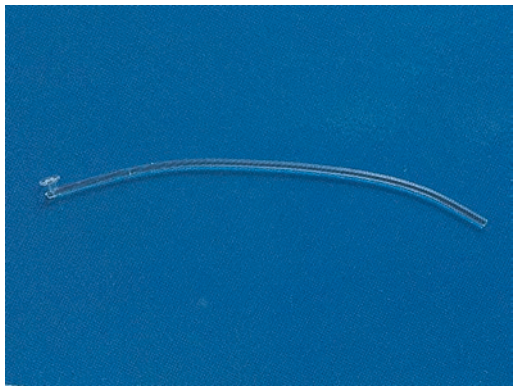

Fig. 4 Mini monoka stent. (FCI ophthalmics)

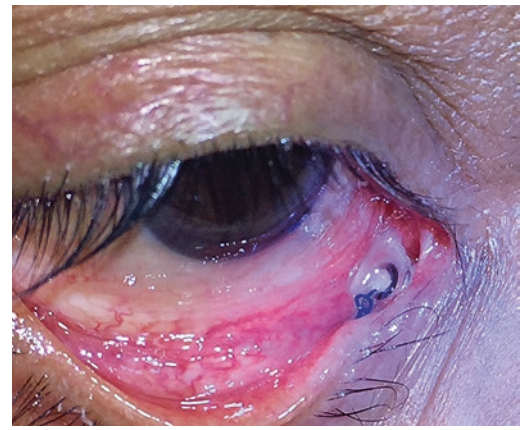

Fig. 5 Lester Jones Pyrex glass tube at the medial fornix

stent (Fig. 4) is passed through the canaliculus. Since the advancing edge of the trephine is very sharp, the surgeon must be very careful to avoid creating a false passage.

Success with trephination has been reported to be dependent on site of obstruction. More distal the block, higher is the likelihood of success. However, a delayed re-closure of a successfully opened canaliculus remains a possibility even after an 'on-table' successful surgical procedure.

Conjunctivodacryocystorhinostomy: This technique is considered to be the gold standard for managing epiphora associated with bicanalicular blocks and true congenital canalicular agenesis patients. In this procedure, a specially designed Lester Jones Pyrex glass tube is passed directly from the medial fornix into the nose (Fig. 5). Pyrex glass is chosen due to its excellent capillary action. The proximal end remains at medial canthus after removing caruncle, and the distal end should ideally project 2 mm in the nose. Some surgeons prefer to perform a DCR surgery with mucosal flaps, and the tube is inserted between the anterior and posterior sac-nasal mucosal flap anastomosis, but it is not mandatory to do so. Under endoscopic visualisation, direct tube insertion has been reported to be as successful even without an accompanying routine DCR. There are different varieties of tubes available, straight, bent, frosted, covered with PMMA, tubes with a hole for fixing suture. Basically, different methods to ensure that the tube remains in place. Although even with best of techniques, long term tube displacement and extrusion can be as high as 50%.

Canaliculodacryocystorhinostomy: This technique is indicated in cases of distal canalicular or common canalicular obstruction, when at least 8 mm of the lateral canaliculi are patent. In this procedure, an anastomosis is made between the patent medial ends of the canaliculi or the common canaliculus and the nasal mucosa, after excision of the obstructed part. Reported success rate is approximately 80% when the procedure is performed for common canalicular obstruction and 60% when it is performed for more lateral obstructions. Owing to technical complexity involved in performing this procedure, it never gained much popularity.

Endocanalicular laser surgery: Holmium, erbium or KTP (potassium-titanium phosphate) laser have been described for treatment of focal stenoses (approximately 2 mm or less) within the canaliculi. Success of laser canaliculoplasty is varied, symptomatic success at 12 months has been reported to be around 43–84%.

Retrograde intubation dacryocystorhinostomy: This technique involves performing a DCR, and then retrograde probing of the canalicular system from the common canalicular side. Mid or proximal canalicular obstruction is bypassed, a pseudo-punctum is created, and silicone intubation tube is passed. Success rate of 73% of patients with proximal or midcanalicular disease has been reported. Postoperative failure

occurs in a higher proportion of cases with mid-canalicular obstruction (39%) compared with proximal canalicular obstruction (23%).

Botulinum Toxin: Botulinum toxin injection into the lacrimal gland is an office-based procedure performed under topical anesthesia. Under topical anaesthesia, the patient is instructed to look infero-medially. The upper eyelid is gently elevated to expose the palpebral lobe of the gland. Using a 30-G needle mounted onto a 1-ml insulin syringe, 2.5 or 5 units of Botulinum toxin A are injected transconjunctivally slowly into the lacrimal gland. Published studies have preferred transconjunctival route over transcutaneous route. Transient partial or complete ptosis can occur following injection into the gland as the drug sometimes diffuses and affects the levator aponeurosis function. To prevent this potential complication, the patient is advised not to massage the eyelids post-injection. The injections can be repeated at 3–6 monthly intervals depending upon the response. The response is highly variable and subjective. It is often useful for symptomatic relief in patients who are not willing for an invasive procedure.

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Dacryoadenitis, Dacryocystitis, and Canaliculitis

David R. Jordan and Bazil Stoica

Dacryoadenitis

Dacryoadenitis is a general term used to describe any inflammation of the lacrimal gland. It may be infectious or noninfectious in etiology and can occur at any age. Acute infectious dacryoadenitis is an uncommon, usually unilateral condition that presents rapidly over a few days with temporal upper eyelid swelling, pain, and discharge. The lacrimal gland may be infected exogenously from the skin or as a result of a penetrating trauma, seeded in the course of a bacteremia or as a result of an ascending infection from the conjunctiva. The latter is most common and it is the palpebral lobe of the lacrimal gland that is most often involved.

Infectious dacryoadenitis may be caused by several bacteria. Common organisms include *Staphylococcus aureus* or *Streptococcus pneumoniae* (i.e. ocular surface and skin commensals known to be common causative agents for other orbital infections such as cellulitis and dacryocystitis). *Pseudomonas aeruginosa*, *Acanthamoeba*, *Actinomyces, Neisseria gonorrhoeae* and several other bacteria have also been reported. Viral dacryoadenitis may be associated with systemic infections including infectious mononucleosis, measles, mumps, influenza, herpes zoster, or herpes simplex. On rare occasions various fungi, including *Blastomyces*, *Histoplasma*, *Nocardia*, and *Sporotrichum*, may infect the lacrimal gland. Tuberculosis, leprosy, and syphilis can also rarely involve the lacrimal gland. The onset of dacryoadenitis may be the first sign of HIV infection associated with tuberculosis. Dacryoadenitis secondary to Lyme disease has also been reported.

Patients generally feel unwell and are febrile. On examination, the upper lid typically is ptotic and has an S-shaped curve to it as a result of the inflamed lacrimal gland (Fig. 1a). The eyelid skin is red and swollen, while the bulbar conjunctiva is chemotic and erythematous in the superior temporal fornix where the lacrimal ductules exit. Discharge may also be seen in this area (Fig. 1b). The globe may be shifted inferiorly and medially, and there is generally discomfort when one tries to palpate the enlarged lacrimal gland through the eyelid. The preauricular lymph node may be enlarged. A complete ophthalmic exam is required to determine the extent of inflammation and rule out other conditions such as an acute hordeolum (stye), preseptal cellulitis, orbital cellulitis, or ocular inflammation. Computed tomography (CT)

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_25

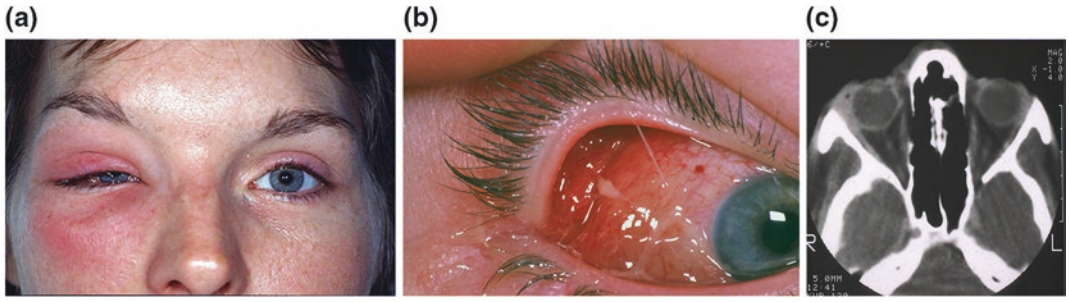

Fig. 1 **a** A 25-year-old female presented with a 3-day history of malaise, swelling and discharge of the right eye. Clinically a swollen, "s-shaped" lid was seen with tenderness to palpation over the lacrimal gland. **b** Conjunctival inflammation and discharge were seen in the superior-temporal fornix area. **c** The right lacrimal gland was uniformly enlarged with no sign of bone erosion. The patient responded well to Cloxicillin over 7 days and a broad-spectrum antibiotic eye drop (Moxifloxacin)

reveals an enlarged lacrimal gland with irregular margins and no bony erosion (Fig. 1c). CT scanning also allows one to visualize the sinuses, orbital tissues, and surrounding bone, which should be uninvolved in dacryoadenitis. Cultures of any discharge may be helpful in identifying the offending organism. A complete blood count and appropriate viral antibody titers are also useful when a viral etiology is suspected.

Bacterial infections of the lacrimal gland require systemic antibiotics. Therapy is usually initiated with an oral antibiotic effective against *Staphylococcus* and *Streptococcus* such as cloxacillin or an oral cephalosporin such as cephalexin. A response to appropriate antibiotic therapy should be apparent within the first 24–48 hours with complete resolution of disease in approximately 1 week. With an increasing incidence of orbital infections due to methicillin-resistant *Staph. aureus* (MRSA), this entity should be considered as a potential causative organism especially in the presence of multiple loculated pockets on CT scanning, a draining abscess, or worsening of symptoms and signs despite antibiotic coverage (i.e. cloxacillin, cephalexin) Intravenous vancomycin followed by oral trimethoprim-sulfamethoxazole combination therapy may be required in such cases. For those allergic to penicillin, clindamycin or erythromycin are also effective. Hospitalization and intravenous antibiotic therapy is rarely required. Hot compresses and a topical broad-spectrum antibiotic drop are also helpful. If a viral etiology is suspected, treatment may be limited to supportive measures such as maintaining hydration. Complications secondary to infectious dacryoadenitis are rare. If a lacrimal gland abscess develops, abscess incision and drainage are indicated.

Noninfectious dacryoadenitis is a type of nonspecific or idiopathic orbital inflammation (IOI) previously known as "pseudotumor" that may present acutely as lacrimal gland inflammation. The immunopathogenesis remains to be identified. An infectious antigenic precursor some weeks before the onset has been suggested which might alter the immune regulatory stem including T-cells, B-cells, mast cells and fibrocytes. IOI occurs in all age groups but the incidence peaks at 50 years in dacryoadenitis and is slightly more prevalent in females.

The clinical picture may at times be difficult to differentiate from infectious dacryoadenitis. The patient may have all of the clinical findings one sees with a true infection of the gland: i.e. pain; erythema; S-shaped swollen upper lid; tender, palpable lacrimal gland; and superotemporal conjunctival chemosis (Fig. 2a). The CT scan appearance may be identical to that seen with infectious dacryoadenitis (Fig. 2b–c). Patients with infectious dacryoadenitis commonly have fever, a feeling of malaise and some pain in the lacrimal gland area whereas those with the nonspecific inflammation (IOI) do not have fever or malaise but the pain is the major symptom and severe. Noninfectious dacryoadenitis (IOI) may be associated with systemic diseases such as Sarcoidosis, Sjögrens syndrome, Systemic Lupus

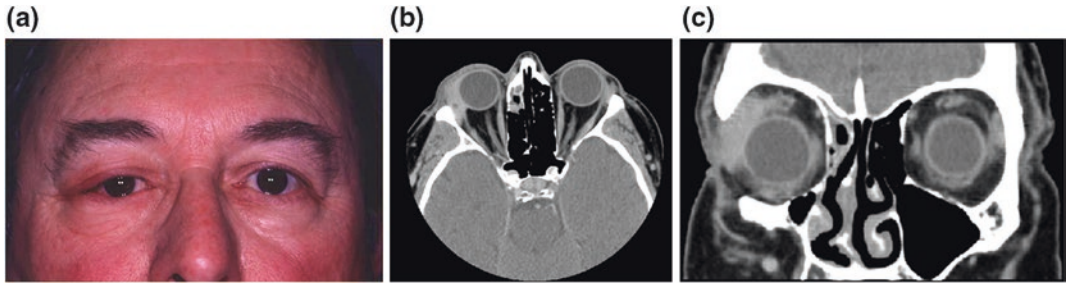

Fig. 2 **a** A 63-year-old male presented with a 4-week history of right upper lid swelling, redness and discomfort on palpation over the right lacrimal gland area. A 10-day course of cephalexin was not helpful. **b** Axial CT scan showed uniform enlargement of the lacrimal gland with out any sign of bone erosion. **c** Coronal CT scan also demonstrated an enlarged lacrimal gland. A lacrimal gland biopsy confirmed non-specific inflammation involving the right lacrimal gland. The patient responded well to an 8-week tapering course of prednisone

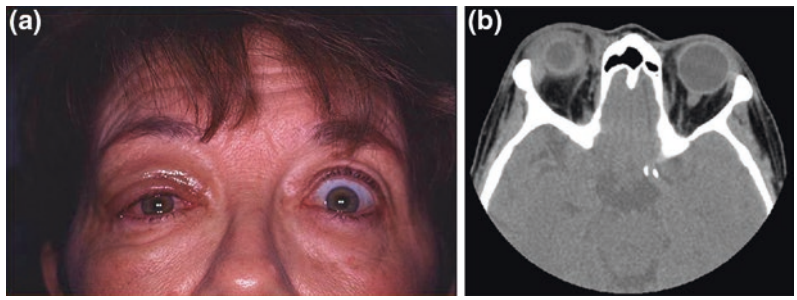

Fig. 3 **a** A 50-year-old female presented with right upper eyelid swelling and redness over 4 weeks. There was no response to oral antibiotics. She felt otherwise well. Clinically she had swelling and erythema of the right upper lid, 3 mm of proptosis and slight underactivity in upgaze. There was a palpable mass in the area of the lacrimal gland that was non-tender. **b** Axial CT scan showing uniform enlargement of the right lacrimal gland without bone erosion or molding. A biopsy was performed and revealed a noncaseating type of inflammation consistent with Sarcoidosis. A systemic work-up did not reveal any other areas of involvement; the patient responded to prednisone but relapsed on a tapering dose and required methotrexate to settle the lacrimal gland inflammation

Erythematous, Granulomatosis with polyangiitis (GPA), IgG4-related disease, Graves disease, Churg Strauss Syndrome or other autoimmune diseases (Fig. 3a–b). Lacrimal gland enlargement in a patient with a history or systemic symptoms of these diseases is often bilateral and the diagnosis is readily apparent. Unilateral presentation has been reported and occasionally as the sole manifestation of the systemic disease making a diagnosis more difficult. A wide spectrum of features is evident on CT and MRI, ranging from a well-defined mass to a diffuse infiltrating lesion, which might be confused with a malignancy. Contralateral involvement may be identified even in cases that clinically appear unilateral.

If there is doubt about whether one is dealing with an infectious or a noninfectious process, it may be preferable to treat the patient with an antibiotic over 24–48 hours in conjunction with pain relievers. If there is little or no improvement, a biopsy is required to confirm the diagnosis. Histopathology may show non-specific inflammation or a more specific type of inflammation (e.g. granulomatous inflammation, IgG4-plasma cell inflammation). Optimal treatment of a noninfectious inflammatory gland mass should be based on the histopathologic diagnosis. Steroids are the first line of treatment, and a notable response to corticosteroids within 24 hours helps confirm the diagnosis of nonspecific inflammatory dacryoadenitis. High doses of systemic corticosteroids with a slow taper (e.g. 70 mg prednisone tapered by 5 mg every five days until gone) have been suggested as the

standard treatment despite their limited sensitivity, high recurrence, and high systemic morbidity rate. The accepted regimen is to start with the standard dose (1 mg/kg body weight) until resolution of the disease, then start a slow taper of 5 mg every five days while checking for disease recurrence or systemic side effects. Using lower than the required standard dose, or for a shorter period than the time necessary for resolution will increase the chances of recurrence and change the disease from an acute to a chronic form. Most cases of acute idiopathic inflammations will respond to several weeks of oral corticosteroids on a tapering dose regime; however, refractory disease such as GPA, sclerosing inflammations and IgG4-related disease may require several months of low-dose corticosteroid, often in combination with other immunosuppression. The sclerosing variant of the idiopathic orbital inflammation constitutes a peculiar subgroup with a tendency to progress despite immunosuppressive medication. To avoid systemic steroids, or if the inflammatory process does not resolve or returns when the oral corticosteroids are finished, intralesional intermediate acting steroids (Triamcinolone) or long-acting steroids (Dexamethasone) have been used successfully as an alternative to the systemic steroids for reduced morbidity. 1 ml of the steroid is injected directly into the orbit, with ultrasonic guidance if necessary. Improvement occurs within 2–3 days and lasts for few weeks. The injection can be repeated two or three times. A low dose of systemic steroids (10 mg/day) can be given with the injection and can be maintained for several months to further reduce the incidence of recurrence.

The addition of immunosuppressives (e.g. methotrexate, azathioprine) under the direction of an internist or rheumatologist is another option that may be considered to help settle the inflammatory process as well as avoid some of the complications associated with long-term steroid use. However, these latter drugs are nonspecific in their action with respect to inflammatory disease and have potential side effects that may be unacceptable.

Biologic agents targeting more specific aspects of the inflammatory process have been introduced as another treatment alternative. Infliximab is a chimeric (human and mouse) antibody that targets the tumor necrosis factor molecule. Its use in orbital inflammatory disorders such as myositis and dacryoadenitis has recently been reported. Low-dose radiotherapy (2000 rads) is also available if the lesion fails to respond to corticosteroids or if the patient has a medical contraindication to the use of corticosteroids. Mombaerts et al. 2017 have recently recommended debulking the lacrimal gland (orbital lobe) at the same time as the orbital biopsy. In addition to being diagnostic, it may also be therapeutic. The authors reported an 80% success rate and 8% recurrence rate after surgery; much better than long-term corticosteroid treatment. The reason why surgery, even simple debulking surgery, may lead to improvement of the inflammation in idiopathic orbital inflammation is not well known. Proinflammatory cytokines are produced early at the site of the surgical trauma and mediate an acute inflammatory response leading to increased microvascular permeability as a start of the wound healing. This may help to reduce inflammation in the orbit. Another possible mechanism is that by surgically decreasing the volume of the inflammatory mass, the disease has converted into a mild self-limited condition.

Dacryocystitis

Acute dacryocystitis (bacterial infection of the nasolacrimal sac) is a result of an obstruction within the nasolacrimal duct. It may occur at any age but is more commonly encountered in infants, young adults (mid 30's), and those over 65 years. It may begin very quickly over 1–2 days and be associated with increasing pain as discharge builds up and distends the nasolacrimal sac. Prompt diagnosis and initiation of treatment are important.

A distended noninfected lacrimal sac which may have a bluish discoloration may be present at birth and is known as a congenital dacryocystocele, amniotocele, or amniocele (Fig. 4a). It is a result of amniotic fluid entering the nasolacrimal sac but not getting out due to a block at the nasolacrimal duct level and a ball-valve effect at

the common duct level (valve of Rosenmüller). Infants are obligate nasal breathers and airway obstruction with respiratory distress from the dacryocystocele may occur in some patients and requires urgent treatment. Rarely, congenital dacryocystoceles extend into the orbit causing proptosis. Controversy exists regarding the optimal management of dacryocystoceles. Some physicians advocate conservative treatment with antibiotics and massage, whereas others recommend early surgical intervention such as nasolacrimal duct probing or nasal cyst marsupialization. If the infant simply has a blue cystic mass, our initial management is conservative with digital massage for 2–3 weeks. If resolution does not occur, the child develops any sign of inflammation (dacryocystitis) (Fig. 4b), or if there is any degree of airway obstruction, we move on to surgery promptly, which involves probing the nasolacrimal system with endoscopically guided marsupialization of the dacryocystocele on the nasal side with placement of silicone tubing (stents) within the nasolacrimal system.

Simple congenital nasolacrimal duct obstruction as a result of incomplete nasolacrimal duct canalization at the level of the valve of Hasner is a more common condition than congenital dacryocystocele. Infants with simple congenital obstruction have a history of epiphora with mattering of the eyelids and minimal if any dilation of the lacrimal sac. It is important to distinguish this common and benign condition (Fig. 4c) from an acute dacryocystitis in infancy, which presents in a much more dramatic fashion (Fig. 4b).

In the newborn or young infant, it may be difficult to tell whether one is dealing with dacryocystitis, orbital cellulitis, or both. It may be preferable to hospitalize them for intravenous antibiotic therapy to decrease the chances of orbital abscess or sepsis from occurring. Cefuroxime provides broad-spectrum coverage, including coverage for upper respiratory tract organisms such as *Staphylococous. aureus*, *Streptococous. pneumoniae*, and *Haemophilus influenzae*. Once an organism has been cultured, antibiotic coverage can be adjusted accordingly.

In young adults, any degree of nasolacrimal duct obstruction (e.g., from infection, trauma, gradual narrowing with age, etc.) permits stagnation of tears, microorganism accumulation, and desquamated cellular debris to build up within the sac, with potential development of a nasolacrimal infection. In the young adult age group, the most common cause of nasolacrimal duct obstruction is trauma or the presence of a nasolacrimal stone (dacryolith). Dacryoliths are concretions of debris, protein, occasional foreign body (eyelash acting as a nidus) which form in the nasolacrimal sac and may cause intermittent nasolacrimal duct obstruction (Fig. 5a, b). Stone formation involves some inherent abnormality of tear drainage causing

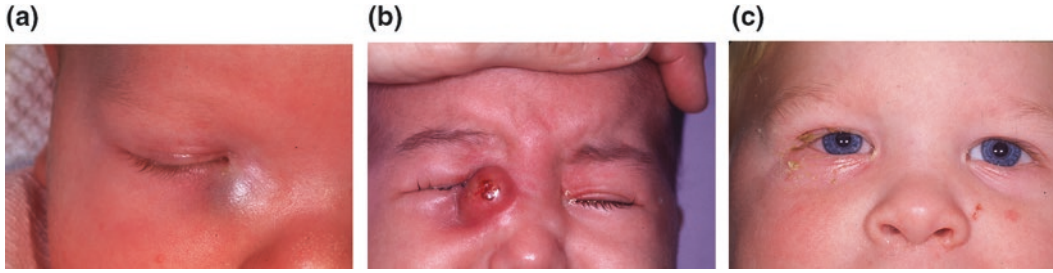

Fig. 4 **a** A 4-day old male is seen with a bluish colored cystic mass in the right nasolacrimal crest consistent with a dacryocele (amniotocele, amniocele). It resolved with massage over the next 10 days. **b** A 4-week old male with a dacryocele that did not resolve with massage presented with acute inflammation consistent with a dacryocystitis. The child was admitted and required IV antibiotics to settle the infection, followed by an endoscopic dacryocystorhinostomy with placement of stent. **c** An 8-month-old presented with tearing and mattering on the right side since birth. It resolved once the child was probed

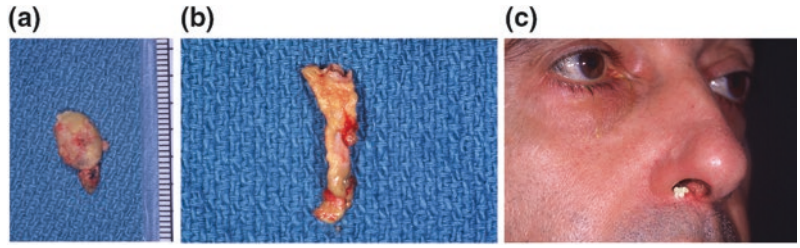

Fig. 5 **a** An example of a dacryolith that was causing recurrent episodes of tearing. It was removed at the time of dacryocystorhinostomy surgery. **b** Another example of a dacryolith that resembled an internal cast of the nasolacrimal system. It was found during a dacryocystorhinostomy procedure in a 50-year-old that presented with dacryocystitis. **c** A 45-year-old man presented with recurrent episodes of tearing, discomfort and a pea-sized mass in the right nasolacrimal crest area that was mildly tender to touch. A dacryolith was expressed from the right nostril during an office visit when the patient was asked to blow each nostril separately during a dye testing sequence. His tearing resolved later in the same day. He had a history of spontaneously expressing dacryoliths with nose blowing in the past

stagnation, turbulent flow and then deposition of substances which adhere creating a deposit that gradually enlarges (dacryolith). Individuals with a dacryolith have a characteristic history, referred to by some as the dacryolithiasis syndrome. Females are more commonly affected than males and are usually in their 30–40's, younger than most patients undergoing dacryocystorhinostomy surgery for nasolacrimal blockage. Patients complain of a pressure sensation in the medial canthal region followed by tearing, discharge and the development of a lump in the nasolacrimal sac area. The dacryolith once attaining a sufficient size blocks tear outflow, causing retention of tears, distension of the nasolacrimal sac, pain and with time, dacryocystitis as a result of the stagnation of tears. Symptoms may resolve before the dacryocystitis develops if the dacryolith spontaneously passes. The patient is asymptomatic (tear free) until the cycle recurs. Patients often have a history of similar episodes in the past, lasting 4–7 days and resolving either spontaneously, with eye drops, or occasionally with oral antibiotics (Fig. 5c).

Acute Dacryocystic Retention (ADR) is related to the dacryolithiasis presentation described above but is less often recognized. In ADR an acute mechanical obstruction of the nasolacrimal passage by a dacryolith, mucous plug, blood clot, or environmental foreign body occurs quickly (hours) and builds to a crescendo, before any sign of inflammation or infection. Patients present with a short history of tearing and sudden, severe pain out of proportion to the clinical findings (described by some as "worse than childbirth"). The diagnosis may be difficult as there is usually no sign of the typical inflammation seen with acute dacryocystitis but evidence of medial canthal and tear sac tenderness with even light palpation. The sudden impaction and obstruction of the nasolacrimal system leads to characteristic tearing, an exquisitively tender nasolacrimal sac, but with minimal externally visible swelling or erythema. The obstruction can be complete or partial. Spontaneous resolution may occur gradually over a few days with the passage of a dacryolith into the nose or nasopharynx. In the acute painful phase, several different treatments have been attempted including; decompressing the distended sac using a probe via the canalicular system, syringing the nasolacrimal system, percutaneous lacrimal sac aspiration, and dacryocystorhinostomy.

Adults beyond 65 years not uncommonly develop tearing as a result of a gradual narrowing of the nasolacrimal duct with time (primary acquired nasolacrimal duct obstruction [PANDO]). As the nasolacrimal duct narrowing develops, the patient develops increased tearing. With continued narrowing, the tearing becomes more constant and a dacryocystitis may develop secondary to complete obstruction of the nasolacrimal duct.

Acute infection of the lacrimal sac (dacryocystitis) often presents over 1–2 days with

redness, swelling, and tenderness of the skin overlying the sac and just inferior to the medial palpebral ligament (Fig. 6a). Responsible organisms are generally upper respiratory tract organisms such as β-hemolytic *Streptococcus* or *Staphylococcus*. If unchecked, infection may spread into the adjacent soft tissues to become a preseptal cellulitis of the eyelid, orbital cellulitis, or abscess. Rarely, loss of vision can occur. The infection may also ascend the canaliculus to enter the conjunctival tissue, producing infectious or hypersensitivity peripheral corneal ulcers.

Treatment of acute dacryocystitis includes pain relief, warm compresses, topical and systemic antibiotics. If it is possible to get material from the lacrimal sac by expression or aspiration, antibiotics should be chosen on the basis of microbiologic results; otherwise, empirical therapy is indicated. Since most of the acute infections in the adult result from Gram-positive upper respiratory organisms (*Streptococcus* or *Staphylococcus*) patients are empirically started on cloxacillin, or a cephalosporin such as cephalexin or cefaclor. For those allergic to penicillin, erythromycin (500 mg four times daily) or clindamycin (150–300 mg orally four times daily) is used. If this does not improve the situation within 48–72 hours and the patient remains ill, intravenous therapy with one of the previous oral medications may be required. A broad-spectrum topical antibiotic eyedrop is also applied four to six times daily to the affected eye. If the acute infection progresses to a superficial fluctuant pointing mass and the patient is uncomfortable, surgical drainage is appropriate (Fig. 6a). A stab incision into the pointing area can be made in the office or minor surgical suite with a No. 11 surgical blade (Fig. 6b). A culture is taken and ½ inch Vaseline gauze (2–3 inches) can be placed in the fistula tract to allow continued drainage over the next few days (Fig. 6c). The patient is instructed to use hot compresses the remainder of the day and gently advance the gauze packing the following day. The patient should be checked within 2–3 days to ensure the symptoms and signs are starting to resolve (Fig. 6d). Once the acute dacryocystitis settles, most patients require a dacryocystorhinostomy (within 2–3 weeks) as a result of blockage within the nasolacrimal duct. Chronic infection of the nasolacrimal sac tends to be indolent, producing symptoms of tearing and mild to moderate recurrent unilateral discharge. The patient may apply pressure over the sac, producing reflux of a mucoid or mucopurulent discharge from the punctum recurrently. The most common organisms responsible for infection are *Strep. pneumoniae* or *Haemophilus influenzae*, but various pathogens can be responsible, including other Gram-positive bacteria (*Staphylococcus* species), Gram-negative bacteria (*Klebsiella pneumoniae*, *P. aeruginosa*), anaerobic bacteria (*Arachnia propionica*) and, rarely, *Mycobacterium tuberculosis*, fungi (*Candida*, *Aspergillus niger*, *Pityrosporum*), and *Chlamydia trachomatis*. A dacryocystorhinostomy (external or endoscopic approach) is the definitive management.

Complications of chronic dacryocystitis originate from its reservoir of pathogens and may

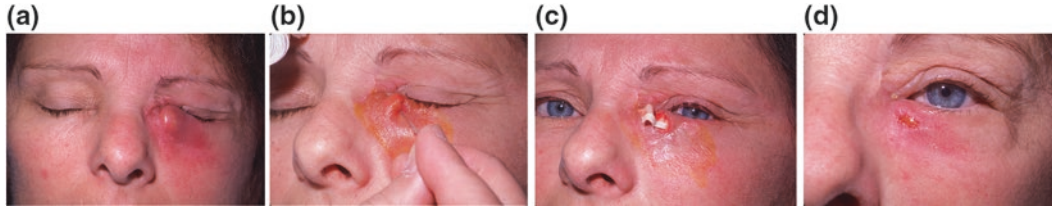

Fig. 6 **a** Acute dacryocystitis developed in a 45-year-old female. She was initially placed on oral antibiotics, but the swelling continued to develop, and the pain intensified over 24 hours. The nasolacrimal sac was pointing and appeared ready to burst. **b** The patient was taken to the minor procedure room and a stab incision with a #11 surgical blade was carried out. **c** A small length of Vaseline impregnated gauze packing (approximately 3 inches in length) was placed within the nasolacrimal sac to act as a drain. **d** The gauze drain was advanced over the next 4–5 days as the dacryocystitis started to resolve. An external dacryocystorhinostomy was carried out

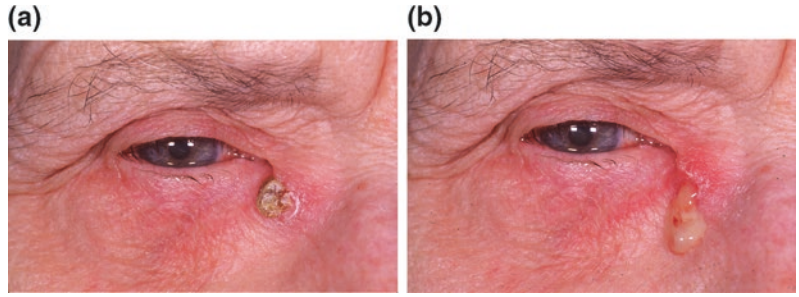

Fig. 7 **a** An 85-year-old female presented with a recurrent crust with discharge over the right nasolacrimal crest area. **b** When the crust was removed and light pressure applied over the nasolacrimal sac, a semi-purulent fluid extruded from a fistula track onto the skin over the nasolacrimal crest area

include acute recurrent dacryocystitis, orbital cellulitis, orbital abscess (with potential visual loss) infectious keratitis, endophthalmitis in the presence of corneal trauma or intraocular surgery. Not uncommonly, the patient develops a fistulous tract draining anteriorly onto the skin (Fig. 7a, b).

Canaliculitis

Infections involving the lacrimal canaliculus (canaliculitis), although uncommon, are often overlooked as a cause for a chronic recurrent unilateral conjunctivitis. Although canaliculitis occurs more commonly in those over the age of 50 years with females three times more commonly involved than males, it should also be included in the differential diagnosis of chronic or recurrent pediatric nasolacrimal duct obstruction as well. Most cases of primary canaliculitis arise without any identifiable predisposition. Patients usually have a history of unilateral conjunctival inflammation and discharge despite numerous antibiotic drops and several visits to more than one physician. This chronic recurrent discharge history with multiple visits (and treatments that have limited help) is a clue to the correct diagnosis.

Canaliculitis is usually unilateral and more commonly involves the lower canaliculus. Examination reveals some typical changes; the patient's redness is generally medial, involving the bulbar conjunctiva or caruncular area and medial eyelid adjacent to the punctum. There is usually swelling in the area of the canaliculus, and the punctum is erythematous and raised (the so-called "pouting punctum" sign) (Fig. 8a). Posteriorly, directed pressure over the swollen canaliculus produces a milky yellow discharge, often with concretions (sulfur granules) from the punctal orifice (Fig. 8b). This confirms the diagnosis of canaliculitis.

Punctal plugs increase the risk of developing infective canaliculitis as well as potential irreversible stenosis and occlusion. Tear plugs may have a collar on them and are designed for placement at the punctal level while other plugs have been designed for intracanalicular placement. Either type may lead to chronic canaliculitis with tearing and discharge. Canaliculitis secondary to incarcerated plugs may have pyogenic granulomas protruding from the punctum and/or blood-tinged tears.

The etiology of primary canaliculitis includes a spectrum of bacteria (*Staphylococcus, Streptococcus, Actinomyces*, *Nocardia, Pseudomonas, Moraxella, Corynebacterium, Proteus, Haemophilus, Mycobacterium*, and a variety of others), viruses (e.g. vaccinia, herpes simplex, herpes zoster), and fungi, including *Candida albicans* and *Aspergillus niger*. The most common fungal etiologic agent is Candida albicans, identified in 5% of cases. Numerous case series report *Actinomyces* species as the most common etiologic organism overall; however, there is also considerable variation in the most commonly isolated species. Recent studies demonstrate greater rates of infection with

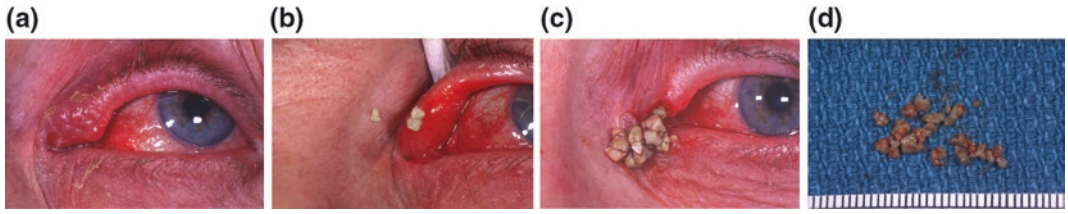

Fig. 8 **a** A 60-year-old female presented with recurrent discharge and medial conjunctival redness of the left eye despite numerous antibiotic drops. A prominent, red, inflamed upper puncta ("pouting punctum") was identified. **b** With pressure over the canaliculus using a cotton tipped applicator, yellow concretions were expressed from the puncta. **c** The patient had a 3-snip punctoplasty of the left upper canaliculus and several canaliculiths were expressed. **d** Over 2 dozen canalicular stones were removed. Her tearing resolved within days of opening the superior canaliculus and expressing the multiple stones

streptococcal and staphylococcal species. The *Actinomyces* organism has been mistaken for a fungus because of its branching filaments under the microscope, but it is actually an anaerobic, nonsporulating, higher bacterium. It is part of the normal flora found in mucous membranes and has also been cited as an etiologic agent for dental caries and periodontal disease. *Actinomyces* is a strict anaerobic Gram-positive bacillus that is usually arranged in thick filaments. Its colonies appear grossly as glistening white pearls on blood agar plates. *Actinomyces* filaments are easily fragmented into bacillary and coccoid forms with variable Gram-positive and acid-fast staining characteristics. Canaliculitis isolates with these morphologic characteristics have traditionally been assumed to be *Actinomyces* species. It is now clear, however, that other organisms may share some of these characteristics, including *Fusobacterium*, *Arachnia*, and other anaerobic bacteria. Similarly, the yellow sulfur granules or concretions thought to be characteristic of *Actinomyces* have been observed with other organisms, including *Fusobacterium* and *Staph. aureus*.

Successful treatment of canaliculitis once diagnosed, is primarily surgical and involves opening the canaliculus (Fig. 8c, d). Resolution with medical management (digital massage, warm compresses, antibiotic drops, etc.) is most often limited to those patients who present early in the course of the disease process. The responsible organisms reside in diverticula within the dilated canaliculus and may be unexposed to antimicrobial agents administered by drops. Topical antibiotics and canalicular irrigation has been found beneficial by some but requires repeated irrigations in most, carries the risk of canalicular scarring with each irrigation attempt, and in our experience is of limited benefit. Although insertion of Crawford stents on their own has also shown success in a small number of patients, most physicians surgically open the canaliculus as their treatment of choice for canaliculitis. Surgery removes concretions that serve as a reservoir for bacteria. Various surgical techniques have been described including dilating the punctum with curettage, punctoplasty with canalicular curettage, canaliculotomy with canalicular curettage, canaliculotomy with and without stenting, vertical canaliculotomy, as well as others. Dilating the punctum and carrying out an extended three-snip punctoplasty (i.e. a "mini-canaliculotomy") is simple and has been successful in the authors' hands. Essentially, the horizontal cut of the three-snip punctoplasty is a little longer (2–3 mm) than one would ordinarily make with a standard three-snip punctoplasty (1 mm), (Fig. 9a–f). The canalicular concretions (or retained punctal plug) are carefully milked out with cotton tipped applicators on either side of the canaliculus followed by gentle irrigation of the canaliculus with balanced salt solution to rinse out any remaining debris. Rinsing with iodine or an antibiotic solution is unnecessary in our experience. We strongly recommend against curetting the walls of the canaliculus

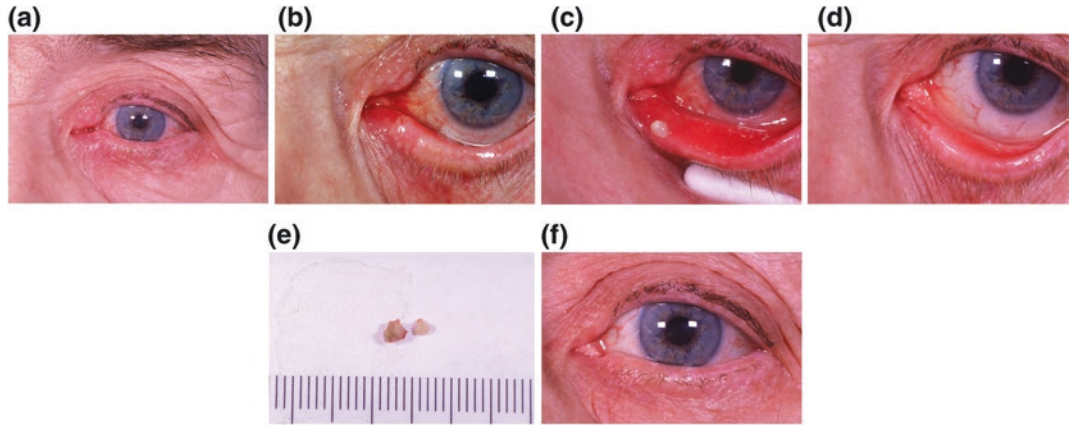

Fig. 9 **a** An 85-year-old female presented with recurrent discharge of the left eye despite numerous antibiotic drops. A prominent left lower lid punctum (pouting punctum) was identified. **b** The inflamed "pouting punctum" was well seen on examination. **c** With cotton-tipped applicator pressure over the canaliculus, yellow concretions were expressed. **d** A 3-snip punctoplasty was carried out with a longer horizontal cut than normal was made (3 mm) to express the canalicular stones. **e** The canaliculiths that were expressed. **f** Postoperatively the patient was placed on tobramycin-dexamethasone eye drops and her symptoms resolved within 5 days as did the pouting punctum

with a small chalazion curette. A curette may be used to gently lift out the canalicular stones but curetting the walls of the canaliculi has no role and simply leads to further inflammation and scarring of the canalicular walls. The primary surgical goal is to open the canaliculus, remove the concretions and re-establish tear flow. Penicillin G has been suggested as the drop of choice against *Actinomyces*, but simply opening the canaliculus and removing the concretions may be the most effective treatment in conjunction with a steroid–antibiotic drop (e.g. tobramycin–dexamethasone) to settle the inflammation associated with the canalicular infection and the surgery required to open the canaliculus. If there is a specific fungus (or bacteria), and the above steroid-antibiotic drop routine is not working, one can use more specific agents such as amphotericin for *Candida* or *Aspergillus*, but this is rarely necessary. We do not recommend intubating the nasolacrimal system with silicone tubing as the canalicular epithelium is inflamed and intubation risks trauma and scarring to the canalicular lining.

Diagnosis and appropriate treatment are gratifying for both the patient and physician. The small canaliculotomy (or slit canaliculus) created after the extended three-snip punctoplasty does not require repair and remains as a slit opening. Resolution of the redness and discharge occurs over 5–7 days. Continued tearing occurs in a small percentage of patients (<5% in our experience). This persistent tearing is most commonly due to distal canalicular obstruction at the level of the common canaliculus secondary to the canaliculitis. If the patient is symptomatic, a dacryocystorhinostomy (with possible Jones tube) may be required.

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Part V
Interaction with Other Specialities

Pediatric Ophthalmology and Oculoplasty

Ali Abdul Razzaq Mahmood Al-Mafrachi

Lid Anomalies in the Pediatric Population

The development of the lids plays a crucial role for the normal function of the eyes as well as the impact of the cosmetic appearance on the functional and psychological welfare of the child. Knowledge of the normal embryological development of the lids is needed o understand these anomalies and their management.

The Eyelids

The eye lids develop from the surface ectoderm as two folds from above and below. They grow towards each other and fuse together at the horizontal midline at the third month of gestation. Separation starts at the fifth month and is complete at the seventh month.

The orbicularis oculi muscle is derived from the mesenchyme of the second pharyngeal arch at week 12 as a condensed fold which invades the eyelids.

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The Extraocular Muscles

The EOM are of mesenchymal origin. The develop from paraxial and prechordal mesoderm. The four recti and two oblique muscles start as one mass then separate into four recti, the inferior oblique and the superior oblique at the insertion then at the origin. The levator plapebrae superioris is the last muscle to develop from the mesenchyme that froms the superior rectus muscle.

Congenital Anomalies of the Lids

This includes a wide spectrum of lid abnormalities. The most common include the following:

Ankyloblepharon
This refers to the fusion of the eyelids. Failure of the upper and lower lids to separate during embryological development leads to this condition. It could be complete fusion or more commonly partial fusion. Treatment is by surgical separation.

Epiblepharon
Is a characterized by a horizontal fold of skin under the lower eyelid that may turn the lashes inward causing it to rub against the cornea. The upper lid is less commonly involved. The condition must be distinguished from congenital

E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_26

entropion. Epiblepharon often resolves spontaneously by preschool age with the midfacial bone growth. Ocular irritation can be alleviated by lubricants. Surgical repair is indicated in severe or chronic corneal irritation and failure of spontaneous resolution. Surgery involved excision of a strip of skin and orbicularis from the lower lid margin with fixation sutures to the tarsus (Fig. 1).

Ablepharon

Is a very rare condition in which there is congenital absence or severe hypoplasia of the eyelids. The condition is a high risk for exposure keratopathy and prompts urgent surgical intervention with lid reconstruction

Cryptophthalmos

Is partial or complete fusion of the eyelids with the cutaneous epithelium continuous with the conjunctiva. The underlying globe is microphthalmic with severe anterior segment dysgenesis and is fused with the overlying skin. The lashes are aberrant or absent. The condition maybe unilateral or bilateral, partial or complete, mostly sporadic but could be autosomal recessive and less commonly autosomal dominant. A rare association is Fraser's Syndrome where the crypophthalmous is associated with systemic abnormalities (syndactyly and urogenital abnormalities). Treatment is difficult, through reconstruction of the lids and separation of the skin from the globe with high risk of perforation of the globe during the procedure.

Fig. 1 (Epiblepharon)

Epicanthus

Epicanthal folds are folds of skin which extend from the upper or lower eyelids toward the medial canthus. If this fold partially covers the medial canthus from above it is called epicanthus tarsalis. If from below, epicanthus inversus, or from both directions in equal amount where it is called palpebralis. Epicanthal folds are usually isolated or epicanthus inversus maybe associated with blepharophimosis. Treatment is by surgical correction by Z plasty.

Coloboma

In its milder form is referred to as congenital notching of the lid. It could involve the medial part of the upper lid where the defect is usually isolated. Or the lower lid where it is associated with other lid and facial anomalies such as Goldenhar's syndrome or Treachers Collins. the management depends on the size of the defect which is variable. Small defects involving less than 25% of the lid length are repaired by direct suturing after trimming of the edges of the defect. Moderate size colobomas involving 25–50% of the lid length can be repaired by a lateral canthotomy and cantholysis allowing adavancement of the edges of the defects for suturing. Large defects involving more than 50% are usually the most site threatening due to exposure keratopathy and need lid reconstruction of both anterior and posterior lamellae. Another option for these severe cases is lid sharing procedures from the lower lid but here we have to weigh the risk of amblyopia from the temporary closure of the palpebral fissure and aggressive anti-ambylopia therapy is recommended after surgery (Fig. 2).

Entropion

It should be distinguished from epiblepharon. In congenital entropion there is malpostion of the tarsal plate while in epiblepharon there is an extra fold of skin causing the misdirection. It has been postulated that maldevelopment and

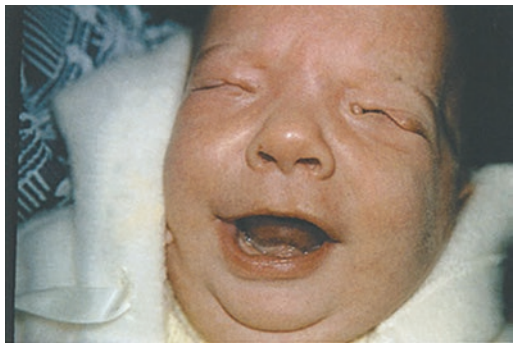

Fig. 2 Upper lid coloboma (Goldenhar syndrome)

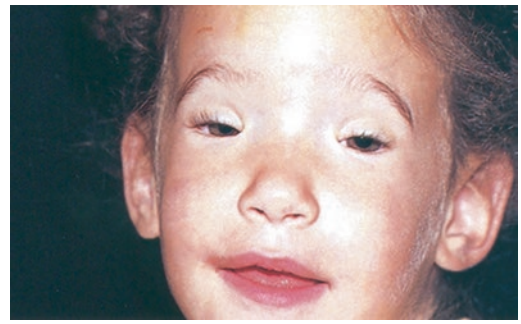

Fig. 3 Blepharophimosis syndrome

disinsersion of the lower lid retractors are behind the eitiology of primary congenital entropion. Unlike epiblepharon urgent treatment is required due to the risk of keratopathy from lashes rubbing against the cornea. Treatment is achieved by surgical reattachment of the lower eyelid retractors to the inferior border of the tarsus.

Ectropion

This condition is usually associated with other syndromes such as Downs Syndrome and blepharophimosis. It may be also be secondary to skin disorders that pull the lid outward such as Icthyosis. Treatment is usually conservative aimed at lubrication of the lids. Surgery is indicated in cases of exposure keratopathy and is achieved by lid shortening surgical procedures.

Blepharophimosis (see also chapter. "Blepharophimosis and Marcus Gunn as Special Types of Pediatric Ptosis")

It means (blepharo = lids, phimosis = small) small eye lids. It is usually part of a syndrome (Blepharopimosis syndrome or Blepharophimosis-ptosis- epicanthus inversus syndrome (BPES)). This is an autosomal Dominant syndrome, though sometimes it may be sporadic. It is characterized by blepharophimosis, epicanthus inversus, telecanthus, and ptosis. This syndrome is caused by mutation of the FOXL2 gene. Two types have been described BPES type I in which the eye findings are associated with premature ovarian failure, and type II with only eyelid findings. syndrome. Amblyopia is common either from obscuration of the visual axis by the ptotic lid or the induced astigmatism from the ptosis. Surgical correction is done in multiple stages. Epicanthus inversus, telecanthus can be corrected by medial canthal plication and V-Y plasty. Ptosis surgery with frontalis suspension can be delayed for a second session unless there is a fear of ambylopia (Fig. 3).

Congenital ptosis is discussed in chapter Congenital Ptosis

Effect of Strabismus surgery on the palpebral fissure appearance

The position of the upper and lower lids is usually changed after any surgery on the extraocular muscles most likely due to the close embryological, anatomical and innervational relations between the lid muscles, extraocular muscles and orbital connective tissues.

Horizontal muscle surgery

As a General rule, recessions of the Medial and/or the Lateral recti will lead to widening of the palpebral fissure while resections will lead to narrowing of the palpebral fissure mostly due to the effect on the lower lid position. The amount of change in the width of the palpebral fissure can be calculated from the following equation.

A Change in lid fissure width, $= 0.13 \times$ surgical dose in millimeters; $r^2 = 0.35$; $P = 0.0001$)

Vertical muscle surgery

The superior and inferior recti have the most effect on the palpebral fissure because of the close anatomical location and connection with

the upper and lower lids respectively. That is why in hypotropia for example, the upper eyelid follows the superior rectus leading to a pseudoptosis.

The inferior rectus muscle and the lower lid are connected by the fascial extension from the inferior rectus muscle sheath. So, any surgery on the inferior rectus muscle may change the palpebral fissure appearance. Recession of the inferior rectus muscle leads to widening the palpebral fissure with lower lid retraction. Inferior rectus resection however, results in narrowing of the palpebral fissure by elevating the lower eyelid.

The superior rectus: At its origin at the orbital apex, the levator palpebrae superioris muscle blends with the superior rectus muscle inferiorly and with the superior oblique muscle medially The levator palpebrae superioris passes anteriorly, lying just above the superior rectus muscle; The superior rectus muscle is loosely connected to the levator palpebrae superioris muscle through their facial sheaths.

Thus, a recession of the superior rectus causes the eyelid to be elevated upward thus, widening of the palpebral fissure. On the other hand, upon resection of the superior rectus muscle the upper lid may be pulled downward thereby narrowing the palpebral fissure. [11]

Oblique muscle surgery

With inferior oblique muscle surgery, anterior transposition of the muscle causes narrowing of the palpebral fissure. It was found also in some cases that elevation of the lower lid in up gaze may happen in weakening procedures on the inferior oblique.

Superior oblique muscle surgery has the least effect on the position of the lid. Some certain clinical studies have found that Browns Syndrome may happen following upper lid ptosis repair.

Craniosynostosis

Craniosynostosis is a clinical feature of premature fusion or congenital absence of cranial vault suture. It may affect only one suture or more. It occurs in 1:2000–1:2500 live births. Most cases are nonsyndromic. More than 150 of identified Craniosynostosis syndromes affect 1:25,000–1:100,000 infants. Craniosynostosis may appear at birth alone, as a congenital disease or after birth by 3–4 months as one of the clinical features of a lot of syndromes such as Crouzon, Apert and Pfeiffer syndrome.

A: Isolated or non-syndromic

Virchow's law states that premature closure of the cranial sutures will limit growth of the skull in the plane perpendicular to the closed suture but at the same time it allows growth to continue parallel to the fused suture.

Various skull and orbital deformities will result according to the sutures which are prematurely closed including:

Brachycephaly: (short head). results from premature closure of both coronal sutures resulting in restricted growth of the antero-posterior axis with flattening of the forehead and occiput due to compensatory sideway growth.

Scaphocephaly: (boat head). premature closure of the sagittal suture resulting in restricted sideway growth and compensatory antero-posterior growth. this will lead to the child having a prominent forehead (frontal bossing) and prominent back head. These features along with the long antero-posterior diameter gives the child's head the shape of a boat on sideview.

Plagiocephaly: (oblique head). This type could be either anterior or posterior plagiocephaly. Anterior type results from unilateral coronal synostosis or unilateral lambdoid synostosis. In the former the unilateral coronal synostosis will lead to depressed forehead and supraorbital rim on the synostotic side while a bulging forehead on the non synostotic side. Posterior plagiocephaly results from unilateral lambdoid synostosis leading to similar deformity in the occiput.

Oxycephaly: premature closure of the coronal suture combined with another suture most commonly the lambdoid suture.

Kleeblattschädel: (cloverleaf skull) or pansynostosis: this type results from premature closure of 3 cranial sutures mostly coronal, lambdoidal, and sagittal sutures leading to bulging of the different bones of the cranial vault. In Fig. 4 we can see some of the different types of craniosynostosis.

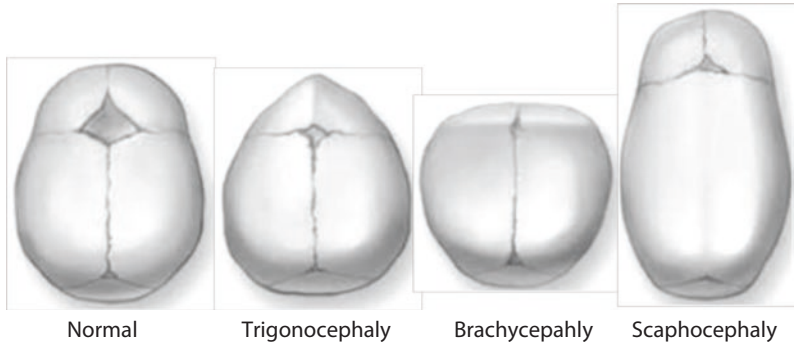

Fig. 4 Showing different types of craniosynostosis

B: Syndromic craniosynostosis

A group of genetic disorders that have has been found to be associated with mutations of the fibroblast growth factor receptor family (FGFR1, -R2, -R3), TWIST1, MSX2, and EFNB1.

A spectrum of cranial, facial and limb abnormalities along with serious neurological, ophthalmological and airway complications.

Of the many Syndromic craniosynostosis the most common are

Crouzon, Apert and Pfeiffer syndromes.

Crouzon syndrome: An Autosomal Dominant disorder. Patients have a spectrum of abnormalities including brachycephaly, midface hypoplasia. a flattened forehead, a beaked nose, hypertelorism and proptosis (Fig. 5).

Other abnormalities include deafness, cleft lip and/or palate and dental problems. Strabismus is also very common. In contrast Apert and Pfeiffer syndromes, patients with Crouzon syndrome have normal hands and feet as well as normal intellectual activity.

Apert Syndrome: An Autosomal Dominant disorder. It is characterized by craniosynostosis (similar to that in Crouzon) along with syndactyly of both hands and feet (mitten hands and sock feet).Children with this syndrome also have mental retardation along with respiratory, cardiovascular and genitourinary malformations. hydrocephaly is less common (Fig. 6).

Pfeiffer syndrome: The least common of the 3 main craniosynostosis. An Autosomal Dominant disorder. Craniosynostosis and limb deformities vary in severity. Clinically it can be divided into three subtypes which may overlap. Type 1 "classic" has mild signs and symptoms including brachycephaly, midface hypoplasia

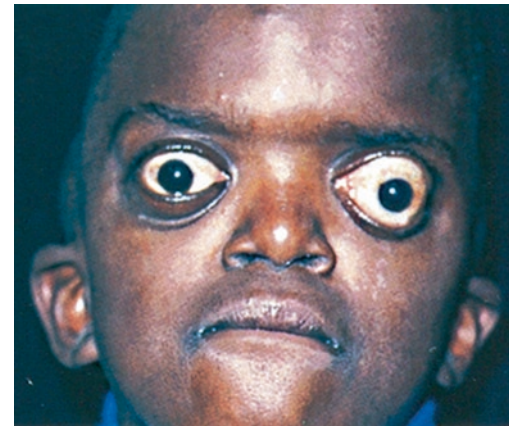

Fig. 5 Crouzon syndrome

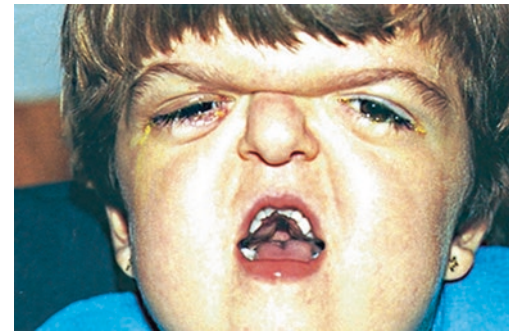

Fig. 6 Apert syndrome

and finger and toe abnormalities. Intellectual function is normal. Type 2 is the most severe form consisting of severe craniosynostosis leading to trilobed cloverleaf skull, severe proptosis, upper and lower limb abnoramilties. Developmental delay and neurological complications are common. Type 3 is similar to type 2 but without a cloverleaf skull.

Ocular Complications of Craniosynostosis include proptosis, globe luxation, exposure keratopathy, strabismus, amblyopia due to strabismus and/or ametropia and optic atrophy secondary to raised intracranial pressure.

Management

The management of craniosynostosis is complex and requires a complete craniofacial team from different specialties including neurosurgery, oculoplastic, orbital, ophthalmology, ENT, audiology and speech, dental, orthodontic, anesthetic and psychological support.

The most important indication for treatment is raised intracranial pressure.

While in multiple sutures involvement when the cranial pressure is very high the intervention is earlier than in the single suture involvement, surgical management should be started from the second week after birth. The earlier surgery is performed, the better the result achieved as the re-ossification is faster.

Primary surgery is directed to expansion of the cranium to allow space for the developing brain to grow. Recently endoscopic instrumentation is used to carry out a strip craniotomy for release of the involved sutures and creation of multiple (barrel-stave) osteotomies within the cranial vault. This technique has an advantage of decreasing the length of hospital stay, risk of mortality and blood transfusion.

Subsequent surgeries directed towards the facial and cosmetic appearance are done in later stages of life.

Congenital Clefting syndromes are a spectrum of congenital disorders caused by embryonic failure of apposition or fusion of the neighboring structures due to developmental disruption of the first and second branchial arches.

The two most common clefting disorders are Treacher-Collins syndrome and Goldenhar syndrome.

Treacher-Collins Syndrome: (Fig. 7) is a rare autosomal dominant disorder occurring in 1/50,000 births. It is the result of mutations in the TCS gene (TCOF1) at chromosome 5q32. Features include zygomatic and mandibular hypoplasia which is usually bilateral but asymmetrical, cleft palate, external and middle ear abnormalities and conductive hearing loss, lower lid coloboma, limbal dermoid, antimongoloid slanting of the palpebral fissures, lacrimal drainage disorders, and finally airway obstruction which could be an emergency.

Management depends on the age and severity of complications and requires a multi team as illustrated in the table below.

Birth and infancy up to the age of 2 years	Childhood (2–12 years)	Teenage and adolescence (13 years and above)
Airway obstruction: tracheostomy	Coloboma repair	Orthognathic surgery
Exposure keratopathy: tarsorrhaphy	Limbal dermoid excision	Facial flap surgery
Feeding problems: cleft palate repair	Facial reconstruction	Orthodontics and dental repair
	Repair of ear deformities and management of hearing disorders	
	Orthodontics and dental repair	

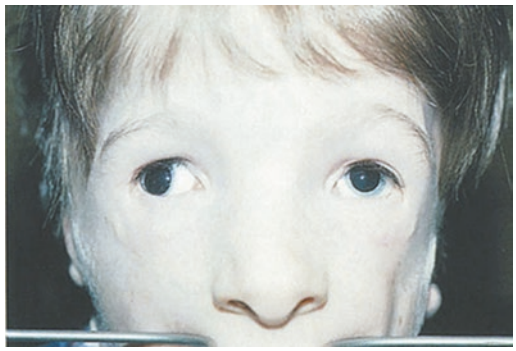

Fig. 7 Treacher collins syndrome

Goldenhar syndrome (Fig. 2), also known as oculo-auriculo-vertebral dysplasia is a rare, congenital disease arising from the abnormal development of the first and second branchial arches. The incidence is between 1:3500 and 1:5600, with a male: female ratio of 3:2. It is Mostly sporadic but familial cases have been associated with a deletion on the long arm of chromosome 22 (22q11.2).

Features include general features as facial asymmetry, preauricular skin appendages, ENT anomalies as laryngomalacia and low set ears, cardiac anomaliesas tetralogy of Fallot and ventricular septal defects, and CNS malformations as microcephaly, hydrocephaly, midline disorders like hypoplasia of the corpus callosum and Arnold-Chiari malformation.

Ocular features are usually multiple and include coloboma of mid third of upper lid, dermolipoma: usually in the superotemporal orbit, epibulbar dermoid usually atinferotemporal limbus and can cause astigmatism and amblyopia, coloboma of the iris, microphthalmos, motility disorders or Duane's syndrome, ptosis, nasolacrimal duct obstruction and cataract

Treatment of Goldenhar's Syndrome requires a multidisciplinary approach.

Lid coloboma is considered an ocular emergency and should be corrected surgically in the early neonatal period to prevent exposure keratopathy. Epibulbar dermoids causing astigmatic and deprivation amblyopia should be excised within the first few years of life. Similarly, lipodermoids causing significant strabismus and motility defects should be excised.

Suggested Readings

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Refractive Surgery and Oculoplasty

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Introduction

Refractive surgery is unique in so many ways as it deals with more or less a client rather than a patient. In most cases it is optional and there are usually other alternatives for vision correction like glasses and contact lenses. With recent advances in technology, those refractive surgery clients are becoming more demanding and are more focused on quality of vision.

Such an increased demand of better vision quality and with such refinement of refractive surgery techniques, the relation between Refractive Surgery and other subspecialties has gained a growing interest because of the impact of such relation on the postoperative quality of vision and patient satisfaction.

Oculoplasty is so intimately related to refractive surgery as the cornea is an integral part of the ocular surface and is affected by the anatomical and functional status of the ocular adnexa and tear production and function. Such an intimate relationship is best understood in view of the different steps of refractive Surgery.

Pre-refractive Surgery Considerations and Decision Making

The aim of pre-operative screening is to select the ideal candidate for refractive surgery, and decide which technique is mostly appropriate for his particular case. A person seeking refractive surgery should be screened before surgery, both generally and locally, for any coexisting conditions that may influence the prognosis of the procedure.

Identifying those who may be subject to operative difficulties and/or postoperative complications helps to either refrain from doing surgery for them or at least be ready to avoid or manage those challenges. The presence of certain findings can guide the refractive surgeon to prefer one technique over the other or force him to postpone surgery until the patient is properly treated to give him best chance for a satisfactory quality of vision.

Examination of the ocular adnexa is crucial to detect any pathology that may affect the refractive procedure intraoperatively or influence the postoperative course thus affecting the refractive outcome, quality of vision and patient satisfaction.

Ptosis, whether primary or residual after lid surgery, has direct impact on patient refraction

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_27

by pressing on the upper cornea leading to corneal astigmatism and abnormal topography (Fig. 1). If it is severe enough to cover the pupil since birth, it may lead to amblyopia that cannot be corrected by refractive surgery. Ptosis or tight lids, if missed or left untreated, may also affect the Lasik flap postoperatively leading to flap wrinkles or strea.

Lagophthalmos can follow facial palsy or be a sequel of lid surgery like ptosis, entropion or lid tumors. It may result in unstable tear film, exposure keratitis, dry eye or even corneal opacity. Failure to discover and document this preoperatively and managing it can lead to serious post refractive surgery healing problems and exaggeration of dry eye symptoms.

Lid margin abnormalities like rubbing lashes, entropion or ectropion should be checked as they may lead to intraoperative difficulties of proper corneal exposure or pressing against the LASIK flap distorting it. Other lid abnormalities that can affect refractive surgery technique include lid swellings like chalazia or tumors or scarring of the palpebral conjunctiva.

Lid margin inflammation like blepharitis and Meibomian gland dysfunction (MGD) should not be missed during preoperative examination. They can affect the accuracy and reliability of preoperative investigations like corneal topography and tomography leading to wrong decision making. They may also lead to serious intraoperative challenges by pouring meibomian secretions on the corneal surface or under the lasik flap.

These secretions may interfere with femtolaser pathway and gas bubble formation, block excimer laser ablation or become trapped under a Lasik flap or in a SMILE pocket. In rare cases, they may also lead to diffuse lamellar keratitis (DLK) or interface debris.

All types of Blepharitis can also be a source of postoperative inflammation like diffuse lamellar keratitis (DLK) if the secretions were trapped under the lasik flap. They can cause delayed epithelialization after surface ablations like PRK or PTK leading to postoperative haze or even scarring. They can be the source of the serious sequel of postoperative infections with its damaging effect that may even lead to unfortunate loss of vision.

Floppy lid syndrome should be suspected in obese patients who sleep with their face down and occasionally have sleep apnea. Those patients with lax lids can have intra-operative difficulty in speculum insertion and may lead to inadequate corneal exposure. They are more prone to postoperative flap apposition and irregularities or surface healing problems.

Those patients and others with lid inflammation and sleep apnea are also more liable to eye rubbing with its serious effect on Lasik flap leading to flap wrinkles, flap striae or even flap displacement. Any faulty sleeping position with face down may also lead to post LASIK flap distortion and are risk factors for post Lasik ectasia with its serious progressive effect on visual acuity and quality. This should be explained to the patient and his family as a serious warning.

It is also important to look for the blinking pattern, frequency and its relation to corneal sensation. Both infrequent blinking and excessive blinking can affect the ocular surface health, tear stability and tear clearance. Not only can this exaggerate symptoms of dry eye but can also affect postoperative healing and flap adherence, especially in surface ablation procedures.

Blinking abnormalities are very common in patients who have been contact lens wearers for a long time with subsequent diminished corneal sensation and lack of the stimulus to blink. This may be also associated with large myopic globes with exposure and poor tear film quality and function. As these patients are particularly more keen to get refractive surgery and are usually very reluctant to remove their contact lenses long enough, the refractive surgeon must be strict in applying the guidelines and make sure the contact lenses are taken off long enough to restore ocular surface health.

It is also crucial to identify other causes of diminished corneal sensation and blinking abnormalities before surgery. These may include past or recurrent herpetic infection or some general conditions like diabetes or in very rare

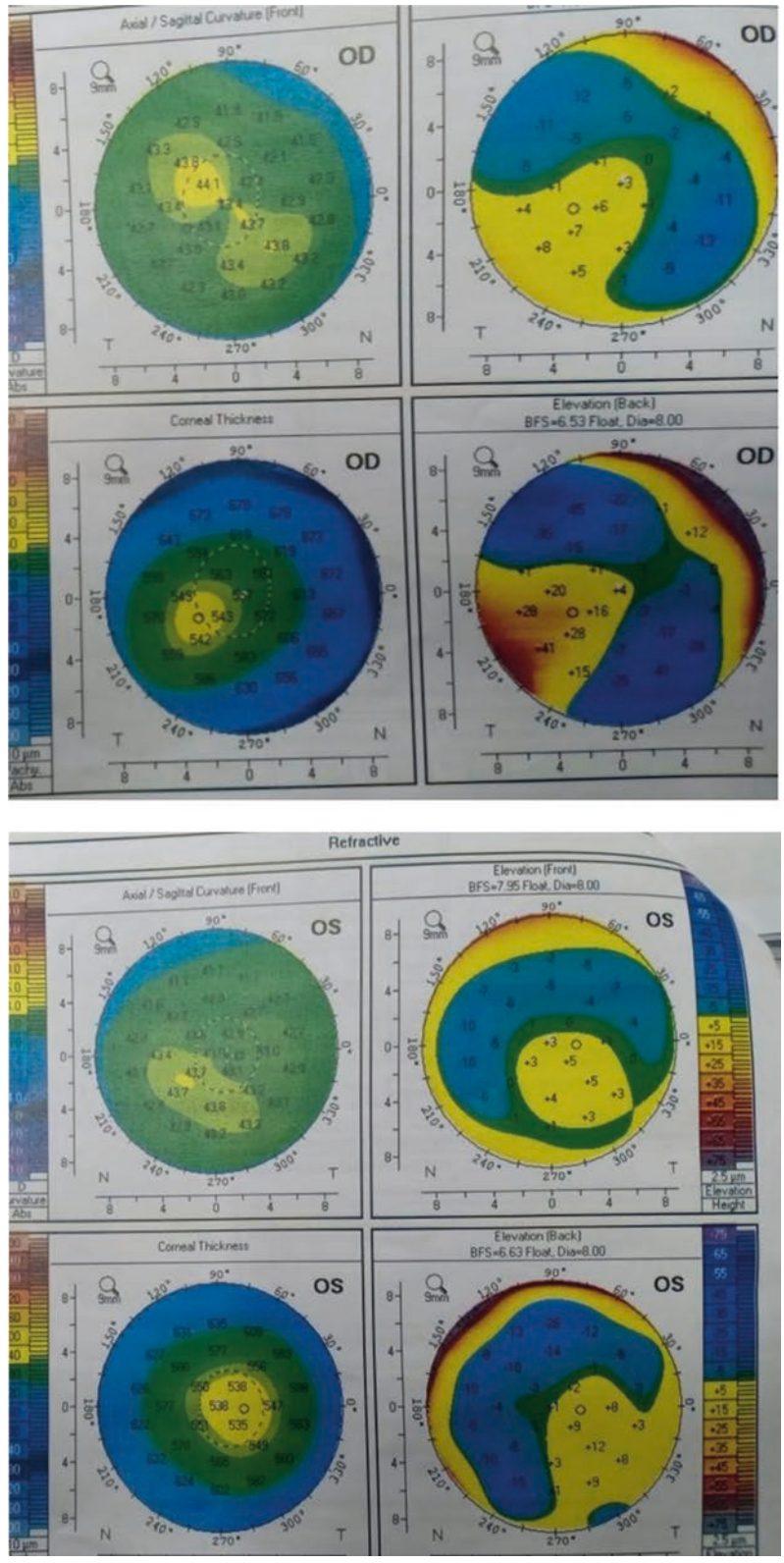

Fig. 1 Effect of unilateral right ptosis on pentacam causing astigmatism

conditions an affection of trigeminal nerve, up to a brain lesion. Any of these conditions needs to be identified and treated or surgery should be delayed until they improve. Persistence of such conditions should be documented to anticipate any post-operative complication and change the routine course of management accordingly.

Both exophthalmos and enophthalmos or deeply sunken globes should be noted for the same reason. Both can have an impact on the surgical technique and may influence the preference of one surgical technique over the other. Exophthalmos should be differentiated from a normal large myopic eye specially if both are associated with exposure and tear film instability. If exophthalmos is a part of thyroid disease, it should be properly investigated as disturbance in thyroid function can have an impact on ocular and lid motility. Moreover, it can affect the refractive results and even make the cornea more susceptible to postoperative ectasia.

Examination of the lacrimal apparatus for patency, swellings, active or recurrent inflammations not only could explain cause of epiphora but the presence of positive regurgitation of pus or even clear fluid from the puncta represents a contra-indication for surgery until it is treated. Acute or recurrent dacryosystitis is a definite contra-indication to any ocular surgery for fear of inducing serious postoperative infection especially for intra-ocular procedures like phakic IOLs or refractive lens exchange. Failure to identify such septic focus may lead to postoperative infection.

Tearing complaints attributable to problems with tear distribution should also be evaluated, classified, and managed. This can be done according to the mnemonic BLICK, which stands for Blink dynamics, Lid malposition, Imbrication, Conjunctivo-chalasis, and Kissing puncta.

Starting with just the tear film, this mnemonic is well established to assess the cause of the epiphora whether it is a drainage problem or a reflex hypersecretion. Therefore, preoperative evaluation of each item of BLICKS is of utmost importance before refractive surgery.

Above all, the most important preoperative examination is for ocular surface health, tear volume, tear stability and tear clearance as indicators of dry eye disease (DED). Tear film abnormalities whether epiphora or unstable tear film seriously affect preoperative investigations including placido-based corneal topography, optical scheimflug tomography or all types of wave front aberrometry measuring systems. This can lead to a false diagnosis of irregular corneal surface like keratoconus or can mask an existing abnormality.

Therefore, it is essential for those operating such investigations to make sure the patients blinks frequently or instill lubricant eye drops before capture (Fig. 2). This is particularly important for patients scheduled for custom treatment to avoid a final result that will be disappointing for both surgeons and patients. In many cases, treatment of a preexisting tear film problem may improve patient's abnormal visual symptoms and may change the decision making for custom versus conventional techniques.

All techniques of kerato-refractive surgery lead to diminished corneal sensation to a variable degrees and hence symptoms of postoperative dry eye. It is crucial to include a detailed dry eye evaluation before surgery to classify candidates based on their tear film characteristics into good, borderline or established dry eye. Those will be dealt with accordingly either by proceeding immediately to surgery or by deferring surgery until the condition is managed properly.

The importance of the tear film for the quality of vision after refractive surgery led to more emphasis on studying tear film impact on corneal topography, tomography, aberrometry and recently ocular scattering. It is now advised to have a dry eye clinic in each refractive surgery center to ensure proper diagnosis and management of dry eye patients or those at a higher risk of developing it and treating them before they undergo refractive surgery. This will increase the number of patients satisfied with their postoperative quality of vision and avoid a lot of dissatisfaction frequently encountered despite adequate surgery.

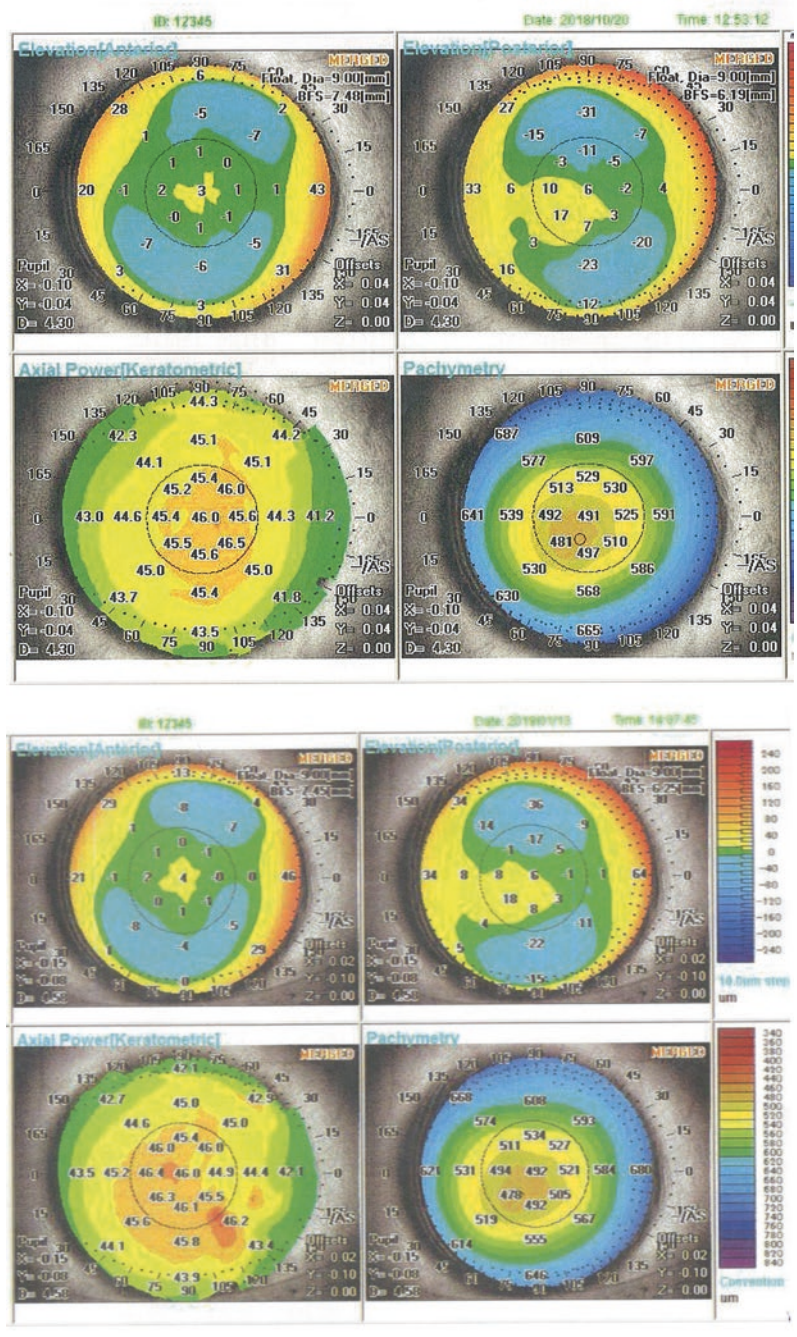

Fig. 2 Change in topography maps with installation of artificial tears in a case of dry eye

Operative Considerations and Challenges

Timing of surgery should be assigned only after all previous topics have been addressed. No active inflammations should be present around the cornea at the time of surgery.

Choice of the surgical technique has already been made and discussed with the patient based not only on age, refraction, corneal tomography and pachymetry but also on preoperative evaluation of ocular surface and ocular adnexa. In patients with persistent lid problems like lagophthalmos, infrequent blinking or lid margin abnormalities, it is better to avoid Lasik and shift to either surface ablation, refractive lenticule extraction (SMILE) or to intra-ocular surgery like phakic IOLs.

The same principle applies to cases of dry eye who are kept on preservative–free replacement artificial tears. Those cases are better treated by SMILE or surface ablation rather than Lasik which induces more decrease in corneal sensation and hence more dryness postoperatively. Those cases can also benefit from intra-operative punctal occlusion by temporary punctal plugs to keep normal tears.

Certain cases require special attention with eye exposure using a special speculum. Patients with very narrow palpebral fissures, asian features or floppy lid syndrome are examples that need attention. Additionally, patients with enophthalmos or deeply-sunken eyes require smaller suction rings with a mechanical microkeratome Lasik or small patient interface cones in femtoLasik. Failure to pay attention to such detail may lead to suction loss with its further chain of complications.

In patients with persistent Meibomian gland dysfunction (MGD), a special speculum with solid plates or better one with aspiration should be used to remove any Meibomian secretions, especially if the patient is a squeezer. These secretions may interfere with femtolaser pathway and gas bubble formation, block excimer laser ablation or become trapped under a Lasik flap or in a SMILE pocket. In rare cases, they may also lead to diffuse lamellar keratitis (DLK) or interface debris.

At the conclusion of surgery, placing a bandage contact lens can protect the corneal epithelium particularly in patients with dry eye, unstable tear film or unhealthy epithelium. It also protects the flap from expected or potential friction with an uneven lid margin or rough palpebral conjunctiva.

Postoperative Considerations

Following all techniques of refractive surgery especially LASIK (Fig. 3), patients are expected to have a decrease in corneal sensation depending on how many corneal nerves are severed and consequently decreased tear production and symptoms of dry eye. In all cases, the use of artificial tears for extended periods postoperatively is a routine.

These drops should be used very frequently in the immediate postoperative period, hourly or even more frequently as needed. The frequency of instillation can be reduced gradually as the patient regains his corneal sensation and normal stimulus for tear production. This usually takes an average of 6 months, although in certain conditions it may take much longer. It is always advisable to use preservative—free drops to avoid the deleterious effect of preservatives on the cornea with such prolonged use.

As stated earlier, some refractive surgery techniques affect the corneal nerves less than others. Small incision Lenticule Extraction (SMILE), for example, affects less corneal nerves than Lasik or surface ablation making it the procedure of choice in patients with frank or borderline dry eye.

Several factors may influence the severity of post LASIK dry eye, not just a pre-existing dry eye but also the operative parameters used in Lasik surgery. Since corneal nerves are transected during both flap creation and laser ablation of the corneal stroma, a thicker flap and deeper ablation have been considered as two risk factors of post LASIK dry eye. Therefore,

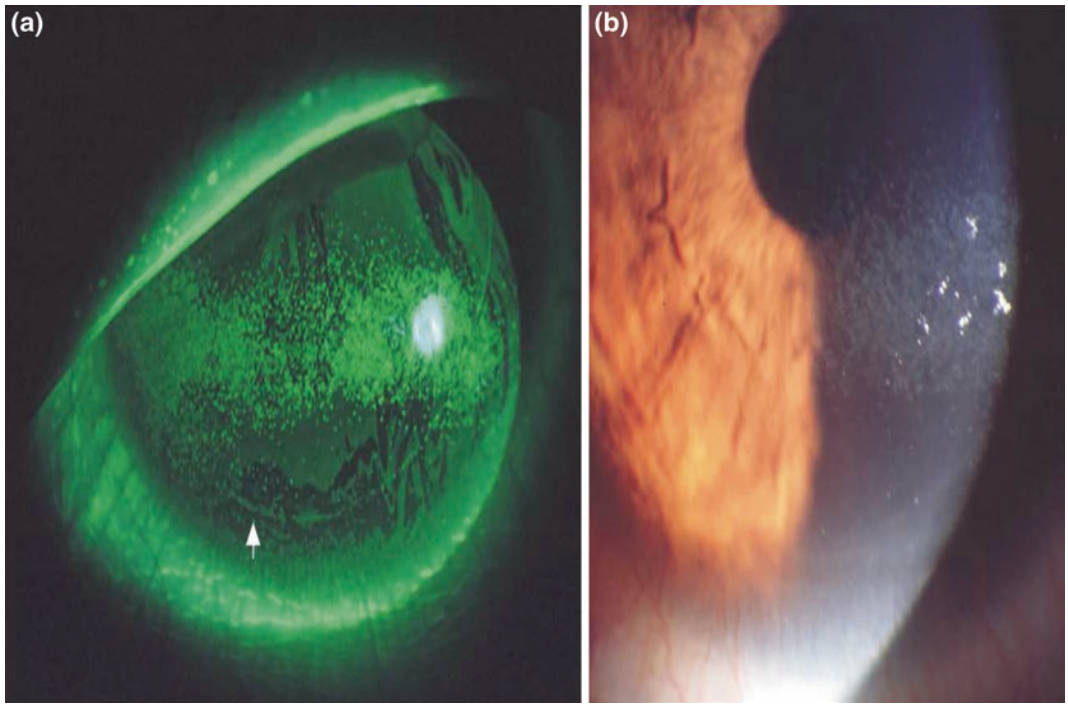

Fig. 3 **a** Severe dry eye/neurotrophic keratitis in a patient, **b** Biomicroscopical image on the same eye. Who underwent an uneventful LASIK procedure 5 days earlier. Fluorescein staining reveals confluent epithelial surface lesions. The flap margins can also be observed

cutting a thinner flap causes less corneal nerve damage so preserves corneal sensation and blink rate decreasing the severity and duration of postoperative dry eye.

Cases with preoperative frank dry eye disease, unstable tear film or abnormal blinking mechanism may need more aggressive management such as punctal occlusion to preserve the already diminished tears. This can be done either intraoperatively or in the immediate postoperative period as an office procedure. It can be temporary self-absorbing plugs, permanent ones or thermal cauterization of one or both puncti in severe cases.

Another option for managing severe post LASIK dry eye is the use of twice daily dose of cyclosporine A 0.05% ophthalmic emulsion for up to 3 months to control both the inflammatory and neuropathic aspects of dry eye. Autologous serum has also been advised with good success.

Patient management for dry eye disorders following refractive surgery should be customized to each individual case with possible combination of more than one treatment modality to control inflammation and preserve normal tear film. However, proper preoperative patient selection with good control of ocular surface prior to surgery is still the gold standard key to have less dry eye symptoms. Wider use of SMILE technique with its less damaging effect on corneal innervation compared to conventional flap based surgery may also provide refractive surgeons with more control on dry eye diseases.

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Pathology and Oculoplasty

Mohammad Kamal

Introduction

The basis of an effective pathological evaluation is rooted in a well-thought out systematic approach. This approach allows the pathologist to apply a consistent process to eliminate all possibilities included in the differential diagnosis list, ensuring a thorough review of the samples. When the pathologist applies this meticulous approach through the systematic analysis, the chances of reaching an accurate diagnosis are significantly improved. Areas of uncertainty are frequently encountered, and the pathologist must be able to handle them with objectivity and confidence. In these instances, expert opinions may be needed, and the surgeon is required to appreciate the difficulty any singular case can provide and, consequently, the expected resultant diagnostic limitations. The surgeon must have a supportive and patient attitude. This healthy approach will facilitate a productive and collaborative relationship between the surgeons and the pathologist. The last part of this chapter will address how to build this relationship through effective communication between the surgeons and the pathologists.

Specimen Handling and Specimen Preservation

Most pathology samples are submitted in formalin containers which are provided by the laboratory. The size of the formalin jar must be appropriate for the specimen. Submitting large specimens in smaller jars can result in inadequate fixation and subsequently poor processing. In special circumstances, particularly when infection is suspected, a separate sterile sample must be submitted for culture. Furthermore, culture swabs should also be used, when appropriate. Since cultures cannot be performed on formalin fixed specimens, the clinical staff needs to prepare ahead by communicating with the lab and acquiring the appropriate media. If tuberculous or fungal infections are suspected, separate media are required. It is worth noting that, if there is suspicion of lymphoma, it may be better to submit a fresh sample for lymphoma work-up, which includes touch imprints and dividing the sample for cytogenetics, flow cytometry etc.

Pathology Requisition:

The pathology requisition has requirements, without which, samples may not be accepted by the laboratory. The requisition must include the following:

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_28

1 Patient's details
2 Requesting physician's details
3 Specimen(s) location/site
4 Brief clinical history and preferably a question or a "rule out"
5 Procedure date
6 Referring facility's details
7 When multiple samples are submitted, the numbering and site identification on the requisition must match those on the specimens.

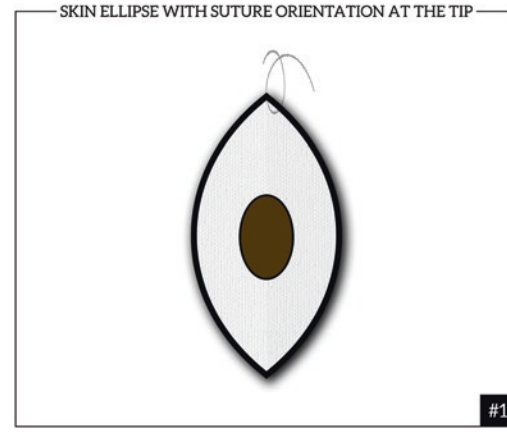
Pathology Specimen

The clinical impression plays an important role in the selection of the procedure used to acquire the sample and the preservative used to the submit the specimen. Communication between the surgeon and the pathologist before, during, and after the acquisition and processing of the specimen is of paramount value. In many situations, particularly when complete excision of malignant tumors is intended, proper orientation of the specimen is required. Consequently, handling of the specimen in the laboratory impacts the histologic assessment allowing the pathologist to comment on the status of the margins. Many lesions are initially diagnosed by shave biopsies. In our experience, some clinicians expect the pathologist to comment on the lateral and deep margins of shave biopsies, while others feel that because the sample is a shave biopsy, a positive margin is not unexpected and a statement of positive margin on the report may give a false impression of an inadequate removal of the lesion.

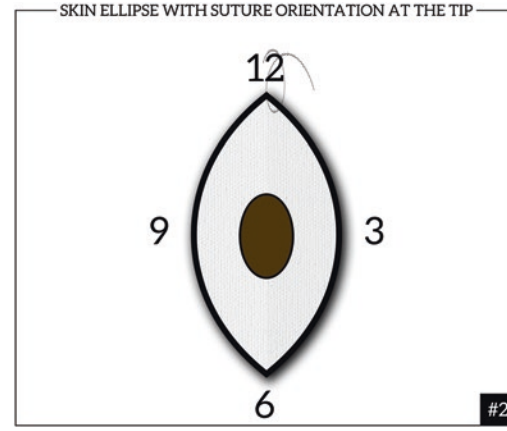
Grossing of Oriented Specimens

There is a detailed protocol for grossing of excisional biopsies specimens that are oriented by sutures. The process can be summarized in the following steps:

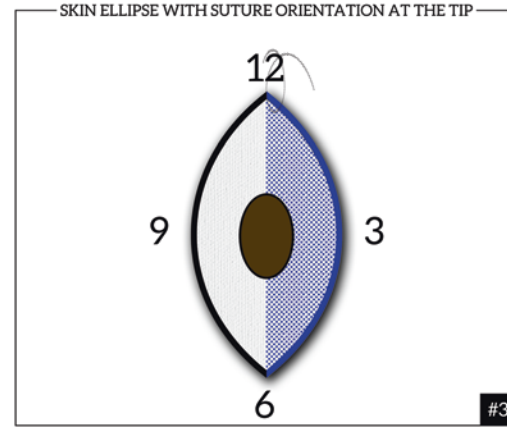
A. **Samples Oriented with Sutures at the Tip**: Skin Ellipse with an orientation sutures at the tip labeled with an anatomic location (e.g.; superior, inferior lateral or medial) Diagram 1:



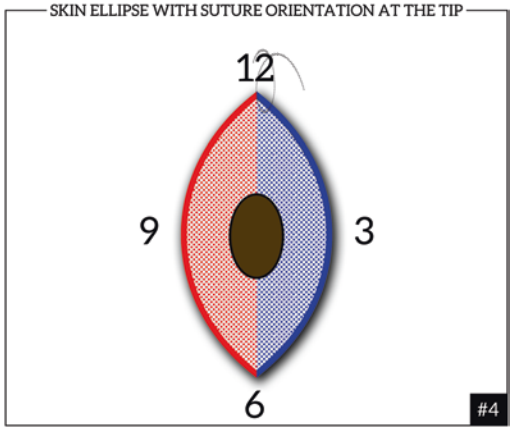
1 The suture site is designated as 12:00 o'clock Diagram 2.



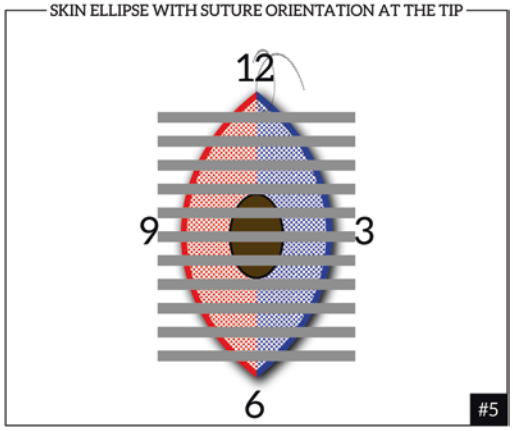
2 The resection surface half covering 12-3-6 o'clock is inked with one color (blue) Diagram 3.



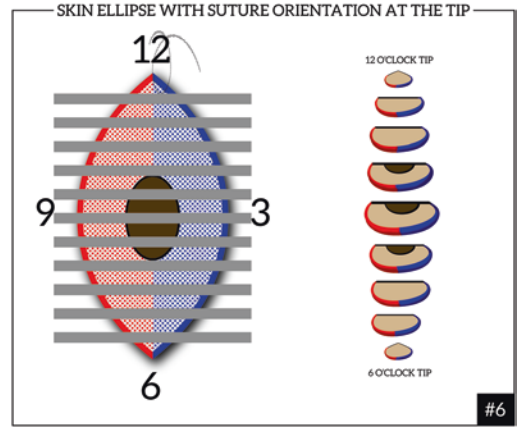
3 The opposite half covering 6-9-12 o'clock is inked with another color (red) Diagram 4.



4 The specimen is serially sectioned (bread-loafed) Diagram 5.



5 Each tip is submitted in a separate cassette A1 and A2. The rest of the specimen is submitted sequentially in the remaining cassettes, preferably indicating, in the grossing description, the cassettes in which the 12 and 6 o'clock halves are submitted and the cassettes containing the lesion Diagram 6.



6 If the tumor is seen in A1 or A2, additional deeper (step levels) sections should be obtained before reporting a positive margin at the corresponding tip location.

7 In the report, the pathologist is required to translate the positive margin to the anatomic locations identified by the sutures.

Examples:

a A specimen is submitted with a suture marking superior margin and the grossing technician designates the suture as 12 o'clock. If this margin is positive, the pathology report must refer to a positive superior margin rather than positive 12 o'clock.

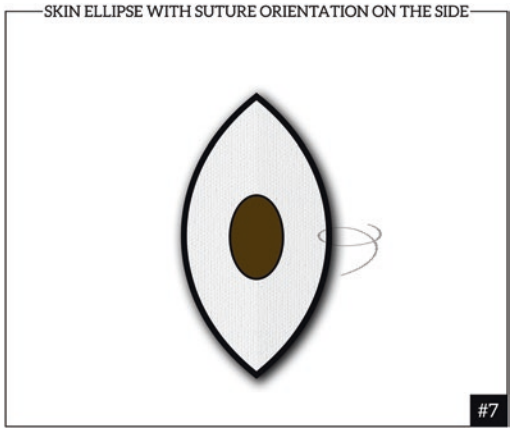
b The medial margin, which was inked in blue, is positive. Instead of reporting, the tumor extends to the blue margin, the report shall state "the tumor extends to the medial (blue) margin."

8 In oriented specimens, it is always a good practice for the grossing technician to include a diagrammatic sketch explaining the specimen orientation and colors used. This will allow the pathologist to refer back to the drawing during the microscopic evaluation.

9 The pathologist is required to proofread the grossing description to ensure it accurately reflects the work done. This would be particularly helpful when cases are referred for a second opinion, as it provides the

consulting pathologist adequate information to interpret the specimen.

B. **Samples oriented with sutures on the side rather than the tip Diagram** 7:

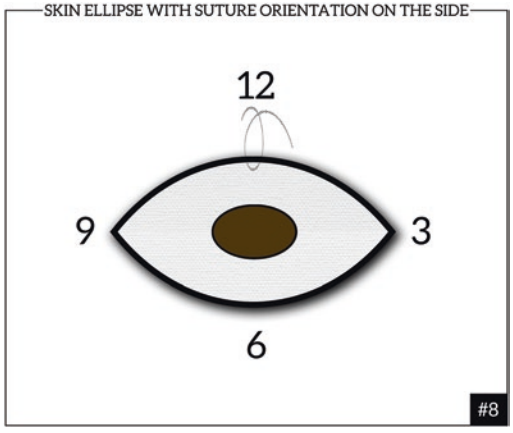


There are several ways to handle this example. There are 2 main options to choose from and either one is acceptable as long as the steps are accurately documented in the grossing description.

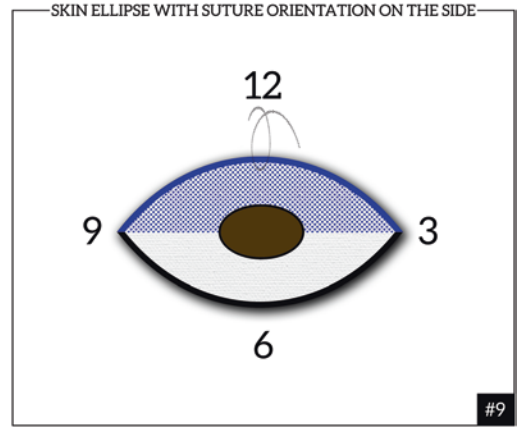
Option 1:
Designate the suture as 3 or 9 o'clock and process the specimen as in Diagrams 1 through 6.
OR

Option 2:

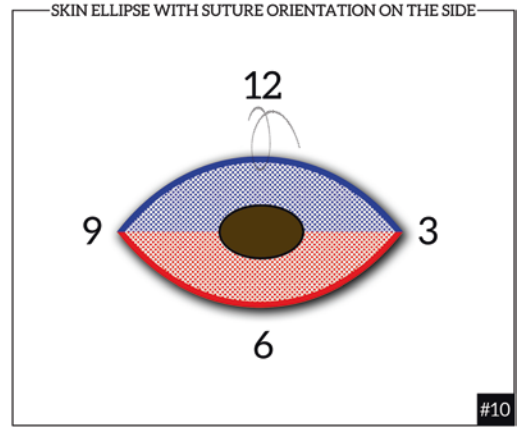
1 Rotate the specimen 90 degrees clockwise or counter-clockwise to designate the suture as 12 o'clock placing the tips at 3 and 9 O'clock positions Diagram 8.



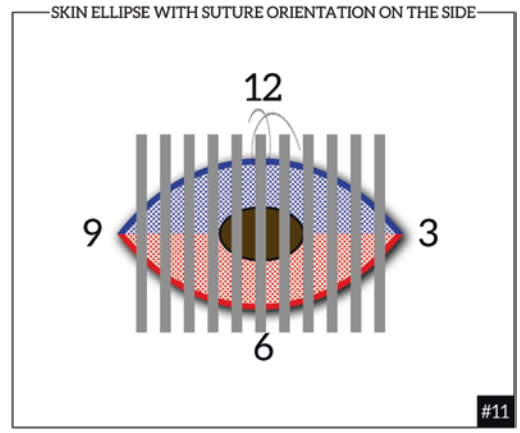
2 The resection surface half covering 9-12-3 o'clock is inked with one color (blue) Diagram 9.



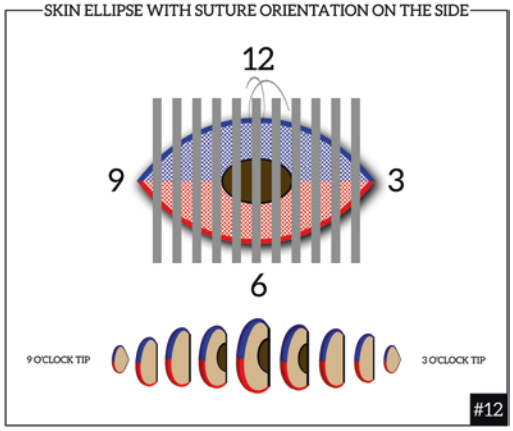
3 The opposite half covering 3-6-12 o'clock is inked with another color (red) Diagram 10.



4 The specimen is serially sectioned (bread-loafed) Diagram 11.



5 Each tip is submitted in a separate cassette A1 and A2. The rest of the specimen is submitted sequentially in the remaining cassettes, preferably indicating, in the gross description, the cassettes in which the 3 and 9 o'clock halves are submitted and the cassettes containing the lesion Diagram 12.



C. **Samples submitted with 2 sutures**:
In some cases, surgeons orient the sample with long and short sutures. The approach that we find to be most practical is not to designate clock to either sutures and to ink the specimen referring to the anatomic orientation provided by the surgeon. The 2 tips should still be submitted separately.

D. **Un-oriented ellipse**:
This type of specimen can be inked with one color and the positive margin can be reported as positive deep or lateral margin. Keep in mind that the term "lateral" in this case is referring to the specimen, not to an anatomic site. This must be clearly explained on the report. To avoid this confusion, some pathologists prefer the term "peripheral" over lateral. In unoriented specimens the tips can be submitted in one cassette.

Final Note: The steps above are just examples on how to handle oriented samples. We recognize that there are many other situations with more complex orientation. We hope that the steps above provide a guideline to follow and improve upon in more complex situations.

Common Oculoplastic Pathological Conditions

Histology of the Eyelid:

The eyelid has two main components; the dermal section, which is mainly stratified squamous epithelium with the skin adnexa, and the conjunctival section, which is made of columnar epithelium. The adnexal structures include sebaceous, apocrine and eccrine sweat glands.

Like any areas of the body, epithelial and melanocytic lesions can be seen in the skin of the eyelid. These conditions range from benign to premalignant and malignant lesions. Table 1 shows the list of the common lesions

A. Melanocytic Lesions Nevi
   a. Intradermal Nevus
   b. Junctional Nevus
   c. Compound Nevus
   d. Atypical/Dysplastic Nevi
   e. Lentigo Maligna
   f. Malignant Melanoma
B. Epidermal Lesions:
   a. Squamous papilloma (Skin Tags-Achrocordon)
   b. Actinic Keratosis
   c. Seborrheic Keratosis
   d. Basal Cell Carcinoma
   e. Squamous Cell Carcinoma
C. Adnexal Tumors:
   a. Sebaceous hyperplasia/adenoma
   b. Sebaceous carcinoma
   c. Epidermal Inclusion Cyst
   d. Pilar/Trichelemmal cyst
D. Stromal Tumors:
   a. Rhabdomyosarcoma of the Orbit
   b. Schwannoma
E. Xanthomatous lesions:
   a. Xanthelasma
   b. Juvenile Xanthogranuloma
   c. Necrobiotic Xanthogranuloma

Table 1 Common oculoplastic pathological lesions

Cell origin	Benign/dysplastic	Malignant

• Melanocytic	• Lentigo simplex
	• Solar lentigo
	• Nevi
	  • Intradermal
	  • Junctional
	  • Compound
	• Kissing nevus
	• Nevus of ota (congenital oculodermal melanosis)
		• Malignant melanoma

• Epidermal	• Squamous papilloma • Seborrheic keratosis • Actinic keratosis	• Basal cell carcinoma • Squamous cell carcinoma • Keratoacanthoma

• Adnexal
  • Sebaceous glands
  • Hair follicle
  • Apocrine and eccrine glands
	• Sebaceous hyperplasia/adenoma
	• Epidermal inclusion (follicular infundibular) cyst
	• Pilar/trichilemmal cyst
	• Hidrocystoma
		• Sebaceous carcinoma

• Miscellaneous	• Lobular capillary hemangioma (Pyogenic granuloma) • Kaposi Sarcoma • Schwannoma • Xanthelasma and Juvenile Xanthogranuloma	• Rhabdomyosarcoma

F. Miscellansous:
   a. Chalazion
   b. Molluscum Contagiosum
   c. Pyogenic granuloma.

Melanocytic Lesions of the Eyelid

Benign Lesions

1. **Lentigo Simplex (LS)**
   LS presents as small flat pigmentation of the eyelid similar to a junctional nevus. Microscopically it is characterized by increased number of basal melanocytes with elongation of the rete ridges. The dermis does not show solar damage.
2. **Solar Lentigo (SL)**
   SL is clinically similar to lentigo simplex however, microscopically in addition to the proliferation of the basal melanocytes and rete ridges elongation, there is solar elastosis of the dermis (Fig. 1).
3. **Melanocytic Nevi**
   They can be in the cutaneous or conjunctival surfaces of the eyelid. They have several clinical presentations. In kissing or split nevus involvement of the upper and lower eyelids is seen. A junctional nevus shows melanocytic nesting at the dermal-epidermal junction. In intradermal nevus, the nevus cells are limited to the dermis with no junctional component (Fig. 2). Compound nevus shows features of intradermal and junctional nevus. Atypical or dysplastic changes are frequently seen in junctional and compound nevi. Dysplastic nevus demonstrates

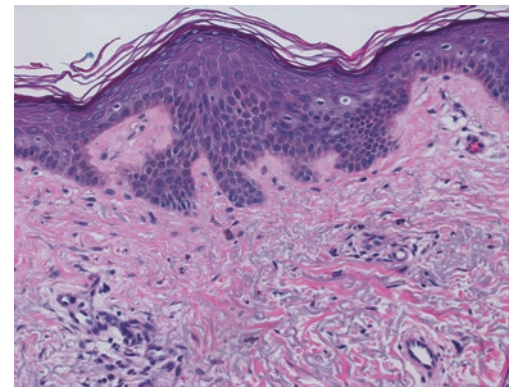


Fig. 1 Solar Lentigo 20x, Hematoxylin and Eosin; basal epidermal melanin hyperpigmentation with mild elongation of rete ridges overlying dermal solar elastosis

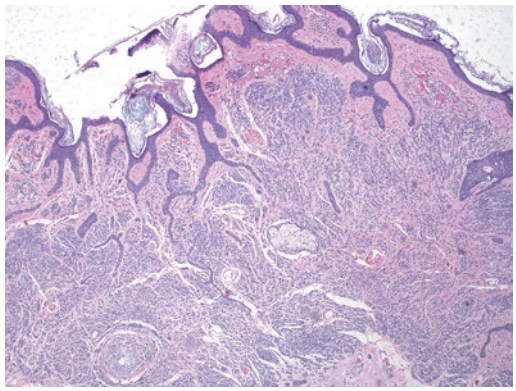


Fig. 2 Intradermal nevus

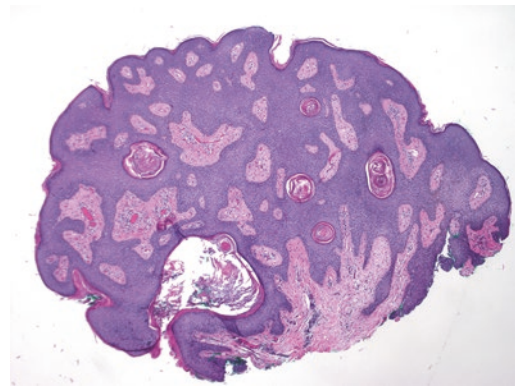


Fig. 3 Seborrheic keratosis

cytological changes in the form of nuclear enlargement, pleomorphism and/or architectural changes in the form of asymmetrical growth and lentiginous pattern. Dysplastic nevi can be graded as mild, moderate and severe based on the degree of cytologic and architectural atypia.

Nevus of Ota (Congenital Oculodermal Melanosis)

It presents as a unilateral dark discoloration of the areas of the face supplied by the ophthalmic and maxillary branches of the trigeminal nerve. This includes the eyelid and periorbital skin. Scleral discoloration can also be noted. Bilateral involvement is extremely rare and when seen, it is associated with a small risk of malignant transformation into cutaneous or uveal melanoma.

Epidermal Lesions

Benign Lesions

1. **Seborrheic Keratosis (SK)**
   SK is one of the most common benign lesions seen in dermatopathology. Clinically, it presents as a well-demarcated pigmented lesion. Clinically it is often mistaken for basal cell carcinoma, however the histologic appearance is unmistakable. SK is a benign proliferative lesion arising from the epidermal layer of the eyelid skin. It is usually associated with sun exposure.
   Microscopically SK can be endophytic or exophytic. It is characterized by thickening of the epidermis with basaloid cells and intervening pearls known as pseudo-horn or horn cysts (Fig. 3). Complete removal is not always needed. Given the fact that most SK are seen on shave biopsies, an agreement between the pathologist and the surgeon, regarding the need to report the margin status in shave biopsies, needs to be reached.
2. **Actinic Keratosis (AK)**
   AK is another benign epidermal lesion which is seen in sun-damaged skin. It clinically presents as erythematous scaly lesions or nodules. Warty patterns can be present in Verrucous AK. Microscopically, these lesions show atypia of keratinocytes at the epidermis (basal atypia) overlying solar elastosis of the dermis. In advanced cases of AK more epidermal layers become involved and the term "Bowenoid AK" is used when full thickness involvement is noted. This features leads to the belief that AK is a precursor for squamous cell carcinoma of the skin.
3. **Squamous Papilloma (Skin Tag, SP)**
   SP is benign polypoid usually pedunculated epithelial tumor arising in the skin of the eyelid. Microscopically, there is polypoid epidermal protrusion with a distinctive fibrovascular

core. The surface is smooth and may show acanthosis and hyperkeratosis.

Adnexal Lesions

Benign Lesions

1. **Chalazion**
   Chalazion is one of the most common conditions encountered in any part of the eyelids. It is caused by obstruction of the meibomian gland duct. Its clinical significance rests in its simple treatment by curettage. However, when the lesion recurs, the possibility of a missed sebaceous gland tumor should be considered.
   Microscopically, Chalazion is a lipogranulomatous reaction arising in close proximity to meibomian glands. The most characteristic morphologic feature is the presence of mixed inflammatory infiltrate and multinucleated giant cell reaction with fat droplets in the middle.
2. **Sebaceous Hyperplasia and Sebaceous Adenoma**
   Sebaceous hyperplasia is seen in older people, while sebaceous adenoma is seen in younger individuals. The presence of adenoma is suggestive of Muir-Torre Syndrome. Clinically they present as smooth elevated soft nodules.
   Microscopically, they form lobular well-defined lobular clusters of sebaceous glands with no cytologic atypia (Fig. 4).

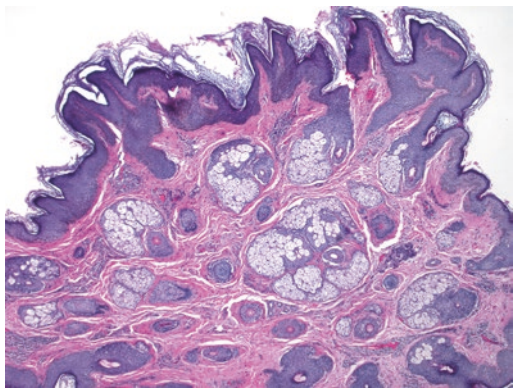


Fig. 4 Sebaceous hyperplasia

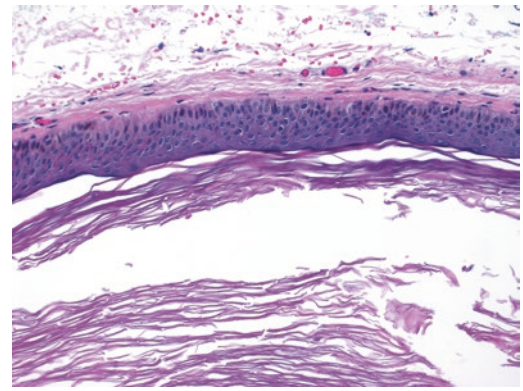


Fig. 5 Epidermal inclusion cyst

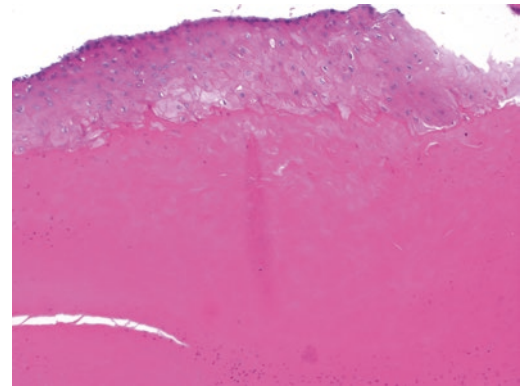


Fig. 6 Pilar cyst

3. **Epidermal Inclusion (EIC, Follicular Infundibular Cysts)**
   These are benign cystic tumors arising in infundibular portion or the hair follicle. Clinically it presents a smooth surfaced elevation of the skin. Microscopically, multiple or single cystic space, lined by keratinized and stratified squamous epithelium with a prominent granular layer and filled with lamellated layers of keratin material. Frequently rupture of the cyst results in marked mixed inflammatory reaction with multinucleated giant cell reaction in response to tissue exposure to keratin content (Fig. 5).
4. **Pilar Cyst (Trichilemmal Cyst)**
   Pilar cysts are benign keratin filled cysts arising from the outer hair root sheath. They are more commonly seen in the scalp, but are sometimes seen in the eyelids. Like

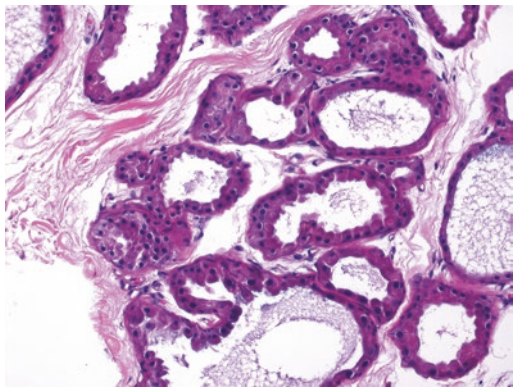


Fig. 7 Hidrocystoma

epidermal inclusion cyst they present as smooth bumps, however, the have firmer consistency due to the compact nature of the keratin content (Fig. 6).

Microscopically, pilar cysts are lined by stratified squamous epithelium and filled with compact keratin. The lining keratinocyte are pale. Unlike EIC, the lining of the pilar cysts lacks the granular layer.

5. **Hidrocystoma**
   a. Apocrine Hidrocystoma arises from the duct of Moll's gland. Microscopically there are multiple cystic spaces lined by cuboidal cells with distinct pink cytoplasm with luminal snouts and an outer myoepithelial layer (Fig. 7).
   b. Eccrine Hidrocystoma arises from eccrine sweat glands of the eyelid. Microscopically, they are unilocular, lined by small flat to cuboidal cells which lack the apocrine pink cytoplasm.

Malignant Lesions

1. **Sebaceous Gland Carcinoma (SGC)**

SGC is one of the common malignant neoplasms of the eyelid. It is more common in the upper eyelid and more common in women than men. In the USA, it is more common in whites than blacks. It appears in older age with a mean age of 57–72 years. It arises in the Meibomian glands-tarsal plate.

Clinical Features:

SGC usually presents as a small firm eyelid nodule. It can be mistaken for a chalazion. It can also present as a diffuse thickening of the eyelid. SGC can frequently present as a recurring chalazion. Loss of lashes due to infiltration into the hair follicles is a common feature of SGC. When the tumor involves the conjunctival epithelium, it can cause a "masquerade syndrome" where persistent unilateral conjunctivitis or blepharitis misleads the clinician into considering an inflammatory process rather than neoplastic.

Histological Diagnosis:

SGC are classified into well, moderately or poorly differentiated. The well differentiated tumors exhibit more sebaceous foamy cells with vacuolated cytoplasm. Moderately differentiated tumors show rare sebaceous cells with predominance of basophilic cells. In poorly differentiated sebaceous carcinoma, the cells show pleomorphic hyperchromatic nuclei with increased mitotic activity and no sebaceous differentiation giving the appearance of anaplastic carcinoma. Pagetoid spread is when the tumor cells infiltrate the overlying dermal epithelium. The Pagetoid cells appear in single cell formation or small clusters resembling Paget's disease of the breast.

Diagnostic Tips:

- Avoid the diagnostic pitfall of mistaking well differentiated tumor for a benign condition. Early diagnosis and treatment are important prognostic factors.
- Pathology report must include assessment of the margin and the presence or absence of perineural, lymphatic and vascular invasion and Pagetoid spread.
- Role of Frozen Sections: Complete resection with adequate margin is an important prognostic criterion. Therefore, submitting margin samples for intraoperative frozen section can be helpful in difficult cases. Sentinel node biopsies is considered to be an important contributing factor to long term survival.

Prognosis:

SGC can spread through direct invasion of adjacent structures (orbit, lacrimnal glands, paranasal sinuses). Lymphatic invasion can result in metastatic lesions in the preauricular and cervical lymph nodes. Distant hematogenous spread involves lungs, liver, brain and skull. Perineural invasion is an important prognostic factor. Other factors affecting prognosis are listed in Table 2.

SGC is not responsive to radiotherapy, however radiation treatment can be used as a palliative measure in advanced inoperable cases.

2. **Basal Cell Carcinoma (BCC)**

BCC is the most common malignant neoplasm of the skin. Clinically it arises in the skin of the eyelid and presents as nodular pearly painless elevation. Frozen section diagnosis can be used to ensure complete removal with clear margins. Microscopically, several patterns of growth are seen. Nodular, micronodular (Fig. 8a, b), superficial (Fig. 9), pigmented, and infiltrative (sclerosing-morphea) types are among the most common patterns. BCC arises the from the basal layer of the epidermis. The tumor is characterized by nests of basaloid dark blue cells with hyperchromatic nuclei and scant cytoplasm demonstrating peripheral palisading with frequent retraction artifact noted.

3. **Squamous Cell Carcinoma (SCC)**

SCC is seen less frequently than BCC, however it is a more aggressive tumor. Lymphovascular invasion with involvement of regional lymph nodes can be seen. Clinically, they present as painless firm plaques or nodules. Microscopically, SCC arise in the squamous cells of the eyelid epidermis. The tumor is graded as well, moderately and poorly differentiated. The well differentiated show keratin pearls hence the term "keratinizing" SCC (Fig. 10). Moderately differentiated tumors contain less keratin and the cells show more pleomorphism and increase mitotic activity. Poorly differentiated tumors are usually non-keratinizing and show

Table 2 Sebaceous gland carcinoma prognosis

Prognostic factors	Poor prognostic factors
Location	Upper eyelid
Size	10 mm or more
Duration of symptoms	More than 6 months
Pattern of growth	Infiltrative pattern
Histologic factors	Poorly differentiated tumors with perineural and lymphovascular and Pagetoid invasion
Treatment	Late diagnosis and incomplete resection

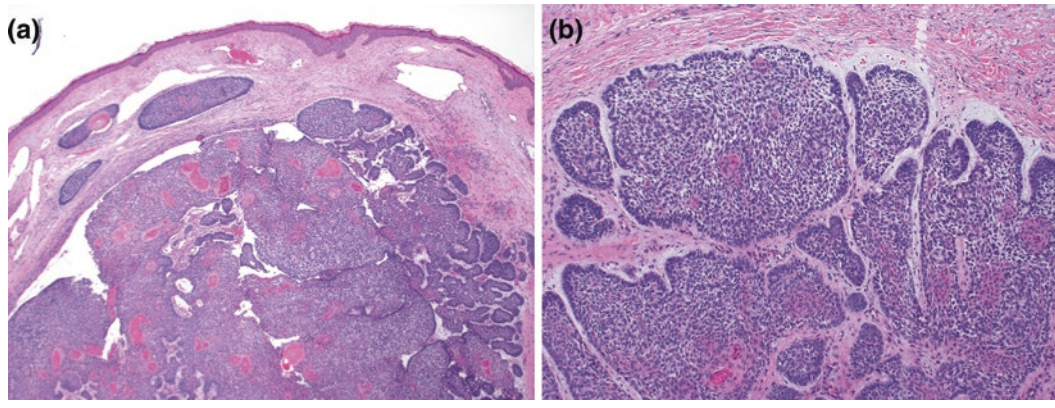


Fig. 8 **a**, **b** Nodular and micronodular basal cell carcinoma

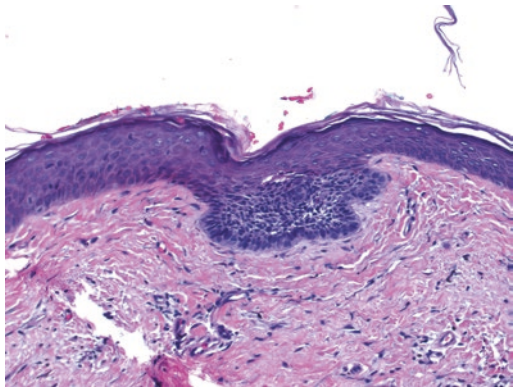


Fig. 9 Superficial basal cell carcinoma

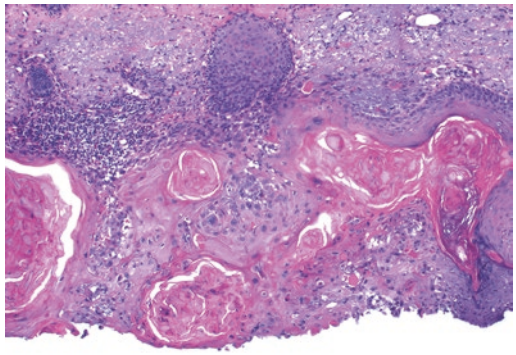


Fig. 10 Keratinized squamous cell carcinoma showing keratin pearls

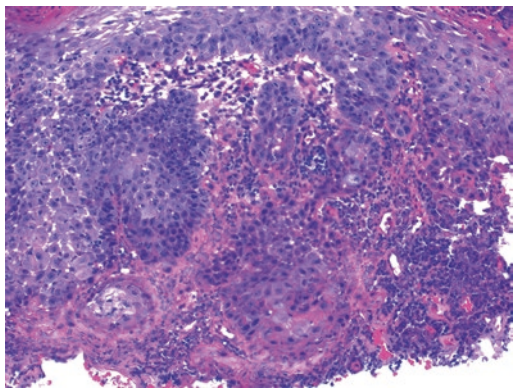


Fig. 11 Poorly differentiated squamous cell carcinoma

marked pleomorphism with numerous bizarre cells and brisk mitotic activity (Fig. 11). They are usually associated with a high incidence of local recurrence and metastasis.

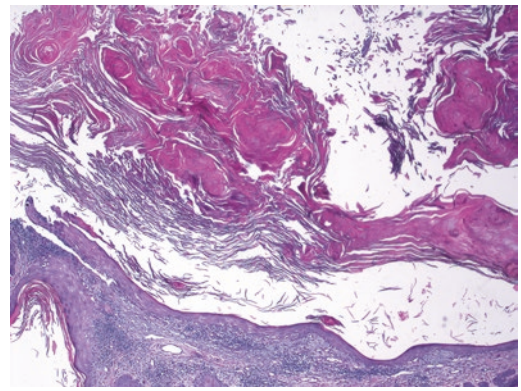


Fig. 12 Keratoacanthoma

4. **Keratoacanthoma (KA)**
   KA is squamous cell neoplasm. Clinically it presents as a rapid growing mostly solitary lesion that can be seen in the eyelid and conjunctiva. They can cause extensive local destruction.
   Microscopically KA is a dome or cup-shaped epidermal thickening of squamous cells with a keratin plug with nests of well differentiated squamous cells. In most institutions, including ours, KA is reported as "well differentiated squamous cell carcinoma, keratoacanthoma type." However, we acknowledge that there are reports that dispute this categorization based on distinct pathogenesis (Fig. 12).
5. **Malignant Melanoma**
   Malignant melanomas are less common tumors that can arise in the skin of the eyelid, bulbar conjunctiva or the uvea. Eyelid melanomas are not rare and can arise do novo or from a severely dysplastic nevus or lentigo maligna. In some cases, the proliferation of the melanoma cells infiltrates into the palpebral conjunctiva and a clear distinction of the origin cannot be made. Eyelid melanoma generally have worse prognosis than conjunctival and uveal melanomas. This is attributed to the tendency of the eyelid melanoma for early lymphatic and vascular metastasis. Sentinel node biopsy can have a significant impact on the prognosis and management of patients with melanoma.

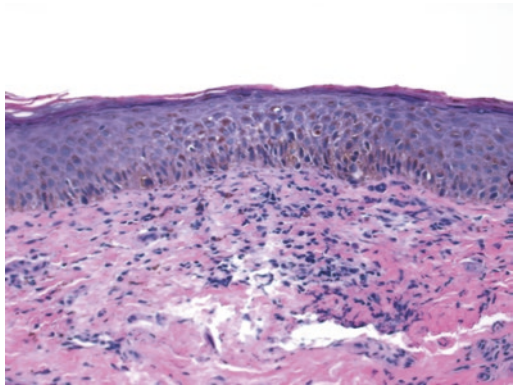


Fig. 13 Lentigo maligna

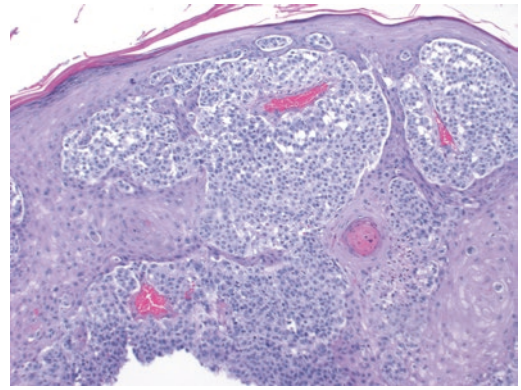


Fig. 15 Dermal and epidermal nests of malignant melanoma

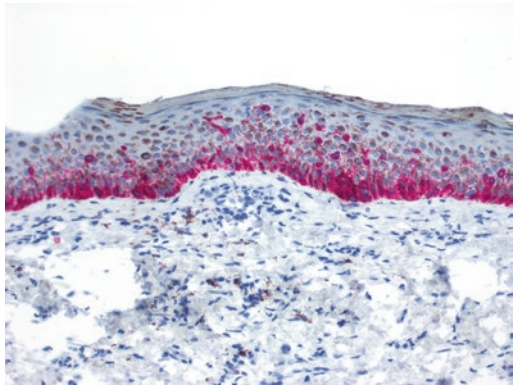


Fig. 14 Immunohistochemical staining of Lentigo maligna

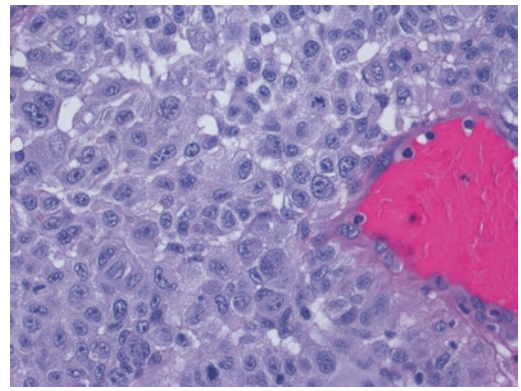


Fig. 16 Pagetoid spread of malignant melanoma

Histologic varities:

- Lentigo Maligna (Malignant Melanoma In Situ):

They are characterized by proliferation of highly atypical melanocytes along the basal layer of the epidermis. The cells vary from large with dark hyperchromatic nuclei to vacuolated and irregular (Fig. 13). Solar elastosis is usually seen in the upper dermis. Immunohistochemical staining with a melanocytic marker such as Melan-A can be very useful by highlighting a confluent (uninterrupted) staining pattern throughout the affected area of the specimen (Fig. 14). We find this to be useful in assessing lateral margins of lentigo maligna specimens. Furthermore, the stain helps in highlighting areas of microinvasion, which may be difficult to see on the hematoxylin and eosin slides.

- Malignant Melanoma:

There are various patterns for melanoma spanning cellular, architectural and growth patterns. In general melanomas grow in asymmetrical pattern and form dermal and epidermal nests showing confluent and haphazard arrangements (Fig. 15). Pagetoid spread and ulceration can be seen (Fig. 16). The dermal growth lacks maturation. The cells are highly pleomorphic and mitotic activity is usually noted (Fig. 17). Tumor infiltrating lymphocytes (TIL) are important features to include in the pathology report (Fig. 18). Melanin production can vary from

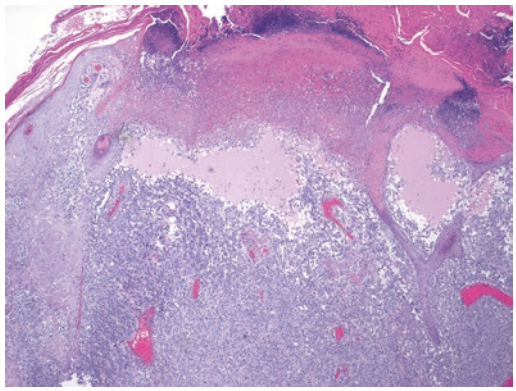


Fig. 17 Highly pleomorphic cells with mitotic activity in malignant melanoma

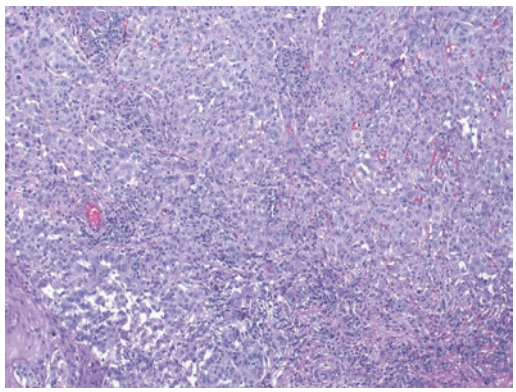


Fig. 18 Tumor infiltrating lymphocytes (TIL) in malignant melanoma

one area to another within the same tumor. Spindle cell melanoma are often amelanotic.

Prognosis:
Poor prognostic Factors include ulceration, involvement of eyelid margins, increase depth of invasion/Breslow thickness, regional lymph node involvement and distant metastasis.

6. **Rhabdomyosarcoma (RMS)**

Rabdomyosarcoma is the most common primary tumor of the orbit in children with a mean age of diagnosis of 7 years. Boys are more affected than girls. Rabdomyosarcoma is an aggressive malignant tumor that infiltrate adjacent structures and presents with "fulminant proptosis".

Histologic Diagnosis:
There are three types of rabdomyosarcoma; embryonal, alveolar and pleomorphic. In the orbit, embryonal is the most common type followed by alveolar with pleomorphic being the least common type. The cells in embryonal are polyhedral and spindle in a loose myxoid stroma. Alveolar type is seen in older children and is characterized by the presence of variable shaped alveolar spaces separated by fibrous septa. Rhabdomyblasts or strap cells are the cell of origin of Rhabdomyosarcoma. They have eccentric eosinophilic cytoplasm with cross striations. They are less common in alveolar rabdomyosarcoma.

Prognosis:
A combination of surgical (orbital exenteration), chemotherapy and radiation has improved survival in recent years.

Miscellaneous Lesions:

1 Lobular Capillary Hemangioma (Pyogenic Granuloma, PG)
PG is the most common acquired vascular lesion of the eyelid. It presents clinically as a fast-growing polypoid lesion. The term pyogenic granuloma is a misnomer as the lesion is not granulomatous in nature. Microscopically there are lobular clusters of small blood vessels admixed with inflammatory infiltrates. Complete removal usually prevents local recurrence (Fig. 19).

2 Schwannoma (Neurilemmoma)
Schwannoma is a rare benign slow growing firm and well-defined neural neoplasm that can be seen in the eyelid or the orbit. The term "bag of worms" has been used to describe the eyelid on palpation. Microscopically the tumor is comprised of spindle cells in a unique palisading arrangement. The most characteristic microscopic feature is the presence of 2 patterns of known as (Antoni A) and (Antoni B). Antoni A

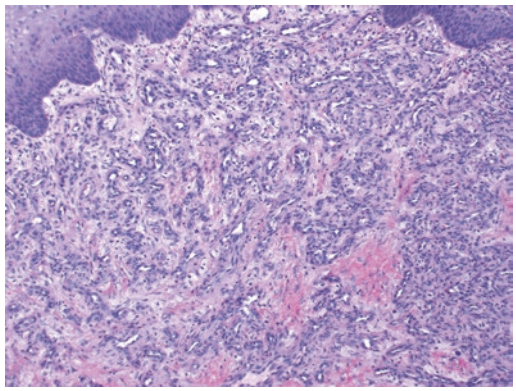


Fig. 19 Lobular capillary hemangioma (Pyogenic Granuloma, PG)

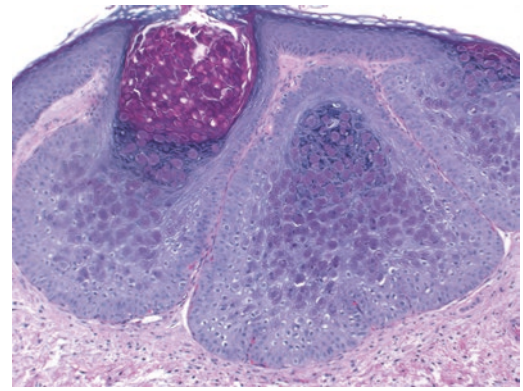


Fig. 21 Molluscum contagiosum

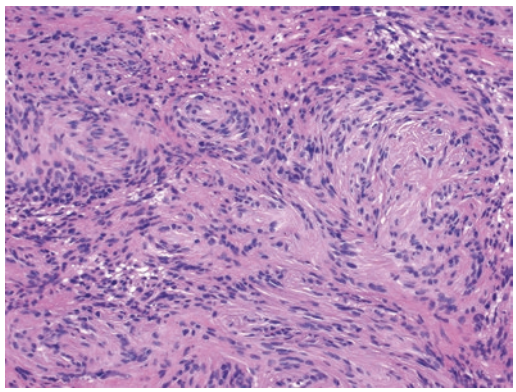


Fig. 20 Schwannoma with (Antoni A) and (Antoni B) patterns

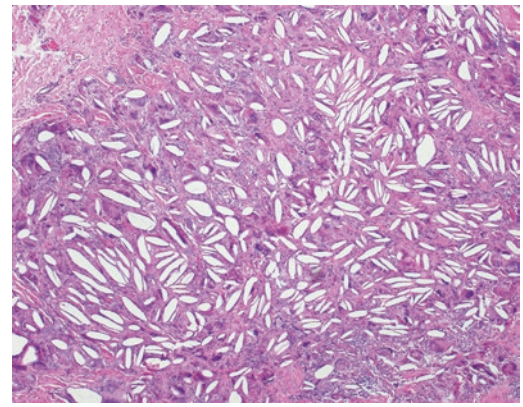


Fig. 22 Xanthelasma

pattern is hypercellular with compact spindle cells. In Antoni B, the cells are separated by edematous fluid. A combination of the 2 patterns can be seen (Fig. 20). Schwannomas are usually positive for S-100 immunohistochemical stain. Malignant transformation is extremely rare.

3 Molluscum Contagiosum
Is a poxviral infection that can be frequently seen in the skin if the eyelid. It presents as multiple cup-shaped nodules with central core. Microscopically, there are epidermal indentations filled with round eosinophilic inclusions known as molluscum bodies (Fig. 21).

4 Xanthoma (Xanthelasma) and Juvenile Xanthogranuloma
Flat xanthomas of the eyelid are a very common bilateral eyelid lesions seen in middle aged and elderly individuals as yellow-tan plaque like elevations. A minority of the cases is associated with hyperlipidemia. Microscopically, they show ill-defined collection of lipid-laden macrophages. Occasional needle-shaped cholesterol clefts are seen (Fig. 22).
Juvenile Xanthogranuloma (Nevoxanthoendothelioma) is a self-limited histiocytic proliferation seen in the ocular globe, iris and eyelid. Microscopically, it shows multinucleated giant cells with mixed histiocytic and lymphocytic infiltrates.
The details of the clinical presentation and management of the common types of these lesions is further discussed in other chapters.

Lymphoproliferative Disorders

The eyelid and orbital adnexa can show various types of lymphoid infiltrations. In inflammatory and infectious conditions reactive lymphoid hyperplasia usually present as lymphoid aggregates that are comprised of lymphocytes at different stages of maturation, hence the size variability. Germinal centers are usually identified and the presence of tingible body macrophages indicates a benign (reactive) process. In a neoplastic process the lymphoid cells are usually monotonous. Neoplastic lymphoid lesions of the eyelid and ocular adnexa are predominantly non-Hodgkin B-cell type. They include extranodal marginal zone lymphoma of mucosal associated lymphoid tissue (MALT), follicular lymphoma, diffuse large B cell lymphoma. Other less common types include mantle cell lymphoma and lymphoplasmacytic lymphoma. Cutaneous T cell lymphoma (mycosis fungoides), which arise from natural killer T cells is very rare.

In patients with leukemia, ocular involvement can be seen presenting as diffuse or nodular infiltration comprised predominantly of leukemic blast cells.

Immunohistochemical Staining

To differentiate between neoplastic and reactive lymphoid cells, it is recommended to perform a comprehensive panel that includes B-cell marker CD20 and T-cell markers CD3, CD20, CD43, CD5, follicular markers CD10, BCL2 and BCL6. Other stains to include in the panel are BCL1 (Cyclin D1) for mantle cells and CD23 for small lymphocytic lymphoma.

A reactive process will show polyclonal cells of mixed B and T lymphocytes. In this case the B-cells are highlighted by CD20 and the T-cells will be highlighted by CD3, CD5 and CD43. In MALT, the majority of the cells are positive for CD20 and aberrant expression of CD43 in B cells is noted. In this case, CD43 will show positive staining in more cells than CD3. In follicular lymphoma, the lymphoid aggregates on hematoxylin and eosin stain will show a nodular architectural due to the follicular formation. The majority of the cells are positive in CD20. The neoplastic follicular cells within the germinal center will show positivity for CD10 and BCL6. BCL2, which is normally positive in the marginal and mantle zones, will be positive in the germinal center. The combination of the 3 stains (CD10, BCL6 and BCL2) is essential in differentiating follicular lymphoma from reactive follicular hyperplasia in which BCL2 will be negative within the germinal center of the reactive condition.

In mantle cell lymphoma the cells will be positive for CD20 and BCL1 (Cyclin-D1) stains.

Idiopathic Orbital Inflammation (IOI)

IOI is an inflammatory condition of unknown etiology, which can involve the orbit and eyelids. It is believed that IOI is linked to systemic immunologic disorders such as idiopathic inflammatory bowel disease (Crohn's disease), systemic lupus erythematosus, rheumatoid arthritis and diabetes mellitus. The histopathologic features of IOI are nonspecific. They range from diffuse mixed inflammatory infiltrate to granulomatous inflammatory or eosinophilic reactions. When extensive fibrosis is present, the term idiopathic sclerosing orbital inflammation is used. When granulomatous inflammation is noted the differential diagnosis must include granulomatous infections such as TB and fungus and other granulomatous conditions such as sarcoidosis. Stains for acid fast bacilli and fungal stains should be part of the routine work-up of any granulomatous condition.

The Dialogue Between Pathologists and Surgeons

There is no doubt that more communication between healthcare providers results in better care. In case of communication between pathologists and surgeons, it is important to emphasize

the term "dialogue" to highlight the need of the two sides to participate in the communication. The basic forms of this communication are in the information provided by the surgeon on the test requisition and the information conveyed by the pathologist in the pathology report. The dialogue should not be limited to this impersonal form. In many cases, direct conversations are needed to communicate various issues. These issues may include the surgeon communicating a specific difficulty in obtaining the specimen, a certain gross finding of the lesion, or the pathologist communicating artifacts in the specimen or morphologic findings that cause a diagnostic dilemma precluding a more definitive diagnosis. It may also include discussing a working differential diagnosis that both the surgeon and the pathologist participate in resolving. In our practice, we find this process to be extremely helpful as in many occasions we collectively decide on a course of action, which may include, among other options, obtaining additional sample, ordering additional stains, requesting a second opinion or a close follow up.

Frozen Section

In case of frozen sections, we strongly advocate that the pathologist on call for frozen section be dressed in scrubs to facilitate quick access into the operating room to discuss findings, ask for further margin information or to communicate the diagnosis directly. Any communication of frozen section results must be preceded by clear statement of the patient's full name and date of birth, which is then matched with the specimen label and the patient's wrist band. The surgeon can also step out of the operating room and review the findings with the pathologists at the double-headed or multi-headed microscope. The pathologist should not be pressured to make definitive diagnosis in cases where such certainty is not possible. In these cases, the best decision for the pathologist is to defer to the permanent section. In general, frozen sections should be limited to situations in which a diagnosis would result in a different surgical decision. For example, if there is a clear malignant tumor removed with adequate margin without a

Table 3 Pathology report

Patient Identification and Demographics	• Name: (first and last) • Date of birth • Sex
Requesting physician/ ordering facility	• Name, address, telephone and fax numbers of requesting physician • Name, address, telephone and fax numbers of ordering facility
Clinical information	• A summary of the information provided on the requisition • Clinical impression or "rule outs"
Specimen information	• Site, location, laterality (right vs left) • Procedure type (biopsy, excision, resection)
Gross description	• Clear naked-eye description with measurement in centimeters, color and consistency
Diagnosis	• Specimen number, location and procedure • Clear and concise diagnosis for each specimen • Frozen section diagnosis (when applicable) • Synoptic diagnosis following college of American pathologists CAP guidelines) (when applicable)
Microscopic description	• For malignant diagnoses • Most benign lesion do not require a detailed microscopic description
Additional information (Comment)	• Documentation of notification of the physician for critical results • Description of special or immunohistochemical stains • Recommendations: Ex. Additional sampling, follow up • Documentation of departmental review or extramural second opinion • Review of and/or comparison with previous or concurrent relevant cases

need for sentinel node dissection, a frozen section would not be needed.

The final pathology report must include the frozen section diagnosis.

The Pathology Report

Table 3 shows the information that the pathology report must include. Some institutions include photomicrographs in the report. Although this provides a better appearance of the report, our experience is that it yields little clinical value.

Suggested Readings

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The Nasal Sinuses and Oculoplasty

Hussam ElBosraty

Introduction

The orbit is closely related anatomically to the paranasal sinuses. It is related superiorly to the frontal sinus, medially to the ethmoid sinuses, inferiorly to the maxillary sinus and posteromedially to the anterolateral wall of the sphenoid sinus. Owing to this close anatomic proximity, both can share same diseases, and/or extension from one of them to the other can occur.

A variety of diseases are unique in their ability to involve both the sinonasal (SN) cavities and the orbits. It is more common for SN pathology to affect the orbit than the reverse, and primary sinus pathology may initially present with predominantly orbital, rather than sinus, symptomatology.

Generally, there is more than 1 ocular symptom found in each patient with sinonasal disease extending to the orbit. Proptosis is the commonest occurring about 60% of cases. The direction of proptosis is an important clue of the location of the involved sinus. Frontal sinus proptosis occurs inferiorly and is accompanied by swelling of the brow area. Direct lateral proptosis occurs in ethmoid sinus disease. With maxillary sinus pathology, the proptosis is upwards.

Other less common symptoms include ophthalmoplegia and visual loss. A decrease in visual acuity indicates of optic nerve involvement. The underlying pathophysiology may be caused by direct compression of the nerve fibers, nonperfusion of its blood vessels or inflammation/infection in proximity to the nerve.

Ophthalmoplegia can be caused by a mechanical restriction on extraocular muscles or nerves paresis. Force duction test can distinguish between both. Positive test denotes mechanical restrictions. Abnormal ocular motility can cause diplopia both at the primary gaze position and the position of the extremes gaze.

Disease entities affecting the sino-orbital region may arise primarily in the SN cavities, the orbits, or the surrounding bones; or they may result from secondary involvement by systemic disorders. Generally, sino-orbital pathologies can be classified broadly into four groups: (1) Infectious and inflammatory conditions; (2) Granulomatous disease; (3) Fibro-osseous lesions; and (4) Neoplasms.

Infectious and Inflammatory Conditions

These can be of acute onset as orbital cellulitis and subperiosteal abscess. A special but rather rare pathology is acute invasive fungal

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_29

rhinosinusitis (AIFRS). Chronic inflammatory conditions include allergic fungal sinusitis, mucocele, and acquired maxillary atelectasis. These entities affect the orbit either by direct extension or by distortion of the orbital walls.

Acute Bacterial Sinusitis and Orbital Cellulitis

It occurs most often in fronto-ethmoid sinusitis and is particularly common in children. Symptoms of orbital involvement include red swollen eye, proptosis, and impaired ocular motility. Most cases are treated medically; however, immediate surgical intervention with drainage is recommended in patients with visual loss as an initial symptom, in patients with rapid visual deterioration, and in those without a response to 48 h of aggressive intravenous antibiotic therapy.

Infection may spread directly into the orbit via direct trans-osseous route, blood born, or by retrograde extension via the valve less diploic veins. The thin lamina papyracea does not offer much resistance to the spread of infection from the ethmoid sinuses. The periorbita is more resistant and fluid/pus may accumulate between the bone and the periosteum forming a subperiosteal abscess which is the most common imaging finding in sino- orbital infection. Orbital and intracranial extension may coexist and early recognition is critical.

On imaging, orbital fat stranding is an early sign of periorbita breech. Orbital abscess typically appears as a rim-enhancing, fluid attenuation (CT) or signal (MRI) collection along the medial wall or roof of the orbit (Fig. 1).

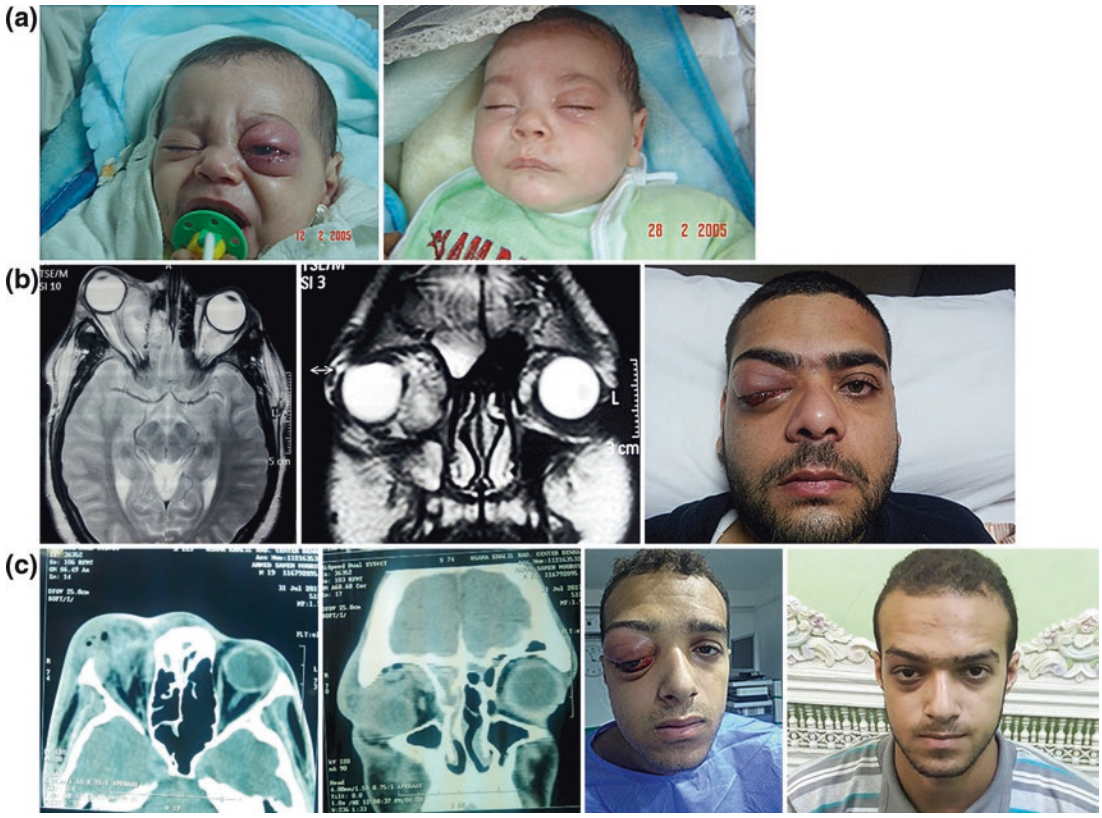

Fig. 1 Orbital cellulitis/abscess. **a** Pre and post Endoscopic drainage. **b** MRI and clinical appearance. **c** Pre and Post CT picture and clinical appearance

Acute Invasive Fungal Rhinosinusitis

Acute invasive fungal rhinosinusitis (AIFRS) is a rapidly progressing infection with a high morbidity and mortality (50–80%). The initial presentation is in the form of nonspecific rhinitis, with nasal discharge or fever; however, visual symptoms and neurological deficits may rapidly develop. AIFRS occurs almost exclusively in two groups of patients: immunocompromised patients, particularly individuals with cellular immune deficiency such as HIV/AIDS; and poorly controlled diabetics. Fungal infection in the diabetic group is most often caused by organisms in the Zygomycetes order such as *Mucor*. In the immunocompromised group, *Aspergillus* species are responsible for up to 80% of AIFRS cases. The mucosa over the turbinates and nasal septum appears pale and ischemic then progress to necrosis and gangrene with characteristic black eschar. Infection spreads to the palate with palatal necrosis and perforation. Spread to the orbit is early and even out of proportion to the sinus involvement. Intracranial complications can occur later if not managed early (Figs. 2 and 3).

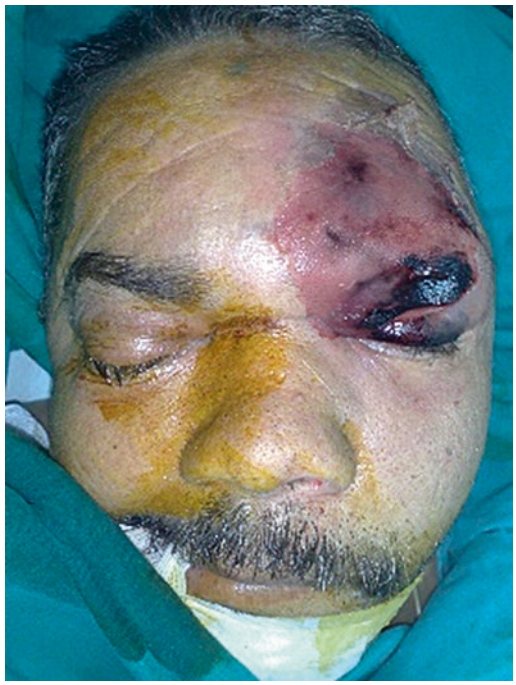

Fig. 2 Mucormycosis

Successful treatment requires prompt and early diagnosis. MRI is superior to CT in evaluating orbital and intracranial extension. CT and MR angiography may help to identify vascular narrowing/occlusion, particularly of the cavernous segments of the internal carotid arteries in cases of sphenoid fungal disease.

On imaging, early disease may appear as mucosal thickening or soft tissue in the SN cavities with a predilection for the ethmoid and sphenoid sinuses. Ethmoid disease can spread easily into the medial orbit and sphenoid disease into the orbital apex. On CT, early orbital involvement shows infiltration and soft tissue stranding in the orbital fat surrounding the extraocular muscles. Bone erosion may or may not be present, as the organisms are angioinvasive and infection can spread along the blood vessels traversing the bone. On MR, the presence of areas of hypointense long TR signal related to the presence of fungal hyphae and

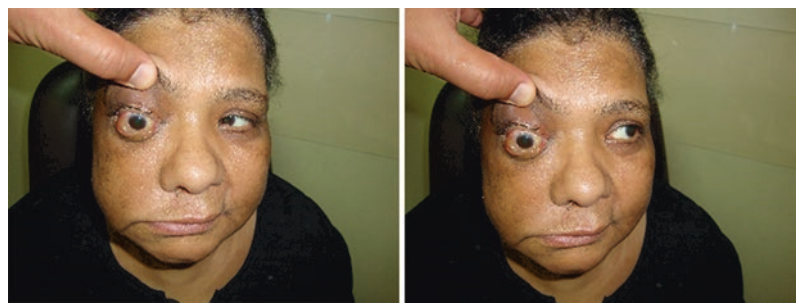

Fig. 3 Mucormycosis with ophthalmoplegia

metal chelates may be seen. Areas of tissue necrosis, with absence of enhancement, are characteristic of advanced disease.

Allergic Fungal Sinusitis (AFS)

AFS is common in warm, humid climates and affects hypersensitive patients, often with a history of atopy, including allergic rhinitis and asthma. AFS is characterized by the presence of nasal polyps, thick, eosinophilic rich mucin looking like peanut butter. Bone expansion and then thinning to egg- shell cracking is common. Extension to the orbit or intracranially is limited by the periorbita and dura respectively. The CT characteristic features of AFS are the sinus expansion by a heterogeneous opacity with areas of hypo and hyper densities (Fig. 4). Intensity of the allergic mucin varies depending upon the water and protein content. The hypointense MRI T2 signal is related to deposition of heavy metals such as iron, magnesium, and manganese concentrated by the fungal organisms.

Mucocele

Mucous retention inside the sinus results from sinus obstruction leading to subsequent expansion. Fronto-ethmoidal sinuses are frequently more affected than the posterior ethmoid and sphenoid sinuses. However, the latter is more liable to complications as optic neuropathy and

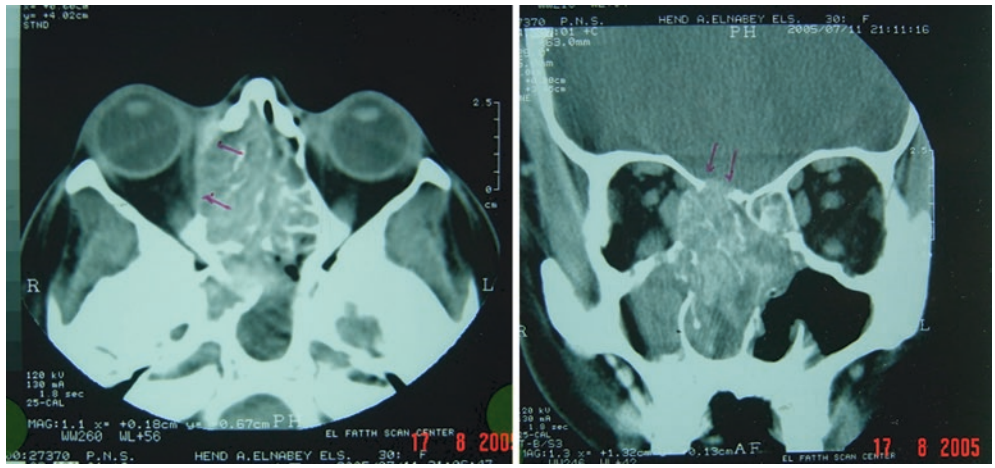

Fig. 4 CT findings of AFS: notice the heterogenous opacity of the lesion

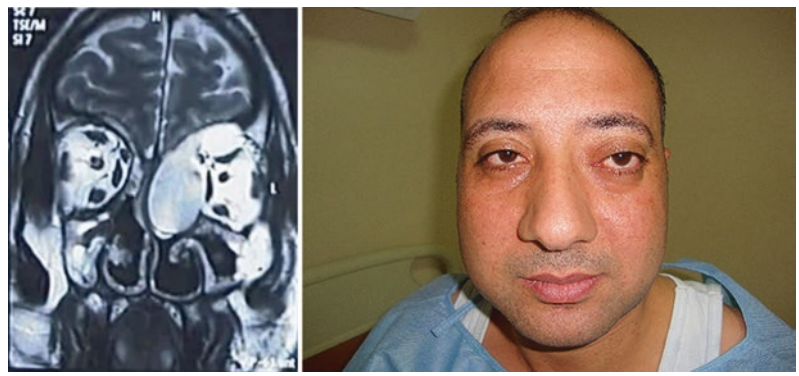

Fig. 5 Lt. Fronto-ethmoidal mucocele

cranial nerve palsies due to proximity to the optic nerve and cavernous sinuses. Severe rapid visual loss may occur if a mucocele becomes infected (mucopyocele). CT reveals smooth expansion of the walls of the sinus with or without foci of bone dehiscence. MRI signal intensity is highly variable and depends on the proportions of water, mucus and protein (Fig. 5).

- **T1**
  - water-rich content: low signal (most common)
  - protein rich content: high signal
- **T2**
  - water rich content: high signal (most common)

  protein rich content: low signal
- **T1 C+(Gd)**: enhancement, if present, only occurs at the periphery.

Acquired Maxillary Sinus Atelectasis "Silent Sinus Syndrome"

Chronic maxillary sinus obstruction leads to negative pressure inside the sinus with gradual inward retraction of the sinus walls, including the orbital floor resulting in increased orbital volume, and enophthalmos. The patient usually presents with painless progressive enophthalmos. Imaging shows opacification and volume loss in the affected maxillary antrum, inward retraction of the sinus walls, obstruction of the maxillary infundibulum, lateralization of the uncinate process and widening of the retroantral fat pad. The maxillary walls may be thinned, normal or slightly thickened. Anterior bowing of the posterolateral wall is a useful clue for diagnosis.

Granulomatous Disease

The sinonasal tract and the orbit may be affected by various granulomatous inflammatory diseases.

Granulomatosis with Polyangiitis (GPA, Wegener Granulomatosis)

Is an autoimmune necrotizing granulomatous vasculitis that most commonly involves the respiratory tract and kidneys. GPA is most common in Caucasian males. Non specific nasal symptoms in the form of chronic rhinitis, septal perforation or saddle-shaped deformity may occur.

Orbital manifestations occur in 18–50% of patients, usually in the form of scleritis, lacrimal gland hypertrophy, orbital masses, and nasolacrimal duct obstruction. CT findings include nodular soft tissue masses in the nose and sinuses, chronic osteitis and or bone destruction, and nasal septal perforation. MRI shows low signal intensity nodular masses on T1W and T2W images with variable enhancement. MRI better delineates orbital involvement and intracranial spread through the cribriform plate or along skull base fissures and foramina. cANCA antibodies against proteinase is positive in GPA.

Sarcoidosis

A noncaseating granulomas more commonly affecting females. Orbital involvement is more common than SN involvement, occurring in up to 80% of patients. The most common structure involved in orbital sarcoidosis is the lacrimal gland, and may be unilateral or bilateral. Sarcoid can also present as diffuse infiltration of orbital soft tissues, extraocular muscles or optic nerve-sheath complex. The most frequent sites of SN involvement are the nasal septum and turbinates in the form of small nodules (cobble stone). The nasal mucosal soft tissue nodules of sarcoid are typically isodense to other soft tissue on CT. On MR, hypointense T1 signal, variable hyperintense long TR signal and diffuse, homogeneous enhancement are seen. The infiltrative soft tissue of sarcoid may mimic lymphoma or GPA. Diagnosis is confirmed on biopsy, but patient demographics and absence of cANCA positivity help differentiate sarcoid from GPA.

Chronic Invasive Fungal Rhinosinusitis

Chronic invasive fungal rhinosinusitis and granulomatous invasive fungal rhinosinusitis are very closely related diseases which could be differentiated: The former, usually developing in immunocompromised patients, is characterized by the dense accumulation of the hyphae, occasional invasion of the blood vessels, and the involvement of adjacent tissues, whereas granulomatous invasive fungal rhinosinusitis develops in immunocompetent patients and is characterized by noncaseating granuloma with foreign bodies or Langhans-type giant cells, occasional vasculitis, vascular proliferation, and perivascular fibrosis. This disease has been reported primarily in Sudan, India and Pakistan. The commonest causative agent is *Aspergillus* (Fig. 6).

Rhinoscleroma

Rhinoscleroma is a rare chronic granulomatous infection caused by *K rhinoscleromatis* and should be considered in patients from countries in which the disease is endemic. Patients have nasal masses that adhere to the nasal septum or inferior turbinates with relative sparing of the sinuses. Orbital invasion in rhinoscleroma is usually in the form of dacroscleroma of the nasolacrimal duct, but it is extremely rare to find true granuloma invasion from the sinuses.

Fibro-Osseous Lesions

Osteoma

Is the most common benign sinonasal tumor. Fronto-ethmoid sinuses are the commonest site. In the majority of cases, they are accidentally detected and only manifest if blockage of the sinus or lacrimal drainage pathways occur. They are usually well circumscribed with a broad base or pedicled from the sinus wall.

Fibrous Dysplasia

Fibrous dysplasia (FD*)* is a non-neoplastic disorder involving one or more craniofacial bones. It may be solitary or multiple (polyostotic). Pathologically, medullary bone is replaced by immature tissue that varies from fibrous-to- osseous. It usually presents in the first two decades and progresses till the age of skeletal maturity. FD may be asymptomatic or presents with symptoms as cosmetic deformity, diplopia, epiphora, visual disturbance, or sinus obstruction. The imaging features of FD depend upon the amount of bone and fibrous tissue present as well the degree of mineralization. The classic appearance of FD is bony expansion with thinning of the cortex with ground glass appearance of the matrix. The MR appearance of FD can be confusing but often shows Intermediate-to hypointense areas of signal on both T1 and long TR sequences (Fig. 7).

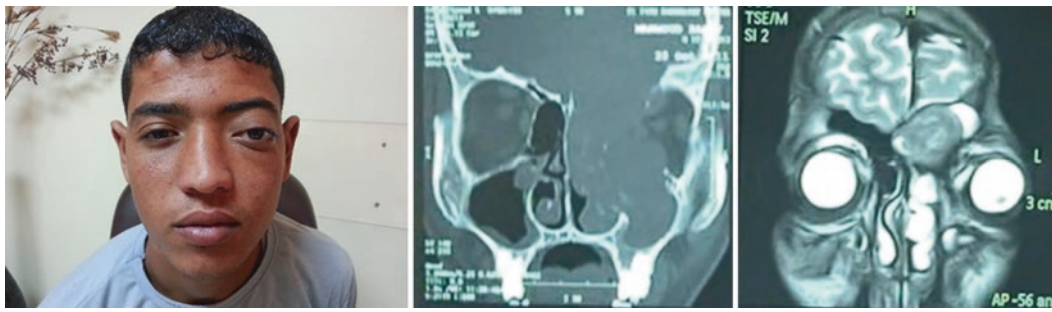

Fig. 6 Chronic invasive fungal granuloma, MRI differentiates between the granuloma and retained secretion

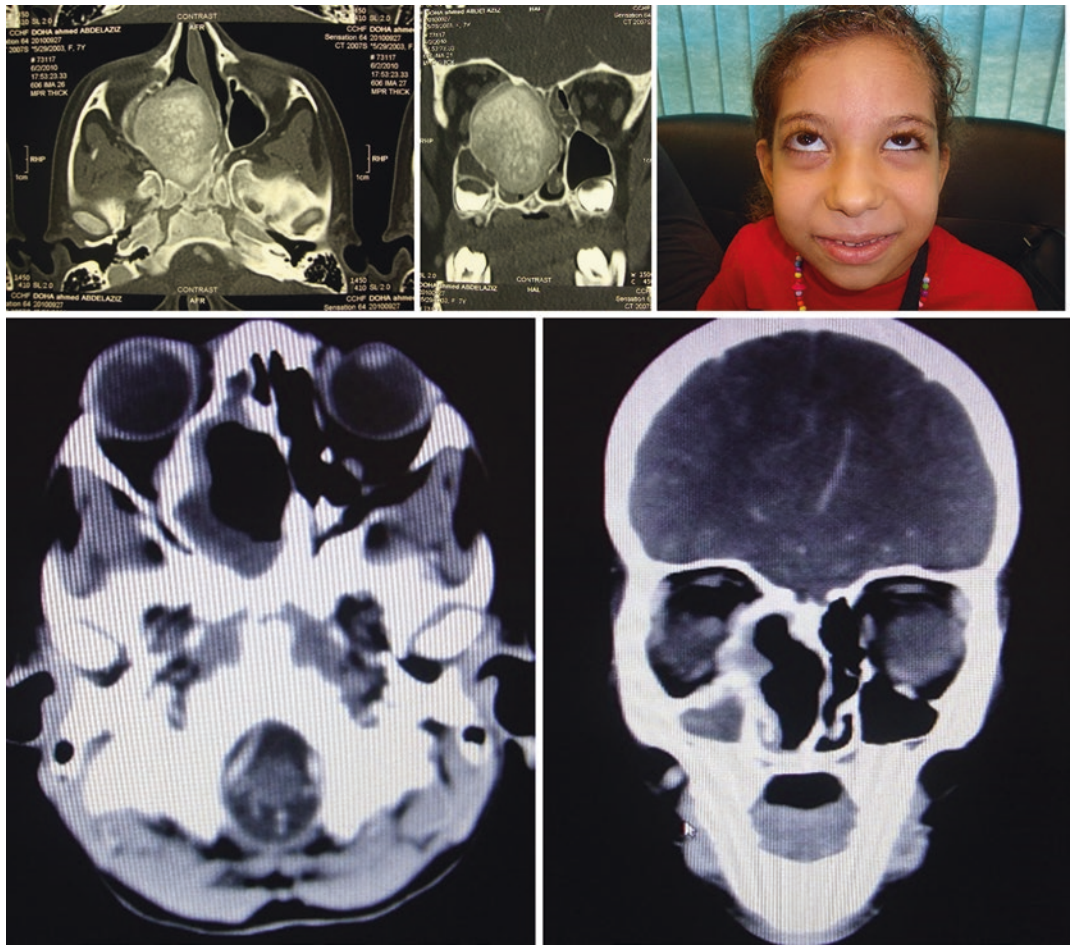

Fig. 7 Fibro-osseous dysplasia (Pre and post endoscopic resection)

Ossifying Fibroma

A solitary benign neoplasm that continues to grow after skeletal maturity. It is characteristically more common in females between the 2nd and 4th. decades.

Sinonasal Neoplasms

Sinonasal tumors entail a very big number of diverse benign and malignant tumors. Among the commonest SN benign tumors that may invade the orbit is juvenile nasopharyngeal angiofibroma. It is a locally aggressive tumor which occurs in adolescent males and presents with nasal obstruction, epistaxis, proptosis (frog face deformity). Extension into the orbit usually occurs through the inferior orbital fissure from a tumor in the pterygopalatine fossa. Tumor imaging by CT and MRI shows the extremely vascular nature of the tumor. Endoscopic excision after vascular embolization is the treatment of choice (Fig. 8).

Malignant SN Tumors

Environmental risk factors predisposing to malignancy of the SN tract include irradiation, inhalation of wood dust, metallic particles,

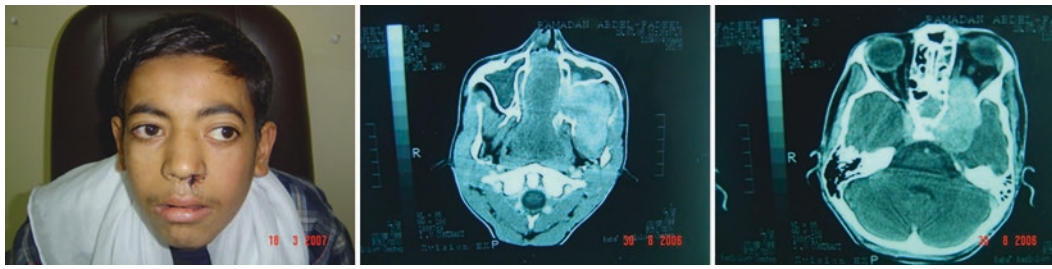

Fig. 8 Nasopharyngeal Angiofibroma (frog face deformity)

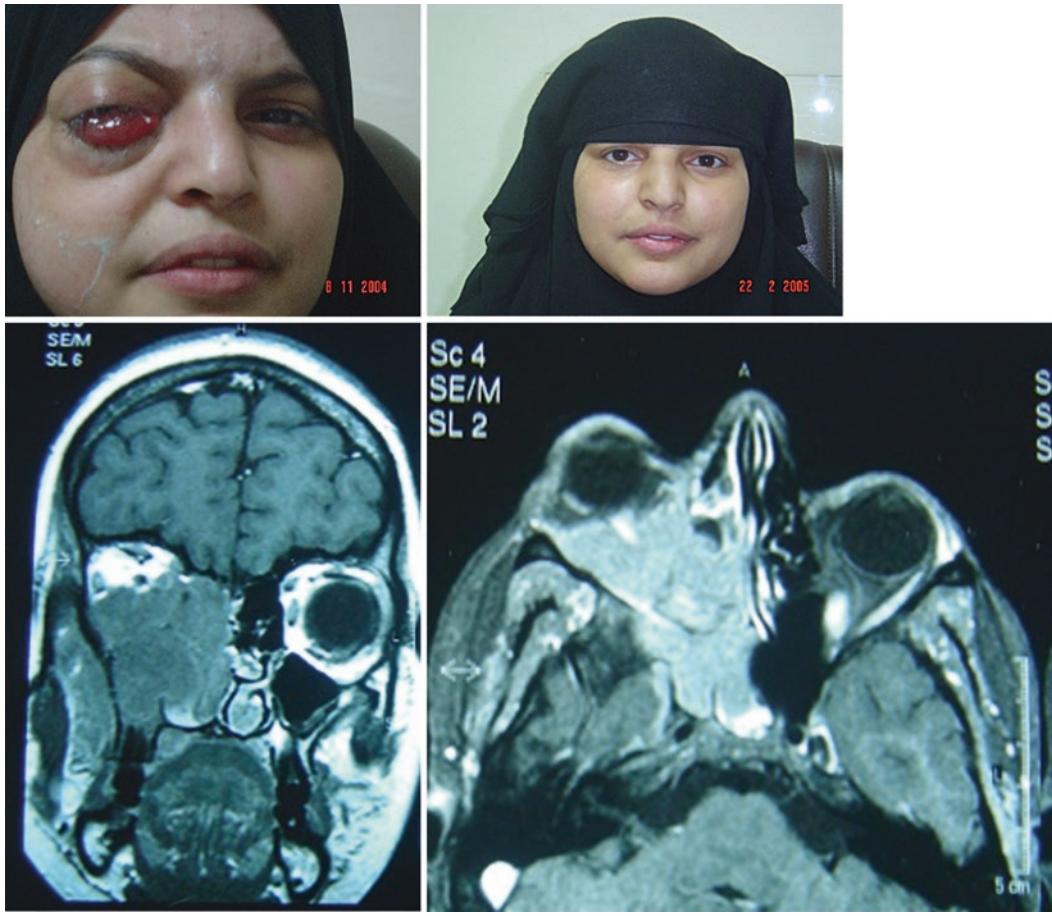

Fig. 9 Sino-orbital non-Hodgkin lymphoma and results after chemotherapy

chrome pigment, and nickel. There is a wide diversity of SN malignant tumors. The commonest is squamous cell carcinoma (SCC), adenocarcinoma, undifferentiated carcinoma (SNUC), sinonasal small cell neuroendocrine carcinoma, adenoid cystic carcinoma, non-Hodgkin lymphoma, esthesioneuroblastoma, melanoma, rhabdomyosarcoma, chondrosarcoma and many more.

Malignant SN tumors present with non-specific symptoms like epistaxis, nasal obstruction, discharge, pain, proptosis, epiphora, visual deterioration, diplopia or facial swelling. Imaging studies in general will show poorly defined,

heterogeneously enhancing mass with areas of necrosis and bone destruction. There are features peculiar to some tumors, as more enhancement is seen in esthesioneuroblastoma and lymphoma (Fig. 9). Bone remodeling might happen with lymphoma. Tumor like esthesioneuroblastoma tends to appear near the cribriform plate with early bone destruction and intracranial and intra orbital invasion. Adenocarcinoma is more common in the ethmoids, regional and distant metastases are found with SNUC, perineural spread is common with adenoid cystic carcinoma

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Neuro Ophthalmology and Oculoplasty

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Myasthenia Gravis

Myasthenia gravis (MG) is one of the most common autoimmune antibody-mediated disorders. It disturbs neuromuscular transmission by autoantibodies' attack against the acetylcholine receptors (AChR) of the postsynaptic membrane. Typically, MG causes fluctuating weakness and fatigue in the ocular, bulbar and skeletal muscles. It is classified as ocular and generalized subtypes. Ocular MG involves only extra ocular muscles and eyelid, presenting with painless diplopia, ptosis and fluctuating, often fatiguable, extra ocular muscle weakness with normal sensory function, pupillary reaction and visual acuity. Gaze-evoked nystagmus, inter-saccadic fatigue and Cogan's lid twitch can also be seen in ocular MG. When a patient initially presents with ocular MG, generalized MG may subsequently develop; if so, it usually does so within the first 24 months. Cyclic relapse, remission and crises of ptosis, diplopia, dysarthria, dysphagia, extremity weakness and dyspnea (in severe cases) are characteristics of MG.

The diagnosis of MG is based on the clinical presentations, serological and pharmacological tests and electrophysiological assessments. Documented fatiguable ptosis and/or significant variability in ocular alignment are virtually pathognomonic for MG. The additional presence of orbicularis weakness can also be diagnostically important. Other clinical tests include the sleep test, positive if transient improvement of ptosis occurs after 30 minutes of eyelid closure. The ice test is an economic and easy test in which an ice pack is placed on the ptotic eyelid for 2 minutes. Greater than 1 mm ptosis improvement is highly sensitive and specific for MG. Acetylcholinesterase inhibitors (Edrophonium chloride and/or neostigmine) can be administered to reverse MG signs but are being used much less frequently given the other previously less invasive tests described above. Acetylcholine Receptor (AChR) antibodies are found in 85% of patients with the generalized form of MG, but they are present in only about half of the patients with pure ocular MG. Thus, the absence of AChR antibodies does not rule out MG. Antibodies against muscle specific kinase, agrin and low-density lipoprotein-4 should be considered in clinically suspicious cases with negative AChR antibodies. In the seronegative cases, electromyography and single fiber electromyography have

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_30

high specificity and low sensitivity in the diagnosis of MG. Thymoma is associated with MG and thus computerized tomographic (CT) scan of the chest should be obtained after making a definite diagnosis of MG.

Treatment of MG is symptomatic as there is no "cure." Of course, if the initial CT scan shows thymic enlargement, thymectomy should be considered and can result in symptom resolution.

If there is no thymic enlargement (usually the case) and if symptoms are very mild or the patient is in remission, then no treatment may be appropriate. If medical treatment is needed, a neurologist should be involved because of the potential for severe systemic manifestations of MG and most ophthalmologists are not comfortable with treating this condition. First-line medical therapy is usually either pyridostigmine or a corticosteroid. Pyridostigmine generally has less side effects than corticosteroids but may also be less likely to improve symptoms. However, there is suggestion that corticosteroids may prevent the progression of ocular MG to generalized MG. Initial treatment with either of these medications is based on the patient's medical status and relevant side effect profile of each medication. If these first-line medications are ineffective, other immunomodulatory therapies such as cyclosporine, methotrexate, tacrolimus, mycophenolate mofetil and azathioprine with and without corticosteroids have been used to improve symptoms and possibly prevent the development of generalized MG from the ocular form. Unstable and refractory cases should be managed with plasma exchange, plasmapheresis or intravenous immunoglobulins (IVIG) which remove the circulatory autoantibodies and immune factors. Newer treatments such as Eculizumab, a monoclonal antibody, are being investigated for the refractory generalized form in patients with positive AChR antibodies. It inhibits the complement system and is administrated as an intravenous infusion. Management with these medications and modalities should involve physicians familiar with their use, monitoring and potential side effects. Patients without good response to medical treatment and who have relatively stable ptosis or ocular misalignment can be treated with prism glasses, eyelid and strabismus surgery.

Giant Cell Arteritis

Giant cell arteritis (GCA), also known as temporal arteritis, is one of the most important emergencies in ophthalmology because of its irreversible and devastating effect on vision in approximately half of patients. It usually presents with headache, transient or permanent visual loss, diplopia, jaw claudication and rarely stroke. GCA usually occurs in adults more than 50 years of age and the prevalence in woman is 3 times higher than men. GCA involves the mid and large-sized arteries, mostly branches of the internal and external carotid arteries. Ophthalmic manifestations can include anterior or posterior ischemic optic neuropathy, retinal artery occlusion, and ocular motor cranial neuropathy(s). Headache has been reported as the most prevalent symptom which is related to the inflammation of the external carotid arteries' branches. The most specific symptom in GCA is jaw claudication due to masseter muscle ischemia because of involvement of the maxillary arteries.

GCA should be considered in every patient over age 50 with symptoms or signs described above. Ancillary diagnostic testing should include complete blood count, erythrocyte sedimentation rate (ESR) and the C-reactive protein (CRP) (combined sensitivity of 99%). Fundus fluorescein angiography is helpful if it shows delayed choroidal perfusion and temporal artery ultrasound is a non-invasive test that can be used in the diagnosis of GCA. However, temporal artery biopsy is the gold-standard for diagnosis and should be done in every patient where clinical suspicion is high; regardless of the results of any of the tests described above. In GCA, the biopsy shows internal elastic lamina necrosis and granulomatous inflammation containing multinucleated histiocytes and lymphocytes (giant cells). Although most patients with biopsy-proven GCA have high level of

ESR and CRP, non-concordance of these two tests has been reported. Elevation of both ESR and CRP is more sensitive in the diagnosis of GCA than measuring either test alone. Because some parts of the artery may not be affected by inflammation ("skip areas"), a long (>2.5 cm) bilateral or sequential temporal artery biopsy is recommended.

High dose corticosteroid is required to be administrated immediately to protect vision loss. Although there is a controversy in the rout of corticosteroid administration, at least one dose of intravenous steroid (1000 mg methylprednisolone) may be beneficial in patients presenting with severe vision loss. Theoretically, a similar high dose could be administered orally if the intravenous route is not feasible. Oral corticosteroids are then typically tapered over a 1-year interval. Recurrence of visual loss in patients on maintenance corticosteroid therapies and refractory cases despite careful corticosteroid tapering have been also reported. Recently, in a clinical trial, the superiority of tocilizumab, interleukin-6 receptor alpha inhibitor, on the recurrence of GCA during glucocorticoids tapering was reported. Combination of tocilizumab with tapering the prednisolone was superior to placebo group. However, the methodology in this study did not employ standard of care corticosteroid doses and there was a very rapid taper of corticosteroids and very high rates of relapse. Additionally, this medication is expensive and not readily available in most parts of the world. In a recent prospective study, the effect of ustekinumab in patients with refractory GCA was evaluated. No recurrence of GCA was reported in cases receiving ustekinumab despite tapering the glucocorticoids.

Horner Syndrome

Horner syndrome (HS) is an oculo-sympathetic palsy which may include the triad of eyelid ptosis, ipsilateral miosis and facial anhidrosis. Damage to the hypothalamus pathway through the spinal cord to the eye interrupts the sympathetic innervation of the eye, and leads to HS. This pathway includes three orders of neurons; first order neuron originates from posterolateral nuclei of the hypothalamus to spinal cord (level C8–T2); second order neurons extend from spinal cord and travel over the lung apex to the superior cervical sympathetic ganglion; and the third order neuron exits from superior cervical ganglion ascending through wall of the common and internal carotid arteries. Vascular occlusion in the lateral medulla, upper cervical spinal diseases and tumors can cause first order neuron involvement. Pancoast syndrome (apical lung tumors), thoracic aortic aneurysm, thoracic surgery and brachial plexus injury may lead to second order neuron lesion and injury to the wall of the carotid artery, internal carotid dissection and surgery on the carotid artery can cause third order neuron involvement. Most HS are idiopathic but neoplasia, trauma and iatrogenic injuries must be considered.

The clinical findings of HS include the upper eyelid ptosis (1–2 mm) and anisocoria (miosis in the affected side). We would note that ptosis is not always present. Forehead or facial ipsilateral anhidrosis may also be detected but it is not a reliable symptom for diagnosis. Some factors may influence the degree of anisocoria as they affect the autonomic system, including environment light, accommodation, emotions, medications and severity of underlying condition. Pupils must be examined in both bright and dim illumination. In the bright light, there is a significant increase in parasympathetic tone and a significant decrease in the sympathetic tone to the pupillary constrictor and the difference in pupil size is minimized. However, anisocoria is more detectable in darkness as the HS pupil dilates less than the normal pupil. In addition, the HS pupil may dilate somewhat more slowly the normal pupil in dim illumination. This slower dilation of the HS pupil is called dilation lag. Thus, one should always check the pupils in bright and dim illumination. Anisocoria is minimum in light; but, after turning the light off, for the first

5 seconds, there is a large difference in pupil size which becomes less as the affected pupil is going to dilate passively. The dilation lag can be detected by taking photos from pupils after 5 and 20 seconds in darkness.

Although the diagnosis of the HS is based on clinical suspicion, pharmacologic testing with eye drops can be used for the definitive diagnosis and localization of HS. Cocaine inhibits the re-uptake of norepinephrine and thus a normal pupil will dilate whereas a HS pupil does not. Cocaine drops can be difficult to obtain however, and apraclonidine is gaining in popularity. As an alpha-2 adrenergic agonist with weak alpha-1 adrenergic effects it will dilate a HS pupil but not a normal pupil because of denervation super sensitivity of the alpha-1 receptors on the iris-dilator muscles of the affected side. However, an acute HS pupil may not dilate after apraclonidine administration because denervation supersensitivity has not yet developed. Hydroxyamphetamine causes the release of stored norepinephrine from the presynaptic terminal and can be used for localizing the damage to 1st and 2nd order neurons versus 3rd order. If there is damage to the 3rd order neuron, there will be no norepinephrine to release and thus the pupil will not dilate. However, if there is 1st or 2nd order lesion, then there will be stored norepinephrine in the 3rd order neuron and the pupil will dilate.

Although HS often has only minimal signs and symptoms and may be asymptomatic, rapid diagnosis of the underlying conditions is crucial due to possible life-threatening conditions. Since hydroxyamphetamine is not usually available, MRI and MRA or CTA of the head and neck to lung apex is required. If there is suspicion of carotid artery dissection (recent neck injury, pain) then neuroimaging should be obtained immediately.

Of course, treatment of HS includes addressing the cause if one is identified. Fortunately, ophthalmologic symptoms of HS are only mild ptosis which may be treated with surgery, usually in the form of Muller's muscle resection, or administration of phenylephrine drops if the patient desires.

Idiopathic Intracranial Hypertension

Idiopathic intracranial hypertension (IIH), aka pseudotumor cerebri, is characterized by elevated cerebrospinal fluid (CSF) pressure, normal CSF composition and neuroimaging that shows no causative lesion. It usually occurs in overweight women in the age range of 20–44 years. It also can affect females in other ages, males and children as well. Symptoms of IIH may include headache, transient visual obscuration, pulsatile tinnitus, vision loss and diplopia. The major concern is vision loss which can be prevented by early diagnosis and management. Although, increased CSF production and/or decreased CSF absorption may lead to IIH, the definite pathophysiology of IIH is still unclear.

As mentioned above, the diagnostic criteria for IIH include brain MRI and MRV (or CT scan in case of MRI contraindication) that show no cause of increased intracranial pressure (ICP), normal CSF composition, elevated ICP (greater than 25 mm H_2O for adults and greater than 28 mm H_2O in children) and absence of focal neurological deficits. Papilledema is the characteristic hallmark of IIH but is not necessary for the diagnosis. Papilledema may be asymmetric or unilateral in some cases. The absence of papilledema does not prove CSF pressure is normal but there should be no risk of optic nerve damage in this case. The severity of papilledema is graded based on Frisén scale, which is helpful in planning the treatment strategy. Moreover, it is crucial to differentiate pseudopapilledema caused by optic disc drusen or congenital disc anomaly from true papilledema using stereoscopic viewing, ultrasonography, fluorescein angiography or OCT. Unilateral or bilateral abducens nerve palsy may be present and will resolve as ICP decreases.

Various medical conditions may increased ICP and produce a IIH-like syndrome. Sleep apnea, anemia, venous thrombosis syndrome and medications such as tetracycline derivatives, isotretinoin and vitamin A, may result in IIH-like syndrome. Some studies have shown the high prevalence of IIH in patients with the history of tetracycline consumption especially

minocycline. Moreover, the combination of tetracycline and isotretinoin for the treatment of acne increases the risk of developing IIH symptoms. Single treatments with tetracycline or isotretinoin with a wash–out period after prescribing tetracycline should be protective. Obstructive sleep apnea may also cause IIH-like syndrome which is mostly reported among males. In addition, different types of anemia including, iron deficiency, megaloblastic and sickle cell anemia may also lead to IIH-like syndrome. Treating the underlying cause or discontinuing the medication usually results in resolution of the elevated ICP.

Treatment and management of IIH requires multi-specialty team work. Preserving/improvement of vision and relieving the headache are the major target of treatment. Central visual loss is a late feature of this condition and thus serial automated perimetry is necessary for monitoring peripheral visual field loss. This is the most important test guiding our treatment recommendations. Of course, severe headache is the other main factor in treatment. Treatment of IIH is thus based on visual loss and headaches and may include modification of diet, weight loss, acetazolamide and less commonly other diuretics (e.g. furosemide, thiazides, spironolactone and triamterene), short-term corticosteroids, lumbar puncture and surgery. Therefore, the treatment of IIH varies from gradual weight loss to emergent surgery based on the severity of signs, symptoms and progression rate. Aggressive immediate treatment is considered in patients with severe and rapid progressive vision loss and also in cases with high risk of rapid progression e.g. male gender and African-Americans, irrespective of disease severity.

Medical and life style modification is indicated in cases presenting with primary symptom of headache and good vision. The Idiopathic Intracranial Hypertension Treatment Trial (IIHTT) is a multi-center, randomized, double blind placebo-controlled trial which investigated the effect of weight-loss, low-sodium diet and acetazolamide compared to weight-loss and low sodium diet with placebo in IIH cases with mild vision loss. The results of this study demonstrated that weight-loss and modified diet improve the IIH signs and symptoms in both groups, while acetazolamide has a larger effect than placebo. If visual loss is severe at presentation or vision is worsening despite medical treatment, then surgery should be considered. Optic nerve sheath fenestration (ONSF) surgery creates an outlet for CSF and immediately decreased CSF pressure around the nerve. Although, ONSF has a satisfactory success rate mainly in acute papilledema, revisions maybe necessary. Although rare, complications include ischemic optic neuropathy, central retinal artery occlusion, and transient diplopia. If vision is normal or mildly affected and not worsening dramatically, then ventriculoperitoneal or lumboperitoneal shunting may be considered. When the shunt is working the patient usually does very well. Unfortunately, shunt failure is not uncommon. Endovascular stenting can be performed in cases with focal stenosis of the venous sinuses. There is some debate on whether increased ICP causes focal venous sinus stenosis or if focal stenosis causes increased ICP. Nevertheless, several studies have shown that if a pressure gradient across the stenotic segment is present, stenting can cure the elevated ICP.

Chronic Progressive External Ophthalmoplegia (CPEO)

Chronic progressive external ophthalmoplegia (CPEO) is a condition of progressive bilateral ptosis and reduced ocular motility caused by mitochondrial dysfunction due to either mitochondrial or somatic DNA mutation. Weakness of the levator palpebrae muscle is the characteristic earliest finding in CPEO. Kearns Sayre Syndrome is characterized by CPEO, pigmentary retinopathies, cardiac conduction disturbances, non-ocular muscle weakness, neurologic dysfunctions and endocrine disorders. This is potentially lethal if not treated with cardiac pacemaker. Thus, the diagnosis of CPEO may be crucial, because it could be a component of a debilitating or deadly mitochondrial

syndrome. CPEO presents in all age ranges with progressive symmetric ptosis and gradual chin-up compensatory head position followed by diffuse ophthalmoplegia. Although, ptosis is the most prevalent symptom in patients with CPEO, there are some reports of CPEO without ptosis or with asymmetric/unilateral ptosis. The movement of the upper eyelid from maximal downgaze to upward gaze with stabilization of the brow in cases with CPEO is reported to be <8–10 mm (normal ≥ 12 mm). Moreover, the limited extraocular motility may lead to complete ophthalmoplegia and strabismus. The diagnosis of concurrent abnormalities with CPEO such as retinopathy and optic neuropathy is important. The CPEO-related pigmentary changes are mostly in the macula, peri-papillary and in the equatorial region (often called "salt and pepper" retinopathy because of its speckled pattern) which rarely results in severe visual loss. Retinopathy can also be detected by electroretinogram (ERG). Diagnosis is usually clinical although genetic testing can be considered. Other modalities which could be useful in diagnosis of CPEO and underlying syndrome are imaging (CT-scan or MRI, non-specific, diffuse extraocular muscle atrophy), muscle biopsy and genetic testing.

Several entities should be considered in the differential diagnosis of CPEO. Myasthenia gravis can mimic CPEO. Comprehensive history taking and examination should distinguish MG from CPEO. CPEO is very slowly progressive, not fatigable and usually does not cause diplopia even if there is ocular misalignment. Wernicke's encephalopathy may cause similar findings that need to be differentiated by taking history of alcoholism, malnutrition or malabsorption. Other conditions less commonly in the differential diagnosis of CPEO are thyroid-associated ophthalmopathy, progressive supranuclear palsy, Miller Fisher syndrome (a variant of Guillain-Barre), congenital fibrosis of the extraocular muscles, and chronic use of nucleoside reverse transcriptase inhibitor for human immunodeficiency virus (HIV). The very slow progressive nature of CPEO usually will allow differentiation from these entities.

One treatment option in managing the ptosis is using eyelid crutches which may not be well tolerated. Frontalis sling is the treatment of choice in cases with severe CPEO-related ptosis to restore the visual field. The lids should be elevated just enough to clear the visual axis because of absent Bell's phenomenon in such patients and the risk of corneal exposure. Strabismus surgery is rarely needed for diplopia but can be considered.

Carotid Cavernous Sinus Fistula

Carotid cavernous sinus fistula (CCF) is an abnormal communication between the carotid arteries or their branches with the venous cavernous sinus. CCF can be traumatic following head injury or spontaneous usually from small dural branches of the internal or external carotid artery. Rarely a pre-existing cavernous sinus internal carotid artery aneurysm will rupture producing a CCF. The classification of CCF is thus based on the underlying causes (spontaneous or traumatic), hemodynamic flow (high or low), and the structure (direct or indirect fistula). They are further classified into 4 types including type A, the most common type of CCF, a direct communication between the internal carotid artery (ICA) and cavernous sinus with high flow and type B, C and D, which are formed by communication between the small branches of the ICA and/or external carotid artery (ECA) with cavernous sinus. These types are spontaneous, are low-flow and most often are detected in older females. Signs and symptoms are caused by increased pressure in the venous structures which results in increased orbital venous pressure. Typically, traumatic, direct CCFs are high flow and produce marked exophthalmos and elevated intraocular pressure. Ophthalmoplegia may also develop due to the compression of cranial nerves III, IV, V and VI. Dural CCFs are typically low flow and can produce mild, slowly progressive symptoms of eyelid swelling, proptosis, chemosis, hyperemia and elevated IOP. However, one cannot necessarily differentiate low flow from high flow CCF just on clinical

grounds. Graves' ophthalmopathy, orbital cellulitis and idiopathic intra-orbital inflammation should be considered in the differential diagnosis. Occasionally, the patient may note a facial bruit and the face should be auscultated if CCF is suspected.

CT-scan or MRI are often sufficient to diagnosis a CCF. Enlargement of the superior ophthalmic vein can often be seen in CT or MRI which sometimes has already been read as normal. However, if suspicion is high despite normal non-invasive imaging, the gold standard is digital subtraction angiography (DSA). DSA is also necessary to categorize CCF's in the Barrow A–D scale described above.

Treatment of CCF depends on severity of signs and symptoms. Direct CCFs always require treatment, usually endovascular occlusion of the fistula. Dural fistulas are more difficult to treat and options depend in part of the exact anatomy of the feeding blood vessels. Endovascular embolization and more recently radio-surgery has been successful. The low flow CCFs can resolve spontaneously so one option in patients with mild symptoms is observation. Endovascular embolization may lead to complications such as ophthalmoplegia, decreased visual acuity, retroperitoneal hematoma and cerebral infarction. In a study, the success rate of endovascular embolization in CCFs was reported to be 88.8%. On occasion, the vascular anatomy precludes access to the fistula and embolization. The oculoplastic surgeon may be asked to do a superomedial anterior orbitotomy to expose the superior ophthalmic vein. The interventional neuro-radiologist then accesses the fistula directly via catheter.

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Oncological and Maxillofacial Considerations of Periorbital Lesions

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The most common malignant tumor of the eyelids is the Basal cell carcinoma accounting for 86–96% of malignant eyelid tumors. Other important malignant tumors include squamous cell carcinoma (SCC), sebaceous carcinoma (SebCa), melanoma and Merkel cell carcinoma (MCC). The periorbital area contains multiple organs; the upper and lower eyelid with their appendages, the lacrimal gland, and the nasolacrimal passages.

Basal cell carcinomas (BCC) have a very low metastatic potential (0.03%) and most commonly spread to regional lymph nodes. Local recurrence is generally very low when properly managed. This tends to increase with more advanced lesions and perineural spread, which is seen in 19% of patients that present with orbital invasion. Nodal metastasis can be seen in as high as 24% of patients with squamous cell carcinoma (SCC). Most nodal metastases occur in the parotid, preauricular, and submandibular nodes. Distant metastasis is much less common, reported in 6.2% of cases. Factors associated with a higher risk of nodal metastases include tumor stage AJCC T2b or greater or tumor diameter more than 18 mm.

Microscopic perineural invasion may manifest with trigeminal-distribution sensory deficit, ophthalmoplegia, orbital pain, or facial palsy and is encountered in 8–14% of cases of facial and periorbital SCC. Careful pathological examination is important for detection of perineural invasion in all specimens and in particular aggressive tumors. Separate margins from adjacent or involved nerves should be considered during surgical resection, preferably sent for frozen section to ensure negative margin status. Patients with perineural invasion should be considered for postoperative radiation.

Sebaceous carcinomas of the eyelid are very rare tumors (<1%), and tend to be missed. A good portion of these patients are diagnosed as having recurrent chalazia until a biopsy is taken that reveals the true nature of the lesion.

Sebaceous gland carcinoma (SGC) is capable of aggressive local behavior and metastasis to regional lymph nodes and distant organs. It is considered among the most lethal of all ocular adnexal tumors. Originating from cells of the sebaceous glands and most often in the periorbital area, usually in the eyelid. These most commonly metastasize through the lymphatic

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_31

channels to regional lymph nodes in about 30% of cases. From the upper eyelid, it tends to metastasize to preauricular and parotid nodes and from the lower lid to the submandibular and cervical nodes.

The recommended safe margin of excision varies by histologic subtype: A 2–3 mm clear clinical margin may be appropriate for BCC, whereas, larger margins may be needed for more aggressive carcinomas, such as SCC, Sebaceous carcinoma, and MCC. For BCC, the abnormal cell on a histologic section should be at least 0.2 mm from edge of section to decrease the recurrence rate.

Patterns of Lymphatic Spread and Management of the Neck

The incidence of nodal metastasis varies according to pathology. Patterns or pathways of lymphatic spread have not been fully interpreted due to the rarity of eyelid carcinomas. Because of this the extent of parotidectomy or neck dissection is still unclear. Subsequent lymph node metastasis could be observed over a relatively long period of time after initial treatment of the primary tumor (up to 133 months), indicating the importance of long-term surveillance.

Earlier anatomical studies showed that the medial portion of the eyelids provides the orbital sources of lymphatic drainage to the submandibular lymph nodes via facial nodes along the facial vein, and the lateral half of the eyelid drains first into the preglandular parotid group of lymph nodes (Fig. 1). On the other hand, the lacrimal apparatus has a rich lymphatic system that runs predominantly to the preauricular or interglandular parotid lymph nodes with later spread to the upper cervical nodal groups. However, Jeong et al. in 2006 reported that tumors that originated in not only the lateral half but also the medial half of the eyelid can metastasize to the upper cervical nodes through the parotid gland nodes. Another study also reports the tendency for lateral half tumors to metastasize only to the parotid nodes, whereas medial half tumors were likely to spread along both the submandibular and parotid pathways. Shields et al. report that carcinomas originating in the upper eyelid tend to metastasize to parotid node groups and that the lower eyelid carcinomas tend to metastasize to submandibular node groups.

Jeong et al., did not find that the periorbital tumors drained directly to the submandibular group of lymph nodes via facial nodes even in the medial half of the periorbital area, from which they concluded that the drainage to the parotid group of lymph nodes is more important than the drainage to the submandibular lymph node group even from tumors of the medial half of the periorbital area. This is followed by subsequent spread to level II lymph nodes. Parotid metastases were observed in patients with relatively large (>4 cm) tumors and high-grade pathology.

The extent of parotidectomy is also debatable. A less radical approach implementing only a superficial parotidectomy in SCC with parotid node metstasis is supported by some authors because most intra-parotid lymph nodes lie lateral to the facial nerve Particularly that more radical parotid surgery is more detrimental on the quality of life with no impact on tumor control. However, in one study four of the 11 patients with parotid-area metastases who underwent a superficial parotidectomy eventually developed parotid-area recurrence, whereas none of the five patients who underwent a total parotidectomy developed parotid-area recurrence. This suggests that a more aggressive approach with facial nerve preservation may be necessary in parotid area metastases, in order to control the disease without affecting the patient's quality of life, especially for more biologically aggressive tumors like sebaceous carcinomas.

One third of patients with head and neck cutaneous carcinomas and parotid area metastasis are likely to develop cervical lymph node metastasis or already have occult metastasis at presentation. Therefore all patients with parotid metastases and a clinically negative neck should undergo an elective neck dissection (at least levels I/II) in addition to a parotidectomy. Especially for those whose primary tumors

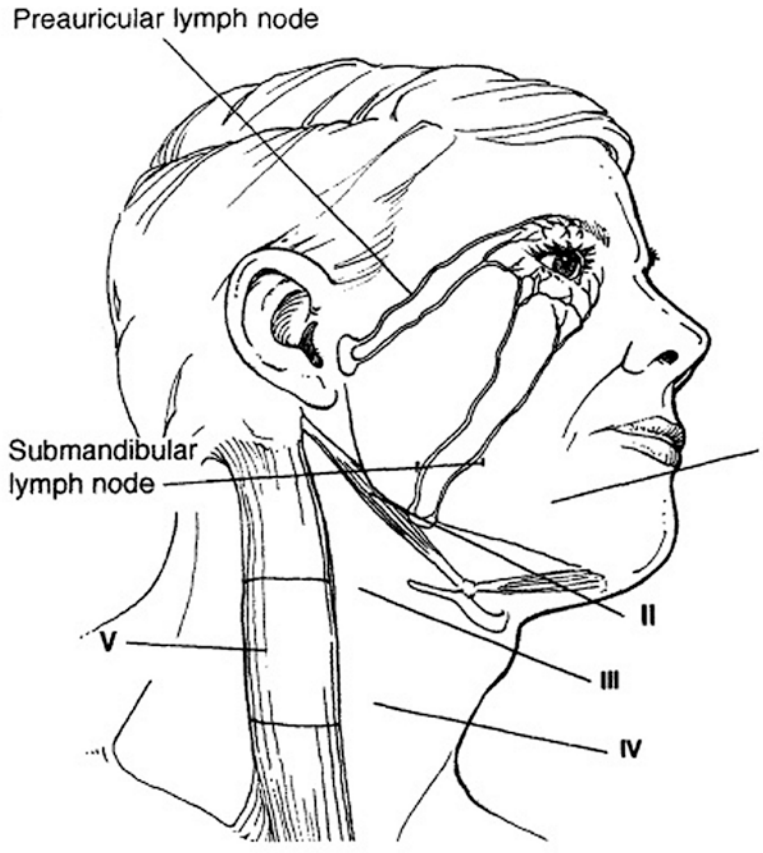

Fig. 1 Lymphatic drainage pathways of the eyelids: Medially to the submandibular lymph nodes via the facial lymph nodes. Laterally to the upper cervical lymph nodes via the parotid lymph nodes

originated in the medial half of the eyelid. Patients with parotid metastases, should have a total parotidectomy preserving the facial nerve and elective neck dissection of levels I/II or I–III. For patients with primary tumors at the lateral half of the eyelid, level I can be spared. For patients with cervical-area metastases, complete dissection of the cervical nodes is required. A superficial parotidectomy may be considered for patients with clinically negative parotid nodes.

The above findings support the necessity of a thorough evaluation of the parotid group of lymph nodes. Even in the absence of regional metastases at initial presentation, a prophylactic management of the parotid group of lymph nodes in periorbital tumors with a high risk of regional metastasis must be taken into consideration. Patients with malignancies associated with a high risk of nodal metastasis should undergo ultrasonography of the parotid, submandibular, and cervical nodes, and fine-needle aspiration biopsy of suspicious lymph nodes. For patients with eyelid tumors associated with a risk for metastasis, baseline chest radiography should be considered, and chest radiography should be performed as needed during the follow-up period.

Post-operative radiation and appropriate selection of patients that will benefit is very important. A lower incidence of regional recurrence was observed among the patients who received adjuvant radiotherapy (14.3%) compared to that of the patients who did not receive adjuvant radiotherapy (57.1%).

Rates of regional lymph node metastasis in tumors involving the eyelid and conjunctiva are up to 24% for SCC, 18% for SebCa, 21% for MCC, and 11% for eyelid melanoma.

Sentinel lymph node (SNL) biopsy has been recommended for eyelid malignancies associated with high risk for regional metastasis, such as melanoma, SCC, SebCa, and MCC. For SCC of the eyelid, Nasser et al. (2014) found that SCC ≥ 18 mm or AJCC stage T2 b or more advanced is associated with nodal metastasis at presentation or during the follow-up.

In a study of 1269 patients with intermediate thickness melanoma (1.2–3.5 mm), SLN biopsy resulted in a higher 5 year disease free survival (78%) compared to patients that were observed instead of undergoing a SLN biopsy (73%). The same study also showed that patients with a positive SLN that underwent immediate lymphadenectomy had a significantly higher 5 year survival in comparison to those that had a delayed lymphadenectomy when their nodal disease was clinically apparent (72% vs. 52%; p = 0.004).

Sebaceous carcinomas of the eyelid larger than 10 mm and lesions designated as T2b or greater according to the AJCC, were significant risk factors for nodal metastasis. These patients should be considered for SLN biopsy, provided the experience and facilities permit, as an alternative to elective lymphadenectomy and any potentially associated morbidities.

The infamous predilection of nodal metastasis for Merkel cell carcinoma is reported to be as high as 43%. Positive SLN biopsy has been shown to be associated with increased diameter, tumor thickness, high mitotic rate, and infiltrative growth pattern in primary MCC.

The management of patients with a positive SLN biopsy result entails completion lymph node dissection and possible parotidectomy, if the positive SLN is in the parotid area. Despite there being no overall survival benefit from immediate completion lymphadenectomy following a positive SLN biopsy there does seem to be a regional disease control benefit from immediate surgery versus observation and delayed intervention at the cost of increased complications.

A summary of management of the neck in orbital tumors is as follows:

- There is almost no role of neck dissection (ND) for tumors confined to the globe
- Elective (prophylactic) ND is indicated for N0 (negative) neck for advanced tumors with high propensity to spread to the lymph nodes (LN)
- Therapeutic ND should be carried out for N + (positive) when orbital tumors presented with cervical or preauricular LN enlargement, however, exclusion of distant metastasis should be confirmed before proceeding with heroic procedures.
- Fine needle aspiration cytology (FNAC) is a good tool to differentiate between metastatic and inflammatory LN enlargement.

The extent of neck dissection will depend on the stage of the tumor, in case of elective ND or just intraparotid LN metastasis, combined superficial parotidectomy and supraomohyoid ND is enough, however, if the patient presents with cervical LN metastasis in this case combined superficial parotidectomy and modified radical neck dissection is indicated.

Adjuvant Therapy

Adjuvant radiotherapy has been recommended for eyelid malignancies with aggressive histologic subtype, perineural invasion, or nodal metastasis at presentation.

The role of systemic therapy is generally very limited in head and neck tumors, however, it has been recommended for patients with distant metastasis and can be considered for patients with extensive nodal disease with Merkel cell carcinoma and sebaceous carcinoma. A 41% complete response rate to systemic therapy has been reported to last if followed by radiation therapy. A variety of chemotherapeutic agents are described including combinations of cyclophosphamide, methotrexate, and 5-FU, cisplatin and cisplatin and etoposide.

Surveillance and Follow Up

Patients with eyelid malignancies require long-term follow-up even after surgical resection with negative margins. The frequency and duration of follow-up is dependent on the type of

malignancy. For primary BCC of morpheaform subtype or recurrent BCC, as well for Sebaceous carcinoma, MCC, and SCC, a minimum of 5 years of follow-up is recommended.

Careful clinical examination for regional disease at the preauricular and cervical nodal basins as well as neck sonography particularly for carcinomas associated with an increased risk of nodal metastasis is recommended. Any suspicious nodes should undergo a fine-needle aspiration biopsy. Nodal disease will usually manifest within the first 2–3 years of follow up in the majority of cases. However, unusually late metastasis can still occur.

The lungs are the most common site of distant metastasis. Imaging of the lungs with chest X-rays or computed tomography is recommended in carcinomas associated with a high risk for distant metastasis such as Merkel cell carcinoma or advanced cases of sebaceous carcinoma.

For patients who have undergone an orbital exentration for their advanced carcinoma of the eyelid or periocular region, imaging of the orbit is indicated during the follow-up surveillance period.

Orbital Involvement

The incidence of orbital invasion from periorbital BCC and SCC is relatively low, reported to be 2.5%. Unlike paranasal sinus (PNS) tumors which have a 30–80% incidence of orbital invasion. The highest incidence is seen with ethmoidal sinus tumors (60–80%), and can be explained mostly by the delay in presentations and variation in bone structure shared with the orbit. Also, the biological behavior of PNS tumors may differ significantly from histologies that more commonly affect the skin of the eyelids and periorbital region. Malignant PNS tumors with orbital invasion have demonstrated a negative impact on survival, both overall and disease specific, 41 and 48% with gross invasion and 61 and 62% without gross invasion.

These tumors may extend to involve the orbit by direct destruction, spread via natural foramina and fissures or by perineural invasion. Absence of ocular symptoms does not exclude orbital involvement hence the importance of radiological assessment.

In the presence of symptoms and signs the most common presentation proptosis, seen in 56.9%. Other signs include diplopia 12%, limitation of ocular motility 17%, orbital mass 4.9%, eyelid edema 17% and loss of visual acuity with posterior wall and apex involvement.

Proper preoperative assessment is essential for appropriate management of these cases and should include evaluation for distant metastasis particularly if exentration is being considered. The imaging modalities used may include either a CT, MRI or both. Skull bone relations and bone involvement is best assessed by CT while MRI is used for better assessment of orbital tissues, perineural invasion, extent of intracranial involvement.

The extent of orbital involvement can be classified as follows:

1. Orbital wall (thinned, bowed or eroded without periorbital involvement)
2. Eroded with resectable periorbital involvement
3. Extraocular muscle, intraconal fat, globe or apex invasion
4. Nasolacrimal system eyelids, ducts or sac invasion
5. Cavernous sinus, optic canal or massive intracranial invasion

The decision for an orbital exenteration should not be taken lightly in the presence of a functioning eye and in the event of subtle invasion, like minimal periosteal involvement or limited intraorbital extension, careful intraoperative assessment is important. Several studies show similar survival and recurrence rates between orbital preservation and exentration in properly selected patients with minimal involvement thus justifying a more conservative approach.

Multidisciplinary discussions of each case help identify patients that will benefit from a more conservative approach. Certain factors may hinder preservation of the eye. Globe

preservation in cases that will require post-operative radiotherapy with anticipated visual loss seem to be of no value.

Recently and with improved treatment modalities a more conservative approach is being considered. The concept of induction chemotherapy, and in some cases preoperative radiation, has been used based on results from other sites of the head and neck. However, because of the various pathologies encountered in PNS tumors there are no absolute indications or regimens. The decision is usually based on the histology and expected response to treatment along with the presentation and extent of surgery at that time.

Chemoreduction is generally by regimens consisting of platinum based agents and taxanes are used like in head and neck SCC. Several studies have reported good response and ability to preserve the orbit with this approach. Some have even reported complete response rates. Treatment is usually followed by surgery and radiation or chemoradiation and in some cases definitive radiotherapy or chemoradiation.

The extent of orbital involvement dictates the boundaries of surgical resection. Rehabilitation depends on the extent of surgery. The orbit can be lined with split thickness grafts in cases of exenteration without removal of any of the orbital walls and with preservation of the orbital periosteum. If the periosteum is included in the resection, lining of the bony walls is mandatory. This can be achieved using local vascularized tissue. Examples include approximating the lids within the orbital socket (Fig. 2). A temporoparietal fascia flap can be used to line the orbit in place of the periosteum removed. The temporalis muscle can also be harvested and delivered into the orbit through lateral orbital wall. The lateral orbital rim should be preserved for a better esthetic result without compromising the viability of the muscle flap as it passes through the lateral wall.

Rehabilitation of more extensive resections that include loss of orbital walls relies on which wall was removed. The aim of reconstruction is to prevent diplopia and preserve/restore the cosmetic outcome. In craniofacial resections the anterior cranial fossa must be protected and isolated from any communication with the sinuses. This is achieved using free fasciocutaneous and muscle flaps and microvascular surgery.

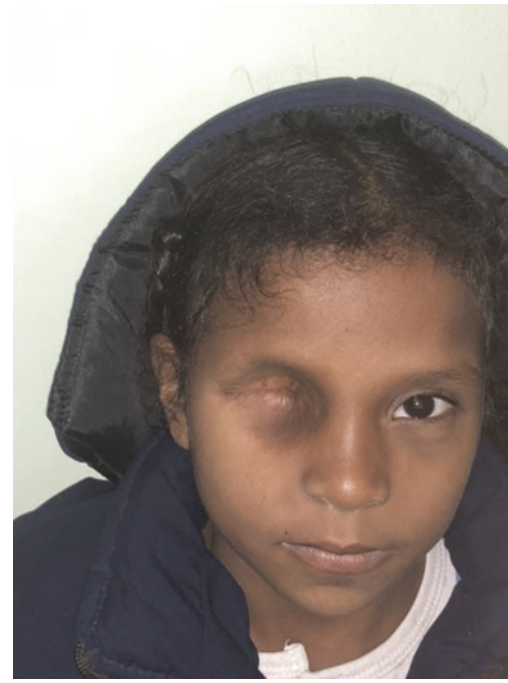

Fig. 2 Approximation of the eyelids to layer the orbital socket after exenteration

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Periorbital Dermatology and Oculoplasty

Khaled El Hoshy and Mona El-Kalioby

Introduction

The skin of the eyelid has a similar structure to the skin elsewhere in the body with some unique features. The eye lid skin is the thinnest in the body particularly the medial aspect of the upper eyelid. Glands in the eyelids include the sebaceous glands (meibomian glands and sebaceous gland of Zeis), and both eccrine and apocrine sweat glands (apocrine sweat gland of Moll). Terminal hair is also present in the form of eyebrows and eyelashes. Therefore, a wide variety of skin conditions that originate from these skin structures can present in the periorbital area. Periorbital skin diseases can be classified into melanocytic and vascular nevi, neoplastic, inflammatory, infectious, manifestations of systemic diseases, disorders of pigmentation and disorders of eyebrows and eyelashes.

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Melanocytic and Vascular Nevi of the Eyelids

Periorbital Hemangioma

Clinical picture

Hemangioma is one of the most common benign vascular tumors in infancy (Fig. 1). Infantile hemangioma (IH) is characterized by rapid growth in the first few months of life followed by slow regression over several years. Periorbital hemangiomas can compromise vision and these infants are at risk of developing astigmatism, strabismus, amblyopia, ptosis, and proptosis (Fig. 2). The upper eyelid is the most common location.

Management

The natural course of hemangioma is spontaneous regression. In other locations, small hemangiomas need no clinical intervention. However, the IHs located in the periorbital region always affect the appearance and function and are associated with infection or ulceration, which needs prompt treatment. Classic treatment for infantile hemangioma included Intralesional corticosteroids, systemic corticosteroids, IFN-α, chemotherapy, surgery and Pulse dye laser. Imiquimod 5% and timolol 0.5% were reported for superficial lesions.

E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_32

Fig. 1 Small infantile hemangioma affecting left lower eyelid

Propranolol, a non-selective β-receptor antagonist, was found to be of high efficacy and well-tolerated in hemangiomas generally, including periorbital hemangiomas. It achieves regression in the size of hemangioma and, consequently, reduce the size of the residual lesions. In a comparative study, oral propranolol was found equally effective as intralesional corticosteroid in improving amblyopia in infantile hemangioma; with fewer complications.

Port-Wine Stain

Clinical picture

Port-wine stain (PWS, or nevus flammus) reflects an embryonic vascular developmental abnormality. Port-wine stain is present at birth. It appears as pink-to-red macule or patch. Distribution is usually unilateral affecting the skin area supplied by sensory branches of the trigeminal nerve (V1, V2, V3). More than one area may be affected. The lesion does not blanch on pressure. It grows proportionally with age and often progressively darkens to deep red or purple color and become more hypertrophic (Fig. 3). Facial PWS significantly affect the patient's quality of life. Port-wine stain might also be associated with other vascular anomalies and genetic syndromes including Sturge-Weber syndrome, which is associated with brain and eye lesions.

Management

Children with PWS affecting any part of the forehead should have an ophthalmology review and a brain MRI with gadolinium contrast to exclude Sturge-Weber syndrome.

Pulse dye laser (**PDL**) (585 or 595 nm) is the classic treatment for port-wine stain. Early intervention gives better results before progressive thickening and darkening of the lesion. Using **topical sirolimus** 0.5–1% following PDL was recently reported to achieve significant improvement over a shorter duration.

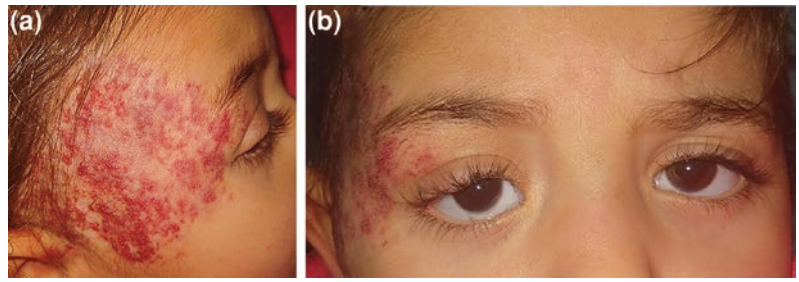

Fig. 2 Infantile hamangioma of the right temple and upper eyelid causing ptosis **a** side view **b** frontal view

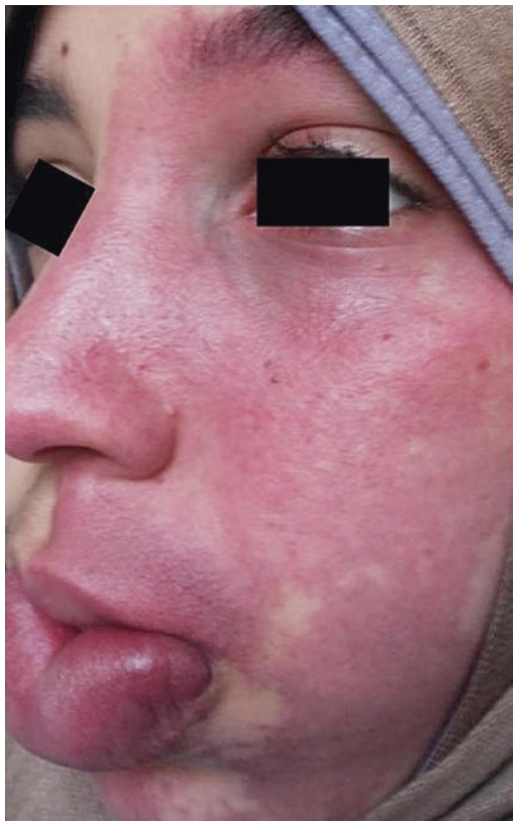

Fig. 3 Port-wine stain affecting the left half

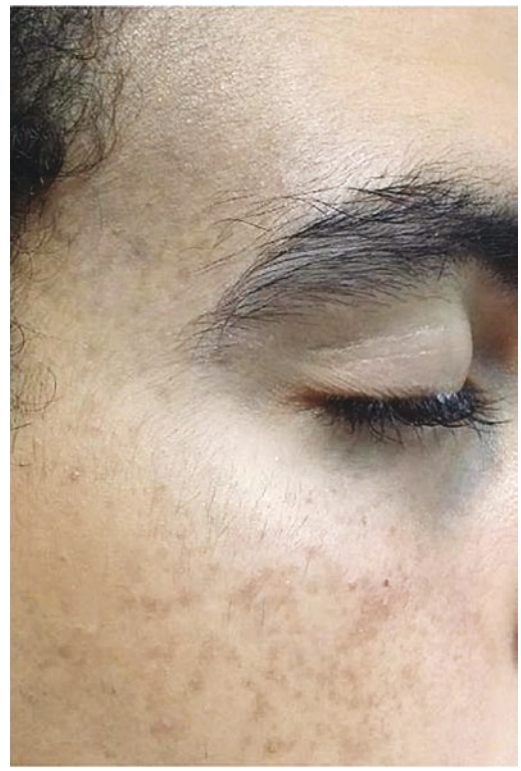

Fig. 4 Nevus of Ota with affection of periorbital area

Nevus of Ota

Nevus of Ota is an oculocutaneous melanosis due to aberrant development and migration of melanocytes from the neural crest to the epidermis.

Clinical picture

Nevus of Ota appears as blue-gray colored "macule/patch" distributed along the first and second divisions of the trigeminal nerve, appearing before the age of 1 (Fig. 4). The majority of lesions are unilateral, but approximately 5–15% of cases will be bilateral (Fig. 5).

The sclera is affected in 2/3 of cases (Fig. 6). Also, the conjunctiva, cornea, retina, and optic disc may also be involved. Periodic eye checkups are recommended for possible increased risk of glaucoma, which can develop due to extensive pigmentation in the chamber angle.

Management

Current treatment of choice of nevus of Ota is Q-switched lasers, particularly Q-Switched: neodymium: Yttrium-aluminum-garnet laser (Nd-YAG) laser (1064 nm). It shows high success levels and minimal side effects.

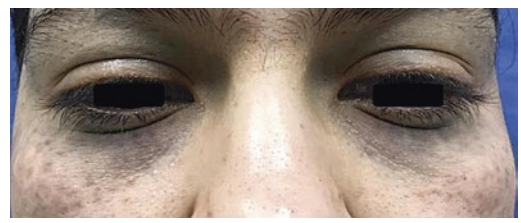

Fig. 5 Bilateral nevus of Ota

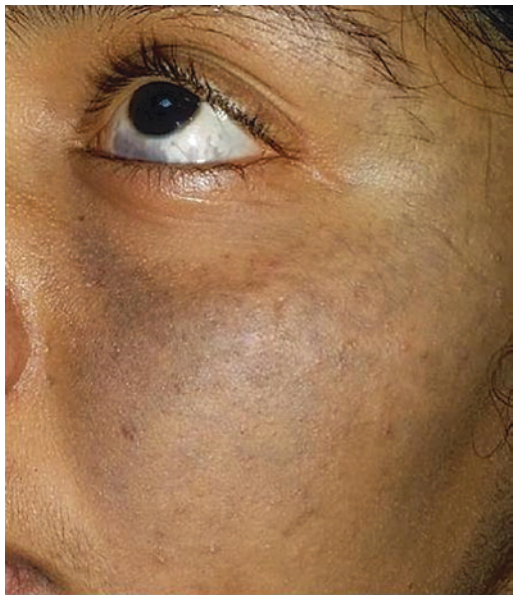

Fig. 6 Nevus of Ota. Note scleral involvement

Congenital Melanocytic Nevi

Congenital melanocytic nevi (CMN) of the eyelid are uncommon (Fig. 7). They may be confined to the eyelid only or be a part of a more extensive nevus of the periorbital region, half of the face, or bilateral on the face. CMN present as hairy dark brown to black macule or plaque, with verrucous surface. Satellite lesions may be present.

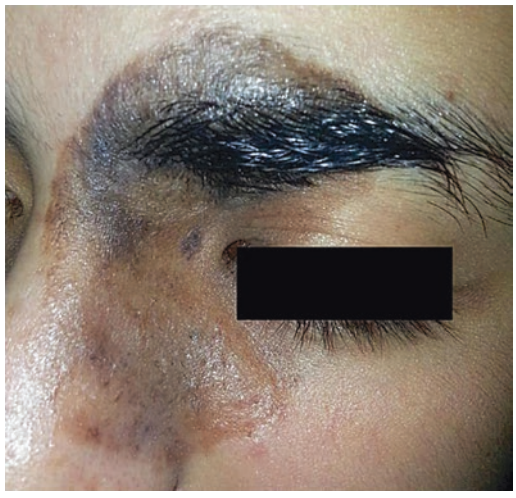

Fig. 7 Congenital melanocytic nevus. *Note the thickening of the eyebrow*

The risk of malignant transformation in giant congenital nevi is well established. Fortunately, the risk of malignant transformation in smaller congenital facial nevi is rare. However, there is a psychological impact on the child and his/her family. Conjunctival involvement can be seen. Eyelid nevi can produce functional problems e.g. ptosis, ectropion, and chronic corneal irritation.

Treatment

Excision and reconstruction provide good results. Successful treatment with Q-switched lasers such as Ruby (695 nm), Alexandrite (755 nm), and Nd-YAG lasers, as well as, with ablative laser with carbon dioxide (CO_2) (10,600 nm) and erbium:yttrium aluminum garnet (Er:YAG) laser (2940 nm) was reported.

Inflammatory Diseases

Periorbital (Eyelid) Dermatitis

Periorbital dermatitis is a common dermatological disorder that presents as red itchy skin of the eyelids. The clinical appearance of various differential diagnoses of periocular dermatitis is sometimes non-specific and is not diagnostically conclusive, and the condition is often challenging in management.

Clinical Picture and Differential Diagnosis

The most commonly reported causes of periocular dermatitis are contact allergy (allergic contact dermatitis) (54%), atopic dermatitis (25%), irritant contact dermatitis (9.1%) and periorbital rosacea (4.5%). Other causes include periorbital psoriasis vulgaris, drug reaction and seborrheic dermatitis.

Allergic contact dermatitis

A thorough history should be taken to identify possible allergens. Details of cosmetics, hobbies and occupation may be relevant. Appropriate patch tests may need to be performed. Type IV hypersensitivity to nickel is the most prevalent sensitization. Nickel has been identified in cosmetic products used around the eyes such as mascara, make-up base, eye shadow, contact lens solution, and Kohl pencils. The topical antibiotic neomycin sulfate was also shown to be a relevant trigger. Other potential triggers of contact dermatitis include air fresheners and preservatives, nail polish, and glues.

Atopic dermatitis (Fig. 8)

The periorbital region is a prime location for atopic dermatitis. Other symptoms and signs of atopic dermatitis support the diagnosis (e.g. xerosis, pruritus, personal or family history of atopy, and Dennie–Morgan infraorbital fold). The defective skin barrier in atopic dermatitis can increase sensitization to allergens.

Irritant contact dermatitis

Irritant contact dermatitis mostly affects the hands where various (commonly occupational) irritant exposures are possible. Less commonly, irritant contact dermatitis may affect periocular sites.

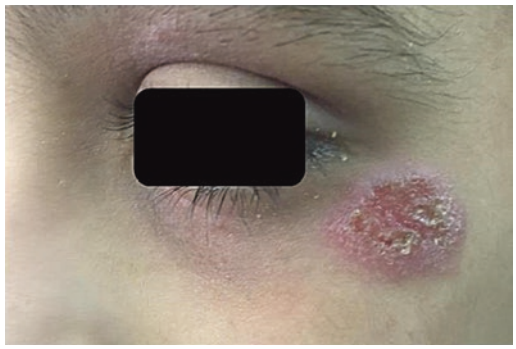

Fig. 8 Eczema affecting periorbital area

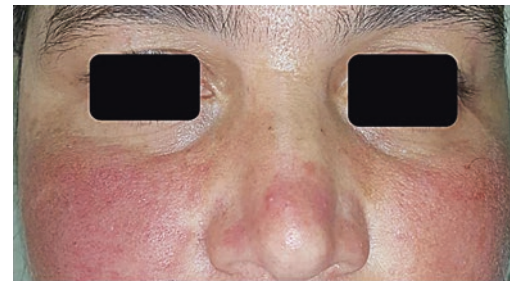

Fig. 9 Rosacea. *Note the ertheyma, telangiectasia and papules affecting cheeks and nose*

Dust, fumes, and mechanical factors can have an irritating effect on facial skin and can be potential triggers.

Periocular rosacea

The presence of multiple erythematous papules may be a sign of periocular rosacea. The presence of pustules and telangiectasias on the cheeks (Fig. 9), around the mouth and/or eye can support the diagnosis. Patients can also report a burning and stinging sensation. Contact allergy can occur with rosacea. Sensitivity can coexist to topical treatment used for rosacea e.g. gentamicin sulfate.

Seborrheic dermatitis

Predilection sites for seborrheic dermatitis on the face are the nasolabial folds and the forehead, including the eyebrow region. Periocular involvement is rare.

Management

For cases of contact allergy, avoiding the allergen is important. Calcineurin inhibitors can be used for treatment of symptoms. They are FDA approved for atopic dermatitis. Calcineurin inhibitors do not have the atrophogenic properties of topical corticosteroids. However, they can be irritant on application. They have shown effectiveness in the treatment of periorbital contact dermatitis, irritant contact dermatitis, seborrheic

dermatitis, rosacea, and facial psoriasis vulgaris. If calcineurin inhibitor therapy fails to achieve a significant effect, short-term topical corticosteroids can be used. Corticosteroids are not suitable for long-term therapy of periorbital dermatitis.

Eyelid Edema

Angioedema

Angioedema is defined as localized edema of the subcutaneous and submucosal tissue, due to a temporary increase in vascular permeability caused by the release of vasoactive mediators. In practice, the majority of angioedema cases are associated with urticaria presenting by wheals. Urticaria may or may not be related to exposure to allergens.

When angioedema recurs without significant wheals, the patient is identified as having angioedema as a distinct disease. Angioedema without wheals can be hereditary or acquired. Both can be related to C1 inhibitor deficiency. Acquired angioedema can be related to angiotensin-converting enzyme inhibitors intake or lymphoproliferative diseases. Causes of angioedema are illustrated in Fig. 10.

A detailed medical history should be taken to guide to correct diagnosis and management. Insect bites on the face may present with swelling and mild erythema in the eyelids. The swelling can be severe, resembling angioedema but the condition is usually localized (Fig. 11).

Edema Due to Hair Dyes

Allergic contact reaction to hair dyes occurs mostly due to sensitization to para-phenylenediamine

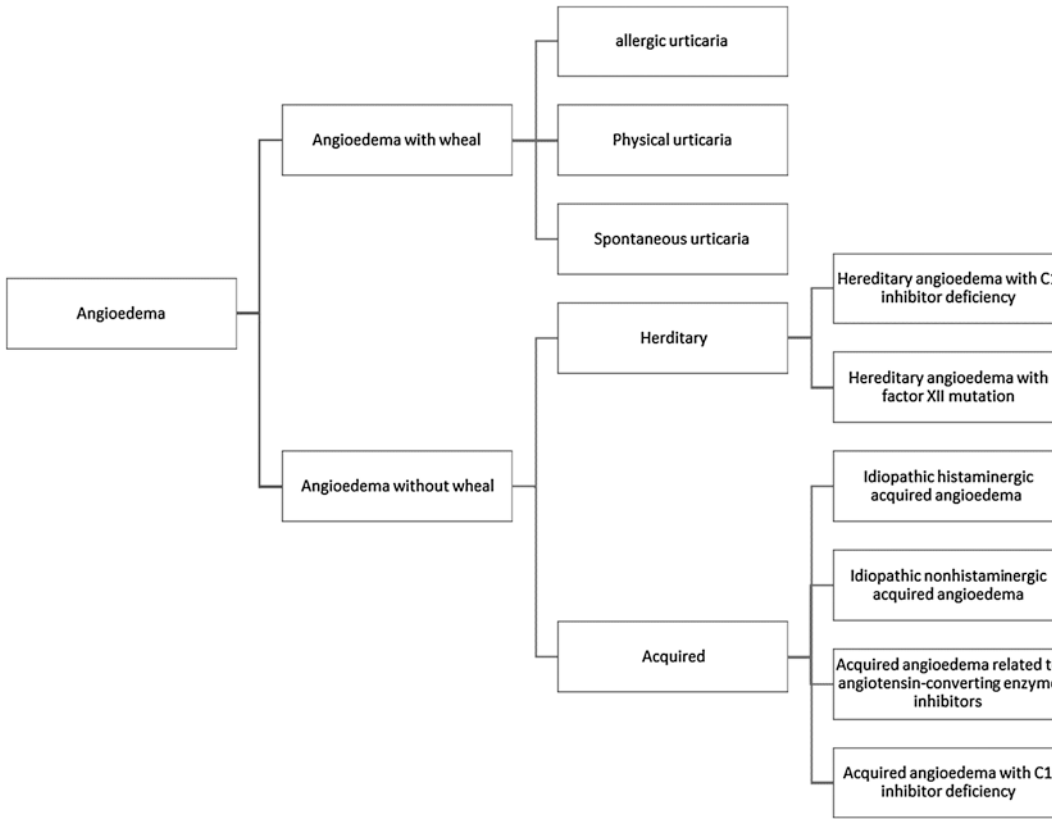

Fig. 10 Classification of angiodedema. Adapted from (Wu et al. 2016; Cicardi et al. 2014)

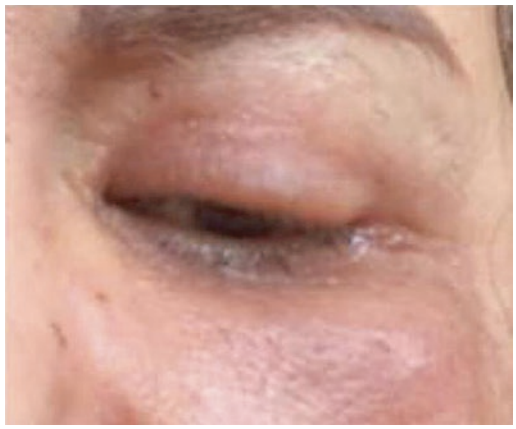

Fig. 11 Left eyelid swelling due to insect bite reaction

(PPD). PPD is also found in black henna. Subsequent exposure to PPD leads to delayed type IV hypersensitivity reaction presenting as acute contact dermatitis.

Clinical picture

Presentation is usually in the form of neck and facial swelling. Edema may involve scalp, forehead, eyelids, ears and may extend to the neck. Eczematous reaction can be present. Patients usually have a previous medical history of allergy to hair dye or henna tattoo. Angioedema like reaction may occur with severe bilateral eye edema (Fig. 12).

Management

When severe edema of the eyelids occurs, systemic steroids are indicated e.g. prednisone (1–2 mg/kg) for 3–4 days. A repeated course is rarely needed. Antihistamines and wet dressings help relieve itching and reduce redness. Identification and avoidance of the offending allergen is important to prevent recurrence.

Growths and Tumors in Periocular Area

Periorbital malignant neoplastic disorders arising from the skin are discussed elsewhere in this book. Common periorbital benign tumors arising from the skin include syringomas, hidrocystoma, milia, acrochordons (skin tags) and dermatosis papulosa nigra.

Syringomas

Syringomas are common benign adnexal tumors, derived from intraepidermal eccrine ducts, having characteristic histopathologic features.

Clinical Picture

Syringomas present by asymptomatic, small, firm, smooth, flesh-colored or yellowish papules, measuring 1–3 mm in diameter. Lesions are often multiple with symmetric distribution. Localized involvement is most commonly periorbital (Fig. 13).

Classification

Based on clinical features, syringoma has 4 variants: **localized, familial**, a form **associated with**

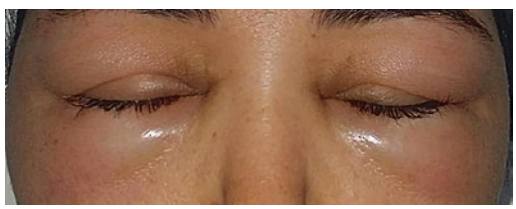

Fig. 12 Bilateral severe eye edema following application of hair dye

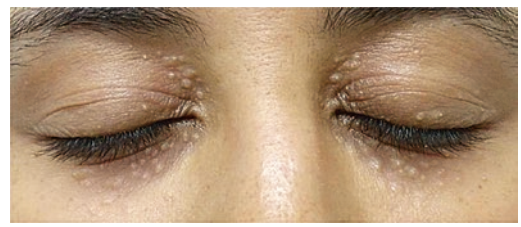

Fig. 13 syringomas

Down syndrome, and a **generalized** variant, including multiple and eruptive syringomas.

Diagnosis

Periorbital syringomas usually have peculiar clinical presentation and diagnosis is clinical. A skin biopsy may be needed in overlapping cases, particularly in cases of eruptive syringomas. Skin biopsy shows a distinct histopathologic features where there are multiple small ducts and epithelial cords within the dermis, and cystic eccrine ducts with a characteristic "tadpole tail" appearance.

Treatment

Syringomas are benign and asymptomatic. The aim of treatment is to improve cosmetic appearance. Both surgical and medical interventions have been described in the literature.

Carbon dioxide laser is an effective in syringomas with tolerable side effects. Other destructive methods include Erbium YAG laser, low energy radiofrequency, low voltage electrosurgery and cryotherapy. Side effects include dyspigmentation, recurrence, scarring, and persistence of residual lesions.

Fractional photothermolysis has modest efficacy but multiple sessions are needed. Entire face dermabrasion was also reported. **Carbon dioxide laser can be combined with Trichloroacetic acid (TCA) peels**. **Botulinum toxin A** blocks cholinergic terminals of autonomic nerve that regulates eccrine sweat gland secretion, and was reported effective in syringomas probably by decreasing of activity of eccrine duct cells. **Surgical excision** has also been used for syringomas.

Medical therapy in the treatment of syringomas require further evidence by larger studies. **Retinoids** target cellular proliferation, differentiation, and keratinization. Systemic Isotretinoin therapy had mixed results. Topical tretinoin was also reported.

Atropine 1% was reported where it may work by inhibiting sweat production. **Tranilast** is a N-[3,4-dimethoxycinnamoyl]-anthranilic acid which can decrease the release of some chemical mediators by mast cells. It may work by inhibiting the release of interleukin-1 beta from eccrine ducts, which subsequently suppress the proliferation of stromal connective tissue in syringoma.

Hidrocystoma

Hidrocystoma is a rare benign cutaneous cystic lesion, originating from sweat glands (either apocrine or eccrine). Apocrine hidrocystomas are cystic lesions that arise from the apocrine secretory coil, while eccrine hidrocystomas represent retention cysts of the eccrine duct. Both types can be differentiated histopathologically (Table 1). These lesions are usually located in the head particularly around the eye.

Clinical Presentation

Eccrine hidrocystomas may manifest as single (Smith type) or multiple (Robinson type) small (1–6 mm in diameter), translucent, bluish, tense thin-walled cysts. Lesions in the head and neck region are most often located periorbital (around eye lid skin) and in malar area. Eccrine hidrocystomas generally increase in size with hot humid weather in summer and regress in cooler weather.

Apocrine hidrocystomas are usually solitary, clear, cystic nodules, and larger in size (3–15 mm in size). They occur commonly in the periorbital region, and are often located in the eyelid, along eyelid margin and inner canthus (Fig. 14). There is no evidence of seasonal variations.

Associations

Goltz-Gorlin syndrome and Schopf-Schulz-Passarge syndrome are two inherited disorders, that can be associated with the presence of multiple eccrine/apocrine hidrocystomas.

Table 1 Comparison between eccrine and apocrine hidrocystomas. Adapted from Sarabi and Khachemoune (2006)

		Eccrine Hidrocystomas	Apocrine Hidrocystomas
Clinical presentation	No. of lesions	Solitary or multiple	Primarily solitary (occasionally manifesting as multiple lesions)
	Size	1–6 mm in diameter	3–15 mm in diameter
	Gender distribution	More prevalent among females	Both genders are equally affected
	Special features	Worse in hot, humid weather	No change with temperature
	Body location	Malar, periorbital, chest, axilla, neck	Face along eyelid margin, ears, head, chest, shoulders
Histopathological features	Epithelium types	1–2 layers of cuboidal epithelium	Single or double cuboidal-columnar epithelium
	Special cellular features	No decapitation of cells, no secretory cells	Decapitation of secretory cells, papillary projections seen under microscope
	Stains	S-100 positive (solitary type) PAS negative	S-100 negative PAS positive

Goltz-Gorlin (also known as Jessner-Cole syndrome, or focal dermal hypoplasia) occur sporadically, with few familial cases having X-linked dominant transmission; it occurs mostly in females. Its cardinal features are microcephaly; midfacial hypoplasia; malformed ears; microphthalmia; periocular multiple hidrocystomas; papillomas of the lip, tongue, anus, and axilla; skeleton abnormalities; and mental retardation. **Schopf-Schulz-Passarge** is an autosomal recessive syndrome characterized by multiple eyelid apocrine hidrocystomas, palmoplantar hyperkeratosis, hypodontia, and hypotrichosis.

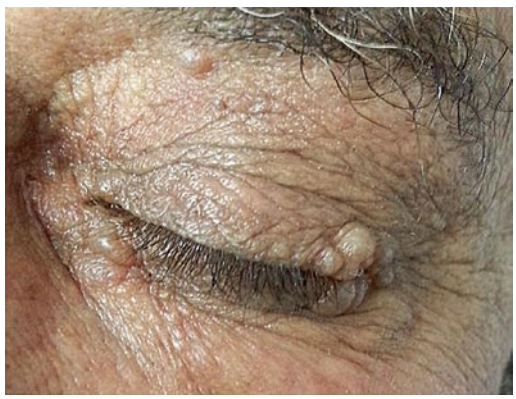

Fig. 14 Multiple hidrocystomas affecting upper, lower eyelids, inner and outer canthus

Graves' disease has also been rarely associated with multiple eccrine hidrocystomas, possibly due to hyperhidrosis, which is seen in hyperthyroid patients. This is supported by the disappearance of lesions after treatment of hyperthyroidism.

Treatment

Simple puncture is usually associated with recurrence. Excision, ablation by carbon dioxide laser and electrodessication are usually performed, with no recurrence if totally removed.

For eccrine hidrocystomas, other treatment can include topical 1% atropine, and botulinum toxin injection particularly in multiple lesions, due to their antiperspirant effect. Systemic retinoids use was also reported for multiple lesions. Avoiding hot temperatures or humid conditions will help prevent worsening of symptoms in patients with eccrine-type hidrocystomas.

Milia

Clinical Picture

Milia are of common occurrence that present as small (usually <3 mm) white/yellow, superficial keratinous cysts. Milia may arise spontaneously (primary milia) or secondary to various processes (secondary milia). Lesions may be single

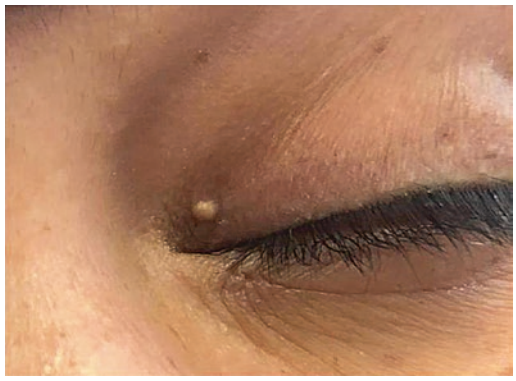

Fig. 15 Individual milium affecting inner aspect of left upper eyelid

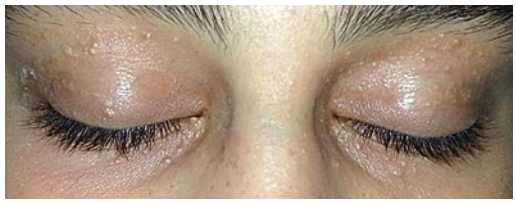

Fig. 16 Milia affecting both upper and lower eyelids. Patient had history of frequent eye rubbing

(Fig. 15), few or many (Fig. 16), and can be isolated or associated with other clinical findings.

Congenital milia occur spontaneously in around 50% of newborns, favoring the face, and resolve spontaneously within several weeks to months. **Benign primary milia** of children and adults also occur spontaneously but they favor the cheeks and eyelids. They tend to be more persistent than congenital lesions.

Secondary milia present as a localized form of milia that may be associated with trauma, medications or diseases e.g. Epidermolysis bullosa, herpes zoster, and Stevens-Johnson syndrome. Trauma may create milia through epidermal implantation or by providing a stimulus for undifferentiated pilosebaceous cells to proliferate. Atopic patients can also develop milia in the nasal creases.

Treatment

An individual milium can be removed by simple evacuation, e.g. nicking it with a needle, scalpel blade or by applying tangential pressure with a comedone extractor or curette. Topical retinoids and mild electrocautery or electrodesiccation can be used for multiple milia.

Acrochordons/Skin Tags

Acrochordons, or skin tags, are extremely common benign connective tissue growths that appear as small soft, usually multiple, skin-colored papules. They could be sessile with wide base or pedunculated, non pigmented or slightly pigmented to appear brown or black. They commonly occur in the neck and flexural areas. The periorbital area is also a common site (Fig. 17). The condition increases with age and during pregnancy. Some studies showed association with metabolic syndrome. Pathologically they are finger like projections that have a fibrovascular connective tissue core covered by layers of squamous epithelium that show acanthosis and hyperkeratosis. Removal for cosmetic reason can be easily performed.

Dermatosis Papulose Nigra

Dermatosis papulose nigra (DPN) appears as multiple small filiform dark brown papules. Lesions are usually bilateral. A common site

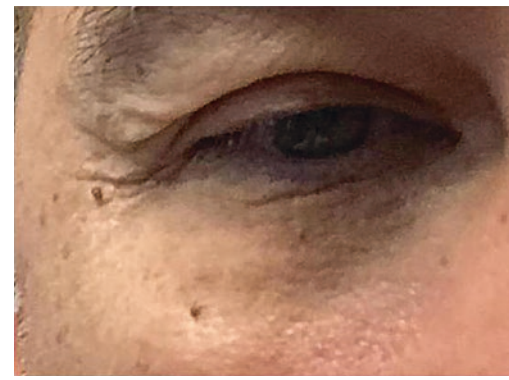

Fig. 17 Periorbital skin tags

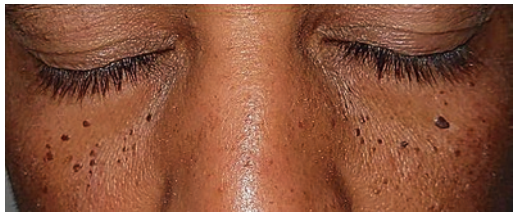

Fig. 18 Dermatosis papulose nigra

is the lateral aspects of the eyes (Fig. 18). It is more common in darker skin and in young and middle-aged people. Sun exposure is a proposed aggravating factor. Removal can be done by electrodesiccation or curettage.

Periocular Manifestations of Systemic Diseases

Deposition Disorders

Xanthelasma

Xanthelasma palpebrarum is the most common cutaneous xanthoma. The reported incidence of xanthelasma ranges from 0.56 to 1.5%.

Clinical Picture

Xanthelasma appear as soft, yellow papules or oblong plaques over the periorbital skin. It can be unilateral or bilateral, and it can affect upper and/or lower eyelids (Fig. 19). Women are more commonly affected, and the peak incidence is in the 4th–5th decade of life. The condition can be associated with an underlying lipid disorder in 50% of the patients.

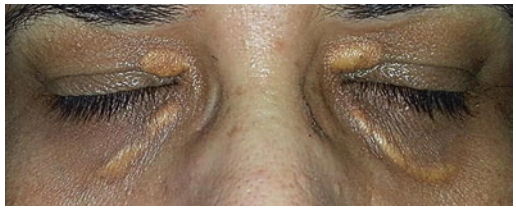

Fig. 19 Bilateral xanthelasma affecting both upper and lower eyelids

However, patients with normolipidemic xanthelasma were reported to have a higher risk of atherosclerosis independent of the lipid concentrations. Pathologically, the dermis shows perivascular macrophages with foamy cytoplasm due to lipid content that dissolves on preparation. The epidermis and the subcutaneous layers are normal.

Treatment

Screening and treatment of the underlying lipid abnormalities is mandatory. Patients usually seek removal of xanthelasma for their cosmetically disfiguring appearance. Ablation of xanthelasma by ablative laser like CO2 laser and Er: YAG laser provide good results but risks of scarring and post-inflammatory pigmentary changes have to be considered. Non-ablative lasers has also been described e.g. Nd:YAG, Q-switched (Nd):YAG, diode and Pulsed dye laser. Fractional ablative CO_2 laser can also be used with shorter down time, but more sessions are needed. Removal of xanthelasma can be achieved surgically. When the lesions are extensive or encroach too close to the palpebrae, there is a risk for ectropion, medial canthal tenting, and poor cosmetic outcome. There are reports of improvement of xanthelasma with trichloroacetic acid (TCA) 70% Ablation. Bichloroacetic acid application can improve the lesions.

Amyloidosis

Amyloidosis is a heterogeneous group of disorders characterized by extracellular deposition of amyloid. The clinical presentation can vary from a localized, focal lesion to extensive systemic disease that can involve any organ of the body. Ocular amyloidosis can occur both as a localized lesion or as a part of a systemic disorder. Sites of periocular and orbital amyloid deposit are the lacrimal gland, eyelid, conjunctiva, and ocular adnexa. Periocular and ocular amyloidosis is of rare occurrence, and therefore diagnosis can be delayed, leading to disease progression.

Clinical picture

Dermatological and ocular signs can provide a clue for the diagnosis of primary systemic amyloidosis. Ocular manifestations include racoon eye, a mass lesion, irritation, bloody tears, epiphora, eye pain, ptosis, and ectropion. Involvement of the lacrimal sac is rare. Racoon eyes develop due to easy bruising. Conjunctival amyloidosis manifests as a yellow-pink hemorrhagic mass deep in the epithelium. Ptosis occurs due to localized amyloid in the levator muscle.

Classical cutaneous lesions of primary systemic amyloidosis include: petechiae, pinch purpura, and ecchymosis due to infiltration of blood vessel wall by amyloid. In addition, macroglossia and waxy translucent skin papules and plaques can be present (Fig. 20). Systemic organ affection includes cardiac, cerebral, or renal involvement. It is important to confirm the diagnosis by histopathology and refer all cases for workup of systemic involvement.

Autoimmune Diseases

Dermatomyositis

Dermatomyositis is an autoimmune connective tissue disease presenting by inflammation in the proximal extensor muscles and characteristic skin eruption. Amyopathic dermatomyositis is defined as characteristic cutaneous findings of dermatomyositis without clinical or laboratory evidence of muscle involvement for 6 months. Both conditions in adults are associated with increased incidence of internal malignancy, therefore screening is mandatory.

Clinical picture

The characteristic cutaneous manifestations include Gottron's papules, cuticular changes around nail including periungual telangiectasia, a photo-distributed erythema or poikiloderma (telangiectasia, atrophy and pigmentary changes), atrophic erythematous scaly plaques of the scalp, and heliotrope rash. The heliotrope rash is a violet poikilodermatous eruption around the eyes and is subtle at times and may appear as periorbital edema (Fig. 21). Other cutaneous signs include panniculitis (inflammation of subcutaneous fat), violaceous discoloration on the elbows and knees, calcinosis cutis, and vasculitis.

Ocular involvement in dermatomyositis is a rare finding that usually manifests as weakness of the extraocular muscle or retinopathy. Myositis of the extraocular muscles has been documented through electromyography and muscle biopsy. Patients can present with ptosis, blurry vision or diplopia. Asymptomatic retinopathy can be seen.

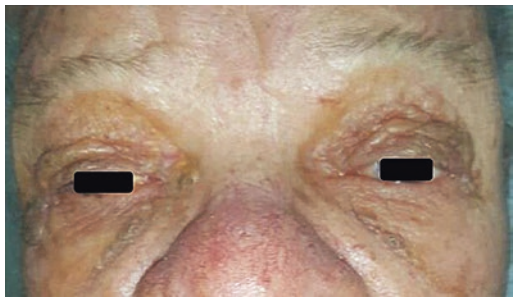

Fig. 20 A patient with primary systemic amyloidosis. *Note waxy periorbital papules*

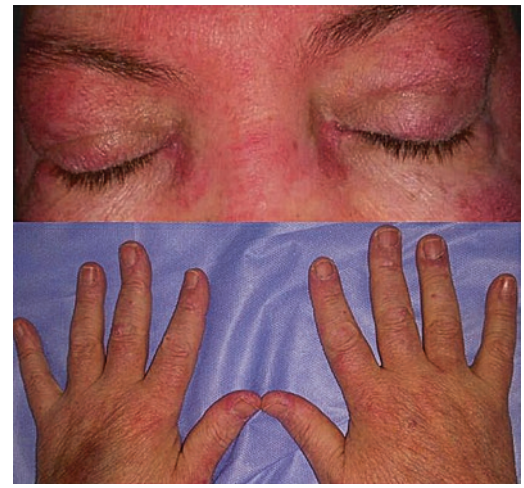

Fig. 21 A case of dermatomyositis presenting by heliotrope rash. *Note Gottron's papules (erythema and scaling over the knuckles)*

Treatment

As with any inflammatory autoimmune disease, the cornerstone of treatment is immunosuppressives; systemic steorids, either as monotherapy or combined with a second agent such as methotrexate, cyclophosphamide, or mycophenolate mofetil.

Other Inflammatory Diseases

Sarcoidosis

Sarcoidosis is a systemic granulomatous disease. The disease most commonly affects the lungs, lymph nodes, liver, spleen, phalangeal bones, parotid glands, eyes, lacrimal glands and skin. Cutaneous sarcoidosis has many different morphologies; therefore it is known as the "great imitator". Ocular manifestations include uveitis, uveoparotitis, retinal inflammation, conjunctivitis, and sicca syndrome.

Cutaneous Manifestations of Sarcoidosis

Skin lesions caused by sarcoidosis can be specific (where non-caseating granulomas are found in histopathology) or nonspecific (where lesions develop as a result of a reactive immunological response without the formation of granulomas).

The most frequent specific lesions are the papular or nodular form. The color varies from red, brown–red, violet to brown. Sarcoidosis plaques may arise de novo or originate from a confluence of papules. Plaques may be annular with a central clearing. Subcutaneous sarcoidosis, also known as Darier–Roussy sarcoidosis, appears as multiple asymptomatic firm, mobile, subcutaneous nodules, usually present on the upper extremities. Lupus pernio is another form characterized by chronic, violaceous to telangiectatic induration, predominantly on the nose and cheeks. This form may be an indicator of current or impending organ involvement. Angiolupoid sarcoidosis is a rare manifestation localized to the malar region, bridge of the nose, or the area around the eyes. The lesions are orange–red or red–brown in color, because of the marked telangiectatic component. Scar- and tattoo-associated sarcoidosis are also quite common (Fig. 22). Other less common forms of sarcoidosis are psoriasiform lesions, alopecia, erythroderma, hypopigmented sarcoidosis, ichthyosiform sarcoidosis, ulcerative sarcoidosis and verrucous sarcoidosis.

The most common nonspecific skin lesion is erythema nodosum, which presents as tender nodules usually located on the lower limbs. Other rare nonspecific skin findings are neutrophilic dermatoses, Sweet's syndrome and pyoderma gangrenosum. Involvement of the nose and lacrimal sac can present as nasolacrimal duct obstruction.

Management

Cutaneous lesions of sarcoidosis can mimic a wide variety of skin disorders, therefore skin biopsy showing non-caseating granuloma usually provide the clue. Further workup includes chest x-ray and high resolution CT of the chest to detect pulmonary manifestations. Serum

Fig. 22 **a** Sarcoidal tissue reaction following eyebrow tattoo **b** 3 weeks after injection of intralesional triamcinolone 10 mg/ml

angiotensin-converting enzyme (ACE) levels can be elevated. Hypercalcemia or hypercalciuria may occur, but neither is diagnostic.

Corticosteroids are the most frequent treatment of sarcoidosis. Topical, intralesional, and systemic steroids may be used. Other treatment options include doxycycline, thalidomide, antimalarials e.g. hydroxychloroquine and chloroquine, systemic immunosuppressives including methotrexate, Azathioprine., mycophenolate mofetil, cyclosporin, and TNF inhibitors.

Inherited Disorders

Xeroderma Pigmentosum

Xeroderma pigmentosum (XP) is a rare autosomal recessive disease characterized by defective DNA repair following exposure to ultraviolet radiation.

Clinical picture

Cutaneous manifestations of XP include cutaneous photosensitivity, pigmentary and atrophic changes, and susceptibility to malignancy in sun exposed and mucocutaneous structures. Ocular changes include severe photophobia, conjunctivitis, corneal opacification with vascularization, pterygium, lid freckles, conjunctival nevi, epibulbar and ocular neoplasms (Fig. 23). Associated neurological abnormalities e.g. mental retardation and microcephaly can be rarely present.

Fig. 23 Xeroderma pigmentosa. Note the atrophic and pigmentary skin changes and photophobia. A graft over right lateral canthal area was performed following removal of BCC

Treatment

Strict sun protection is mandatory. Multidisciplinary approach is needed, in addition to genetic counseling and excision of neoplasms. Eye care consists of sunglasses, artificial tears, steroid drops, and bland ointment at night. Surgical treatment includes excision of neoplasms, release of symblepharon, and keratoplasty for corneal opacification. Oral retinoids and topical enzyme T4 endonuclease V application have significantly reduced the onset of these oculocutaneous malignancies.

Lipoid Proteinosis

Lipoid proteinosis is a rare autosomal recessive disorder caused by mutations in ECM1, encoding extracellular matrix protein 1, a glycoprotein expressed in many organs and which has important protein-protein interactions in tissue homeostasis. The disorder leads to diffuse deposition of hyaline material.

Clinical picture

Eyelid involvement in lipoid proteinosis is in the form of multiple, skin colored, linearly arranged, closely aggregated 1–2 mm-sized papules predominantly over eyelid margins (eye lid beading). Hyaline deposits have been also described in the conjunctiva, cornea, and retina. Corneal opacities or secondary glaucoma can develop due to infiltration in the trabecular meshwork that may appear later. Hoarseness of voice and horse cry is usually a prominent feature due to laryngeal involvement. Cutaneous lesions usually in the form yellowish papules, multiple atrophic scars, keratotic warty plaques over elbows and knees and waxy infiltration. Thickening of the sublingual frenulum may be present leading to limitation of tongue movements. Neurological manifestations, such as epilepsy, memory loss, and schizophrenic behavior can be present and is sometimes in association with intracranial calcification in the temporal lobes or hippocampus, easily detected by brain imaging. Treatment for lipoid proteinosis and clinical care is largely supportive. Respiratory distress caused by diffuse infiltration of the pharynx and larynx may require tracheostomy.

Tuberous Sclerosis

Tuberous sclerosis complex (TSC) is a genetic disorder caused by a mutation in either the TSC1 or TSC2 gene leading to dysfunction of hamartin or tuberin, respectively. Hamartin and tuberin helps regulate cellular hyperplasia, and dysfunction leads to hamartomas affecting skin, heart, brain, eye and kidneys.

Clinical picture

Tuberous sclerosis complex affects multiple organ systems. Cutaneous manifestations include facial angiofibromas (Fig. 24), hypomelanotic macules or confetti lesions, ungual fibromas, shagreen patch, defects in tooth enamel, and gingival fibroma.

Retinal hamartomas are the most common ocular finding. Other reported findings include hypopigmented sectoral lesions of the iris and ciliary body as well as colobomas of the iris and choroid. Other organ affection is commonly in the form of cardiac rhabdomyoma, renal angiomyolipoma, renal cysts, subependymal nodule, subependymal giant cell tumor and lung Lymphangiomatosis.

Initial workup in a patient with suspected TSC should include dilated retinal evaluation, dermatologic exam with a Wood's lamp, echocardiogram, renal ultrasound and brain MRI or CT. Treatment of tuberous sclerosis complex is in part symptomatic; however, for certain clinical manifestations, specific treatments may be indicated.

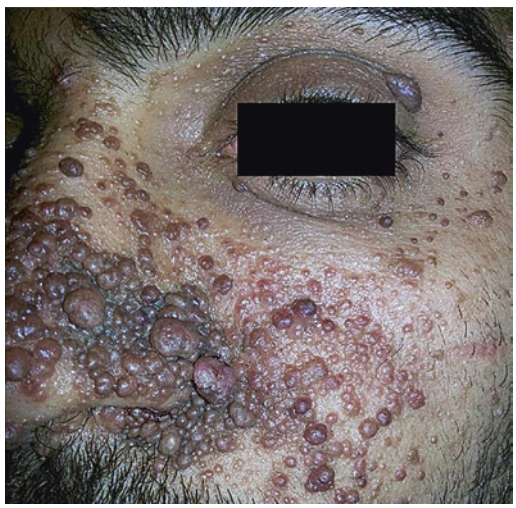

Fig. 24 Tuberous sclerosis with extensive angiofibromas extending to eyelids

Infections and Infestations Around the Eye

Herpes Zoster

Herpes zoster (HZ) occurs from reactivation of latent varicella-zoster virus (VZV) within sensory ganglia. VZV is a neurotropic herpes virus that affects sensory neurons in the form of HZ, following childhood infection with varicella (chickenpox). Reactivation of the virus in the ophthalmic division of the trigeminal nerve leads to herpes zoster ophthalmicus.

Clinical picture

Herpes zoster ophthalmicus (HZO) presents with a prodrome of headache and neuralgia around the eye and forehead. Within a few days, a vesicular eruption occurs along the trigeminal dermatome that respects the midline. Eruption begins as erythematous papules that rapidly coalesce to form multiple crops of clear vesicles. These lesions rupture and crust over, requiring several weeks to heal completely.

The frontal nerve of the ophthalmic nerve is the most commonly involved, and it supplies the upper eyelid, the forehead, and superior conjunctiva. Classically, involvement of the tip of the nose (Hutchinson's sign) is considered a clinical predictor of ocular involvement because the nasociliary branch (external nasal nerve) innervates the tip of the nose as well as ocular structures such as conjunctiva, sclera, cornea, iris, and choroid; however, up to one-third of patients with a negative sign still develop ocular manifestations.

Ophthalmic involvement can occur by neural connections or direct spread. Affection can involve periorbital skin, cornea, in addition to, the iris, retina, optic nerve, and other cranial

nerves. Immunocompromised patients suffer a much more severe and necrotizing disease.

A frequently debilitating and refractory complication of HZ is postherpetic neuralgia (PHN). Up to 20% of HZO patients may develop PHN. Patients who are older or who had some form of HZO beyond skin involvement (keratitis, conjunctivitis, or uveitis) are more likely to develop PHN.

Management

The standard therapy is to initiate **antiviral therapy** (acyclovir or valacyclovir). When valacyclovir (1000 mg orally three times daily for 7 days) was compared with acyclovir (800 mg orally five times daily for 7 days) over 6 months of follow-up, valacyclovir was associated with earlier resolution of acute neuritis, however, pain intensity and quality of life outcomes were not significantly different between acyclovir and valacyclovir groups. Intravenous antivirals are used for more severe ocular complications including necrotizing retinopathy or in the immunocompromised. Patients with a dermatitis or conjunctivitis should be monitored for signs of a secondary bacterial infection. Appropriate **antibiotic** coverage should be initiated when needed. **Acute pain** and PHN have been treated with antivirals, nonsteroidal anti-inflammatories, analgesics such as opiates, corticosteroids, tricyclic antidepressants, neuromodulators such as gabapentin, and nerve blocks. Whether oral glucocorticoids reduce the risk of PHN is not clear because of conflicting study results. Topical pain therapy alone is reasonable to consider as first-line treatment for mild pain e.g. Capsaicin 0.075% cream and 5% lidocaine patches. Referral to a pain specialist can also be considered.

Herpes Simplex

Human herpes simplex (HHS) virus is a contagious infection and is one of the most widespread infections, affecting nearly 60–95% of human adults. It persists during the lifetime of the host, often in latent form. The clinical manifestations are variable according to the portal of viral entry, host immunity, and primary or secondary nature of the disease.

Clinical picture

Clinical presentations of herpes simplex virus range from asymptomatic infection to mucocutaneous conditions such as orolabial, ocular, genital herpes, herpetic whitlow, herpes gladiatorum, and eczema herpeticum. It may lead to central nervous complications in the form of neonatal herpes and herpetic encephalitis and fatal dissemination in the immunosuppressed host.

Ocular HSV inoculation may lead to unilateral or bilateral keratoconjunctivitis, recurrent ocular ulcerations, and blindness. Periocular skin involvement can occur (Fig. 25). Distribution may resemble herpes zoster (Fig. 26).

Management

Systemic antivirals e.g. acyclovir, valacyclovir and ganciclovir are indicated for ocular or periocular herpes. Oral antivirals also used for long-term suppressive therapy in patients with frequent, severe outbreaks of herpes infection. IV Antivirals are reserved for severe cases.

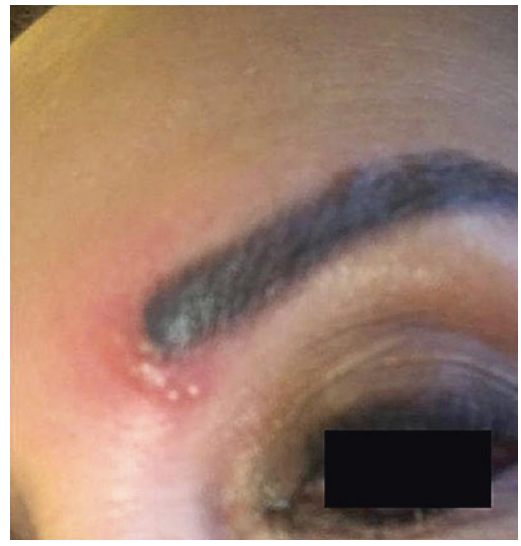

Fig. 25 Herpes simplex affecting eyebrow following tattooing

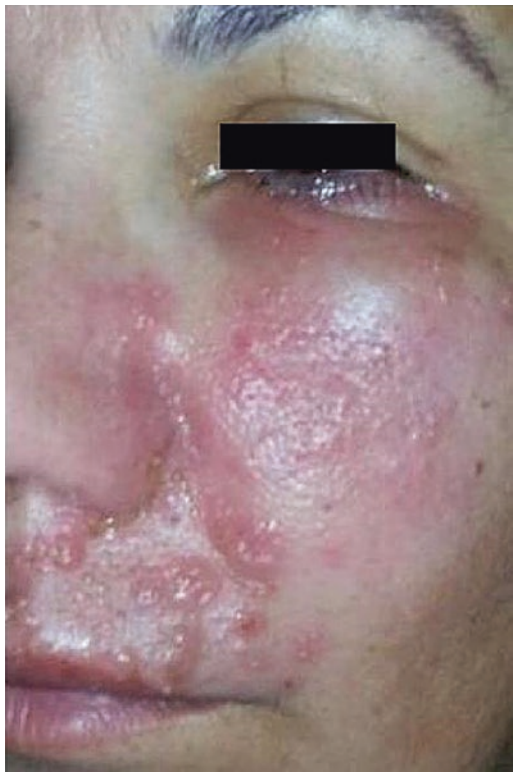

Fig. 26 Facial herpes simplex extending to lower eyelid resembling herpes zoster

Warts Around the Eye

Warts are extremely common contagious viral infections of the skin. The human papilloma virus (HPV) is responsible for warts and it represents a large group of closely related viruses with over 100 types. HPVs can infect any site with stratified squamous epithelium and many of them roughly correspond to different clinical phenotypes. Common, flat and filiform warts can occur in the face, including periorbital area, and they usually cause frustration and cosmetic problems for the patients (Fig. 27).

Waxing, threading, shaving in the salons, laser for hair removal and tattoo can induce eyebrow warts. These traumas disturb epidermal-barrier function, allowing seeding of the virus. HPV can survive for many months, and at low temperatures it can survive without needing a host.

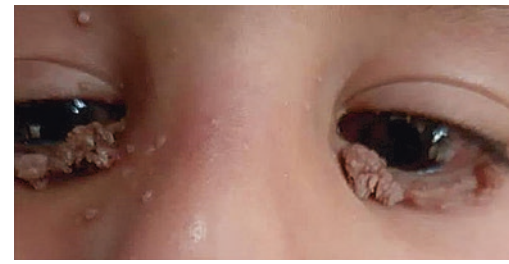

Fig. 27 Warts around the eye

Clinical picture

Flat viral warts are circumscribed papules with hyperkeratotic surfaces that can occur singly or in groups. These warts are small in size (1–5 mm), flat, or slightly elevated lesions. They typically present as skin-colored or light brownish, flat-topped papules. Their evolution is variable, and although two thirds of cases regress spontaneously in the course of two years due to immunological mechanisms, they occasionally are long lasting. Filiform warts commonly occur around eyelids as a long thin projection of the skin. Warts grow very gradually, and are usually asymptomatic.

Treatment

No single treatment is fully effective in all patients. Treatment options for flat warts include topical salicylic acid, topical retinoids, topical imiquimod, cryotherapy, intralesional immunotherapy, pulsed dye laser, topical cantharidin, electrodessication, and topical immunotherapy.

Molluscum Contagiosum

Molluscum contagiosum is a contagious viral skin infection caused by a large double-stranded DNA pox virus. The disease mainly affects children, in addition to, sexually active adults and immunosuppressed patient. In children, it is transmitted by close physical contact and by fomites, such as infected clothing and towels.

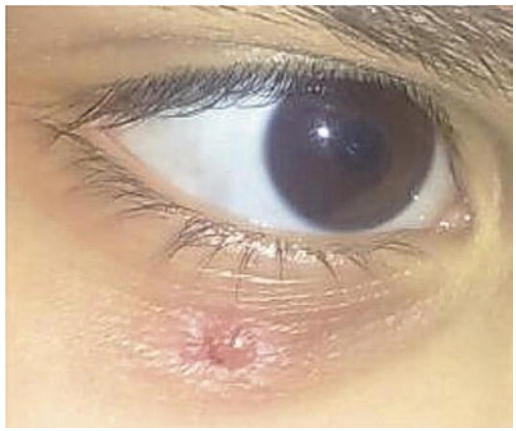

Fig. 28 Molluscum contagiosum

Clinical presentation

Usual presentation of periocular molluscum contagiosum is the classic presentation of a white, pink or flesh colored, dome-shaped nodule with central umbilication that contains a highly infective white cheesy material (Fig. 28). Other presentations can be erythematous, inflamed and tender, giant in size or pedunculated. Extensive large lesions in immunosuppressed patients were reported to induce obstruction of vision. Lesions at the lid margin are usually associated with chronic follicular conjunctivitis due to virus shedding into the tear film.

Molluscum contagiosum presenting as white dome-shaped lesion on bulbar conjunctiva was also reported.

Treatment

The disease is usually self-limited. If parents accept, watchful observation can be the approach. Lesions can be removed by excision, curettage, electrodesiccation, cryotherapy, laser surgery, and cyto-destructive methods. 0.05% tretinoin cream can be used topically.

Phthiriasis Palpebrarum

Phthiriasis palpebrarum is a rare eyelid infestation caused by *Phthirus pubis* (crab louse). The primary site is pubic hair, these lice are also found on the hair of the axillae, abdomen, and thighs. Less commonly they may infest the eyebrows and eyelashes. Sexual contact and parent-child interactions are the most typical routes of transmission. Infestation can also occur through shared infected towels, sheets or clothes. The condition is generally associated with poor hygiene and overcrowding.

Eyebrows and eyelashes are the most common sites among children with infestation because they lack terminal hairs in other body regions. Diagnosis is difficult and can be delayed. Common misdiagnoses are atopic dermatitis or allergic conjunctivitis. The presence of lice and nits can be detected by dermoscopy and by slit lamp examination.

Clinical picture

Patients present with palpebral pruritus, gritty sensation, blepharitis, conjunctivitis, marginal keratitis, color changes in eyelids, excretions over eyelashes, and occasionally preauricular lymphadenopathy due to secondary infection at the site of the louse bites.

Management

Mechanical removal with forceps can be effective in treating the disease. Treatment options also include, trimming of the eyelashes, fluorescein eye drops 20%, physostigmine 25%, yellow mercuric oxide ointment 1%, pilocarpine gel and oral ivermectin (50mcg/kg; two doses given at one-week interval).

Clothing, towels, and bedding should be mechanically washed (with water at least 55 °C) and dried on the hot cycle for 5–10 minutes. Items that cannot be washed should be dry cleaned or stored in a sealed plastic bag for at least two weeks. Follow-up examinations to detect any residual lice or nits are necessary. Patients should undergo diagnostic tests for other sexually transmitted diseases. All family members should be also examined.

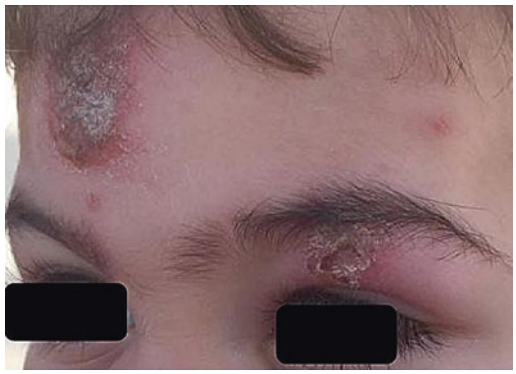

Fig. 29 Impetigo contagiosum

Impetigo Contagiosum

Impetigo contagiosum is a common bacterial infection among school-aged children. It is caused by Staphylococcus aureus or Streptococcus pyogenes. It can occur on top of insect bites, eczema, or herpetic lesions. Lesions appear as vesicles followed by golden yellow crusting, usually affecting the face (Fig. 29) and extremities. Treatment is by frequent washing with soap and water, and topical antibiotics e.g. mupirocin, or fusidic acid. Systemic antibiotics may be needed in extensive and resistant cases.

Disorders of Pigmentation

Periorbital Hyperpigmentation

Periorbital hyperpigmentation (POH) is a common condition, which can cause significant embarrassment and low self-esteem particularly in females.

Etiology

Many exogenous and endogenous factors can be involved in the pathogenesis of POH. It is important to identify the cause and type of POH to guide the treatment plan.

1. **Genetics**: A genetic susceptibility may be implicated in the condition. Positive family history was estimated to be present in 63% of the patients.
2. **Post-inflammatory hyperpigmentation**: Periorbital hyperpigmentation can be post-inflammatory following atopic dermatitis or allergic contact dermatitis.
3. **Thinning of the skin and superficial location of blood vessels**: Prominent vasculature covered by a thin layer of skin can be the underlying cause of POH. In this condition, periorbital affection usually have a violaceous color. It usually affects the entire lower eyelids, more in the inner aspect. It is usually accentuated during menstruation.
4. **Tear trough depression**: Tear trough is located over the infero-medial orbital rim. It becomes depressed with age causing hollowness. This occurs mainly due to loss of subcutaneous fat and thinning of overlying skin.
5. **The Shadowing effect**: With the development of skin wrinkles in the lower lids, each wrinkle casts a shadow on the skin beneath it, resulting in a darker appearance that disappears on stretching the skin and straightening the wrinkles.
6. **Topical eye drops for glaucoma** e.g. prostaglandin analogues, including latanoprost and bimatoprost, can also cause POH. This usually occurs 3–6 months after starting bimatoprost therapy. Complete reversal of POH can occur after discontinuation of bimatoprost. Prostaglandin analogues can increase melanogenesis in dermal melanocytes and increase transfer of melanin granules to basal epidermis inducing hyperpigmentation. Prostaglandin analogues are also used to increase hair growth of eyelashes and to induce pigmentation in vitiligo.
7. Other causes: ultraviolet radiation, anemia, stress, lack of sleep, alcohol overuse, and smoking may contribute to developing POH.

Clinical picture

POH presents with brownish-black rounded or semicircular homogenous pigmentation surrounding the eyelids. It occurs bilaterally and can be light- to dark-colored. It gives a tired look to the patient. Classification of POH is shown in Table 2.

Table 2 Types of periorbital hyperpigmentation and their treatment approach. Adapted from Gendler (2005) and Sarkar et al. (2016)

Type	Color	Appearance	Effect of stretching of lower eyelid	Possible suitable lines of treatment
Pigmented (P) (Fig. 30)	Brown	infraorbital brown hue	the area of pigmentation spreads out without any blanching or significant lightening of the pigmentation	Topical bleaching agents Chemical Peeling Lasers PRP
Vascular (V) (Fig. 31)	blue/pink/purple	infraorbital blue, pink, or purple hue ± with or without periorbital puffiness.	the area of darkness spreads out without blanching or significant lightening and results in deepening of violaceous color	Filler Autologous fat transplantation Lasers PRP
Structural (S) (Fig. 32)	skin-colored	structural shadows formed by facial anatomic surface contours ± infraorbital palpebral bags, blepharoptosis, and loss of fat with bony prominence	improve or completely resolve darkening appearance	Surgery Filler
Mixed type	A combination of the above forms			

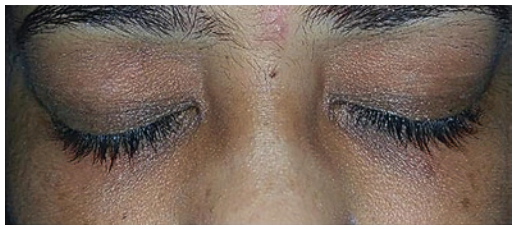

Fig. 30 Periorbital hyperpigmentation (Pigmented type)

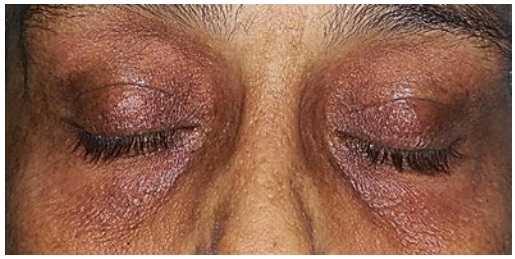

Fig. 31 Periorbital hyperpigmentation (Vascular type)

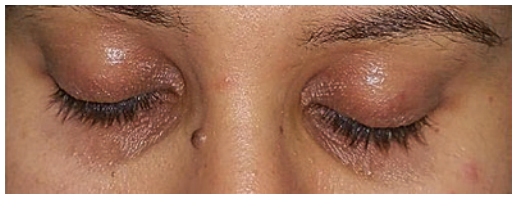

Fig. 32 Periorbital hyperpigmentation (Structural type)

Management

The aim of treatment should be to identify and treat the primary cause and the contributing factors for POH. Proper hydration, adequate sleep and lifestyle changes are mandatory. Different modalities are used according to cause of POH.

Topical Agents

Most lightening agents work by inhibition of tyrosinase enzyme, which inhibits the conversion of dopa to melanin, leading to a reduction of the melanin content of the epidermis.

Hydroquinone 4% can be used in the periocular area. Side effects include skin irritation, itching, post-inflammatory hyperpigmentation, and transient hypochromia. Long-term use can lead to exogenous ochronosis. **Tretinoin** 0.025–0.1% can be used for POH. It accelerates the turnover of epidermal melanin and induces the production of collagen in the dermis.

Other bleaching agents include **kojic acid** 1–4%, **azelaic acid**, **arbutin 3%** and **topical vitamin C**. Ascorbic acid is unstable in many topical preparations. Esterified derivatives, such as L-ascorbic acid 6-palmitate and magnesium ascorbyl phosphate are the preferred preparations. Vitamin C can induce its lightening effect by scavenging the free oxygen radicals which trigger melanogenesis, regulating the collagen synthesis, increasing the dermal collagen which conceal color of underlying blood stasis. Topical vitamin C lotion can be used in concentrations of 10% or 20%.

Broad spectrum sunscreen and ultraviolet protection sunglasses are considered beneficial in POH. Patients should be cautious while using chemical sunscreens in the delicate eye area.

Physical Therapies

Chemical peels (refer to periorbital chemical peeling)

Lasers targeting pigment, vascularity and rejuvenation have been used with some success for the treatment POH. Various lasers that have been used for treating dark circles are: Q-switched ruby laser (694 nm), Q-switched alexandrite laser, and Nd:YAG laser (1064 nm). Laser therapy can be combined with topical therapy (0.1% tretinoin and 5% hydoquinone). Fractional ablative laser resurfacing can improve skin laxity and tear trough deformity. Pulsed dye laser, diode laser, 1064 nm Nd:YAG laser, 1320 nm Nd:YAG laser, 1540 nm erbium glass laser, and intense pulsed light sources were also used for POH.

Mesotherapy refers to minimally invasive techniques that consist of intracutaneous or subcutaneous liquid injections. Vitamin C can be used, where burning sensation is the main side effect. In one study, vitamin C mesotherapy was reported superior to chemical peeling and carboxy therapy.

Microneedling also known as collagen induction therapy is a simple office-based procedure. The dermaroller or dermapen needles pierce the stratum corneum and create microchannels without damaging the epidermis. This leads to the release of growth factors and formation of new collagen and elastin in the papillary dermis. The needle depth used for POH is usually of 0.5 mm. Microneedling combined with 10% trichloroacetic acid solution was also reported for treatment of POH.

Fillers. Hyaluronic acid gel is used as a filler for three-dimensional reshaping of periorbital complex. Patients experience immediate improvement after the procedure in the form of tear trough contour improvement and under eye dark circle improvement. Post-injection erythema and edema can occur.

Autologous fat transplantation. Autologous fat transplantation is used to treat periorbital hyperpigmentation due to thin and translucent lower eyelid skin overlying the orbicularis oculi muscle.

Platelet-rich plasma has been used in treating dark circles. Platelet-rich plasma has the potential to act as a stimulant for fibroblast proliferation and collagen release. It can improve color homogeneity, tear trough deformity and wrinkles.

Surgery. ***Blepharoplasty*** serves to remove fat deposits and redundant skin, improving dark circles caused by shadowing. Transconjunctival blepharoplasty is a better approach than transcutaneous blepharoplasty so there is no external visible scar.

Carboxytherapy is noninvasive procedure that involves the transcutaneous injection of carbon dioxide (CO_2). Carbon dioxide increases the level of growth factors, enhancing the production of new blood vessels. This increased blood flow supplies oxygen and nutrients to the skin and vessels. Side effects include pain, edema and hematoma.

Proper technique and caution should be considered with any of the above-mentioned invasive therapies. Post-inflammatory hyperpigmentation is a possible side effect, that might worsen the condition.

Camouflage

Camouflage can be the last resort for covering the bothersome appearance of POH. It is the easiest and least expensive option.

Vitiligo

Vitiligo is an acquired disorder characterized by well-defined depigmented macules. The exact mechanism for the loss of functional melanocytes of involved skin is still unknown.

Clinical Picture

Affection of periorbital area can be the sole involvement in vitiligo in the segmental type which affect one segment of the body. Eyelids can also be affected with other areas in non-segmental vitiligo e.g. generalized type (Fig. 33). In addition, depigmentation of the eyelids and eyelashes (poliosis) are commonly seen in vitiligo. The uveal tract and retinal pigment epithelium contain pigment cells and the association of vitiligo with inflammation of the uveal tract has long been recognized primarily in the form of uveitis, as seen in Vogt–Koyanagi–Harada and Alezzandrini syndromes. Vitiligo shows Koebner phenomenon which describes the appearance of new lesions at the site of trauma.

Treatment

Classic treatment of vitiligo includes topical treatment e.g. topical steroids and topical calcineurin inhibitors. Topical prostaglandin analogues such as bimatoprost were reported effective in periorbital lesions. Systemic corticosteroids are used mainly to halt progression. Surgical therapy e.g.

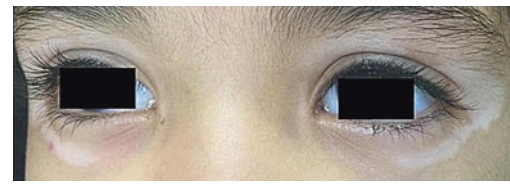

Fig. 33 Periorbital vitiligo

split-thickness skin graft, punch grafting, autologous melanocyte suspension transplant can be used for resistant lesions in stable cases which show no Koebner phenomenon. Camouflage can be a satisfactory option in some cases.

Eyelashes and Eyebrows Disorders

Madarosis

Madarosis is defined as the loss of eyebrows and eyelashes. Madarosis can reflect a long list of various disorders listed in Table 3.

Alopecia areata (AA) is an autoimmnune disease, more common in children. It presents by patchy non-scarring alopecia. Loss of eye brows and eyelashes can be an isolated presentation or associated with scalp hair/total body hair loss (alopecia totalis/universalis respectively). Frontal Fibrosing Alopecia is a distinct form of scarring alopecia in postmenopausal women. It is characterized by loss of eyebrows and a receding hairline. The loss of eyebrows may be the presenting sign. Ectodermal dysplasia is another cause of madarosis that manifests since birth and can be associated with scalp alopecia, loss of teeth, nail dystrophy, palmoplantar hyperkeratosis and absence of sweating.

Management

A careful history, examination and appropriate workup are important to find the cause. Ophthalmic, dermatologic and general medical history should be taken. Madarosis associated with other hair loss from the scalp suggests dermatological, endocrinological, drug-induced, systemic diseases, or congenital causes. However, isolated madarosis is more likely to result from localized eyelid disease. Management of madarosis primarily depends upon treatment of the predisposing disorder. Topical prostaglandin analogues, help increase the length and thickness of eyelashes. Camouflage e.g. tattooing and autologous hair transplantation could be considered.

Table 3 Causes of madarosis. Adapted from Khong et al. (2006) and Kumar and Karthikeyan (2012)

Ophthalmologic
Infectious: Staphylococcal blepharitis
Inflammatory: Seborrheic blepharitis, posterior blepharitis, Rosacea, trachoma
Dermatologic
Autoimmune: Alopecia Areata (Fig. 34), Discoid Lupus Erythromatosus, Frontal Fibrosing Alopecia (Fig. 35)
Infectious: Herpes Zoster
Dermatitis: Seborrheic Dermatitis, Atopic dermatitis, Contact dermatitis, Psoriasis
Neoplasia: SCC, BCC, Folliculo-tropic Mycosis Fungoides
Congenital: ectodermal dysplasia (Fig. 36), progeria (Fig. 37)
Systemic diseases
Infectious: Leprosy, Tuberculosis, syphilis
Endocrine: Hypothyroidism, Hyperthyroidism
Nutritional deficiency: Biotin, Iron, Zinc, Hypoproteinemia Sarcoidosis, Amyloidosis
Drugs
Chemotherapies, Systemic retinoids, Anti-thyroid drugs, Anticoagulants, Lipid lowering agents, Propranolol, Immunosuppressants
Trauma
Trichotillomania (Compulsive pulling of hair)
Tattoo
Physical, chemical, or thermal injuries

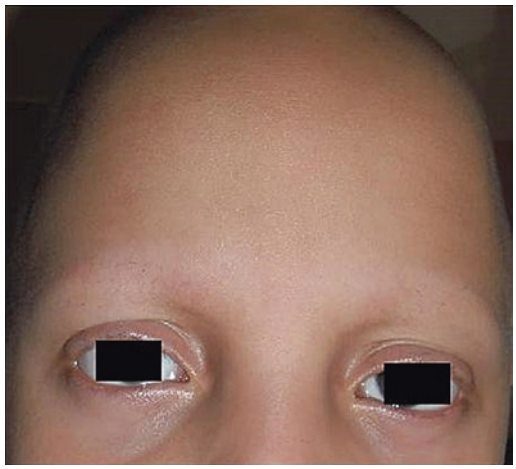

Fig. 34 Alopecia areata with loss of eyebrows and eyelashes

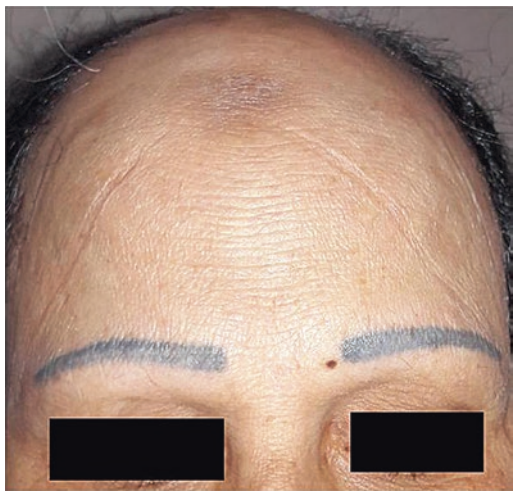

Fig. 35 A severe case of frontal fibrosing alopecia

Fig. 36 Sparse eyebrows and eyelashes due to ectodermal dysplasia

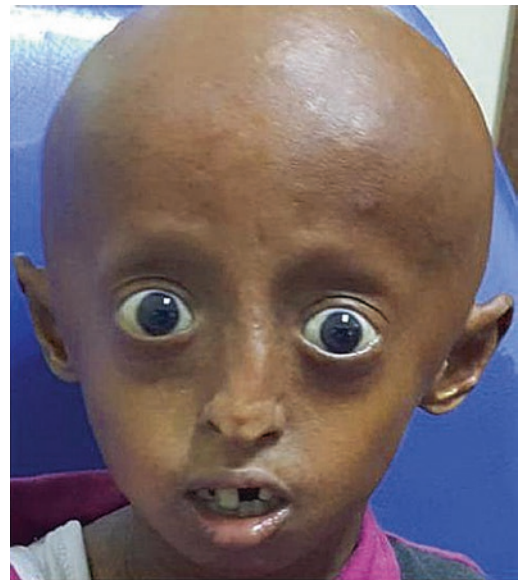

Fig. 37 Madarosis associated with a case of progeria. Progeria is a rare disease characterized by premature aging. Note the special facies; frontal bossing, big open eyes, pinched nose and protruding ears

Miscellaneous

Favre-Racouchot Disease

Favre–Racouchot disease is a disorder characterized by solar elastosis and multiple open and closed comedones. The condition is probably related to sun exposure.

Clinical appearance

The disease usually appears in the periorbital and temporal areas, and tends to be symmetric. It presents as open and cystically dilated comedones, together with wrinkles and furrows. The area appears yellowish and atrophic (Fig. 38). The comedones in Favre–Racouchot disease appear similar to those that develop in acne but do not become inflamed.

Treatment

Good results may be seen with the topical application of tretinoin. Carbon dioxide laser

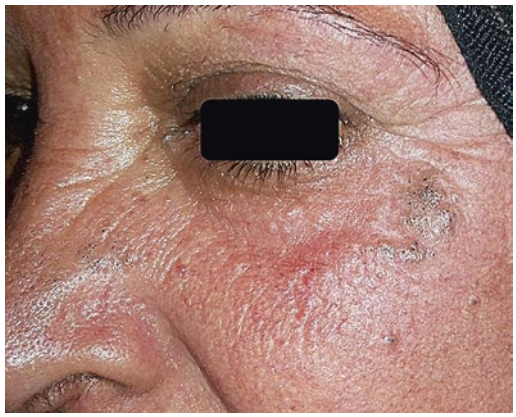

Fig. 38 Favre-Rachouchot disease. *Note the comedones, periorbital wrinkles and actinic damage*

vaporization can be used. Other treatment options include comedo extraction, chemical peeling, dermabrasion, curettage, and surgical excision (in extensive cases).

Periorbital Chemical Peeling

Indications

Main indications for periorbital peeling includes periorbital hyperpigmentation (POH) and periorbital wrinkling. It was also reported for other indications as xanthelasma.

Preparation

Pretreatment with priming agents e.g. tretinoin and hydroquinone bleaching agent for 2–4 weeks is recommended by some authors before doing a chemical peel. Priming can improve the outcome, and also minimize post-inflammatory hyperpigmentation.

Chemical Peeling Used

Peeling can be superficial, medium or deep depending upon the layer targeted by the process. Deep peels need a special level of expertise because of the possible unexpected complications, in amateur hand. The choice of the chemical peel will depend on many factors including the indication, Fitzpatrick skin phototype and thickness of the skin. For periorbital hyperpigmentation, salicylic acid 30%, glycolic acid 20%, Lactic acid 15%, trichloroacetic acid (TCA) 3.75% can be used. A combination of trichloroacetic acid (TCA) 3.75% and lactic acid 15% was also reported. For periorbital wrinkling, a medium depth peel can be used e.g. Jessner's solution followed by 35% trichloroacetic acid (Fig. 39). Periorbital deep peels for rejuvenation (chemical blepharoplasty) can be performed using phenol-croton oil. Edema and erythema are expected following these procedures.

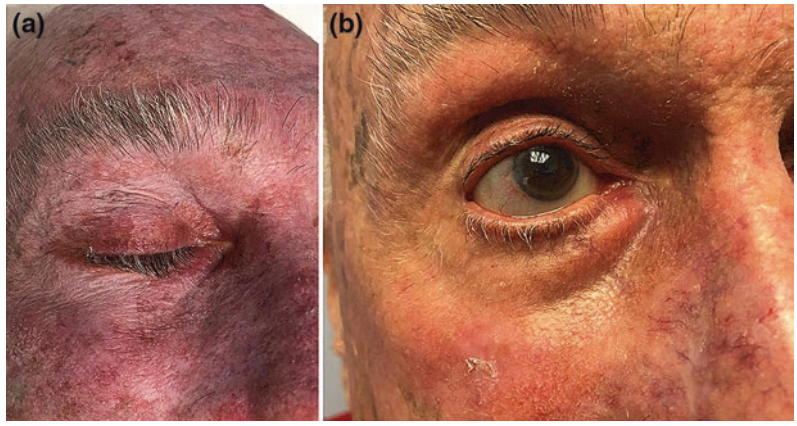

Fig. 39 **a** Medium depth peel Jessner's solution followed by 40% trichloroacetic acid of the upper and lower eyelid; **b** the result 10 days after the procedure

Complications

Complications include prolonged erythema, infection, splotchy hyperpigmentation or hypopigmentation, cicatricial ectropion, ocular damage, and scarring. Incidence of complication is more with medium-depth and deep peels.

Precautions

Extreme caution should be taken while performing periorbital peeling. Before beginning the procedure, a sterile ophthalmic ointment is advised to be instilled into the eye, prevent any damage that might result from accidental leaking of the chemical into the eye. The peels are applied using either one or two cotton-tipped applicators. The cotton-tipped applicator(s) should be dipped into the peel and wrung tightly against the container to avoid dripping and ensuring that application from the cotton to the skin is even and controlled. It is better to feather the edges of chemical peeling application to avoid a sharp line of demarcation. Dry swabs should be kept ready to absorb any tears. Peeling agents should not be passed over the eyes. Antiviral prophylaxis may be needed for patients with a positive history of recurrent herpetic infections.

Many surgeons apply a superficial or medium-depth peel at the end of the blepharoplasty procedure to maximize its effect on the skin. This is especially true with transconjunctival lower lid blepharoplasty.

Periorbital Laser Procedures

Eye Protection During Laser Procedures

Wavelength-specific goggles or spectacles and **eyewear** are essential during all laser procedures and shouldn't be removed any time during the procedure. It is possible for laser radiation to be reflected back from shiny metal surfaces into the observer's eye, potentially causing injury to the user. When treating the areas around the eyes, laser-impenetrable metal **corneal ocular shields** must be used.

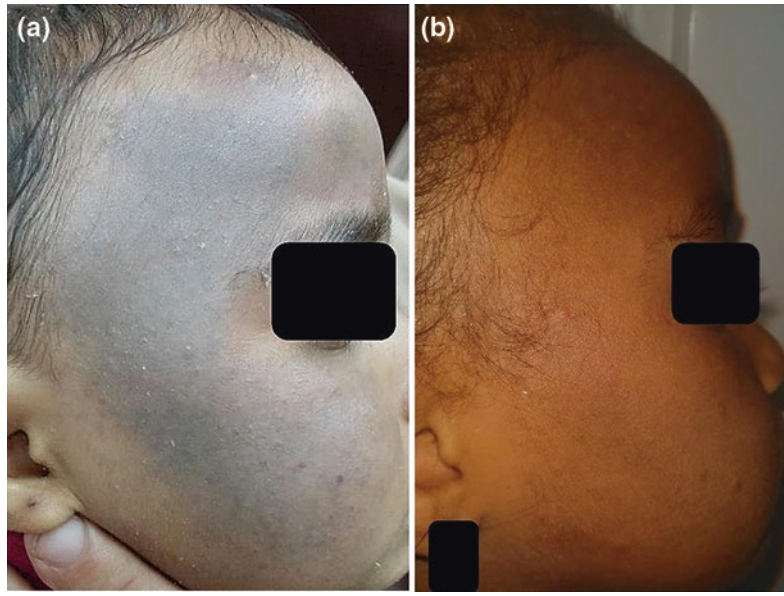

Fig. 40 **a** Nevus of Ota, **b** after treatment with Q-switched Nd:YAG

Periorbital Laser Resurfacing

Indications

Periorbital laser resurfacing is performed for periorbital wrinkles, hyperpigmentation and rejuvenation to improve skin laxity. It can be used also for xanthelasma ablation.

Method

Resurfacing can be performed using total ablative laser, non-ablative or fractional laser. Total ablative laser resurfacing (with an ultra-pulsed CO2, or Er:YAG laser) ablates 100% of the epidermal surface, and is associated with prolonged healing with an increased risk of scarring and infection. Fractional lasers deliver microscopic columns of energy which vaporize tiny holes covering only a small to moderate percentage of the skin surface. This is associated with less downtime.

Precautions

Complications of laser resurfacing include ectropion, scarring, infection and ocular injury. Care should be taken when treating areas of thin skin such as the eyelids, by decreasing the energy and density to avoid complications.

Eyebrow Laser Hair Removal

Eyebrow laser epilation can be performed using Alexandrite, diode or Nd:YAG laser.

Eyebrow Tattoo Removal

Removal of eyebrow tattoos can be achieved by Q-switched laser e.g. Q-switched Nd-YAG laser, Q-switched Alexandrite, and Q-switched KTP (532 nm). Q-switched Nd-YAG can be combined with fractional carbon dioxide laser to increase efficacy.

Q-Switched Lasers Around the Eye

Apart from tattoos, Q-Switched Nd-YAG lasers can be used for other indications e.g. Nevus of Ota (Fig. 40) and melanocytic nevus. Multiple sessions are usually needed.

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Glaucoma and Oculoplasty

T. Shaarawy and A. Aref

Glaucoma Medications and Its Effect on Eye Cosmesis

Glaucoma eye medications affects eye appearance and orbital fat content. These medications include both preservatives and active ingredients, that are both, independently from each other or combined, can result in a myriad of side effects.

Adverse Reactions to Preservatives Present in Glaucoma Eye Drops

Effects of preservatives have been indicated as a causative factor of ocular surface disease (OSD) associated with ophthalmic antiglaucomatous agent administration. More than 60% of patients with glaucoma have signs and symptoms of OSD.

A large number of products are available, combining in various proportions a limited number of ingredients such as glycerin, polyvinyl alcohol, propylene glycol, hydroxypropyl guar, carbomers, cellulose derivatives, and sodium hyaluronate. Most of the eyedrops contain preservatives to maintain the sterility of eye drops in multidose containers. The preservatives act in a totally unspecific manner as a detergent or by oxidative mechanisms and thereby cause damage not only to contaminating bacteria and other microorganisms but also to the cells of the ocular surface. It has also been demonstrated that they also affect the contact lenses physical properties, the trabecular meshwork, and the retina. Benzalkonium chloride (BAK) is the most commonly used preservative in ophthalmology, even though it is considered as the most toxic. New preservatives, as Purite or Polyquad have unfortunately, several toxic and inflammatory effects not less than BAK on the ocular surface.

Eye drops including glaucoma local treatment contain main therapeutic agents, along with various additives. Additive compounds may facilitate preparation, stabilize the solution/suspension, and/or increase product safety. Common additives include solubilizing agents, thickening agents, isotonizing agents, preservative agents, buffering agents, and stabilizing agents. Adverse reactions to eye treatments are caused by either the main active agent or the additive agents, particularly preservatives. A preservative is an additive agent that extends the shelf-life of a drug. Preservatives may have bacteriostatic or sterilizing properties and often accentuate product transparency. Most preservatives also act as surfactants which destabilize bacterial cell membranes. This causes destruction of the cell membrane, inhibition of cell growth, and reduction of cell adhesiveness. However, preservatives also exert these effects on normal corneal and conjunctival cells, resulting in

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_33

ocular surface disorders (OSD). OSD include superficial punctate keratitis, corneal erosion, conjunctival allergy, conjunctival injection, and anterior chamber inflammation. There are many compounds which cause preservative-induced superficial punctate keratitis but benzalkonium chloride is often the cause. Thereafter, when this condition develops, switching the patient to eye drops with preservatives other than benzalkonium chloride, or eye drops without preservatives (unit dose instillation containers or membrane filter-incorporated eye drop bottles) is often beneficial. As an example, in cases where latanoprost formulations with benzalkonium chloride were changed to latanoprost formulations without preservatives, the IOP remained stable and 42.9% of patients had improvements in corneal epithelium disorders. Lopez et al. 2019 reported improvement of symptoms and signs of dry eye in patients who shifted from prostaglandin analogs BAK-preserved to tafluprost preservative-free with similar IOP reductions. Reducing benzalkonium chloride exposure was often sufficient to result in ocular surface improvements as in cases where the patient switched to a combination. A deleterious effect of BAK has been demonstrated both in vitro as well as in vivo. A concentration of 0.007% of BAK induces a lysis of 50% of cultured epithelial cells in less than 2 minutes. BAK exerts its damaging action mainly through a direct cytotoxic mechanism, accentuated by the cumulative effect of repeated administrations of preserved eyedrops. Alternative preservative could be used, such as polyquaternium, which is known to have less corneal toxicity, as well as less rupture of cellular junctions, when compared to BAK. Additionally, benzalkonium chloride has been reported to be involved in the appearance of macular edema after cataract surgery.

Adverse Reactions to Main Agents in Glaucoma Eye Drops

The ultimate objective of glaucoma treatments is to stop visual field defect deterioration. Intraocular pressure (IOP) reduction is the only proven treatment to prevent visual field defect progression. Eye drops, oral medications, laser therapy, and surgery have all been used to decrease IOP in glaucoma patients. Among these therapies, topical treatments are usualy employed as the first choice because they are not associated with vision threatening complications that we can encounter with surgery.

Prostaglandin Analogs

Conjunctival allergy, conjunctival hyperemia, corneal epithelial disorders, and blepharitis are characteristic adverse reactions associated with prostaglandin analogs. Patients receiving these drugs might have eyelash bristling/lengthening, vellus hair, eyelid pigmentation, ris pigmentation, and deepening of the upper eyelid sulcus (DUES).

In the beginning of treatment with prostaglandin analogs, patients sometimes have intense conjunctival hyperemia, but this gradually diminishes over time. It has been shown in a meta-analyses of several systematic reviews, that conjunctival hyperemia occurred significantly less often with latanoprost than with travoprost or with bimatoprost. Conjunctival hyperemia was evaluated and graded in eyes in which latanoprost was currently being used. Medication regimens were left unchanged or patients were switched from latanoprost to bimatoprost or travoprost. Twelve weeks later, there were no differences in conjunctival hyperemia change score for any of the three eye drops types examined. The reported incidence of conjunctival hyperemia differs between various prostaglandin analogs, occurring more often with bimatoprost use than with other prostaglandin analogs.

The incidence of eyelash lengthening/bristling may also differ between various prostaglandin analogs. In a study where only one eye was administered a prostaglandin analog, eyelash lengthening/number increase occurred 54%, 46%, 26%, and 46% more often in the eye treated with bimatoprost, travoprost, latanoprost, and tafluprost, respectively. Differences

between individual drugs were not significant. In another study, eyelash changes in the lower lids were measured after administration of latanoprost only in one eye. Eyelash length was 6.95 ± 0.91 mm in the treated eye and 5.83 ± 0.76 mm in the untreated eye, a difference that was statistically significant. Gel suspensions with and without bimatoprost were also applied to each upper eyelid. After 6 weeks of daily application, the length of the longest eyelash was compared to that measured at baseline. The eyelashes in the bimatoprost group grew 2.0 ± 1.5 mm, significantly more than those in the bimatoprost-free (control) group, which only grew 1.1 ± 1.1 mm. Casson and Selva in 2005 described a patient whose trichomegaly secondary to the chronic use of latanoprost resulted in eyelash ptosis that obstructed his visual field and required a bilateral eyelid anterior lamellar transposition procedure. Eyelash length and increase in length was especially remarkable with the use of bimatoprost. Therefore, bimatoprost had been used for cosmetic reasons as an eyelash enhancer.

All prostaglandins seem to have similar effects on eyelid pigmentation. It is known that eyelid pigmentation changes caused by latanoprost resulted from markedly increased melanin levels. An increase in tyrosinase activity was thought to cause these changes because tyrosinase was involved in this melanin increase, which occurred at the RNA level. Iris pigmentation often occurs in patients, in whom iris pigments are green-brown, yellow brown, blue-brown, and/or of mixed color.

The occurrence of DUES with prostaglandin analog use was first reported with bimatoprost use in 2004 by Peplinski and Albiani Smith. They reported upper eyelid sulcus deepening and dermatochalasis involution in 3 patients who were unilaterally treated with bimatoprost. his was attributed to a possible effect of bimatoprost on Muller muscle. In another study 5 patients in whom chronic daily unilateral treatment with bimatoprost 0.03% caused upper eyelid sulcus deepening, clinically apparent relative enophthalmos, and involution of dermatochalasis. They hypothesized that preaponeurotic and deep orbital fat atrophy are responsible for the majority of these periocular changes. They documented that these adnexal changes were not evident prior to starting treatment with bimatoprost. Among patients for whom the medication could be stopped, partial or complete reversal of the clinical picture was observed in 3–6 months. Romano and colleagues in 2007 showed that bimatoprost induced smooth muscle contraction. Some patients with Prostaglandin-Associated Periorbitopathy (PAP) have inferior scleral show, which could be related to contraction of the inferior eyelid's smooth muscle retractors. In terms of atrophy, the number of a person's fat cells increases from birth until young adulthood and then remains relatively constant thereafter. Thus, it is the volume of lipid fat per cell that dictates one's physical appearance from middle age onward.

Fat metabolism is under intense regulation by hormones, mainly insulin, catecholamines, and natriuretic peptides, and paracrine factors such as cytokines, adenosine, and prostaglandins. The FP prostanoid receptor is thought to mediate, at least in part, the pharmacologic effect of bimatoprost as evident by the lack of IOP response in FP-prostanoid receptor knockout mice. FP-receptor activation has been associated with inhibition of preadipocyte differentiation in several cell lines that are prevented from expressing adipocyte-specific genes and accumulating fat droplets. Furthermore, FP-receptor agonists have been shown to down-regulate fatty acid binding protein expression, which is important for the uptake of free fatty acids and triglyceride synthesis in adipocytes. In addition, pharmacokinetic studies indicate that eyelid specimens contain more than 2,000 times higher concentrations of bimatoprost compared with aqueous and more than 16 times higher concentrations compared with iris and ciliary body, which indicates significant periorbital absorption of the medication. Prostaglandin F2alpha can inhibit fat production. Therefore, it was thought that prostaglandin analogs reduced orbital adipose tissue mass, resulting in DUES. In a study,

in which one eye was administered a prostaglandin analog and one eye was left untreated, photographs of the face were taken and DUES was evaluated using a score. The condition occurred in 60%, 50%, 24%, and 18% of patients using bimatoprost, travoprost, latanoprost, and tafluprost, respectively. The condition was noted significantly more often in patients using bimatoprost and travoprost than in patients using latanoprost and tafluprost.

Many patients find these effects disturbing, and in many cases the physician has to switch to a different class, or to consider Selective LASER trabeculoplasty (SLT) or even surgery.

Beta Blockers

Ocular adverse reactions to β-blockers include conjunctival allergies, conjunctival injection, corneal epithelium disorders, blepharitis, and ocular pemphigoid. Additionally, corneal sensitivity may be reduced because of the local anesthetic effect (membrane-stabilizing effect) of betaxolol. The subsequent reduction in reflective tearing may also lead to corneal epithelium disorders. Carteolol has intrinsic sympathomimetic activity so administration of this drug does not lead to a reduced corneal sensitivity. Therefore, carteolol administration was associated with fewer cases of corneal epithelium disorders than timolol. Timolol is available in a preservative-free formulation. Combining beta blockers with prostaglandins in fixed combinations seem to reduce hyperemia commonly associated with prostaglandins.

Alpha Agonists

Ocular adverse reactions associated with long-term sympathetic α2-receptor agonist use include conjunctival hyperemia, pupil dilation, and allergic conjunctivitis. Alphagan P(TM) has a purite preservative that breaks down into natural tear components and may be better tolerated in people who have allergic reactions to preservatives in other eye drops.

Carbonic Anhydrase Inhibitors (CAIs)

Ocular adverse reactions associated with carbonic anhydrase inhibitors include conjunctival allergy, conjunctival hyperemia, corneal epithelial disorders, blepharitis, Stevens–Johnson syndrome, and toxic epidermal necrosis. Dorzolamide is viscous and has a fairly acidic pH (pH = 5.5–5.9), which generally causes ocular irritation. Foreign body sensation and blurred vision often occur in patients receiving brinzolamide because intraocular transitivity is slightly poor. Moreover, carbonic anhydrase naturally exists in the corneal endothelium, and caution is needed in patients with corneal endothelial disorders.

Rho Khinase Inhibitors

Netarsudil is a new class of glaucoma drug that increase the drainage of intraocular fluid. It is prescribed once-daily at night in the form of an ophthalmic solution 0.02% (Rhopressa) and is approved for lowering elevated intraocular pressure (IOP) in patients with open-angle glaucoma or ocular hypertension. It is a Rho kinase (ROCK) inhibitor that lowers IOP primarily by increasing trabecular outflow. The most frequent adverse events were ocular: conjunctival hyperemia, conjunctival hemorrhage, and cornea verticillata. Conjunctival hyperemia is an extension of the pharmacology of ROCK inhibitors, which cause vasodilation of blood vessels by inducing relaxation of vascular smooth muscle. In most part the hyperemia was mild, transient, and self-resolving, Conjunctival hemorrhage was similarly relatively mild and self-resolving, and typically described as small petechial hemorrhages. Cornea verticillata was typically scored as mild with no associated decrease in visual function.

Combined Medications

Combination can offer an alternative for patients who need more than one type of medication. In addition to the convenience of using one eye drop bottle instead of two, there is decreased exposure to preservatives. There may also be a financial advantage. Some types are also available in generic form and also as a preservative-free formulation. Side effects of combined medications may include any of the side effects of the drug types they contain.

Oculoplastic Effects of Glaucoma Surgeries

Ptosis

Ptosis have been reported as a complication following glaucoma surgery that can lead to cosmetic and functional defects. Its incidence tends to be around 10.7–12% in trabeculectomy without mitomycin C (MMC) and 19% with MMC 6 months after surgery. The incidence of ptosis following trabeculectomy was not influenced by the type of conjunctival flap, combined surgery, or previous intraocular surgery. Some of the proposed mechanisms behind the cause of ptosis after surgery include lid edema from locally administered anesthetic, initial myotoxic effects, and the compression of the upper eyelid against the orbital bones from the eyelid speculum reducing blood flow to the levator muscle contributing to the edema. Another theory is that the use of a lid speculum, stiffness of the lid speculum, and a smaller palpebral fissures may play a greater role.

In general, ptosis that arises after ophthalmic surgeries are associated with myogenic or neurogenic factors due to anesthetic effects, mechanical factors due to edema or hematoma of the eyelid, or aponeurotic factors due to traction on the aponeurosis of the levator palpebrae muscle separating it from the tarsal plate. Specially in trabeculectomy where adequate exposure is mandatory, manipulations are often necessary to obtain an adequate surgical field, which may partially account for the incidence of ptosis. In addition, the use of antimetabolites, postoperative globe massage or needling, chronic stimulation of the eyelid by the filtering bleb, and other factors may also contribute to the high incidence of ptosis. Unfortunately in glaucoma patients with visual field defect, the additional visual field impairment due to ptosis will further decrease the quality of vision. Ptosis have been reported to Occurs in 22.5% in patients with shunting procedures, a higher percentage compared with filtering surgery. The potential cause of increased ptosis in patients with shunting surgery could be due to the need for increased exposure required during shunting surgery to place a glaucoma drainage device 8–10 mm posterior to the limbus. The need for increased exposure possibly resulted in more pressure on the levator palpebrae aponeurosis by the lid speculum compared with the fornix-based filtering surgery.

Eyelid Retraction After Glaucoma Surgeries

Upper eyelid retraction as a complication after trabeculectomy have been reported in several studies. Mechanical, chemical, and myogenic mechanisms have been suggested. The mechanical hindrance from a diffuse, large superior bleb is supported by the fact that the retracted eye lids assumes the contours of the bleb. Putterman and Urist advocated that sympathetic stimulation of Muller muscle from chemical substances in the aqueous humor would cause eyelid retraction. This argument was further supported by a widened palpebral fissure in affected eyes, the use of a sympathetic antagonist such as guanethidine to reduce lid retraction, and increased sensitivity to phenylephrine. Awwad and colleagues in 2004 suggested that lid retraction was due to a myogenic mechanism of Muller muscle fibrosis.

Medical and surgical options on both filtering bleb and eyelid can be used to treat eyelid

retraction in patients with glaucoma. Botulinum toxin injections to induce ptosis to neutralize the lid retraction in cases of sight-threatening bleb exposure are used. Alternatively retro septal injection of Hyaluronic acid gel in the affected upper eyelid skin fold to restore the normal upper eyelid position can be used. In term of surgical procedures weakening of the upper eyelid retractors can be performed. These include lengthening or excision of either or both the levator and Muller muscle through an anterior or posterior approach. Both anterior and posterior-approach techniques, carry the risk of possible disruption of the conjunctival filtering bleb. A conjunctiva-sparing recessions of levator and Muller muscle in patients with glaucoma filtering blebs minimizing the risks of bleb injury have been also described. Some manipulation procedures that reduce the height of the bleb may help in treatment of lid retraction. Bleb compression sutures, posterior bleb needling, and cautery-induced scleral fibrosis alter the geometry of the bleb, thus decreasing the superior forces that cause lid retraction.

Glaucoma Draining Implants

Glaucoma drainage implants (GDIs) have been an effective therapeutic option in the management of refractory glaucoma. The complications associated with GDIs, however, include hypotony, choroidal effusion, corneal decompensation, cataract, endophthalmitis, diplopia, and migration of the implant. Transconjunctival tube erosion is an infrequent but well-known complication of GDIs surgery. It is estimated that 2–7% of patients undergoing GDIs procedure develop melting of the overlying scleral or pericardial patch with erosion of the tube through the conjunctiva. Possible causes of conjunctival erosion include mechanical abrasion of the conjunctiva by the lid, excessive conjunctival tension over the tube, tube malposition, or lack of a smooth and tapered surface between the patch graft and the host along with poor ocular lubrication. Various methods such as a conjunctival advancement, a conjunctival patch graft, an amniotic membrane patch graft or an interpolated conjunctival pedicle flap have been described to cover the exposed tube. If the tube exposure is accompanied by the infectious inflammatory signs which do not respond to antibiotics, the tube and the valve plate should be removed to help stop the propagation of the infectious process and prevent the subsequent development of endophthalmitis.

Glaucoma drainage devices allow outflow of aqueous humor from a tube inserted into the anterior chamber to the subtenon space around the ocular equatorial area. The body connected to the rear outlet of the tube prevents closure of the tube outlet by surrounding tissue and forms a large retention area beneath the bleb, which is helpful in long-term IOP control. The most common cause of IOP elevation after GDI implantation is the formation of an encapsulated bleb due to excessive fibrosis around the body of the GDI during the wound-healing process.

A case of Bleb incarceration following Ahmed valve surgery have been reported. The patient had a large superotemporal filtering bleb following Ahmed valve surgery for uncontrolled glaucoma. While instilling her glaucoma medication, she retracted her eyelids sufficiently to pull the upper lid over her filtering bleb where it became entrapped causing a similar presentation to globe luxation. Traditional methods of repositioning the globe were unsuccessful. Bleb needling was ultimately required to return the globe to a normal position.

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Part VI
The Orbit

Orbital Evaluation and Proptosis

Jeffrey Nerad and Trevor Smith

Introduction

The orbit is defined by the four boney walls surrounding the eye and all of the contents contained within that space. Understanding the anatomy of the relevant nerves, extraocular muscles, vascular system, adipose tissue, lacrimal system, lymphatics, and anterior segment structures in addition to the adjacent intracranial neurosurgical anatomy is a must. Orbital pathology can be caused by any process that involves the structures within and directly opposed to the orbital walls, as well as distant disease processes including metastasis or those causing inflammation of the orbit. The examination will allow you to form a differential diagnosis that will often be refined by imaging and laboratory studies. Orbital surgeons use a series of principles that are distilled into mnemonics described within this chapter. Based on a patient's presentation and physical exam, this approach will result in a well-organized knowledge base that will guide you to the next step in decision-making, allowing you to advise your patient of the most likely treatment and outcome.

The causes of orbital pathology are numerous. We will benefit from approaching each patient with a helpful mnemonic (the "seven P's" of proptosis) and the categorization of the various types of patholog. These categories include vascular, inflammatory, traumatic, autoimmune, metabolic, infectious, neoplastic, congenital, and endocrine (mnemonic: VITAMIN CE). With only these two tools we will be able to determine what further testing, if any, the patient will require. A third and final principle is that proptosis in adult patients is most commonly thyroid eye disease, whether unilateral or bilateral.

Clinical evaluation:

History	Physical examination
Pain	Proptosis
Progression	Palpation
Past medical history	Periocular changes
	Pulsation

For many general ophthalmologists, the orbital evaluation may seem to involve structures that are away from a general ophthalmologist's usual structures. However, an organized approach to the exam will make this area feel like familiar territory as well. Remember, all relevant aspects of the patient's history and physical exam start with the **letter P**: pain, progression, past medical history, proptosis, periorbital changes, palpation, pulsation. The sum of these components will allow us to create an accurate picture of the patient's pathology, i.e. a differential diagnosis.

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_34

Always start with the basics: what is the patient's chief complaint? In this case we are primarily assessing proptosis, which is the commonest orbital manifestation. It is important to note, however, that the vital signs of the eye are critical to evaluating urgency and potential long-term visual consequences. We always check vision, pupils, pressures, confrontation visual fields, and eye movements. Evaluate these as we normally would as a ophthalmologists, while adding a specific orbital exam to our toolbox. There will be more orbital considerations on a few of these vital signs throughout the assessment.

The first consideration is the patient's **pain**. The patient in pain will almost certainly volunteer this information. The *level, character, onset and progression* of the pain are helpful in determining the etiology of the orbital process. Pain is most commonly caused by inflammation, either autoimmune or infectious. Orbital inflammatory disease and orbital cellulitis are examples of these processes. Both processes cause pain via the inflammatory cascade (Fig. 1). This is why orbital inflammatory syndrome is sometimes difficult to differentiate from orbital cellulitis when both are unilateral and causing pain. Each result from the same mechanism. The pain is severe and acute (occurring over hours) in both situations. Cellulitis will be associated with malaise, and a leukocytosis in most cases. Benign processes generally do not cause pain. Large slow growing benign masses typically do not cause severe pain, but a large mass may cause a pressure type or discomfort. Chronic orbital processes include thyroid eye disease (by far the most common cause of proptosis), sarcoidosis and granulomatosis with polyangiitis. Thyroid eye disease typically has an indefinite onset and is slowly progressive over weeks and months. Malignant tumors, late in the course, can invade sensory nerves and cause pain associated with hypesthesia. In some cases the proptosis may be present for years, progress very slowly, and cause no pain (benign mixed tumor of the lacrimal gland).

Past medical history

It can be helpful to have photos for comparison. A history of any cancer should alert the physician to the possibility of a metastasis with lung, breast, colon, and prostate cancer being the most common. Previous surgery and trauma also notably affect the orbital structures allowing physicians to contextualize any proptosis measured.

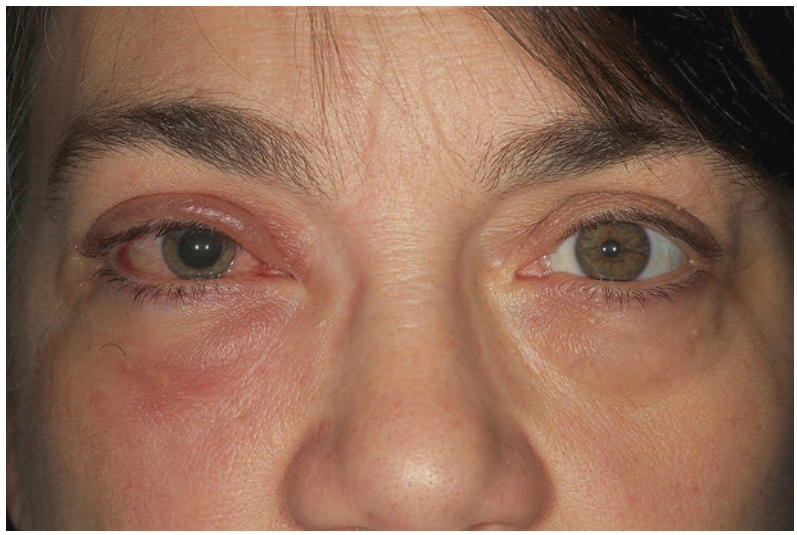

Fig. 1 Acute, recurrent presentation of the painful condition, idiopathic orbital inflammatory disease, while weaning from prednisone after one month of treatment

Physical Exam

An appropriate physical exam includes slit lamp evaluation of the anterior segment and all the usual components of a complete eye exam. Unique to the orbital exam is the evaluation of proptosis, periorbital changes, palpation, and detection of globe pulsation.

Proptosis

The external eye exam begins the moment we walk into the patient room. Gross proptosis or prominent eyes will be immediately obvious and probably indicates that the individual has asymmetry outside of the range of normal. Quantification of this finding is performed using the Hertel exophthalmometer. Different normal ranges exist in varying racial groups. The prominence of the globe is least evident in Asians whose average Hertel measurement is 18 mm, while African Americans tend to have more prominent eyes with an average 22 mm. Caucasians fall halfway in between at 20 mm. This is due to the varied bone structure surrounding the globe rather than the position of the globe itself. A worm's eye view photograph can be an excellent way of documenting a patient's current level of proptosis. This is performed by having the patient tilt their head back in a comfortable position, while the physician takes a photo directly from the patient's feet to the tip of their nose.

The most important component of measurement is asymmetry between the two eyes. A measurement of the tip of the cornea to the lateral orbital rim differing more than 2 mm between the two eyes should be considered abnormal. Even in the absence of pain, progression, or relevant past medical history, incidental asymmetry of the orbits that is greater than 2 mm should be investigated further with imaging if progression is observed. For those who have had previous trauma that permanently affected the lateral orbital rim, an alternative type of exophthalmometer can be used that measures the apex of the cornea as compared to the prominence of the forehead and cheek bones (Thomas Naugle exophthalmometer). Asymmetry and progression are the greatest red flags for proptosis

The types of globe displacement also add additional clues to the etiology of an orbital process. A slow-growing tumor within the muscle cone will cause axial proptosis, meaning the eye will be pushed directly forward out of the socket. Masses within the extraconal spaces result in displacement of the globe away from a mass. A superior mass will result in inferior displacement of the globe. Lacrimal gland tumors result in inferior and possibly medial displacement of the globe. An exception to this rule is the scirrhous carcinoma breast cancer metastasis. The sclerosing tumor can cause enophthalmos. Lateral displacement of the globe is typically seen in sinus disease including carcinoma or a mucocele. Superior displacement of the globe is relatively rare, but may occur from maxillary sinus tumor. Interestingly, the most common inferior orbital mass is lymphoma (Fig. 2), despite the fact that most lymphomas arise in the superior orbit.

Periorbital Changes

Most periorbital changes can be identified using only a pen light. The pen light can help illuminate suspicious skin lesions, check the pupils, and assess the eye movements including the eyelid excursion. This quick exam would allow to identify retraction of the upper eyelids showing exposed sclera above the limbus, lid lagophthalmos in downgaze due to tightened levator muscle and temporal flare, all caused by thyroid eye disease. Other pathognomonic findings include fullness of the temple in sphenoid wing meningioma, an s-shaped eyelid in a patient with neurofibromatosis type 1 with a plexiform neurofibroma (a finding associated with increased risk of glaucoma), or a diabetic patient with routine orbital cellulitis that have a necrotic black lesion in the nasopharynx indicating a phycomycosis. During slit lamp examination we may identify a salmon colored patch of the conjunctiva—a clue toward confirming diagnosis of lymphoma of the orbit. During fundus examination we

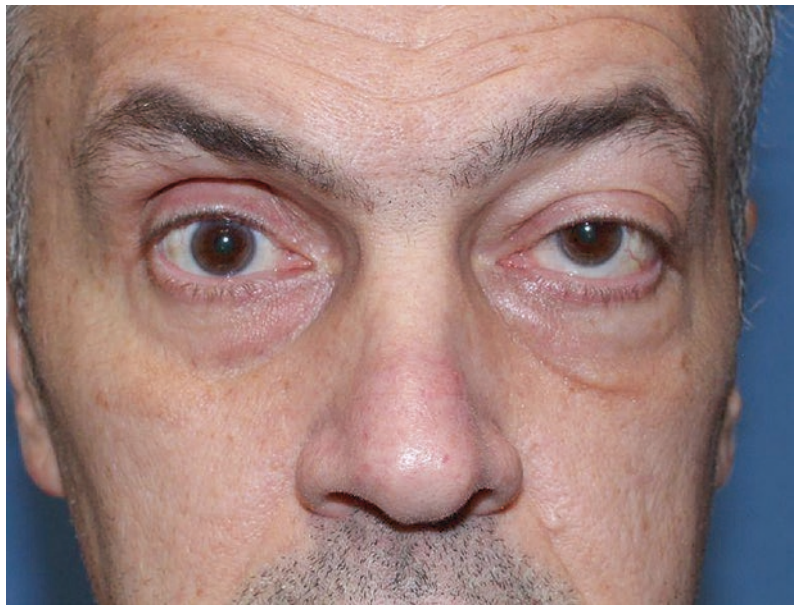

Fig. 2 Subacute presentation of hyperglobus in the left eye. Note the "pseudoptosis" of the left upper eyelid due to the inferior rectus enlargement by the most common cause of an inferior orbital mass: lymphoma

may see ciliary shunt vessels of the optic nerve (consistent with an orbital meningioma) or the "candle wax dripping" periphlebitis associated with sarcoidosis.

Palpation

Next palpate the orbit. we may be able to identify a specific mass or a general fullness of the orbit (resistance to retropulsion). Note the position and character of any masses. A child presenting with a slow growing superotemporal, discrete, smooth mass likely has a dermoid cyst. Upon palpation of the skin overlying the lacrimal gland, the patient may note some diminished sensation. This hypesthesia is associated with lacrimal gland malignancies deriving from the lacrimal gland epithelium (the classic being adenoid cystic carcinoma). we may identify the heat and pain due to orbital inflammation or infection, associated with the redness that we have noted on your initial inspection.

Any possible restriction of extraocular muscles identified on exam can be further tested with forced ductions. Use proparacaine or an ophthalmic gel anesthetic on the conjunctiva of the limbus or overlying the extraocular muscle insertion and then grab the eye with a toothed forceps and pull away from the muscle to determine if it is tight. In a patient with other thyroid signs and bilateral disease, it is exceedingly unlikely that the patient would have an alternative pathology in addition to restrictive muscle pathology—no imaging would be necessary if the clinical context all points toward thyroid since the pre-test probability would be so low for any other diagnosis.

Pulsation

The final P of the mnemonic would also be noted on palpation wherein the examiner would see rhythmic, axial protrusion of the globe. This is a sign suggesting a pulsatile vascular lesion such as an AVM or high flow carotid cavernous fistula. we may also see pulsations after the removal of the orbital roof or lateral wall following a sphenoid wing meningioma excision. Auscultation can also be applied to the globe and orbit where a high-flow fistula may produce a bruit, typically accompanied by dilated episcleral vessels.

VITAMIN CE

The various orbital diagnoses under the mnemonic, VITAMIN CE, will be described in the corresponding chapters; however, a brief discussion practice using the P's is included below and demonstrates how easily differentiation can be performed using these few components of the history and physical. Further elucidation often requires labs and imaging.

VITAMIN	CE
Vascular	Congenital
Infection	Endocrine
Trauma	
Autoimmune	
Metabolic	
Iatrogenic	
Neoplastic	

Vascular

Many vascular pathologies affect the orbit. In children, the infantile hemangioma usually appears in the first few weeks of life. These hemangiomas grow over a period of several weeks and involute to a degree over 5-10 years. In contrast to this childhood vascular lesion, adults may present with slowly progressive axial proptosis due to a cavernous vascular malformation in the muscle cone. Following trauma, a direct high flow carotid cavernous fistula can occur, typically of acute or subacute onset associated with pain. Accompanying symptoms usually include high intraocular pressure, unilateral proptosis, and acute progression. This is where auscultation can be used. Indirect fistulas can occur spontaneously in older adults. These have low flow and are more likely to have normal intraocular pressure and slower progression without a bruit.

Infection

Orbital bacterial cellulitis presents acutely with pain, unilateral proptosis, and rapid progression. There is tenderness on palpation with notable edema and erythema, often with induration. Fungal cellulitis occurs in immunosuppressed patients. The inadequate immune response allows the normally docile fungus to infect the orbital tissues. In this case, typical signs of orbital inflammation are not present due to the lack of normal immunocompetency.

Trauma

Proptosis resulting from trauma is caused by a retrobulbar hematoma resulting in pain of rapid onset with periorbital ecchymosis, edema, chemosis, and vision loss due to high intraocular pressure or stretching of the optic nerve if severe.

Autoimmune

This etiology includes the continuum of idiopathic orbital inflammatory syndrome to IgG antibody-mediated inflammatory disease. It occurs and typically results in unilateral proptosis with pain, acute onset, chemosis and injection, a lack of response to antibiotics, and rapid improvement with high-dose oral steroids. In contrast to this immune related process, thyroid eye disease presents less acutely, over weeks with slowly progressive signs of inflammation, eyelid retraction and possible motility disturbance and proptosis (Figs. 3 and 4).

Metabolic

In rare instances, fluid shifts in burn victims can result in orbital compartment syndrome following aggressive IV rehydration, resulting in a similar picture as that of a retrobulbar hematoma.

Iatrogenic

Surprisingly some proptosis can be purposeful and beneficial cosmetically. Orbital volume augmentation with implants or fillers can restore ocular prominence. Intraorbital implants are commonly used to restore symmetry. Filler is rarely used to improve enophthalmos.

Neoplasm

Benign and metastatic tumors vary significantly in their presentation. Pleomorphic adenoma of the lacrimal gland may slowly progress over

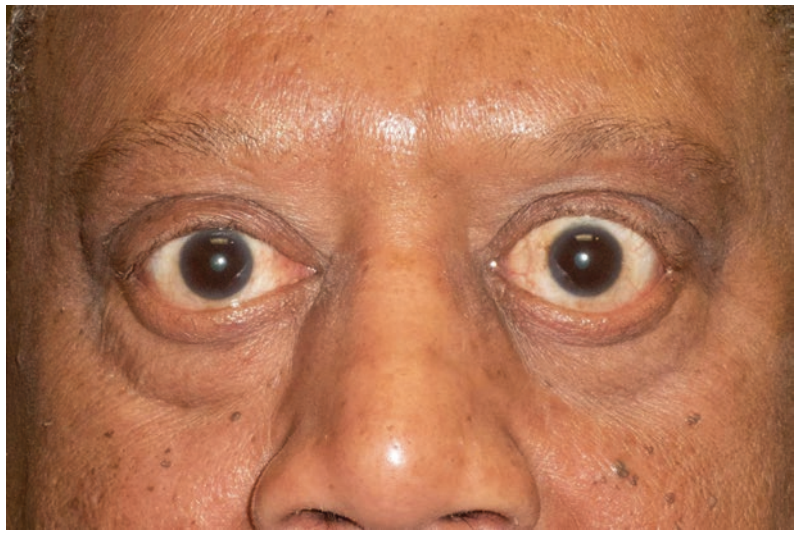

Fig. 3 Inactive thyroid eye disease. This patient has had small lateral tarsorraphies done to improve the temporal flare seen in many patients with thyroid eye disease. Thyroid eye disease is the most common cause of bilateral proptosis

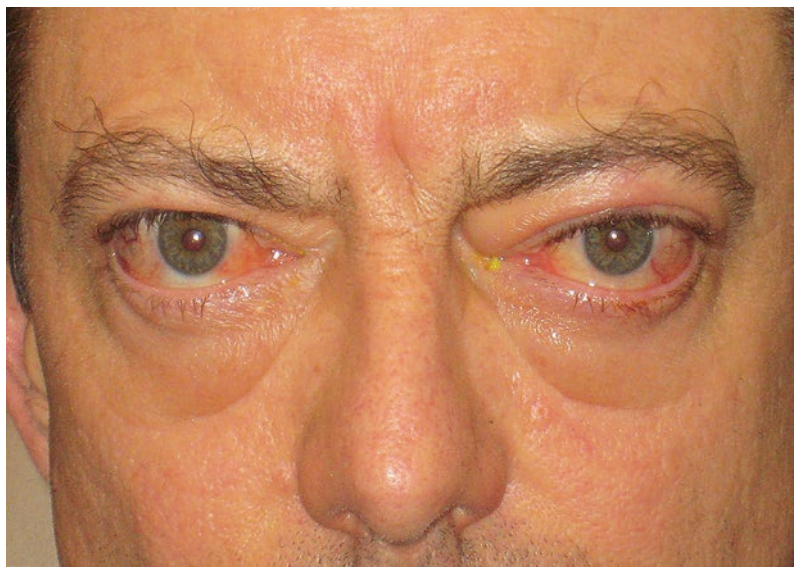

Fig. 4 Active thyroid eye disease presenting subacutely over weeks with presence of conjunctival injection, eyelid edema, proptosis, and lower eyelid retraction

many months to result in non-axial inferonasal displacement of the globe while rhabdomyosarcoma in a child could have an aggressive orbital cellulitis-type presentation with onset over days. Differentiation within the category of neoplasm typically requires imaging (Fig. 5).

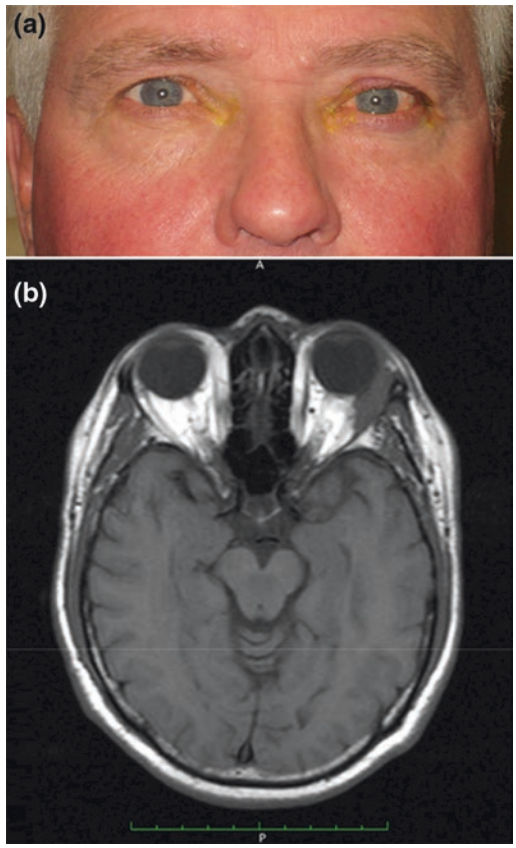

Fig. 5 **a** Non-axial displacement of the globe inferonasally is secondary to the lacrimal gland tumor seen on the CT scan. **b** This malignant tumor, ductal adenocarcinoma of the lacrimal gland, presented chronically after 6 months of vague pressure and eventual hypesthesia over the lateral eyebrow

Congenital

A dermoid cyst can be differentiated from an encephalocele by location and progression. Most dermoid cysts arise laterally from within the frontozygomatic suture. Encephaloceles are present medially and often increase with the Valsalva maneuver.

Endocrine

Thyroid eye disease (TED) is an autoimmune and endocrine related disease due to its antibody acting directly on fibroblasts that result in fibrosis of muscles and differentiation into adipocytes in the orbit. It is the most common cause of bilateral and unilateral proptosis in adults and a full chapter is dedicated to this disease, which typically presents bilaterally with many periorbital changes including eyelid retraction, eyelid flare, proptosis, and has both an acute and chronic form.

Management

Now that we have evaluated your patient's condition in terms of the P's of the history and physical and the possible etiologies (VITAMIN CE) we have narrowed your diagnosis down to one or two processes. Imaging of the orbit is often indicated for further evaluation of proptosis. Both CT and MRI studies have benefits and weaknesses. CT is best for imaging bone and planning surgical approach. MRI is best for evaluating the craniofacial junction. CT is used for most urgent trauma evaluations since it is readily available and quickly performed. Additionally, in trauma or any other condition in which the patient may have a ferrous metal implant in their body, MRI is not an option. In some cases, both MRI and CT may be useful. In children MRI is favored due to the lack of radiation.

Before we review any type of scan, consider your original exam. When the patient has globe displacement, investigate the area of the scan where we could imagine a mass pushing the globe. If we have identified a mass, then the next consideration is if it is discrete or infiltrative. we can consider lesions to be "eaters" or "pushers". Eaters invade surrounding tissue and are more likely malignant. Pushers tend to be benign. Both types will cause proptosis pushing the globe forward. Erosion of the bone is more indicative of a malignant process. A fossa that is formed from a mass or from the pressure of long-standing thyroid eye disease is indicative of a chronic process and usually represents a benign process. Generally smaller lesions are better lesions but are not necessarily prognostic. Therefore, a small, well circumscribed, homogeneous, mass indenting but not eroding the bone is likely a benign process. If this lesion was to be found in the lacrimal gland fossa and was more oval than round, it would likely be a

pleomorphic adenoma that could be removed by excisional biopsy. Most other tumors and masses are diagnosed with incisional biopsy except where removal of the entire lesion is easier such as a cavernous hemangioma or a dermoid cyst. A "biopsy" in those cases would be curative for both lesions. The incisional biopsy allows for minimal damage to surrounding structures while providing specific information or further non-surgical intervention including radiation, chemotherapy, and the more recent treatment of checkpoint inhibitors. A growing list of targets allows the native host immune system to attack cancer cells with a high degree of specificity based on tissue DNA testing. This has resulted in multiple cases that in previous decades would have been treated only with exenteration but can now be approached differently.

Summary

The orbital examination includes a thorough history and physical exam. Remember to use all seven P's (pain, progression, past medical history, proptosis, palpation, periocular changes, pulsation) in order to narrow the differential from the VITAMIN CE mnemonic. While there are hundreds of pathologic diagnosis to be made in the orbit, these two principles will guide us toward a very limited number of possibilities and will allow us to proceed confidently with a plan for the specific patient sitting in the exam chair.

History	Physical examination
Pain	Proptosis
Progression	Palpation
Past medical history	Periocular changes
	Pulsation

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Radiology and Oculoplasty

Sally Emad-Eldin and Ashraf Selim

Orbital Imaging

- Plain Radiography (X-Ray).
- Ultrasonography (US).
- Computed tomography (CT).
- Magnetic resonance Imaging (MRI).
- Angiography (Conventional, CTA and MRA).

Imaging

Imaging Modalities

The imaging modalities most commonly used in the evaluation of orbital lesions are ultrasonography (US), computed tomography (CT), and magnetic resonance (MR) imaging.

1-Ultrasound (US)
Ultrasound (US) with Doppler can be used in the diagnosis and follow up of various globe and orbital lesions. It is the first imaging modality in children with superficial lesions. The technique is non-invasive, cost-effective and easy to perform, and has a high accuracy for the characterization of vascular lesions. However, it is operator dependent and cannot visualize the orbit completely. Also, it is contraindicated if rupture globe is suspected.

2-Computed Tomography:
CT is the initial imaging modality for the evaluation of orbital trauma; infection and detection of a foreign body. It is superior to MRI in the detection of calcification, or acute hemorrhage; evaluation of orbital osseous lesions; as well as the assessment of orbital soft-tissue lesion with suspicion of bony erosion. CT is preferred in the setting of an emergency or if there is a contraindication for MR examination.

Thin slice multi-detector CT scan of the orbit provides rapid volumetric image acquisitions. Coronal and sagittal reconstructed images are routinely obtained in bone and soft tissue windows (Fig. 1). 3D reconstructed images are beneficial in the assessment of complex orbital fractures, orbito-cranial masses, fibrous dysplasia or neurofibromatosis.

CT scan of the orbits is usually performed following the intravenous (IV) administration of an iodinated contrast medium in the venous phase. Contrast-enhanced CT examination is indicated if an orbital mass is suspected to allow differentiation of different orbital lesions according to their enhancement pattern. Non-contrast CT examination is performed in cases for orbital trauma or thyroid orbitopathy as

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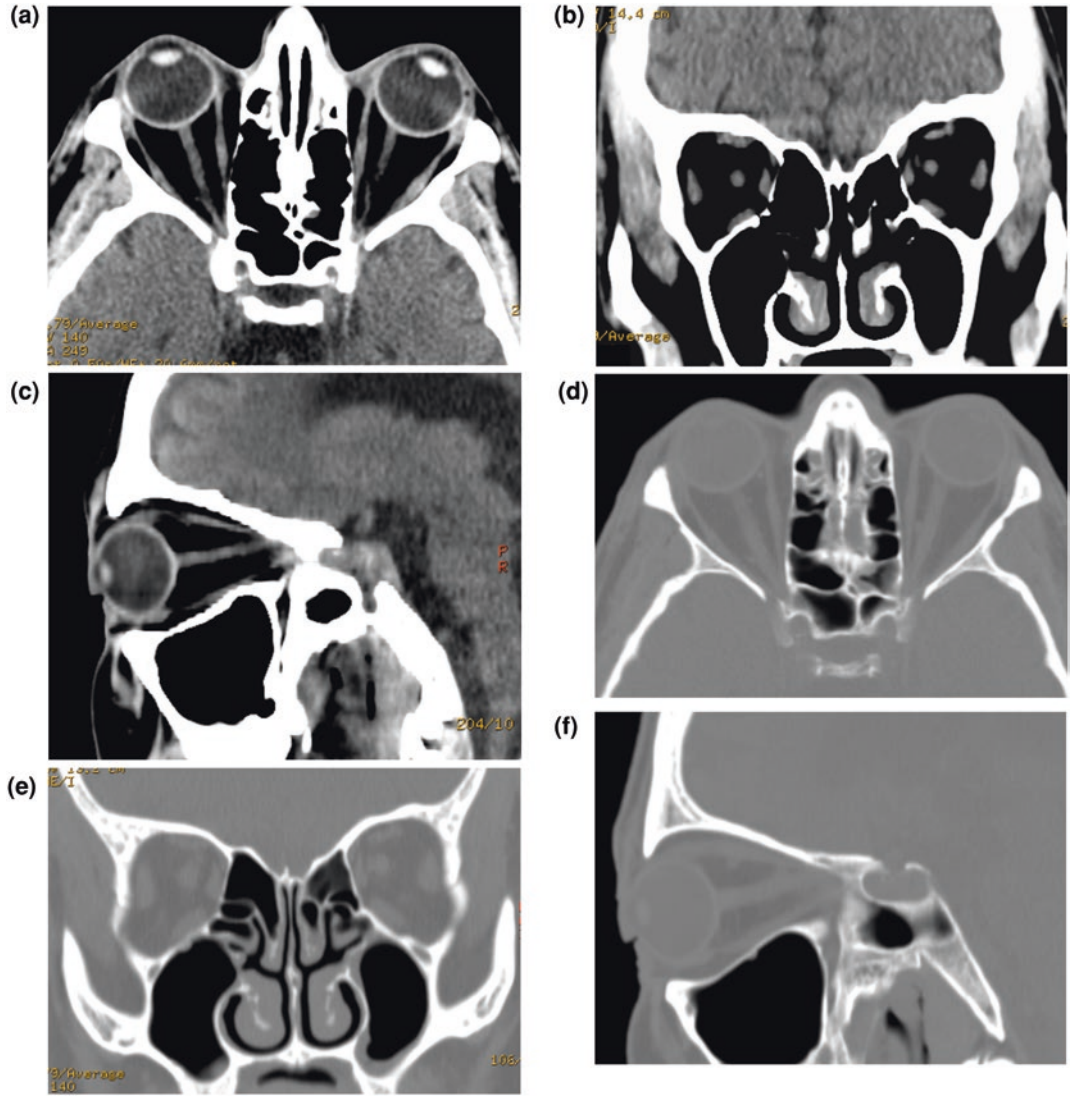

Fig. 1 Normal orbit on CT imaging. **a–f** Axial, coronal and sagittal reformatting CT images in soft tissue **a–c** and bone windows **d–f** showing normal appearance of the extraocular muscles, optic nerve and retro-orbital fat

these pathologies are very well delineated by hypodense orbital fat.

It is crucial to note that, CT of the orbits is not performed both without and with contrast administration; as it does not yield significant diagnostic improvement, with the risk of doubling the radiation dose to the lens.

The eye is a sensitive organ to radiation, and exposure to higher doses of radiation may lead to the development of early cataract. The risk of radiation exposure is especially important in the pediatric patients with special attention in children having malignant lesions who require long-term follow-up imaging to assess response after therapy and to diagnose early recurrence.

CT angiography (CTA) and CT venography (CTV) are helpful for assessment of orbital

vascular lesions. Also, it can be useful in planning further evaluation and management of these lesions.

3-Magnetic resonance imaging

MRI is the modality of choice for evaluating most of the orbital lesions, particularly in non-emergency settings, with imaging of patients presenting with subacute or chronic symptoms.

MRI has higher soft tissue resolution and tissue characterization compared to CT and provides more precise delineation of the different orbital compartments (Fig. 2). Thus, MRI is preferred in the evaluation of suspected orbit neoplasms, orbit inflammatory disorders, orbit vascular malformations, optic nerve sheath complex lesions. Moreover, MR is ideal for visualization of intracranial extension of orbital lesions, as well as lesions at the orbital apex, orbital canal and cavernous sinus.

However, MR is more expensive with longer examination time compared to CT. It requires sedation in some patients; additionally, it is contraindicated in patients with a cardiac pacemaker, aneurysmal clip, or metallic foreign bodies.

The standard protocol for MRI orbit examination is to acquire both unenhanced and enhanced imaging after IV administration of gadolinium contrast medium. Unenhanced MRI examination is performed alone, if there is a contraindication to gadolinium IV administration like renal failure, contrast allergy or pregnancy.

MRA and MRV examinations can be used in imaging of orbital vascular lesions; however, they are more susceptible to artifacts and lower spatial resolution than CTA and CTV studies. However, they can be done without contrast medium, with no risk of ionizing radiation, thus they can be used in patients who cannot tolerate iodinated contrast material.

Diffusion-weighted imaging (DWI) is based upon assessing the random Brownian motion of water molecules within the tissue. A lesion with high cellularity demonstrates restricted diffusion and low apparent diffusion coefficient (ADC) value. The use of DWI has been reported to further increase the diagnostic utility of MRI in the characterization of orbital masses. Tumors composed of tightly packed cells with a high nuclear-to-cytoplasmic ratio like lymphoma show restricted diffusion. Additionally, DWI is valuable in differentiating abscess from other inflammatory processes as the thick purulent material in an abscess demonstrates diffusion restriction.

4-Conventional angiography

Conventional *angiography* has advantages over CTA and MRA examinations, as it is real-time imaging that provides better temporal resolution with evaluation of blood flow dynamics.

However, because of its invasive nature, it is only indicated in selected cases. It is used as a problem- solving tool when the findings of initial CT or MR angiography examination are unclear. Also, it provides intra-procedural guidance of endovascular treatment.

Disorders of the Orbit

Orbital Infections

According to the location of orbital infection relative to the orbital septum, they are classified as preseptal (periorbital) or post septal (orbital) cellulitis. The orbital septum represents the anatomic border in-between the orbit and eye lid. It consists of a fibrous band that extends from the orbital periosteum of to the tarsal plate of the eyelid. It prevents the spread of periorbital infection to the orbit proper.

The orbital septum is not detected by CT or MR imaging but could be figured as a line anterior to the globe that extends between the orbital rim margins.

1-Preseptal Cellulitis

CT is the modality of choice for diagnosis of preseptal infection. It is useful to differentiate preseptal from postseptal cellulitis. CT

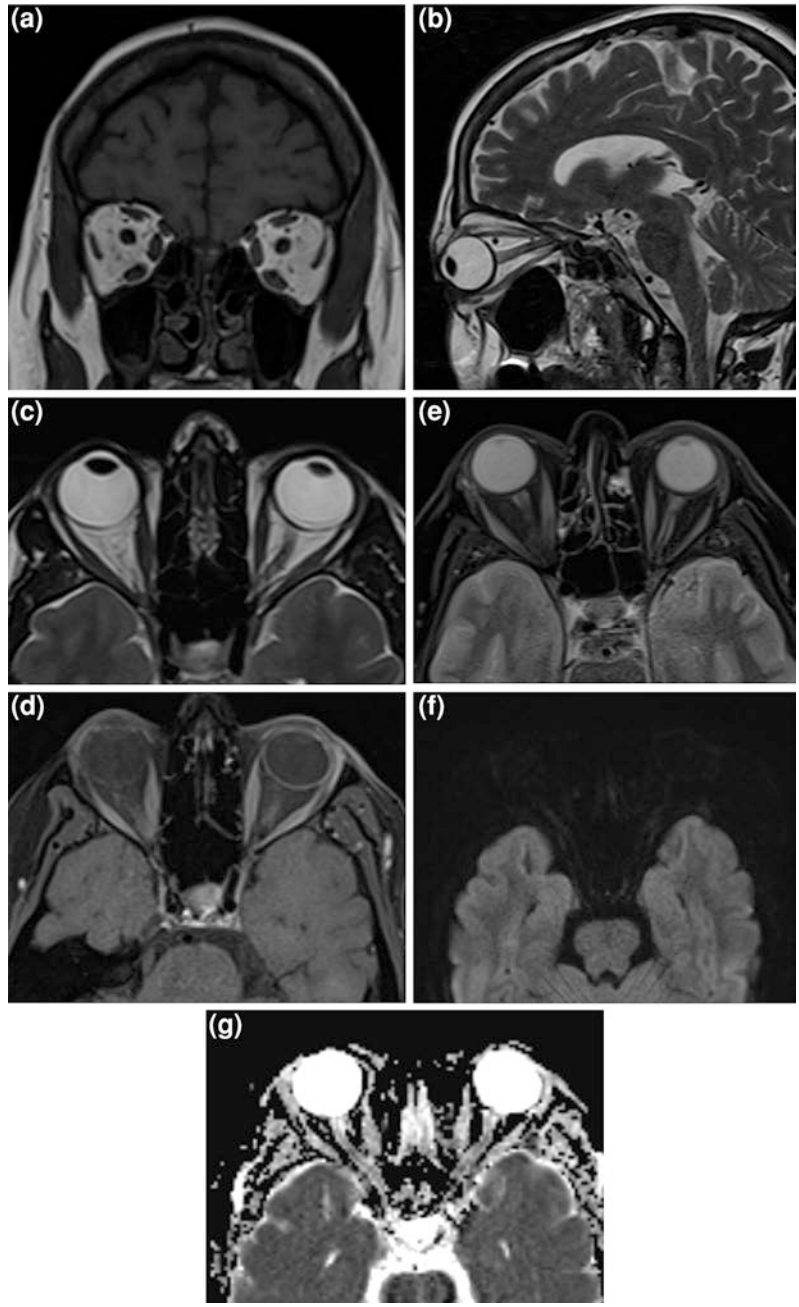

Fig. 2 Normal orbit on MR imaging **a** Coronal T1 WI, **b** Sagittal T2 WI **c–e** axial T2WI, T2WI with fat suppression, post contrast T1WI with fat suppression MR images demonstrate normal signal intensity of the orbital fat and extraocular muscles **f–g** DWI and ADC map, DWI are obtained at b value of 0, 500 and 1000

images demonstrate stranding, swelling as well as variable enhancement of the preseptal soft tissues anterior to the globe (Fig. 3). On MR, the preseptal soft tissue demonstrates iso-intense T1 and hyperintense T2 signal (Fig. 3).

Frontal sinusitis may lead to periorbital cellulitis or frontal bone osteomyelitis with

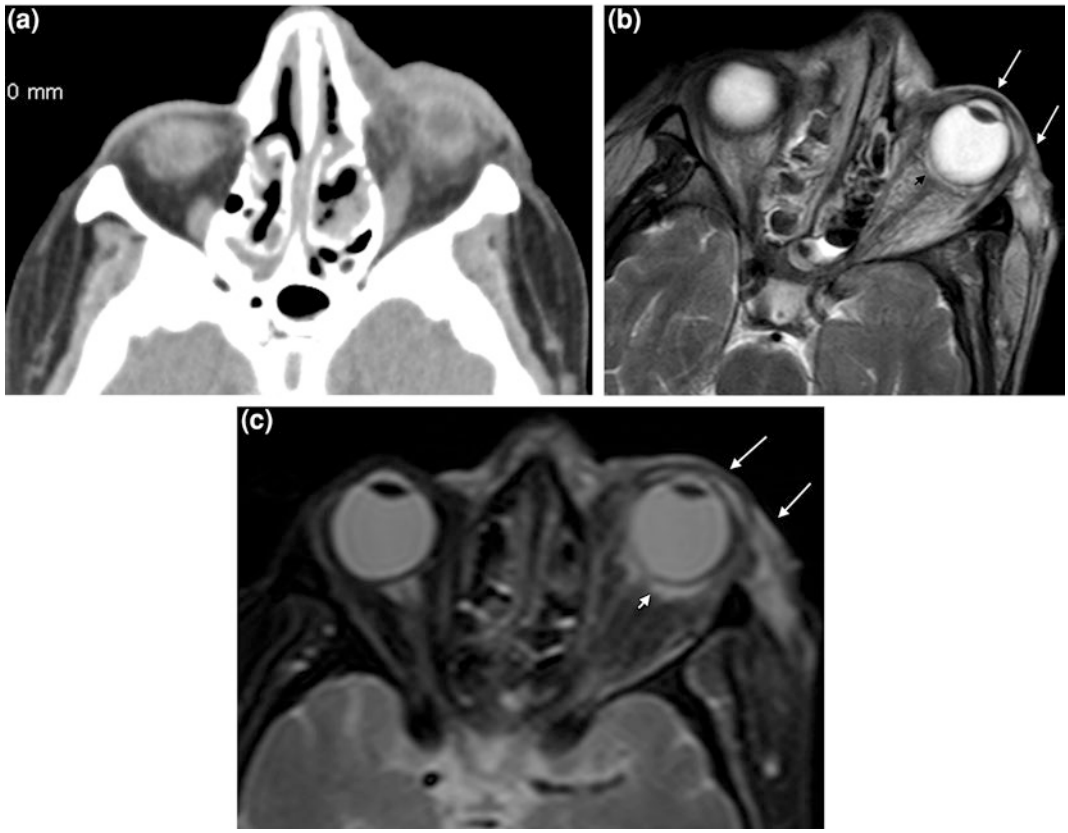

Fig. 3 Periorbital and orbital cellulitis. **a** Axial non-contrast enhanced CT image demonstrates left periorbital soft-tissue edema, extending to the left cheek with proptosis of the left eye globe. **b**, **c** Axial T2WI, and T2WI with fat suppression images demonstrate edematous swollen perseptal tissue (arrows), together with retro-ocular orbital inflammation of high T2 signal (arrow head)

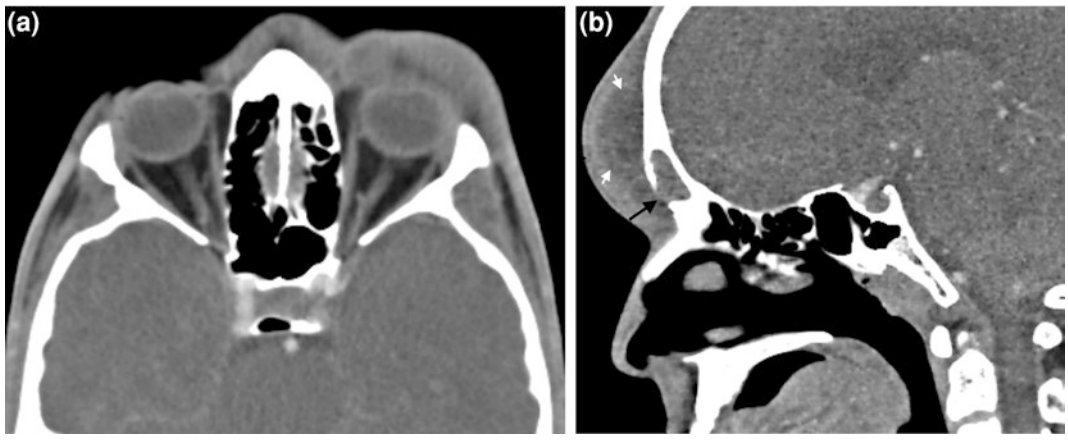

Fig. 4 Frontal sinusitis complicated by frontal osteomyelitis and Pott Puffy tumour. **a**–**b** Axial and sagittal reformatted contrast-enhanced CT images reveal opacified left frontal sinus with small defect at its anterior wall due to osteomyelitis (arrow). There is large periorbital cellulitis and extracranial abscess with an enhancing rim (arrow heads), a finding suggestive of a Pott puffy tumor. No evidence of intracranial abscess formation

development of extra-cranial abscess which is known as a Pott puffy tumor (Fig. 4).

2-Postseptal Cellulitis

According to the location of involvement, it is either extraconal, subperiosteal or intraconal.

Cross sectional images depict stranding, edema and inflammatory changes in the soft tissues posterior to the orbital septum. On MR, post septal soft tissue demonstrates hypo intense T1 and hyperintense T2 signal with post contrast enhancement. With disease progression and abscess formation, there is marginally enhancing lesion of high T2 weighted fluid signal that shows restricted diffusion.

It is essential to recognize potential complications like thrombosis of the superior ophthalmic vein or cavernous sinus as well as bacterial meningitis and intracranial abscess formation.

3-Subperiosteal Abscess

On CT, it presents as an extraconal marginally enhancing hypodense collection along the orbital wall with adjacent paranasal sinus infection. It is frequently detected along the lamina papyracea with adjacent acute ethmoidal sinusitis (Fig. 5). On MR, it appears as marginally enhancing fluid collection that shows restricted diffusion.

4-Orbital Invasive Fungal Disease

CT images demonstrate opacification of the affected paranasal sinuses with high attenuation content associated with enhancing adjacent orbital soft tissue with or without bony rarefaction or erosion (Fig. 6).

MRI is superior to CT in identifying intraorbital and intracranial involvement. The content within the involved sinuses has a heterogeneous appearance on T1 images ranging from low to high intensity; whereas on T2 images most of the content will show marked hypointensity (Fig. 6). Absent mucosal enhancement of the involved sinuses is suggestive of necrosis.

Orbital Inflammations

1-Orbital Pseudotumor: idiopathic orbital inflammatory syndrome (IOIS)

Imaging appearance of idiopathic orbital inflammatory syndrome is variable, including: stranding of the orbital fat, enlargement of the extra ocular muscles with involvement of their tendinous insertion (myositis), lacrimal gland enlargement and enhancement (Fig. 7), optic nerve sheath enhancement, a focal intraorbital mass or diffuse orbital involvement. These inflammatory masses are iso to hypointense to

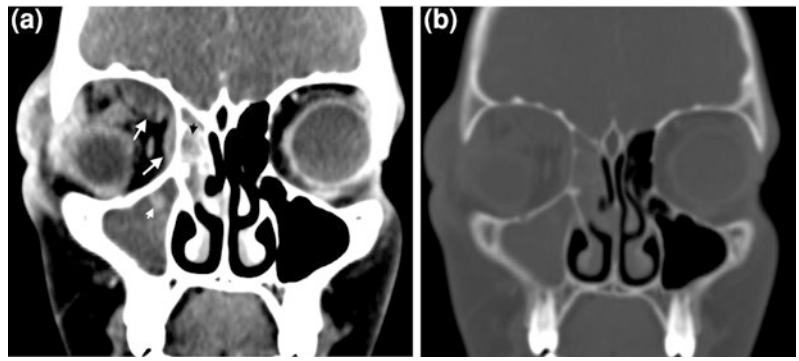

Fig. 5 A-13-year-old boy with sub-periosteal abscess Coronal CT image demonstrates right orbital extraconal superior and medial orbital marginally enhancing fluid collections, consistent with subperiosteal abscess (arrows). Opacified right ethmoidal air cells and right maxillary antrum with soft tissue density with hyperdense content likely due to fungal infection/inspissated secretion (arrow heads)

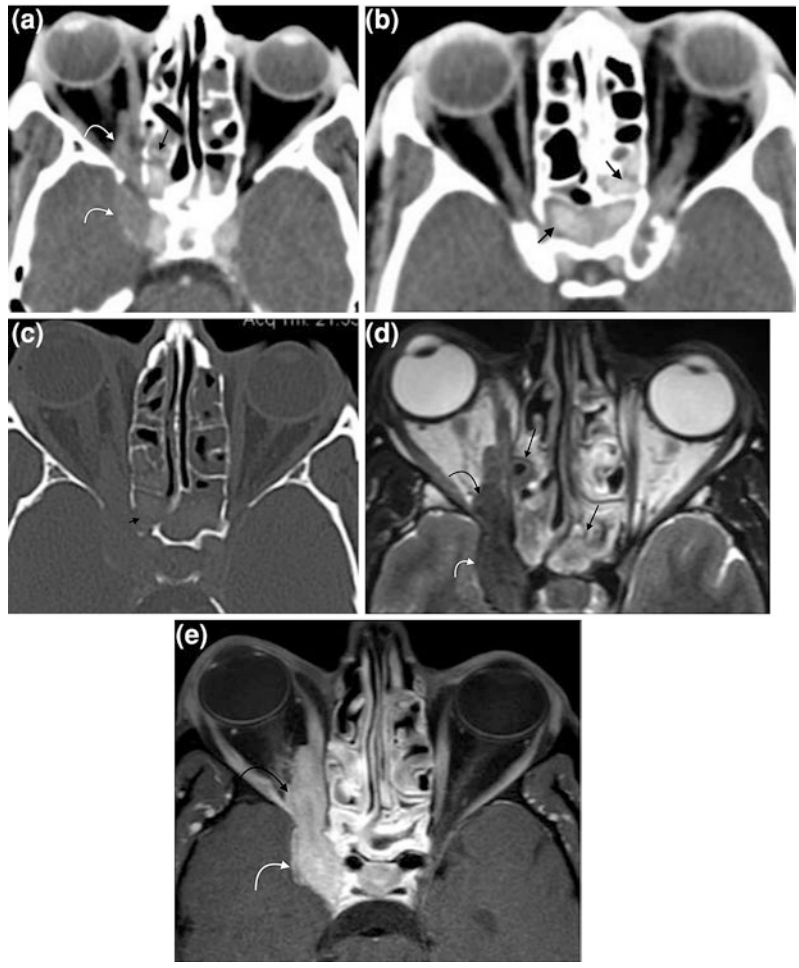

Fig. 6 Intraorbital and intracranial spread of invasive fungal sinusitis. **a–c** axial non-contrast CT images soft tissue window and bone window and **d–e** axial T2WI and axial post contrast T1WI demonstrate soft tissue opacification of the PNS with high attenuation content which appears of low signal on T2WI (arrows). Associated osseous defect at the lateral wall of the sphenoid sinus is noted (arrow head). There is an adjacent right orbital enhancing soft tissue that extends intracranially through the right optic canal to the right parasellar region (curved arrows). Note that the osseous defect is better demarcated on CT images, whereas the intracranial extension is better depicted in MR

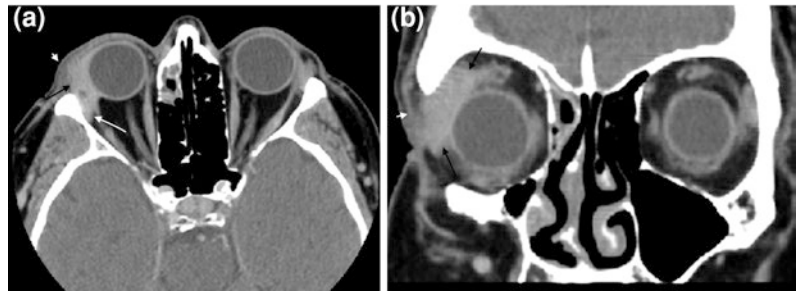

Fig. 7 A- 43-years-old female patient with orbital pseudotumour involving the lacrimal gland. **a–b** Axial and coronal contrast enhanced CT images reveal enlargement of the right lacrimal gland (arrows) with stranding of the preseptal fat (arrow head) suggestive of dacryoadenitis. The patient showed a favorable response with steroid therapy

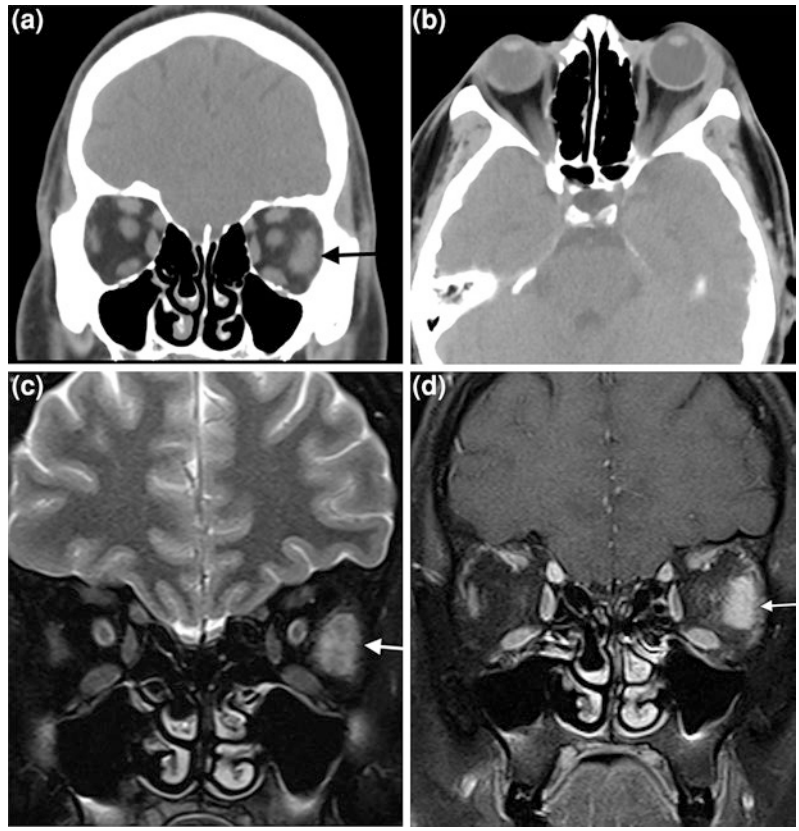

Fig. 8 Orbital pseudotumour with enlargement of the lateral rectus muscle. **a–b** Axial and coronal non-enhanced CT images, **c–d** Coronal T2WI and contrast-enhanced fat suppression T1WI demonstrate enlargement of the left lateral rectus muscle with stranding of the adjacent fat (arrows)

the fat on T2W images and hypointense on T1W images (Fig. 8).

Orbital myositis manifests as diffuse enlargement of the extraocular muscles including their tendons, with the medial rectus muscle is most frequently affected followed by the superior rectus, lateral rectus and inferior rectus.

Differential diagnostic possibilities include thyroid ophthalmopathy, lymphoma, orbital cellulitis, granulomatosis with polyangiitis (Wegener granulomatosis), and orbital cellulitis. DW imaging may be useful in differentiating orbital pseudotumour from lymphoma and orbital cellulitis. Lymphoma typically demonstrates more diffusion restriction and lower ADC than orbital pseudotumour and cellulitis.

Tolosa-Hunt syndrome is a subtype of orbital pseudotumour involving the cavernous sinus. MR images demonstrate cavernous sinus infiltrative enhancing lesion of isointense T1 and T2 signal, that extends to the orbital apex.

2-Immunoglobulin G4–related orbital disease

Immunoglobulin G4 (IgG4)-related orbital disease is a systemic inflammatory disorder of unknown etiology, characterized by IgG4 plasma cells tissue infiltration and sclerosing inflammation with high IgG4 levels.

The disease is usually bilateral, the most common primary imaging findings include enlargement of extra-occular muscle sparing the tendonous insertion, preferentially involving the lateral rectus muscles, as well as the lacrimal gland involvement (IgG4-related dacryoadenitis). Supportive findings like Intraorbital infiltrative inflammatory changes, infraorbital

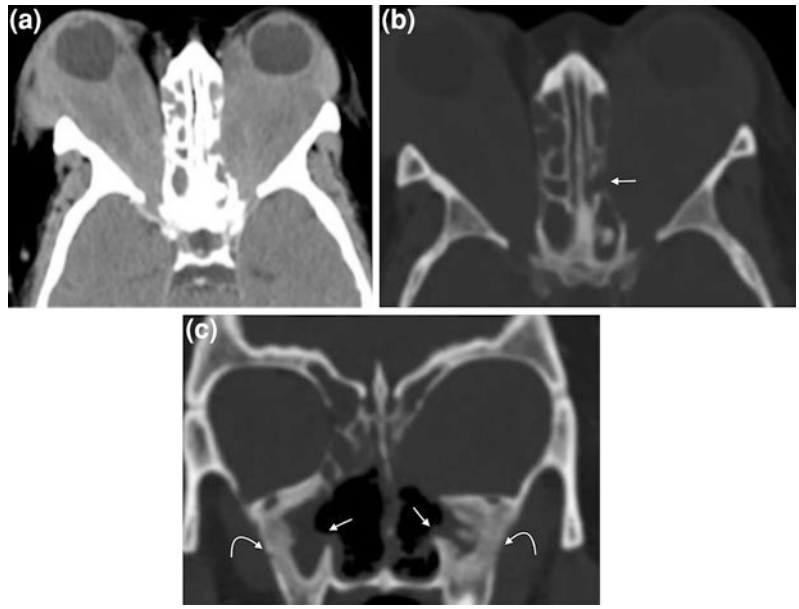

Fig. 9 Orbital involvement in a case of granulomatosis polyangiitis on CT **a–c** Non contrast axial and coronal CT images in soft tissue and bone windows showing bilateral orbital large infiltrative extra and intraconal soft tissue masses that mold to the orbital contour associated with proptosis of the eye globes. The paranasal sinuses show pansinusitis with destruction of medial wall of both maxillary sinuses, left lamina papyracea and nasal turbinates together with perforation of nasal septum, and sclerotic thickening of both maxillary antra lateral walls suggestive of chronic neo-osteogenesis

nerve enlargement, and inflammatory mucosal thickening of the paranasal sinuses may be present. The presence of a soft-tissue mass extending from the posterior orbit into the cavernous sinus and/or Meckel cave is an uncommon finding. On MRI, the affected region is typically demonstrating significant hypointense signal on T1 and T2W images with marked post contrast enhancement.

3-Sarcoidosis

Bilateral diffuse enhancement and enlargement of the lacrimal glands with infiltration of the adjacent fat are highly suggestive of sarcoidosis.

Involvement of the optic nerve sheath complex in orbital sarcoidosis is less common than lacrimal gland involvement or uveitis. MR findings include high T2 signal, thickening and enhancement of the optic nerve with linear enhancement of the optic nerve sheath (tram track sign).

4-Granulomatosis with polyangitis (GPA) (Wegener Granulomatosis)

On imaging, nonspecific mass-like inflammation may involve any of the soft tissues of the orbit. Lacrimal gland involvement is rare, presented as unilateral lacrimal gland enlargement due to enhancing soft tissue mass. Associated nasal septum destruction together with features of chronic sinusitis such as extensive mucosal thickening, polypopsis and osseous sclerosis can be found (Fig. 9).

5-Thyroid associated orbitopathy (TAO)

Cross-sectional imaging typically demonstrates spindle-shaped extraocular muscle enlargement with sparing of the tendinous insertions. The inferior rectus is most frequently involved, followed by the medial, superior and lateral rectus muscles. These findings are frequently bilateral and symmetric (Fig. 10); nevertheless, unilateral involvement can occur (Fig. 11).

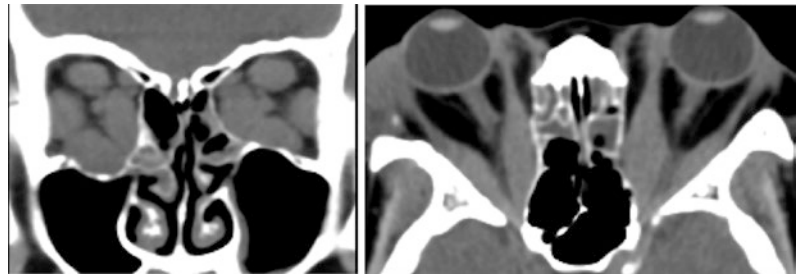

Fig. 10 Bilateral thyroid ophthalmopathy in a 40-year-old female. **a**, **b** Coronal and axial CT images demonstrate bilateral fusiform enlargement of the extraocular muscles sparing the tendinous insertion

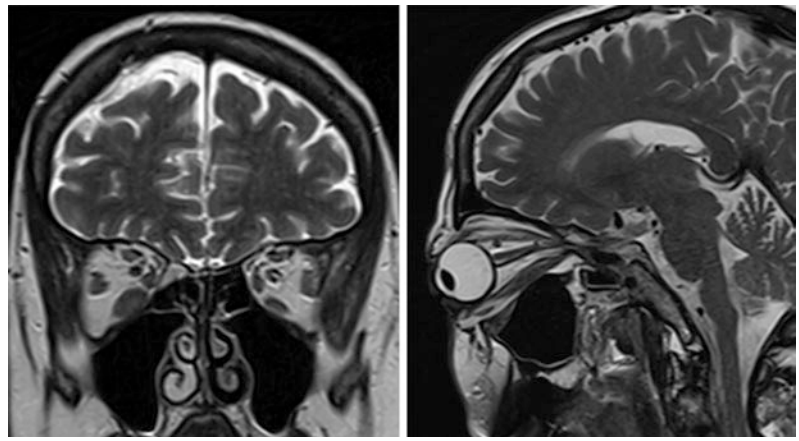

Fig. 11 Unilateral thyroid ophthalmopathy in a-35-year-old female. **a**, **b** Coronal and sagittal T2W images demonstrate fusiform enlargement of the right inferior rectus with enlargement of the muscle belly and sparing of its tendenious insertion

On MR imaging, the involved muscles may demonstrate T2 hyperintensity and enhancement of the affected muscles due to inflammation. In Chronic phase, there are atrophy and fibrosis of the extraocular muscles and intramuscular fat deposition. Additionally, there may be increased orbital fat and proptosis, together with stretching of the optic nerve, tenting of the posterior globe. Enlargement of the lacrimal gland and eye lid edema are rarely seen.

Neoplastic

1-Dermoid and epidermoid inclusion cysts

Clinical examination is usually sufficient for the diagnosis of most superficial dermoid cysts. On US, they appear as capsulated well circumscribed lesions with low-reflectivity contents.

Most dermoid inclusion cysts have the fat attenuation and signal intensity because of their sebaceous secretions. On CT, they appear hypodense with their CT attenuation value ranges from −60 to −90 HU (Fig. 12). Fat-fluid level and wall calcification may be seen. On MR images, dermoid cysts demonstrate hyperintense signal as the subcutaneous fat on T1WI and T2WI, with loss of signal on fat-suppressed images (Fig. 13). Rim enhancement may be infrequently seen on both CT and MR images.

Epidermoid inclusion cysts are usually similar to water or CSF on both CT and MR, likely due to their proteinaceous contents. Measurement of their CT attenuation value

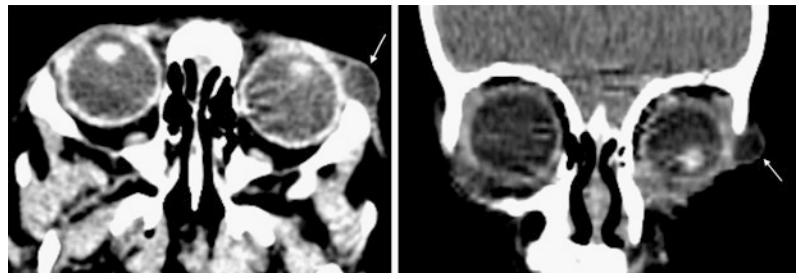

Fig. 12 Paraorbital preseptal dermoid cyst in an infant girl. **a–b** Axial and coronal CT images show a small well-defined subcutaneous hypodense fat density lesion seen at the supero-lateral aspect of the orbit along the fronto-zaygmoatic suture (arrow)

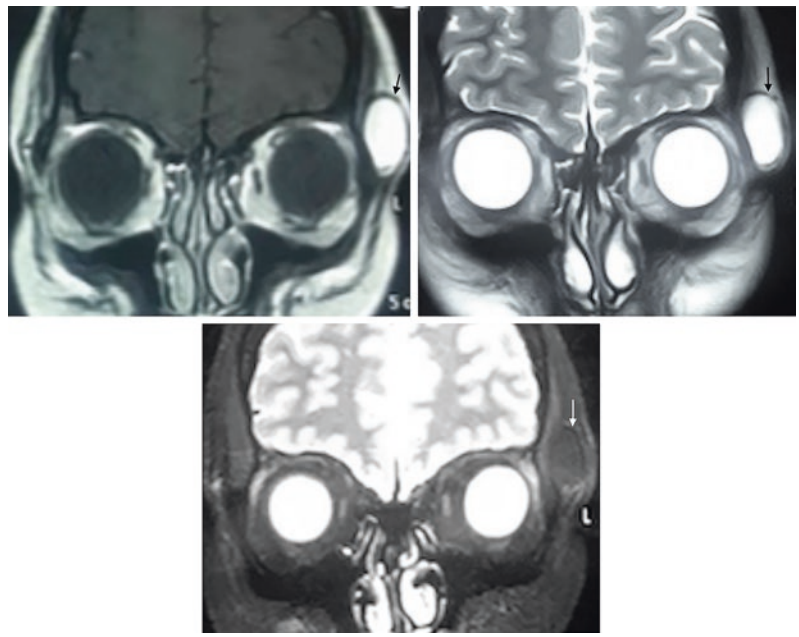

Fig. 13 Superficial paraorbital dermoid on MR images. **a–c** Coronal T1WI, T2WI and T2WI with fat suppression images demonstrate superficial ovoid shaped mass at the superolateral aspect of the orbit. The mass has high T1 and T2 signal with signal drop on fat suppression sequence(arrows)

shows slightly higher attenuation coefficient compared with that of CSF. On MR, epidermoid cysts demonstrate hypointense signal and hyperintense on T1 and T2WI respectively. However, their high signal is not suppressed in FLAIR WI. Additionally, they show high signal on DWI due to a combination of restricted diffusion and T2 shine through) and reduced signal on ADC map.

2-Optic nerve glioma (ONG)

Contrast-enhanced MRI is the imaging modality of choice for evaluation of the optic pathway gliomas. They are typically iso- to hypointense signal on T1WI and have hyperintense signal on T2WI. Most of the tumors enhance homogeneously, however, they may demonstrate peripheral enhancement with central necrosis or cyst formation (Figs. 14 and 15).

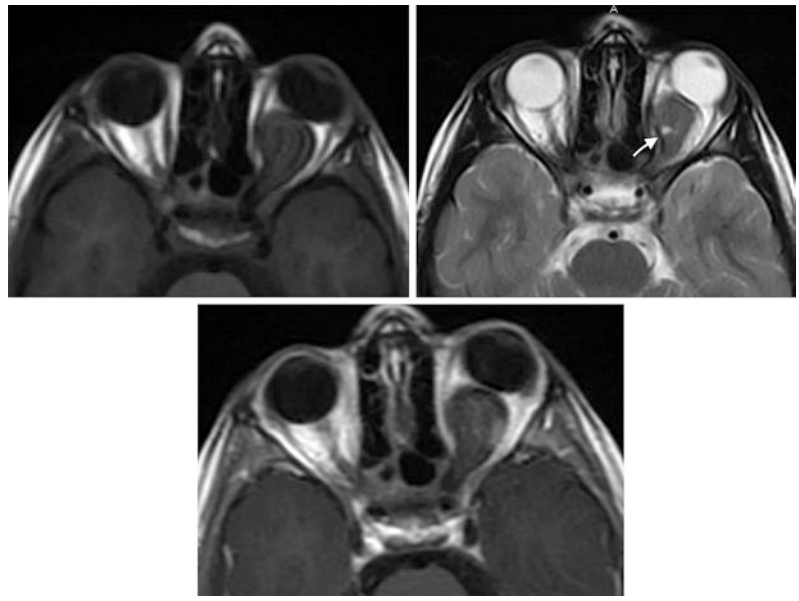

Fig. 14 Isolated optic nerve glioma in a 6-years old boy. **a–c** Axial T1, axial T2WI and post contrast T1WI MR images demonstrate left optic nerve globular shaped mass of hypointense T1 and hyperintense T2 signal with mild post contrast enhancement. Note the presence of small area of cystic degeneration inside the lesion (arrow)

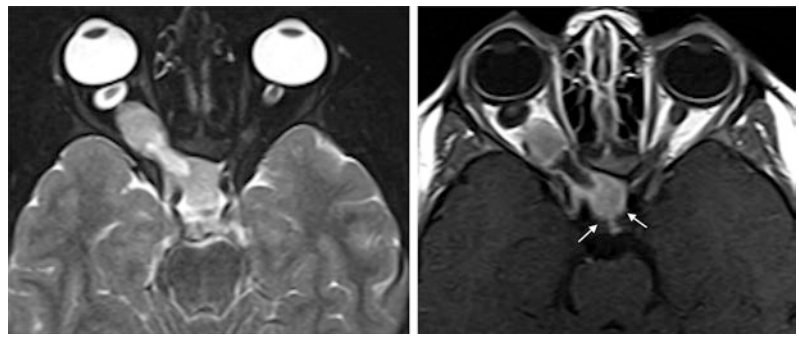

Fig. 15 Optic nerve glioma with chiasmatic extension on MR imaging. **a**, **b** Axial T2WI and post contrast T1WI MR images demonstrate right optic nerve oblong shaped lobulated heterogeneously enhancing mass extending through the widened optic canal into the right side of chiasm (arrows)

The appearance of optic nerve gliomas is different in patients with and without NF-1. Patients without NF-1 have unilateral fusiform enlargement of the optic nerve. In contrast, patients with NF-1 tend to have bilateral optic nerve gliomas with intracranial involvement. Moreover, in patients with NF-1, the intracranial extension of the tumour manifests as diffuse enlargement of the chiasm. Whereas, in non-NF1 patients there is globular chiasmatic-hypothalamic mass with central cystic component.

3-Optic nerve sheath meningioma (ONSM)

Primary ONSM typically involve the intraorbital and intracanalicular segments of the optic nerve (Fig. 16). Secondary lesions are the most common type of orbital meningiomas. They represent intraorbital extensions of intracranial meningiomas usually greater wing of sphenoid (Fig. 17).

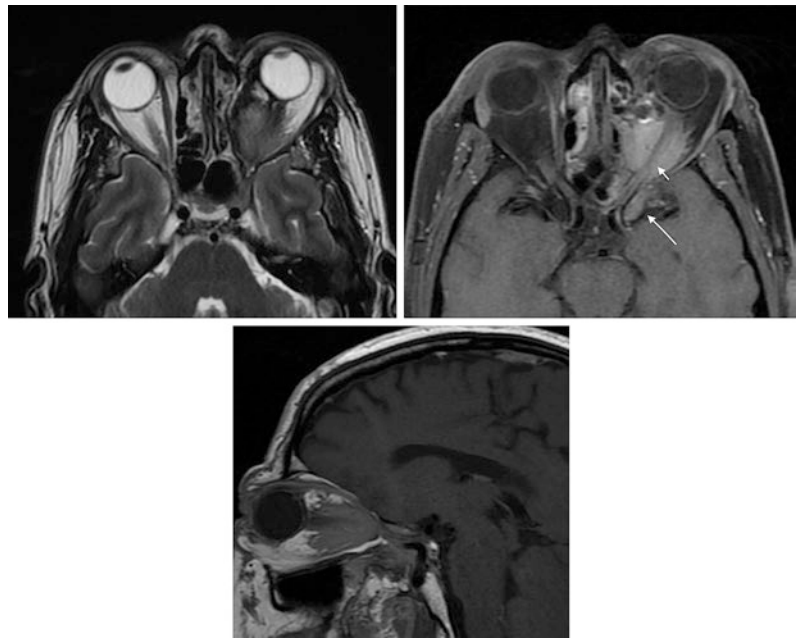

Fig. 16 Optic nerve sheath meningioma in a 55 years old patient. **a–c** Axial T2WI image (**a**), Axial and sagittal contrast-enhanced T1-weighted fat-suppressed images (**b** and **c**) demonstrate left intraconal enhancing lesion along both sides of the optic nerve with typical tram track sign (short arrow). The tumor involves the intraorbital and intracanalicular portions of the left optic nerve and extends intracranially through the optic nerve canal (long arrow)

Non-enhanced CT (NECT) commonly shows tubular thickening of the optic nerve sheath and calcifications which are detected in 20–40% of cases. Hyperostosis and enlarged optic nerve canal may be also seen.

Although MRI is particularly invaluable in the assessment of intra canalicular lesions as well as intracranial extension of ONSM however, it is less sensitive than CT for detection of calcification.

On MRI these lesions demonstrate isointense signal as the optic nerve on T1W and T2W images. Contrast-enhanced T1W images with fat suppression demonstrate a tubular enhancing lesion around the optic nerve with characteristic tram track sign on axial images and target sign on coronal images (Fig. 16). Apart from this classic tubular growth pattern on either side of the nerve, ONM may appear as a fusiform or eccentric mass.

The presence of calcification favors the diagnosis of meningioma over optic nerve glioma. Furthermore, ONG is more frequent in children, commonly associated with other manifestations of NF-1, and may show intracranial extension along the optic pathways.

The classic tram track/target sign may be also seen in other conditions such as inflammatory pseudotumour, lymphoma and leukemia. Also, it can be caused by CSF tumor seeding into the subarachnoid space due to the communication of the optic nerve sheath with the intracranial subarachnoid space.

4-Sphenoid wing meningioma (Spheno-orbital meningioma, Meningioma en-plaque of the sphenoid wing).

On CT the intraosseous component appears as bone hyperostosis and expansion (Fig. 18). On MRI, it has extremely hypointense signal on T2W images. Post contrast fat T1W images can detect meningeal enhancement, delineating the dural and orbital involvement (Fig. 19).

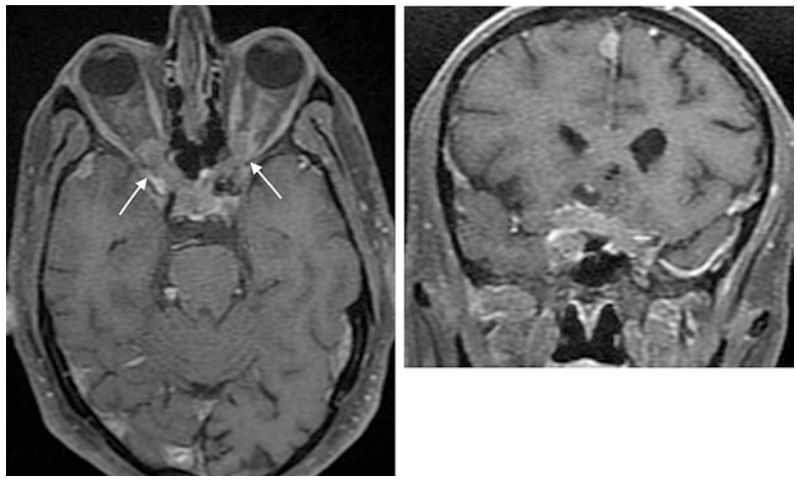

Fig. 17 Bilateral intraorbital extension of suprasellar meningioma. **a–b** Axial and coronal post contrast T1W images with fat suppression reveal suprasellar meningioma extending through the optic canals into both orbits (arrows). Note the presence of multiple small sized convexity meningiomas

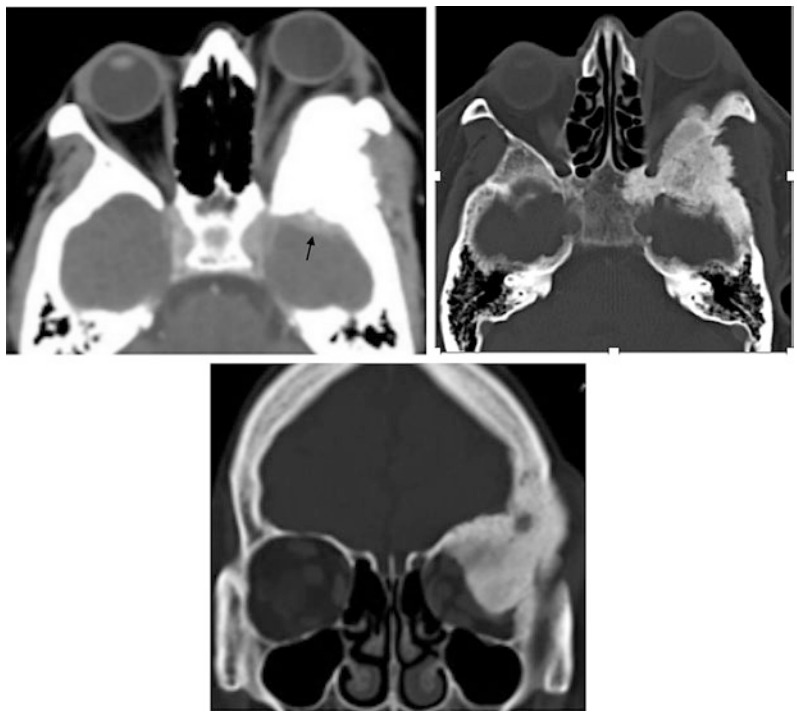

Fig. 18 Sphenoid wing en plaque meningioma on CT. **a–c** Non-contrast axial and coronal CT images in soft tissue and bone windows demonstrate expansion and sclerosis of the left greater wing of sphenoid, left orbital plate of frontal bone and squamous temporal bone. Associated is significant encroachment on the left orbital cavity with left proptosis. There is a small extra-osseous intra-cranial extra-axial enhancing soft tissue sheet at the anterior left temporal region (arrow)

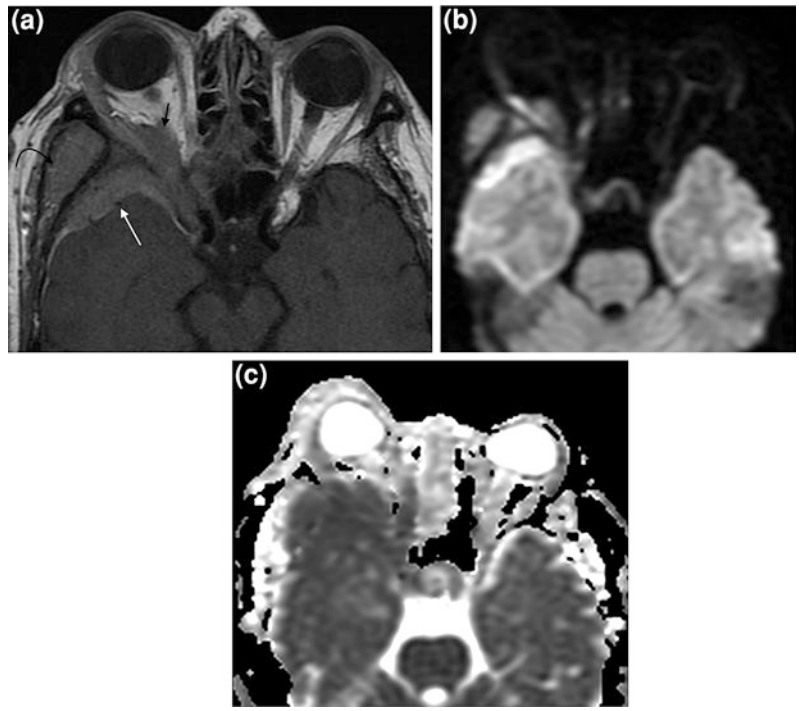

Fig. 19 Sphenoid wing meningioma with large intra orbital, intracranial and extracranial extension. **a** Axial contrast-enhanced T1-weighted MR image demonstrates an enhancing lesion centered on the right greater wing of sphenoid. The lesion extends into the intra and extra-conal spaces, displacing the optic nerve and lateral rectus muscles with associated mild proptosis of the eye globe (short arrow). There is an intracranial dural based component (long arrow) as well as extracranial component (curved arrow). **b** and **c** DWI and ADC images demonstrate diffusion restriction of the lesion

5-Orbital lymphoproliferative disorders

Whole body staging using PET-CT is necessary when orbital lymphoma is diagnosed. Lymphoma is usually bilateral. It can occur anywhere in the orbit; however, the most frequent sites of involvement include the anterior extra conal space, lacrimal gland, conjunctiva, and eyelid. CT most commonly reveal a homogenous hyperdense lacrimal gland mass (Fig. 20). Bony destruction is usually absent and, if present it is suggestive of aggressive histology.

MRI demonstrates a lesion of isointense T1 and hypointense T2 signal with strong post contrast enhancement. Isolated extraocular muscles affection or ill-defined diffuse orbital infiltration may be detected (Figs. 20 and 21).

6-Plexiform neurofibroma

Enlargement of the bony orbit is usually seen with large lesions. Extension of the lesion beyond the orbit leads to widening of the fissures along the orbital apex. Sphenoid wing dysplasia may be another manifestation of NF-1. They may coexist with optic nerve glioma.

On cross-sectional images, plexiform neurofibromas appear as serpentine soft-tissue masses with heterogeneous contrast enhancement. Lesions extend through the superior orbital fissure, produce cavernous sinus enlargement. On MR imaging, they demonstrate hypointense signal slightly higher than muscle on T1WI; whereas, on T2W images, they are typically hyperintense. Frequently, the lesions are heterogeneously bright on T2W images, showing central hypointensity, which represents the fibrous component of the tumor, with the markedly hyperintense peripheral portion consists of a myxoid matrix; this has been referred to as the "target sign" (Fig. 22). Thus, on T2W images, the presence of a lesion with lobules that show characteristic target sign is pathognomonic of plexiform neurofibroma.

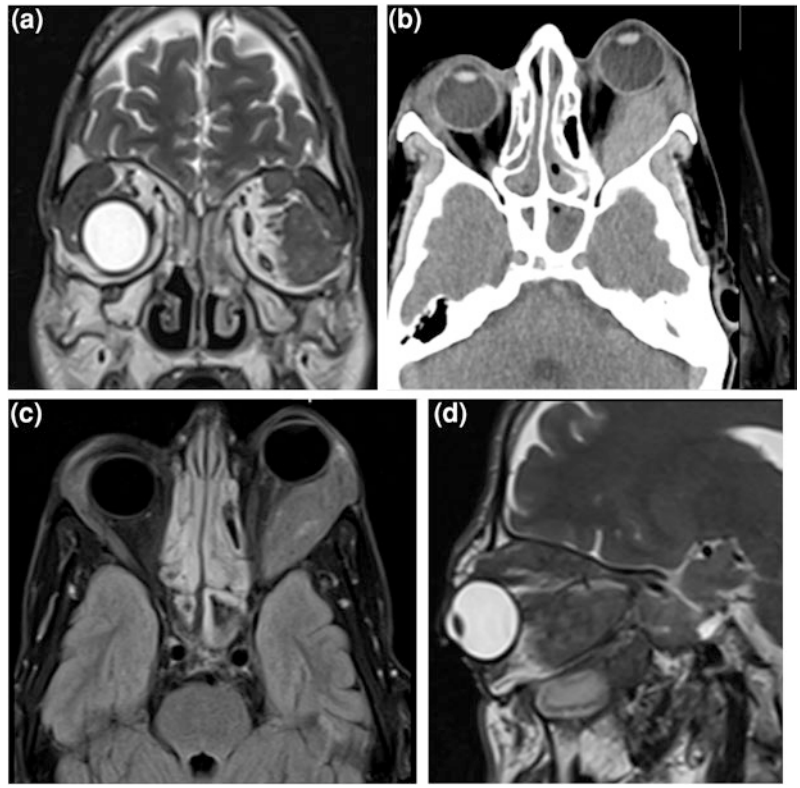

Fig. 20 MR and CT images for a case of lymphoma. **a**, **b** Coronal and sagittal T2 WI and **c** FLAIR WI with fat suppression showing bilateral enlargement of both lacrimal glands larger on the left side with left intraorbital extraconal masses of isointense T2 signal. These lesions appear hyperdense on the unenhanced CT scan (**d**)

7-Rhabdomyosarcoma (RMS)

Although orbital rhabdomyosarcomas are aggressive tumors, there may be no bone destruction at presentation or there may be only bone scalloping thus mimicking a more slowly growing lesion. Bony destruction more frequently occurs with paranasal rhabdomyosarcomas.

Imaging of rhabdomyosarcoma usually require the combined use of CT and MR imaging. CT is particularly useful for detection of bone involvement; whereas, MR imaging is sensitive for the identification of intracranial extension and invasion of the adjacent paranasal sinuses in aggressive tumors.

They are identified on CT as homogeneous, well-defined extraconal masses, that are isodense to slightly hyperdense relative to extraocular muscles (Fig. 23). On MRI, these tumors are isointense to the muscle on T1WI, and slightly hyperintense on T2WI and show moderate to marked contrast enhancement (Fig. 24). In later stages of the disease, their appearance may be more heterogeneous due to necrosis or hemorrhage. Thickening and enhancement of the eye lid is a common finding, even without tumor extension to the eyelid.

Rhabdomyosarcomas often show marked diffusion restriction due to high cellularity of the lesions. However, they may show moderate restriction depending on the presence of edema and necrosis. Resolution of the restricted diffusion indicates favorable response to therapy.

8-Orbital metastases in adults

Imaging findings range from a well-defined focal lesion to diffusely infiltrating mass that may be intra or extra conal. On CT, lesions

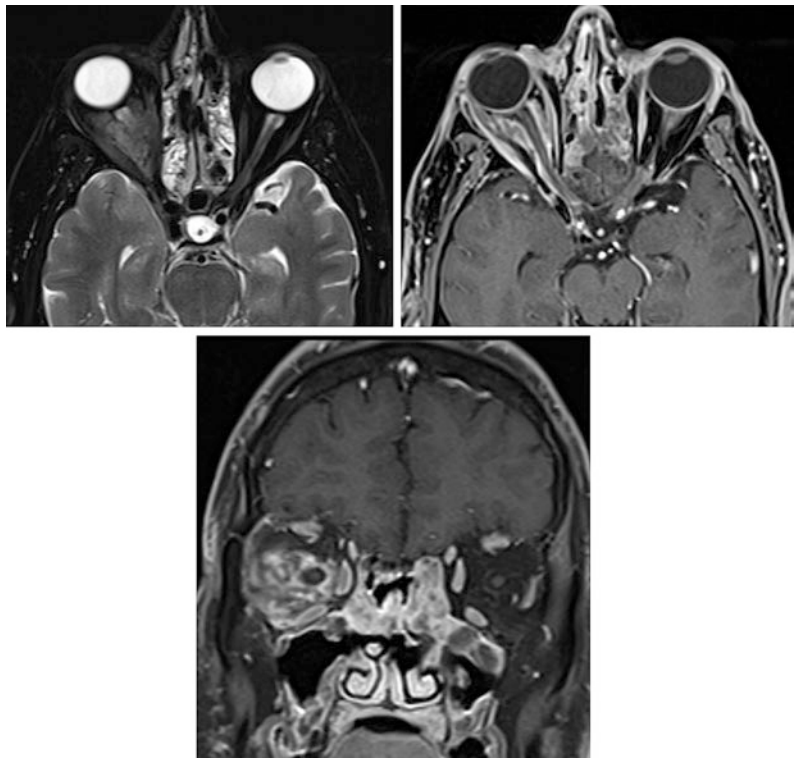

Fig. 21 A-65 years old female patient with right orbital lymphoma. **a–c** Axial T2WI, axial and coronal T1WI with fat suppression MR images demonstrate enhancing right orbital intraconal infiltrative soft tissue mass extending along the optic nerve. The mass has instead of shows low T2 signal and intense homogenous enhancement showing tram track/target sign

are isodense to muscles, with homogeneous post-contrast enhancement. Metastatic disease involving the retrobulbar fat is usually hypointense on T1WI, intermediate to low on T2WI (Fig. 25). Metastases from scirrhous breast cancer usually demonstrate very low T2 signal reflecting fibrotic nature of the lesion. Extraocular muscle involvement presents as nodular enlargement of the muscles that may spare their tendinous insertion (Fig. 26).

9-Orbital metastases in children

On CT and MRI, neuroblastoma metastases appear as extraconal masses that usually involve the lateral orbital wall. Adjacent permeative bone destruction and bony spicules of the lateral orbital wall and orbital roof can be well demonstrated (Figs. 27 and 28). On CT, the mass is relatively hyperdense to the muscles, and small calcific foci may be seen within.

On MRI, orbital neuroblastomas typically demonstrate low and high signal intensity relative to the muscle on T1WI and T2WI respectively. They may have inhomogeneous appearance caused by necrosis or hemorrhage with heterogeneous post contrast enhancement (Fig. 28).

The tumor may extend to the infra-temporal fossa, face, and intracranially; however, a preseptal extension is uncommon.

10-Lacrimal glands tumours

Pleomorphic Adenomas (benign mixed tumor)

CT and MRI demonstrate a well-circumscribed homogenous lacrimal fossa soft tissue mass. On MR imaging, the lesion is hypointense on T1WI, hyperintense on T2WI, with vivid enhancement. Larger lesions may appear heterogeneous caused by cystic degeneration, necrosis or hemorrhage.

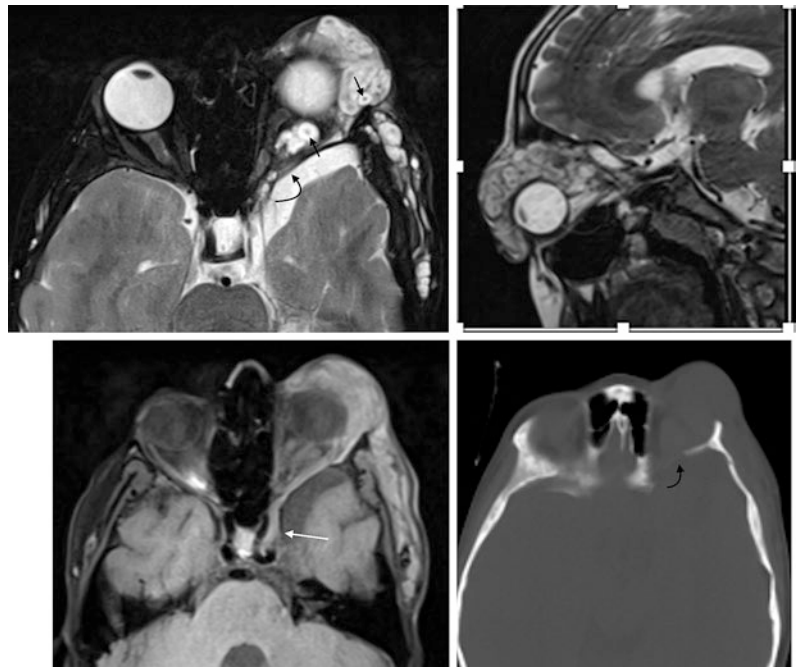

Fig. 22 A 12 years old boy with plexiform neurofibroma of the orbit and the left temporalis fossa. **a**, **b** Axial and sagittal T2WI demonstrate marked expansion of the left orbit by an infiltrative lobulated pre and post septal intraorbital lesion that extends into the left temporalis fossa. The mass appears lobulated with each lobule show slightly high signal intensity on the periphery and low signal intensity in the center. This is the typical pattern of plexiform neurofibroma (*arrows*). **c** Axial post contrast T1WI with fat suppression demonstrate mild homogenous enhancement of the lesion. The neurofibroma also extends posteriorly into the cavernous sinus (arrow). There is dysplasia of the left greater wing of the sphenoid with widened subarachnoid space at the left temporal region and extension of the temporal lobe anteriorly into the area of the sphenoid wing dysplasia (curved arrow). The bone defect is clearly seen in CT image (curved arrow) (**d**)

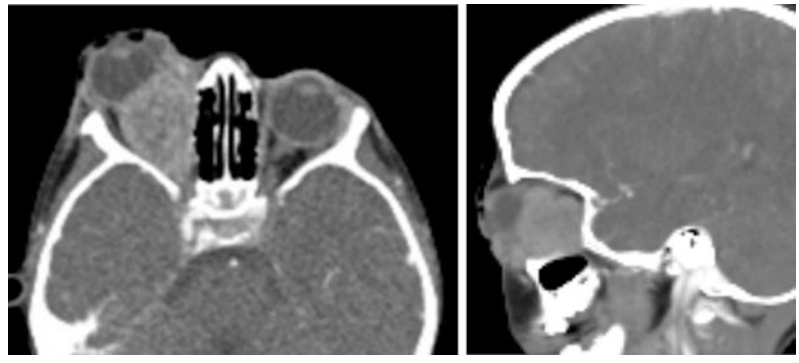

Fig. 23 A 4 years old boy with rhabdomyosarcoma of the right orbit. **a**–**b** Axial and sagittal post contrast CT images reveal right intra-orbital homogenously enhancing lesion with associated marked proptosis of the right eye globe

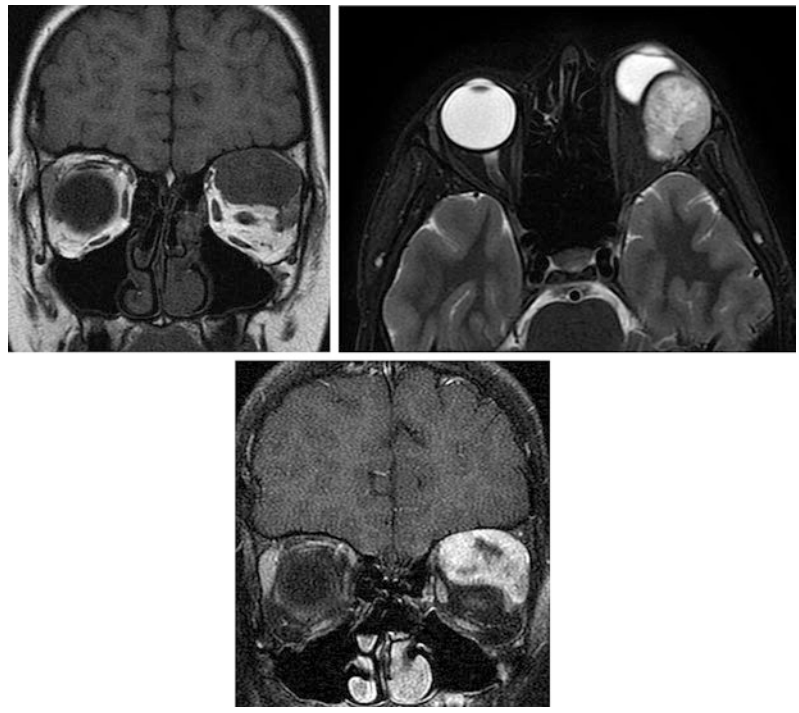

Fig. 24 Rhabdomyosarcoma on MR imaging. **a–c** Coronal T1WI, axial T2WI and post contrast T1WI with fat suppression demonstrate left orbital extraconal mass of isointense signal on T1WI (**a**), hyperintense signal on T2WI (**b**) and homogenous post contrast enhancement (**c**)

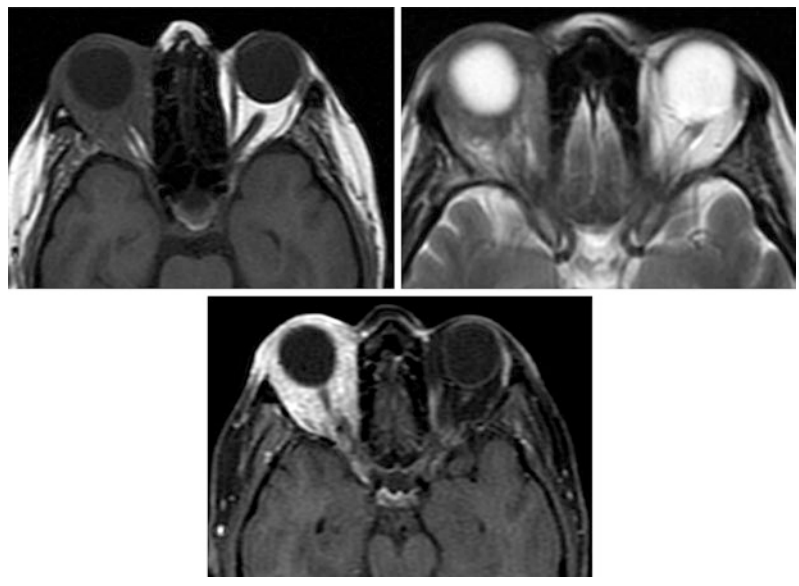

Fig. 25 A 42 years old female patient with orbital metastases from breast cancer. **a–c** Axial T1, T2 and post contrast T1WI with fat suppression demonstrate right orbital infiltrative mass lesion involving the periorbital preseptal soft tissue, intra-conal orbital fat and extra-occular muscles. The mass is hypointense on T1WI and T2WI with mild post contrast enhancement

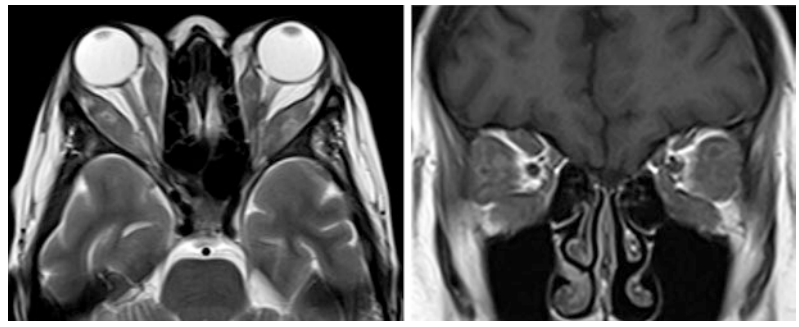

Fig. 26 A 52 years old female patient with bilateral extraocular muscles metastases from breast cancer. **a** Axial T2WI, **b** Coronal post contrast T1WI showing bilateral enlargement of the extra-ocular muscles sparing their tendinous insertion. They demonstrate heterogeneous high signal on T2WI and mild post contrast enhancement

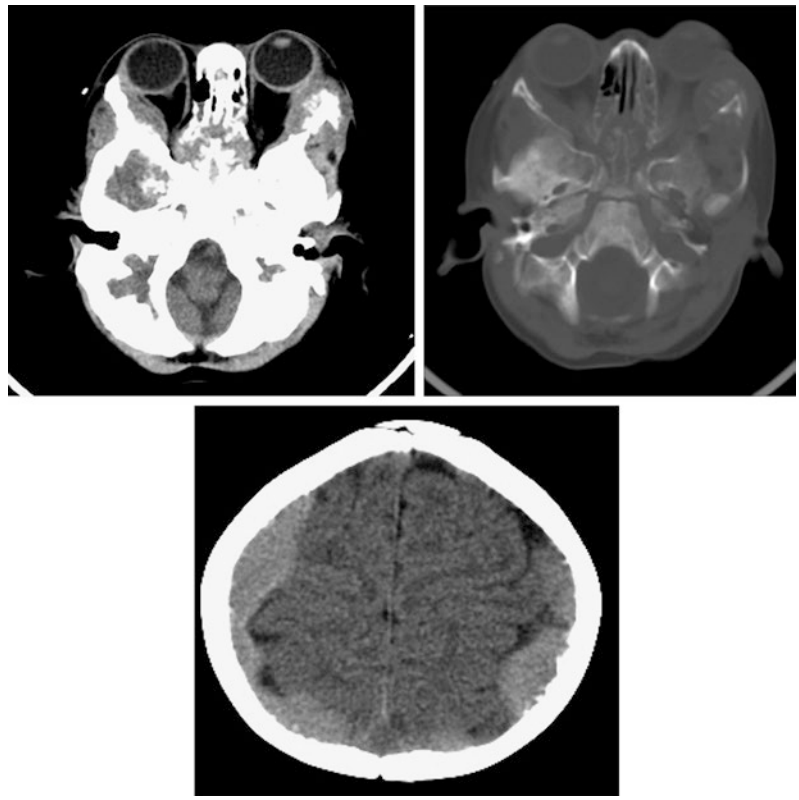

Fig. 27 Orbital and calvarial metastatic neuroblastoma as first presentation of neuroblastoma in a 4 years old girl. Axial CT images in soft tissue (**a**) and bone window (**b**) showing bilateral slightly hyperdense soft–tissue masses along the lateral orbital wall with associated bony speculations. **c** Axial image at higher level demonstrates bilateral fronto-parietal extradural metastases

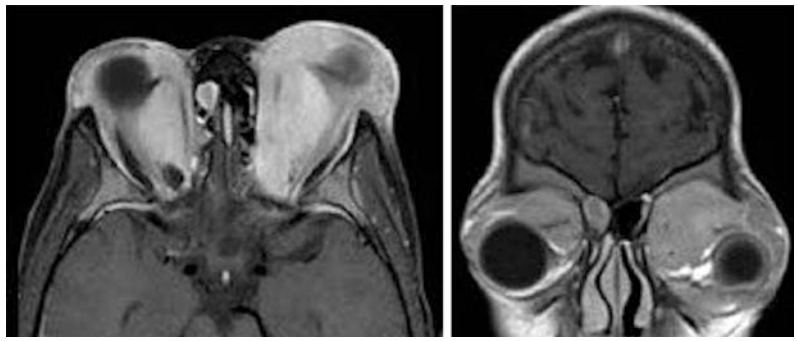

Fig. 28 Metastatic neuroblastoma on MR imaging. **a** Axial and coronal post contrast T1WI with fat suppression demonstrate bilateral orbital extra and intraconal enhancing soft tissue masses with proptosis of both eye globes

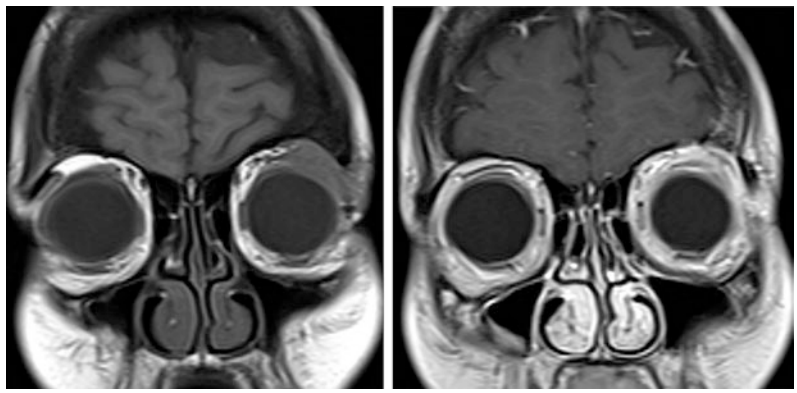

Fig. 29 Adenoid cystic tumor of the left lacrimal gland in a 48 years old male. **a**, **b** Coronal pre and post contrast T1WI demonstrate left lacrimal gland mass of isointense signal with mild homogenous enhancement

Because of its slowly growing nature, bone remodeling of the lacrimal fossa without bony destruction may be seen.

Adenoid Cystic Carcinoma

On imaging, adenoid cystic carcinoma appears similar to pleomorphic adenoma. Nevertheless, the presence of infiltrative and ill-defined margins as well as bony erosion, and calcification favor the diagnosis of carcinoma (Fig. 29).

Recently, DWI and ADC value measurement were shown to be useful in distinguishing benign from malignant lacrimal gland lesions. As malignant lesions demonstrate lower apparent diffusion coefficient values compared to benign ones.

Mucoepidermoid Carcinoma

On cross-sectional imaging, it resembles adenoid cystic carcinoma and appears an irregular, infiltrative mass with calcification and bony invasion.

Vascular Abnormalities

1-Capillary hemangiomas

On Doppler US examination, hemangiomas are hyperechoic. They are hypervascular lesions with marked intralesional flow, low arterial resistance as well as increased arterial and venous flow velocity.

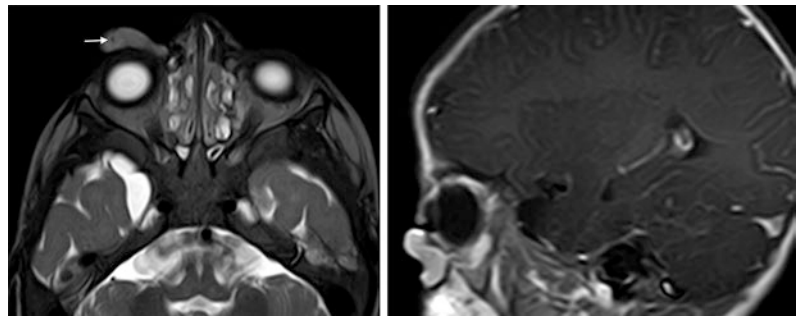

Fig. 30 4 months old boy with small lower eye lid capillary (infantile) hemagngioma. **a** Axial T2WI demonstrates hyperintense lesion in the lower eye lid confined to the preseptal space with internal signal void likely represent high flow vessels (arrows). **b** Post contrast sagittal T1W image demonstrates intense enhancement of the lesion

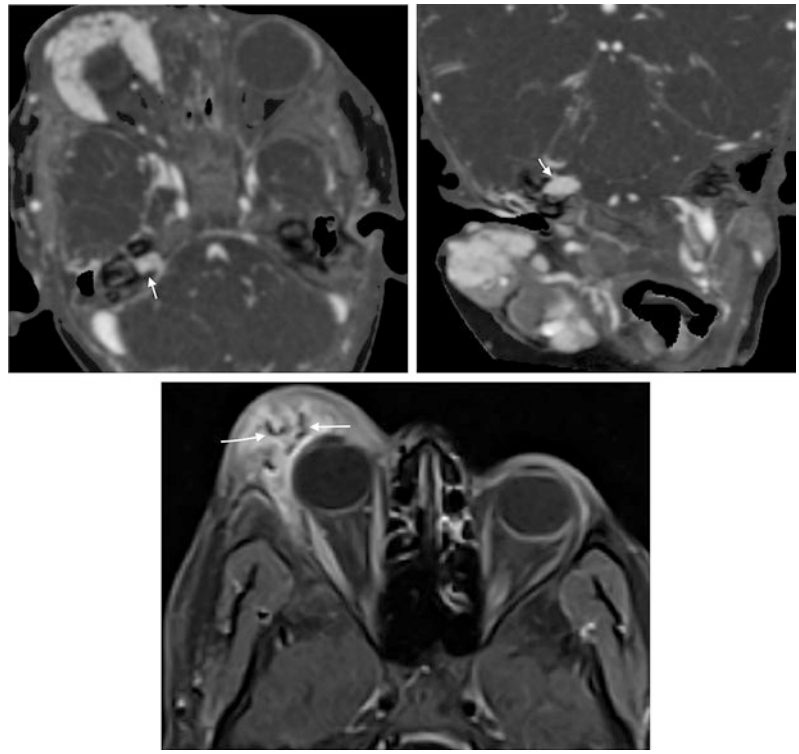

Fig. 31 A 4 months old boy with periorbtial capillary (infantile) hemangioma. **a**–**b** MR axial and coronal images demonstrate right periorbital hemangioma, with similar hemangiomas are noted involving the right parotid gland and a small intracranial hemangioma at the right CPA region (short arrow). **c** Post contrast T1WI with fat suppression showing intense enhancement of the periorbital hemangioma with intralesional flow voids (arrows)

On both CT and MRI, capillary hemangiomas are lobulated lesions that enhance intensity after intravenous injection of contrast material. The lesions internal structures are not well identified on CT while MRI is the best imaging modality for characterization of hemangiomas (Figs. 30, 31 and 32).

Capillary hemangiomas demonstrate intermediate signal on T1W images and hyperintense signal on T2W images. The presence of lobules

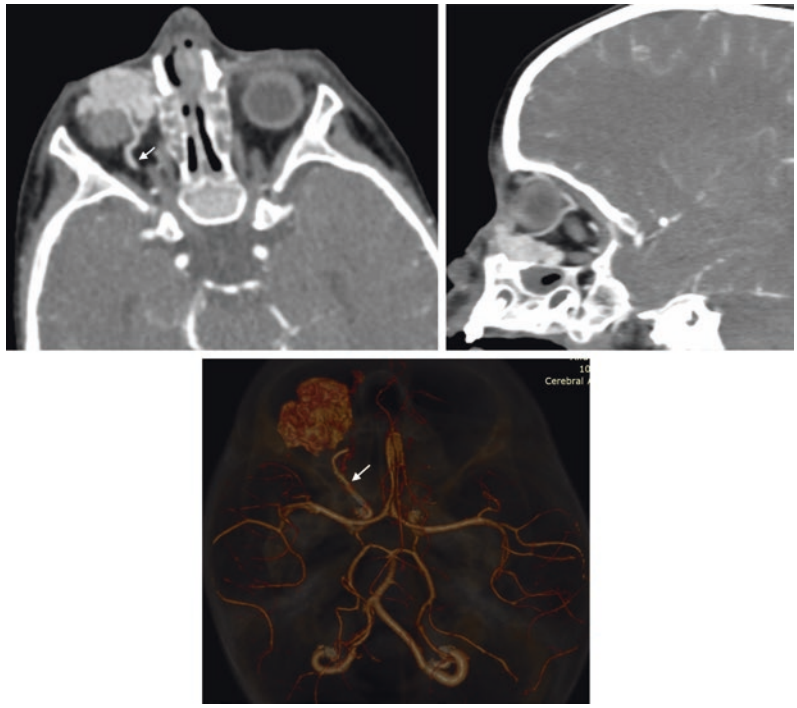

Fig. 32 A 6 months old boy with right orbtial capillary (infantile) hemangioma. **a**, **b** Post contrast CT images in axial and sagittal planes demonstrate extraconal avidly enhancing lesion, with prominent vessels seen at the periphery of the lesion representing feeders from the enlarged ophthalmic artery (arrow) **c** CTA reconstructed image showing dilated right ophthalmic artery (arrow)

among thin septa, associated with intra-lesional and perilesional flow voids, are characteristic (Fig. 31).

During involution phase, there is diminished vascularity of the lesion together with a decrease in the size of the tumor lobules, and increase in fibro-fatty tissue in between. Consequently, involuting hemangiomas are heterogeneous with fibro-fatty replacement and less prominent enhancement.

Associated bony changes as expansion of the orbital cavity by large hemangiomas or focal bone scalloping by small lesions are well demonstrated on both CT and MR imaging.

2-Venous Vascular Malformations

Cavernous Malformations

They are commonly seen in the middle third of the orbit, more frequently in the intraconal space lateral to the optic nerve. They have a propensity to surround and displace adjacent structures, such as optic nerve and extraocular muscles, rather than direct invasion. Bony expansion and remodeling of the orbital walls may be present; however, bone erosion is rare.

The typical appearance of a cavernous malformation on US is a well-circumscribed lesion with medium to high internal reflectivity and absent internal flow.

On CT and MR, cavernous malformations are typically homogenous well-circumscribed ovoid intraconal lesions. They typically spare the orbital apex however they can occupy the orbital apex with a characteristic pear-shaped appearance (Fig. 33). On MR imaging, they are isointense relative to muscle on T1W images; uniformly hyperintense on T2W images, with no flow voids. Internal septations may be visualized on T2W images in larger lesions. They show progressive filling of contrast material with more uniform enhancing pattern on late phase

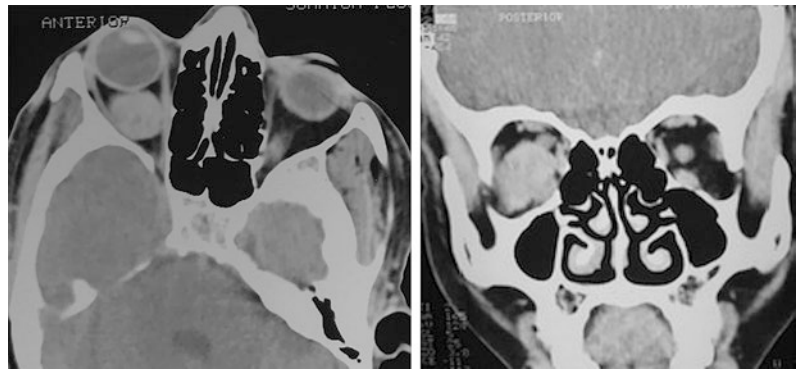

Fig. 33 Cavernous hemangioma on CT scan in 42 years old female. **a**, **b** Axial and coronal reformatted contrast-enhanced CT images demonstrate a well-circumscribed intraconal enhancing lesion

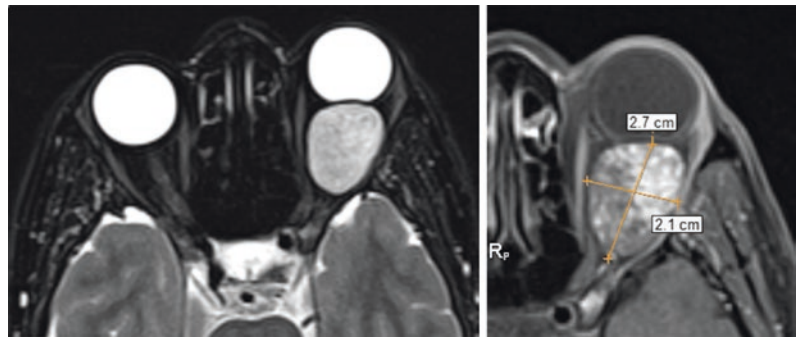

Fig. 34 A 45 years old female patient with cavernous hemangioma. **a** Axial T2WI shows a left intraconal ovoid soft tissue mass that indents the posterior aspect of the eye globe associated with mild proptosis. **b** Post contrast axial T1WI with fat suppression demonstrates progressive heterogeneous enhancement of the lesion

dynamic images and delayed images, yet larger lesions may demonstrate a heterogeneous pattern in later phases (Fig. 34).

At multiphase dynamic CT, these lesions are poorly enhancing on early arterial phase images, due to the low flow arterial supply, with progressive filling from periphery to center and complete filling within 30 minutes.

Orbital Venous Varix

Orbital venous varix (OVV) is the most frequent cause of spontaneous orbital hemorrhage. It typically presents in the 2nd or 3rd decade of life and equally affecting both males and females.

Orbital wall defects may be detected in few patients including pitting and thinning of the orbital wall, enlargement of the superior orbital fissure and orbital roof defects which may lead to encephalocele formation.

On US, the typical appearance of orbital varix is intermittently anechoic lesion that appears distensible with intrinsic flow during the Valsalva maneuver. Color Doppler demonstrates flow reversal toward the transducer during the Valsalva maneuver.

Dynamic CTA with venous phase Valsalva maneuver is very beneficial for characterization of varix. It shows an initial smaller area of filling on the arterial non-Valsalva phase with progressive filling and expansion on the venous phase. Orbital varix has a variable appearance depending on its complexity and number of involved veins. It may appear as well circumscribed, irregular, segmentally dilated, or distinct tangle

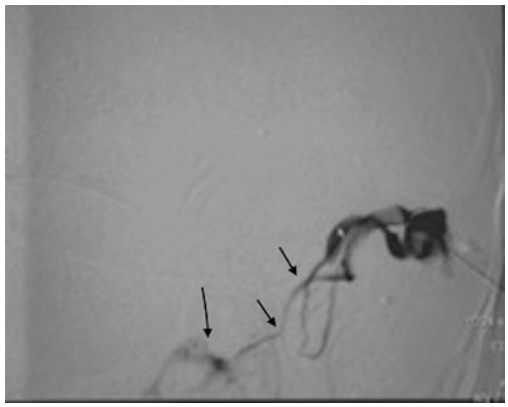

Fig. 35 A 35 years old male with orbital venous varix Digital subtraction angiography image after direct injection of CM in the venous varix, demonstrates dilated dysmorphic tangle of veins communicating with the SOV and cavernous sinus (arrows)

of vessels. Phleboliths are commonly seen (Fig. 35). CT is valuable to detect bone anomalies associated with orbital varices.

On MRI, orbital venous varix demonstrates hypo- to hyperintense signal on T1W images, hyperintense signal on T2W images, and usually enhance intensely after the administration of contrast material. Imaging with provocative measures to increase venous pressure such as scanning in the prone position, the Valsalva maneuver or jugular vein compression with a neck tourniquet is helpful to detect lesion distensability.

Orbital lympahticovenous malformation

US can be used to differentiate between the cystic and solid components of combined lesions and to evaluate the vascularity of the solid venous component. The macrocysts typically appear as anechoic spaces divided by septa. US is helpful to evaluate prior hemorrhage which appears hyperechoic and demonstrate fluid-fluid levels (Figs. 36 and 37). Microcysts on the other hand appear hyperechoic owing to the small size of their cavities.

MRI is superior to CT in delineation and characterization of this malformation, as it best demonstrates various components of the lesion. On CT, they are multi-compartmental, poorly circumscribed and heterogeneously hyperdense

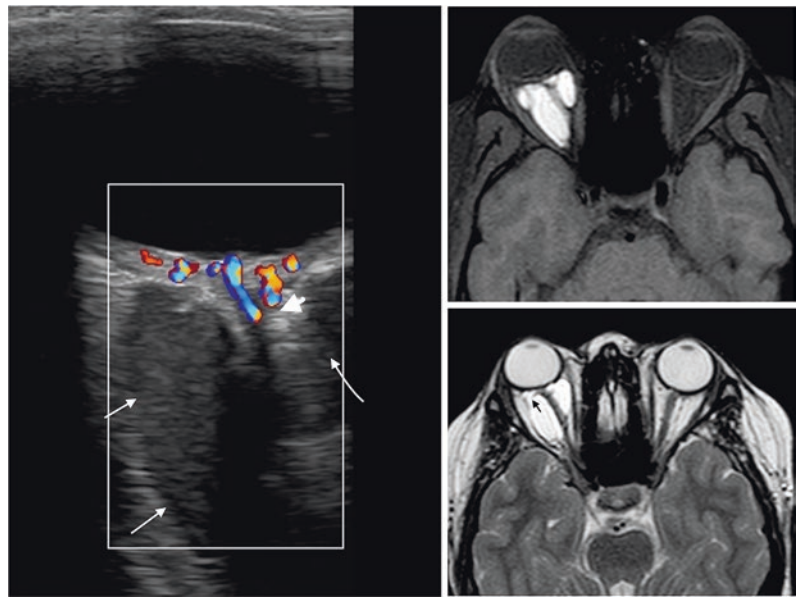

Fig. 36 A 10 years old body with macrocystic lymphatic malformation. **a** US image demonstrates intraconal macrocystic lymphatic malformation encasing the optic nerve (arrow head) with high levels echoes (hemorrhagic) are noted within (arrows). **b**, **c** Axial T1 WI with fat suppression and T2 WI, demonstrate intraconal macrocystic lesion with hemorrhagic content of hyperintense T1 and T2 signal. It shows thin internal septa of hypointense T2 signal (arrows)

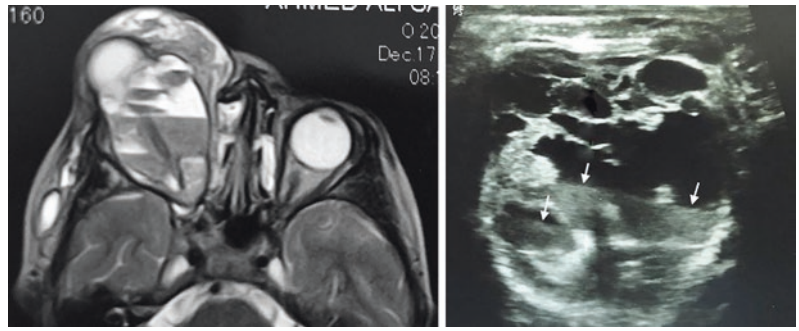

Fig. 37 A 10 years old boy with known orbital lymphatic malformation presenting with acute exacerbation of proptosis and orbital pain. **a** Axial T2W image demonstrates right orbital infiltrative macro-cystic lesion showing preseptal and deep intra and extra-conal components with involvement of the right temporalis muscle. It shows dependent hemorrhagic content of low T2 signal with multiple fluid-fluid levels (arrows). **b** US image demonstrates echogenic hemorrhagic sediment forming fluid-fluid level (arrows)

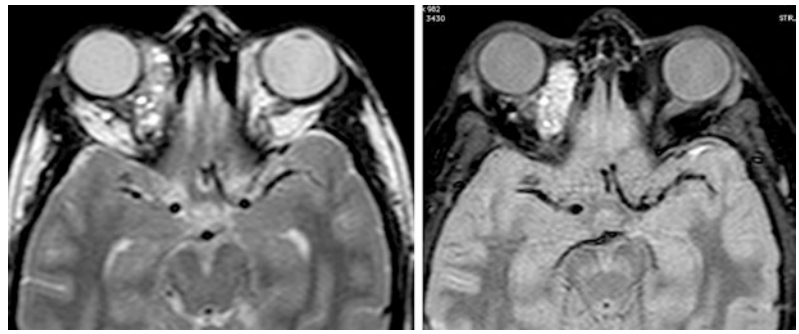

Fig. 38 A 16 years old girl with microcystic lymphatic malformation. Axial T2WI and FLAIR WI with fat suppression images demonstrate right orbital microcystic lymphatic malformation showing multiple microcysts (less than 1 cm in size) of hyperintense T2 signal

lesions. Phleboliths may be present at the venous component of combined lesions.

On MRI, the microcysts typically appear as solid masses with irregular margins, they demonstrate an intermediate signal on T1 WIs and an intermediate to high signal on T2W images (Fig. 38). They do not enhance after contrast injection. The macrocysts show variable signal depending on the type of fluid within the cysts either porteinaceous or hemorrhagic. Typically, they demonstrate T2 hyperintensity and variable T1 signal intensity (Fig. 39). The presence of fluid-fluid levels produced by hemorrhages of various ages is pathognomonic (Fig. 37). T1W fat-suppressed images after contrast administration demonstrate minimal enhancement of the wall of the cysts. Also it helps to identify the venous component of a combined lesion which corresponds to the site of most prominent contrast enhancement.

Dynamic CTA with venous phase Valsalva maneuver demonstrates distensibility and enlargement of the venous component of combined lesion. However, its use should be limited in young children because of increased radiation exposure compared to routine CT.

Additionally, MRI provides crucial information for patient's management by evaluating the effect of the lesions on the adjacent structure as the optic nerve as well as identifying the location of the hemorrhagic component especially if needle drainage, sclerotherapy or decompressive surgery is planned.

Recently, percutaneous sclerotherapy with sclerosing material is used as an effective first

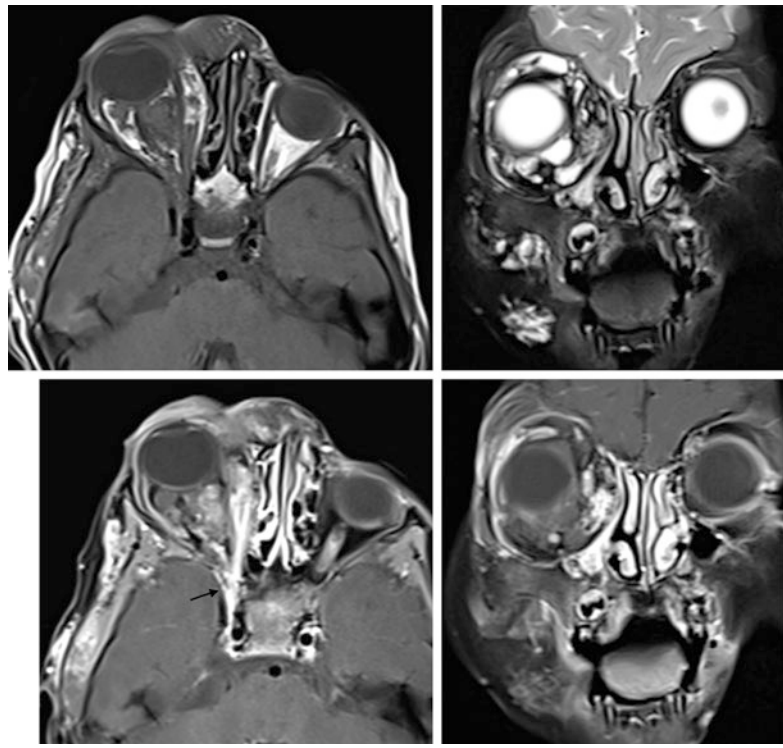

Fig. 39 A-9 years old girl with large trans-spatial venolymphatic malformation. **a** axial T1 WI, **b** coronal T2 WI, **c** Post contrast axial and coronal T1WI with fat suppression images demonstrate right orbital infiltrative trans-spatial lesion extending to the right cheek and right temporalis region with small intracranial extension through the right superior orbital fissure (arrow)

line therapy for macrocystic and microcystic OLMs. It has negligible recurrence rates, with significant improvement in vision and proptosis after treatment. Moreover, it can also be used for recurrence after surgical intervention (Fig. 40).

Arteriovenous malformations

According to their location, they are categorized into three types: purely orbital, orbital and periorbital, and orbital with retinal or cerebral AVMs (Wyburn-Mason syndrome). The last type is the least common; it includes any combination of cutaneous angiomas with orbital, retinal and cerebral AVMs. Most lesions occur in the superior orbit.

Non-invasive diagnostic imaging such as CT and MR imaging with the standard and angiographic protocol may be used to diagnose these lesions and detect their extent. However, conventional angiography is essential for precise diagnosis and treatment planning. On selective angiography, these lesions usually demonstrate enlargement and rapid filling of the proximal arterial system; with early drainage into distal venous outflow before contrast is seen in other venous structures (Fig. 41). Orbital lesions often have supply from the external carotid circulation.

Orbital arterio-venous fistula (AVF) is the only lesion that may be confused with orbital AVM on imaging. These lesions are rare with only 10 reported cases, they may be spontaneous or traumatic. They are purely orbital, with no connection to the cavernous sinus. Conventional angiography shows direct arteriovenous connection without intervening nidus which is pathognomonic of AVMs.

Carotid Cavernous Fistulas

Direct, high- flow CCF typically manifests with the sudden development of Dandy's triad:

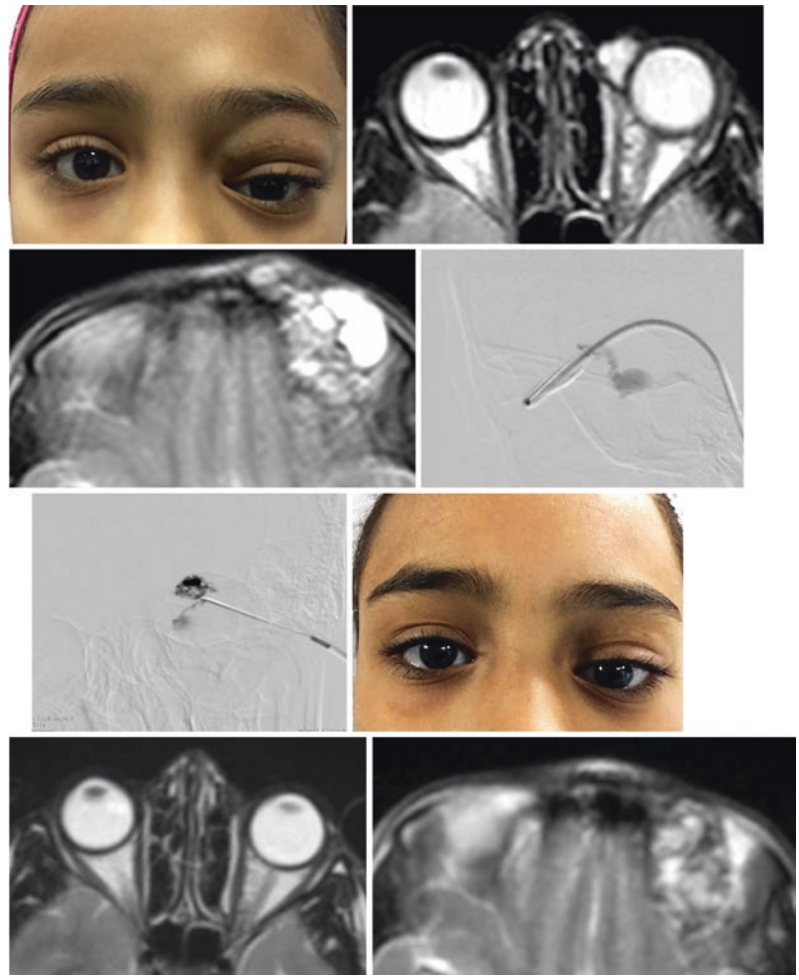

Fig. 40 Scleotherapy of orbital lymphatic malformation in a 9 years old girl presenting with proptosis and dystopia. **a** Pre-procedure clinical photo showing inferior displacement of the left eye globe with focal mass at the left frontal region. **b**, **c** Axial T2W images demonstrate mixed left orbital lymphatic malformation which has a large preseptal mainly macrocystic component extending to the left frontal region and a smaller deep intraconal microcystic component. **d**, **e** The patient underwent repeated sessions of image-guided bleomycin sclerotherapy. Digital subtraction images at two different sessions showing opacification of different non-communicating cystic compartments of the lesion. **f–h** Follow up clinical and MRI images obtained one year after treatment show considerable improvement. Axial T2WI demonstrate reduction of the size of the lesion with residual low signal intensity of fibrosis (Case courtesy of Dr. Omar Abdelaziz, Cairo University)

pulsatile exophthalmos, conjunctival chemosis and bruit. Complete clinical triad is not commonly seen. Indirect CCFs usually present with gradually progressive signs and symptoms and predominantly manifest as progressive glaucoma, proptosis or conjunctival injection (red eye).

Color Doppler US is helpful in the diagnosis and follow-up of patients with CCFs. Increased velocity with reversal of blood flow direction, dilated SOV and arterial pulsations are characteristic findings.

CT and MR imaging are usually the initial diagnostic tests of a possible CCF. Findings include proptosis, extraocular muscles enlargement, dilatation and tortuosity of the superior ophthalmic vein (SOV), together with engorgement and early enhancement of the ipsilateral

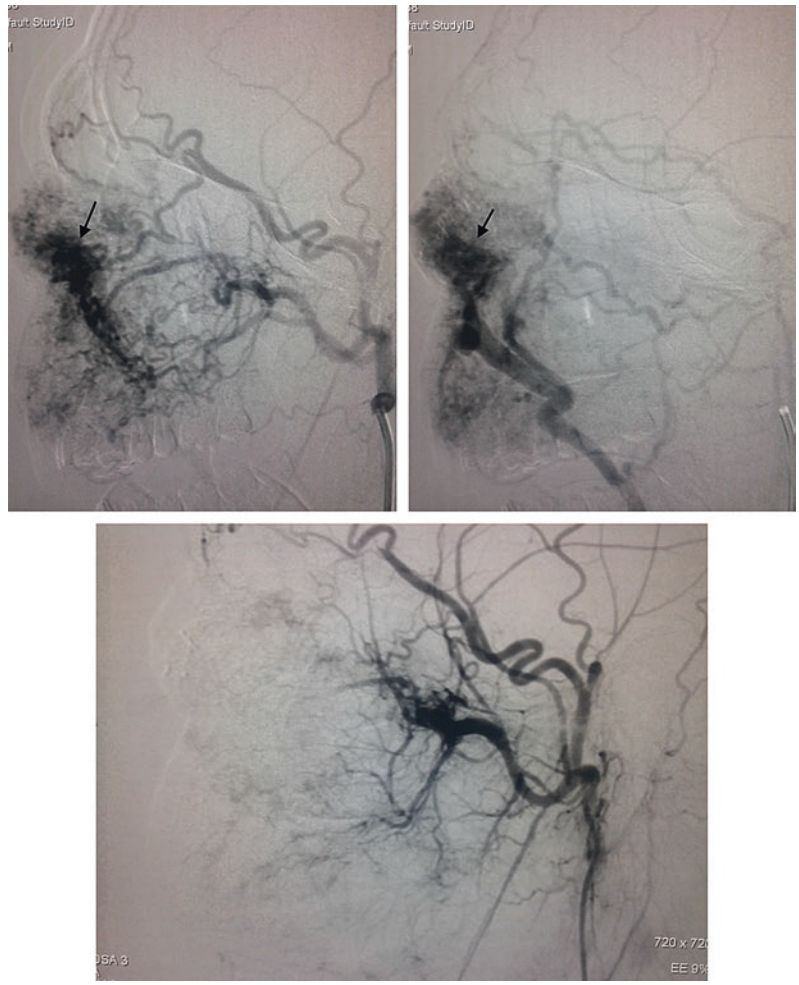

Fig. 41 Orbital and facial AVM. **a**, **b** Digital subtraction images reveal right orbital and facial AVM supplied by hypertrophied external carotid artery branches, with large nidus and early venous drainage (arrow). **c** Control image obtained after embolization of the feeding arteries and nidus using glue (Case courtesy of Dr. Farouk Hassan, Cairo University)

cavernous sinus (Figs. 42 and 43). Additionally, MR can detect orbital edema and abnormal flow voids within the cavernous sinus. A non-contrast CT scan is useful for detection of possible cranial injuries like intracranial hematomas or bony fracture.

CTA is considered a valuable tool in the diagnostic work up of CCF. The presence of dehiscent ICA can differentiate direct CCFs from indirect CCFs. CTA reliably depicts draining veins; however, it rarely identifies the exact location of fistulous communication in direct CCFs or the small feeding arteries in dural CCFs. Additionally, it cannot provide information regarding the blood flow within these fistulas.

Cerebral angiography is the gold standard for the precise diagnosis, classification, as well as guidance of further endo-vascular intervention (Fig. 44). It allows dynamic evaluation of the blood flow in the cavernous sinus, differentiation of direct from indirect fistulas and provide information about the presence of complete or partial steal phenomena and any other associated vascular injuries (e.g., arterial dissection, traumatic pseudo-aneurysm).

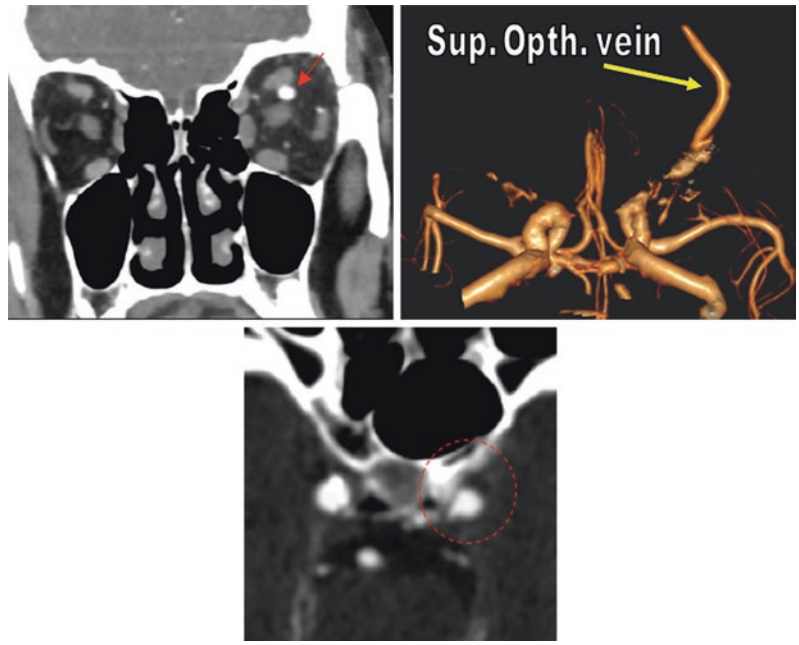

Fig. 42 CTA images idiopathic carotid cavernous fistula a 45 years old female patient. **a**, **b** Coronal CTA through the orbit and 3D reconstructed images demonstrate dilation of the left superior ophthalmic vein along its whole course with early enhancement in the arterial phase images (arrows). **c** Axial CTA image at the level of the cavernous sinus demonstrates early arterial enhancement of the cavernous sinus (circle). Associated engorgement of the left extraocular muscles compared to the normal right side

Orbital Trauma

1-Orbital fractures:

Orbital floor fracture

It is important to assess the position and shape of the inferior rectus muscle and of the orbital adipose tissue on coronal and sagittal CT reconstructed images thus, giving information about entrapment of the inferior rectus muscle and the fascial sling of the globe. If the inferior rectus remains in place and flattened, the fascial sling is likely intact with minimal entrapped periorbital tissue found at surgery. On the other hand, if the inferior rectus is inferiorly displaced and rounded in shape the fascial sling is likely affected, with consequent prolapse of the muscle through the orbital floor defect.

A large fracture defect may be associated with enophthalmos due to an increase of the orbital volume. In trapdoor fracture, the fracture fragment return back in place after herniation of inferior rectus muscle or infraorbital fat herniates through the fracture defect into the maxillary sinus. It is usually seen in children, due to the high elasticity of bone in younger patients.

On coronal CT imaging, there is entrapment of the inferior rectus muscle or infraorbtial fat through a non-displaced or minimally displaced inferior orbital wall fracture (Fig. 45).

Medial Orbital Wall Fractures

Only 10% of the medial wall fractures are isolated, it usually occurs as part of compound medial and inferior wall fractures (Fig. 46).

On CT, axial images demonstrate loss of the normal posterior-medial bulge (lamina papyracea) of the orbit with a consequent increase in orbital volume and enophthalmos (Fig. 47).

Superior Orbital Wall Fracture

The fractures are best identified on coronal reformatted CT images (Fig. 48). Associated orbital roof fractures may be associated with

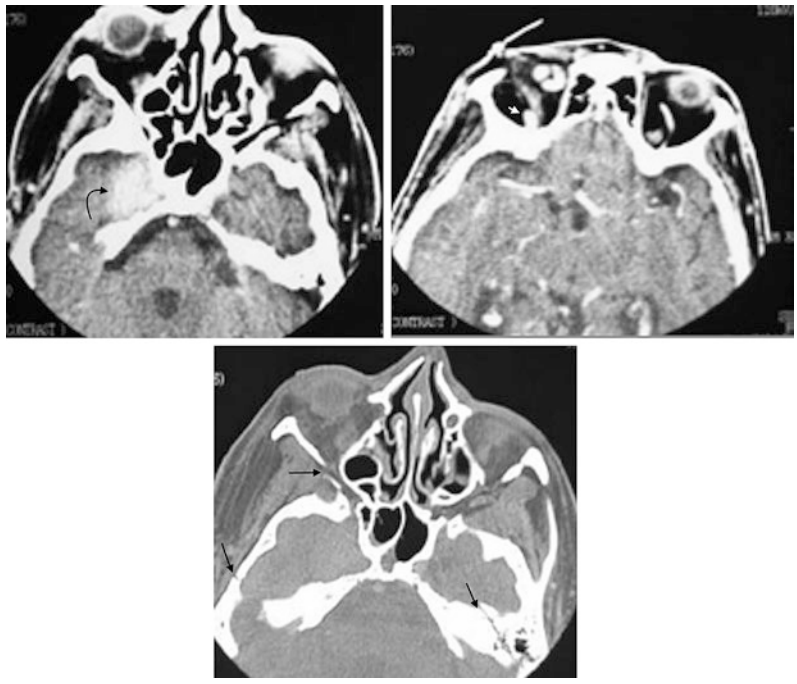

Fig. 43 Traumatic CCF in a 29 years old male patient. **a**, **b** Post contrast axial CT image demonstrates enlargement of the right cavernous sinus (curved arrow) together with dilation and tortuosity of the right superior ophthalmic vein (arrow head). **c** axial CT in bone window demonstrates fractures of the right squamous temporal bone, right zygoma as well as left petrous bone (arrows)

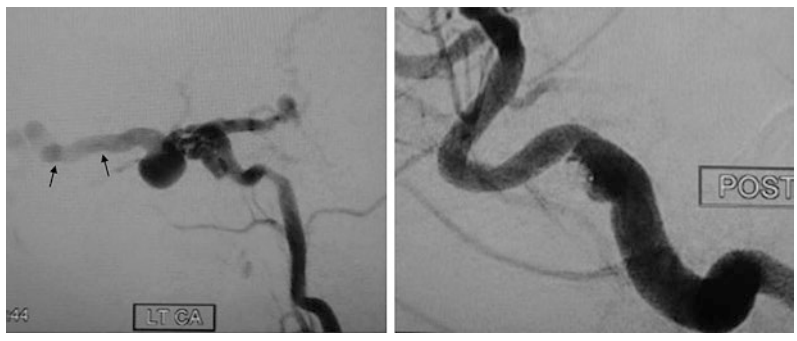

Fig. 44 Direct CCF on digital subtraction angiography. **a** Left internal carotid artery angiography image demonstrates direct CCF with abnormal filling of the ipsilateral cavernous venous sinus with early filling of the dilated superior opthalamic vein (arrows). **b** Control images obtained after closure of the fistula (Case courtesy of Dr. Farouk Hassan, Cairo University)

pneumocephalus, intracranial hematoma, cerebrospinal fluid (CSF) leaks, and violation of the dura, necessitating early neurosurgical consultation.

Growing fracture of the orbital roof is a late complication, seen only in children, usually less than 3 years old. There is herniation of brain parenchyma through fracture line coursed by dural laceration, CSF pulsation and normal cranial growth. CT images demonstrate a fracture defect that increases in width several months to years after the initial injury.

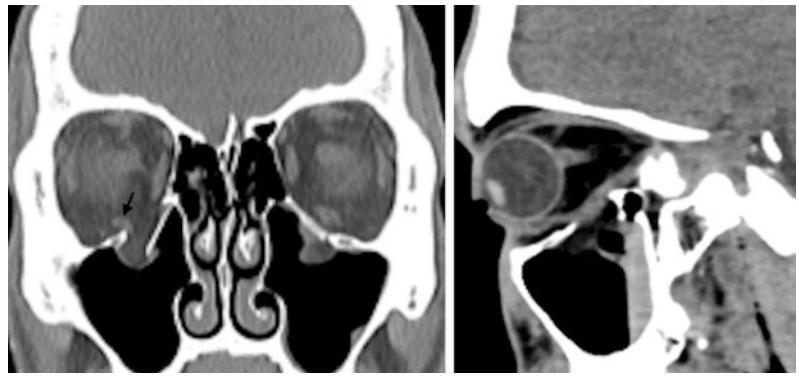

Fig. 45 Blow out fracture of the inferior orbital wall. **a**, **b** Coronal and sagittal reformatted CT images demonstrate fracture of right orbital floor with inferior displacement of the fracture segment and entrapment of the inferior rectus muscle (arrow)

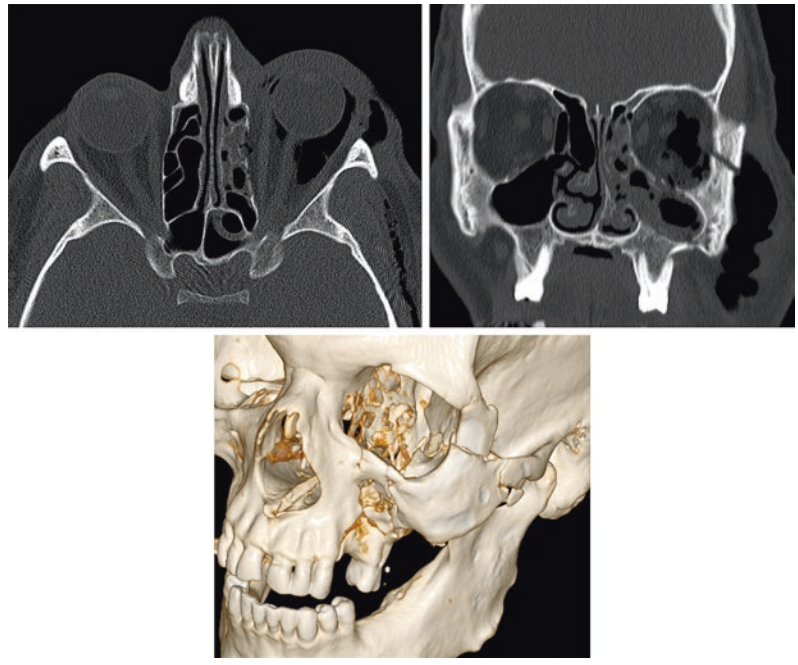

Fig. 46 Complex lateral, medial and inferior wall fracture with orbital emphysema. **a–c** Axial, coronal and 3D reformatted CT images reveal fracture of the medial, inferior and lateral walls of the left orbit associated with orbital and left temporal extracranial emphysema

Zygomaticomaxillary Complex Fracture

CT demonstrate fractures of the lateral and inferior orbital walls with extension into the zygomatic arch, the anterior wall of the maxillary antrum as well as internal lateral orbital wall (Fig. 49).

Marked lateral angulation of the internal lateral orbital wall or coincident orbital floor blowout fractures can lead to increased orbital volume and enophthalmos, together with ZMC fracture fixation. CT is necessary to detect comminution and angulation of the internal lateral

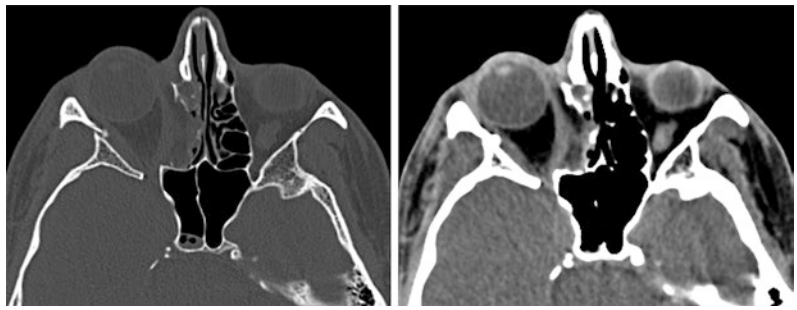

Fig. 47 Fracture of the medial orbital wall. Axial CT image demonstrate fracture of the medial orbital wall (lamina papyracea) with loss of its normal medial bulge. Associated entrapment of the medial rectus muscle is noted

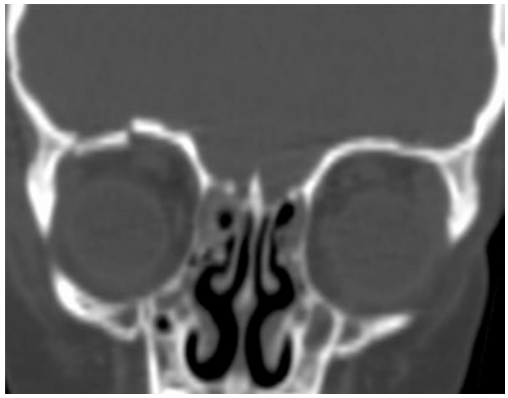

Fig. 48 Blow in fracture of the superior orbital wall Coronal reformatted CT image demonstrates fracture of the superior wall of the right orbit with inferior displacement of the fracture segment into the orbital cavity

orbital wall fracture, in addition to the identification of coexistent orbital floor fracture.

Naso-orbitoethmoid Complex Fracture

Naso-orbitoethmoidal (NOE) complex fracture originates from high-impact posteriorly oriented force to the nasal region. It typically results in marked comminution of the nasal bones bilaterally and the septum, medial orbital wall and ethmoid sinuses including the cribriform plate (Fig. 50).

On CT images, as the medial canthal tendon is not detected, the degree of comminution of the medial orbital wall at the presumed site of attachment of the medial canthal tendon in the lacrimal fossa is beneficial in surgical planning of tendon repair. Disruption of the nasofrontal duct must be assessed on CT images as it may lead to future mucocele formation.

Le Fort Complex Fractures

Pure bilateral Le Fort II is known as "pyramidal fracture" as the separated portion of the central mid face is roughly triangular in shape that may move separately from the lateral face and skull base. There is an oblique fracture line that extends inferolaterally from the naso-frontal suture (apex of the pyramid) through the medial and inferior orbital walls as well as anterior and lateral maxillary sinus walls along the zygomatico-maxillary sutures. Involvement of the inferior orbital walls is exclusive to the Le Fort II fracture (Fig. 51).

Le Fort III fracture complex leads to complete separation of the mid face from the cranium. Transverse fracture extends from the naso-frontal suture laterally and involves the medial and lateral orbital walls, as well as the zygomatic arches.

Axial and coronal reformatted CT images help to differentiate between Le Fort II and III fracture through detection of extension of fracture through the zygomatic arch which is particular to the Le Fort III fracture.

Orbital Apex Fracture

Orbital apex fractures extending through the optic canal may result in loss of vision due to

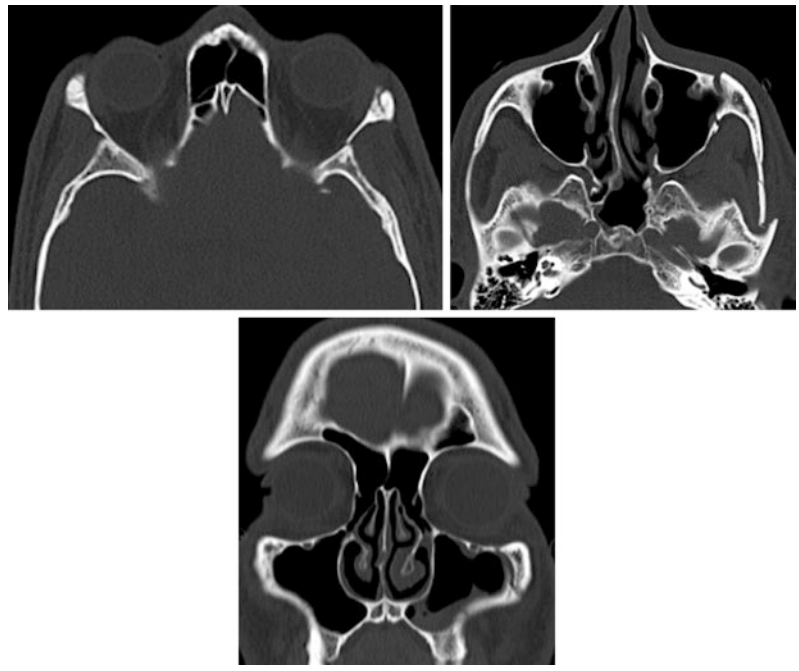

Fig. 49 Zygomaticomaxillary complex fracture. **a**, **b** Axial and **c** Coronal reformatted CT images demonstrate fracture of the lateral and inferior orbital wall and left zygoma, without angulation of the lateral orbital wall or changes in orbital volume

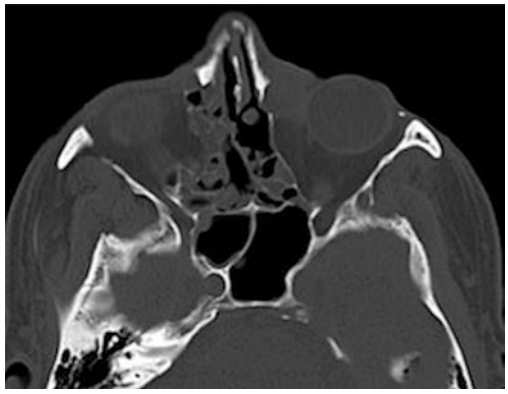

Fig. 50 Bilateral naso-ethmoidal complex fracture. Axial non-enhanced CT image demonstrates bilateral multiple comminuted fractures of the nasal bones, ethmoid air cells and medial wall of both orbits as well as fracture of the nasal septum

compression of the intracanalicular segment of the optic nerve. The presence of impinging bone fragment or retrobulbar hematoma indicate optic nerve damage and represent surgical emergency particularly if associated with decreasing vision.

2-Orbital Foreign Body

Identification and localization of intraorbital foreign bodies (IOFBs) are crucial in the radiological examination of orbital trauma.

Conventional radiography can detect the presence of opaque foreign bodies; however, it does not depict its exact site in relation to orbital soft tissues. Accordingly, conventional radiography is used only in the non-emergent condition to evaluate the presence or absence of an opaque foreign body before CT or MR examination.

CT is usually the first imaging test performed. It is sensitive for the detection of most foreign bodies, can reveal the presence of associated orbital and soft tissue injuries, and allows safe identification of metallic ferromagnetic foreign bodies (Figs. 52, 53 and 54). MR may be used in doubtful cases, but only after the presence of a metallic foreign body is excluded.

CT imaging is useful in the detection for most foreign bodies. High-resolution CT image can detect metal foreign bodies about 1 mm in size.

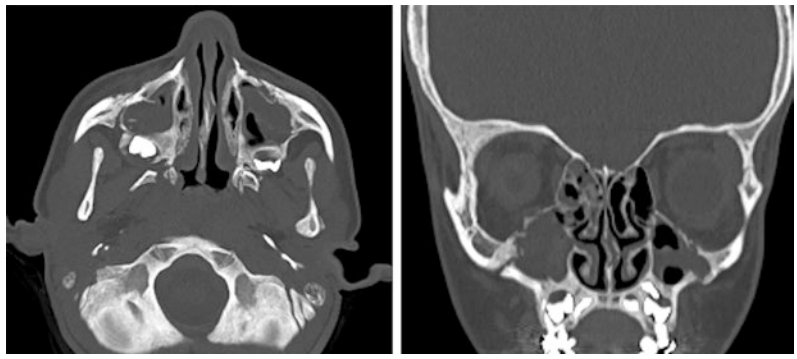

Fig. 51 Mid face Le Fort fracture. **a** Axial and **b** coronal reformatted CT images (bone window) demonstrate fracture of both pterygoid plates, with bilateral fractures of inferior orbital walls and infero-lateral maxiallry sinuses walls

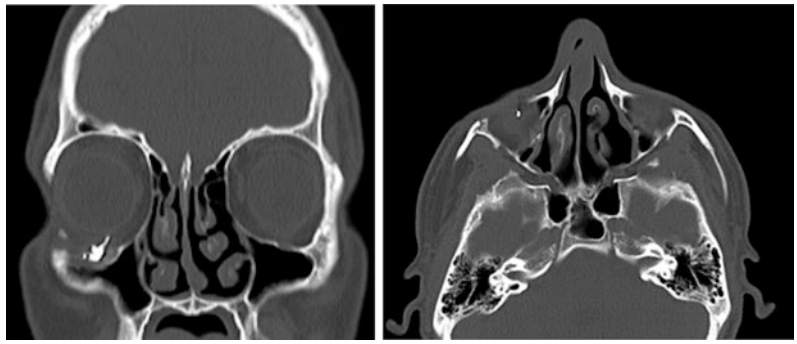

Fig. 52 Intraorbital foreign body in a 37 years old male with history of previous gun injury in the right eye. **a–b** coronal reformatted and axial CT images in bone window demonstrate fracture of the inferior and lateral walls of the right orbit with extraconal small dense foreign body (shrapnel)

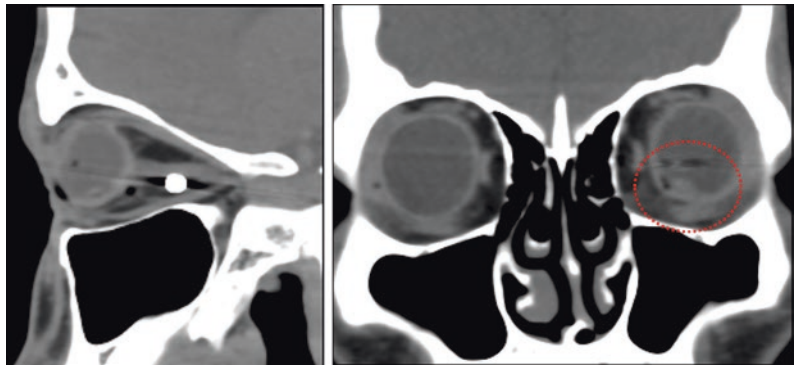

Fig. 53 Intraorbital foreign body associated with ocular hemorrhage. **a–b** Sagittal and coronal reformatted images reveal a small dense intraconal foreign body close to the inferior aspect of the optic nerve. Note the hazy outline of the eye globe with small dependent vitreous hemorrhage (Circle). Associated small retroorbital and eye lid emphysema

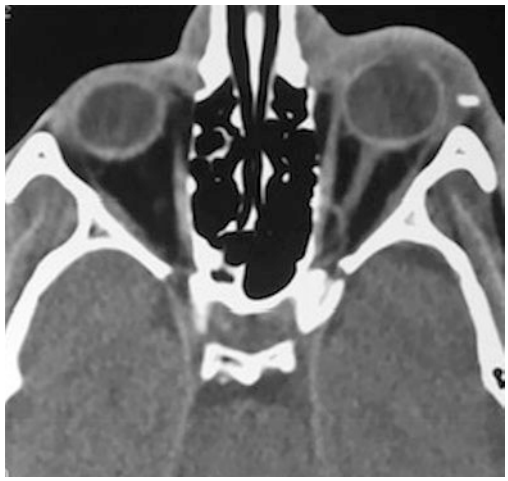

Fig. 54 Preseptal orbital Foreign body complicated with inflammatory changes. Axial CT image demonstrate left preseptal foreign body associated with preseptal soft tissue swelling

However, the identification of other foreign bodies like glass, wood, as well as organic material could be challenging. Wooden foreign bodies appear hypodense at CT, having an initial attenuation value of −100 to −200 HU that is increasing over the time due to fluid accumulation. Thus, it can be initially confused with orbital emphysema however, their geometric margins are highly suspicious.

MR examination using T2-weighted or contrast-enhanced MR performed with fat suppression demonstrate inflammatory response surrounding a non-ferromagnetic foreign body.

As CT and MRI are not able to detect all foreign bodies, close monitoring of the patient under conservative management is necessary to assess the development of abscess or fistula that can help in foreign body localization.

3-Traumatic optic neuropathy (TON)

TON is a clinical diagnosis; however, a clinical examination may not be feasible in patients with severe poly trauma. CT is the modality of choice in the setting of orbital trauma. It can detect optic canal fracture, IOFBs, and orbital hemorrhage (Fig. 55). Additionally, the increased attenuation of the fat around the intracanalicular optic nerve is highly suspicious for optic nerve injury. MRI can detect swelling and increased T2 signal intensity of the optic nerve. However, both imaging modalities have a high false negative rate as they detect only gross changes of the optic nerve, being unable to identify early post-traumatic changes that occur at the axonal bundle at microvascular levels.

Recent studies have described the value of DW and Diffusion tensor imaging (DTI) in the detection of early post traumatic changes. They have found decreased ADC value of the injured optic nerve together with alteration in diffusion tensor imaging parameters like fractional anisotropy and mean diffusivity that have been correlated with optic nerve injury.

Optic nerve avulsion is uncommon. As a result of severe injury, transection of the optic nerve may occur anywhere along the course

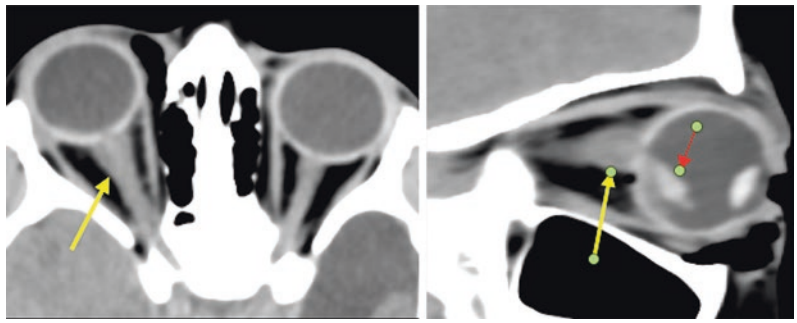

Fig. 55 Traumatic optic neuropathy on CT. **a**–**b** Axial and sagittal reformatted non-contrast CT images demonstrate diffusely swollen right optic nerve yet preserving its continuity, impressive of optic nerve injury (long arrow). There are associated right sub-retinal/intraocular vitreous hemorrhage (short arrow) as well as minimal blurring of the retro-orbital fat, mild proptosis of the eye globe with intraorbital and eye lids emphysema

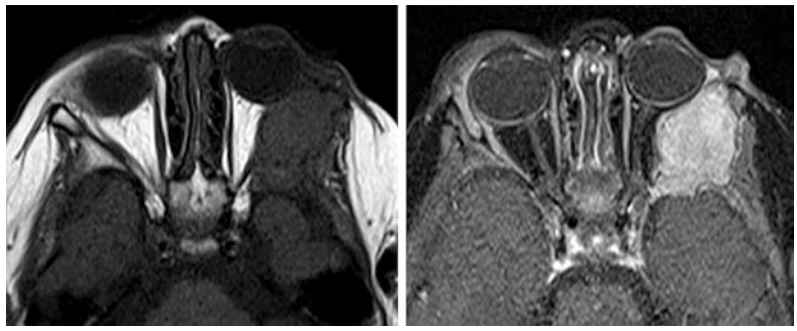

Fig. 56 Histocytosis of the left orbit on MR. **a–b** Axial T1W and post contrast T1W images with fat suppression reveal an expansile bone lesion involving the lateral wall of the left orbit with encroachment on the orbital cavity

of the optic nerve; head, intracanalicular portion, or anterior to the chiasm. It is identified on MR imaging as subtle discontinuity of the optic nerve yet the optic nerve sheath is intact. Complete transection of the optic nerve and sheath, are commonly caused by penetrating foreign body or fracture fragment.

4-Orbital Hemorrhage

On CT, retrobulbar hemorrhage is identified as an ill-defined high attenuation of the soft tissues posterior to the globe. On MRI, acute hemorrhage demonstrates hyperintense signal on T1W images.

Miscellaneous

Langerhans Cell Histiocytosis

Orbital disease usually occurs at the superior or superolateral quadrant of the orbit, forming a soft tissue mass with sharply marginated bone destruction. On CT, the mass appears homogeneously enhancing with slightly hyperdense margin. The soft-tissue mass may show orbital or intracranial extension into the epidural space, it may extend into the face, forehead or infratemporal fossa as well. On MR imaging, the mass demonstrates intermediate T1 signal and hypointense T2 signal relative to the hyperintense signal of bone marrow fat. Post-contrast T1W images with fat suppression demonstrate enhancement of the bone lesion and it is particularly important to detect any extra-osseous soft tissue extension (Fig. 56).

Fibrous Dysplasia

CT images typically demonstrate expansile bony lesion with ground glass appearance (Fig. 57). It is essential to assess the presence or absence of narrowing of the optic canal and superior orbital fissure with consequent optic nerve impingement. On MR, lesions are typically isointense on T1WI, hypointense on T2W images due to the presence of fibrous stroma and sclerosis with areas of high T2 signal due to cystic degeneration. After contrast administration, there is marked heterogeneous peripheral or central enhancement (Fig. 58).

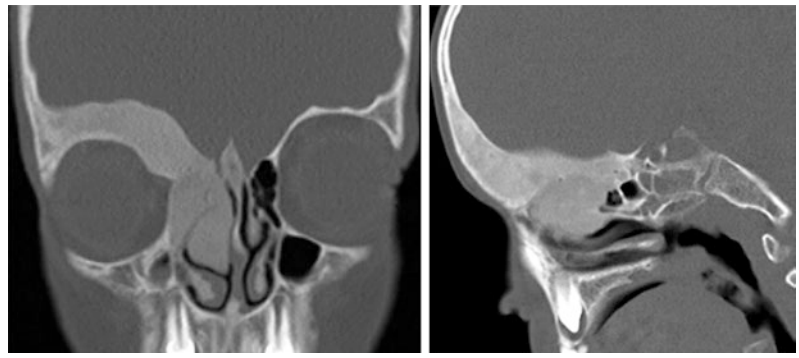

Fig. 57 A 6 years old boy with fibrous dysplasia. **a**–**b** Coronal and sagittal CT images (bone window) reveal an expansile bone lesion with typical ground glass appearance involving the right orbital roof and right ethmoid bones. There is encroachment on the orbital cavity

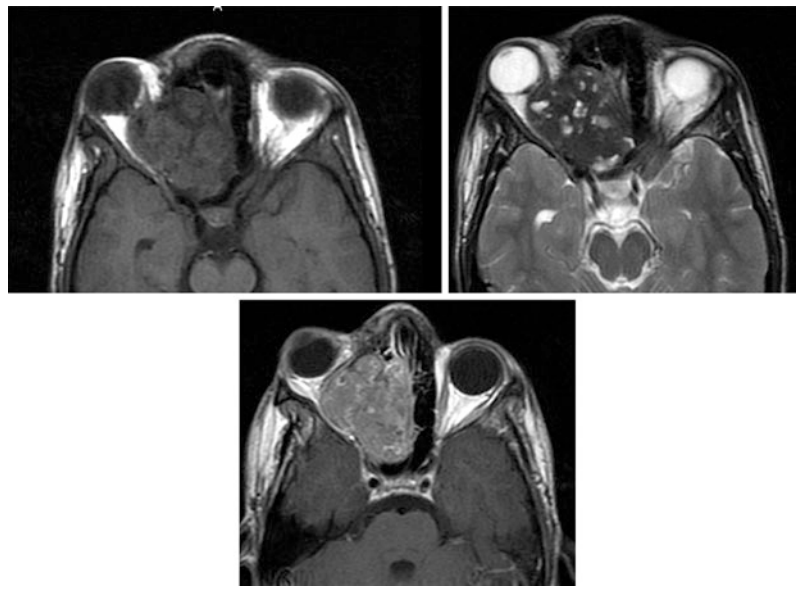

Fig. 58 Fibrous dysplasia on MR imaging. **a**–**c** Axial T1WI, T2WI and post contrast T1WI MR images showing expansile lesion of the right ethmoid air cells with marked encroachment upon the orbital cavity. The lesion demonstrates isointense signal on T1WI (**a**), hypointense signal on T2WI with intra-lesional foci of high T2 signal due to cystic degeneration (**b**) and mild heterogeneous enhancement after contrast administration (**c**)

Lacrimal System

See chapter "Acquired Lacrimal Obstruction".

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Common Orbital Disorders in Children

Davin C. Ashraf and Robert C. Kersten

Introduction

The pediatric patient may present with a wide variety of orbital pathology. While nearly 70% of orbital lesions are benign in children, practitioners must respect the aggressive minority of malignant neoplasms. There is significant overlap in the presentation of malignant and benign orbital masses. In general, rapid onset and an inflammatory component may increase the likelihood of a malignant neoplasm; however, infectious and inflammatory disorders present similarly and are statistically much more common.

Cystic Lesions

The majority of orbital lesions are cystic in nature, with a prevalence ranging from 23–52% depending on the reporting center. A cyst is characterized by a cellular capsule encompassing an acellular central lumen. The contents of the lumen usually reflect the secretory products of the cellular lining, and may be fluid or semi-solid in composure.

Dermoid/Epidermoid Cysts

Dermoid cysts are by far the most common cystic lesion found in the orbit, accounting for 72–89% of cystic lesions. These cysts are congenital choristomas composed histologically of keratinized epithelium, which represent ectodermal rests of tissue that are pinched off by mesoderm as it forms bony sutures. Dermoid cysts are characterized by a dermal capsule that contains adnexal structures such as sebaceous glands and hair follicles, with a lumen filled with a mixture of keratin, hair, and sebaceous material with a soft, cheese-like texture. Epidermoid cysts are a variant with an epidermal capsule that contains no adnexa, and a lumen filled only with keratin.

Dermoid/epidermoid cysts are most often found at the superotemporal frontozygomatic suture (72%), though they may occur at any suture line, with the majority of the remainder occurring medially over the maxillofrontal suture. Superficial dermoids/epidermoids usually present in the first few years of life as a firm sub-cutaneous mass. Patients typically present with a slowly growing, painless subcutaneous mass along the lateral brow that is frequently fixed to the underlying bone. Though the cysts are thought to be congenital, deeper dermoids/epidermoids may not become evident until the first decade of life or later. Occasionally, deep orbital growth can lead to proptosis, downward

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_36

and medial displacement of the globe, or ocular motility deficit. Some dermoid cysts may spontaneously rupture, leaking the highly inflammatory contents into surrounding tissues and leading to a presentation that may mimic cellulitis.

Diagnosis is usually clinical, though radiographic imaging can help to assess the degree of deep orbital involvement for purposes of surgical planning. Computed tomography identifies a well-circumscribed lesion with contrast enhancement of the lining but not lumen; bony remodeling may be found in 85% of cases. Magnetic resonance imaging with fat suppression is preferable in the pediatric population when available. Surgical excision via orbitotomy is curative if the cyst is removed in totality and is undertaken early in life before bony erosion or leakage with inflammation supervenes. It is advised to remove it "en toto" without opening the capsule. This can usually be done in small cysts where the lesion is small and the incision can be fashioned along a natural line as the lid crease as shown in Fig. 1. In cases of large cysts, the editor uses a small incision followed by a small opening of the capsule and complete meticulous suction of the contents, followed by complete stripping and excision of the capsule and closure of the incision. This results in complete removal with minimal or no risk of inflammation. A large study has confirmed the low risk of inflammation associated with such technique (in press, personal communication) (Fig. 2).

Mucoceles

Mucoceles are the second most common orbital cystic lesion, making up approximately 10% of cystic lesions. These cysts are formed from pseudostratified columnar epithelium that secretes mucus into the central lumen. They are associated with chronic inflammation of the paranasal sinuses. It is thought that chronic obstruction of the sinus outlet leads to cystic dilation of the sinus and eventual erosion of the orbital bones with subsequent prolapse into the orbit. Due to the chronicity of the process, mucoceles are more commonly found in the adult population; however, they should be considered in children with chronic sinus disease, such as those with cystic fibrosis.

Patients present with slowly progressive proptosis, sometimes with a fluctuant mass beneath the orbital rim. The most common sinuses of origin are the frontal and ethmoidal, which may lead to displacement of the globe inferiorly or temporally, respectively. Computed tomography assists in the diagnosis by demonstrating bony erosion by a cystic lesion herniating into the orbit, with opacification of the affected sinus. Successful treatment typically requires consultation with ear, nose, and throat surgery for marsupialization of the affected sinus. It is usually preferable to re-establish drainage and then allow spontaneous re-modeling of the displaced orbital contents rather than primary orbital reconstruction. Re-establishment of the bony architecture with orbital implants may then follow if necessary.

Vascular Lesions

Vascular lesions are the second most common pediatric orbital tumor, accounting for 6.8–15.9% of cases. Recently, a systematic perspective has been arranged by the International Society for the Study of Vascular Anomalies (ISSVA). Currently, vascular lesions are categorized into three lines. First, based on their histopathological features lesions are either tumor (endothelial cell proliferation) or malformation (endothelial cell dysmorphogenesis). Second, based on their hemodynamics characteristics, they are categorized as low flow (venous malformations, lymphatic malformations, lymphatico-venous malformations) or high flow (arteriovenous malformations, congenital arteriovenous fistulas). Lastly, lesions are broadly classified as capillary, arterial, venous, lymphatic, or of mixed type.

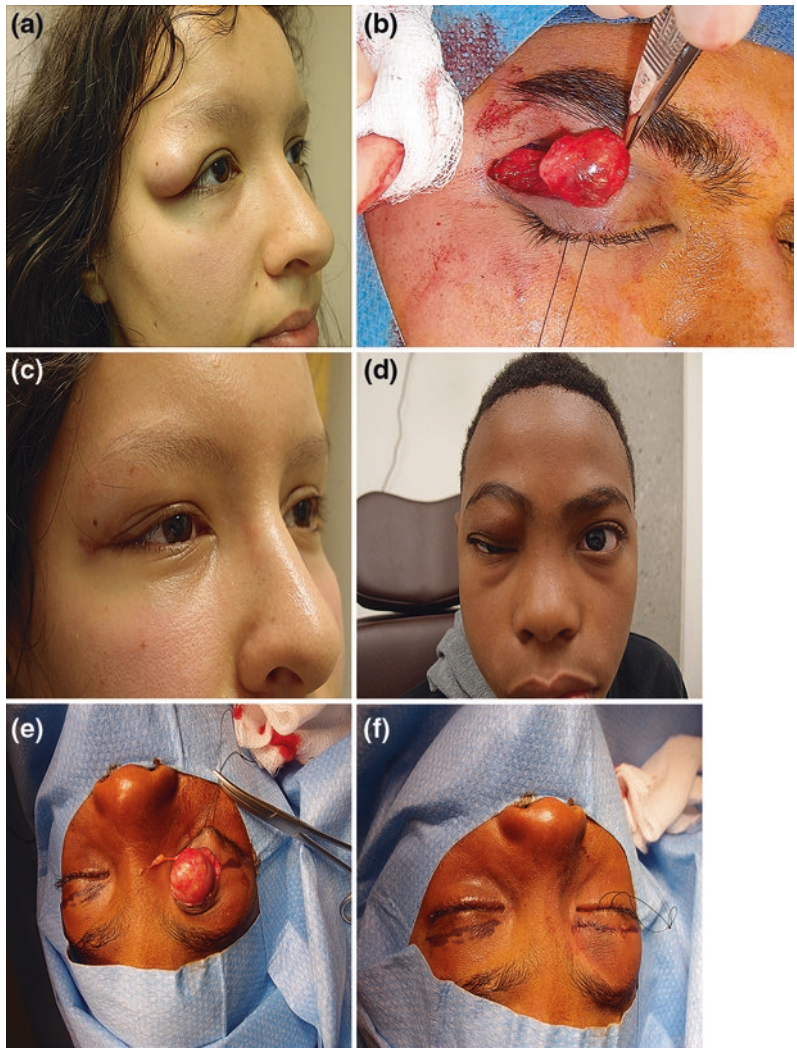

Fig. 1 **a–f** Dermoid cysts removed via lid crease incision

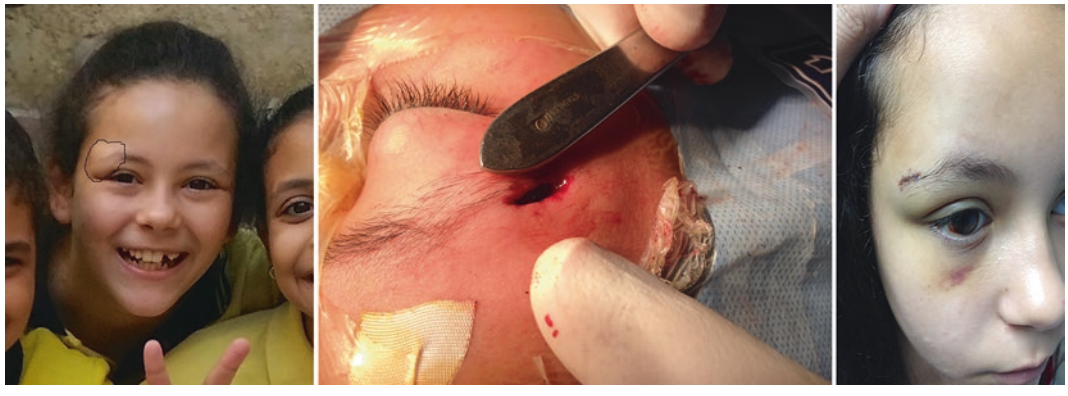

Fig. 2 Dermoid cyst removed through a small incision

Infantile (capillary) hemangiomas make up more than half of vascular tumors. They are more frequent in females, with a female to male ratio of 3:2. They are commonly isolated, but can be combined with a neurocutaneous syndrome, PHACES (Posterior fossa malformation- Hemangioma- Arterial anomalies- Cardiac defects- Eye Abnormalities- Sternal Cleft). They are composed of lobular clusters of endothelial lined capillary channels. Orbital hemangiomas have variable extent and location, ranging from the common location at the superomedial orbit to total orbital infiltration and even intra-cranial extension through the superior orbital fissure or optic canal. Additionally, they may involve the scalp, face, and neck. These benign congenital tumors typically follow a self-limited course consisting of presentation within months of birth, rapid growth for several months, and then slow shrinkage with eventual involution within the first decade of life. The classic infantile hemangioma lies superficially in the skin and is called the strawberry nevus due to its irregular, bright red appearance. The deeper lesions affecting the orbit instead may appear as a blue-tinged lid mass or solely present with orbital signs such as proptosis or globe displacement. Their size varies from that of a pencil eraser to a large mass encompassing the globe.

Diagnosis is typically clinical, though imaging may help to identify deep orbital cases without associated skin findings. Given the self-limited course of most capillary hemangiomas, treatment is primarily directed toward amblyopia prevention. Close observation is acceptable in the absence of visually significant astigmatism, visual obstruction, or severe orbital signs. In those requiring treatment, minimally invasive management is preferable. Historically, treatment involved systemic or intralesional steroids, but the adverse effects of steroid use and growing efficacy of alternatives have led these to fall out of favor. Systemic propranolol has been shown to safely induce regression of infantile hemangiomas over the course of four months. It is dosed at 2–3 mg/kg/day in two daily doses. It is generally advisable to initiate treatment in conjunction with a pediatrician to evaluate for potential cardiac or pulmonary contraindications; many practitioners choose to initiate treatment during a 24-hour hospital admission for continuous monitoring of vital signs and blood sugars. Topical beta-blockers such as timolol or propranolol are also effective for small hemangiomas, but penetration and thus efficacy are limited for deep orbital masses.

Large, visually significant tumors unresponsive to conservative therapy may necessitate invasive management. The tumor can be debulked by maximal surgical excision or by causing sclerosis of feeding vessels (Fig. 3). The vascular nature can lead to intraoperative bleeding, and it may be difficult to completely excise the tumor. Laser therapy is employed effectively for superficial capillary hemangiomas, but is of limited use for deep orbital tumors.

Orbital lymphatic malformations formerly called lymphangiomas, account for about one fifth of pediatric vascular tumors. These tumors are composed of lymphatic channels forming a diffuse, multilobulated mass. Presenting symptoms can include slowly progressive proptosis, ptosis, a heterogeneous subconjunctival mass, or a soft blue subcutaneous lid mass. Rapid enlargement of the tumor may occur in the setting of a viral illness or spontaneous hemorrhage, leading to dramatic swelling and rarely an orbital compartment syndrome. A chocolate cyst may form, composed of old hemorrhagic byproducts. Unfortunately, these malformations do not regress like capillary hemangiomas, and may be challenging to treat. When symptomatic, surgical excision or debulking may be attempted, but the diffuse nature of the tumor makes complete excision difficult or impossible (Fig. 4). Sclerotherapy with a variety of agents has been described with variable efficacy, and is preferable whenever possible. This is usually carried out by an interventional radiologist using an image guided percutaneous approach (Fig. 5).

Orbital venous malformations (varices) account for about 10% of pediatric vascular orbital tumors. They are categorized as distensible or non-distensible depending on their response to a Valsalva maneuver. These vascular hamartomas are dilatations of orbital veins and

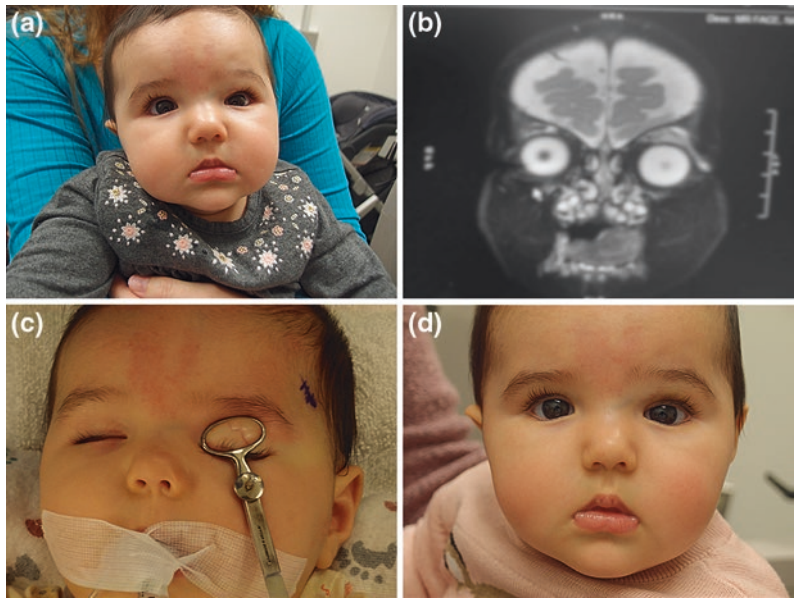

Fig. 3 **a–d** Infantile Hemangioma

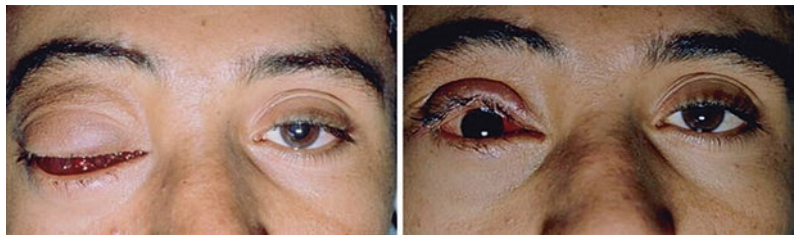

Fig. 4 Orbital lymphatic malformation; Pre and post surgical debulking

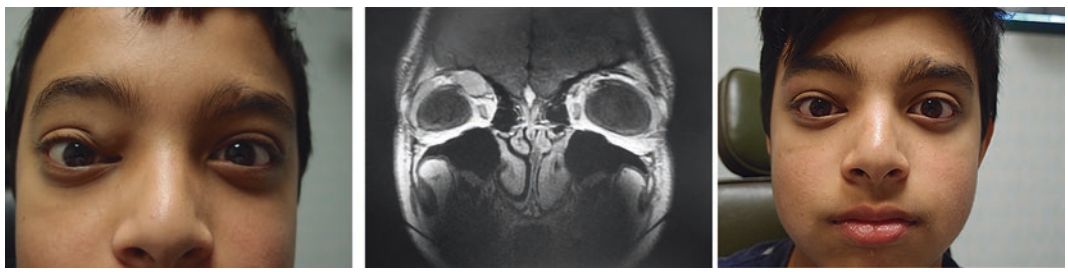

Fig. 5 Mixed venous-lymphatic malformation-pre- and post- percutaneous sclerosing therapy with doxycycline

if distensible indicate communication with the cavernous sinus. They may present with positional, intermittent proptosis, which may be elicited clinically with the Valsalva maneuver. The diagnosis can be confirmed with orbital imaging that identifies a dilated, lobulated ophthalmic vein with phleboliths. These benign malformations may be observed in most cases as they

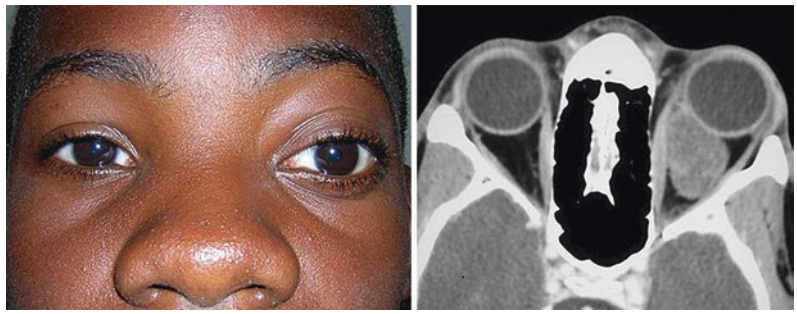

Fig. 6 Proptosis due to cavernous venous malformation

typically do not cause significant morbidity, and surgical excision bears a high intraoperative risk of bleeding. Like orbital lymphatic vascular malformations, paroxysmal hemorrhage may rarely occur.

Cavernous venous malformations (hemangiomas) also make up about 10% of pediatric vascular orbital tumors. These slowly growing vascular abnormalities consist of a globular mass of endothelial-lined channels separated by a fibrous stroma. They are considered to be congenital anomalies, but due to their slow growth are much more common in the adult population. Nevertheless, children may present with slowly progressive, painless proptosis. Orbital signs of optic nerve compression or motility deficit are less common. However, some patients may present with abrupt acute-onset proptosis during puberty or pregnancy, caused by cytokine and hormonal stimulation. Computed tomography or magnetic resonance imaging can identify a well-circumscribed, homogenous mass that is typically intraconal. Surgical excision is curative (Fig. 6).

Inflammatory Simulating Tumors

Inflammatory simulating tumors account for 2.8–16.4% of pediatric orbital lesions. These lesions involve idiopathic inflammation of orbital structures leading to mass-like enlargement often termed orbital "pseudotumor". They may be difficult to distinguish from infections or inflammatory neoplastic lesions, some of which are discussed in other sections.

Involvement of nearly every orbital structure has been described, but common targets include the orbital fat, lacrimal gland, extraocular muscles, optic nerve, and sclera. Presentation varies based on the structures involved. Most pediatric cases involve rapid progression of bilateral, painful swelling. Proptosis, motility deficits, chemosis, optic nerve dysfunction, and lid edema may occur. Computed tomography or magnetic resonance imaging is helpful for diagnosis. It may identify enlargement of the lacrimal gland or rectus muscles, inflammation or compression of the optic nerve, diffuse inflammation of the orbital fat, or non-specific thickening of the sclera. Imaging is particularly important for ruling out fluid collections or sinus opacification that may suggest infection, or a discrete mass more concerning for a neoplasm. The treatment is classically oral or intravenous steroids, depending on the severity of the presentation. High dose non-steroidal inflammatory agents may also be employed for mild cases or for those in whom steroids are contraindicated. Direct injection of a depot steroid may be helpful in some cases. A rapid response to steroid therapy is characteristic of orbital pseudotumor and may help to clarify the diagnosis. Recurrences are not uncommon and merit further workup including autoimmune serologies and biopsy. Biologic or anti-metabolite immunosuppressive agents may be employed for incalcitrant or recurrent cases (Fig. 7).

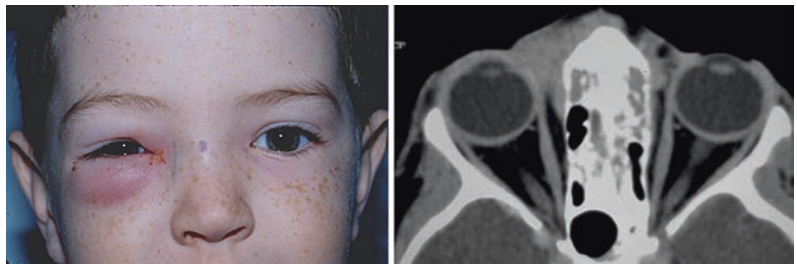

Fig. 7 Idiopathic Orbital Inflammation

Adiopse-Containing Tumors

Adipose-containing tumors make up 6.8–7.8% of pediatric orbital tumors. The most common of these is the dermato-lipoma. This tumor is a benign, congenital proliferation of adipose tissue associated with dense connective tissue and lined by a stratified squamous epithelium. Clinically, they are most frequently observed as a soft, yellow mass along the superotemporal aspect of the orbit. The overlying conjunctiva is often thickened and less elastic. They are rarely progressive or visually significant, and thus can be observed in nearly all cases. When necessary, surgical excision should be conservative, removing only tissue that is prolapsing into the palpebral fissure to avoid restrictive strabismus from scarring.

Rhabdomyosarcoma

Rhabdomyosarcoma is the most common malignant orbital tumor in the pediatric population, accounting for 2.1–10.3% of all pediatric orbital biopsies, and approximately one third of malignant orbital tumors. These mesodermal tumors arise from undifferentiated orbital mesenchymal cells, and histologically resemble striated muscle. The majority of cases occur in the latter half of the first decade of life, though later onset occurs in approximately one third of cases. Most patients present with rapidly progressive proptosis, and may additionally have globe displacement. Most commonly, the tumor is located superonasally leading to inferotemporal displacement of the globe. The fulminant presentation may appear inflammatory in nature, with ptosis, lid and conjunctival swelling, and pain. Imaging is important to distinguish rhabdomyosarcoma from infectious or inflammatory etiologies that appear with a similar, rapid onset. Computed tomography identifies a homogenous, well-circumscribed mass isodense to muscles. Advanced disease may show bony erosions or invasion of the mass to surrounding structures. T1-weighted magnetic resonance imaging shows a mass isointense with extraocular muscles and hypointense with orbital fat; T2-weighted imaging shows a mass hyperintense to both extraocular muscles and orbital fat. Thickening and enhancement of the eye lid is a common finding, even without tumor extension to the eyelid (Fig. 8).

Orbital biopsy is necessary for diagnosis; however, treatment is predominantly with chemotherapy and radiation. Modern treatment yields a 5-year survival of 94% for the most common subtype (embryonal) and 74% for the most aggressive subtype (alveolar). Surgical management is generally limited to biopsy due to the superiority of medical therapy. If the lesion is small and encapsulated, excision may be attempted, but medical therapy is still necessary to achieve the best outcome.

Secondary/Metastatic Tumors

Secondary or metastatic tumors to the orbit compose 1.9–3.6% of pediatric orbital tumors.

By far the most common of these is neuroblastoma, a tumor derived from primitive cells of the sympathetic nervous system. These tumors most commonly originate in the adrenal

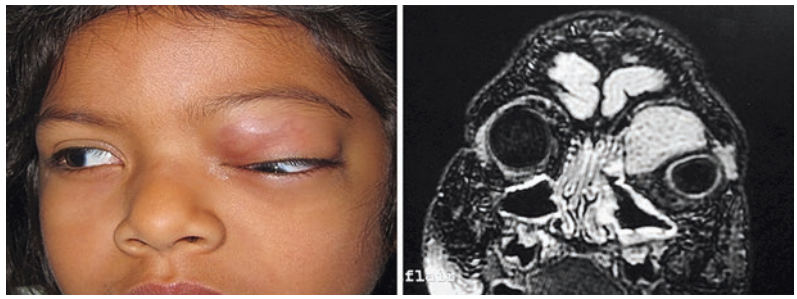

Fig. 8 Rhabdomysarcoma

glands, but may also arise from any site along the sympathetic nervous system. Approximately 10–20% of cases metastasize to the orbit, and in the vast majority of these cases, the primary diagnosis is already known. The majority of cases present bilaterally in the first 3 years of life with either proptosis or periorbital ecchymosis, the latter leading to a characteristic "racoon-eye" appearance. Other orbital signs including restricted motility and optic nerve compromise may be present. Frequently discussed but rare findings include Horner's syndrome or opsoclonus-myoclonus syndrome. Diagnostic testing should include serum and urinary catecholamines, which are elevated in a majority of cases. Computed tomography imaging identifies extraconal lesions preferentially occurring in the lateral orbital bony wall that may range from poorly to well circumscribed, potentially with local invasion or calcifications. Magnetic resonance imaging shows T1 hypointensity of the mass relative to muscle, and T2 hyperintensity relative to muscle. Necrosis or hemorrhage can lead to a heterogeneous appearance.

Treatment of metastatic neuroblastoma may include chemotherapy, radiation, immunotherapy, surgery, and stem cell transplantation. For the orbital metastasis, surgical excision may be performed if the lesion can be safely removed. The remainder of therapy is medical. For cases involving high risk for vision loss due to optic nerve compression, radiation and high dose steroids have been utilized for immediate relief. Prognosis worsens with age; reported 5-year survival is 84.6% for infants, 45% for children, and 36.3% for adults.

Other tumors that may metastasize to the orbit include Ewing's sarcoma and Wilm's tumor, but these are exceedingly rare. Orbital extension of retinoblastoma was historically a relatively common orbital tumor; however, it is now quite rare due to advances in treatment. This primary intraocular tumor arises from primitive retinal cells and is the most common intraocular pediatric malignancy. In primary orbital retinoblastoma, late presentation or lack of access to healthcare may allow spread of the tumor through emissary canals in the sclera into the orbit. Secondary orbital retinoblastoma, more commonly seen, involves orbital recurrence or spread following treatment. Prognosis is generally poor, but multimodal therapy including chemotherapy and radiation may improve survival relative to historical norms.

Lacrimal Gland

Lacrimal gland lesions account for 2.1–2.4% of pediatric orbital tumors. The most common of these is dacryoadenitis related to an orbital pseudotumor (see chapters "Neuro Ophthalmology and Oculoplasty" and "Common Orbital Disorders in Adults"). Primary epithelial neoplasms such as adenoid cystic carcinoma and pleomorphic adenoma that are found in adults rarely occur in children.

Lymphoid Tumors and Leukemia

Hematological lesions account for 2.4–4.7% of pediatric orbital tumors.

Children with **acute myelogenous leukemia (AML)** may develop a granulocytic sarcoma, or chloroma, of the orbit. This solid tumor is composed of primitive granulocytic cells. It most commonly presents around the age of 8–9 years as a rapidly enlarging orbital mass associated with pain, proptosis, motility restriction, swelling, and ecchymosis. The orbital presentation may be coincident with systemic disease, but may also may precede or follow systemic diagnosis by months to years and not uncommonly may be the first sign of relapse in a previously treated patient in remission. The diagnosis of orbital disease merits a systemic workup, either for early systemic involvement of incident AML or for relapse in patients with former treatment of AML.

Computed tomography identifies a uniformly enhancing, homogenous soft-tissue mass with similar attenuation as muscle or brain and hypoattenuation relative to sclera. Bony erosion is uncommon, and calcifications are not seen. The mass may exhibit invasion of orbital fat and the eyelids. Magnetic resonance imaging shows iso- to hypointensity of the mass to gray matter and muscle on T1-weighted imaging, and iso- to hyperintensity of the mass relative to sclera with homogenous contrast enhancement.

Incisional biopsy of the orbital lesion for immunohistochemistry, flow cytometry, and molecular analysis is important for diagnosis. Once granulocytic sarcoma has been identified, it is important to perform a systemic workup including bone marrow biopsy to evaluate for coincident systemic disease. If AML is found, treatment is with chemotherapy and/or hematopoietic stem cell transplantation. Isolated granulocytic sarcoma should be treated with systemic chemotherapy, though data is limited regarding the specifics of the regimen. This has been shown to reduce the rate of progression to AML from 71% to 41% in one cohort; in others, the rate of progression to AML with local radiotherapy or surgery alone have been as high as 81–100%. The primary role of surgery and radiotherapy are the rapid debulking of tumors for relief of mass-effect such as optic nerve compression.

Prognosis is poor with a five-year survival estimate of 46%, though slightly favorable relative to the 29% estimate for AML alone.

Langerhans cell histiocytosis describes a group of diseases that may cause granuloma-like lesions in the orbit, accounting for 1–3% of pediatric orbital tumors. The tumor arises from clonal proliferation of abnormal Langerhans cells; it is not yet clear whether this represents a true malignant neoplastic process, or an unusual immunoreaction. Langerhans cell histiocytosis (LCH) is currently the commonly used name for the disease spectrum that previously was categorized as eosinophilic granuloma, Hand–Schüller–Christian disease, and Letterer–Siwe disease. Orbital LCH most frequently present as eosinophilic granuloma. Orbital disease typically presents between the ages of 1–4 years. Onset before the age of 2 years may be associated with progressive systemic disease, while later onset disease is usually localized. Orbital presentation is typically with a unilateral bony lesion associated with a soft tissue mass. The most common location is the superior or superotemporal orbital roof. Orbital signs such as proptosis and motility restriction may be present, and the mass may be accompanied by inflammation of the periocular tissues. Diagnosis of orbital histiocytosis merits a referral to oncology for systemic workup, though patients over the age of 2 years typically will not have systemic involvement.

Radiographic imaging is helpful to identify these osteolytic lesions. Computed tomography shows a fairly homogeneous, well-defined or diffuse mass that is destroying and replacing osseous structures. Intravenous contrast leads to moderate to marked enhancement. Magnetic resonance imaging shows a heterogeneous mass of moderate T1-weighted signal intensity replacing the higher signal intensity of fat in bone. The use of gadolinium contrast and fat-suppression techniques can be especially helpful in evaluating the extent of the lesion. Technetium 99 m skeletal scintigraphy may be helpful in evaluating for multifocal disease.

Orbital biopsy is necessary for diagnosis. Isolated orbital lesions often respond well

to excision and curettage in conjunction with intralesional steroids. Cure is achieved in some cases, but recurrences may occur and thus long-term monitoring is required. Chemotherapy is used for multifocal disease. Radiation and bone marrow transplantation are most often reserved for incalcitrant recurrences.

Juvenile xanthogranuloma is a form of non-Langerhans cell histiocytosis, a histological distinction. It is most commonly known for its manifestation as a yellow-brown iris nodule, but may also present with orbital disease, accounting for 1.4% of pediatric orbital tumors in one series. Children present in the first two years of life with proptosis and occasionally restricted motility. Diagnosis can be challenging if there is no cutaneous component with characteristic appearance as a yellow-brown papule. Computed tomography may reveal a homogenous, ill-defined mass with minimal contrast enhancement. An orbital biopsy should be pursued if there are no characteristic cutaneous findings to assist diagnosis. Treatment is with intralesional or systemic steroids. Radiotherapy may be used in refractory cases.

Orbital lymphoma is predominantly an adult disease, occurring only rarely in the pediatric population. Orbital lymphoblastic lymphoma is the corollary of granulocytic sarcoma—associated with acute lymphoblastic leukemia rather than acute myelogenous leukemia. Leukemic infiltration of the orbit with mass-like proptosis has also been reported as a rare occurrence in the literature.

Optic Nerve and Meningeal Tumors

Optic pathway gliomas are tumors of the anterior visual pathway that account for 2–3% of pediatric orbital tumors. These tumors may arise anywhere along the course of the optic pathway, but are of orbital relevance when occurring anterior to the apex. Most pediatric ONG cases occur in the intra-orbital as well as the intra-cranial portions of the optic nerve with 20% of cases have lesions involving the optic chiasm, hypothalamus, and optic tracts. On the other hand ONG in adults usually involve the optic chiasm. The most common variant in childhood is the juvenile pilocytic astrocytoma, which is a benign and slowly-growing tumor. Malignant variants are almost exclusively found in adult populations. Children typically present between the ages of 2 and 6 years, but 10% of cases may not become evident until the second decade. When the tumor involves the orbit, slowly progressive proptosis may develop; however, children more commonly present with signs of optic nerve compromise, strabismus, or nystagmus. Sequelae of increased intracranial pressure such as headache or nerve palsies may occur when there is a large intracranial tumor burden. Funduscopic examination may reveal optic nerve edema or atrophy.

Computed tomography identifies an isodense, fusiform enlargement of the optic nerve. Bony remodeling, such as enlargement of the optic canal, may be observed. Magnetic resonance imaging with thin cuts through the optic nerve is superior in assessing the extent of the tumor. On T1-weighted imaging, the glioma appears as a fusiform enlargement of the optic nerve that is isointense to normal nerve tissue. On T2-weighted images, the glioma may be slightly hyperintense relative to normal nerve tissue (Fig. 9).

Orbital biopsy is typically not necessary for diagnosis, and may carry risk of vision loss. Diagnosis should initiate a systemic workup for neurofibromatosis type 1, as 50% of unilateral lesions and 100% of bilateral lesions are associated with this genetic disorder. Treatment is typically conservative. These slowly growing tumors can remain asymptomatic or minimally symptomatic for decades, and thus observation with clinical and radiographic examinations is reasonable. In general, sporadic gliomas have a more aggressive course than those associated with neurofibromatosis, and may require more frequent monitoring. When treatment is necessary due to significant proptosis, vision loss, or other sequelae, medical management is typically preferable. Radiotherapy demonstrates a high efficacy with progression free survival rates up to 90% at 10 years; however, adverse effects may be significant, including radiation-related

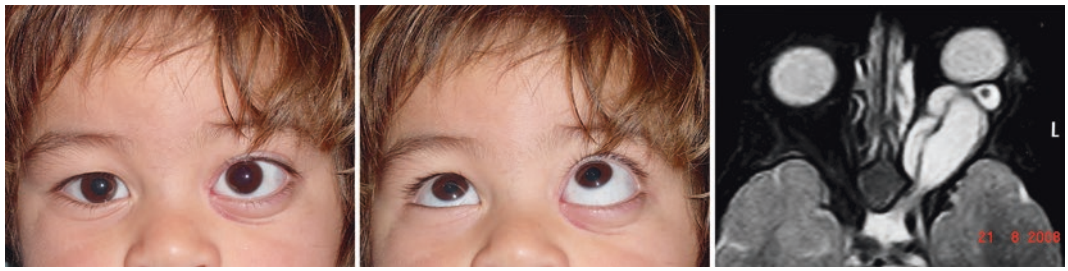

Fig. 9 Optic nerve glioma

vision loss, neurodevelopmental delay, and neuroendocrine dysfunction. Chemotherapy can lead to progression free survival of approximately 70% at 3 years, but visual outcomes are not as favorable. A systematic review identified improvement of vision in only 15% of cases and deterioration in 40%. Surgery is rarely utilized due to high risk of visual compromise. It may be necessary when an advanced tumor has led to a blind, painful, or disfiguring eye, or when tumor invasion of the chiasm risks spread to the contralateral eye.

Meningiomas involving the orbit are relatively rare in the pediatric population, accounting for about 1.4% of pediatric orbital tumors. These tumors are typically benign and slow growing proliferations of the meninges. Primary orbital meningiomas include optic nerve sheath meningiomas, arising from the arachnoid matter, and primary ectopic meningiomas. Secondary orbital meningiomas extend into the orbit from the skull base, most commonly the sphenoid bone. These tumors present with slowly progressive visual loss with later onset of proptosis. Funduscopic examination may reveal optic nerve pallor or optociliary shunt vessels. Computed tomography of optic nerve sheath meningiomas shows a diffuse tubular enlargement of the optic nerve. The sheath is thickened and enhances with contrast, in comparison to the relative sparing of the nerve tissue, leading to a "tram-track" sign on axial sections. Calcification may be present in 20–30% of cases. Secondary orbital meningiomas will show a mass arising from the skull base and expanding into the orbit. Magnetic resonance imaging shows isointensity or hypointensity to gray matter on T1-weighted imaging and isointensity to hyperintensity to gray matter on T2-weighted imaging. A "dural-tail" may be observed in 52–78% of cases. This strip of thickened and enhanced dura adjacent to the meningioma likely represents reactive vascular congestion and edema rather than invasion.

Unfortunately, pediatric meningiomas tend to be more aggressive than those in adults. Systemic workup should be undertaken to evaluate for neurofibromatosis type 2. Treatment is dependent on symptomatology. Patients should be monitored biannually for optic nerve compromise, with testing of visual acuity, pupillary response, visual fields when able, and color. Imaging may be repeated in conjunction with the clinical examination. When treatment is necessary, radiation therapy has been shown to have superior visual outcomes to observation, surgery, and surgery with radiation. Surgical excision is useful for blind eyes that are painful or disfiguring, or for cases with intracranial extension to the optic chiasm.

Peripheral Nerve Tumors

The most common orbital tumor derived from peripheral nerves is the neurofibroma, accounting for 1.6–6.5% of pediatric orbital tumors. These tumors arise from the peripheral nerve sheath and histologically contain axons, Schwann cells, perineural cells, and fibroblasts. The most common orbital subtype is the plexiform neurofibroma. These tumors have a strong association with neurofibromatosis

type 1. Patients typically present before the age of 5 with orbital signs including proptosis, globe displacement, ptosis, motility deficits, or (uncommonly) optic neuropathy. For tumors involving the eyelid, palpation may reveal a multinodular mass sometimes termed a "bag of worms." Imaging should be pursued to evaluate the extent of orbital involvement, even in the absence of orbital signs. Computed tomography shows an infiltrative, multi-lobulated, non-encapsulated tumor with ill-defined margins and low attenuation. The associated peripheral nerve is typically diffusely thickened. On magnetic resonance imaging, the mass is isointense with muscle on T1-weighted imaging and hyperintense relative to fat on T2-weighted images. Contrast enhancement in both modalities is variable. Other neurofibroma subtypes are less common in the orbit. Diffuse neurofibromas are vascular, infiltrative tumors that are more commonly found subcutaneously. Localized neurofibromas are focal, well-circumscribed tumors that are more common than plexiform neurofibromas in other regions of the body. When present in the orbit, they can be distinguished with imaging. They appear as smooth, ovoid lesions with defined margins, in contrast to the more disorganized appearance of plexiform variants.

If a diagnosis of neurofibromatosis is already established, a biopsy is not necessary. Neurofibromas generally have a low malignant potential. Therefore, treatment is driven by symptomatology. In the asymptomatic individual, observation is reasonable. Localized neurofibromas may be surgically excised with relative ease due to their well-circumscribed nature and low vascularity. In contrast, plexiform neurofibromas can represent a challenge due to their infiltrative nature. Subtotal resection or recurrence is common.

Schwannomas, or neurilemomas, are benign proliferations of Schwann cells. They are more common in the young adult population, but may rarely occur in children. They are sometimes associated with neurofibromatosis type 1, particularly if there are multiple lesions. They lead to slowly progressive proptosis and lid swelling. Growth typically occurs in the superior orbit, leading to inferior displacement of the globe. Orbital signs may develop in advanced cases. Paresthesia or dysesthesia may occur in the distribution of the affected peripheral nerve. Imaging shows a well-circumscribed, dense, homogenous mass with displacement but not invasion of nearby structures. There is low to intermediate attenuation on computed tomography with intense contrast enhancement. Magnetic resonance imaging shows high signal intensity on T2-weighted imaging and low signal intensity on T1-weighted imaging, again with intense contrast enhancement. Malignant transformation is rare, and treatment is dictated primarily by symptomatology. Surgical excision is often curative; normal nerve tissue can frequently be separable from the tumor mass, allowing preservation of nerve function. Even in the event of partial resection, recurrence is uncommon.

Osseous, Fibro-Osseous and Cartilaginous

Tumors of osseous, fibro-osseous, and cartilaginous nature make up 1.2–5% of pediatric orbital tumors.

Osteomas are benign tumors arising from proliferation of bony tissue. These tumors typically occur in the sinuses and may eventually affect the orbit due to invasion, most commonly from the ethmoidal, frontoethmoidal, or frontal regions. The tumor is rare before the second decade, and is generally more common in the adult population. Most osteomas are asymptomatic, but when the orbit becomes involved patients may present with slowly progressive proptosis and globe displacement. There may a coincident sinusitis due to obstruction. Motility deficits and optic neuropathy are uncommon. Computed tomography identifies well-circumscribed osteoblastic masses. Asymptomatic or minimally symptomatic lesions may be observed. Surgical excision is generally curative, with low reported rates of recurrence. A combined approach with neurosurgery or head and neck surgery may be required depending on the location.

Fibrous dysplasia is a benign proliferation of bone and fibrous tissue that may rarely occur in the pediatric orbit. These tumors most commonly occur in the frontal, sphenoid, and ethmoid bones. The monostotic fibrous dysplasia is more common than polyostotic type. It is limited to one site but involves more than one bone and crosses sutures. Patients generally present in late childhood or early adulthood with proptosis, globe displacement, and facial asymmetry that have slowly developed over years. Motility deficits, optic neuropathy, nerve palsies, and nasolacrimal duct obstruction may occur depending on the location of the bony abnormality. Though growth is slow, there may be sudden changes in symptomatology due to intralesional hemorrhage, mucocele, or aneurysmal bone cyst. Slow growth often continues into adult life. A sudden acceleration of painful growth may indicate a rare occurrence of malignant transformation into sarcoma. Computed tomography shows a well-defined expansion of bone with ground glass opacities and occasionally cystic or sclerotic features. Magnetic resonance imaging shows heterogeneous signal of intermediate intensity on T1-weighted images and low intensity on T2-weighted images. Treatment is reserved for cases with substantial disfigurement, pain, motility deficits, optic neuropathy, or malignant transformation. A multidisciplinary approach with resection and reconstruction is generally recommended.

Aneursymal bone cysts are benign lesions that rarely may occur in the orbit. They consist of blood-filled cystic spaces that are separated by bone and connective tissue. They most commonly develop in the orbital roof and present with gradual displacement of the globe. Occasionally, hemorrhage may lead to rapid progression. The cysts occur secondary to existing bony pathology such as fibrous dysplasia in approximately one third of cases. Computed tomography shows expansile osteolytic lesions with well-defined sclerotic margins. Magnetic resonance imaging may be useful to appreciate intralesional fluid-fluid levels and to distinguish the cyst from potential solid pathology that may indicate a secondary origin of the cyst. Signal intensity is variable, likely due to the presence of blood of varying age. When symptomatic, surgical excision and/or curettage is typically curative. Recurrences may be addressed with repeat excision or radiotherapy.

Infection

Orbital cellulitis is an infection of the orbital soft tissues. Children present with a rapid onset of lid edema and erythema, as well as variable conjunctival injection and chemosis. The clinical distinction between a pre-septal cellulitis, affecting only superficial soft tissues, and an orbital cellulitis, affecting deeper post-septal structures, is the presence of orbital signs. These include proptosis, optic neuropathy, pain with eye movement, or motility deficits. The presence of fever and leukocytosis are variable but relatively uncommon. The most common pathogens are bacterial, including group A streptococcal and staphylococcal species; fungal infections may occur in immunocompromised children, such as those with organ transplants or hematological malignancies. In the vast majority of orbital cellulitis, infection spreads from an adjacent paranasal sinusitis. Less often, infection can occur following penetrating trauma or orbital or strabismus surgery. Orbital cellulitis of odontogenic origin accounts for less than 10% of reported cases. The odontogenic source of infection is usually a result of dental abscess related to maxillary molars or premolars. Odontogenic infections can spread to the orbit either by direct backward extension into pterygo-palatine and infratemporal fossa and through inferior orbital fissure, thus reaching the orbital content or as thrombophlebitis through the venous route. Historically, hematogenous spread from a distant focus of Haemophilus influenza infection occurred commonly, but this has largely been eliminated by widespread vaccination against the bacteria's capsular protein.

Imaging is important in the diagnosis in order to evaluate for an associated subperiosteal abscess which occurs in approximately 50% of cases of sinusitis with orbital cellulitis (Fig. 10).

Fig. 10 Orbital cellulitis with medial subperiosteal abscess and proptosis

It is also helpful to assess for cavernous sinus or intracranial involvement, and to rule out an inflammatory neoplastic masquerade. Computed tomography is the preferred modality due to the speed and availability of the imaging. It may show inflammatory fat stranding, poor definition of orbital planes, and edema of the extraocular muscles.

More serious complications can occur if the orbital infection spreads intracranially, as it can lead to brain abscess or cavernous sinus thrombosis. The ophthalmic veins connect directly with the cavernous sinus and lack valves, thus acting as a two way route between the face and the cavernous sinus. Cavernous sinus thrombosis presents with increased eyelid edema, bruising, ophthalmoplegia with cranial nerve III, IV, and VI palsies, hypoesthesia in the distribution of V1 and V2, in addition to more severe constitutional symptoms and alteration in mental status.

Treatment should include admission for broad spectrum intravenous antibiotics, with eventual transition to oral antibiotics if improvement is noted in 48–72 hours. Those patients with a subperiosteal abscess are managed based on age and other risk factors established by Garcia and Harris. Children younger than age 9 without evidence of optic neuropathy may be observed closely on antibiotic therapy with a high probability of resolution. Children older than 14 years should undergo surgical drainage of the abscess, as it is likely polymicrobial with an anaerobic component and a low probability of resolution. Children between the ages of 9 and 14 years may be observed unless they have high risk features including frontal sinusitis, a large non-medial abscess, suspected anaerobic infection (e.g. prior dental surgery or intralesional gas on imaging), chronic sinusitis, recurrence of a previously drained abscess, or acute optic neuropathy.

Trauma

Blunt trauma to the periocular region may result in fracture of an orbital wall. The ease at which the thin orbital walls fracture likely reflects an evolutionary mechanism to buffer the globe from the force of trauma. In children younger than 7 years, the roof is the most common location of fractures. As children mature, the maxillary sinus pneumatizes and the proportions of bones in the midface and upper face change. As

a result, the orbital floor is the most common fracture site in older children and adults.

Children may present with swelling of the periocular soft tissues, as well as variable subconjunctival hemorrhage and chemosis. There may be enophthalmos secondary to volume loss from herniation of orbital contents into the sinuses; alternatively, there may be proptosis in the acute phase due to hemorrhage or swelling. Substantial proptosis associated with vision loss, optic neuropathy, and elevated intraocular pressure is concerning for retrobulbar hemorrhage and merits emergent canthotomy and cantholysis without delay for radiographic confirmation.

The most important diagnostic consideration for fractures is entrapment of rectus muscles. While adults with orbital fractures may have diplopia and motility deficits, these are more commonly related to acute swelling or paresis than entrapment. The pediatric population differs largely because of the elasticity of immature bone. Similar to a greenstick fracture, many pediatric floor fractures involve a "trapdoor" effect (27–93%) with a high risk of muscle entrapment. In these cases, the fractured portion of the floor is herniated into the sinus, but a "hinge" of bone remains that snaps the floor back to its approximate anatomic location. During this process, orbital contents including the inferior rectus can herniate into the sinus and risk being trapped once the bone returns to its origin. Entrapped muscle can become ischemic, leading to an irreversible motility deficit.

An additional confounder in the timely diagnosis of pediatric fractures is the potential to present as a "white-eyed" fracture. This presentation, fairly unique to children, involves a history of blunt head trauma but no periorbital swelling or subconjunctival hemorrhage. In these cases, it is of utmost importance to perform a careful motility examination and be wary of signs of entrapment such as nausea, vomiting, or bradycardia due to the oculocardiac reflex.

Computed tomography assists in the diagnosis by identifying the presence and extent of orbital fractures and revealing the location and course of extraocular muscles; however, entrapment is ultimately a clinical diagnosis. Examination under anesthesia with forced duction testing is the gold standard to determine whether motility deficits are the result of a restricted, entrapped muscle. Indeed, concordance between pre-operative computed tomography imaging and intraoperative findings of entrapment were demonstrated to be only 50% in children, versus 87% in adults.

Orbital fractures with entrapment require urgent surgery, ideally within 48 hours. Surgical repair involves the return of herniated orbital contents to the orbit, often with an implant to reconstruct the orbital wall when necessary. Repair after this period has been associated with worse long-term motility. If entrapment is not present, delayed repair or observation are reasonable. Indications for a delayed repair include enophthalmos or diplopia developing during the healing process.

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Common Orbital Disorders in Adults

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Orbital Vascular Malformations

Introduction

Vascular anomalies are divided into vascular tumors (neoplasms) and vascular malformations according to the classification recommended by The International Society for the Study of Vascular Anomalies (ISSVA, available at issva.org/classification). A clear distinction between tumors and malformations does not merely have an intellectual and academic relevance: misclassification frequently leads to suboptimal therapeutic approaches.

New growths or neoplasms are usually not present at birth and develop as a result of proliferation of growing cells (especially plump endothelia) with or without a superimposed involutional process. In contrast, malformations are present at birth, which may be occult, and tend to grow with the individual. Radiologically, neoplasms are usually well-circumscribed, may or may not be lobular, and are characterized by parenchymal staining with contrast injection. Hemodynamically, they are connected to inflow and out-flow vessels of otherwise normal vascular system. Malformations, on the other hand, tend to be diffuse or infiltrative, usually do not stain parenchymally or in patchy fashion, and are associated with ectatic, irregular, often enlarged vessels, with focal calcification.

Vascular malformations of the orbit are described by their locations: superficial, deep, combined (superficial and deep) and complex (orbital and extra-orbital). Clinical manifestations and management, on the other hand, can be understood within the context of their hemodynamics into three types.

Type 1 (no flow) lesions have no or minimal connection to the systemic vascular system and include lymphangiomas and combined venolymphatic malformation (lymphatic dominant).

Type 2 (low or venous flow) lesions appear as either distensible lesions with direct and rich communication with the venous system or non-distensible anomalies that have minimal communication with the venous system and include pure venous malformation (varix) and combined venolymphatic malformation (venous dominant).

Type 3 (high or arterial flow lesion) includes arteriovenous malformation and congenital arteriovenous fistula characterized by direct antegrade high flow through the lesion to the venous system.

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_37

According to ISSVA classification, vascular malformations are broadly divided into high flow (type 3) and low flow (type 1 and type 2). Low-flow lesions are further divided into venous malformations (VMs), lymphatic malformations (LMs), and combined lymphaticovenous malformations (LVMs). Pure VMs include distensible and nondistensible lesions while pure LMs can be macrocystic, microcystic, and mixed macrocystic/microcystic, all of which may have solid stromal components. The combined LVMs include 2 types based on hemodynamics. The venous dominant (VD-LVM distensible) has a significant venous element that may demonstrate distensibility while the lymphatic-dominant malformation (LD-LVM) has a less evident, or minimal, venous component and is a nondistensible lesion (Table 1).

Lesions can be clinically categorized based on the presence of classic features, including presence of pulsation or bruit (Type 3), postural or Valsalva-related expansion (Type 2), cystic (Type 1) or venous (Type 2) appearance of the superficial component (conjunctiva, episcleral or skin).

Table 1 Classification of orbital vascular malformations according to ISSVA recommendation

High flow
Arterial aneurysm
Arteriovenous fistula
Arteriovenous malformation
Low flow
Simple
Venous malformation
Distensible[a]
Non-distensible
Cavernous venous malformation
Lymphatic malformation
Macrocystic
Microcystic (diffuse/ microscopic)
Mixed (macrocystic/ microcystic)
Combined[b]
Lymphaticovenous malformation
Venous dominant
Lymphatic dominant

[a]Some or all of a VM may have distensible components on Valsalva maneuver

[b]Combined malformations may be composed of any combination of distensible or non-distensible venous components and any subtype of LM (macrocystic/ microcystic/ mixed)

Radiologically, cystic, venous and soft tissue components with characteristic pattern of opacification can be readily detected with contrast enhanced computed tomography (CT) or CT angiography (CTA); changes in the size of the malformation (distensibility) between axial and direct coronal CT scans or with Valsalva maneuver or what has been described as dynamic arterial and Valsalva-augmented venous phase multidetector CT angiography. It is important to confirm a successful Valsalva maneuver by noting enlargement of the superior ophthalmic vein during the Valsalva phase compared with the earlier phase. Additional flow characteristics can be evaluated using magnetic resonance imaging (MRI) or MR angiography, and flow patterns during percutaneous or intraoperative venography, or digital subtraction angiography (DSA).

Understanding orbital vascular malformations using the hemodynamic concepts (Table 2)

Type 1: No-flow (Lymphatic Malformation, LM or previously known as lymphangioma, and lymphatic-dominant, combined lymphaticovenous malformation (LD-LVM))

These malformations are hemodynamically isolated vascular hamartomas that derive from the venous system embryologically and have differentiated, in part or whole, to lymphatic vessels. They are present at birth and are composed of abnormal, dilated lakes of lymphatic tissue that result from defective embryologic development of the primordial lymphatic channels. LM are classified radiographically as macrocystic (cysts $\geq$2 cm), microcystic (cysts <2 cm), or mixed, which has important implications for treatment. In the orbit, some authors proposed using 1 cm as cut-off which is relevant clinically to identify lesions which may respond to different therapies.

The lesions grow with the patient and growth ceases when the patient is in adulthood. However, LM of the orbit can present at any age with swelling, erythema, pain, infection, or hemorrhage into the lesion. Furthermore, LMs are often part of a mixed type malformation and can contain anomalous venous, capillary, and or arterial channels, which are more accurately termed as lymphatic–venous malformation

Table 2 Classification of orbital vascular malformations using the hemodynamic concepts

Type/ Features	Hemodynamics	Clinical	Imaging
Type 1—**NO FLOW** Lymphatic and combined venous-lymphatic malformations	No connection to the venous system	Recurrent bouts of hemorrhage; frequently ill- defined margins	Irregular, patchy uptake on contrast CT; MRI may show evidence of blood-filled cysts; direct injection stays within lesion
Type 2—**VENOUS FLOW** Distensible	Direct and rich communication with venous system	Enlarges with Valsalva manoeuvre or bending; may be painful on expansion; may be multiple	Expand on coronal CT; demonstrate flow (Doppler); uniform contrast enhancement; direct injection can demonstrate connection to the venous system; retrograde injection fills the lesion Type 1: ectasias with normal out-flow Type 2: malformations with tangled normal out-flow Type 3: single or multiple vessels
Type 2—**VENOUS FLOW** Nondistensible	Direct but minimal communication with the venous system	Do not enlarge on Valsalva manoeuvre; subject to recurrent hemorrhage; similar to Type 1	Direct injection leads to out-flow; retrograde injection partially fills lesion; with CT or MRI tend to enhance uniformly; may have focal areas of recent and old haemorrhages
Combined venous-lymphatic	Features of Type 1 and Type 2		
Type 3—**HIGH FLOW** Arteriovenous malformation	Direct antegrade flow through malformation to venous side; intraorbital; extraorbital – collateral flow to extraorbital shunt	pain on Valsalva; rarely hemorrhage; gradual expansion with time	CT & CT angiography show uniform enhancement; MRI demonstrates flow voids; occasional old and new haemorrhages
Cavernous venous malformation	Direct low-flow through the malformation	Painless expansion	Patchy to uniform enhancement of a well-defined regular lesion; arteriography shows late pooling; direct injection fills the lesion

(LM + VM), lymphatic–capillary malformation (LM + CM), and lymphatic–arteriovenous malformation (LM + AVM). Mixed malformation is another term that is often used. Lymphatico–venous malformations are the commonest orbital vascular malformation.

The presence of lymphatic tissue often helps in the clinical diagnosis because the lesion will expand when the lymphoid tissue is stimulated or upregulated (e.g. during/after viral infection of the upper respiratory tract). Microcystic LMs are solid, infiltrative lesions, and are usually found more anteriorly. Macrocystic LMs are large cysts that can be seen with orbital imaging and often display fluid-fluid levels when patients are supine. They are more commonly found in the intraconal space, and are typically more stable than microcystic lesions, which are more prone to recurrent hemorrhages (Fig. 1).

Sudden expansion of the anomalous lymphatic channels can lead to breaks in the normal capillary network that feeds them thus leading to bleeding into the dead-end lymphatic channels. These channels then turn into hemorrhagic cysts (so-called chocolate cysts), which have no route to clear and can cause persistent mass effect. Expansion of the LM, in the context of a viral infection or hormonal changes associated with puberty, can also lead to similar bleeding into dead-end lymphatic channels. It is the dynamic nature of the malformation coupled with the multitude of dead-end lymphatic channels that make this anomaly particularly symptomatic and dangerous to visual function.

Physical Examination and Investigation

The clinical features of LM are based on their extent and locations.

Superficial lymphangiomas consist of multiple clear cystic structures, which may contain an admixture of xanthochromic, partially filled blood cysts, or subcutaneous bluish cysts. If cosmetically unacceptable, they may be removed with relative ease.

Deep lymphangiomas typically present with sudden proptosis due to spontaneous hemorrhage related to upper respiratory traction infection. Occasionally, they may present as progressive proptosis and may rarely be confused with cavernous venous malformation (cavernous hemangioma) but with severe posterior adhesion.

Combined lesions involve both superficial and deep orbital spaces and are characterized by a greater degree of disfigurement with episodes of spontaneous hemorrhage, expansion with upper respiratory conditions, and occasionally compressive optic neuropathy. The combined lesion may extend through orbital fissures and be associated with intracranial vascular anomalies.

Complex lesions involve not just the periorbital regions but face, neck, and other sites in the body.

Imaging may demonstrate either a deep cyst with rim enhancement or a solid lesion with cystic components. MR imaging is particularly useful for demonstrating the cystic and solid

Fig. 1 Periocular swelling and bruises secondary to spontaneous bleeding of microcystic LM after an episode of viral URTI. Complete resolution with conservative management

components as well as their contents. In long-standing and larger lesions, the orbits are often expanded and the lesions may extend beyond the orbital fissures.

Management

Conservative management includes observation or simple aspiration of the anterior cystic components. The indications for intervention are acute orbital hemorrhage, progression, or significant cosmetic disfigurement. Surgery can be challenging because of the unencapsulated nature of LM, which intertwines and interdigitates with surrounding normal vital structures in the orbit. Incomplete resection may result in recurrence. The risk of bleeding also increases with venous components.

The development of new agents allows multimodal management either as monotherapy or combined therapies to achieve better outcomes. Options for sclerosants include absolute alcohol, sodium tetradecyl sulfate 3%, sodium morrhuate 5%, bleomycin A5, doxycycline, and pingyangmycin. The use of systemic medication such as sirolimus has revolutionized the medical management of LM. For a more anterior lesion, thrombosis with a thrombin/ fibrinogen combination, such as Tisseel (Baxter) or Evicel (Ethicon) can be used to facilitate complete excision. Simple embolization with glue or Onyx (Covidien) leaves behind the abnormal endothelium, and recanalization often occurs with time. Combining intralesional injection of sclerosants and/or liquid polymers with excision has therefore evolved as a preferred approach.

Alternatively, Hill et al. in 2012 reported percutaneous drainage and ablation as a first line therapy for LM and VLM under deep intravenous sedation or general anesthesia. Macrocysts (>1 cm) were treated with dual-drug chemoablation after complete cyst drainage with aspiration using sequential intracystic sodium tetradecyl sulfate (STS) 3% for 2 minutes followed by 98% ethanol for 15 minutes. STS as a detergent increase membrane permeability and allows for greater membrane penetration of ethanol for intracellular protein denaturation and cell death. Maintaining cyst drainage by keeping a suction catheter in-situ for 3 days provides egress of acute inflammatory edema, prevents edema reinflation and re-endothelialization of treated cysts, and facilitates fibrous adhesion of de-endothelialized cell membranes in the early healing phase.

For microcysts, high concentrations (5 mg/ml) doxycycline foam are used, rather than a solution. This prevents drug leakage outside the microcyst walls. It is important to ensure complete cyst aspiration before treatment to prevent dilution of the doxycycline sclerosant.

Type 2: Low-flow (Venous malformation, VM or previously known as varices and venous-dominant, combined lymphaticovenous malformation (VD-LVM))

VM of the orbit, also known as orbital varices, are low-flow vascular lesions resulting from vascular dysgenesis. The venous malformations are dysplasias of small and large venous channels associated with a variable amount of hamartomatous stroma. The venous channels connect with adjacent veins. VM rarely regress and may have less prominent, arterial components.

VM are associated with two different clinical syndromes based on the size of the connections to the venous system. Large connections are associated with distensibility and constitute the majority of the so-called purely venous malformations. In contrast, venous lesions with a small systemic venous connection are clinically and radiographically non-distensible. These lesions are characterized by stagnant blood flow, thrombosis, or spontaneous hemorrhage. These non-distensible venous lesions may blend imperceptibly, from a clinical and management point of view, with the no-flow (Type 1) LM above.

(1) Distensible Venous Malformations

Distensible VM appear as superficial, deep, combined or complex lesions. The superficial components are easily noted as tortuous, epibulbar or eyelid venous malformations with/without overlying eyelid skin thickening. When confined to the deeper spaces of the orbit, the clinical picture is characterized by intermittent, sometimes uncomfortable proptosis there could be evidence of enophthalmos or deep superior sulcus (due to orbital fat atrophy), occasional bruising, and pain on expansion brought about by either physical effort or bending. Other problems related to VM include pressure or congestive pain and decreased range of extraocular movement and deformity. The more complex lesions may involve periorbital tissues and scalp and may show evidence of intracranial vascular anomalies as well as malformations of the adjacent bone. Some of these patients may have VM elsewhere in the body.

Imaging features of distensible VM consist of enlargement on direct coronal CT scan or expansion with Valsalva maneuver during dynamic CT or MR scanning, on B-scan ultrasonography, and venous flow on Doppler echography. A direct injection, either through draining veins or intralesionally, demonstrates enlargement with intraoperative Valsalva maneuver (induced by the anesthesiologist raising intrathoracic pressure) and either ectactic dysmorphic vessels flowing out to normal venous channels or saccular tangles of malformed vessels extending out through multiple malformed venous out-flow channels, including those of the cavernous sinus, pterygopalatine fossa and facial veins.

(2) Non-distensible Venous Malformations

They are characterized by acute exacerbation and remission due to hemorrhage or thrombosis, leading to sudden proptosis, pain, and increase pressure. There may be subconjunctival ecchymoses and if a superficial component exists, swelling and disfigurement of the lid and conjunctiva. It may be difficult to distinguish clinically between deep-seated non-distensible VM and LM. The presence of superficial component characterized by tortuous vascular channels, some of which containing blood or menisci but are mostly filled with clear fluid in LM, compared with the larger venous blood-filled channels of VM is helpful clinically.

The appearance on MR imaging of non-distensible VM depends on the relative composition of lymphatic and venous components. The venous portions will appear as a collection of serpentine structures separated by septae. These serpentine structures represent slow-flowing venous blood in the venous channels and appear as high signal intensity on T2-weighted images and intermediate signal intensity on T1-weighted images. Phleboliths may be present reflecting resolution of previous thrombosis and appearing as round, low-signal-intensity lesion on MR imaging and high(bone)-density, small round lesions on CT scans (Fig. 2). In-flow and out-flow channels (e.g. superior ophthalmic vein or orbital fissure) can be visualized on digital subtraction angiogram (DSA) or intraoperative venogram.

(3) Combined low-flow (Lymphaticovenous, LVM) Malformations

Combined LVMs are on a clinical and imaging spectrum based on the dominance, size, and location of the venous or lymphatic components.

Generally, there are 2 types: those that are distensible clinically or on dynamic imaging reflecting a significant venous component (venous-dominant, VD-LVM) and those that are not distensible (i.e., dominated by the lymphatic component, lymphatic-dominant, LD-LVM classically referred to as “lymphangiomas”). All VD-LVMs with distensible venous components extend to include the mid or deep orbit, whereas most of the LD lesions have primary or significant anterior components. It is therefore, important to suspect the presence of a venous component in deep lesions particularly if the superior orbital fissure is enlarged.

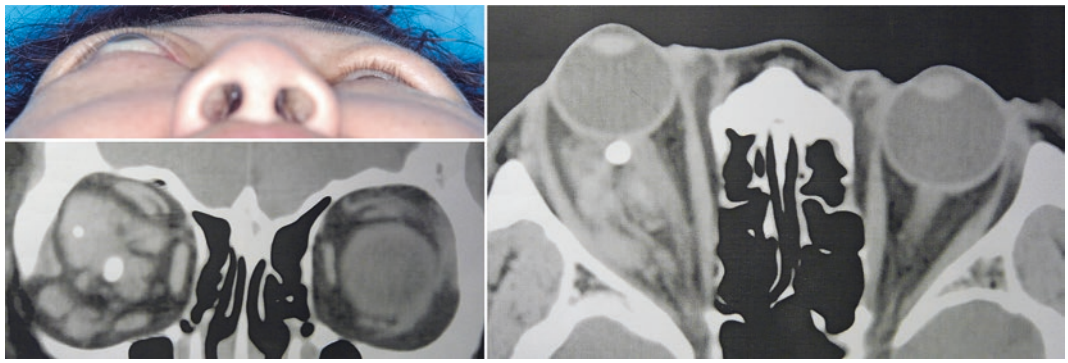

Fig. 2 Non-distensible venous malformation causing severe right-sided axial proptosis. CT scan showing intraconal, venous malformation. Presence of phleboliths reflects previous episode(s) of thrombosis. They appear as high(bone)-density, small round lesions on CT scans

Management

Treatment of all types of LVM can be conservative if asymptomatic. Because of the risk of hemorrhage, incisional biopsy should be avoided unless there are atypical features suggestive of an alternative diagnosis. Surgery is reserved and indicated in patients with symptomatic LVM causing resting pain, limitation of daily activities (e.g. exercise), significant cosmetic concern or for lesions which cause vision-threatening amblyopia in children or compressive optic neuropathy.

Direct surgical excision is extremely difficult because of the thin walled, malformed vessels and their tendency to rupture and bleed excessively. Traditionally, surgical management consists of deep orbital exposure with evacuation of clotted blood and attempted excision with the use of carbon dioxide laser. More superficial components can be handled by subcutaneous anterior orbital dissection with either frequent use of bipolar cauterization or carbon dioxide laser.

Recent advancement includes percutaneous injection of liquid polymers or glues e.g. n-butyl cyanoacrylate (NBCA) which can be reformulated at various concentrations with contrast agent with or without post-injection surgical removal under fluoroscopic control. Using higher concentrations allows quicker polymerization for treatment of faster flowing lesions but requires more material to be injected for adequate treatment. More often, intraoperative venography and controlled glue embolization are combined with obstruction of the out-flow channels, followed by excision of the solidified glued cast. Use of glue embolization substantially aid surgical removal because of the difficulty for hemostasis and complete surgical removal as these lesions are fragile (venous channels), bleed easily and intensely, and are connected with surrounding normal orbital structures and drain into the cavernous sinus. The hybrid procedure for managing orbital VM in the endovascular operation room is one of the emerging options. It allows real-time, high-quality, biplanar digital subtraction angiography (DSA) to monitor the outflow during glue injection.

The isolated use of sclerosants in LVMs has been limited because of the risk of leakage into the venous system and toxicities to the eye and/or cavernous sinus. However, the development of microballoons occluding the outflow channel of LVM from an endovascular approach has enabled the use of gentle sclerosing treatments (such as bleomycin A5 and doxycycline), followed by active decompression of the LVM to promote collapse and permanent scarring. Careful embolization can also be used to block outflow, although this is much trickier and not as well controlled. A percutaneous approach to the LVM, or an open approach during an

orbitotomy, represents additional options for accessing the LVM for embolization and/or sclerosant treatment.

Type 3: High (Arterial) Flow Lesions

Lesions that have an arterial component are considered high-flow malformations. These include arteriovenous malformations (AVMs) and arteriovenous fistulas (AVF), the latter which are often but not always acquired vascular anomalies.

Arteriovenous Malformations (AVMs)

Physical Examination and Investigation

AVMs are high-flow developmental anomalies resulting from vascular dysgenesis. They are composed of abnormally formed anastomosing arteries and veins without an intervening capillary bed. In other words, AVMs represent a direct connection between the arterial and the venous systems and hemodynamically characterized by antegrade flow through the malformation to the venous side. Thus, these lesions may act as a sump bypassing the orbital vascular system. The lesion may present in childhood or adulthood as pulsatile swelling with/without proptosis, secondary venous thrombosis or hemorrhage. These lesions typically enlarge with time as they recruit more arterial feeders and are often exacerbated during puberty or pregnancy. CT imaging of these lesions is characterized by irregular, rapidly enhancing masses, which show high-flow characteristic on Doppler studies and flow voids on MR imaging. DSA demonstrates an engorged, rapidly filling, proximal arterial system (ophthalmic artery and/or external carotid system), the malformation, and the distal venous out-flow.

Management

A key to treatment of AVMs is the proper diagnosis and mapping of the arterial and venous components, including the feeding and draining vessels. The most effective treatment for AVMs is preoperative selective angiography with embolization, followed by resection of the nidus. Embolization using coils or glues to obstruct the fistula is generally accomplished through an endovascular trans-arterial route. In periocular AVMs, percutaneous embolization can also be used. Of note, the AVMs will recur if the nidus and diseased endothelium are left behind. Hence, post-embolization excision is necessary.

Arteriovenous Fistula (AVF)

AVF are rare lesions caused by abnormal direct communication between an artery and a vein. Blood flows directly from artery to vein without passing through an intervening capillary bed. Apart from rare congenital AVF, trauma or degeneration are the commonest causes of an arteriovenous fistula. There are 2 forms of AVF: the carotid cavernous fistula (CCF) and the spontaneous dural cavernous fistula. CCF typically occurs after a basal skull fracture. Spontaneous dural cavernous fistula forms most often as a degenerative process in older patients with systemic hypertension and atherosclerosis. Dural cavernous fistula occurs when small meningeal arterial branches communicate with venous drainage.

Physical Examination and Investigation

CCF produces characteristic engorged, radially-oriented conjunctival vessels surrounding the corneal limbus as “corkscrew episcleral vessels” and a *bruit* that may be audible to the examiner and the patient. Usually patients may hear “whoosing” sound in one or both ears synchronous with pulse (pulsatile tinnitus). Pulsatile proptosis and lid swelling may be present. Elevated intraocular pressure (IOP), choroidal effusions, retinal vein engorgement, blood in the Schlemm’s canal, and non-granulomatous iritis can be seen. These are secondary to venous

outflow obstruction and ocular ischemia resulting from diversion of arterialized blood into the venous system. Palsy of the cranial nerves III, IV, or, most commonly, VI due to compression by the increased pressure in the cavernous sinus can lead to double vision.

Onset of dural cavernous fistula can be insidious with only mild orbital congestion, proptosis and periorbital pain. Patients may complain of chronic red eye(s). The patients with chronic fistulas are at risk of secondary ocular hypertension due to raised episcleral venous pressure, leading to glaucomatous optic nerve damage and retinal venous obstruction.

While digital subtraction angiography (DSA) is the gold standard for diagnosis of orbital AVM, non-invasive imaging techniques, such as CTA or contrast dynamic MRA, are playing an increasingly important role in the diagnosis and treatment planning for an AVM. CT scans show diffuse enlargements of extraocular muscles resulting from venous engorgement. Enlargement of superior ophthalmic vein (SOV) is the most characteristic finding on CT or MRI. DSA may be necessary to diagnose a slow-flow or partially/previously thrombosed fistula. DSA is indicated when the fistula requires endovascular closure.

Management

Treatment should be focused on closing the fistula. In low-flow types, this may occur spontaneously. When intervention is required, endovascular embolization from an arterial or venous approach is the preferred treatment for a CCF. Occasionally, a dilated SOV may be the best option for accessing the CCF. In such cases, the orbital surgeon can expose the dilated SOV through a superior eyelid crease incision followed by careful blunt dissection between the medial and superior recti muscles. The dilated SOV is often readily identified. This procedure can be performed in a hybrid operating room or endovascular suite. Alternatively, the orbital surgeon can secure an intravenous cannula in the SOV and close the incision prior to transferring the patient to the endovascular suite for embolization. Direct fistulas must be closed by endovascular embolization performed by an interventional radiologist the success rate is high but neurologic complications may still occur.

Orbital Cavernous Venous Malformation (CVM)

Cavernous venous malformation of the orbit (CVM) is the most commonly observed benign orbital lesion in adults and thus deserves separate discussion. Although considered to be vascular hamartomas, in some respects they behave more like low-flow AVM with a direct arterial in-flow and venous out-flow hemodynamically. CVM typically presents as a slowly enlarging lesion causing gradual symptoms due to mass effect. It is most commonly seen in females of 40–50 years of age. CVM is usually solitary, unilateral and is rarely associated with systemic conditions such as blue rubber bleb nevus syndrome and Maffucci syndrome. Although rare, lymphatic or arteriovenous malformations may also be associated with CVM of orbit.

Histologically, CVM is a vascular malformation with an intact capsule and numerous large vascular channels. CVM does not stain positive for glucose transporter type 1 protein (which is highly expressed in endothelium of barrier microvasculatures of the central nervous system, retina, iris), distinguishing it from infantile hemangioma. It is proposed that CVM arises post intraluminal thrombosis, leading to a cascade of neovascular activity with stromal remodeling and myofibroblastic infiltration.

Clinical Presentation and Diagnosis

Up to 70% of CVM patients present with progressive axial proptosis (on average 5 mm proptosis at presentation) due to the tendency of these lesions to occur within the intraconal space. Some studies reported a higher incidence

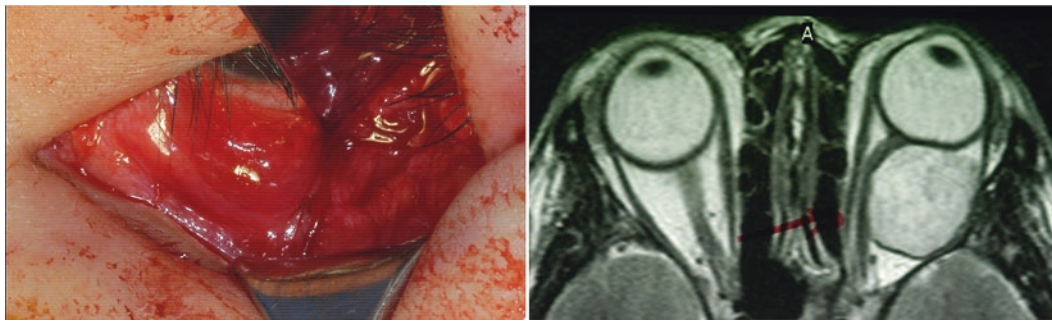

Fig. 3 Conjunctival incision for removal of CVM in the retrobulbar region occupying the inferotemporal quadrant

of it being lateral to the optic nerve (Fig. 3). As CVMs have limited connection with the arterial system, clinically bruit or pulsation are absent. The volumetric size of lesions increases at approximately 0.2 cm^3 each year, leading to an average of 2 mm increase in proptosis per year. The level of circulating estrogen-progesterone may influence CVM progression as it has been found that CVM tend to halt progression in post-menopausal women. Other common clinical presentations include visual deterioration (~50%) due to optic nerve compression or hyperopic shift caused by posterior indentation of the globe, extraocular movement limitations and manifest strabismus in primary gaze (20–30%), choroidal folds, optic disc changes (blurred disc margin, peripapillary venous congestion and optic atrophy). Pain is not a common feature. Gaze evoked amaurosis is sometimes observed. Acute presentations may occur in the rare event of intralesional haemorrhage.

Imaging is an important diagnostic tool for CVM. While A-scan USG may show a regular structured mass with high reflectivity and moderate attenuation of echoes, B-scan ultrasound can show an encapsulated lesion with medium-high reflectivity with no signs of internal vascularization. Computerized tomography (CT) commonly reveals a well-circumscribed mass with distinct posterior and anterior margins and homogenous soft-tissue density, globe indentation and possible bone remodeling (rarely erosion). Many arise laterally with medial displacement of the optic nerve. During dynamic contrast CT, enhancement is typically focal in early to heterogeneous in intermediate then diffuse in late phase. MRI typically shows isointense lesions to muscle and gray matter (hypointense to fat) on T1-weighted and hyperintense to fat on T2-weighted films. Contrast enhancement evolves from patchy and heterogeneous to more uniform in later phases similar to hepatic hemangioma. This feature is useful in differentiating CVM from e.g. Schwannoma. These lesions angiographically show only small puddles of contrast appearing late in the arterial phase, suggesting low flow arterial input.

Treatment

Treatment of CVM should be individualized, depending upon patient's symptoms and optic nerve function while balancing complications and cosmesis. The mainstay of treatment is still surgical excision. Alternative treatments for candidates unsuitable for surgery include multi-session gamma knife surgery, stereotacic radiotherapy or intralesional injection of sclerosant (e.g. pingyangmycin) to induce apoptosis of the vascular endothelial cells. The choice of surgical approach to excision of CVM should be determined by anatomical location and the relationship with orbital structures especially the optic nerve.

Possible approaches are outlined in Table 3

Due to the difficulties imposed by anatomical locations of orbital apex lesions, judicious care is needed when considering a patient with

Table 3 Possible surgical approaches for cavernous venous malformations

Approach	Lesion locations	Surgical Procedure
Anterior orbitotomy	Extraconal or intraconal lesions that do not involve the orbital apex	Conjunctival or cutaneous incision, retraction of extraocular muscles by silk sutures away from the CVM. Suture or needle exsanguination to reduce the size of CVM. Concomitant lateral canthotomy or vertical lid-split may be used to allow better exposure
Lateral and transcranial orbitotomy	CVM in posterior third of the orbit, especially those superior or lateral to the optic nerve	Krönlein's operation or modified Kroenlein's lateral orbitotomy, transcranial approach with superior orbitotomy
Endoscopic transethmoidal, transsphenoidal	CVM in the medial or inferior orbit Orbital apex	Endoscopic transnasal ethmoidectomy, maxillary antrostomy. Fracture of the lamina papyracea and the orbital floor. Open up the periorbita. Medial and/or inferior rectus muscle may be retracted by suture
Caldwell luc antrostomy	Orbital apex (inferior, posterior lesions)	Sublabial incision, the posterior inferior orbital wall is removed and the inferior rectus is retracted to access the tumor in the inferior and posterior region of the orbital apex

apical CVM for surgery. If complete resection is deemed difficult or dangerous, apical decompression, debulking or bipolar shrinkage of CVM with/without additional intralesional sclerosant or postoperative radiotherapy (gamma knife surgery or fractionated stereotacic radiotherapy) may be considered. Recurrence of CVM after surgical resection is rare.

Possible post-operative complications include:

- Loss or deterioration of vision due to vasospasm of posterior ciliary vessels
- Mydriasis (2.7–7%) due to ciliary ganglion injury
- Diplopia (5–38%)
- Oculomotor palsy (5%)
- Enophthalmos (15–40%)
- Lid hematoma
- Seizure
- Subdural hematoma.

Idiopathic Orbital Inflammatory Disease (Orbital Pseudotumor)

Idiopathic orbital inflammatory disease (IOID) describes a spectrum of inflammatory orbital diseases of which the underlying pathogenesis is still not well understood. IOI describes a condition characterized by tumefactive, non-granulomatous inflammation with variable degree of fibrosis. Several etiologies have been proposed including infection (post streptococcal pharyngitis, Lyme disease, post herpes zoster ophthalmicus), autoimmune and aberrant immune-mediated process. More recently gene expression profiling studies are shedding light on different phenotypes of IOI.

IOI is usually confined to the orbit with rare extraorbital involvement when the disease process extends through the fissures, foramina or via erosion through the orbital bone(s). The reported incidence of IOI ranges from 5.2 to 11% of orbital mass lesions.

Clinical Presentation

IOI is a diagnosis by exclusion. A combination of case history, physical examination, radiological and histopathological findings as well as response to steroid therapy should be taken into consideration during diagnosis. It is important to rule out differential diagnoses of **v**ascular, **e**ndocrine (thyroid-associated), **i**nflammatory (specific and systemic-related), **i**nfective and **n**eoplastic (VEIN) origins. While IOI typically presents unilaterally, simultaneous or sequential

bilateral involvements have been reported. IOI can be classified based on anatomical location into:

(a) **Idiopathic dacryoadenitis**

Diffuse enlargement of the lacrimal gland is the most common subtype of IOI. Clinically patients may present acutely with painful S-shape swelling of the upper eyelid, with periorbital erythema, edema and conjunctival chemosis. Patients may also present with a minimally tender lacrimal gland mass in chronic dacryoadenitis.

CT or MRI classically shows diffuse lacrimal gland enlargement (typically the orbital lobe) with preservation of the glandular shape.

(b) **Idiopathic orbital myositis**

Patients with extraocular muscle involvement usually present with pain on eye movement (especially on gaze away from the action of the involved muscle), diplopia with demonstrable extraocular muscle restriction, proptosis and conjunctival injection overlying the inflamed extraocular muscle. The medial rectus is the most commonly affected muscle, followed by the superior rectus, lateral rectus and inferior rectus.

Contrast-enhanced MRI of the orbit can demonstrate fusiform enlargement of the extraocular muscle classically with tendon involvement. Lesions are hyperintense on T2-weighted, fat suppressed images due to the presence of inflammatory edema. Sometimes, a central area of hypointense necrosis may be seen within the muscle belly. The edge of the muscles may be blurred due to perimuscular inflammation.

(c) **Anterior orbit involvement (Fig. 4)**

In this subtype, several orbital structures may be involved including the sclera, Tenon capsule and uvea. Patients present with orbital pain, decreased visual acuity, conjunctival chemosis, uveitis, choroidal effusions, and eyelid edema.

Imaging may demonstrate blurring of the scleral-uveal interface due to thickening of the scleral uveal rim and extension of edema into the Tenon space. Contrast enhanced, fat-suppressed T1 weighted MRI may show enhancement of the Tenon space. Ultrasound may reveal the characteristic T sign of posterior scleritis.

(d) **Orbital apex and optic perineuritis**

IOI may involve the orbital apex and present as orbital apex syndrome with pain. Imaging may show diffuse, infiltrative lesion in the apex with

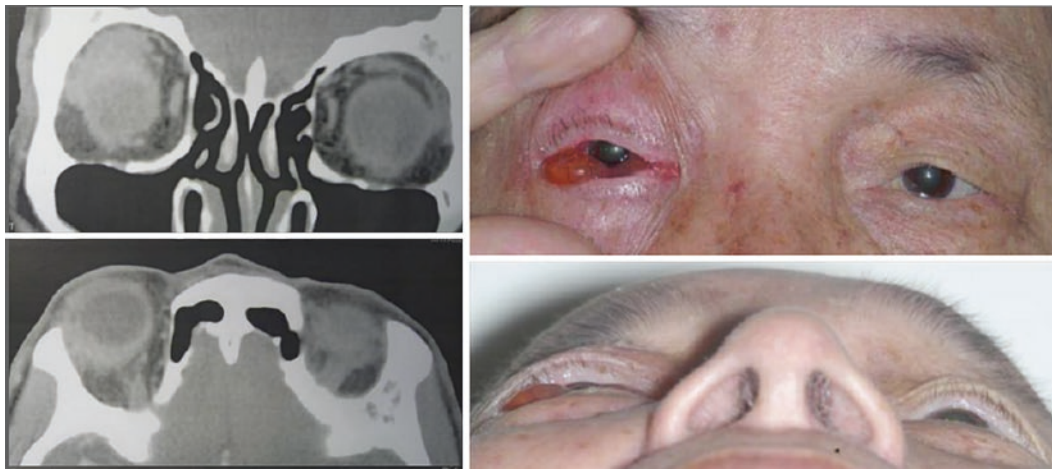

Fig. 4 Idiopathic dacryoadenitis, myositis and anterior orbital involvement of IOI. CT showing swelling of right superior rectus/levator complex, lacrimal gland and thickening of the scleral uveal rim. Clinically patient presented with right periocular swelling, ptosis, chemosis and mild proptosis

possible optic nerve compression. This may extend beyond the orbit via the superior or inferior orbital fissure or the optic canal to the cavernous sinus or other intracranial structures (inflammation in the middle or anterior cranial fossa as meningeal enhancement). On the other hand, rare involvement of the optic nerve sheath may cause optic perineuritis, when patient may demonstrate arcuate or paracentral visual field loss.

(e) **Diffuse orbital inflammation**

These patients present with diffuse inflammation of the orbital fat and/or more than one of the structures described in the previous 4 categories. A sclerosing variant (sclerosing IOID, SIOID) may lead to serious morbidity with chronic, progressive and painful involvement of orbital structures. SIOID typically leads to fibrosis and obliteration of orbital planes. Imaging of sclerosing variant may show ill-defined borders and the pathology is usually located in the superolateral orbit. In contrast to IOID, patients with SIOID often show poor response to anti-inflammatory medications, steroids and radiation, but good responses to chemotherapies such as cyclosporine or biologics such as infliximab. Extra-orbital manifestations of SIOID can occur in patients with multifocal fibrosclerosis, IgG-4 related disease, and diseases characterized by histiocytosis (Rosai-Dorfman disease and Erdneim-Chester disease). Systemic involvement often includes retroperitoneal or mediastinal fibrosis, cardiac involvement and long bone sclerolytic destruction.

Investigations and Diagnosis

Due to the wide spectrum of clinical and histological findings, several classifications and diagnostic criteria have been proposed based on anatomy, clinical presentation or histopathology, although none of which have been widely adopted. In 2017, Mombaerts et al published a Consensus statement on but this Diagnostic Criteria of IOI– the CDCIOI remains to be validated clinically. The recommended blood tests are shown on Table 4.

The role of tissue biopsy for pathological diagnosis has been confirmed with a consensus favoring earlier diagnostic confirmation. This is because certain differential diagnoses including lymphoid-related malignancy, IgG4 related disease and TAO may improve with steroid trial, giving false impression of IOI and delay the diagnosis and treatment. The panel of experts from the consensus statement recommends tissue biopsy for all suspected cases of IOI with the exception of (1) orbital myositis (initial systemic steroid trial), or (2) orbital apex IOI which carries high risk of surgical morbidity.

Biopsy is recommended to be done at several involved sites and depths to reduce sampling error and achieve adequate tissue for examination. Surgical approach depends on the anatomical structures involved. While skin or conjunctival approach can be used for superficial lesions, orbitotomy is indicated for deeper orbital tissues. Fine needle aspiration biopsy is not recommended due to low yield and insufficient tissue architecture for pathological diagnosis.

The histopathological findings of IOI include a nonspecific, polymorphous infiltrate of well differentiated lymphocytes, plasma cells and neutrophils and eosinophils arranged in lymphoid follicles with reactive germinal centers. The degree of associated fibrosis is variable. Immunostaining of plasma cells for IgG4 is important to exclude IgG4-RD.

Table 4 Recommended blood tests for patients with suspected idiopathic orbital inflammation

Type of patient	Laboratory blood test
All	White cell count with differential, platelet count, calcium and liver function test, erythrocyte sedimentation rate, C-reactive protein, ANCA (proteinase 3 antineutrophil cytoplasmic antibody), IgG4, angiotensin-converting enzyme, lysozyme
Idiopathic dacryoadenitis	Anti-Ro, Anti-La, rheumatoid factor, anti-cyclic citrullinated peptide antibody, anti-citrullinated protein antibody, antinuclear antibody
Idiopathic myositis	Thyroid function test, thyroid stimulating hormone, thyroid stimulating hormone receptor antibody

Treatment

Systemic corticosteroids remains the first-line treatment for IOI. The recommended regimen begins with oral prednisolone at 1 mg/kg per day or higher and has been shown to lead to rapid clinical response within 2 days of initiation. Oral steroids should be slowly tapered over a period of weeks to months to reduce the risk of rebound or relapse. The use of high dose intravenous methylprednisolone has not shown to infer more favorable outcome but can be an option for compressive optic neuropathy. However, high dose systemic steroid carries risk of severe side effects and has been reported to have suboptimal response in some patients with idiopathic dacryoadenitis. Local steroid injection (with betamethasone followed by 2 weeks of nonsteroidal anti-inflammatory drugs) have shown promising results with dramatic clinical improvements. Patients should be closely monitored for short-term and long-term local and systemic steroid side effects.

Nonsteroidal ant-inflammatory drugs (NSAIDs) e.g. indomethacin 150 mg daily may be used in mild cases of IOI.

Steroid sparing agents (methotrexate, cyclosporin A, mycophenolate mofetil, cyclophosphamide and azathioprine) should be initiated in patients who are (1) steroid non responders, (2) recurrent, (3) steroid dependent or (4) steroid intolerant.

Biologics, such as Rituximab acting against CD20 on B cells, have been used successfully in patients with refractory idiopathic IOI. The dosage tested ranged from weekly dose of 375 mg/m^2 for 4 weeks to 1000 mg every 2 weeks. The reported success rate was approximately 70%. Other researchers have tried intraorbital injection of rituximab with favorable outcome (10 mg/week for 4 weeks). Infliximab, an antibody targeting TNFα, has also been shown to be useful in patients with refractory IOI. Adalimumab, also targeting TNFα, has successfully treated 2 patients with orbital myositis.

External Beam Radiotherapy (EBRT)

EBRT provides a useful adjuvant therapy or even an alternative to steroids in recurrent or refractory cases. EBRT has been shown to lead to complete cessation of steroid therapy in 56.3% of patients and steroid dose reduction in 25% of patients.

Surgery

The role of surgery in IOI is usually a diagnostic one. However, for patients with disease refractory to medical or radiation treatment, surgical debulking may be considered and orbital decompression for eyes with compressive optic neuropathy. Surgical debulking of the orbital lobe of the lacrimal gland has been used as initial treatment for idiopathic dacryoadenitis with 80% success rate and 8% recurrence requiring medical treatment.

IgG4 Related Orbitopathy

Immunoglobulin G4 related disease (IgG4 RD) is a chronic, relapsing, systemic, immune-mediated fibroinflammatory condition characterized by tumefactive lesions in the affected organs. Histopathology remains the gold standard to differentiate IgG4RD from simulating lesions. Striking histopathological consistency over broad-range of involved organs include dense IgG4-positive lymphoplasmacytic and eosinophil infiltration, reactive lymphoid follicles, storiform fibrosis and obliterative phlebitis. IgG4 is the least abundant IgG subclass with putative roles in anti-inflammation and tolerance induction via antigen capture, preventing the antigens from driving inflammatory response.

Clinical Features

IgG4 RD commonly involves the ocular adnexa and organs such as the pancreas, hepatobiliary system, lung, breast, retroperitoneum, lymph nodes, thyroid gland and salivary gland. The prevalence and incidence of IgG4RD is currently unknown. Contrast to other classic autoimmune diseases, IgG4 RD showed a male predominance with male: female ratio of 8:3. However, amongst patients with IgG4 related ophthalmic disease (IgG4-ROD), men and women are roughly evenly affected (1.3:1). IgG4 RD typically presents around 50 years of age. IgG4RD has been diagnosed in children, with similar systemic disease characteristics as those seen in adults while ocular manifestations (e.g. dacryoadenitis) are more frequently observed.

Patients with IgG4RD often present insidiously without constitutional symptoms. The disease may remit and relapse with spontaneous improvement. Although the classic presentation involves painless swelling of the lacrimal gland which is often bilateral (reported up to 58–71% in patients with IgG4 ROD), it may involve any orbital tissue including the extraocular muscles (EOM) (19–25%), orbital fat (29–40%) (presenting as inflammatory pseudotumor or tumefactive lesions), trigeminal nerve branches (9.5–39%) especially infraorbital and frontal nerves, eyelid and the nasolacrimal duct system (1.5–9.5%).

Patients typically complain of bilateral periorbital and/or eyelid swelling, erythema and proptosis with minimal pain (in contrast to patients with idiopathic orbital inflammation). Patients with EOM involvement may experience diplopia and restricted eye movement. The most commonly affected EOM is the inferior rectus, followed by the superior-rectus-levator complex, while the superior oblique is least commonly affected (Fig. 5). Patients may rarely present with visual loss due to compressive or infiltrative optic neuropathy. Nasolacrimal outflow involvement will lead to epiphora. There are a few reports of bony orbit destruction as well as scleritis and conjunctival involvement. It is important to note that patients with IgG4-ROD are at higher risks of non-Hodgkin Lymphoma (e.g. MALT lymphoma).

Systemic manifestations of IgG4 RD are summarized in Table 5.

Diagnosis

The diagnosis of IgG4 RD is complex due to the myriad of organs involved with heterogeneity in

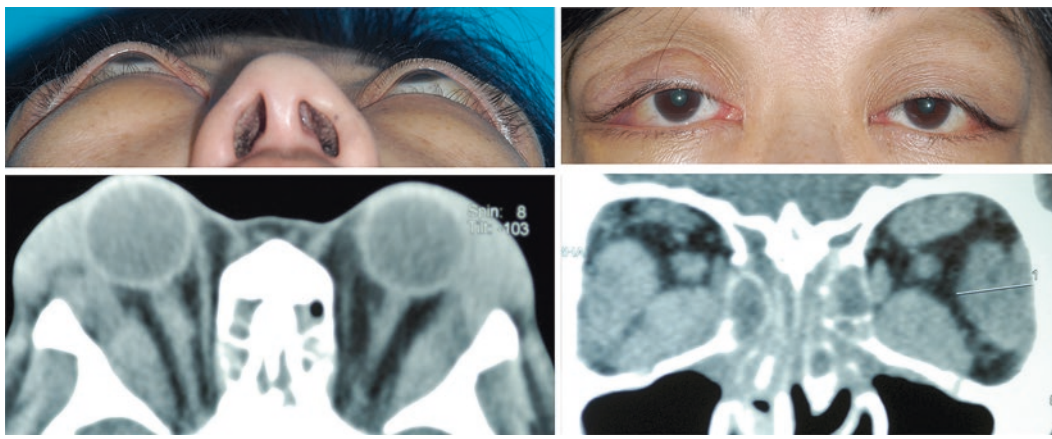

Fig. 5 CT of a middle-aged female with definite IgG4 related ophthalmic disease showing bilateral lacrimal gland, inferior and lateral recti, and left superior rectus enlargement. Clinically she showed bilateral proptosis, lid swelling and the classic "S-shaped" ptosis. Noted the bilateral ethmoid sinusitis

Table 5 Systemic manifestations of IgG4-related disease

Organ/system	Clinical features
Orbital adnexa	Orbital pseudotumor, tumefactive lesion, dacryoadenitis, orbital myositis
Salivary gland	Kuttner's tumour (chronic sclerosing sialadenitis), characteristic submandibular gland involvement
Ear, nose, sinus	Allergic rhinitis, nasal polyp, chronic sinusitis, nasal obstruction
Thyroid	Riedel thyroiditis
Intracranial	Pachymeningitis, hypophysitis, cranial nerve palsies, spinal cord compression, mass (hypertrophic patchymeningitis)
Lung	Inflammatory pseudotumor, pulmonary nodules, interstitial lung disease, pleural thickening, pleural effusion, obliterative phlebitis
Vessels	Aortic aneurysm, aortic dissection, fibrosing mediastinitis
Pancreas	Type 1 autoimmune pancreatitis diffuse or focal (mass like lesion typically at pancreatic head) patterns
Hepatobiliary system	Sclerosing cholangitis, inflammatory mass lesions (pseudotumor), obstructive jaundice
Kidney, retroperitoneum	Retroperitoneal fibrosis, tubulointerstitial nephritis

Table 6 Diagnostic criteria for IgG4-related disease and IgG4-related ophthalmic disease

Unmehara (2012) IgG4 RD	Goto (2015) IgG4 ROD
(1) Clinical examination with characteristic swelling or masses in single or multiple organs	(1) Imaging studies show enlargement of the lacrimal gland, trigeminal nerve, or extraocular muscle as well as masses, enlargement, or hypertrophic lesions in various ophthalmic tissues
(2) Hematological evidence of elevated serum IgG4 concentration (≥135 mg/dl)	(2) Histopathologic examination shows marked lymphocytic and plasmacytic infiltration, and sometimes fibrosis. A germinal center is frequently observed. IgG4+ plasmacytes are found and satisfy the following criteria: ratio of IgG4+ cells to IgG+ cells of 40% or above, or more than 50 IgG4+ cells/HPF (×400)
(3) Histopathological features of marked lymphocytic and plasmacytic infiltration and fibrosis and infiltration of IgG plasma (ratio of IgG4+/IgG+ cell >40% and >10 IgG4+ plasma cells/HPF)	(3) Blood test shows elevated serum IgG4 (≥135 mg/dl)

clinical and laboratory features. While physical examination, radiological imaging and serology are necessary, histopathological features remains the gold-standard. In 2012, Unmehara et al. devised the diagnostic criteria for systemic IgG4-RD (Table 6). Definite IgG4-RD is diagnosed when all the 3 criteria are present while probable disease with criteria 1 and 3 and possible disease with criteria 1 and 2. In 2015, Goto et al. proposed the organ-specific diagnostic criteria for IgG4-ROD (Table 6).

Biochemically, patients may have elevated levels of serum IgE, gammaglobulin, eosinophil and decreased level of complement. Other blood tests to be considered for the differential diagnoses include complete blood count, lactate dehydrogenase (abnormal in lymphoproliferative disease), anti-neutrophil cytoplasmic antibody (granulomatosis with polyangiitis), anti-Ro and anti-La antibodies (Sjogren's syndrome), anti-nuclear antibody, angiotensin converting enzyme (sarcoidosis) and thyroid function test (thyroid eye disease or thyroid involvement in systemic IgG4 RD). Microbiological workup including eye swab and culture may be indicated to rule out chronic orbital infection or "cold abscess".

Elevated serum IgG4 levels (≥135 mg/dL) were observed in up to 84% of patients with IgG4RD and most studies reported a mean IgG4 level of four to six times higher than the upper limit of normal. However, there's still a wide

range of IgG4 levels amongst patients with IgG4 RD. Some studies reported up to 30–40% of patients with normal serum IgG4 level despite clinical and histopathological confirmation. Although initially included as one of the diagnostic criteria of IgG4RD, recent studies argue for its role in diagnosis. Some studies have reported increased serum IgG4 to total IgG ratio (usually <5%) in 25–86%.

Imaging studies with either computed tomography (CT) or magnetic resonance imaging (MRI) play important role in diagnosis. In the periorbital region, imaging may show enlargement of the lacrimal gland, swelling or inflammatory changes of the adnexal structures. These lesions typically have well-defined margins and appear isodense on plain CT, while MRI typically shows T1-isointense and T2-hypointense lesions with homogeneous internal architecture and homogenous gadolinium enhancement. Bone remodeling without destruction is also characteristic. In view of possible systemic involvement, some studies have suggested the use of 18F-fluorodeoxyglucose (FDG) positron emission tomography/CT (PET-CT) for detecting systemic organ involvement.

Histopathological analysis is crucial. IgG4 RD display consistent morphological features across organs of involvement. Presence of 2 out of the 3 key features are considered histopathologically diagnostic: (1) dense lymphoplasmacytic infiltrate, (2) fibrosis with storiform pattern (fibroblasts and inflammatory cells arranged in a cartwheel pattern); and (3) obliterative phlebitis. Other supportive features include mild-to-moderate tissue eosinophilia. Of note, lacrimal gland rarely shows storiform fibrosis or obliterative phlebitis' instead, T-lymphocytic infiltrates are typically seen. Other histopathological findings in IgG4-ROD are epineurium involvement without fibrosis, germinal centers and obliterative arteritis. On immunohistochemistry, >100 IgG4+ cells/HPF in lacrimal gland biopsies is sufficient for diagnosis. Although the presence of high numbers of IgG4 positive plasma cells in inflammatory infiltrates are suggestive of IgG4RD, it may be seen in other conditions such as xanthogranulomatous disease, granulomatosis with polyangitis and neoplastic disorders. Clonal studies are also recommended to rule out lymphoma as there are vast similarities in the histologic features of lymphoma and IgG4RD.

Management

For treatment of IgG4-ROD, systemic corticosteroid is often used as first-line medical therapy. There is no guideline for steroid regimen, although 0.6 mg/kg/day (following the regimen for IgG4-related pancreatitis) with a taper of 5 mg every 1–2 weeks may be used. Studies have shown that a maintenance dose of 5 mg/day of oral prednisolone may decrease relapse rates from 92 to 23% over a 3-year period in autoimmune pancreatitis. Unfortunately, relapse rates are high (up to 70% either during tapering or after treatment).

In relapse cases, an additional course of oral prednisolone (e.g. 6–10 weeks) or addition of biologic (e.g. rituximab which target-CD20 on B cells) may be considered. Rituximab is given as two doses of 1 g infusions at 2 weeks' interval. Steroid sparing agents such as methotrexate, azathioprine or mycophenolate as well as adjuvant radiotherapy have been reported with variable success. Finally, patients should be monitored and treated for dry eye in view of infiltration and fibrosis of the lacrimal glands. In IgG4 ROD, surgical biopsy is indicated for initial diagnosis. Otherwise, surgery is reserved for patients who develop vision threatening compressive optic neuropathy or rarely, symptomatic, medically refractory lesions.

Infection

Preseptal and orbital cellulitis are uncommon infections involving contents of the orbit (fat, extraocular muscles and soft tissues surrounding the globe) anterior to or posterior to the orbital septum respectively. Both diseases are found predominantly in the pediatric population. Peak incidence of preseptal cellulitis has been

reported in children under age of 5 while the mean age of patients with post-septal cellulitis is 6.8. While preseptal cellulitis generally has more favorable outcome, orbital cellulitis may lead to vision or even life threatening complications including cavernous sinus thrombosis, meningitis, osteomyelitis, frontal abscesses and death. The percentage of patients with blindness resulting from orbital cellulitis has been reported to range between 7.1 and 23.6%.

Orbital cellulitis often results from extension from paranasal sinusitis where the infection can spread through the bony wall from the ethmoid (via fenestrated lamina papyracea) or maxillary (via orbital floor) or frontal sinuses (roof). Other causes of orbital cellulitis include post periorbital trauma, post ocular or dental surgery, dacryocystitis, endophthalmitis, septicemia and intraocular and orbital tumours.

It may be difficult to identify the causative organisms in orbital cellulitis as cultures are only representative if surgical intervention is done. Positive blood culture is rare in adults (5%) and variable in children (0–33%). The most commonly identified organism are *Staphylococcus aureus* and *streptococci*. *Hemophilis influenzae* has also been frequently identified in various studies but the incidence of *H. influenza* type b has decreased after the widespread use of the Hib vaccine. Abscess cultures rarely grew anaerobes (e.g. *Eikenella corrodens, Fusobacterium*) and gram-negative bacilli (e.g. *Pseudomonas aeruginosa, Klebsiella* and *Morganella*). Fungal organisms, although rare, can lead to life-threatening invasive orbital infections (mucormycosis and aspergillosis). They should be especially considered in immunocompromised hosts e.g. transplant recipient, or patients with poorly controlled diabetes.

Clinical Presentation and Diagnosis

The key distinguishing features of orbital cellulitis from preseptal cellulitis include extraocular muscle involvement (opthalmoplegia and diplopia), proptosis and visual loss due to compression, inflammation or ischemia of the optic nerve. Other associated clinical features include eyelid swelling with or without erythema, ocular pain, chemosis and constitutional symptoms e.g. malaise and fever. Complications arising from orbital cellulitis include orbital and subperiosteal abscess (SPA). The presence of edema beyond the margin and an absolute neutrophil count exceeding 10,000 cell/ul have been identified as independent risk factors for orbital abscess formation. Orbital cellulitis can further spread intracranially via the valve-less superior and inferior ophthalmic veins that drains directly into the cavernous sinus. This may cause cavernous sinus thrombophlebitis and brain abscess. Therefore, it is prudent to not only closely monitor the patient's visual function but also mental, neurological and systemic status including signs of meningism (Fig. 6).

In patients with suspected orbital cellulitis, laboratory investigations followed by prompt systemic antimicrobial treatment is important. Investigations should include blood tests to look

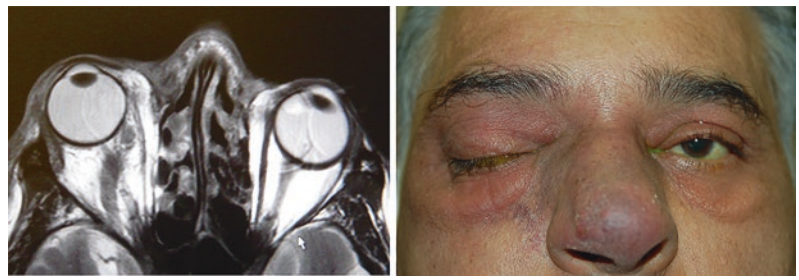

Fig. 6 Newly diagnosed type 2 diabetes patient presenting with orbital cellulitis complicated by cavernous sinus thrombosis. Enlarged superior ophthalmic vein and proptosis shown on T2-weighted axial MRI (left)

for leukocytosis (usually neutrophil predominant), elevated inflammatory markers and blood culture. Contrast-enhanced orbital imaging (e.g. computed tomography) may provide further information and detect complications such as SPA, orbital abscess and intracranial extension.

Treatment

Most patients with uncomplicated orbital cellulitis respond to systemic antibiotics alone. Empirical antibiotics (e.g. ceftriaxone, cefotaxime, vancomycin) should be chosen with a broad-spectrum of activity that covers for *S. aureus, Streptococci* and Gram negative bacilli. MRSA coverage is advisable especially in patients with risk factors. Anaerobic coverage (e.g. with metronidazole) is necessary in cases of suspected intracranial involvement or in patients with chronic sinusitis or odontogenic source of infection. Patients should show clinical response within 24–48 hours of antibiotic treatment. If no clinical improvement is observed, repeat CT imaging is warranted while surgical biopsy and/or drainage should be considered to look for resistant or atypical organisms, as well as to rule out noninfectious causes (for example, idiopathic orbital inflammatory disease or granulomatosis with polyangiitis).

Surgical drainage is indicated in cases complicated with abscess formation, especially if they are >10 mm in diameter or >1250 mm^3, refractory to antibiotic therapy or threaten in volume vision. SPA has been conventionally treated with surgical drainage, but in recent years, the trend is towards conservative management, which may be safer and equally effective under specific conditions. The argument against immediate surgical drainage is that the orbital periosteum provides a strong barrier against spread of infection and surgery may destroy this natural protection. In a prospective study, Garcia and Harris showed favorable outcome from conservative management of patients who are aged <9 years old, have a medially located abscess, whose SPA is of modest size and who have no visual changes. Another study found that SPA >2 cm have a tendency to reaccumulate after surgical drainage if nasal sinuses are not drained concurrently.

Possible surgical approaches include:

(1) External (cutaneous), Lynch incision
(2) Endoscopic (transnasal approach to medial SPA)
(3) Transcaruncular/transconjunctival

Collaboration with ENT surgeons with simultaneous sinus drainage or debridement should be considered in patients with significant rhinosinusitis. Sinus disease should be treated with nasal saline spray, nasal corticosteroid, oral antihistamine or even systemic corticosteroids in certain cases.

Neoplastic Disorders

Lymphoproliferative Diseases

Lymphoid tissues are present in eyelid, conjunctiva and lacrimal gland. The term ‘ocular adnexal lymphoproliferative disorders (OALD) has been adopted to include a broad spectrum of pathology ranging from the benign reactive lymphoid hyperplasia to the malignant lymphoma.

Most cases of OALD run an indolent course. They can affect all periocular tissues with wide range of clinical presentations. Lymphoproliferative lesions are believed to be secondary to chronic antigenic stimulation. An enthusiastic association between *Chlamydia psittaci* infection and mucosa-associated lymphoid tissue (MALT) lymphoma of the orbit were described in a few European cohorts, although similar results were unable to be repeated by other groups.

Imaging typically reveals soft tissue lesion molding around orbital structures without compression or erosion. While various radiological parameters have been studied to assist in the differentiation of benign and malignant OALD, the final diagnosis depends on representative tissue biopsy and histopathology.

Recent advances in pathological techniques have greatly improved the characterization of benign and malignant lymphoid disorders. The combination of histomorphology, immunohistochemistry, immunophenotyping, and molecular genetics becomes an essential part to the diagnosis and management of OALD.

Clinical Features

OALD can affect any structure from the eyelid, conjunctiva, lacrimal sac, extraocular muscles, orbital soft tissues and lacrimal gland. The most common presentation is slowly enlarging mass(es), followed by gradually worsening proptosis. Mechanical ptosis can result from lacrimal gland or eyelid involvement. Palpebral conjunctival lesions are evident externally and present classically with salmon-pink patches (Fig. 7). When the lacrimal sac is affected, epiphora and mucoid or blood-stained discharge due to dacryocystitis can occur. Ocular motility may rarely be impaired if extraocular muscles are the primary site of pathology, but visual loss is uncommon as the lesions tend not to compress onto the eyeball or optic nerve. Bony erosion is unusual except in the rare setting of high-grade lesions, e.g. NK-T cells lymphoma.

Classification

OALD can be classified into benign and malignant lesions. It represents a spectrum of evolving lesions and definite differentiation may at times be difficult. Lymphoma lies on the malignant end and is represented by monoclonality and cytological atypia. Lymphoid hyperplasia (LH), on the benign end, shows minimal atypia and no evidence of monoclonality. Lymphoma accounts for around 70% while LH up to around 30% of all OALD. Borderline lesions with cytological atypia but no monoclonality with absence of gene rearrangement on molecular studies are classified as 'atypical lymphoid hyperplasia'.

Lymphoproliferative lesions need to be differentiated from chronic inflammatory orbital diseases. IgG4 related orbital disease is an increasingly recognised clinical and pathological entity. The pathological diagnosis of lymphoproliferative disorders, therefore, also warrants the use and quantification of IgG4 staining of the lymphoplasmacytic infiltrates.

Ocular Adnexal Lymphoma (OAL)

Classification

OAL can be grouped into primary and secondary. Primary OAL is confined to the ocular adnexa. Secondary OAL are orbital lesions which are diagnosed in multifocal disease, or lesions that recur after a distant primary not contiguous to the orbit.

As for lymphoma in other body sites, OAL can be divided into Hodgkin and non-Hodgkin lymphoma (NHL); the latter can be further divided into B cell, natural killer (NK) cell and T cell lymphomas. The most common *primary OAL* is an NHL of B-cell origin termed extranodal marginal zone lymphoma of mucosa-associated lymphoid tissue, also known as mucosa-associated lymphoid tissue lymphoma (MALToma). Less frequently encountered are follicular lymphoma, diffuse large B-cell lymphoma and other subtypes like mantle cell lymphoma (Fig. 8). In contrast, *secondary OAL* are usually associated with the more aggressive histological subtypes.

Clinical Features and Diagnosis

OAL typically affects patients in the fifth to seventh decades. The presentation depends largely on the site of involvement. Occasionally, small lymphomas may be an incidental finding when surgeons noticed atypical macroscopic appearance of orbital soft tissue during blepharoplasty or ptosis correction.

Imaging usually reveals ill-defined, irregular masses that mold around the eyeball and other orbital structures. Bone remodelling is more common than bone erosion. The lesions tend to be hyperdense with moderate, uniform contrast

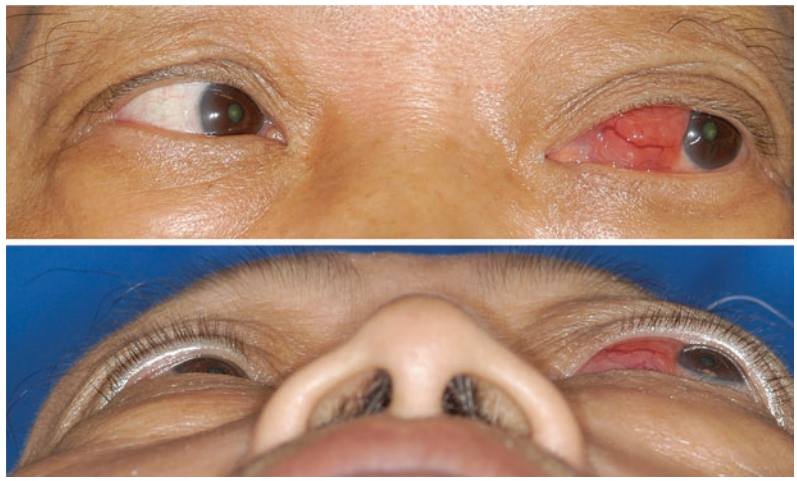

Fig. 7 Classic presentation of left-sided conjunctival and anterior orbital MALToma as "salmon patch" of the medial palpebral conjunctiva associated with proptosis

enhancement on computed tomography. Bony destruction is uncommon unless the lymphoma is of the rare, high-grade subtype. On magnetic resonance imaging, OAL tends to be isointense to extraocular muscles on T1-weighted images and hypointense to isointense on T2-weighted sequences, and demonstrates moderate enhancement with gadolinium contrast. Nodular rather than fusiform enlargement and involvement of the extraocular muscle tendons are typical radiological features to differentiate from thyroid-associated orbitopathy. Significantly lower apparent diffusion coefficient (ADC) in diffusion-weighted imaging (DWI) and significantly lower enhancement ratio (ER) and higher washout ratio (WR) on dynamic contrast-enhanced (DCE) are increasingly reported in multiparametric MRI. Since the definitive diagnosis of OAL relies on histology, open biopsy remains the gold standard. Ultrasound-guided fine needle aspiration cytology has limited role although core-needle biopsy may be a promising alternative.

Staging

In patients with a confirmed diagnosis of OAL, staging includes complete blood count, blood film and bone marrow examination along with systemic workup. Positron emission tomography (PET)/ computed tomography of the whole body has higher sensitivity than total-body contrast CT for systemic multifocal diseases alone, but cost is a major concern. PET-CT is less sensitive than CT or MRI in detecting local OAL due to the high background physiologic activity of the extraocular muscles and the typically small volume of orbital lesions.

Management

Collaboration with oncologists is part of the multidisciplinary management of OAL.

As most primary OAL are represented by low-grade MALToma, treatment of this pathological subtype is well-established in the literature. Radiotherapy (RT) is the commonest modality for primary MALToma localised to the orbit. 3-dimensional conformal RT and intensity-modulated RT fit the shape of the tumour and allow precise delivery of irradiation to the tumour, while minimising toxicity to surrounding normal structures at the same time. This is of particular importance given the adjacent radiosensitive structures like the cornea, crystalline lens, retina and optic nerve. The recommended

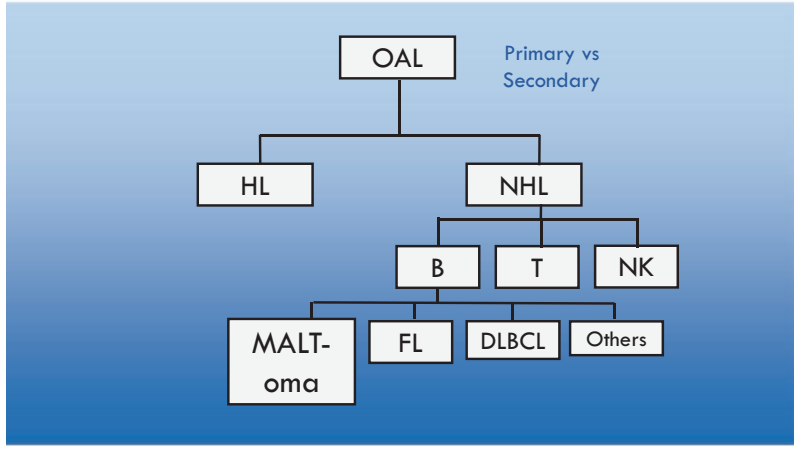

Fig. 8 Similar to lymphoma at other body sites, ocular adnexal lymphoma (OAL) can be divided into Hodgkin (HL) and non-Hodgkin lymphoma (NHL); the latter can be further subdivided into B, T and NK cell lymphomas. The majority of OAL are B cell lymphomas, and MALToma accounts for the majority of primary OAL. Secondary OALs are usually associated with more aggressive subtypes. FL: follicular lymphoma; DLBCL: diffuse large B-cell lymphoma

dose of around 30 Gy can achieve a high rate of remission with a favourable side-effect profile. Recently, some authors have proposed the use of ultra-low-dose irradiation of 2 × 2 Gy with more than 85% of patients showing a complete response. This may further minimise the toxicity of RT to ocular and orbital structures.

Use of chemotherapy in orbital MALToma with cyclophosphamide, vincristine, prednisolone and/or chlorambucil has been tried, with response rate approaching 80%. The role of rituximab in localised MALToma has yet to be confirmed. In general, for lymphoma confined to the orbit, chemotherapy is not necessary except in high-grade histological subtype e.g. diffuse large B-cell lymphoma.

Secondary OAL is usually more aggressive and rapid initiation of systemic treatment is recommended. Conventional chemotherapy with CHOP regimen (cyclophosphamide, hydroxydaunorubicin, vincristine and prednisolone) has well-proven efficacy. Rituximab, a monoclonal antibody (anti-CD20) targeting the specific antigens expressed by B cells, has much fewer side effects while demonstrating good control of the disease; its combination with the CHOP regimen is advocated by many. Orbital RT may provide additional benefit in some cases to enhance local control.

Prognosis and Follow-up

Primary OAL generally has good response to treatment and a favourable 5-year survival of >90%. However, epidemiological studies have demonstrated that systemic NHL can develop in around 15% of patients with primary OAL in 5 years; this rises to one-third at 10 years. Thus, regular monitoring is essential even after remission of OAL.

NK/T Cell Lymphomas

These classically involve the paranasal sinuses and nasal cavity. Primary ocular or orbital involvement is rare and is usually a result of contiguous invasion. They carry a high mortality and extremely poor prognosis despite treatment.

Lymphoid Hyperplasia (LH)

LH lies on the benign end of the spectrum of OALD. With advances in the knowledge of inflammatory and neoplastic diseases of the orbit, and improvement in diagnostic accuracy, along with the availability of immunophenotyping and molecular genetics, misdiagnosis of low-grade lymphoma or IgG4-related orbitopathy as LH is becoming less common.

Clinical Features and Diagnosis

LH more commonly develops in the conjunctiva and orbital space (including the lacrimal gland). It presents similarly to low-grade lymphoma clinically and radiologically, so surgical biopsy is essential for the differentiation.

LH should demonstrate polyclonal expression of immunoglobulin heavy and light chains; and no immunoglobulin heavy chain gene rearrangement on polymerase chain reaction (PCR).

Grey areas do exist where some lesions show inconsistency in terms of histomorphology, immunophenotype and clonality on PCR. These lesions, which do not fall into the diagnosis of lymphoma, are designated as 'atypical lymphoid hyperplasia (ALH)'. They should be taken as potential cases of low-grade lymphomas with inadequate representation on the biopsied specimen. If in doubt, cases with a pathological diagnosis of ALH should be considered for a repeat biopsy, bone marrow biopsy and PET/CT, similar to cases with confirmed lymphoma.

Management

In cases with confirmed LH, observation may be reasonable if the lesion is small, if the patient is asymptomatic or if there are multiple comorbidities rendering treatment with corticosteroids risky.

Oral corticosteroid is considered first-line treatment by many. Some authors are using intraorbital triamcinolone. Low-dose RT and rituximab have also been shown to be efficacious.

Cases with biopsy-designated ALH are best treated as for low-grade lymphoma as described previously.

Prognosis and Follow-up

Ocular adnexal LH is a benign disease and carries a favourable prognosis, especially conjunctival LH which is reported to be of low-risk for malignant transformation. However, recurrence occurs in up to 30% and there is a small chance of subsequent development of lymphoma; the risk is particularly high if PCR demonstrated evidence of monoclonality. Regular follow-up is thus recommended.

Lacrimal Gland Tumours

Classification

Lacrimal gland tumours have an incidence of 1 in 1 million and constitute approximately 10–20% of all orbital tumours. They can be classified into epithelial and non-epithelial and further divided into benign and malignant lesions (Fig. 9).

The most common benign epithelial tumour is pleomorphic adenoma; while the commonest malignant epithelial tumour is adenoid cystic carcinoma, followed by carcinoma ex-pleomorphic adenoma and adenocarcinoma not otherwise specified (NOS). In contrast to salivary glands, mucoepidermoid carcinoma is a relatively uncommon histology in the lacrimal gland.

Non-epithelial tumours can be further subclassified into lymphoid, mesenchymal and secondary (or metastatic) tumours. Lymphoid neoplasm of the lacrimal gland was discussed earlier.

Clinical and Radiological Features of Epithelial Tumours

Dacryops is a ductal cyst of the lacrimal gland; it appears as a transparent, bluish cystic mass arising from the temporal forniceal conjunctiva and is easily diagnosed with eversion of the upper eyelid.

Unlike the lymphoid lesions, epithelial tumours of the lacrimal gland tend to displace the globe inferiorly and nasally. While symptoms may have been present for years in benign cases, malignant lesions usually have a history of less than six months. A mass may be palpable

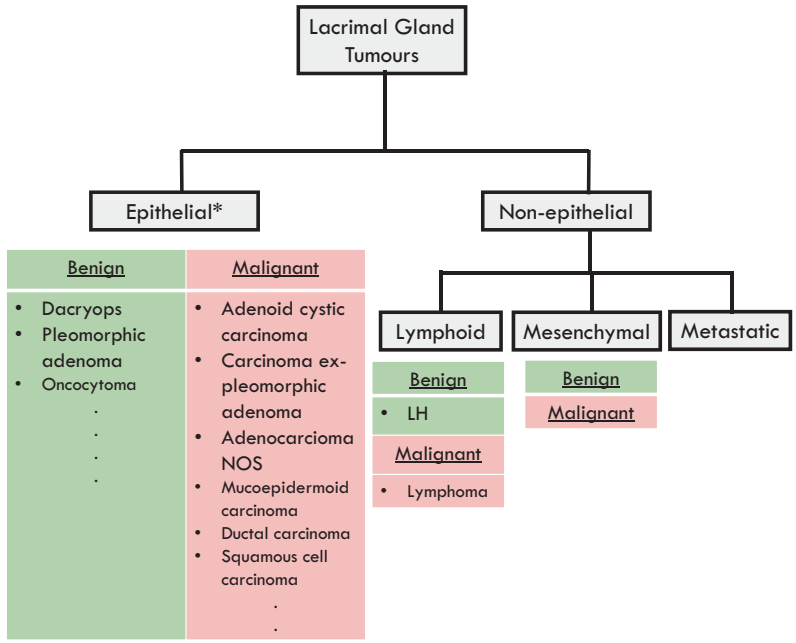

Fig. 9 Classification of common lacrimal gland tumors *Not all histological entities are included; only the more common subtypes are listed.

Abbreviations: **LH = lymphoid hyperplasia; NOS = not otherwise specified**

in the lacrimal gland fossa; S-shaped mechanical ptosis may result. Impaired ocular motility and diplopia can occur with increasing size of the tumour. The final diagnosis of a lacrimal gland tumour relies on histology.

Pleomorphic adenomas usually present in middle-aged with an average age of 40. It appears as a well-circumscribed oval mass on imaging (Fig. 10). There may be bone remodelling but not invasion, due to its slow yet relentless growing nature. It tends to compress instead of molding around the eyeball. It is hypointense or isointense on T1-weighted and hyperintense on T2-weighted images on magnetic resonance imaging (MRI) with moderate contrast enhancement.

Adenoid cystic carcinoma has a bimodal distribution with peaks at 10–20 and 40. It classically presents with pain owing to its propensity to perineural invasion. It is a locally invasive tumour and frequently metastasizes to regional lymph nodes and distant sites like the liver, lungs and brain. While it may appear similar to pleomorphic adenoma on imaging at the early stage, it becomes ill-defined as the disease progresses. Bone destruction and calcification within the lesion can be demonstrated on computed tomography (CT); these features are more common in carcinomas than in benign adenomas. MRI may have an advantage in evaluating perineural, cavernous sinus, sphenoid bone marrow and intracranial involvement. Adenoid cystic carcinoma is isointense on T1-weighted images; variably mixed hypointense, hyperintense and isointense areas may be shown on T2-weighted images. Contrast enhancement is the rule but there may be poorly enhancing regions representing intralesional cystic degenerative changes (Fig. 11). When an adenoid cystic carcinoma is confirmed, screening for systemic metastasis should be considered including chest X-ray, bone-scan, CT of head, neck and/or chest, and positron emission tomography.

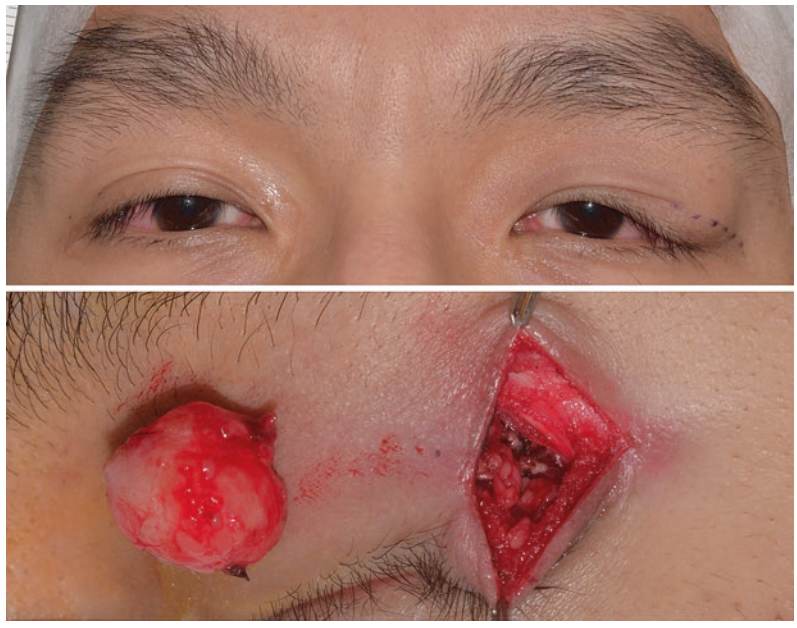

Fig. 10 Pleomorphic Adenoma of the palpebral lobe of the lacrimal gland in a young man causing S-shaped ptosis

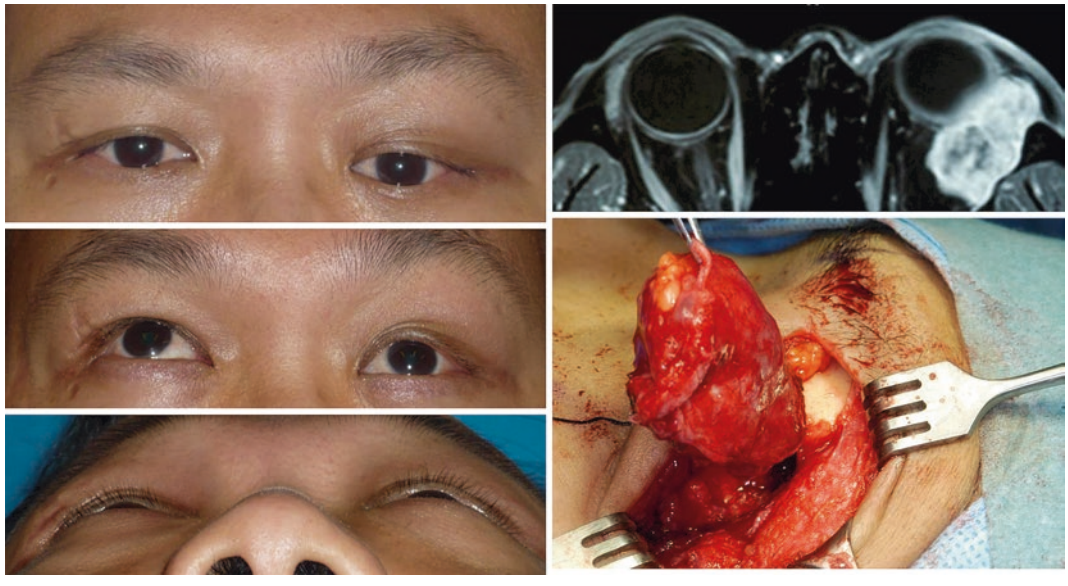

Fig. 11 40-year-old man complaining of progressive left-sided proptosis found to have hypoglobus and restricted elevation. T1-weighted, contrast-enhanced MRI with fat-saturation showed heterogeneously enhanced lesion with globe compression. Histopathology confirmed adenoid cystic carcinoma

Pathology of Epithelial Tumours

Pleomorphic Adenoma

Histopathological features of pleomorphic adenoma include mixed epithelial and mesenchymal components. Cells may form ductal structures and various cell types such as spindle and round cells may be present. The myxoid stroma may also have cartilaginous or bony components. A fibrous pseudocapsule can usually be identified.

Pleomorphic adenomas are slow-growing tumours that generally carry a good prognosis. Incomplete excision often leads to recurrence. Multiple recurrences or long-standing, untreated tumours increase the risk of malignant transformation into carcinoma ex-pleomorphic adenoma.

Adenoid Cystic Carcinoma

Adenoid cystic carcinoma has three histologic patterns, namely cribriform (also known as 'Swiss-cheese' appearance), tubular and solid forms, in decreasing frequency of occurrence. Mixture of these patterns is not uncommonly observed. Solid pattern and large size of the tumour are factors conferring a poorer prognosis.

Advances in molecular genetics have led to the discovery of a fusion oncogene *MYC-NF1B* in the majority of adenoid cystic carcinomas. This arises from a translocation between chromosomes 6 and 9, and may serve as a potential genetic basis for future development of targeted therapy.

The American Joint Committee for Cancer (AJCC) Staging 6th edition placed more emphasis on the size of the tumour (Table 7). In contrast, the 7th edition classified all tumours with periosteal or cortical bone involvement into T4. Many authors have suggested the T staging of the 6th edition correlates better with tumour-related death.

Carcinoma Ex-Pleomorphic Adenoma/ Pleomorphic Adenocarcinoma

This arises from a long-standing or incompletely excised pleomorphic adenoma. Malignant transformation may take years or even decades to occur. Histopathology shows residual benign pleomorphic adenoma mixed with malignant carcinomatous elements, which are most commonly adenocarcinoma not otherwise specified (NOS) and mucoepidermoid carcinoma. Once developed, the tumour is invasive and prone to distant metastasis and local recurrence.

Adenocarcinoma Not Otherwise Specified (NOS)

This usually occurs at an older age compared with adenoid cystic carcinoma, with the mean age of presentation at 50. It is an aggressive tumour with a propensity to metastasise to regional lymph nodes and distant organs. Prognosis is poor once metastasis has occurred.

Treatment of Epithelial Tumours

Benign Tumours

Dacryops can be managed with observation. Simple surgical excision is indicated when there is abscess formation or when it causes restricted ocular motility.

Pleomorphic adenoma should be managed with complete excision together with a cuff of surrounding tissue to minimise the risk of tumour seeding. Incisional biopsy is historically not recommended for the same reason. Some authors have suggested that a carefully planned incisional biopsy did not increase the risk of tumour seeding, provided that the biopsy tract be sealed by glue or marked by sutures and included in the subsequent excisional biopsy specimen.

Table 7 Comparing 6th and 7th Editions of AJCC Staging of Carcinoma of Lacrimal Gland

AJCC Staging of Carcinoma of Lacrimal Gland (6th Ed.)		AJCC Staging of Carcinoma of Lacrimal Gland (7th Ed.)	
Primary Tumor (T)		*Primary Tumor (T)*	
T0	No evidence of primary tumor	T0	No evidence of primary tumor
T1	Tumor 2.5 cm or less in greatest dimension, limited to the lacrimal gland	T1	Tumor 2 cm or smaller in greatest dimension, with or without extraglandular extension into orbital soft tissue
T2	Tumor more than 2.5 cm but not more than 5 cm in greatest dimension, limited to the lacrimal gland	T2	Tumor larger than 2 cm but not larger than 4 cm in greatest dimension
T3	Tumor invades the periosteum	T3	Tumor larger than 4 cm in greatest dimension
T3a	Tumor not more than 5 cm invades the periosteum and the lacrimal gland fossa	T4	Tumor invades periosteum or orbital bone or adjacent structures
T3b	Tumor more than 5 cm in greatest dimension with periosteal invasion	T4a	Tumor invades periosteum
T4	Tumor invades the orbital soft tissues, optic nerve, or globe with or without bone invasion; tumor extends beyond the orbit to adjacent structures, including brain	T4b	Tumor invades orbital bone
		T4c	Tumor invades adjacent structures (brain, sinus, pterygoid fossa, temporal fossa)
Regional Lymph Nodes (N)		*Regional Lymph Nodes (N)*	
N0	No regional lymph node metastasis	N0	No regional lymph node metastasis
N1	Regional lymph node metastasis	N1	Regional lymph node metastasis
Distant Metastasis (M)		*Distant Metastasis (M)*	
M0	No distant metastasis	M0	No distant metastasis
M1	Distant metastasis	M1	Distant metastasis

Incomplete tumour removal increases the risk of recurrence, which often presents as infiltrative growth rendering surgery difficult if not impossible. Adjuvant radiotherapy (RT) may be needed. Malignant transformation is more likely when there were multiple recurrences, or when a pleomorphic adenoma is longstanding.

Long-term follow-up of patients with surgically removed pleomorphic adenoma is recommended to detect local recurrence.

Malignant Tumours

The classic approach to adenoid cystic carcinoma was orbital exenteration. However, this is a functionally and psychologically disabling surgery. Recent studies have evaluated the possibility of eye-sparing surgery with adjuvant high-dose RT (around 60 Gy), especially for early-stage adenoid cystic carcinoma that is still confined to the orbit. Favourable local control and disease-free survival have been demonstrated. It was recommended that globe-preservation surgery with postoperative radiotherapy can be considered for tumours of less than grade T3 (AJCC Staging, 6th edition), because those graded T3 or above have significantly higher risk of local recurrence.

New adjuvant intra-arterial or intravenous chemotherapy has recently been suggested. Similarly, targeted therapy which is based on the genetics of adenoid cystic carcinoma is currently under development and it may play a role in palliative treatment for patients with metastatic disease in the future.

The management of pleomorphic adenocarcinoma and adenocarcinoma NOS is not evidence-based due to the rarity of cases. In aggressive cases, orbital exenteration with adjuvant RT is generally the treatment of choice.

Mesenchymal Tumours

In general, mesenchymal tumours of the lacrimal gland are rare. The vast majority in this group are benign. Vascular lesions make up the greatest proportion and examples include capillary and cavernous haemangioma and angiolymphoid hyperplasias with eosinophilia. Plexiform neurofibroma is associated with neurofibromatosis. Synovial sarcoma and granulocytic sarcoma are rare malignant mesenchymal tumours reported in the lacrimal gland.

Benign lesions can be treated with complete surgical excision whereas malignant ones require surgery and adjuvant radiotherapy.

Metastatic Lacrimal Gland Tumours

Spread of systemic metastases to the lacrimal gland is uncommon and occurs chiefly by haematogenous route. Breast, kidney, prostate, thyroid, skin melanoma and carcinoid tumours are among those reported to have spread to the lacrimal gland.

Mesenchymal Tumours

Solitary Fibrous Tumours

Historically, haemangiopericytoma, fibrous histiocytoma, giant cell angiofibroma and solitary fibrous tumours of orbit have been regarded as distinct disease entities. These are uncommon mesenchymal tumours that are found in the orbit. In recent years, larger case series have been re-examined from which many overlapping histopathological features were found although some features may dominate over others. Some have proposed using an inclusive term ‘solitary fibrous tumours (SFTs) of orbit’ to represent these entities.

SFTs of the orbit are benign tumours histologically characterised by randomly arranged fibroblast-like cells (‘patternless pattern’) with indistinct nucleoli, variable amount of collagen bands between the tumour cells and prominent branching thin-walled vasculature with perivascular fibrosis, sometimes described as ‘staghorn’ vessels. Immunohistochemistry reveals strong

CD34 positivity for SFTs, with the exception of fibrous histiocytoma, which is generally considered to be CD34-negative.

Metastasis is rare but histological features that predict malignant potential include increased mitotic activity, nuclear polymorphism, atypia and necrosis.

SFT of the orbit usually presents as a slow-growing unilateral orbital mass causing painless proptosis and diplopia, mainly in the fifth decade. The superior orbital space is more frequently involved than the inferior. Occurrence in the lacrimal sac results in epiphora, whereas in the conjunctiva and eyelids, it manifests as masses.

Radiologically, SFTs appear as well-defined, round, heterogeneously or homogenously contrast-enhancing masses on CT and MRI. It is isointense to extraocular muscles on T1- and T2-weighted images; hypointense signals may sometimes be seen within the lesion. Invasion into adjacent bone or orbital tissues is not typical.

Treatment of SFTs consists of complete surgical resection. Incomplete resection confers a risk of local recurrence. Adjuvant radiotherapy may be considered when resection is incomplete, or in recurrent or malignant cases.

Optic Nerve Sheath Meningioma

Optic nerve sheath meningioma (ONSM) is the second most common primary optic nerve tumour while optic nerve glioma is the most common and presents within the first two decades instead of in adulthood. ONSM is histologically benign and slowly progressive, but can be associated with significant visual morbidity. Primary ONSM originates in the orbit whereas secondary ONSM arises intracranially with orbital invasion.

There is a female predominance with mean age of presentation in the fifth decade. The fact that progesterone receptors are frequently expressed in these tumours may explain the sex predilection.

Though uncommon, ONSM can be associated with neurofibromatosis type 2 (NF2), when it often presents in childhood. Paediatric ONSM usually has a more aggressive clinical course when compared with adult ONSM.

Clinical Features

The classic triad of visual loss, optic atrophy and optociliary vessels is uncommon in the modern era as diagnosis is usually made at an earlier stage. Symptomatic patients can have variable visual acuity and visual field defect is common. Relative afferent pupillary defect and gaze-evoked transient visual obscuration secondary to intermittent compression of the optic nerve or central retinal artery may be present. Some patients are asymptomatic and are diagnosed during workup of incidental finding of optic disc swelling.

Optic neuritis is often the differential diagnosis of ONSM. However, ONSM tends to be of gradual onset, in contrast to the typical acute to subacute presentation of optic neuritis. If diagnosis is delayed, the tumour may occasionally cause proptosis and strabismus as a consequence of mass effect.

The location of ONSM can be critical in influencing the clinical presentation. Tumours that grow in the optic canal result in more marked optic nerve dysfunction due to the limited space and, therefore, more significant compression onto the optic nerve fibres.

Diagnosis

When the diagnosis is suspected, imaging of the optic pathway should be done. MRI is preferred because it gives better soft tissue differentiation between the tumour and the optic nerve itself. T1-weighted, contrast-enhanced images with fat suppression can best show the classic tubular expansion around the nerve. The tumour is intensely and homogenously contrast-enhancing and may demonstrate a ‘tram-track’ sign on

sagittal or axial images where the tumor appears as parallel lines on either side of the optic nerve. In coronal images, the appearance resembles a donut. Orbital apex or optic canal ONSM can be missed without closely examining the fine-cut images.

CT has its own advantages in showing calcification which is present in up to 50% of tumours as well as enlargement of the optic canal in the case of an orbital apex ONSM. ONSM is contrast enhancing and 'tram-track' sign may also be apparent on CT.

Unlike other orbital tumours, biopsy is generally not recommended with a high risk of iatrogenic visual loss and imaging is usually sufficient to make the diagnosis. Optic nerve sheath biopsy is rarely performed when the clinical course or radiological findings are atypical.

Treatment

Systemic treatment has no proven value in ONSM. Management primarily includes observation, radiotherapy and surgery.

Observation

In view of the slow-growing nature of this benign tumour, observation is indicated especially if optic nerve function is preserved (i.e. reasonable visual acuity, no or minimal visual field loss, good colour vision). Serial monitoring with optical coherence tomography (OCT) of the retinal nerve fibre layer and ganglion cell-inner plexiform layer can help detect subtle progression of compressive optic neuropathy. Repeated visual field testing and neuroimaging are also necessary to look for functional and anatomical progression. Once deterioration is noted, active treatment should be considered.

Radiotherapy

The aim of radiotherapy (RT) is to stop or slow down the growth of the tumour and stabilize visual function. Occasionally, patients may have visual improvement after RT. Complete regression or gross shrinkage of the tumour is unlikely. RT is indicated when there is deterioration in visual function, or when there is possible posterior extension of the tumour into the intracranial segment.

The recommended dose of radiation is 50–54 Gy delivered over 25–30 fractions. Nowadays, 3-dimensional conformal and intensity-modulated RT have improved precision to deliver radiation to the tumour while minimising collateral tissue damage.

Complications that can arise from RT include, but are not limited to, mild dermatitis, dry eyes, cataract, radiation retinopathy and radiation cranial neuropathy. Radiation retinopathy is more likely to occur in patients with pre-existing diabetes mellitus and other vascular risk factors. ONSM that are more anteriorly located and closer to the retina also carry a higher risk. Anti-vascular endothelial growth factor (anti-VEGF) intravitreal injections have proven effective in the treatment of macular oedema and neovascularisation arising from radiation retinopathy. Radiation optic neuropathy has a variable onset ranging from 3 months to 8 years. It is more likely to occur when radiation doses are over 50 Gy. Treatment with corticosteroids has been suggested.

Surgery

Surgical resection of ONSM is bound to result in visual loss. Simple nerve sheath decompression aiming to relieve the pressure on the optic nerve fibres is not feasible because of the risk of tumour seeding. Surgery is recommended mainly in those who already have complete visual loss and, at the same time, significant orbital disfigurement or possible tendency towards intracranial extension.

Orbital Metastases

Metastatic orbital lesions arise most commonly from the breast, followed by prostate, melanoma and lung cancer.

Clinically, these lesions progress rapidly and present with proptosis, ocular motility restrictions and visual disturbance, with or without pain. Less commonly, lesions associated with scirrhous breast carcinoma can produce enophthalmos due to fibrotic contraction of orbital fat.

Radiological appearance of orbital metastases can be highly variable. They can appear as nodular enlargement of extraocular muscles, heterogeneity of retrobulbar fat, or poorly defined orbital masses or lytic orbital bony lesions. Clinical history may provide clues but some patients have undiagnosed primary malignancy prior to presentation to orbital surgeons.

The prognosis of orbital metastases is generally very poor with limited life expectancy.

Structural Disorders

Fibrous Dysplasia

Fibrous dysplasia (FD) is a benign condition in which bone and bone marrow are replaced by immature fibro-osseous tissues. It is associated with an activating mutation in *GNAS1* on chromosome 20. Monostotic FD is defined as involvement of one bone or if the disease is limited to the craniofacial skeleton (even if multiple bones are affected in this region); it is more common than polyostotic FD, in which 3% are associated with hyperfunctioning endocrinopathies and café au lait skin pigmentation. These constitute the McCune-Albright syndrome which in turn is more common in female. Various endocrinopathies including hyperthyroidism, precocious puberty and growth hormone excess can be present.

Clinical Features

Ocular or periorbital involvement is usually unilateral and occurs in around one-third of cases with craniofacial FD. Ophthalmic presentations include proptosis, dystopia, ocular dysmotility, visual loss and periorbital pain. Optic nerve dysfunction can arise from compression by the bony lesion, traction, vascular compromise or other less common mechanisms. It can be associated with tearing, headache, periorbital swelling due to secondary mucocele, sinusitis or aneurysmal bone cyst that affect the paranasal sinuses and nasolacrimal duct. In addition, facial asymmetry, hearing loss and trigeminal neuralgia should alert the clinician that the pathology is not solely limited to the orbit. FD typically presents in childhood or adolescence. The bony lesions expand in childhood and usually become quiescent by adulthood when skeletal maturity is reached.

Radiological Features and Diagnosis

On computed tomography, FD can appear as radiologically hyperdense (sclerotic) or lucent (cystic) lesions. A ground-glass appearance or pagetoid pattern is, however, the most common, representing a mixture of radiolucent and dense areas caused by the fibrous and bony components, respectively. There should be no soft tissue involvement (Fig. 12).

While encasement of the optic nerve by the bony growth may be evident radiologically, this does not necessarily imply optic nerve dysfunction and clinical correlation is necessary. Bone biopsy is rarely necessary as the diagnosis is usually evident on clinical and radiological grounds.

It is important to screen for associated endocrinopathies in collaboration with the paediatrician or physician. Growth hormone excess, if left untreated, is associated with regrowth after surgical resection.

Treatment

Surgical

Treatment of FD is primarily surgical but this is only indicated in the presence of functional deficits or significant deformity. Evidence of optic

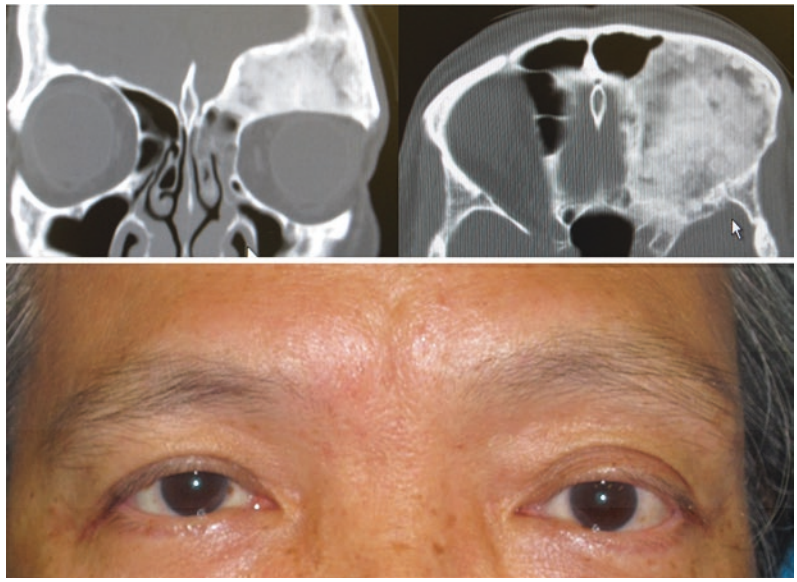

Fig. 12 Left-sided frontal bossing, proptosis, hypoglobus due to mono-ostotic fibrous dysplasia affecting the frontal bone. Note the typical ground-glass appearance on CT scan

nerve dysfunction is the most compelling indication. Various surgical techniques such as tumour debulking and radical subtotal resection and reconstruction have been suggested, but surgical planning should be individualised. Prophylactic decompression of the optic nerve before the onset of optic nerve compromise is controversial and has been shown to be associated with high risk of visual loss.

Expectant Management

Without disfiguring deformity or neurological deficits, observation with clinical monitoring and serial imaging is reasonable. FD is expected to stabilise once the patient has reached skeletal maturity, although rare reports of disease progression in adulthood do exist.

Medical Treatment

Bisphosphonates have been tried in FD but there is no proven role in halting disease progression. These drugs may have a role for pain control.

Steroids may be of short-term use in patients with rapidly progressive optic nerve dysfunction, before definitive surgical decompression is performed.

Prognosis

FD is generally benign and slowly progressive. Presentation can be variable depending on the location of the fibro-osseous growth and associated functional deficits.

Patients in whom surgery was performed should be followed up regularly to monitor for regrowth especially if skeletal maturity has not been reached. There is a small risk of up to 1% of malignant transformation to sarcomas, most commonly osteogenic sarcoma.

Glossary

V: Vascular (Orbital vascular malformation)
Type 1, 2, 3
CVM
E: Endocrine (TED)

I: Inflammation: IOID, IgG4ROD
Infection
N: Neoplasia
Lymphoproliferative diseases: OAL vs LH
Lacrimal gland tumors: epithelial vs mesenchymal vs metastatic
Mesenchymal tumors
S: Structural

Suggested Readings

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Thyroid Eye Disease (TED)

Jeffrey Nerad and Trevor Smith

Introduction

TED is the most common cause of unilateral and bilateral proptosis. Women are six times more likely than men to have TED, and smoking is strongly associated with severity and risk of disease. Age has a first peak early in the third to fourth decade of life and a second peak in the mid-60 s. The course usually follow the typical one described by Rundle (1964): early progression, peak of inflammation at 6–24 months, followed by an inactive phase. Only 5–10% of patients have reactivation. Patients have eye irritation, edema, and finally proptosis from thickening of the extraocular muscles or orbital fat. The majority of patients with TED will experience mild disease with the most common presentation being erythema and eyelid retraction.

Assessment of TED severity and monitoring for progression is critical. An accurate diagnosis of the disease should be confirmed by the presence of two of three criteria, each of which will be further described below: (1) presence of autoimmune related thyroid disease (as proven by labs), (2) typical ocular signs, and (3) radiographic evidence of disease.

The systemic effects of the disease should be managed with the patient's primary care doctor or an endocrinologist. As an ophthalmologist it is important to remember the non-eye, systemic aspects of disease just as endocrinologists must prioritize consideration for the eyes. In patients with TED, 90% of patients have hyperthyroidism and only 1% have hypothyroidism. Twenty percent of patients will present concomitantly with both hyperthyroidism and TED. In another 60% of patients high thyroid levels occur within 1 year of presentation. From the endocrinologists perspective, 30% of patients with hyperthyroidism develop TED.

The systemic findings of thyroid eye disease include pretibial myxedema (subcutaneous edema of the shins) and a similar but more diffuse swelling of the hands termed acropachy. TED may also occur with Hashimoto's Thyroiditis as well, though less commonly.

Pathology

The unique pathogenesis of thyroid eye disease is still not fully understood. However, it is known that the key cell involved is the orbital fibroblast, which has a CD40 marker. This marker allows T cells to bind and upregulate the fibroblast's production of certain inflammatory markers (IL-6, IL-8, and prostaglandin E2). This upregulation results in deposition of

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_38

hyaluronan and glycosaminoglycans (GAGs) to be deposited throughout the orbit and in the muscles. While this explains the thickening of the muscles, the orbital fat enlarges by a different mechanism. Due to the pluripotent nature of the fibroblasts, they are able to differentiate into adipocytes, in response to this proinflammatory environment. Insulin-like growth factor I receptors are also involved and result in inflammation as well. These various markers are the targets of several treatment modalities, one of which is teprotumumab.

Clinical Presentation

The aim of the assessment is to determine the activity and severity, to protect the patient's vision and to determine which appropriate medical and surgical treatments should be recommended.

Several disease scales have been developed including the VISA (vision, inflammation, strabismus, and appearance) and EUGOGO (European Group of Graves' Orbitopathy). The clinical activity score (CAS) is a series of symptoms including pain in the orbit, pain with eye movements, redness of eyelids or conjunctiva, impaired movement or vision, and swelling of the eyelids, conjunctiva, caruncle or orbit (increasing proptosis). Each is given a point that when added together correlates with responsiveness to corticosteroids: the higher the score, the more likely symptoms will improve with medications. While the CAS is helpful for disease activity, the EUGOGO Classification for Severity of Ophthalmopathy allows us to sort patients into three degrees of severity that relate directly to how aggressive medical or surgical intervention must be to protect the patient's vision.

The three primary categories of the EUGOGO scale are: mild, moderate to severe, and sight threatening as follows:

1. Mild: minimal impact on patient's life
   a. Transient or no diplopia, exophthalmos <3 mm but above normal range by race, mild soft tissue involvement, minor lid retraction (<2 mm), corneal exposure responsive to lubricants.
2. Moderate to Severe: benefit of immunosuppression or surgery outweighs the risks due to significant impact of disease on daily life.
   a. Eyelid retraction (>2 mm), exophthalmos >3 mm above normal range for race, inconstant or constant diplopia, moderate or severe soft tissue involvement.
3. Vision threatening: vision loss due to cornea breakdown (rare) or compressive optic neuropathy (Fig. 1).

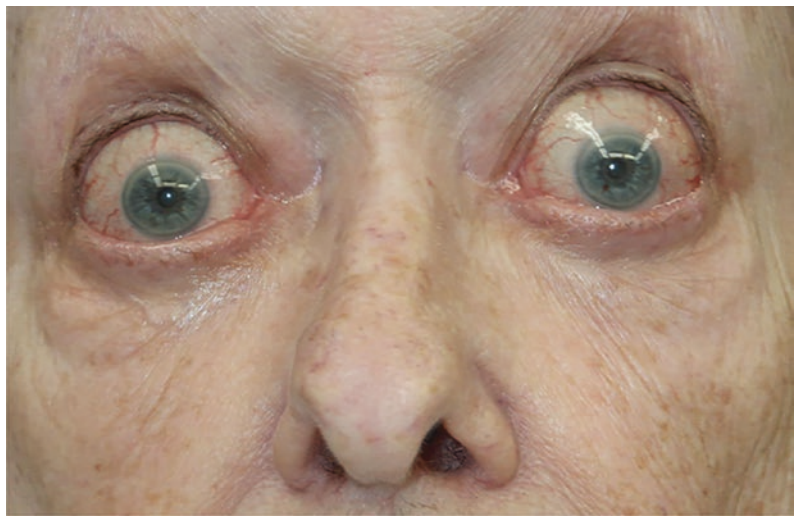

Fig. 1 Severe bilateral eyelid retraction. Note: the eyebrows were severely ptotic and were lifted to reveal the retraction

Table 1 The 10 items of the clinical activity score (CAS)

Pain	1	Painful, oppressive feeling on or behind the globe, during the last 4 weeks
	2	Pain on attempted up, side or down gaze, during the last 4 weeks
Redness	3	Redness of the eyelid(s)
	4	Diffuse redness of the conjunctiva, covering at least one quadrant
Swelling	5	Swelling of the eyelid(s)
	6	Chemosis
	7	Swollen caruncle
	8	Increase of proptosis of ≥2 mm during a period of 1–3 months
Impaired function	9	Decrease of eye movements in any direction ≥5° during a period of 1–3 months
	10	Decrease of visual acuity of ≥1 line(s) on the Snellen chart (using a pinhole) during a period of 1–3 months

For each item present, 1 point is given. The sum of these points is the CAS, e.g. a CAS of 6 means taht six items were present, regardless of which item

Table 1 the clinical activity score.

Of the many signs, the most common presenting sign is eyelid retraction. This is present in 90% of patients during their clinical course. At the time of presentation, 75% of patients have eyelid retraction in one or both eyes. This is measured in millimeters from the limbus to the upper eyelid margin and is part of the "appearance" measure, according to the VISA classification system. Photographs are an excellent way to monitor disease progression for multiple aspects of disease but particularly for eyelid position, periorbital edema, erythema, and proptosis. Additional common findings are the characteristic temporal flare of the upper eyelid, injection over extraocular muscles that does not extend to the limbus, and lid lag on downgaze. Temporal flare of the upper eyelid is a reliable, but sometimes subtle finding that can be helpful in the diagnosis. Normally the eyelid is peaked nasal to the pupil rather than a continuous up sloping laterally (Fig. 2).

Other features include proptosis, found in 60% of patients, and restriction of muscles in 40%. The vague complaint of orbital pain or discomfort is the most common symptom and is present in 30% of patients. Diplopia is noted in 17% of patients. Blurred vision was reported in 7% of patients, while directly attributable compressive optic neuropathy was in less than 2% of patients. Myasthenia gravis, though a classic association to TED, was only noted in a single patient out of 120 in the incidence study by Bartley et al. in 1996.

Examination should include checking vision, pupils (examining for presence of APD), ocular motility, intraocular pressure, color vision, Hertel exophthalmometry, and slit lamp exam for anterior segment disease. Dilated examination of the fundus for detailed assessment of the optic nerve and to rule out other causes of proptosis is indicated as well. Intraocular pressure should be treated if elevated as appropriate. Any change in color vision should prompt visual field testing. Patients can have enlarged muscles and compressive optic neuropathy without proptosis due to the lack of "auto-decompression" that occurs in those with proptosis. These patients can silently lose vision. Color testing can be an early clue to an optic neuropathy.

It should be noted that TED is an autoimmune disease, not an endocrine one. Testing only for thyroid hormones is non-conclusive and can be misleading. Testing for antibodies is more useful and is mandatory. Laboratory studies should be performed in all patient without a pre-existing diagnosis of thyroid disease. These include T3, free T4, thyroid peroxidase antibodies, thyroid-stimulating hormone receptor antibody, thyroid stimulating hormone (TSH), and thyroid stimulating immunoglobulins (TSI). If the patient is hyperthyroid, as most are, the free T4 will be high and TSH will be low.

Imaging is recommended to establish the diagnosis if normal lab testing was present or if

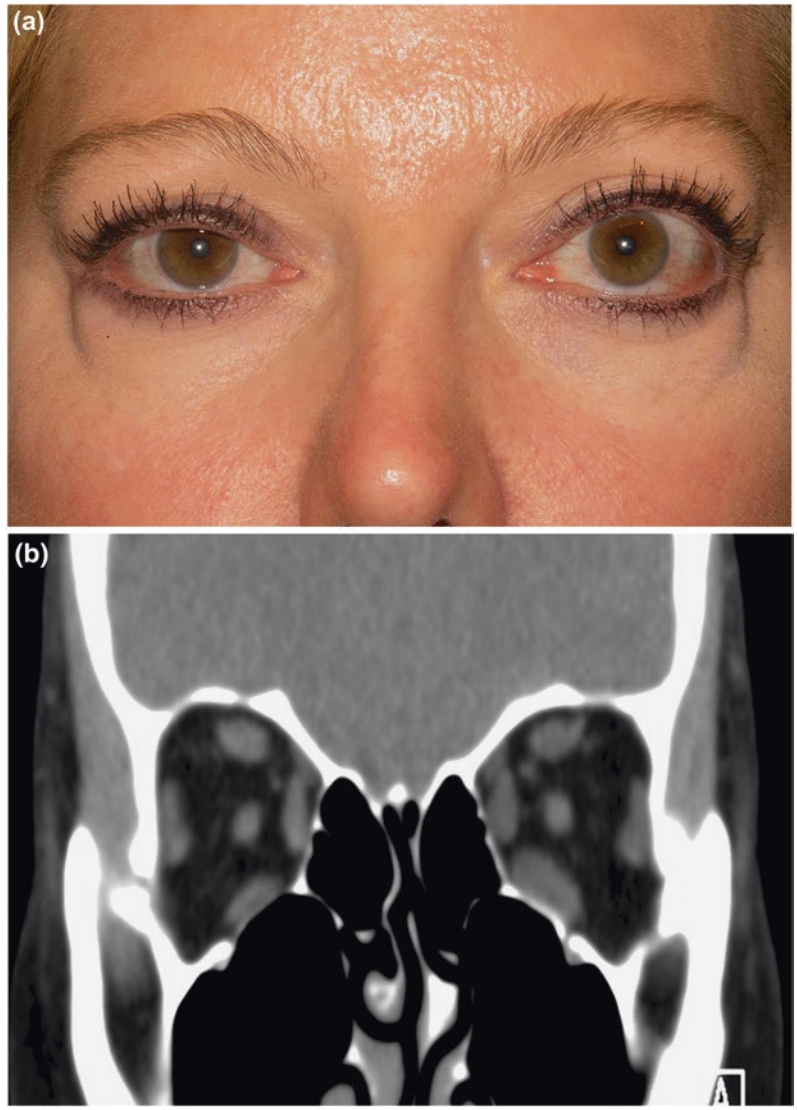

Fig. 2 **a** Inactive thyroid eye disease with bilateral temporal flare and retraction affecting the left eye more than the right. **b** Asymmetric proptosis required decompression of the left eye for restoration of the patient's natural appearance

there is not a history of thyroid disease. It is also required in cases with unusual presentations. Unusual presentations include unilateral disease, absence of upper eyelid retraction, or diplopia as the only symptom. Imaging typically shows bilateral muscle enlargement sparing the muscle tendons, though some asymmetry is expected. The typical pattern of involvement starts in the inferior rectus muscle then progresses to the medial, superior, and lateral rectus muscles. Forced duction testing that reveals a tight inferior rectus muscle or intraocular pressure testing comparing primary to upgaze that is >5 mmHg is also indicative of thyroid eye disease.

The history and examination will determine if the patient is in the active or chronic stage.

Active patients should be seen at least every 2–3 months or sooner if the tempo of the disease is rapid. Patients should be advised to call if there is a significant change in symptoms or signs.

Treatment for Active and Inactive Disease

General Considerations

Smoking is one of the strongest risk factors for TED. Though there are no prospective trials that have demonstrated a lower risk, the retrospective evidence is substantial: there is a four times increased risk of TED in smokers with Grave's Disease versus nonsmokers. Also, active disease typically lasts 1 year in nonsmokers and 2–3 years in smokers With the advent of the nicotinic receptor partial agonist varenicline (Chantix), smoking cessation is more attainable and patients should be strongly encouraged to quit as soon as possible. An additional risk factor to consider treating is selenium levels. There is some evidence that in a population with low selenium levels, some benefit exists in supplementation for periocular inflammation and progression.

All patients with TED benefit from maintenance in a euthyroid state. Coordinated care with an endocrinologist should be maintained throughout the patient's course. Concomitant steroids should be administered to all patients with TED that undergo radioactive iodine ablation (RAI). Bartalena et al. determined that approximately 50% of patients with TED undergoing RAI have worsening of symptoms, while 50% of those treated with steroids for three months following RAI had improvement in TED changes. The steroid dosing in this study was about half (0.5 mg/kg) of that used in an active TED flare that is moderate to severe (1.0 mg/kg).

For patients with mild TED according to EUGOGO, topical lubrication maybe sufficient for improvement of quality of life. Additional treatment with cyclosporine drops (Restasis) is often used, given the known inflammatory mechanism of TED. The degree of lagophthalmos is important to assess and, depending on the upgaze reflex of the eye upon closure (Bell's reflex), more or less corneal irritation is likely to occur. Night time ointment can be very beneficial for mild cases even without daytime lubrication. If there is gaze evoked rise of IOP, many advise using anti glaucoma drops.

Active Disease

Patients with active disease, both moderate to severe disease and sight-threatening disease can be treated with oral or IV corticosteroids. Typically, a dose of 1 mg/kg for one month followed by slow taper if a response is seen. IV corticosteroids administered at an infusion center result in less complications of cushingoid appearance and are dosed at 500 mg to 1 g methylprednisolone weekly for 6–12 weeks. Liver functions must be monitored to ensure no hepatotoxicity occurs or is present before primary administration.

To avoid systemic steroids, or if the inflammatory process does not resolve or returns when the oral corticosteroids are finished, intraorbital intermediate acting steroids (Triamcinalone) or long-acting steroids (Dexamethasone) have been used successfully as an alternative to the systemic steroids for reduced morbidity. One ml of the steroid is injected directly into the orbit, with ultrasonic guidance if necessary, in a manner similar to peribulbar anesthesia. Improvement occurs within 2–3 days and lasts for few weeks. The injection can be repeated two or three times. A low dose of systemic steroids (10 mg/day) can be given with the injection and can be maintained for several months to control the inflammation and further reduce the incidence of recurrence.

Radiotherapy is administered by some practitioners with the theory that it permanently differentiates the pluripotent fibrocytes so that they can no longer contribute to inflammation in the same way and kills the inflammatory cells already in tissue. There was initial thought

that radiation resulted in improved eye movement, but this has not been confirmed by subsequent studies. Its use in optic neuropathy is also suspect given that it takes a full month for full effect and is being used to treat a disease that would benefit from immediate decompression. Radiation also runs the documented risk of 1–2% retinopathy within the study and up to 20% possible retinopathy in the 10 years following the study. As expected, cataract incidence was high (10–30%) as well.

Several studies investigating other drugs have shown promising results equivalent to corticosteroid but with less side effects. These include rituximab, etanercept, IVIG, and Colchicine. Most recently, teprotumumab is a human insulin-like growth factor I (IGF-I) receptor inhibitory monoclonal antibody. In a study by Terry Smith et al., patients who were treated, as compared to placebo, had significant reduction in proptosis and CAS score as well as improvement in quality of life at 6 months and a response as soon as 6 weeks without clinically significant side effects. Longer term follow-up have shown similar results.

Vision loss or threatened vision loss is treated with decompression surgery. This is typically performed in patients with an APD or measurable vision loss on a Humphrey visual field 24-2 that does not improve with steroids. Patients that have a CT scan showing a crowded orbital apex with large muscles that is not expected to change with steroid treatment may benefit from decompression as well. Decompression surgery is performed either unilaterally first on the worse eye or bilaterally depending on the severity and progression of vision loss. Up to three walls may be decompressed: the lateral wall, the floor, and the medial wall. For urgent decompression, all three are typically performed for maximal decompression including posterior decompression of the apex medially removing the most posterior ethmoid air cells anterior to the sphenoid sinus. Medial wall decompression can be performed endoscopically or through an open orbital approach. Endoscopic and transconjunctival approaches are successful in reducing exophthalmos. Each wall allows for further decompression, with varying amounts of decompression obtained depending on the amount of fat versus muscle enlargement. With experience, a CT scan can be used to predict the correction of exophthalmos able to be obtained with fat only or fat and bony decompression. A typical range of improvement in exophthalmos is 4–6 mm for patients with compressive optic neuropathy.

A fat-only decompression can also be performed in which all bones are left intact. Some small studies indicate that this may reduce surgically induced diplopia, though with smaller sample sizes it is difficult to gain statistical significance to evaluate if these are truly reduced rates. In patients with vision loss, bony decompression is favorable in this time sensitive situation and, therefore, fat-only decompression is typically reserved for patients without optic nerve compression.

Of note, patients without preoperative diplopia and normal versions had less than a one in twenty chance of postoperative diplopia and up to 12% in another study. On the other hand, a second type of patient with diplopia within twenty degrees of fixation and with restrictive motility deficits were found to have a 50% rate of diplopia in primary gaze after undergoing a two wall decompression. This indicates that induced diplopia occurs in all type of TED patients but more frequently occurs in those with restrictive movements or preoperative diplopia that subsequently worsens. About a quarter of patients require strabismus correction for resolution of these symptoms. The overall new onset diplopia rate after surgery is between 10–20%.

An additional technique, balanced decompression, emerged to combat the diplopia encountered due to inferior or inferomedial displacement of the globe after decompression of the floor or medial wall. In this technique part of the lateral wall is removed transcutaneously and the medial wall endoscopically or transcaruncularly while sparing the orbital floor. This also spares one of the more common side effects of floor decompression: hypoanesthesia of the infraorbital nerve distribution. In this technique, the lateral decompression involves drilling at

the frontozygomatic suture (superotemporal orbital rim) and, if drilling too superiorly, a CSF leak can occur by puncturing the dura (5% of patients) (Fig. 3).

Inactive Disease

Once the patient has made their way through the active phase of disease over a period of up to 3 years, they will likely have undergone a change to their appearance. If they have diplopia after reaching the chronic phase or after decompression, this should be repaired prior to eyelid surgery. Inferior rectus recession can create or exacerbate lower eyelid retraction Once it is confirmed that there is no change in their disease process over 6–9 months, it is appropriate to pursue surgical correction. Restorative surgery to reconstruct their natural look should be undertaken if the patient is interested. Many patients are reluctant to discuss this option initially and are reassured that this is a surgery to restore them to their normal self, rather than a "cosmetic" surgery.

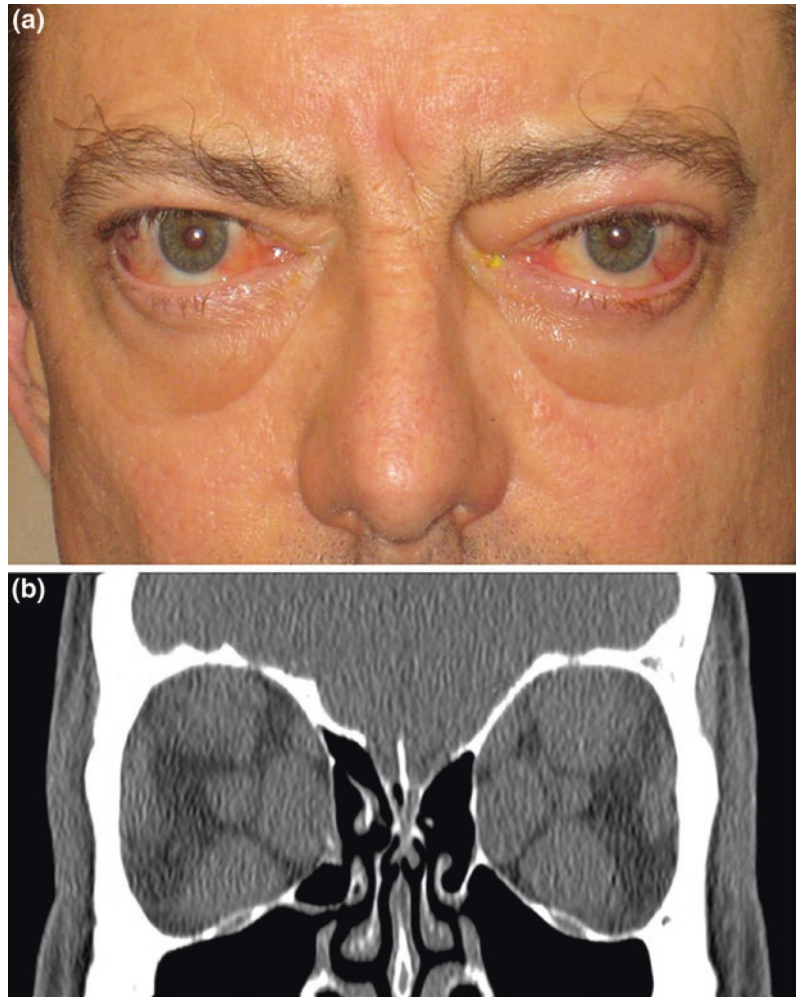

Fig. 3 **a** Active thyroid eye disease presenting subacutely over weeks with presence of conjunctival injection, eyelid edema, proptosis, and lower eyelid retraction. **b** Bilateral severe muscle enlargement resulting in compression of the nerve (dysthyroid optic neuropathy) requiring bilateral decompression

Just as with active disease, surgery in inactive disease is challenging. Fibrosis and inflammation results in unpredictable tissue and frequent bleeding throughout the operation. Common surgeries include recession of the upper and lower eyelid. Upper eyelid recession can be performed by releasing the levator muscle and/or Muller muscle, or by using a full-thickness, horizontal incision (blepharotomy) through the eyelid. Special attention at cutting the lateral horn is important to improve the temporal flare of the upper eyelid. Retraction repair is performed by levator disinsertion much like a levator advancement surgery. A lid-crease incision, followed by post-septal dissection is performed. The levator is then disinserted from the tarsus, taking care to titrate the height by sitting up the patient and periodically inspecting lid height and contour. In the full blepharotomy, a full thickness incision through the eyelid may still be necessary even after the levator and Muller's muscle are incised. The degree of levator function (LF) can be surprisingly high even after near total disinsertion. If LF drops to zero and overcorrection has occurred, a few small recessed vicryl sutures reapproximating the orbicularis may be all that is needed to regain significant height (normal margin reflex distance) and function. (Muller's muscle surgery is described in chapter "Common Eyelid Malpositions"). Since the eyebrow fat pad can be involved in thyroid patients, and there is inevitably orbital fat enlargement and herniation, a blepharoplasty can benefit the patient both in terms of dermatochalasis improvement and to facilitate dissection superiorly via a lid crease incision to debulk some of the enlarged or thickened eyebrow fat pad inferior to the eyebrow cilia.

The lower eyelid retraction can be repaired with or without a spacer to elevate the eyelid. Hard palate grafts as well as ear cartilage can be used and sewn into the "middle lamella" of the lower-eyelid inferior to the tarsus, and superior to the recessed retractors. Ear cartilage is the strongest and can provide 3–10 mm of elevation, but will limit the excursion of the lower eyelid (see chapter "Common Eyelid Malpositions" for management of lower eyelid retraction).

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The Surgical Approach to the Orbit

Xiaqun Fan, Renbing Jia and Hunter Yuen

Introduction

The specific approach to the lesions of orbit depends on their locations, relation to the adjacent structures and optic nerve, and designed extents of exposure and excision. Transcutaneous and transconjunctival incisions are the main access to the orbit, besides transnasal endoscopic and transcranial approaches. Transcaruncular approach may be required for medial orbital lesions and vertical eyelid splitting approach can sometimes be used for superomedial orbital lesions.. Incisions along the relaxed tension lines could produce minimal scars including upper eyelid crease, subciliary, subbrow and lateral canthal incisions. Conjunctival fornix approaches could directly get into central and peripheral orbital space without visible scars. Lower eyelid conjunctival approach with or without lateral canthotomy is getting more and more used than subcilliary approaches, which could greatly avoid the risks of visible scars, fistula formation and lower eyelid ectropion/entropion or retraction. The lateral orbital rim (marginotomy) can be temporary removed and then replaced during the surgery to enhance the surgical exposure.

Upper Eyelid Crease Approach

Indications

The upper eyelid crease approach could get access to upper two-thirds of the orbit. To reach deep areas as the orbital apex and superior orbital fissure, the incision can be extended medially and laterally so that the supereomedial orbit like trochlea and medial canthal tendon area are exposed, as well as the inferolateral wall and floor of the orbit. After the upper lid crease incision, dissection is done at the plane between the orbicularis muscle and orbital septum, till the bony orbital rim. The periosteum is then incised with subperiosteal dissection (Figs. 1 and 2). Temporary removal of the superolateral or lateral orbital rim (marginotomy) (Fig. 3) using high speed oscillating saw will allow wide access to large lacrimal gland lesions, deep retrobulbar orbital lesions and orbital apex lesions.

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_39

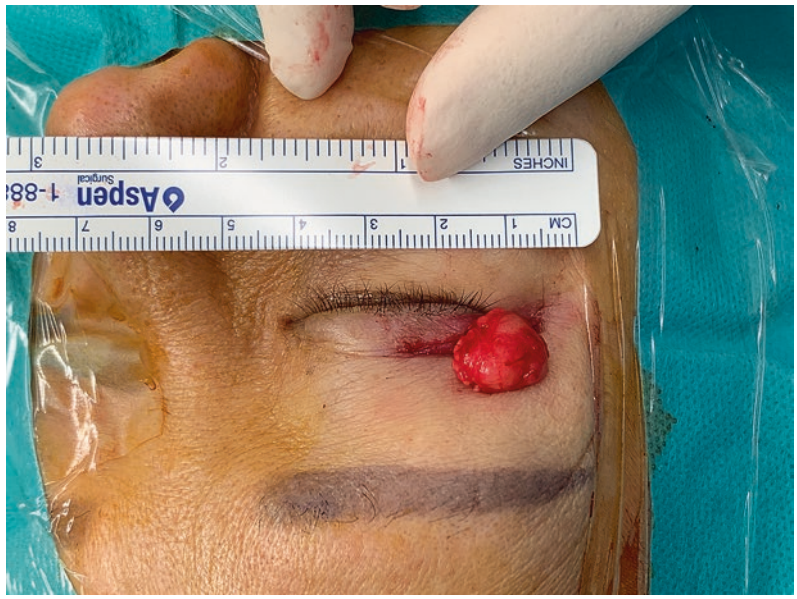

Fig. 1 A pleomorphic adenoma of the lacrimal gland was excised via skin crease approach orbitotomy without osteotomy of the lateral orbital rim

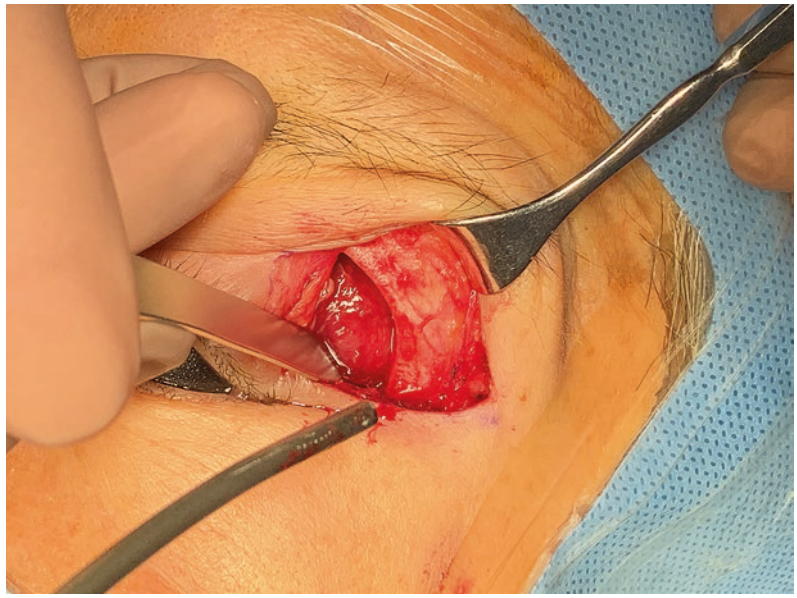

Fig. 2 A tumor was being removed during skin crease approach orbitotomy without osteotomy

Procedure

1. Mark a line along the upper eyelid crease, if there is no natural crease, trying to draw a virtual line 5–8 mm above the eyelash. The line could be medial, central or lateral depending on the location of the lesion.
2. Incise the skin and through the orbicularis muscle, identifying the junction of orbital septum and the orbicularis muscle.

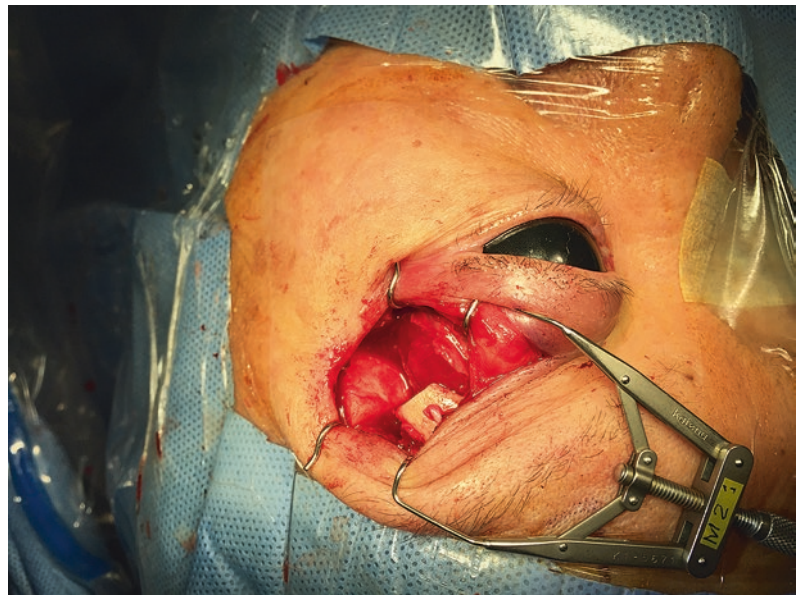

Fig. 3 Lateral orbitotomy with osteotomy of the lateral orbitotomy rim (marginotomy) performed via skin crease approach. In this case, the lateral orbital rim was lateralized without temporary removal

3. Dissect between orbicularis muscle and septum, upward to the orbital rim.
4. For lacrimal lesions, cut the periosteum along the rim, dissect the potential space between periosteum and bone, separate the lesion and normal structures, en bloc remove lesions with or without bony marginotomy. For lesions located in the septum or extraconal orbital space, enter the septum near the lesion, the orbital fat would prolapse, meticulously isolate lesions from surrounding tissues, taking into consideration especially not to injure the levator muscle.
5. Close the orbital periosteum with 5-0 absorbable suture, there is no need to close the orbital septum or central orbicularis muscle.
6. Close the skin wound with 6-0 nylon or prolene running suture.

Potential Complications

Several complications may occur after surgery. Transient ptosis is very common following surgery, it will usually recover in few months. Permanent ptosis may result from injury to the aponeurosis, levator muscle or the oculomotor nerve, it could be corrected by performing ptosis surgery 1 year after the initial surgery. Injury to extraocular muscle may result in transient or permanent diplopia.

Lower Lid Subciliary Approach

Indications

Lesions located around the inferior orbital rim, lacrimal sac, orbital floor and inferior orbital apex could be accessed by a subciliary approach (Fig. 4). Even though the scar is not obvious, for young patients and those with a high concern of cosmesis, the lower eyelid conjunctival approach should be considered

Procedure

1. Mark a line 2 mm below the lower eyelid lash line.
2. Incise the skin and through the orbicularis muscle, identifying the junction of orbital septum and the orbicularis muscle.

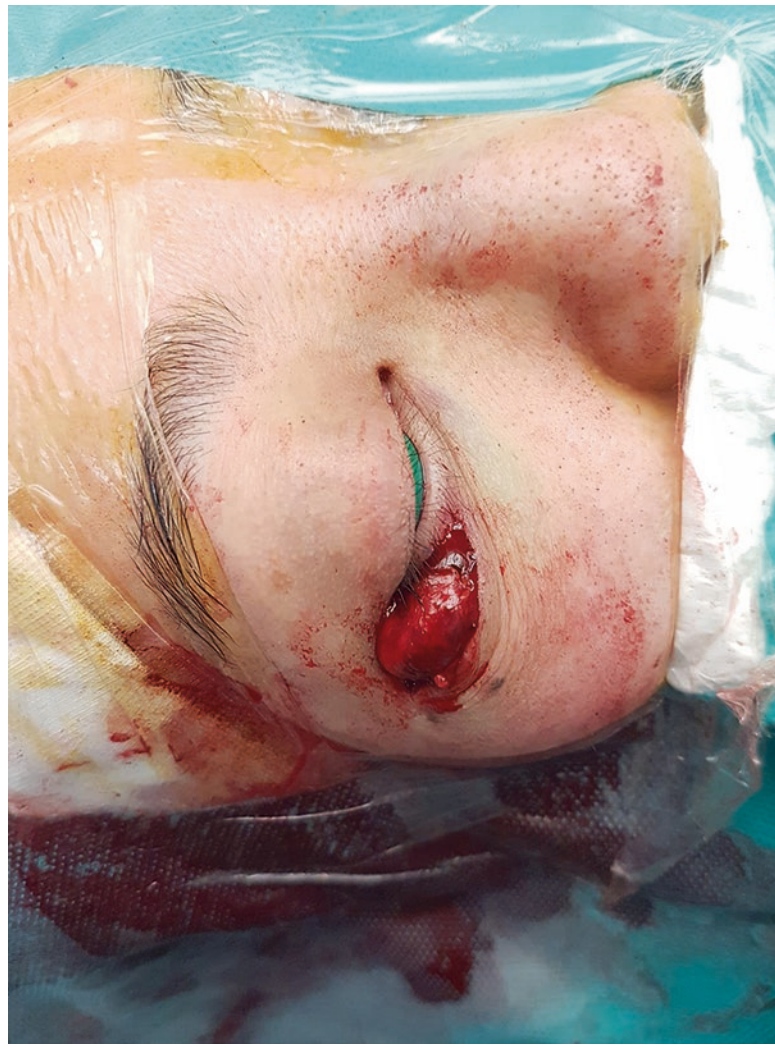

Fig. 4 Inferior orbitotomy via a subciliary incision

3. Dissect between orbicularis muscle and septum, downward to the orbital rim.
4. For lesions located in the septum or extraconal orbital space, enter the septum near the lesion. For orbital floor fracture, dissect the potential space between periosteum and bone. It is to be noted that the inferior oblique muscle origins at the medial part of inferior rim, so as not to injure it.
5. Finally close the orbital periosteum with 5-0 absorbable suture, there is no need to close the orbital septum or central orbicularis muscle.
6. Close the skin wound with 6-0 nylon or prolene running suture.

Potential Complications

Lower eyelid ectropion or retraction due to scar formation between orbicularis muscle and orbital septum or injury to the capsulopalpebral fascia may lead to lower eyelid malposition. Older patients with preexisting eyelid laxity may be susceptible to postoperative lower

eyelid malposition, which can be repaired by lysis of the scar and correction of the eyelid laxity. Diplopia can be due to aggressive dissection with injury to the inferior oblique muscle.

Conjunctival Fornix Approach

Indications

The conjunctival lower fornix approach is the preferred approach for inferior orbital lesions (Fig. 5). It provides direct access to the orbital floor, the inferior orbital fissure, the inferolateral and inferomedial orbital spaces. The upper fornix approach provides direct access to the superomedial orbit especially when facilitated by distracting the globe down and out. A wider exposure for deeper orbital lesions can be achieved when combined with a lateral canthotomy and cantholysis. This is also called swinging eyelid approach when inferior transconjunctival approach is combined with lateral canthotomy and cantholysis (Figs. 6a, b and 7).

Procedures

1. The margins of the upper or lower lid are everted using a 4-0 silk traction suture or a Knapp rake retractor to expose the conjunctival fornix. In patients whose conjunctival fornix could not be fully exposed; scleral traction on the eye in the opposite direction can improve the exposure. For example, with inferior fornix incision, traction of the globe superiorly to open the inferior fornix is done. The lower conjunctival fornix can be easily exposed by eversion, but it is more difficult to expose the upper fornix because it is deeper than the lower fornix, and the upper tarsus is longer vertically than the lower tarsus. To fully expose the upper fornix, a lateral canthotomy with superior cantholysis of the lateral canthal ligament may be required to release the upper eyelid from the lateral orbital rim.
2. According to the tumor location and the size, the incisions can be customized either laterally or medially for exposure. The incision of conjunctiva in the fornix can be done with scissors or monopolar Colorado needle.

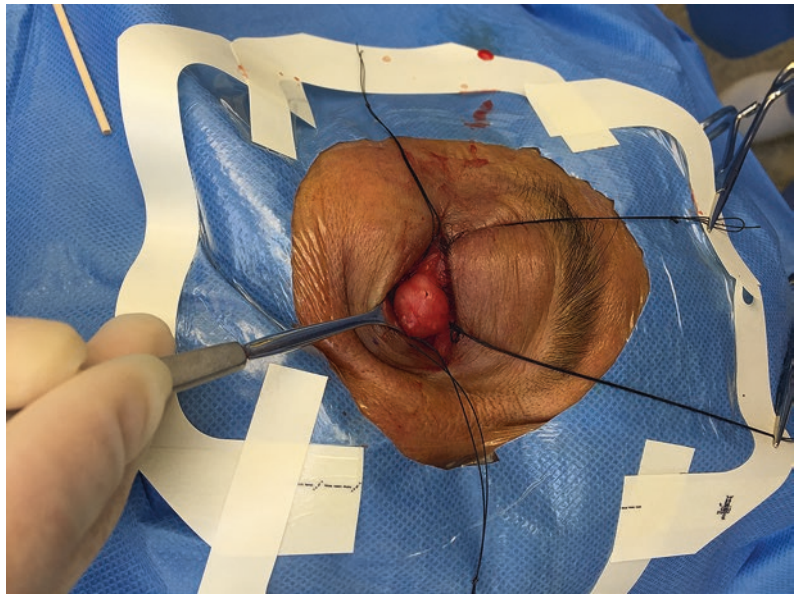

Fig. 5 Inferior orbitotomy via a conjunctival incision without canthotomy and cantholysis

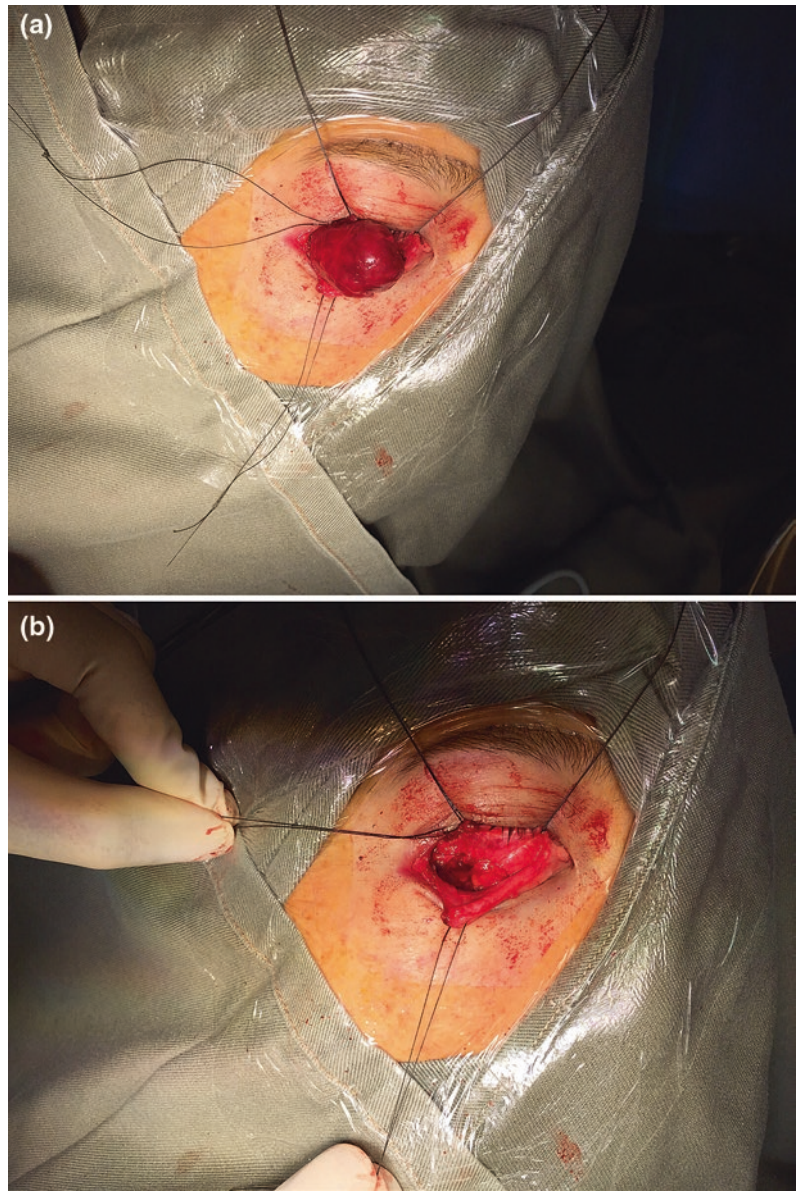

Fig. 6 **a** and **b** Inferior orbitotomy via a conjunctival incision with canthotomy and cantholysis, this is also known as swinging eyelid approach

3. For incisional biopsies, such as diagnosis of inflammation, neoplastic disease, or lymphoma, a surgical specimen is obtained without further dissection of the deeper portion of the lesion.
4. For tumor removal, dissection is carried posteriorly towards the deep space of orbit, blunt-tipped scissors are usually used to spread the intermuscular septum and separate vital structures and blood vessels. In order to optimize visualization and creating a bloodless surgical field, malleable retractors should be used to help the dissection by pushing away orbital fat. Blunt dissection is used to find the anterior tip of the tumor. And then a malleable retractor can be placed between the tumor and the globe.

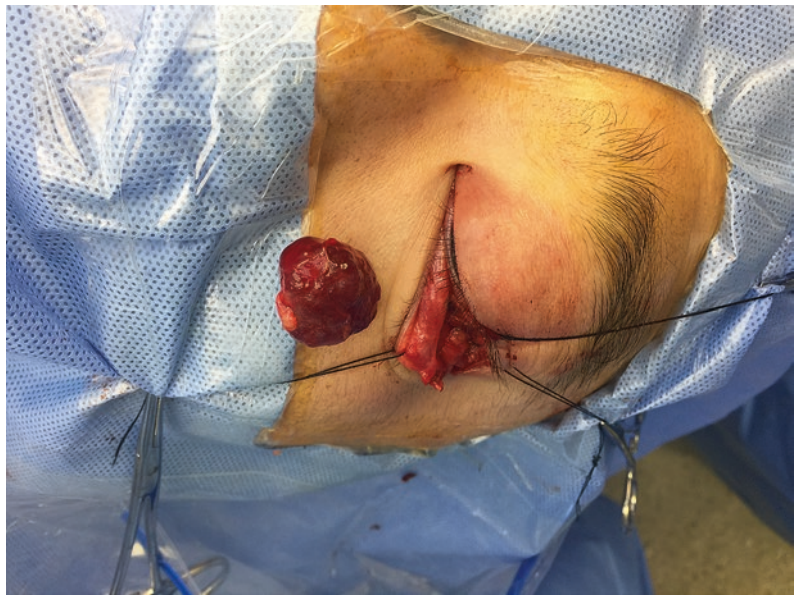

Fig. 7 Another example of orbital mass removal via swinging eyelid approach

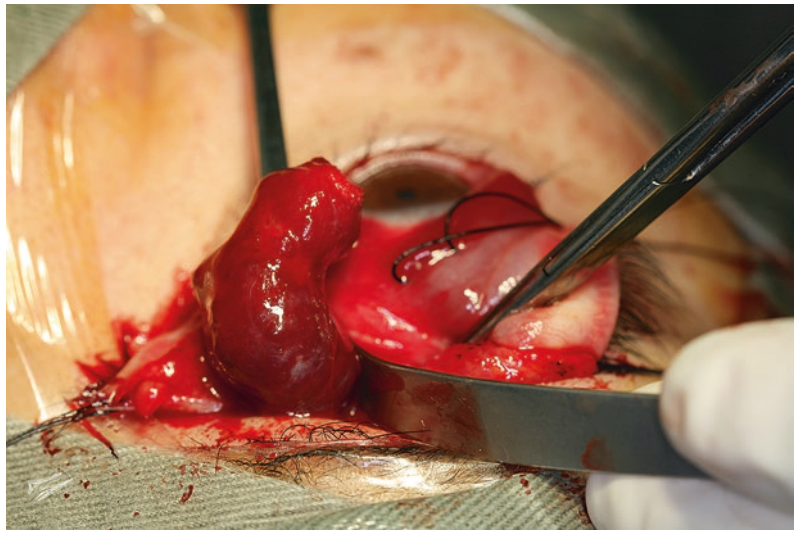

Fig. 8 Removal of an orbital mass during vertical eyelid splitting orbitotomy

5. To get reach of the posterior edge of the tumor, insert neurosurgical patties into the dissection plane between the tumor surface and the surrounding tissue. Then blunt dissection continues posteriorly by using Stevens scissors with disengagement of the attachments on the surface of the tumor. When the tumor is mostly separated from the surrounding tissues, a cryoprobe can be used to extract the lesion.
6. The forniceal conjunctiva wound is closed with interrupted 6-0 or 7-0 Vicryl sutures. If additional incisions were made, 6-0 Vicryl suture can be used to reattach the margins of incision.

Potential Complications

These include transient ptosis and diplopia. Entropion can occur and is due to contraction of conjunctival fornices due to scarring. Scarring in the plane of the septum can result in lower eyelid retraction. These can be avoided by careful identification of and dissection in the tissue planes.

Transcaruncular Approach

Indications

The transcaruncular approach is often used for medial wall decompression in thyroid eye disease and medial orbital fracture repair. Nevertheless, for extraconal and intraconal medial orbital lesions, this is also a useful technique to approach the lesions.

Procedure

1. 3'O silk eyelid traction sutures are placed lateral to the upper and lower punctum or assistant using desmarres retractor over the upper and lower lid for exposure. Corneal protector can be placed for corneal protection.
2. Incision can be made directly over the caruncle or posterior aspect of the caruncle. The incision should extend superiorly and inferiorly over the conjunctiva in a curvilinear fashion.
3. The posterior lacrimal crest is initially palpated with a blunt instrument, which is felt as a prominent bump in the medial orbital wall. A thin malleable retractor is placed posterior to this structure.
4. Blunt tip scissors are then slide over the malleable retractor and spreading dissection is performed to incise the periosteum and access the medial orbital wall.
5. The globe is then retracted and subperiosteal dissection is performed posteriorly. This incision should be sufficient to allow unobstructed access to the medial orbital wall. Depending on the location of the lesion, the anterior and posterior ethmoidal arteries can be cauterized and divided.
6. The periorbita is then opened and the orbital space can be entered. Extraconal medial orbital lesions can then be found, whereas intraconal lesions can be approached over the superior or inferior border of the medial rectus.

Potential Complications

Transient epiphora due to post-operative edema of the lacrimal apparatus and transient diplopia due to medial rectus paresis may occur, these usually resolve spontaneously. Retrobulbar hemorrhage is a more severe potential complication.

Vertical Eyelid Splitting Orbitotomy

Indications

Superomedial orbital lesion can be approached by vertical eyelid splitting orbitotomy (Fig. 8). A wide exposure can be achieved and this is a potential useful alternative approach.

Procedure

1. A vertical full-thickness incision is made perpendicular to the tarsus at the junction of the medial third and lateral two thirds of the upper eyelid. This incision is perpendicular to the lid margin and traverses the skin, tarsus, orbicularis and palpebral conjuctiva.
2. The incision is continued with Colorado monopolar needle, splitting distal levator muscle and Müller's muscle to the fornix of the eyelid, extending into the bulbar conjuctiva to the limbus.
3. The extraconal orbital fat exposed in this space is dissected bluntly, exposing the superior

and medial recti muslces. The superior oblique must be identified and attention should be paid over the superior oblique tendon as it loops posterolaterally from the trochlea.

4. Blunt dissection is then done using malleable retractors in the extraconal or intraconal spaces. Intraconal access is available via dissection between the superior and medial rectus muscles.

5. When the lesion is identified, a biopsy or removal can be carried out. After completion of the procedure, the lid margin is closed with 6'o silk sutures, the tarsus is closed with 6'o vicryl sutures, the skin and orbicularis are sutured with 6'o non absorbable sutures in a manner similar to suturing a full thickness lid wound. Meticulous wound closure is needed for optimal cosmesis upon healing.

Potential Complications

Transient ptosis, eyelid notching and visible scar over the incision.

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Part VII
Trauma

Eyelid Injuries

Nadeen El Toukhy

Introduction

Eyelid and adnexal injuries can be a part of multisystem trauma. The basic ABCs of the trauma management should be considered and applied in every trauma patient. This includes securing a patent airway and stabilization of the circulation. Ophthalmic evaluation and management are deferred until more serious problems are addressed.

Once the patient is stable, attention could be directed to the eye lid injuries. The patient should be evaluated for any globe or optic nerve injuries. This may be difficult especially in patients who are unconscious or uncooperative. The eyelid may be swollen and difficult to open, so care should be taken to avoid forceful opening of the eyelid as this may worsen the already traumatized globe.

Evaluation of Lid Injury

History

Circumstances of the injury can help determine the type and extent of the trauma. The mechanism of injury can give an idea about the depth of the wound as well as the possibility of foreign body presence.

Falling to the grounds or in contaminated places especially of the patient is young to report should raise a high index of suspicion for the presence of foreign bodies especially of organic nature.

Some symptoms can also give a clue about the extent of damage. Drop of vision suggests globe or optic nerve injuries. Presence of diplopia or hypothesis suggests orbital wall fracture. History of any ocular diseases or surgeries should be documented. Any medical problems, topical or systemic medications, drug allergy as well as problems from anaesthesia should be known. History of tetanus immunization is essential. If the patient had not tetanus immunization within 5 years, tetanus toxoid 0.5 ml should be administered. If the patient had never been immunized, 250 units of tetanus immunoglobulins are administered.

In case of animal bite, the rabies immunization of the animal and if the animal has been quarantined should be cleared.

Examination

This should include evaluation of the globe, adnexal tissue, orbit and face. If the patient is conscious and cooperative, visual acuity,

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_40

pupillary responses, intraocular pressure measurement as well as dilated fundus examination should be performed. Sometimes examination under anaesthesia can be done to avoid further globe injuries during manipulation of the eyelid.

The eyelid is examined for the extent of the wound and if it involves the septum, the muscle, lid margin or canaliculus. Canalicular injury is suspected when the injury lies medial to the punctum which is usually laterally displaced compared to the other side or the opposite one. Medial or lateral canthal injuries as well as tissue loss should be ruled out

Evaluation of the orbit includes searching for ocular motility deficit, surgical emphysema, hypoesthesia of the check, nose or upper lip in addition to palpable orbital rim fractures. Orbital imaging with CT is requested when orbital wall fracture or presence of foreign body is suspected.

The lid injuries can be associated with face and neck injuries. A thorough examination of head and neck should be carried out and other specialties may be involved in the repair process. All findings should be documented and photographed.

Principles of wound repair

The wound should be closed as soon as possible. Yet the repair can be delayed if the patient is systemically not stable or there are more life threatening injuries. Any globe injuries should be addressed first. Lid wound repair could still be delayed up to 48 h following trauma without jeopardizing the outcome.

During the repair, the wound should be properly inspected for the presence of any retained foreign bodies, deep orbital injuries or occult globe injuries. The extent of the wound should be established. Foreign bodies should be removed as they may be missed and cause chornic infection, abscess or sinus formation, or granuloma. The lid tissue is highly vascular and minimal debridement is required. Gentle handling of lid thin skin is necessary to minimize further trauma.

It should be remembered to reestablish the integrity of the basic lid parts; anterior lamella, posterior lamella, the lid retractors mainly the levator, the canaliculi and the canthal tendons. The wound landmarks are identified and reattached first. These include the wound angles, apex of skin flaps and brow hair line. The orbital septum should not be incorporated in the repair as it may lead to lid retraction and lagophthalmos.

Most lid wounds could be repaired under local anesthesia using lidocaine 1% with epinephrine 1:100.000. This can be done in the emergency room if minor or in the operative theatre in most injuries. General anesthesia is reserved for extensive injuries, associated canalicular injuries or poorly cooperative patients. The skin is usually closed by non absorbable sutures e.g., 6-0 polypropylene, nylon or silk. Some surgeons use 6-0 poly glycolic acid (Vicryl) for repair in young children. Interrupted sutures are usually used however; linear parts of the skin wounds could be closed by running sutures. Skin sutures are usually removed after 5–7 days.

Major lid reconstructions should be delayed unless the cornea is seriously at risk. It is advisable to defer interference for 3–6 months before repairing a defect such as lid retraction, unsightly scars or ptosis unless the patient develops signs of corneal exposure that cannot be controlled conservatively by local lubricants.

Wounds with No or Minimal Tissue Loss

a. ***Superficial lacerations***

They involve the skin and underlying muscle. It should be emphasized that proper examination of the wound extent is very important as an innocent superficial wound may have a significant underlying injury. Simple wound closure is done with no tension. This could be facilitated by undermining the edges.

Horizontal muscle lacerations will approximate themselves without suturing yet vertical muscle lacerations should be closed with 6-0 Vicryl sutures.

In more complex wounds such as stellate injuries, care should be taken to follow the skin lines as much as possible and avoid shortening of the anterior lamella that may lead to lid retraction. Closure of these wounds is individualized and depends on the site and extent of the wound. Any wound extension or further incisions taken should be fashioned so as to be parallel to the lid margin. For example, lacerations of V type shape could be closed and transformed into Y shape.

b. ***Deep lacerations involving the levator complex***

If the upper lid septum is involved in the injury, the orbital pre-aponeurotic fat

becomes exposed and the levator muscle may be violated. So in such situation, the muscle should be identified while the wound is repaired. If it is found dehiscent, it should be primarily reattached to the tarsal plate at its normal attachment level. Care should be taken to avoid incorporating or suturing the opened orbital septum.

c. ***Marginal wounds***

It is crucial to close the marginal lid wounds meticulously to achieve a proper anatomic repair thus reducing postoperative complications. Bad wound repair will lead to lid notching, lagophthalmos and corneal exposure. If there is no or minimal tissue loss, primary repair of the wound can be done. It should be in two layers. The wound edges are approximated by 6/0 silk suture passing through the tarsal palate and exiting at the meibomian gland orifices 1.5–2 mm from the wound edge. It is approximated to make sure that the wound edges are coapted and slightly everted. Other two sutures are taken at the lash line and the grey line. None of them is secured until the tarsal wound is closed with 6/0 Vicryl sutures that involve 90% of the tarsus thickness so as to avoid rubbing against the cornea (Fig. 1). The marginal sutures arms are left long and tied beneath a skin suture so as to keep them away from the cornea. The skin wound is closed. The margin sutures are removed after 10 days as earlier removal may lead to wound separation and notching. In children the marginal sutures can be taken using 6/0 Vicryl and left to dissolve spontaneously (Fig. 2).

Wounds with Significant Tissue Loss

Tissue loss may be in anterior lamella or it can be full thickness involving the lid margin. In such conditions, it should be remembered to avoid undue tension on the wound margins. This situation can be dealt with in a manner similar to lid reconstruction after tumor excision. Lateral canthotomy and graded cantholysis of the corresponding crus of the lateral canthal ligament can be helpful in a lot of conditions. If more anterior lamellar tissue is needed a Tenzel flap techniques could be used (Fig. 3). Care should be taken to place the lateral canthal angle at

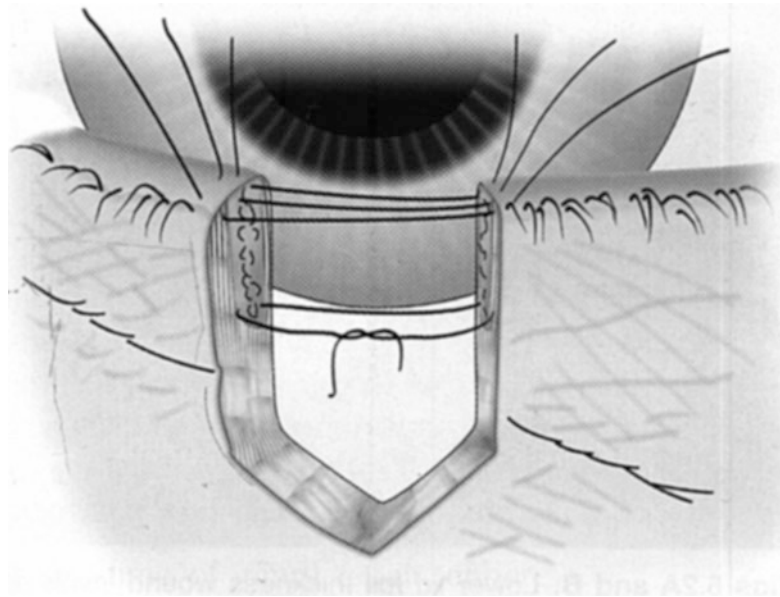

Fig. 1 Diagram showing lower lid marginal wound with marginal approximating sutures and a suture that involves 90% of the tarsal thickness

Fig. 2 Left photos shows lower lid full thickness wound involving the margin in a 5 y child. Right shows the same eye 10 days after the repair with remnants of the vicrly sutures

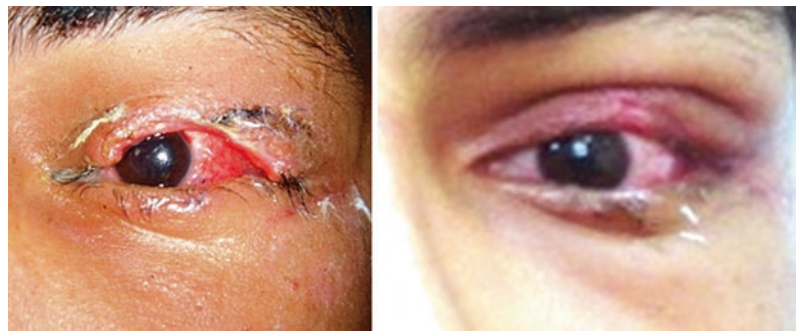

Fig. 3 Left side shows a 24 y old male with upper lid wound with tissue defect. Right side shows the same eye 3 weeks after repair using Tenzel flap

a higher position as it usually descends in few months. Posterior lamella could be formed using periosteal flaps of free tarsoconjunctival grafts form the other eye (in case of upper lid) or even from the same eye (in case of the lower lid injury). Mustarde flaps as well as lid sharing procedures could be considered in defects >50% of the lid length.

Wounds Associated with Canalicular Injuries

They can result from direct trauma to medial canthal area or indirectly by avulsion forces caused by trauma to the orbit. They are common with dog bites and midface injuries. Early repair of the canalicular injury is much easier and more successful than late repair or conjunctivo dacryocystorhinostomy with Jone's tube.

Canalicular lesions may be missed. They should be suspected in injuries medial to the punctum that may be and may be laterally displacement. The diagnosis is confirmed by direct visualization of the cut edge or passing a probe into the canaliculus.

Repair of canalicular injuries is done under general aneasthesia. A stent should be placed through the transected canaliculus. Bicanalicular silicone tube is commonly used however, some surgeons use monocanalicular tubes. In case of bicanalicular tube use, the severed canaliculus is intubated first. Both are retrieved from the nose. The marginal wound is then repaired and canthal tendon wound is also repaired before tying the silastic tube (Fig. 4). After the wound is

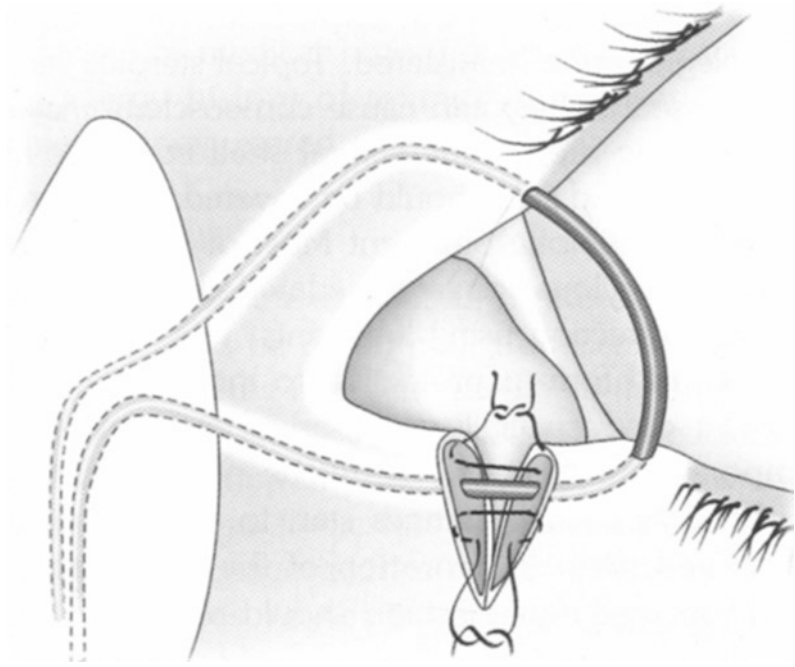

Fig. 4 A diagram showing lower canalicular injury with a bicanalicular tube inserted first before the repair of the marginal wound

Fig. 5 Left shows lower lid marginal wound involving the lower canaliculus. Right photo shows it after inserting the tube and repair of the wound

approximated, the tube is secured by three square knots and left in place for 6 months (Fig. 5).

The medial cut end of the canaliculus could be identified under the microscope with high magnification. It can also be identified using injection of a fluorescein dye or vesicoelastic material into the sac through the intact canaliculus. Pooling saline in the medial canthal area with injecting air into the intact canaliculus will point at the site of cut canaliculus where the air bubbles. If the wound is ragged freshening of the edges may be helpful. Retrograde intubation using Pigtail probes is better avoided as it can cause a false passage.

If the punctum is lacerated, the medial canaliculus could be marsupialized or opened to the conjunctival sac and the lid woundis repaired ignoring the injured punctum and canaliculus.

Wounds Associated with Canthal Tendon Injuries

a. **Medial canthal tendon**
Their injuries are usually associated with canalicular injuries that should be repaired before repairing the severed tendon. The injury may involve any part of tendon. Repair of the cut posterior limb of the tendon is crucial as if not repaired, the lid globe apposition is markedly affected and traumatic telecanthus usually results (Fig. 6). It should be put in mind that repair of medial canthal tendon should provide a posterior pull on the medial canthus thus keeping the lid globe apposition and gives a good cosmetic appearance.
By the time of injury repair, either
   i. *The two ends of the cut tendon could be identified*.
   In this condition, the tendon is repaired using non absorbable or wire suture. A horizontal mattress suture is placed in the distal end of the tendon. The two needles are brought from posterior to anterior through the proximal part (Fig. 7a). If the proximal part of the tendon could not be identified, the sutures are passed through the intact periorbital at the region of the posterior lacrimal crest.
   ii. *The tendon is totally avulsed from the bone:*
   This may be associated with medial orbital wall fractures. If the bone is and the periorbita are intact, suturing into the periorbita at the posterior lacrimal crest using non absorbable suture may be a solution (Fig. 7b). Y shaped microplate could also be used. In case of bone fracture, the bone should be stabilized then a microplate is placed. In case of unstable or absent bone fragment, transnasal wiring of the medial canthal tendons should be done.

Fig. 6 A 3 y old child who had a dog bite with badly repaired medial canthal tendon injury showing medial ectropion and traumatic telecanthus

b. **Lateral canthal tendon**
   i. *The two cut ends of tendon could be identified*
   A horizontal mattress suture is used across the cut ends using non absorbable material. If the lateral end could not be identified, the tendon is fixated to the periosteum, if intact, at a higher position than its normal as wound contracture and the effect of gravity will pull the lateral canthus slightly inferior.
   ii. *The tendon is avulsed from the bone*
   A small drill hole could be done in the lateral orbital rim just above the lateral orbital tubercle. A non absorbable suture attached to the remnants of the lateral canthal tendon is passed through the hole and tied.

Lid Burns

Burns of the eyelid are rare. They can be due to thermal, chemical or electric current injuries. They usually occur in patients who have suffered significant burns over a large surface area of the body. The first priority is to establish and maintain a patent airway. Once stable, the globe should be properly examined. If the globe is injured, topical antibiotics and cycloplegics are administered. Topical steroids should not be used as they can cause corneoscleral melting. An amniotic membrane scleral shell could be also applied. The lid skin should be covered with a broad spectrum antibiotic ointment Most of these patients are semiconscious or heavily sedated and need proper corneal protection using lubricants. The lids may be swollen and form a protection to the cornea. If this is not the case especially with marked exposure, a large temporary tarsorrhaphy could be performed.

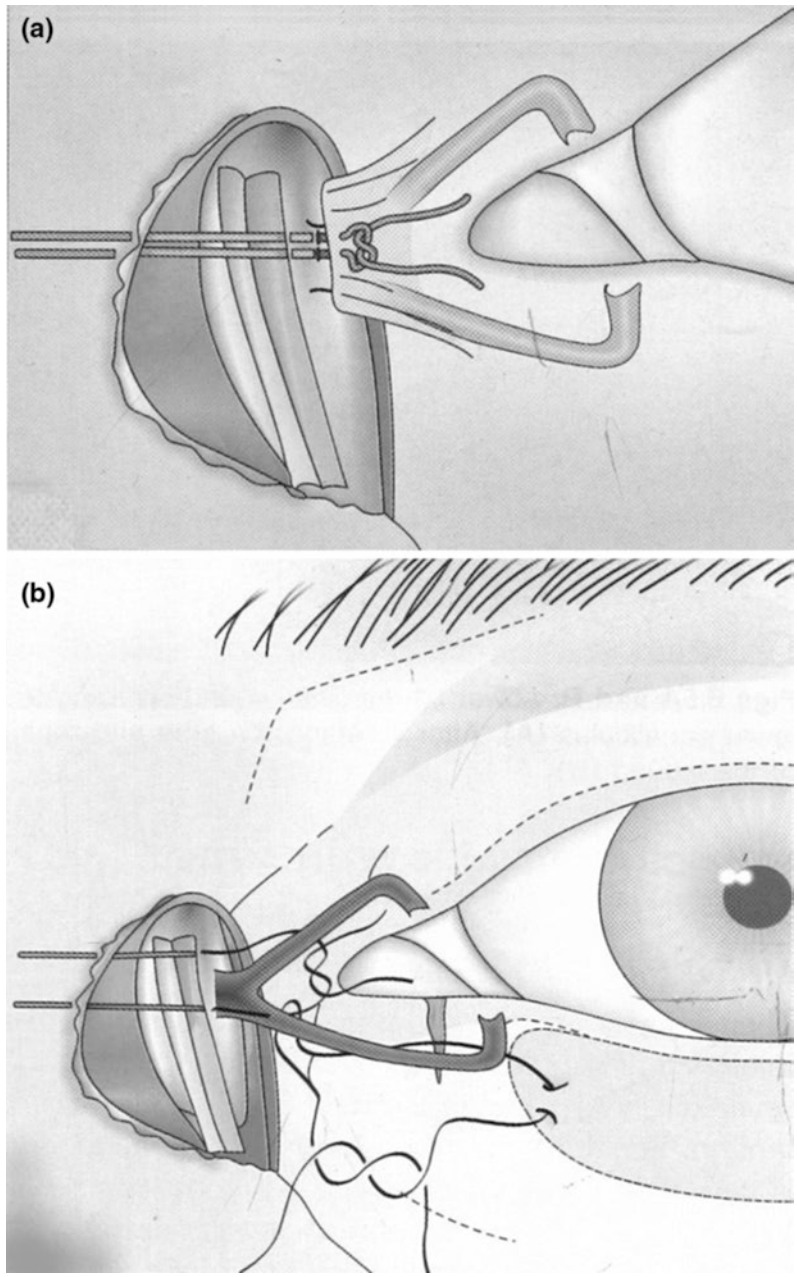

Fig. 7 **a** Shows repair of the medial canthal tendon injury with reattachment to its remnanats. **b** Shows reattachment of the avulsed tendon to the intact periorbita

Once cicatricial changes start to develop usually associated with deterioration of the ocular surface condition, early intervention should occur. Early use of full thickness skin grafts or variable types of flaps had been suggested to reduce the ocular morbidity in selected cases.

Eye Brow Injuries and Defects

Wounds of the eye brow should be meticulously sutured with proper alignment of the upper and lower border of the brows. If the wound is deep it should be closed in layers to minimize scar stretching. However in spite of the best efforts many wounds of the eye brow will show few weeks after healing as a hairless scar. This could be managed by scar revision and follicular hair transplantation from the opposite or the same brow.

In many occasions brow injury is associated with injury to upper eye lid and forehead. It is advisable to correct the brow first and guarantee its proper alignment then consider forehead and lid injury and if there is a forehead skin defect it should be managed without compromising. The brow alignment is by using properly designed flaps or skin grafts. Deformities of the brow resulting from closing forehead defects without respect to brow alignment are more difficult to correct at a second stage.

If the brow is obviously shorter than the opposite brow follicular hair transplant from opposite brow can correct the shortening. In females tattooing can camouflage this starting.

In large or total brow loss a superficial temporal island flap from scalp could be harvested to reconstruct the brow but the hair is usually denser than the normal brow and needs to be regularly cut or shortened. Tattooing especially in females is an alternative.

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Lacrimal Injuries

Nadeen El Toukhy and Essam A. El Toukhy

Lacrimal injuries are usually not isolated. They are almost always associated with lid injuries or orbital or nasal fractures. Eyelid, orbital and adnexal injuries can be a part of multisystem trauma. The basic ABCs of the trauma management should be considered and once the patient is stable, it is possible to properly examine the eyelid with the upper lacrimal passages, orbital injuries as well as the associated globe or optic nerve affection. It should be remembered that upper lacrimal drainage system can be involved in chemical or thermal injuries.

Evaluation of Lacrimal Injuries

History

The conditions of trauma can give an idea about the nature and the extent of injury. Being usually associated with lid or orbital injuries, high index of suspicion should exist to be able to detect lacrimal passage injuries. Lacrimal gland injury is usually rare and may be associated with orbital roof fractures or deep upper lid wound.

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Review of medical history is essential as well as drug allergy history of tetanus immunization and problems encountered with anesthesia.

Examination

Routine systematic examination of the eyelid, globe and orbit should be performed. Canalicular injury is suspected when the injury lies medial to the punctum which is usually laterally displaced compared to the other side or the opposite one. Medial or lateral canthal injuries as well as tissue loss should be ruled out

Lacrimal passage injuries associated with orbital or nasal fractures may be overlooked especially with the edema or ecchymosis. However, associated nasal bone fractures as well as traumatic telecanthus should raise the index of suspicion.

In case of late presentation of lacrimal drainage system injuries, systematic evaluation should be adopted. This includes, evaluation of the conjunctiva for presence of adhesions as well as assessment of the punctual position, direction and patency. Positive regurge test is a sure sign of nasolacrimal duct obstruction. Dye disappearance test show delay as compared to the other side. Probing may show strictures of the canaliculi or fibrosis of the lacrimal sac that usually felt as a soft stop. Irrigation test can show the extent of NLD obstruction. Nasal

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examination is very important is such cases as a deviated septum resulting from the original trauma may be the reason of the lacrimal passage problems.

Orbital CT whether conventional cuts or in three dimensions can show the fractures sites and their extent as well as associated nasal deformities.. Dacryocystography can show nasolacrimal duct obstructions site and extent. Proper lacrimal system evaluation is necessary for choosing the treatment protocol.

Management

I. Lid wounds associated with canalicular lacerations (see chapter "Eyelid Injuries")

II. Lacrimal sac and nasolacrimal duct injuries:

These lesions may be missed as these parts are included in a protective bony structure. A high index of suspicion should be present to anticipate these problems. They are usually associated with nasoethmoidal fractures, sometimes with blow out fractures of the orbit and types II and III Le Fort fractures.

A nasoethmoidal fracture usually results from a force delivered across the nasal bridge and it's very common in automobile accidents in which the face strikes the dashboard. The nasal bones become fractured and displaced. The lacrimal and sphenoidal bones are usually crushed. They are associated with surgical emphysema. Traumatic telecanthus is usually present in association with lacrimal passage injury.

If the fracture is detected and repaired, irrigation of the lacrimal system by the end of the repair should be done. If there is a free system irrigation, nothing more is needed to be done. If there is some minor resistance exists, probing and bicanalicular silicone intubation where the tube is left for 3–6 months may be of use.

If these fractures are not detected and corrected, chronic dacryocystitis can occur and needs dacryocystorhinostomy (DCR). It is sometimes associated with excess bone formation in the area of the nasal and lacrimal bone that accentuates the possibly present traumatic telecanthus. This bone can be debulked while performing the DCR. The surgery can be associated with repair of the present telecanthus.

III. Old traumatic lacrimal passages injuries

Management of such injuries varies according to the site and extent of obstruction and addressed in a similar way as non traumatic cases. For example, destruction of the upper lacrimal system especially with chemical injuries and obliteration of the canaliculi usually necessitates conjunctiveodacryocystorhinostomy (CDCR) with insertion of Lister Johns tube. Chronic dacryocystitis or complete NLD obstruction are treated by conventional DCR.

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Orbital Trauma

Abdullah S. AL-Mujaini, Alyaqdhan S. Al-Ghafri and Essam A. El Toukhy

Introduction

A blunt trauma to the eye and orbit is one of the commonest injuries encountered by ophthalmologists in emergency settings. While most of these injuries tend to be minor and self-limiting, a significant orbital trauma can result in a range of manifestations from orbital contusion to an orbital wall fracture. Orbital wall fractures may also less commonly occur with a penetrating injury. Whenever a penetrating orbital injury is present, the patient must be evaluated for the presence of an intraorbital foreign body.

Although most orbital injuries are self-limiting, orbital trauma may result in serious sequelae that may require emergent intervention such as orbital hemorrhage, traumatic optic neuropathy and oculocardiac reflex secondary to an impinged rectus muscle.

The ophthalmologist should have a low threshold of suspicion for such injuries in the presence of certain clinical features, most notably diplopia, and investigate the patient with appropriate imaging techniques.

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Orbital Anatomy

The bones of the head has three different parts; cranial, facial and mandibular. Out of these three, only the cranial and facial bones make up the orbit. In general, the roof, orbital apex and posterior end of the lateral wall are cranial whereas the rest is facial bones.

The orbit with its seven bones, is a pear-shaped structure, conventionally divided into four walls. The optic nerve passes through the optic canal in the orbital apex. The apex is also the location of the superior and inferior orbital fissures, which transmit various nerves and vessels to and from the orbit.

The medial wall is composed of four bones; lacrimal, ethmoid, maxillary and lesser wing of sphenoid. It is the thinnest wall, hence named the lamina papyracea. Fractures in this area lead to direct communication between the ethmoid air cells and medial orbit. The medial wall transmits the anterior and posterior ethmoidal arteries and nerves at the junction between the ethmoidal bone and the orbital plate of the frontal bone. Trauma to this wall is frequently associated with orbital hemorrhage, epistaxis and surgical emphysema.

E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_42

The orbital floor is composed of the maxillary, palatine and zygomatic bones. It hosts the infraorbital canal and groove through which the infraorbital nerve, a branch of maxillary division of trigeminal nerve, passes. The infraorbital groove, which is located medially in the floor, is an area of weakness, thus orbital floor fractures are usually located in its vicinity. This is an important landmark in relation to orbital floor fractures as damage to the infraorbital nerve presents with loss of sensation in the cheek, side of nose and upper lip. The floor of the orbit is the roof of the underlying maxillary sinus.

The lateral wall is the strongest orbital wall and is composed of the zygomatic bone and greater wing of the sphenoid.

Lastly, the orbital roof is composed of the frontal bone and the lesser wing of sphenoid. This separates the orbit from the intracranial cavity. Although uncommon, orbital roof fractures can result in serious sequelae including intracranial hematomas and encephaloceles.

The orbit is generally divided into an intraconal and extraconcal spaces. The intraconal space is the space within a cone formed by the four recti muscles and their interconnecting fascial sheaths. It hosts the optic nerve and ciliary gangilion, and the third and sixth cranial nerves and nasociliary nerve as they pass through the superior orbital fissure within the tendinous annulus of Zinn in orbital apex. The lacrimal gland and all other orbital structures are located within the extraconal space (Fig. 1). Other potential orbital spaces within the orbit include the subperiosteal (under the periorbita which lines the orbital walls), sub-Tenon (enveloping the globe) and subarachnoid (the space between the optic nerve and its dural sheath).

Clinical Assessment

Orbital injuries may present as part of a multiple trauma and may be associated with a closed-head injury. As the ophthalmologist may be the first clinician to assess such patients, he or she must be vigilant and should perform a thorough and careful assessment to rule out serious or life-threatening injuries.

A quick assessment of the airway, breathing and circulation should be performed in all patients. If cervical spine injury is suspected,

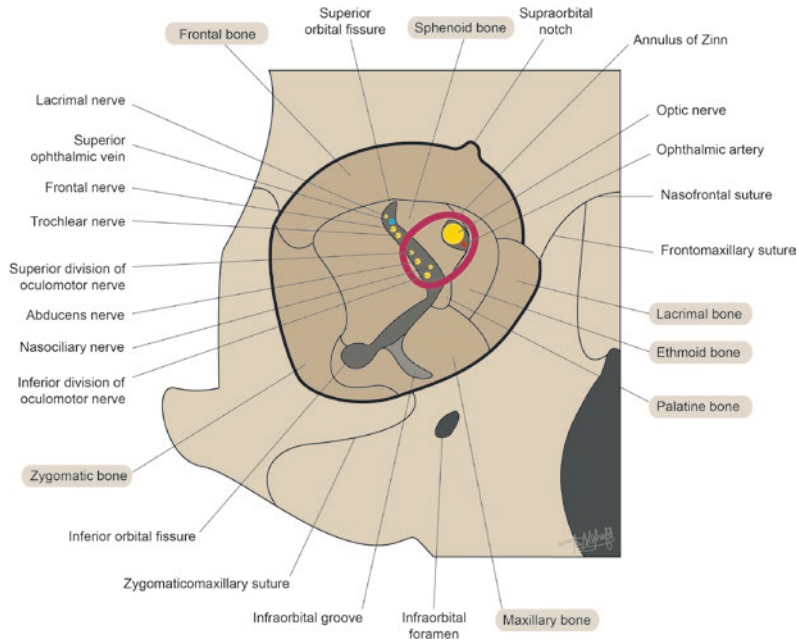

Fig. 1 Simplified orbital anatomy (Courtesy of Alyaqdhan Al-Ghafri)

care should be taken to avoid mobilization of the patient and stabilizing the cervical spine with a collar. The patient should be asked about history of loss of consciousness, drowsiness, nausea, vomiting, seizures and severe headaches. If a serious injury is suspected the emergency physician should be involved immediately and examination of the eye and orbit may be deferred till the patient is stabilized.

History

Orbital trauma history includes questions about the onset, duration and mechanism of injury, including the type and velocity of the object impacting the orbit. Low velocity impact such as a human punch usually produces injury limited to the region of impact. High velocity injury such as motor vehicle accidents is often associated with soft tissues and skeletal injuries that are more extensive and may be remote from the impact. With projectile injuries such as with shattered glass or missiles, intraocular, subcutaneous and orbital foreign bodies should be ruled out.

The patient should be asked about deterioration or loss of vision and diplopia. If diplopia is present, the direction of gaze in which the diplopia or pain is worse should be identified. An orbital floor fracture is typically associated with vertical diplopia that is worse on up gaze, whilst medial wall fractures tend to cause horizontal diplopia if the medial rectus is herniated and tethered within the ethmoidal air cells. It should be noted that diplopia in the acute stage does not necessarily indicate entrapment of muscle or orbital soft tissue, and may simply be due to muscle contusion and soft tissue edema. This usually resolves within the first two weeks after trauma, unlike diplopia secondary to entrapped tissues.

Loss of consciousness, altered sensorium, seizures and nausea and vomiting can be red flags for a closed-head injury. Nausea, vomiting, palpitations and sweating may be symptoms of oculocardiac reflex secondary to entrapment of an extraocular muscle, which more commonly occur in children.

Examination

After ruling out life threatening conditions as outlined above, an orbital injury examination should be started by assessing the visual acuity. This is followed by assessment of optic nerve function, which includes pupillary reaction noting any anisocoria or relative afferent pupillary defect, color vision including red desaturation, and visual fields by confrontation. This is important as orbital trauma may lead to direct or indirect optic nerve injury. The former may be secondary to avulsion of the optic nerve or transection by a foreign body while the latter is often associated with a significant blunt trauma to the superior orbital rim and forehead. *Mellema* et Al in 2009 concluded that about 11–15% of orbital fractures are accompanied with ophthalmic emergencies such as acute hemorrhage or traumatic optic neuropathy. Acute hemorrhage can result in orbital compartment syndrome. However, usually orbital floor fracture will allow the bleeding to accumulate in the maxillary sinus below making orbital compartment syndrome less likely to happen.

The periorbital area should be inspected for any abrasions, ecchymosis, edema, hematoma and eyelid lacerations with or without canalicular involvement. Any globe displacement should be noted, including enophthalmos, proptosis and dystopia. Enophthalmos is typically associated with an orbital floor fracture especially if large. Enophthalmos can be due to orbital expansion due to inferior displacement of the orbital floor. This could be accentuated by soft tissue herniation into the maxillary sinus mainly the periorbita, fat and connective tissue, damage to the Lockwood suspensory ligament as well as collapse of the fine fibrous septa that support the orbital fat and muscles. Immediately after injury, enophthalmos can be masked by orbital hemorrhage and edema posterior and inferior to the globe. If enophthalmos is severe, a prominent superior sulcus deformity can be present.

Proptosis may be secondary to an orbital hemorrhage, hematoma or emphysema. However, globe displacement may be difficult to assess in the acute stage due to significant soft tissue swelling.

Limitation or restriction in extraocular motility should be identified, especially in up and lateral gaze positions. This may give clues to extraocular muscles or orbital soft tissue entrapment and prompt further assessment by imaging. If globe rupture is suspected, assessment of ocular motility should be avoided to prevent extrusion of intraocular contents. Diplopia is a frequent finding in blow out fractures. This was attributed to inferior rectus or inferior oblique muscle entrapment in the fracture. Yet it was found that actual muscle entrapment is rare. Orbital fat entrapment is commoner and the fibrous septa that connect the fat and the periosteum with the inferior rectus and oblique muscles tighten due to edema or intraorbital hemorrhage thus restricting ocular motility and felt as restriction on forced duction test. With time, these septa may stretch and relax improving the ocular motility and diplopia.

The patient usually suffers from vertical diplopia. The patient may have limited supraduction, infraduction or both. If the inferior rectus restriction is anterior to the equator, hypotropia results while if it is posterior to it, hypertropia results.

Injuries to the extraocular muscle or the motor nerves are additional causes for diplopia. Direct contusion or laceration of the muscle can be worsened by muscle hematoma. While the motor nerves can be damaged by hemorrhage within their sheath, stretched by orbital edema or hemorrhage or suffer from concussion.

The orbital margin is palpated for a step deformity, which represents displaced orbital rim fracture, and for crepitus, which is a sign of subcutaneous emphysema. Emphysema occurs due to a direct communication with an adjacent paranasal sinus as in the case of medial and inferior orbital walls fractures.

Facial sensation should be assessed in all patients, as damage to the infraorbital nerve may be the only sign of an orbital floor fracture. It presents as hypoesthesia in the distribution of maxillary branch of the trigeminal nerve (V_2), namely the ipsilateral cheek, lateral aspect of the nose and upper lip.

The eye should be examined carefully for any lacerations or rupture. An occult globe rupture may be suspected in the presence of large subconjunctival hemorrhage and asymmetry in anterior chamber depth between the two eyes as well as low intraocular pressure, limitation of ocular motility and vitreous hemorrhage. A large bulbous 360 degrees subconjunctival hemorrhage may be a sign of a peribulbar or retrobulbar hemorrhage. Moreover, the anterior chamber should be assessed for hyphema and signs of traumatic iridocyclitis. Dilated fundus examination is imperative in all patients.

Orbital Fractures

Orbital fractures are among the common facial injuries, about 30–40% of all facial fractures involve the orbit, and 10% of all facial fractures are isolated orbital fractures. Orbital fractures usually present in the setting of a blunt trauma to the orbit and face. The term orbital blow out fracture implies increase in the orbital volume secondary to an outward deformity in the inferior and/or medial orbital wall(s) which occurs following an impact to the orbit by an object that is equal to or larger than the dimensions of the orbital aperture. This deformity may be accompanied by herniation of the orbital contents into the adjacent cavities; namely the maxillary or ethmoid paranasal sinuses.

Pathophysiology

There are two theories that thought to play a part in the mechanism of a blowout fracture. A fracture may be the result of both mechanisms occurring simultaneously.

The ‘hydraulic’ theory suggests that a blunt trauma to the globe leads to posterior globe displacement and antero-posterior eyeball compression with an increase in equatorial diameter, which leads to a sudden rise in intraorbital pressure. This subsequently leads to a ‘blow-out’ fracture in the weakest areas of the orbital floor and medial wall, which are the infraorbital groove and canal, and the lamina papyracea respectively. This is thought to be a protective mechanism against globe rupture (Fig. 2).

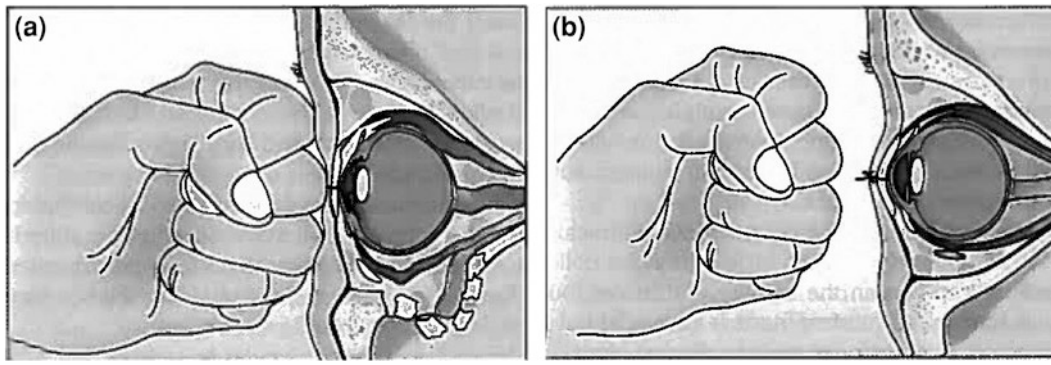

Fig. 2 **a** Shows a blunt trauma to the anterior orbit. **b** Shows that the contents are compressed with increased intraorbital pressure so that the floor gives way

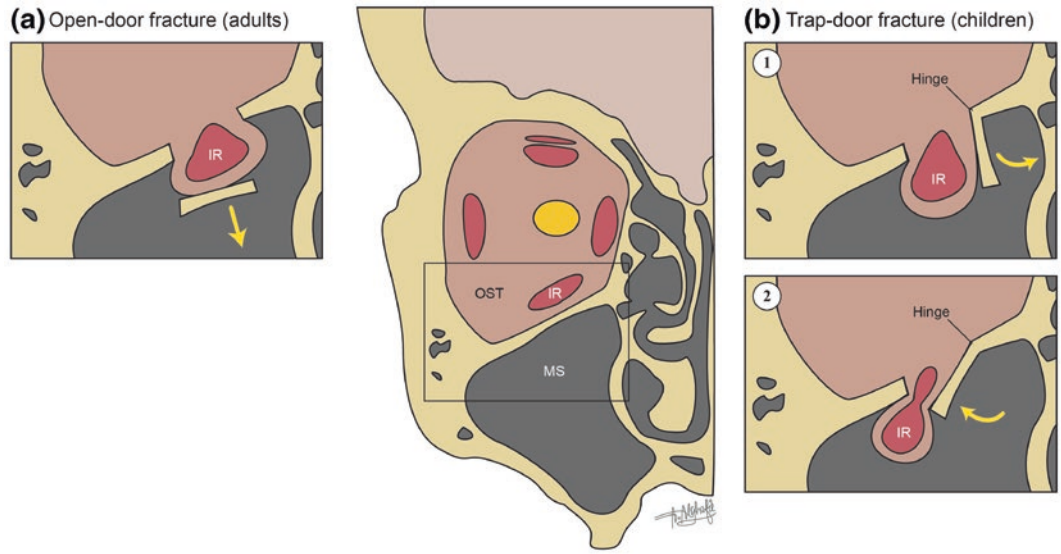

Fig. 3 **a** Adult bones are brittle, therefore their fractures tend to be comminuted, **b** children tend to have trap-door fractures due to the elastic nature of their bones; fractured bone segment hinges on one side (1). When the bone segment recoils back to its original position it impinges on the inferior rectus or orbital soft tissues (2). IR = inferior rectus, MS = maxillary sinus, OST = orbital soft tissue (Courtesy of Alyaqdhan Al-Ghafri)

The 'buckling' theory proposes a different mechanism, in which a blunt impact to the inferior orbital rim transmits force to the orbital floor posteriorly leading to buckling and fracture of the bone at its weakest point.

Special Considerations in Pediatrics

Orbital floor fractures in children tend to differ from those in adults. This is due to the elastic nature of bones in children, which result in greenstick fractures and 'trap-door' phenomenon. This implies a fractured bone segment that hinges on one side thus has the propensity recoiling back. When the bone segment recoils back to its original position it may impinge on the inferior rectus or orbital fat (Fig. 3). This applies constant pressure on the muscle which may lead to oculocardiac reflex, and may compromise the blood supply to the muscle resulting in ischemia and permanent damage. Oculocardiac reflex presents with bradycardia, nausea, vomiting and syncope. In comparison,

adult bones are more brittle and thus a fractured bone segment tend to dislodge and become displaced without exerting pressure on the entrapped muscle, if entrapment occurs.

Moreover, 'white-eyed blow out fracture' is a condition that is seen in children who have orbital wall fracture but no periorbital soft tissue signs and no conjunctival congestion or hemorrhage. Therefore, the ophthalmologist should have a low threshold of suspicion in such cases and consider imaging especially if there is doubt on the extent of ocular motility range.

Imaging

Imaging should be considered whenever there is slight suspicion of an orbital wall fracture, orbital hemorrhage or hematoma, particularly in unconscious trauma patient where it can be easily missed. The preferred imaging technique is computerized tomography (CT) without intravenous contrast. However, if this is not readily available, a skull radiograph may be considered.

Skull X-Ray

Orbital x-ray may not be the imaging modality of choice for orbital trauma, however if it is the only available technique at a particular clinical setting a radiograph with 'Waters view' should be considered. In this view the patient head is in a slight chin-up position, which allows the x-ray beams to be direct at 45 degrees to the skull.

An orbital floor blow-out fracture may be seen as 'tear-drop' sign which represents prolapse of the orbital soft tissue into the maxillary antrum through the orbital floor.

Dark crescent-shaped shadow in the superior aspect of the orbit may represent an orbital emphysema. This is known as 'black-eyebrow' sign.

Orbital CT

This is the most sensitive imaging technique delineating orbital wall fractures. It outlines the location, extent and comminution of fractures, as well as the presence of extraocular muscles and orbital soft tissue entrapment (Fig. 4). Commonly, an air-fluid level can be seen in the maxillary sinus in presence of orbital floor fractures, which represents hemosinus (Fig. 5).

CT also reveals orbital hemorrhage and orbital emphysema, which appear as hyperdense and hypodense areas respectively.

Coronal, axial and sagittal views should be requested, with fine cuts (ideally 1 to 2 mm sections) as this decreases the chance of missing small fractures especially a small trapdoor fracture in children. Coronal images in 2 mm sections delineate the orbital floor, roof, medial and lateral walls, the nasoethmoid region, the orbital rim and the face surrounding the orbit. It helps delineate the size, shape and location of fractures and associated soft tissue injuries.

Axial scans permit evaluation of the lacrimal drainage pathways, nasal and paranasal sinuses, medial and lateral walls of the orbit, superior and inferior orbital rims, zygomatic arch, pterygoid plates, temporomandibular joint, base of the skull, superior orbital fissures and optic canal. It shows globe placement in comparison to the unaffected side.

The combination of axial and coronal scans can give most of the needed information in trauma cases. Three dimensional scans are helpful in obtaining a more accurate evaluation and understanding of the situation, hence help in deciding the best line for treatment. They are generated from the reformatting 1.5 mm slices on conventional CT scan using a special software computer program. They are very helpful in old trauma cases as they show the deformity, the site, size and appearance of bony defects as well as bone fractures.

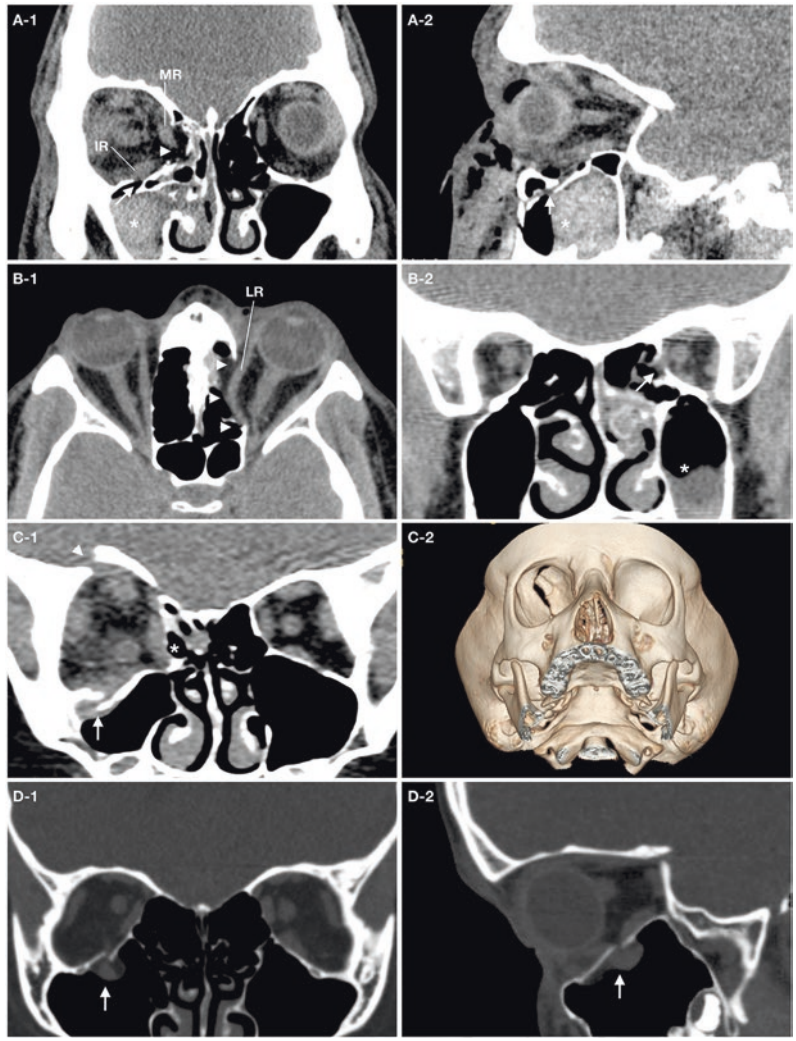

Fig. 4 Coronal (A-1) and sagittal (A-2) views of orbital CT of a 29-year-old male with right orbital floor (arrow) and medial orbital wall (arrowhead) fractures, without entrapment. It also shows adjacent maxillary hemosinus (asterix). (B-1) shows an axial CT of a 34-year-old male with left medial wall fracture (arrowheads) with orbital fat and lateral rectus (LR) herniation within the depressed ethmoidal air cells. The coronal view (B-2) of the same patient reveals entrapment of the lateral rectus posteriorly (arrow). Air-fluid level of maxillary hemosinus can also be seen (asterix). (C-1) is coronal CT of a 6-year-old girl with multiple right orbital walls fractures; roof (arrowhead), medial wall (asterix) and floor (arrow) with possible entrapment of the inferior rectus. (C-2) is a 3-dimentional reconstruction of the same patient's CT, detailing the orbital roof fracture. Coronal (D-1) and sagittal (D-2) CT of 11-year-old boy with orbital floor trap-door fractures with entrapment of the inferior rectus (arrow). IR = inferior rectus, MR = medial rectus, LR = lateral rectus

Orbital MRI

Bones are not clearly delineated with MRI, thus it is not a preferred choice in suspected orbital wall fractures. However, it does provide excellent view of the orbital soft tissues and should be considered whenever an injury to the optic nerves is suspected.

MRI is contraindicated if an intraorbital or intraocular metallic foreign body is suspected. It

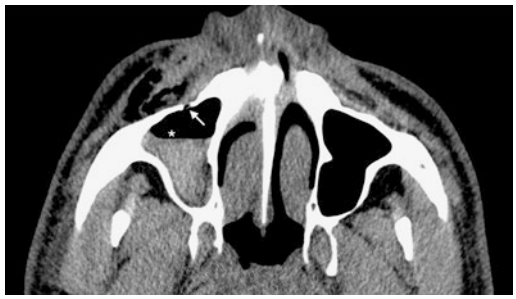

Fig. 5 Orbital floor fracture (not shown) with inferior orbital rim involvement extending to the anterior wall of maxillary sinus (arrow). Air-fluid level within the maxillary sinus is consistent with hemosinus (asterix)

should be avoided whenever the mechanism of a penetrating injury is unknown.

Management and Surgical Indications

This first step in managing patients with orbital trauma is to exclude any life-threatening injury as mentioned above. A multidisciplinary approach is often required according to the extent and nature of the injury. This may include emergency physician, maxillofacial surgeon, ENT surgeon and neurosurgeon.

Once serious injuries have been excluded and a full eye examination including dilated fundus examination is performed, attention is directed towards the fracture.

Frequent ice packs application helps in hastening the resolution of eyelids edema and provides some pain relief. Oral steroids may also be considered to reduce the inflammation and thus edema. The patient should be advised to avoid blowing their nose to prevent positive pressure within the sinuses leading to air tracking into the orbit and increasing the chance of orbital emphysema. Large emphysema may increase intraorbital pressure resulting in orbital compartment syndrome, optic nerve compression and blindness. This is an ophthalmic emergency that requires urgent surgical evacuation of the entrapped air.

Prophylactic antibiotics may be considered as bacteria from adjacent paranasal sinuses may present a risk for orbital cellulitis.

In children with extraocular muscle impingement, release of the impinged muscle and orbital wall fracture repair should be performed within 24–48 h of the injury. This reduces the risk of muscle ischemia and fibrosis, which may result in permanent muscle dysfunction and persistent diplopia.

Patient with oculocardiac reflex must be operated immediately to relieve the compression on the impinged muscle. Delayed treatment of oculocardiac reflex may lead to severe bradycardia, and even asystole.

Classically, if there is no immediate indication for surgery, the patient is typically asked to follow up every 2–3 days during the first two weeks. This allows for better assessment once the periorbital soft tissue swelling has subsided or reduced. The patient can then be assessed again for limitations of ocular motility and enophthalmos or dystopia. However, recent studies have shown that repairing fractures in the first 8 days after trauma has a better long term prognosis as regards motility and enophthalmos than repairing after 8 days. In addition, most surgeons considers early onset or progressive enophthalmos as an indication of early prompt surgery, as the management of late enophthalmos is more difficult and less rewarding. Surgery is also indicated in the presence of one or more of the following; enophthalmos of more than 2 mm, limitation of ocular motility leading to diplopia in primary and reading positions, a defect of orbital floor that is larger than 50%, unresolved or progression of infraorbital nerve hypesthesia, and muscle entrapment. Asymptomatic patients with no diplopia or disfiguring globe displacement may be observed and surgical correction is not indicated. The occurrence of late enophthalmos is a more difficult issue to consider; the amount of internal orbital fractures is co-related to the globe malposition that may occur. The exact location of the orbital fracture defect is quite important to

the existence of enophthalmos. The maxillary sinus below the bony orbit has an upward bulge towards the confluence between the medial wall and the orbital floor, this area is critical in preserving the forward placement of the globe. In addition, the amount of orbital soft tissue herniation can be a critical factor to the development of enophthalmos. It has been proved that increase in the orbital volume from 0.5–1 cc can result in 1 mm of enophthalmos.

Orbital Wall Reconstruction

The general principle in surgical correction of an orbital wall fracture is to reduce any entrapped muscle and orbital tissue back to its place and to close the bone defect using one of various available implant materials. The surgical approach depends on the location and extent of the fracture. All are done under general anesthesia and forced duction test is performed initially to confirm the degree of tissue entrapment.

Orbital floor fractures can be approached transcutaneously through a subciliary or lower eyelid crease incision. However, transconjunctival approach through the inferior tarsal conjunctiva may be preferred for better cosmetic outcome. Once the inferior orbital rim is reached, the periorbita is elevated without breaching the orbital septum. The fractured floor can then be visualised, and any entrapped tissue is retracted into the orbit (Fig. 6). Incarcerated tissues are freed from the fracture using hand on hand maneuver with the periosteal elevator and the metal suction tip or malleable retractors. This is easy in cases of recent fractures yet if the tissues are swollen, the extraction becomes difficult and the bone can be depressed into the maxillary antrum. In case of hinged fractures or in some selected cases, the fracture may be enlarged to achieve atraumatic release. Care should be taken to avoid undue bleeding and trauma to the nearby optic nerve.

Optic nerve should be checked every now and then by detecting the pupillary light reaction or dilating the pupil and noting the optic nerve perfusion by the ophthalmoscope.

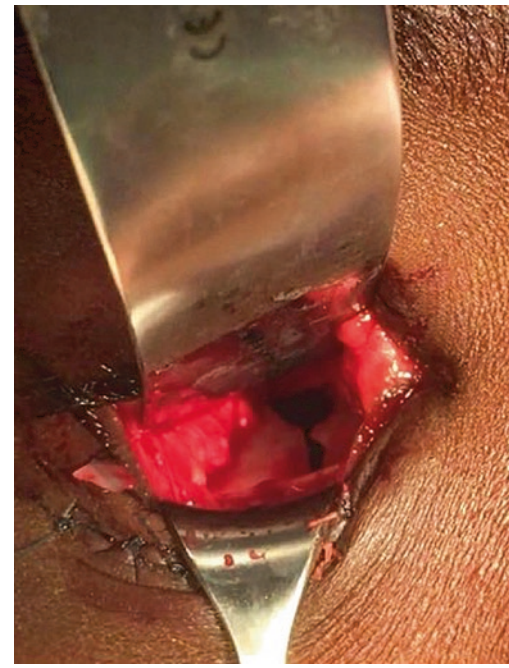

Fig. 6 Intra-operative view of an orbital floor fracture

Forced duction should be repeated to ensure that no more incarcerated tissues are present. Any bone fragments or blood should be aspirated from the maxillary antrum before the defect is covered. An implant such as porous polyethylene can then be used to cover the defect (Fig. 7). The implant material is fashioned to cover the defect completely and overlapping the surrounding intact bone by 3–4 mm circumferentially. This sheet should not be too large or too thick. The edges are smoothened to avoid trauma to adjacent structures or erosion through the covering periostium. The alloplastic material should be soaked in antibiotic before it is inserted. The thickness of the plate usually range from 0.4 to 0.6 mm. Thicker implants are indicated in cases of significant enophthalmos and hypophthalmos yet they have the risk of limiting extraocular muscles. The more posterior the implant is placed, the more it reduces enophthalmos. The more anterior it is, the more it reduced hypophthalmos. The retracted periorbita, orbital tissue and globe are then released to slide back into their original position, exerting pressure on the implant securing it in place.

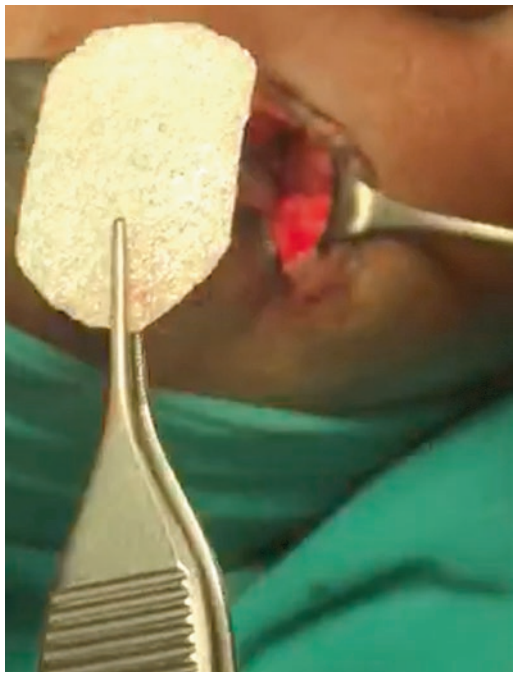

Fig. 7 Porous polyethylene is cut into appropriate size and shape and used to cover the bony defect

Medial orbital wall fractures are typically approached via a transcaruncular incision, with or without inferior transconjunctival incision. The latter provides a good exposure in cases where a coexisting orbital floor fracture is present.

A significantly displaced lateral orbital wall fracture requires open reduction of the zygoma and internal fixation with metallic plates and screws. If the fracture is not displaced, it can be observed and surgery may not be required. Zygomaticomaxillary complex fractures (tripod fractures) are usually displaced inferiorly and thus present with lateral canthus dystopia and diplopia. They may also involve the orbital floor to a varying degree. Proper surgical alignment along the lateral orbital rim is necessary to treat disfiguring globe displacement.

There is a wide variety of implants available for bone defect reconstruction, including biological and alloplastic materials. The ideal material for reconstruction of orbital floor fracture should be strong enough to maintain orbital contents, easy to contour, biocompatible, resorbable and inexpensive.

Biological implants include bone, cartilage and temporalis fascia autografts, and bone and dura allografts. Autogenous bone was always referred to as the gold standard with the potential of revascularization, good mechanical properties, no immune reaction. However, autogenous bone grafts are accompanied with increased surgery time, donor site morbidity, variable resorption rates and incomplete volume correction leading to globe malposition and enophthalmos.

Alloplastic materials are easily available, customizable, predictable, and cost effective. Its disadvantages include infection, foreign body reaction, extrusion, intraorbital mucocele, and globe elevation. Alloplastic implants can be either resorbable or non-resorbable. The former (e.g. polyglycolic acid) are preferred in children as they allow for bone growth as the orbital bones continue to grow. However, they may be associated with delayed enophthalmos and intense inflammation. Non-resobable materials on the other hand offer long-term rigid support but have a higher risk of infection. Implant migration is another disadvantage. Examples of these include porous polyethylene and titanium mesh. These materials are pliable and can be molded to fit the contour of the fractured orbital wall (Fig. 8). Porous polyethylene allows for vascular ingrowth but may form adhesions to extraocular muscles leading to post-operative diplopia. Porous polyethylene (Medpor) sheets are available in a variety of sizes and shapes. These sheets are smooth, trimmed to shape with no soft tissue impingement.

Another type of non-absorbable implants are Silicone implants, they are characterized by being cheap, inert, flexible, and easy to handle. However, its major disadvantages are frequent infections, and high rates of implant extrusion. Polytetrafluoroethylene (PTFE) implant is also a non-absorbable type that is inert, easy to shape, has minimal foreign body reaction, and can be sterilized.

Titanium mesh may be more difficult to place, and the associated intense post-operative fibrosis may make a secondary surgery more difficult. Titanium mesh with porous polyethylene

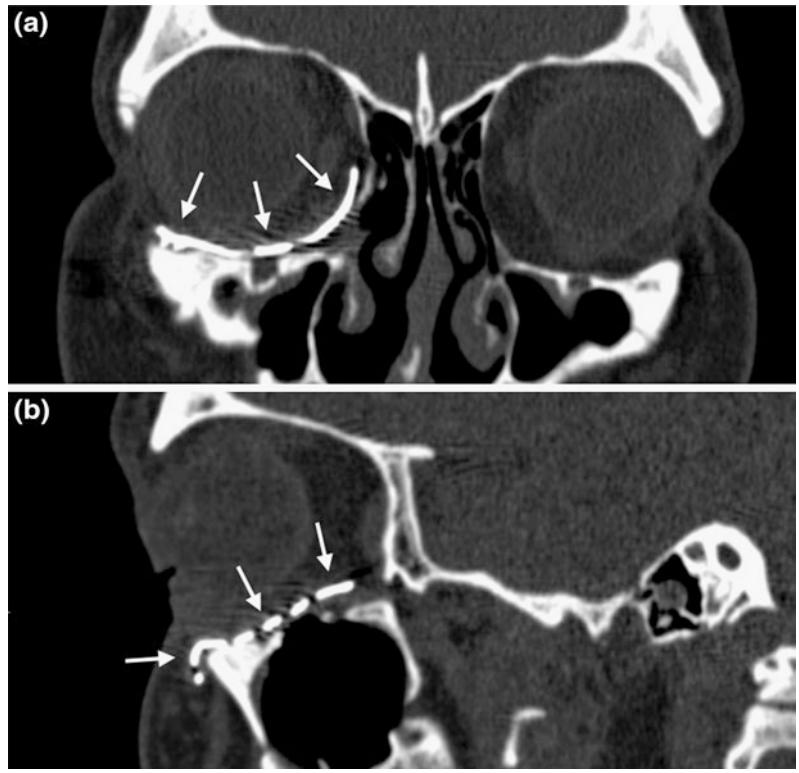

Fig. 8 CT coronal (**a**) and sagittal (**b**) views of a titanium mesh implant that was molded to fit the shape of defect in concurrent orbital floor and medial wall fractures (arrows)

coating is also available. Recently, computer assisted design and manufacturing of customized implants in combination with surgical navigation for orbital floor/walls fractures have allowed optimal reconstruction.

Complications

Diplopia and enophthalmos are the most common complications following surgical repair of orbital blow-out fractures. Diplopia may be transient and resolve within several weeks, or may persists due to either irreversible preoperative extraocular muscle ischemia, postoperative muscle fibrosis, or intra-operative tethering of a muscle or its surrounding sheath the implant. A forced duction test at the end of surgery is important to assess for any residual muscle restriction. A muscle procedure is better deferred 6–12 months after surgery during which the diplopia may improve or the patient can wear prisms.

Enophthalmos may be secondary to inaccurate placement of the implant, or it can be delayed following implant resorption, implant migration, or secondary to fat atrophy. It can be mild requiring no further intervention. In some cases, minimal ipsilateral upper lid elevation using Fasenella Servat procedure or contralateral upper lid blepharoplasty to deepen the superior sulcus can be enough to camouflage the appearance. In more extensive cases, the implant may be exchanged for a thicker one.

Lower eyelid retraction, entropion and ectropion have also been reported. These are thought to be associated with the surgical incision. Subciliary incisions carry more risk of cicatricial ectropion, whereas transconjunctival incisions may cause cicatricial entropion. Persistent infraorbital nerve anesthesia may occur. It may be injured or just compressed by the implant.

If the nerve is not cut, function usually returns within 1 year. Sometimes the implant can be exchanged with widening the foramen decompressing the nerve.

Other complications include implant related complications, such as implant infection, migration and exposure, and more serious but rare complications such as retrobulbar hemorrhage, orbital compartment syndrome, optic neuropathy and blindness.

Orbital Roof Fractures

Orbital roof fractures are skull base fractures and are more likely to occur in children, as the frontal sinuses are not completely pneumatized until later in adolescence. Conversely, orbital roof fractures are rare in adults as the frontal sinuses absorb most of the impact resulting in sinus fractures, thus protecting the skull base.

These fractures warrant neurosurgeon's review, as they can be associated with intracranial hemorrhage, cerebral edema and cerebrospinal fluid rhinorrhea. It may be associated with brow and eyelid ecchymosis, forehead hyposthesia, ptosis and diplopia. The latter is secondary to superior rectus or oblique affection as well as damage to the trochlea. Ptosis results from third nerve affection, direct muscle injury or muscle entrapment. The fracture may extend to the superior orbital fissure and optic canal with resultant damage to the optic, oculomotor, trochlear and abducent nerves.

Non-displaced orbital roof fractures may be observed. Significant displacement may require open reduction and internal fixation.

'Growing skull fracture' refers to an entity in children with displaced orbital roof fracture. This occurs due to a dural tear adjacent to the displaced fracture, where subsequent leptomeningeal cyst formation impedes healing of the fractured bone and leads to non-union of the bone. This may lead to pulsatile proptosis, vertical dystopia and orbital compartment syndrome. Treatment is by cyst excision followed by dura and bone reconstruction.

Mid-Facial Fractures

Le Forte fractures are complex facial fractures that result in discontinuity of the midface. They involve the maxillary bones, nasal bones, zygomas, sphenoids and medial orbital wall bones to a varying degree. All Le Forte fractures involve the pterygoid processes of the sphenoids. These injuries are often associated with high-impact blunt trauma to the face, most commonly secondary to mobile vehicle collisions, falls and assaults.

In Le Forte I the anterior maxilla are horizontally fractured leading to separation of the palate and upper jaw from the midface. This fracture does not involve the orbital walls.

Le Forte II fractures are pyramidal in shape and involve the nasal bridge at the nasofrontal suture, the inferomedial orbital rim and the zygomaticomaxillary sutures. These fractures may damage the nasolacrimal sac and duct and may lead to insufficiency of lacrimal drainage.

Le Forte III fractures involve the orbit to a greater extent as they involve medial, inferior and lateral orbital walls, the nasofrontal suture and the zygomatic arches resulting in craniofacial separation.

The diagnosis is made clinically and radiologically. Signs that support the diagnosis include peri-orbital ecchymosis (raccoon eyes) and midfacial mobility. The most important radiological feature is the presence of pterygoid process fracture; as this is present in all types of Le Forte fractures.

These complex fractures are often managed by open reduction and internal fixation by maxillofacial surgeons. A proportion of cases can be managed conservatively without the need for surgery. The patient should be evaluated carefully as these injuries can be associated with cervical and head injuries, and neurosurgery evaluation may be required. Concurrent ocular injuries may also occur, especially with Le Forte II and III fractures.

Naso-orbito-ethmoid (NOE) fracture are another type of mid-face fractures that occur secondary to impact to the central nasal region.

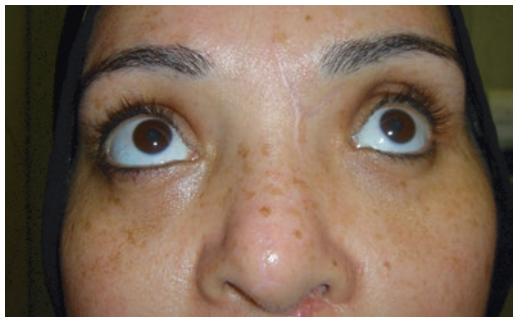

Fig. 9 Left traumatic telecanthus (Courtesy of Dr Rania Abdel Salam)

This leads to fractures of the nasal, lacrimal and ethmoid bones, with unilateral or bilateral infraorbital rim and medial orbital wall fractures. This may lead to avulsion of the medial canthal ligament and thus telecanthus (Fig. 9). This usually requires reduction of the bony fragments and transnasal wiring combined with canthal Y-V plasty. If there is enough bone support Y miniplate is inserted and used for the telecanthus repair.

The lacrimal drainage system should be assessed in these patients as damage to the nasolacrimal sac and duct can occur. CSF rhinorrhea suggests a cribriform plate fracture. Most of cases are managed conservatively. The patient is treated by bed rest, intravenous antibiotics and instructed not to blow the nose or smoke. If the condition persists, neurosurgical interference is required.

Transnasal Wiring

Surgical Technique

A—If the contralateral nasal bone is intact:
Under general anesthesia, a vertical incision is made nasal to the medial canthus. This may take a V-Y or C-U configuration if skin muscle advancement is also required in the reconstruction. The incision is carried to the fracture site adjacent to medial canthal tendon avoiding the lacrimal drainage system. The splayed bone at the posterior lacrimal crest is thinned using cutting burr. Either a 2-0 Supramid suture or 27 gauge stainless steel wire is used to engage the superficial head of the tendon. If insufficient tendon remains, the Supramid or wire may be positioned in the medial portion of the upper and lower tarsi.

On the intact side, a 15 mm vertical incision is made into the skin and subcutaneous tissues just anterior to the insertion of the superficial head of the medial canthal tendon. The periosteum is opened vertically at the anterior lacrimal crest and reflected anteriorly. A 5 mm opening is made by a drill through the bone and nasal mucosa anterior to the attachment.

A Wright needle or 16 gauge trocar is passed from the surgically drilled opening (normal side) through the nasal septum, emerging at the fracture site. Some pressure is needed to penetrate the septum. Care should be taken to prevent momentum from carrying the needle immediately through the fracture site with the possibility of globe injury which lie in close proximity to the medial wall. Malleable retractors are placed to protect the globe.

The Supramid or wire suture are placed within the eyelet of the Wright needle or within the trocar after removing the stylet and this material becomes properly positioned as the needle/torcar is withdrawn. The two ends are tightened around 8 mm metal bloster pin on the sound side and the traumatized canthus is quantitatively drawn medially as the Supramid or wire is secured.

The deeper layers are closed with 5-0 Vicryl mattress suture, followed by skin closure with running 7-0 silk suture. If nasal pads are to be placed, this should be done before the trocar is removed. A second loop of wire is passed through the trocar after the transnasal wiring is completed but before the skin closure, the loop is cut leaving two free skin wires. The end of each is passed through one of two silicone pads. The wires from each side are twisted together over a dental roll to compress the skin in the canthal region. The nose pads and the skin sutures are left in place for 7–10 days, then the skin wires and pads are removed.

B—If bilateral naso-orbital fractures:
If bilateral naso-orbital fractures, the bone may be insufficient on either side to support the reconstruction. In this condition, standard transnasal wiring technique takes place where two medial canthal incisions are made; bone penetration should be done at the posterior lacrimal crest level leaving intact bone anterior to this site to avoid forwards migration of the wire.

The trocar is passed and two looped 32 gauge stainless steel wires are passed; one loop with the ends of the other are tagged with the hemostat and they will become the skin wires, the other fixates the canthal tendons bilaterally. The medial canthal tendon is secured to the loop by 4-0 non absorbable suture. The two ends of the wire are twisted on themselves forming a second loop that is also secured to the medial canthal tendon on this side. The looped wire is tightened pulling the medial canthal angles towards the nasal septum. The skin wires are tied over nose pads to restore the concavity of tissues at the medial canthal area and removed in a similar time to the above.

Problems Associated with Orbital Trauma

Surgical Emphysema

This means accumulation of air in the subcutaneous tissue. This is a common finding in medial wall and floor fractures as they involve walls of the paranasal sinuses. The condition usually increases when the patient blows his nose and there is a crepitus felt on palpation. Reassurance of the patient and instruction not to forcibly blow his nose are usually enough till the symptoms are relieved provided there are no associated orbital or ocular problems detected.

Carotid Cavernous Fistula

It results from shearing of intracavernous carotid artery during deceleration injuries, or direct artery injury by foreign body or bone shrapnel. They develop shortly after trauma but the onset of symptoms may be delayed. They present with progressive proptosis usually pulsatile with subjective and objective bruit. IOP is usually elevated with engorged retinal veins. Brain CT scans with contrast confirm the diagnosis. The fistula can be closed using endovascular occlusion with coils which is the preferred technique.

Septic Cavernous Sinus Thromobsis

Fracture of the posterior ethmoidal or sphenoidal sinuses may allow concomitants with the paranasal sinuses to reach the cavernous sinuses. They usually have a rapid presentation and associated with low grade fever, headache, orbital pain or diplopia. This is followed by progressive proptosis, mydriasis, ophthalmolplegia due to nerve palsy and eventually visual loss due to compressive optic neuropathy. If not treated, septic thrombosis may spread to the cerebral veins leading to increased intracranial tension.

MRI may show a mass caused by thrombus in the sinus compressing the intracavernous part of the internal carotid. Cerebral arteiography and venography may be used however MRA presents a good alternative. Early diagnosis is of extreme importance as it improves the prognosis. Systemic antibiotics are the main line of treatment. Anticoagulant treatment is used to prevent progressive thrombosis if not controlled by antibiotics within 48–72 h; however, they should not be used if a fungal etiology is suspected due to increased risk of mycotic aneurysm formation.

Traumatic Orbital Hemorrhage

Acute orbital hemorrhage may occur in the setting of blunt orbital trauma with or without a concurrent orbital wall fracture. Due to the compact nature of the orbital cavity, a certain degree of proptosis allows for expansion of orbital volume. However, rapid increase of the size of an expanding orbital space-occupying lesion, as is the case in orbital hemorrhage, leads

to a dramatic increase in the intraorbital pressure beyond what proptosis can negate. This results in compression of orbital arterial supply and hence, retinal and optic nerve ischemia and damage.

The diagnosis of orbital hemorrhage can be made clinically and emergent management should not be delayed until imaging is performed. Patients typically present with painful proptosis, tense globe, periorbital swelling and ecchymosis, limitation of ocular motility, subconjunctival hemorrhage that may be bullous and covers the whole ocular surface (Fig. 10), a relative afferent pupillary defect (RAPD) and elevated intraocular pressure (IOP).

The distribution of orbital hemorrhage or hematoma may be retrobulbar in the intraconal, extraconal or peribulbar in the subtenon space. Blood may also accumulate in the subperiosteal space. The extent of the blood is limited by bone

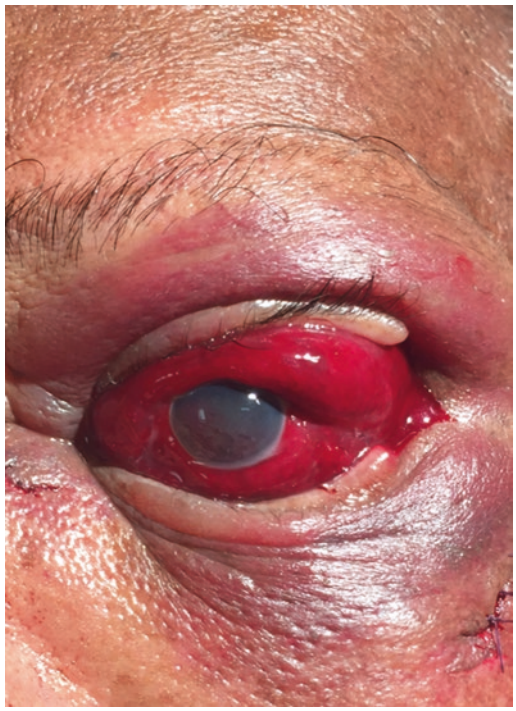

Fig. 10 Patient with acute traumatic orbital hemorrhage following emergency lateral canthotomy and cantholysis (note the site of incision). Bullous 360 degrees subconjunctival hemorrhage, proptosis, periorbital ecchymosis and frozen globe were all clues pointing towards the diagnosis

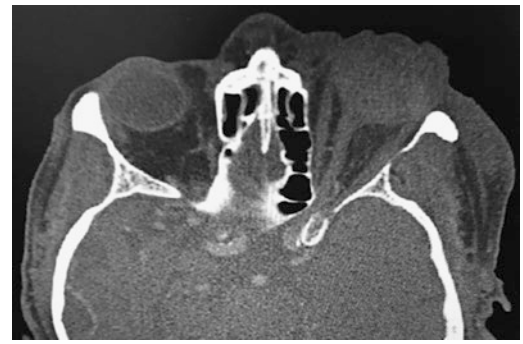

Fig. 11 Axial CT of a patient with acute traumatic peribulbar hemorrhage, vitreous hemorrhage and proptosis

suture lines where periorbita becomes firmly adherent. If the periotrbita is intact, the patient may present with mild proptosis and globe displacement. If the periorbita is disrupted the hemorrhage becomes extensive and moves towards the orbital septum and bulbar conjunctiva.

CT scan provides good views of the hemorrhage and its extension (Fig. 11), and detects any coincident orbital wall fractures, while MRI would be preferred to assess for optic nerve compression.

Management

If an orbital hemorrhage is suspected, treatment should be ensued immediately to prevent irreversible vision loss. If there is mild proptosis with normal or minimally elevated intraocular pressure with no visual compromise, follow up can be safe and the hemorrhage will gradually resolve over 1–3 weeks usually without sequalae.

It is suggested that whenever RAPD is present, an immediate lateral canthotomy and cantholysis at bedside should performed until the patient can be taken to the operating theater for evacuation of the hematoma under general anesthesia. Canthotomy and cantholysis allow for immediate orbital decompression and reduce the intraorbital pressure. A successful procedure will result in an instant increase in the proptosis as the orbital volume expands. In patients with

elevated IOP but no RAPD, surgical management may be deferred and the patient should be admitted for medical therapy and close observation. This includes treatment with high dose corticosteroids and intravenous acetazolamide or mannitol, in addition to topical IOP lowering agents. If optic neuropathy is suspected despite starting medical therapy, emergency orbital decompression should be performed. The hematoma could be drained either through lid crease incision if placed superiorly or though lower lid blepharoplasty incision if inferiorly placed. In either condition, the orbital septum must be opened to allow the egress of the blood from the socket.

Intraorbital Foreign Body

Orbital foreign bodies may be associated with penetrating orbital injury, particularly those caused by high-velocity projectiles. They can be either organic or inorganic. A thorough history is important to determine the mechanism of injury and the type and material of the foreign body as this helps in selecting appropriate imaging technique as well as deciding on the best management approach.

Studies showed that most orbital foreign bodies are metallic, whilst glass, wood, porcelain and plastic were less frequently reported. Organic foreign bodies incite marked inflammatory response and are associated with higher risk of orbital cellulitis. Metallic foreign bodies on the other hand are often inert to orbital soft tissues and may remain in place for years without significant morbidity. However, it should be noted that any type of orbital foreign body, regardless of its composition, may result in restrictive strabismus, orbital infection or inflammation which may be chronic and recurrent, sterile abscess, sinus formation and vision loss due to damage to the globe or optic nerve. Certain metals such as copper can incite inflammation, while others may lead to toxicity, such as siderosis from iron, and systemic toxicity from lead.

Imaging

CT scan is considered the gold standard in imaging intraorbital foreign bodies. Metals (with the exception of aluminum) and glass are radiopaque. Conversely, plastic and wood are radiolucent on CT and are better visualized with MRI. Wood may resemble air on CT, however the hyperdense inflammatory reaction surrounding the foreign body (Fig. 12) may differentiate it from wood. CT is more sensitive in detecting glass compared to MRI.

MRI is reserved for non-metallic foreign bodies. Ferromagnetic objects such as steel can become projectiles in the presence of MRI strong magnetic field, leading to further trauma. However, MRI can still be utilized in the presence of certain metals such as lead, which is not ferromagnetic. This is particularly useful in determining the exact location of the foreign body (e.g. in relation to optic nerve or orbital apex), as MRI does not produce streak artifacts. The clinician must be certain of the nature of the object before ordering MRI. It should be noted that pellets are made from either steel or lead, thus it may be difficult to know the composition

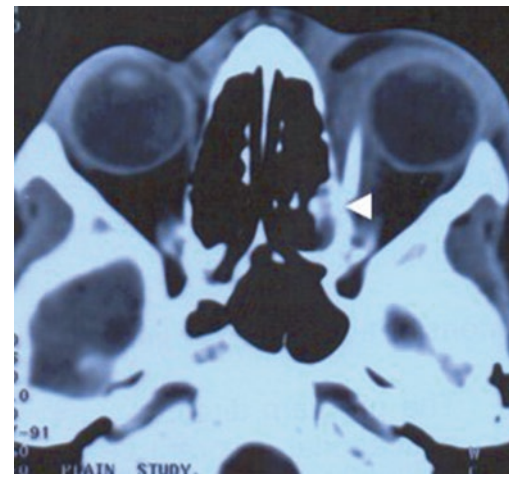

Fig. 12 Axial CT of a 7 years old child revealed presence of an elongated hyper-dense foreign body penetrating the medial rectus muscle and embedded in the left medial orbital wall (arrow) surrounded by soft tissue density in keeping small hemorrhage

of the foreign object in these cases. MRI is contraindicated wherever the type of foreign body is not known.

Management

All patients with acute orbital foreign objects should be started on antibiotics to prevent or to treat infection.

The decision to remove an orbital foreign body should be made on a case-to-case basis. It should take into account the type and location of the object, as well as associated morbidities. As a general rule, organic materials should always be removed due to the high risk of orbital infection and recurrent inflammation. Any foreign body, regardless of the material, should be removed if it causes strabismus, infection or inflammation.

A number of studies reported a relatively low risk with surgical removal of anteriorly located foreign bodies. In contrast, posterior foreign bodies and those in close proximity to vital structures such as the optic nerve can be left in place if they pose low risk to the patient. This is because to risk of surgical removal outweighs the benefit.

Traumatic Optic Neuropathy

Optic neuropathy may accompany orbital and head injuries. This is diagnosed by presence of decreased vision, afferent papillary defect with otherwise normal eye in a patient with trauma history. The cause of this problem is multifactorial including direct or indirect mechanisms.

Direct optic neuropathy results from compression along the course of the optic nerve by bone fragments (Fig. 13), retrobulbar or subperiosteal hematoma, and foreign body or by fractures that narrow the optic canal. Rarely, the optic nerve may be avulsed. When clinically suspected, CT evaluation of the orbit, optic canal and sinuses can identify the cause.

Indirect optic neuropathy is diagnosed when there are no radiologic findings of abnormalities

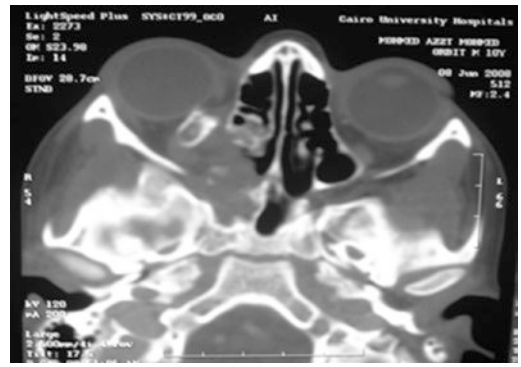

Fig. 13 A case of a 7y old child with trauma to the sinuses and fracture of the ethmoid and sphenoidal bones. There is a bony fragment that is pressing on the optic nerve

damaging the nerve. It may be caused by abrupt brain deceleration with forwards movement causing compression of the intracranial optic nerve. It can also be due to contusion and edema resulting from deformation of the optic canal. The small arterioles in the intracanalicular optic nerve my rupture leading to infarction or hematoma of the optic nerve or sheath. Edema and vasospasm are thought to cause nerve ischemia.

Patients may suffer from sudden complete loss of vision after trauma which is usually caused by actual tear or primary complete optic nerve necrosis. These patients have poor prognosis in spite of treatment. Other patients experience delayed visual loss (hours to days) or partial visual loss usually due to partial ischemic infarction or compression by edema or hemorrhage however, these patients have better prognosis.

Treatment remains controversial. High-dose corticosteroids are used in treating indirect optic neuropathy. Extracranial transethmoidal optic canal decompression is an alternative treatment especially if the vision drops while on steroid treatment. Direct optic neuropathies attributable to mechanical nerve compression usually require surgical treatment and removal of the offending factor such as repair of floor fracture, intracranial optic canal decompression, hematoma drainage and optic nerve sheath fenestration.

Management of Old Standing Orbital Trauma

The patient is evaluated in a manner similar to acute cases with more stress on the globe position, ocular motility, forced duction testing as well as diplopia fields. If globe reposition is indicated, it should be done before muscle or eyelid surgeries. Bony orbit may be restored by osteotomies and open reduction or volume augmentation by placing an implant in the subperiosteal space. Soft tissues incarcerated in the sinus should be carefully removed however, fibrosis render this step difficult with more possibility of tissue injury.

In cases with late enophthalmos, implantation of various materials in the subperiosteal space along the orbital floor can augment this area thus raising the globe and moving it anteriorly. Materials used for orbital floor fractures are used to correct globe malpositions though they should be thicker especially posteriorly. Also, soft tissue fillers have been tried to correct enophthalmos, They include autologous fat, cross linked collagen and self-inflating hydrogel pellets. Calcium hydroxyapatite gel as well as hyaluronic acid can be injected to augment the volume in eyes with mild enophthalmos and intact vision. Hyaluronic acid was described to be injected intraconal.

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Part VIII
The Socket

Evisceration

Mark R. Levine

The ideal socket is a centrally placed well covered implant of adequate size fabricated from an inert material. It should have deep unobstructed fornices with an inferior lid and fornix that can adequately support the prosthetic eye. The superior eyelid should be symmetrical with the normal eyelid and finally prosthetic movement should approach the normal side.

This criteria is most compatible with evisceration over enucleation when a globe needs to be removed. The advantages of evisceration over enucleation is a shorter operating time, minimal orbital disruption, and less conjunctival forniceal disruption. In cases of endophthalmitis evisceration avoids contamination of the orbit and subarachnoid space.

The disadvantage of evisceration is the risk of sympathetic ophthalmia, unexpected intraocular malignancy, and lack of organized pathology.

In a survey of members of the American Society of Ophthalmic Plastic and Reconstructive Surgery Society in 1999, enucleation out numbered evisceration by 72.3 to 27.7%. A lot of this was related to fear of sympathetic ophthalmia. I performed a chart review of evisceration patients operated on at University Hospitals of Cleveland and Mount Sinai Medical Center from 1980–1996 and showed in a series of 51 patients of 90 recalled, that there was no evidence of sympathetic ophthalmia following evisceration. The pendulum subsequently turned to favor evisceration over enucleation. It cannot be emphasized enough that if evisceration is to be performed on a blind painful eye, a B scan ultrasound must be performed to rule out an intraocular malignancy. In addition any history of uveal melanoma or other intraocular tumors should suggest enucleation over evisceration. Finally a severe phthisical eye may make evisceration difficult to perform.

Evisceration from a practical point of view makes sense. Easy to perform, minimal complications and provides good motility. It is a surgical procedure in which the entire contents of the globe are removed through a corneal, limbal or scleral incision. The extraocular muscles are not detached from the sclera, and the optic nerve and its surrounding meninges are left undisturbed. Although the cornea was traditionally always removed, most surgeons now preserve it. Unless the cornea is the seat of infection, the procedure is done through a large 270 degrees limbal incision. The corneal endothelium should be scrapped to transform the cornea into a tough scar that reduces the incidence of implant exposure. Expansion sclerotomies can still be performed and this eliminates the postoperative problems of potential corneal ulcerations and necrosis with prosthetic wear.

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_43

Although some surgeons still perform evisceration with the patient under general anesthesia, monitored attended local anesthesia is very effective. A retrobulbar block and frontal block anesthesia must be used for intraoperative and postoperative pain management due to postoperative discomfort and swelling. This consists of 2% Xylocaine with epinephrine and 0.75% Marcaine. If monitored attended local anesthesia is used, a regional facial nerve block is helpful in producing eyelid akinesia. Perioperative antibiotics is given when evisceration is performed for endophthalmitis. Appropriate microbiologic studies should be done prior to the surgery.

An eyelid speculum is placed between the eyelids. A 360 degree fornix based peritomy is performed 2 mm posterior to the limbus and dissected posteriorly back about 5 mm (Fig. 1). Hemostasis is maintained with bipolar cautery. The sclera is penetrated with a sharp knife at the surgical limbus into the anterior chamber (Fig. 2). A corneal scleral scissors is used to perform the incision or the keratectomy. An evisceration spoon or periosteal elevator is introduced into the suprachoroidal space at the scleral spur and disinsert it. The uvea is elevated away from the overlying sclera for 360 degrees

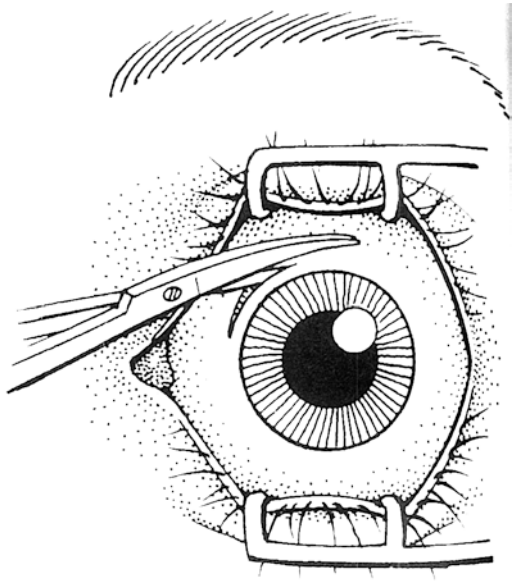

Fig. 1 Peritomy

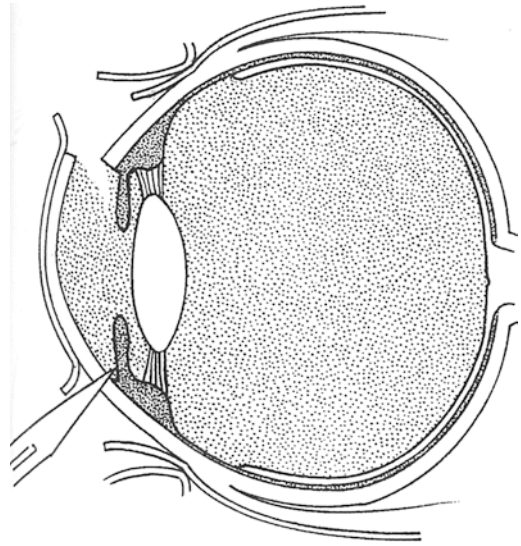

Fig. 2 Entering the anterior chamber

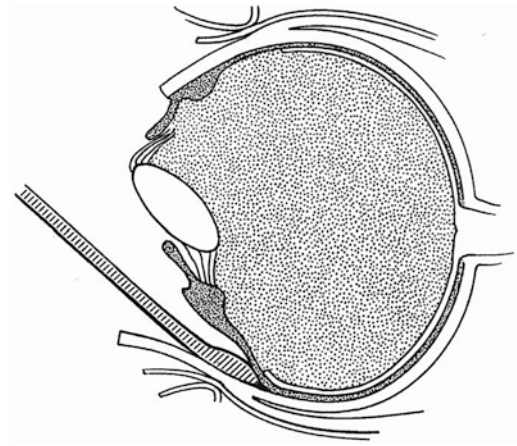

Fig. 3 Evisceration spoon into suprachoroidal space

(Fig. 3). As the dissection proceeds posteriorly to the optic nerve bleeding increases because the vortex veins and the central retinal artery are severed. Once this dissection is completed, the entire content of the globe is scooped out. All specimens are submitted to pathology. Bleeding is controlled with bipolar cautery.

Once the bleeding is controlled, the scleral pouch is irrigated with half strength peroxide. This process has a hemostatic affect and loosens

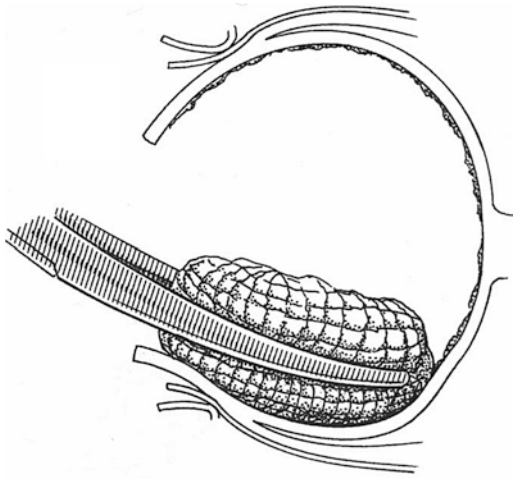

Fig. 4 Uvea removed with peanut dissector

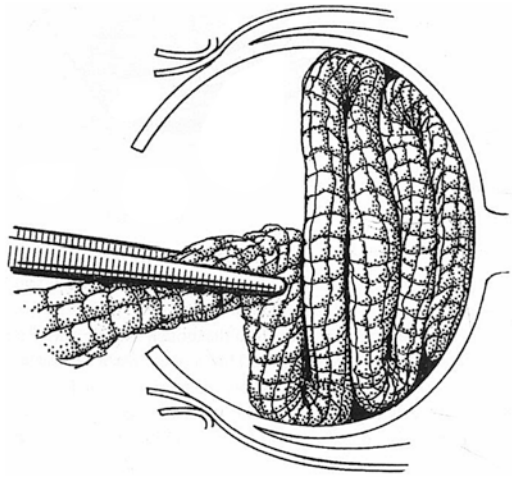

Fig. 5 Scleral shell packed with iodoform gauze

uveal tissue from the scleral pouch and destroys any residual uveal pigments. Residual uveal tissue is removed from the inner surface of the sclera with a cotton tipped applicator or a peanut dissector (Fig. 4) The wound is irrigated with an antibiotic solution if infected, based on prior cultures and sensitivity.

In the case of evisceration with endophthalmitis delayed primary closure is the procedure of choice to insure no infection persists prior to implant placement. The scleral shell is packed snugly with a long folded piece of iodoform

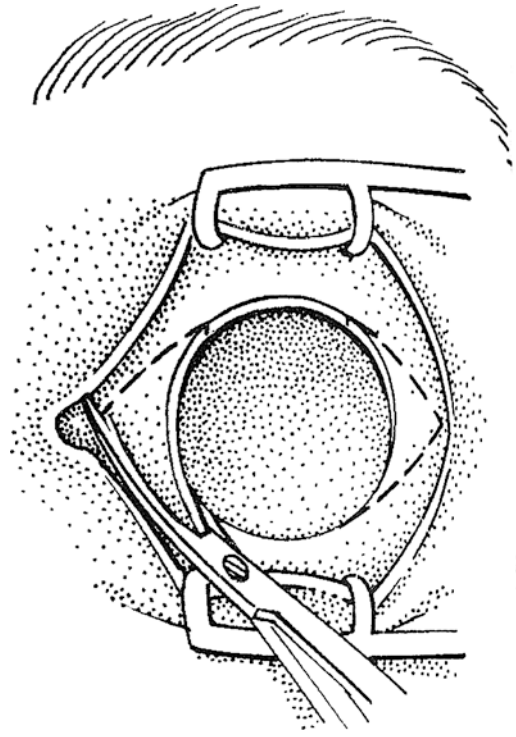

Fig. 6 Scleral triangles excised at 3 and 9 o'clock positions

gauze soaked in antibiotic solution (Fig. 5). A pressure patch is applied. Intravenous antibiotics are continued based on previous culture and sensitivities. Dressing changes are started on the first postoperative day twice a day with gentle repacking with antibiotic impregnated gauze until the wound looks clean which should be around 3–5 days.

At the time of delayed primary closure, it is necessary to enlarge the wound slightly so that the proper scleral implant can be placed. The packing is removed from the wound and small triangles of sclera removed with scissors at the 3 and 9 o'clock positions (Fig. 6). A 14–16 mm solid silicone or methyl methacrylate sphere is placed in the scleral shell (Fig. 7a).

If the cornea was preserved, the incision is closed with 6-0 polyglactin (Vicryl). If the cornea was removed, the sclera is draped over the implant and sutured with interrupted 5-0 polyglactin(Vicryl) (Fig. 7b). Alternately a horizontal mattress suture technique can be used.

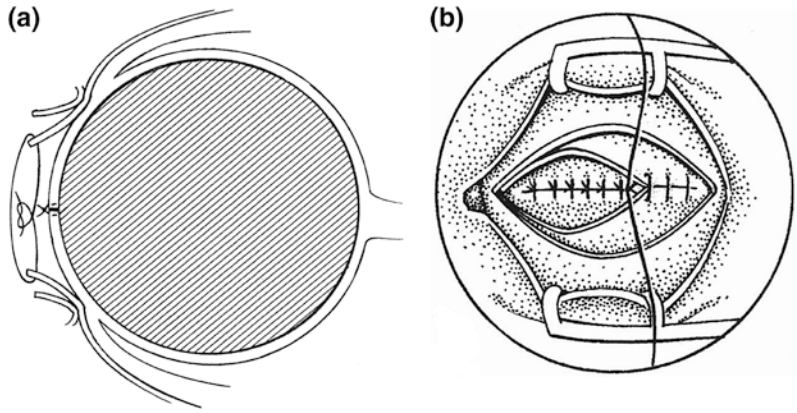

Fig. 7 **a** and **b** Sphere placed in scleral pouch and sutured without tension

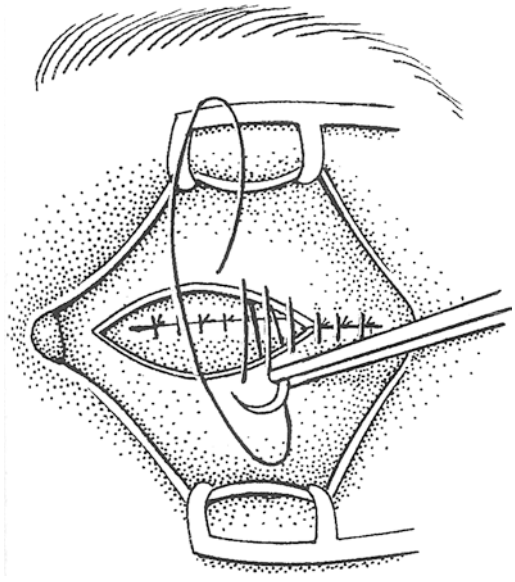

Fig. 8 Closure of sclera and conjunctiva

If the scleral wound is closed under tension extrusion is likely, therefore expansion sclerotomies may be necessary. The conjunctiva and Tenon's capsule should not be incorporated in the scleral closure. Instead Tenon's fascia is closed with interrupted sutures of 6-0 Vicryl with the knots buried. The conjunctiva is closed with a running locking suture of 6-0 plain catgut or Vicryl, taking bites into the underlying Tenon's and cornea to eliminate any potential space between the layers (Fig. 8). Intravenous antibiotics maybe discontinued.

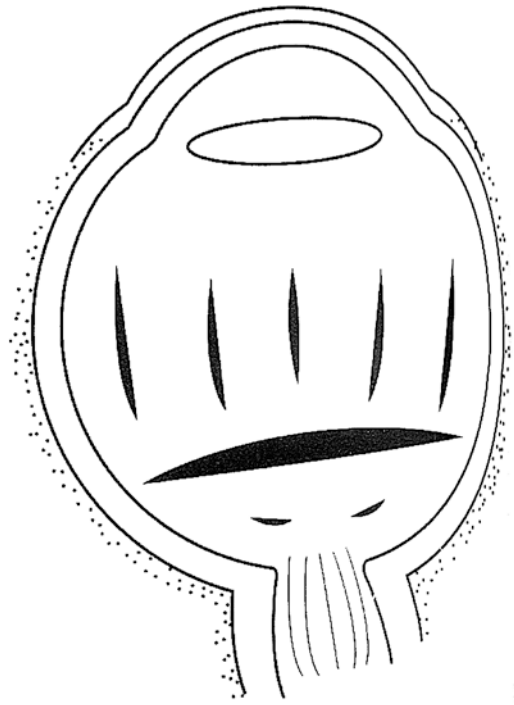

Fig. 9 Evisceration showing expansion sclerotomies

As mentioned, wound closure under tension can result in implant extrusion. In these situations, a smaller implant may be placed or preferably the scleral pouch may be enlarged with expansion sclerotomies. First however, any kind of scleral encircling band and external sponges should be removed to allow for scleral

expansion. The sclerotomies may be made vertically or horizontally in the equatorial portion of the sclera (Fig. 9). This may be combined with removal of the sclera where the optic nerve enters the eye. These relaxing incisions allow more sclera volume to house a larger implant and also encourage vascularization of porous implants if placed. Porous implants should not be used with any evidence of infection in the scleral pouch.

In the event that expansions cannot house an adequate implant, the posterior sclera can be totally transected and an alloplastic sphere placed in the intraconal space. The posterior sclera is closed with 6/0 Vicryl, and the anterior scleral is then closed with 6/0 Vicryl taking bites of posterior sclera to collapse it down and provide another barrier for extrusion. The conjunctiva and Tenon's fascia are closed in one layer with 6/0 Vicryl. A small conformer is placed in the cul de sac, and lateral sutural tarsorrhaphies are performed with 6/0 silk. and a pressure patch applied for five uninterrupted days because of postoperative pain and swelling which will be considerably reduced. Remember that a large of conformer may cause tension on the wound closure and possible wound disruption. The suture tarsorrhapies are removed on day five, antibiotic ointment with out steroids applied, the conformer reinserted and a light pressure dressing applied. A short course of systemic steroids prednisone 10 mg twice a day for five days is most helpful in reducing swelling.

In case of the occasional wound disruption with implant exposure, the patient is taken back to surgery and either a smaller implant placed or expansion sclerotomies performed if not previously done. The goal is to remove all tension off the scleral suture line with meticulous closure. There is no reason to use porous implants with evisceration surgery as motility is excellent and peg implant surgery may be problematic in the short or long term. A prosthetic eye is fit in 6–8 weeks depending upon swelling.

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Enucleation

Shadi Alikhani Davis and Charles B. Slonim

Surgeons performing enucleation must take into account movement of the prosthesis after surgery and the potential postoperative complications such as implant extrusion or socket contraction. Optimal cosmetic results are generally achieved in collaboration with an ocularist. The techniques presented in this chapter are designed to result in a good cosmetic appearance, as well as minimize such postoperative complications.

Preferably, in an anophthalmic socket, the implant should be centrally positioned and buried well beneath extraocular muscles, Tenon's capsule and conjunctiva. The implant may be made up of inert porous or non-porous material. Furthermore, the implant size must be chosen appropriately. Conjunctival fornices should be adequately deep and the lower lid and cul-de-sac must be able to support the weight of the future prosthesis. The upper lid, lashes, and eyelid crease as well as the anterior axial plane of the socket should be similar to the fellow eye.

Different types of implants have been developed since the 1940s to fill the orbital volume after enucleation. The implants with irregular surfaces (e.g., protrusions) for attaching the muscles tend to have a higher extrusion rate than spheres. Although some surgeons believe that these types of implants achieve better movement, most ophthalmologists attain satisfactory movement of the prosthesis using time-honored spherical implants. To decrease the extrusion rate, some surgeons use dermis fat grafts to fill the orbit at the time of enucleation. However, since synthetic spheres have a very low extrusion rate if placed properly into the muscle cone, the additional surgery to obtain the dermis fat graft seems unnecessary.

Implant Size

The optimal size of the chosen sphere should be such that when it is placed within the orbit, the muscles can be tied over the implant without any tension. After placement into the orbit, if the implant appears to rise out of the orbit such that it must be held down by tying the muscles firmly, it is either too big or there is significant orbital pressure because of swelling or hemorrhage. In our experience, an 18–20 mm

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E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_44

Table 1 Preoperative scan values

Globe size	Enucleation (mm)	Evisceration (mm)
AL < 24 mm (hyperopes)	AL-3	AL-4
AL > 24 mm (emmetropes, myopes)	AL-2	AL-3
Children	AL-2	AL-3

AL—axial length

non-porous sphere is the most common size for most adults.

To avoid enophthalmos or distortion of the superior sulcus, most recent oculoplastic literature has focused on replacing optimal orbital volume after enucleation or evisceration. Research by Kaltreider et al. suggested the use of A-scan ultrasonography of the fellow healthy eye to provide a tool for correct orbital implant size to replace 80% of the volume removed at enucleation.

Additional studies have revealed that restoring the appropriate orbital volume should not depend on the ocular prosthesis. Instead, the focus should be on the placement of the appropriate size orbital implant. To assess the optimal orbital implant size, an algorithm was developed to assess the optimal orbital implant size when performing a preoperative A-scan of the fellow eye (Table 1). This method allows a gap in the anterior socket for an ocular prosthetic volume of 2 mL when the orbital implant is placed deep in the intraconal space.

As seen in Table 1, the algorithm divides the preoperative A-scan values into hyperopes and emmetropes/myopes for final orbital implant size calculations. The algorithm can be used to preoperatively calculate the proper orbital implant size for both adults and children undergoing enucleation or evisceration procedures.

Custer et al. have focused on the volumetric determination of enucleation implant size. Accordingly, the volume of implant used should be equal to the volume of the enucleated eye (predisease, if phthisical) minus the volume of the prosthesis. Therefore, if the prosthesis size is 2.5 mL (with spherical diameter of 21 mm) and the volume of an eye is 7.2 mL (with an axial length of 24 mm), then the implant volume should be 4.7 mL (see mathematical illustration below). Table 2 demonstrates calculated orbital implant sizes for different globe volumes and axial lengths.

Globe volume - Prosthesis volume = Implant volume

7.2 mL - 2.5 mL = 4.7 mL

Volume of Sphere = $4/3\ \pi r^3$

$4/3\ (3.14)\ (1.05\text{cm})^3 \approx 4.7\text{mL}$

Note: A scleral wrap adds approximately 1.5 mm to the diameter of the implant.

Table 2 Calculating implant size

Natural eye diameter (mm)	Natural eye volume (mL)	Prosthetic Eye volume (mL)	Implant volume required (mL)	Implant diameter required (mm) unwrapped
20.0	4.19	2.5	1.69	15.0
20.5	4.51	2.5	2.01	15.5
21.0	4.85	2.5	2.35	16.5
21.5	5.21	2.5	2.71	17.5
22.0	5.58	2.5	3.08	18.0
22.5	5.97	2.5	3.47	19.0
23.0	6.37	2.5	3.87	19.5
23.5	6.80	2.5	4.30	20.0
24.0	7.24	2.5	4.74	21.0
24.5	7.70	2.5	5.20	21.5
25.0	8.18	2.5	5.68	22.0
25.5	8.69	2.5	6.19	23.0

Enucleation with a Non-porous Implant

The eye that is going to be enucleated must be clearly marked before the administration of anesthesia. This can be done by the surgeon and/or the patient before being transported to the operating room. Usually general anesthesia is administered, but retrobulbar or peribulbar injections under monitored anesthesia care may also be given. Once in the operating room, the patient is prepped and draped in the usual sterile fashion for ophthalmic surgery. One or both eyes can be prepped and exposed in the sterile field, in which case, the surgeon should re-examine both eyes prior to start of the procedure to ensure that the correct eye is enucleated. It is helpful not to administer any ointment in the fellow eye so that patient can see as clearly as possible while recovering from anesthesia.

An eyelid speculum or sutures may be used to retract the eyelids away from the globe. To maintain adequate fornix depth and conserve as much conjunctiva as possible, a peritomy is made 360 degrees at the limbus. In cases of ocular malignancy (e.g., ciliary body melanoma with possible scleral extension), peritomy must be started posterior to the tumor or area of discernible extrascleral extension. This would help prevent retaining any malignant cells in the orbit. This may compromise the vertical or horizontal dimensions of the conjunctiva for final wound closure which could affect the fornices, but this risk is offset by the benefit of tumor elimination at the time of surgery.

The globe is bluntly dissected from Tenon's capsule (Fig. 2). Despite, being separated from the globe, Tenon's capsule's attachments to the rectus muscles are not disturbed. Using a muscle hook, the rectus muscles are isolated one at a time. While gentle anterior traction is placed on the muscle hook, a second muscle hook is inserted under the muscle and is gently pushed posteriorly as far as possible. This maneuver can neatly separate the muscles from the adjacent tissues and isolate it for further manipulation. A double-armed Vicryl® suture is then placed through the muscle in a locking fashion 2 mm posterior to muscle insertion into the globe.

Using scissors, the isolated muscle is disinserted anterior to the suture and the double-armed suture is gently pulled to retract the detached rectus muscle away from the globe but still maintaining their appropriate orientation (Fig. 1). This is performed for all 4 rectus muscles.

Next, the oblique muscles are isolated in the same manner described earlier using 2 muscle hooks. Inferior oblique muscle can be located by passing the muscle hook in a posteroinferior

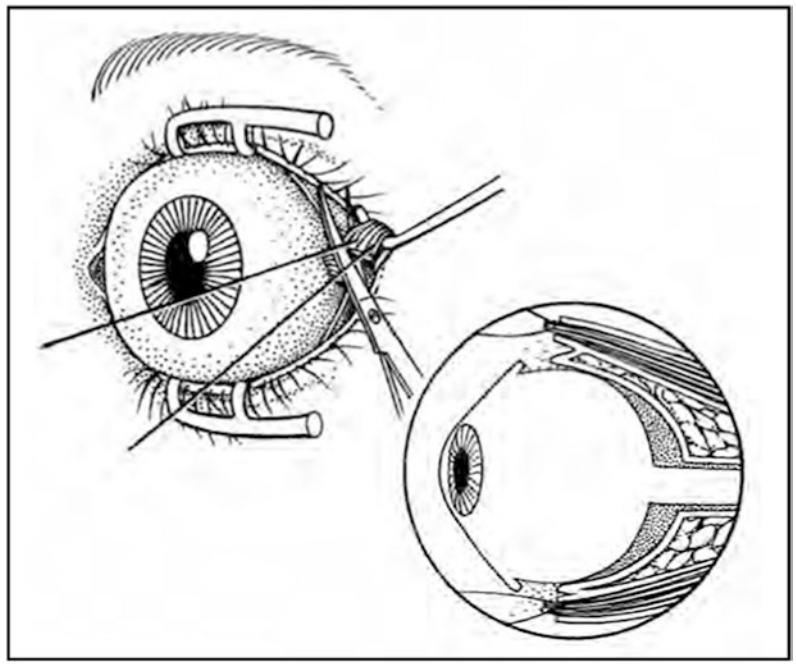

Fig. 1 Isolation and disinsertion of rectus muscle

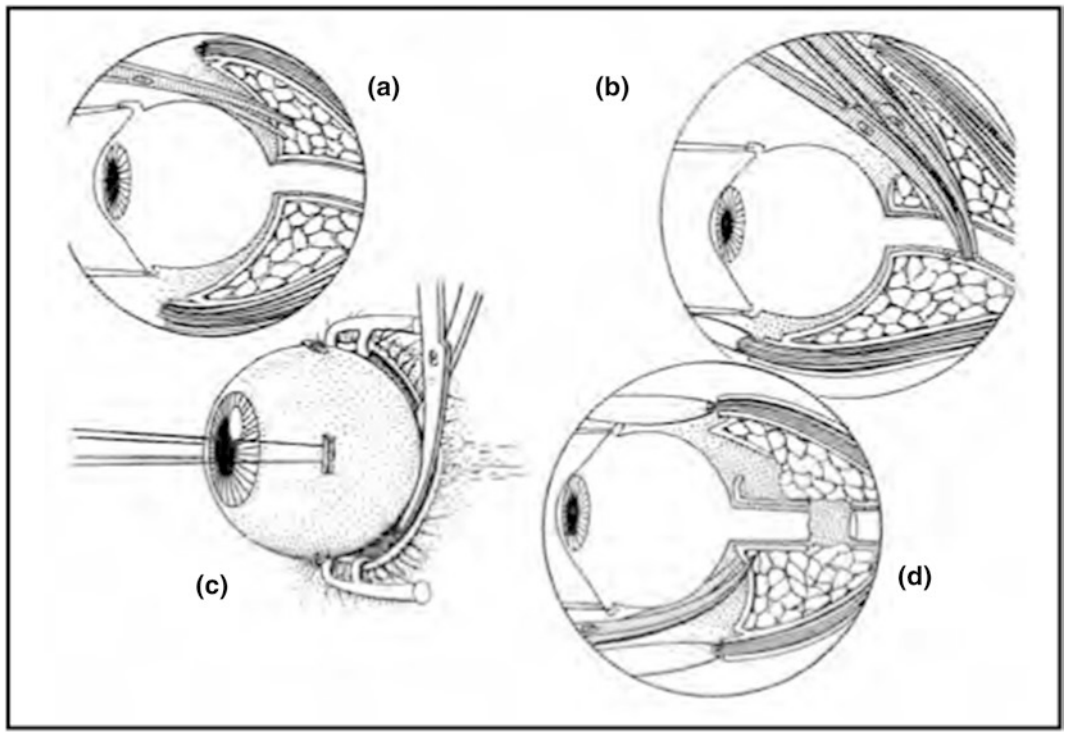

Fig. 2 **a** Anterior traction of globe. **b** Clamping the optic nerve. **c** Cutting the optic nerve. **d** Removal of enucleated globe

direction. The superior oblique tendon can be located by passing the muscle hook in the superonasal direction close to the surface of the globe. The oblique muscles are cauterized in the area they will be cut to prevent excess bleeding and then they are cut and freed to retract.

Two 4-0 silk sutures are then passed through the stumps of the medial and lateral rectus muscles to provide traction anteriorly at the time of globe removal. However, traction sutures should be placed at stumps of superior and inferior rectus muscles instead, if an intraocular malignancy is located near either medial or lateral rectus muscles.

After detaching all extraocular muscles from the globe, a muscle hook can be used to bluntly separate the sclera anteriorly and posteriorly to ensure that all Tenon's capsule attachments to the globe have been broken.

To isolate the optic nerve, a curved or right-angled hemostat is extended posterior to the globe and the optic nerve is identified by touching its superior and inferior borders with the tip of the hemostat. While placing anterior traction on the 4-0 silk traction sutures, the clamp is advanced along the medial or lateral orbital wall and closed over the nerve and its vessels roughly 3–10 mm posterior to the globe. In performing the lateral approach, it is important to proceed with caution to avoid penetrating the very thin medial orbital wall with the tip of the clamp. The clamp is left closed over the nerve for 5 min. Moving the hemostat while it is clamped around the optic nerve and watching the globe move in the appropriate direction (Fig. 2a, b) will assure the surgeon of its proper placement.

After 5 min, the clamp is removed and curved enucleation scissors are then placed such that they will cut the optic nerve and its associated vessels slightly anterior to the previously crushed area (Fig. 2c, d). Anterior traction is applied to the globe before cutting the nerve by softly pulling on the pre-placed traction sutures of the horizontal muscle stumps. The nerve is then cut and the globe is removed. Any remaining globe attachments that were not previously removed can be detached at this time.

Different sizes of stainless steel sizing spheres that have previously been bathed in iced sterile saline are alternately positioned in the socket. This promotes vasoconstriction and at the same time will help establish the appropriate size of the implant to restore the orbital volume. While being held in the socket, modest pressure should be applied to the sizing sphere for several minutes. Sizing spheres should be exchanged with a freshly iced one as often as possible. If bleeding persists, a clamp with a small piece of gauze can be inserted into the socket to facilitate vasoconstriction by tamponade. Careful hemostasis must be achieved before the implant is inserted. Monopolar or bipolar cautery may be used. Care must be taken when applying aggressive monopolar (e.g., Bovie) cautery deep in the socket to avoid damaging intraconal nerves to the rectus muscles or shrinking excessive orbital fat.

After obtaining hemostasis, 2 mL of a long-acting anesthetic (e.g., bupivacaine, mepivacaine, etc) are injected intraconally for postop analgesia. The anesthetic can be dispersed throughout the retrobulbar tissues using the implant sizing spheres.

Once the appropriate size of implant has been chosen, a non-porous methylmethacrylate or silicone sphere is then placed within the socket. Orbital fat should be seen through the posterior opening in Tenon's capsule. The implant is then placed through this opening and into the orbital fat (Fig. 3a). Using a running 5-0 Vicryl suture, the posterior layer of Tenon's capsule from around the optic nerve is sutured over the implant (Fig. 3b).

Using the previously placed 5-0 Vicryl suture, the superior rectus muscle is then tied to the inferior rectus muscle in front of the sphere, and the lateral rectus muscle is advanced and attached to the medial rectus muscle. Since horizontal movement is more important to the patient for postop cosmesis, the horizontal muscles are placed anterior to the vertical rectus muscles, which puts them in closer contact with the conjunctiva. If the superior rectus is advanced too far inferiorly, ptosis may occur (Fig. 4).

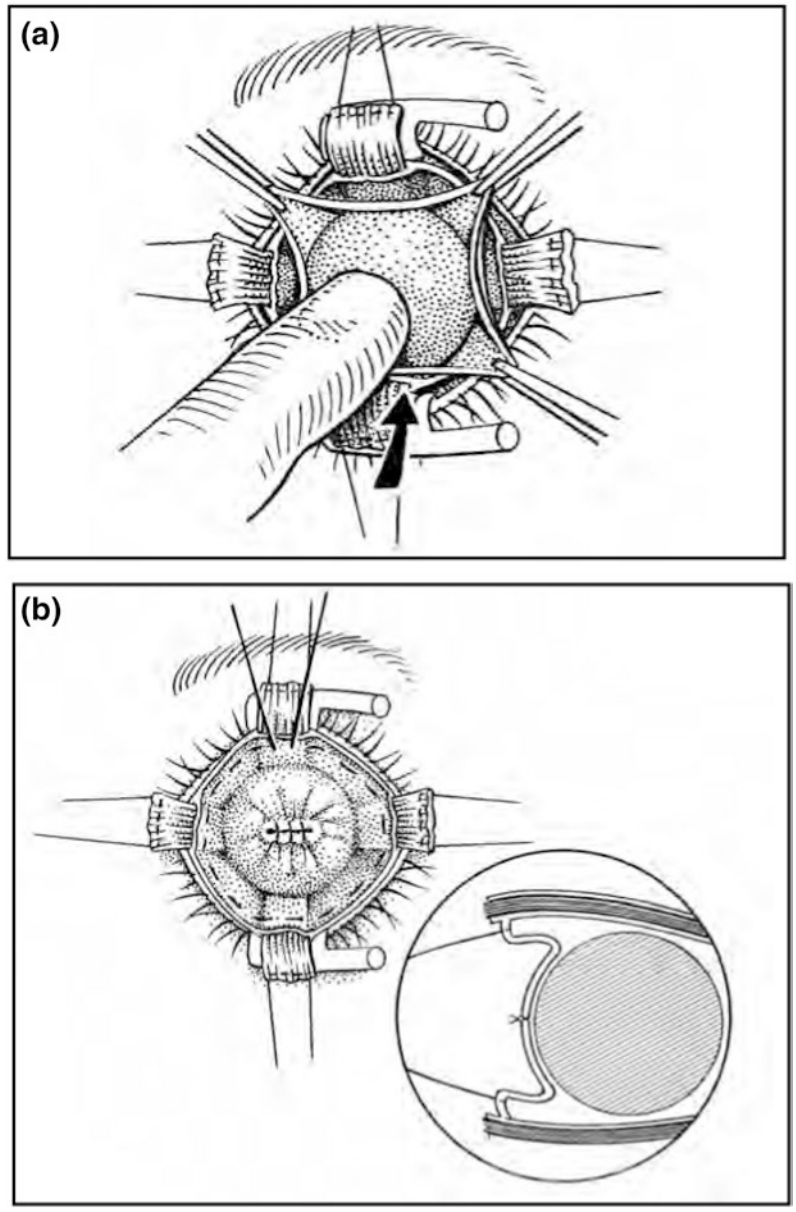

Fig. 3 **a** Inserting non-porous implant behind posterior Tenon's capsule. **b** Closing posterior Tenon's capsule over implant

The anterior aspect of Tenon's capsule is closed with a running 5-0 Vicryl suture in 1 or 2 layers, and the conjunctiva is closed with a running 6-0 plain gut or chromic suture (Fig. 5), preferably in a parallel line to the Tenon's closure

Once the conjunctiva is closed, an ophthalmic antibiotic ointment is administered into the socket and an appropriate size conformer is placed into the fornices. The size of the conformer should permit complete eyelid closure with no tension on the fornices. This approach minimizes any pressure from the conformer onto the conjunctival wound or the closure of Tenon's capsule. The conformer should be transparent and can have holes (optional) at least 2 mm in size to allow for the egress of fluid. In the

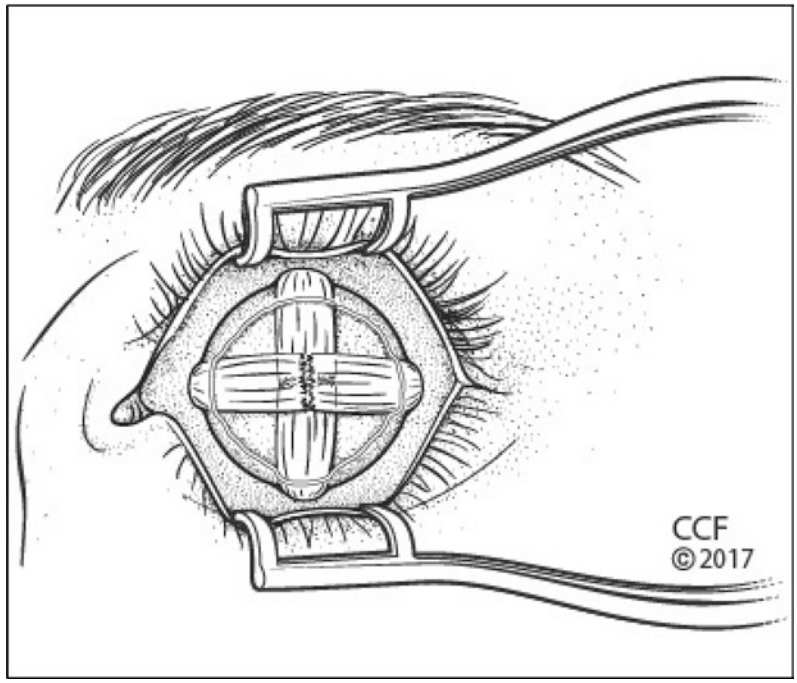

Fig. 4 Tying vertical and horizontal muscles over posterior Tenon's capsule closure

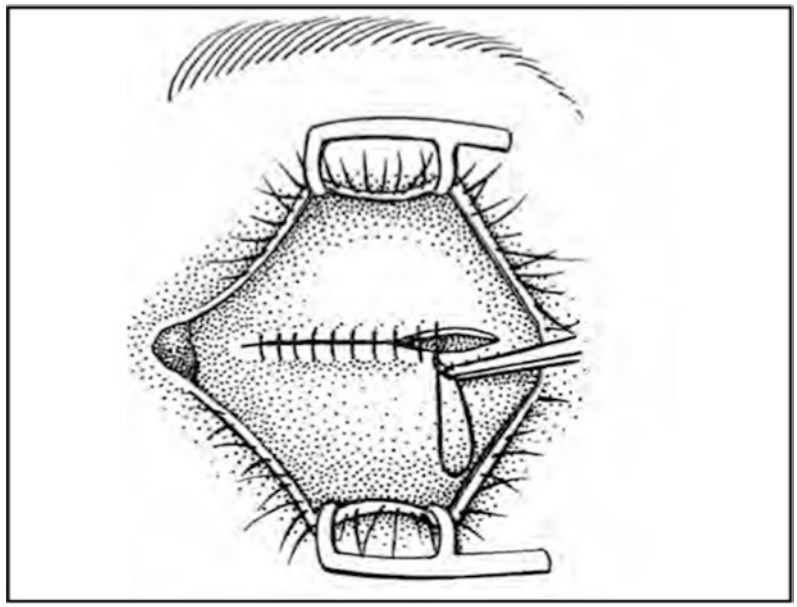

Fig. 5 Closing anterior Tenon's capsule and conjunctiva over rectus muscles

postoperative period, the surgeon can then examine the socket without removing the conformer.

The eye is then pressure patched with 2 eye pads. Unless there is some clinical reason to leave the dressing on longer, the patient can change the dressing on the first postoperative day. The patient should apply iced compresses on the second and third postop days followed

by warm compresses until the eyelid bruising is resolved.

Generally, the ophthalmic antibiotic ointment is continued for 7–10 days. The patient is examined periodically for 3–4 weeks (e.g., 1 week and 3 weeks postop). After this period and if the socket inflammation and swelling have resolved, the patient can be sent to the ocularist for fitting of an ocular prosthesis.

Complications of Surgery with Non-porous Implants

Implant migration is the main complication associated with using a non-porous implant in enucleation surgery. The ocularist may have difficulty fitting the prosthesis if the implant shifts internally and is no longer centrally located in the muscle cone. Typically, the implant tends to migrate inferotemporally or superotemporally. Furthermore, the implant can migrate anteriorly because of substandard suturing techniques or poor wound healing, which may result in a thinly covered sphere that becomes clearly visible under the thin conjunctival surface. Removal and replacement of these implants may be necessary to allow the prosthesis to fit properly. Some surgeons advocate wrapping the second implant with sclera or fascia to prevent a subsequent extrusion. Dermis-fat grafts can also be used in place of a second implant.

Orbital fat necrosis can cause progressive orbital volume loss and lead to enophthalmos and secondary ptosis and/or lower eyelid entropion. This may require replacing the implant with one of a larger size or inserting volume enhancing implants (e.g., porous polyethylene [PPE] enophthalmos wedge [MEDPOR®, Stryker Corp., Kalamazoo, MI]) or a dermis-fat graft to replace the lost volume.

Enucleation with a Hydroxyapatite Orbital Implant

Since the hydroxyapatite (HA) orbital implant was approved by the FDA in 1989, it has gained popularity as an alternative option to the conventional non-porous (e.g., methylmethacrylate, silicone, etc.) sphere implant. Currently, hydroxyapatite is a widely used orbital implant, with different varieties including Bioeye® (Integrated Orbital Implants, San Diego, CA), Molteno M-Sphere® (Molteno Ophthalmic Limited, Dunedin, New Zealand), and the Bioceramic synthetic hydroxyapatite orbital implant (FCI Ophthalmics, Pembroke, MA). Moreover, the synthetic coralline-derived hydroxyapatite sphere is a porous integratable implant that offers improved motility with decreased migration and extrusion rates.

The porous hydroxyapatite implant is derived from the skeletal structure of a specific marine reef-building coral. Hydroxyapatite is composed of interconnecting pores of approximately 500 μm in diameter. Once implanted into the orbit, the interconnecting pores provide a framework for fibrovascular ingrowth, which is important for improved motility, decreased migration and extrusion rates, and possibly decreased infection rates (Fig. 6).

A major disadvantage of the hydroxyapatite implant in today's medical economic setting is the increased cost of the procedure due to the cost of the implant. Other porous implants include porous polyethylene (MEDPOR) (see later) and bioceramic orbital implants.

Generally, adult patients have sockets that can be successfully fit with a 20-mm hydroxyapatite sphere, while children may be best fit with a 16- or 18-mm sphere. Hydroxyapatite implants can be further prepared by wrapping the sphere with a fresh or banked scleral shell, Ocu-Guard (Synovis Surgical Innovations, St. Paul, MN), Vicryl mesh, or autogenous fascia lata. Soaking the wrapped implant in antibiotics and/or povidone iodine prior to insertion adds an additional level of antimicrobial protection. Like donor corneal tissue, the banked scleral tissue is screened for pathogenic antigens using a national protocol.

The surgical steps to detach the globe from Tenon's capsule and extraocular muscles as well as transection of the optic nerve and ultimate enucleation of the globe are carried out the same way as described above. The hydroxyapatite sphere is placed into a 60 mL syringe that contains 20–30 mL of saline and 2 mL of an

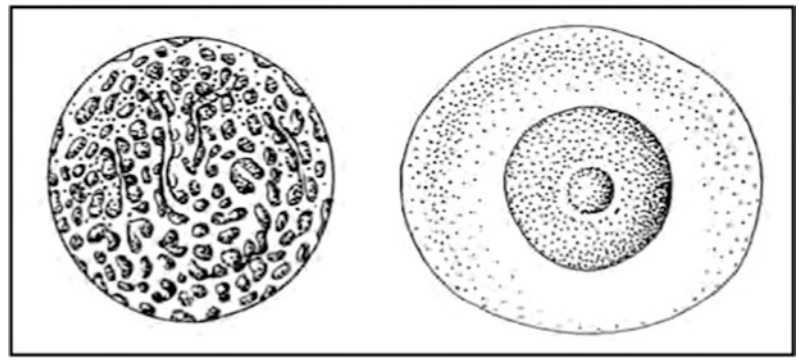

Fig. 6 Porous hydroxyapatite orbital implant

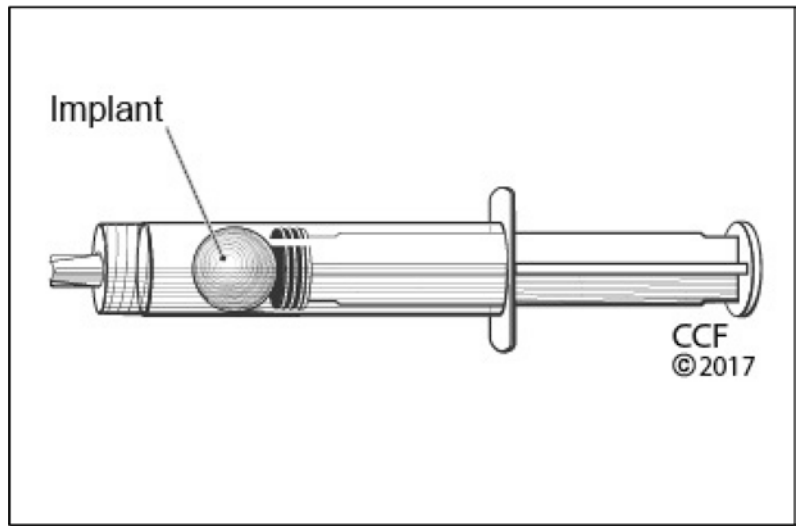

Fig. 7 Impregnating orbital implant with antibiotic

injectable antibiotic (e.g., 2 mL of gentamicin injectable solution [40 mg/mL]). The saline/antibiotic mixture is forced into the porous implant by either a positive pressure maneuver (ie, pressing on the syringe plunger while occluding the tip) or a negative pressure maneuver (ie, pulling and shaking on the syringe plunger while occluding the tip after removing all air from the syringe) (Fig. 7).

Once the implant has been impregnated with the antibiotic solution, the scleral shell is sutured around the hydroxyapatite implant with a running 5-0 Vicryl suture. Four rectangular windows (approximately 6 mm × 4 mm) 90 degrees apart are then excised in the scleral tissue anteriorly for attachment to the rectus muscles and the egress of blood vessels into the porous implant (Fig. 8). These scleral windows are initially pierced with a scalpel and then Westcott scissors are used to extend the incisions into a rectangular shape. A circular opening (approximately 10–12 mm in diameter) is also formed in the posterior aspect of the implant. Drilling 1-mm diameter holes through the implant windows into the core of the hydroxyapatite implant is advocated by some surgeons to stimulate more rapid vascularization. However, this can cause "blind ends" throughout the porosity of the implant in the areas of the contiguous channels and pores.

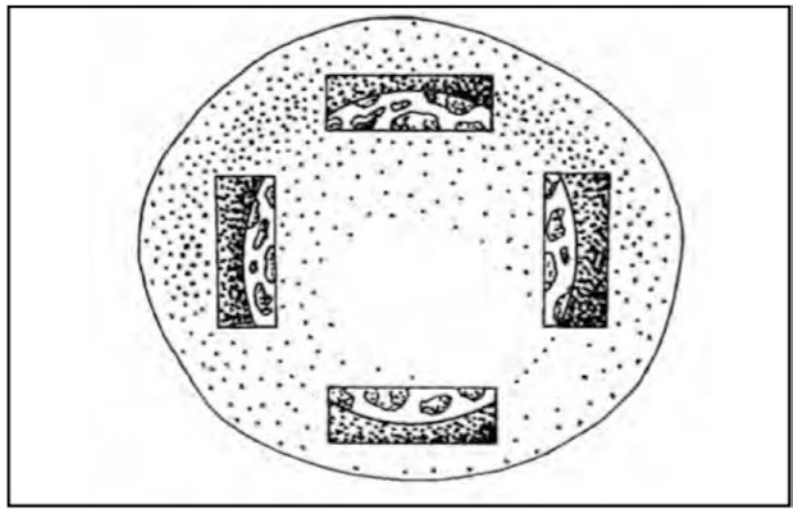

Fig. 8 Windows in a scleral wrapping for attachment of rectus muscles

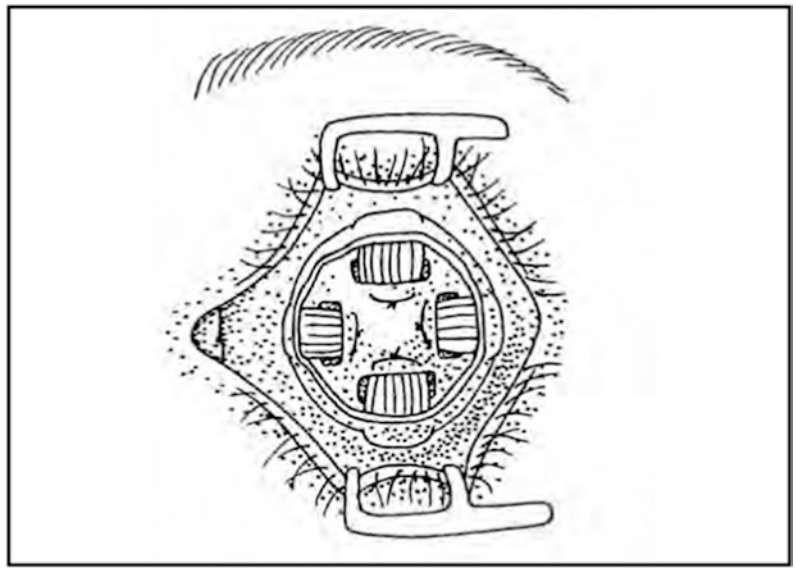

Fig. 9 Rectus muscles attached to scleral wrapping

The sclera-wrapped hydroxyapatite implant is inserted into the orbit in the same manner as a silicone or acrylic sphere. The rectus muscles are attached to the anterior rim of the rectangular scleral windows via the preplaced double-armed 5-0 Vicryl sutures (Fig. 9).

Anterior Tenon's capsule is closed using 5-0 Vicryl sutures and the conjunctiva is closed with a running 6-0 plain gut or chromic suture. A conformer is then inserted, antibiotic ointment is administered, and a pressure dressing is placed, which is typically worn for 1–2 days (same as with non-porous implants).

Enucleation with Porous Polyethylene Implants

Porous polyethylene (PPE) is an inert, white, ultra-high-density material used as an alloplastic implant in humans since the 1940s. In the early 1990s, synthetic porous polyethylene (Medpor®, Stryker Corp., Portage, MI) implants first became accessible for use in the orbit and since then have been widely accepted as an alternative implant to the HA. They have pores similar to HA implants, but they are less uniform in size and more irregular in shape.

Porous polyethylene implants are normally well tolerated in the orbital soft tissue. They are easier to implant because they have a smoother surface than HA implants, and potentially cause less irritation of the overlying conjunctiva following placement. These implants have a high tensile strength, yet they are malleable. This allows easy sculpting of the anterior surface of the implant. They may be used with or without a wrapping material. Additionally, the extraocular muscles can be sutured directly onto the implant; however, most surgeons find this difficult without predrilled holes. Porous polyethylene implants are available in spherical, egg, conical, and mounded shapes.

Enucleation steps are carried out in the same manner as described above.

The PPE implant is prepared in the same manner as a hydroxyapatite one (Fig. 7).

After the porous polyethylene implant is impregnated with the antibiotic solution, it is inserted into the orbit using the accompanying implant inserter. The inserter is placed deep into the orbit behind posterior Tenon's and held in place with one hand while the implant is pushed into the posterior orbit through the inserter. As the implant is pushed into the orbit, the inserter is slowly withdrawn. It is important to ensure that the anterior face of the implant, which contains the positioning holes and predrilled suture tunnels, remains anteriorly once the inserter is finally removed. This requires a slight manipulation with the fingertip as the implant is being pushed posteriorly into the orbit.

The 4 rectus muscles are attached to the anterior surface of the porous polyethylene implant through the factory-created positioning holes and tunnels using the preplaced double-armed 6-0 Vicryl sutures, (Fig. 10a, b). Once the sutures have gone through the respective tunnels, each rectus muscle is brought to the center of the anterior surface of the implant and the knot is secured. For additional security of the insertion of the rectus muscles, each of the 2 suture needles can be passed posterior-to-anterior through the muscle insertion at their respective edges and then tied securely to the anterior surface of the implant (Fig. 11).

The procedure is then completed as described earlier

Complications of Surgery with Porous Implants

It is rare for porous implants to migrate because of the muscle attachments directly to the implant or wrapping. The most common complication is exposure of the anterior surface of the implant. Since there is no immediate vascular bed below the anterior layers of conjunctiva and Tenon's capsule, the anterior lamellar tissues rely heavily on the peripheral blood supplies to these tissues.

Imperfect suturing techniques, lack of multilayer closures, or poor wound healing in the background of no vascular supply to assist in the healing process may result in a thinly covered porous implant. Exposure of a porous implant necessitates immediate correction. Techniques to cover an exposed porous implant vary. The conjunctiva/Tenon's capsule routinely retracts over the area of exposure. Depending on the size of the exposed area, there will likely be a shortage of anterior lamella to cover it.

If the area of tissue breakdown is small, it may revascularize spontaneously. To facilitate reepithelialization, the prosthesis or conformer maybe modified (vaulted) to have greater amount of posterior curvature to prevent chronic rubbing of the prosthesis against a thinned anterior lamella or the exposed area. Large defects

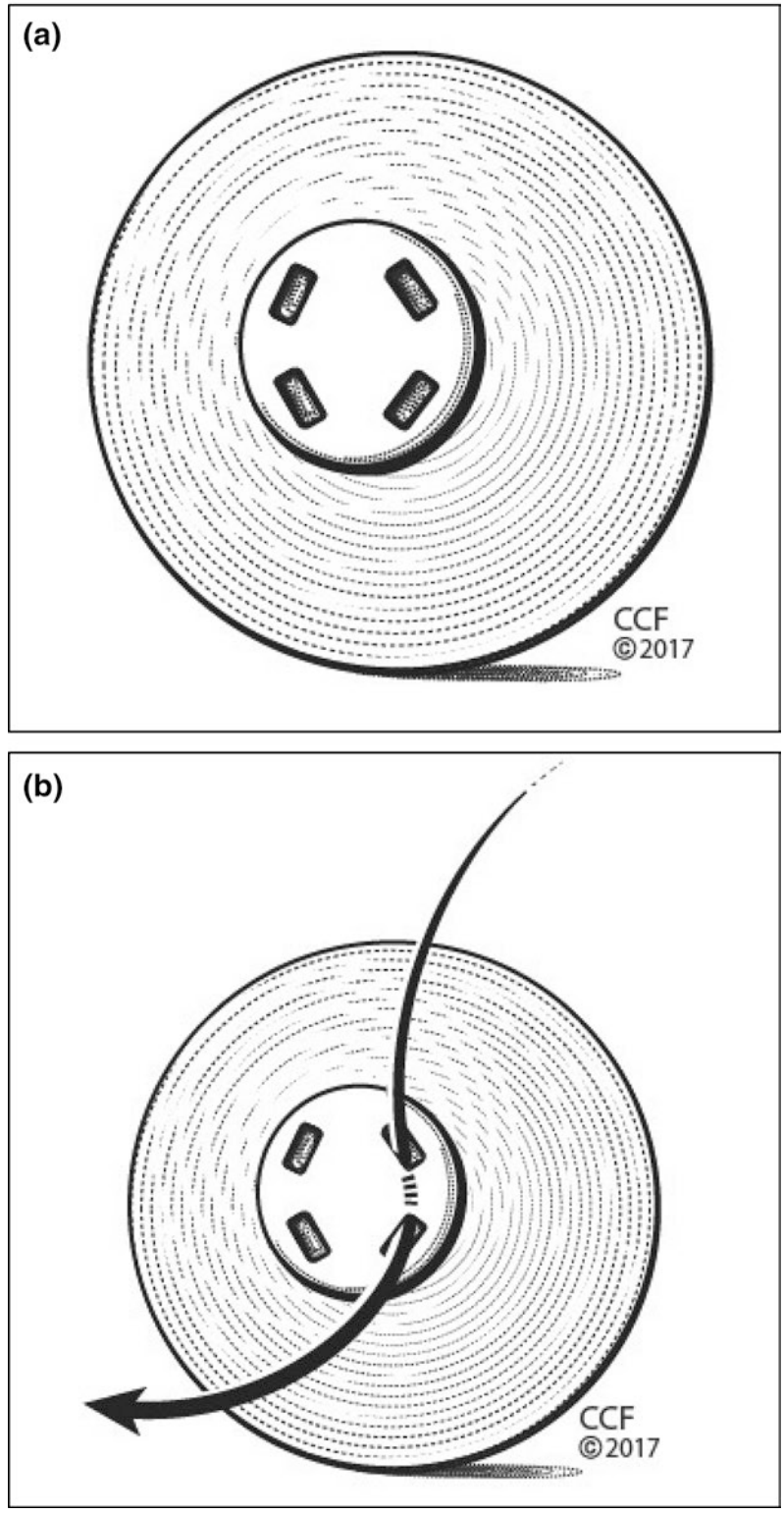

Fig. 10 **a** Porous polyethylene implant with pre-drilled suture tunnels and holes. **b** passage of suture through pre-drilled tunnel

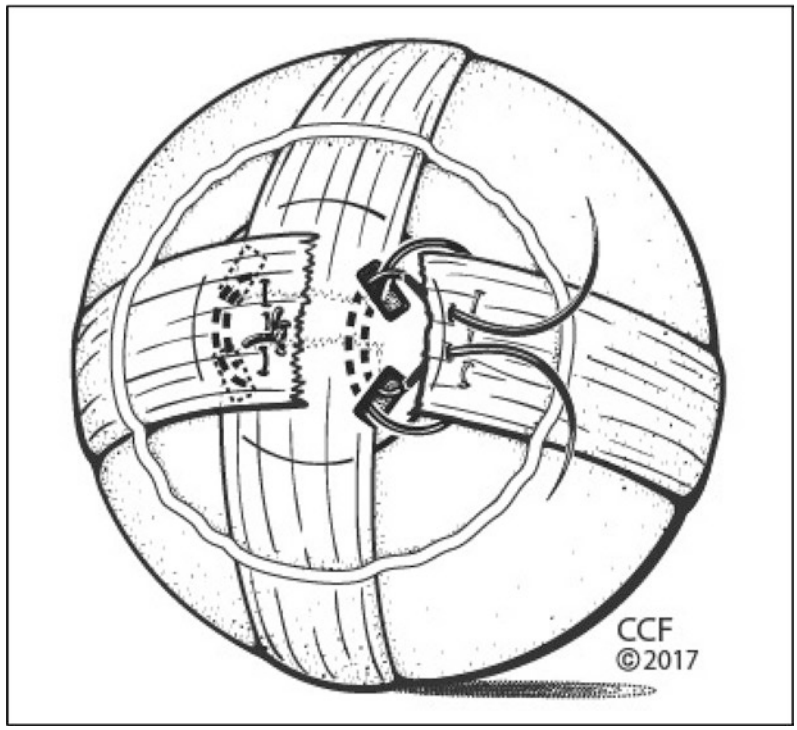

Fig. 11 Attachment of rectus muscle to the pre-drilled tunnels

may require fascial, dermal or scleral patching with a conjunctival or even tarsoconjunctival pedicle flap. Occasionally, the implant surface may require mechanical flattening or reshaping (e.g., shaving down with a burr) to reduce the anterior portion of the exposed implant and allow a patch graft to cover the implant. Removing a porous implant can be technically difficult especially once the fibrovascular ingrowth has had a chance to establish itself inside the implant. Other known complications include socket infections, orbital cellulitis, shallow fornices, and delayed fibrovascular ingrowth.

Pegging Porous Implants

In case of a hydroxyapatite implant, and after 6–12 months, fibrovascular ingrowth is usually complete and the patient who desires further motility may undergo a secondary drilling procedure for insertion of a connecting motility peg. Some surgeons recommend that young children should wait until at least 6 years of age before having secondary drilling. This is primarily because cooperation with the ocularist is necessary for any future revisions. Different radiologic studies have been used to evaluate the fibrovascular ingrowth into the hydroxyapatite implant, such as bone scans and MRI. The timing of the secondary drilling is generally at least 6 months after implant insertion.

The location for the peg drilling should be positioned where the ocularist wants the peg to be inserted and marked by the ocularist using a conformer with a positioning hole. When patient is fixating with the fellow eye in primary gaze, the center of the implant is not always a consistent "central axis of the prosthesis." The mark is made through the positioning hole in the conformer.

After marking the conjunctiva where the peg is to be placed, a local anesthetic (2% lidocaine with epinephrine 1:100,000) is injected into that area. Conjunctiva and Tenon's layer are

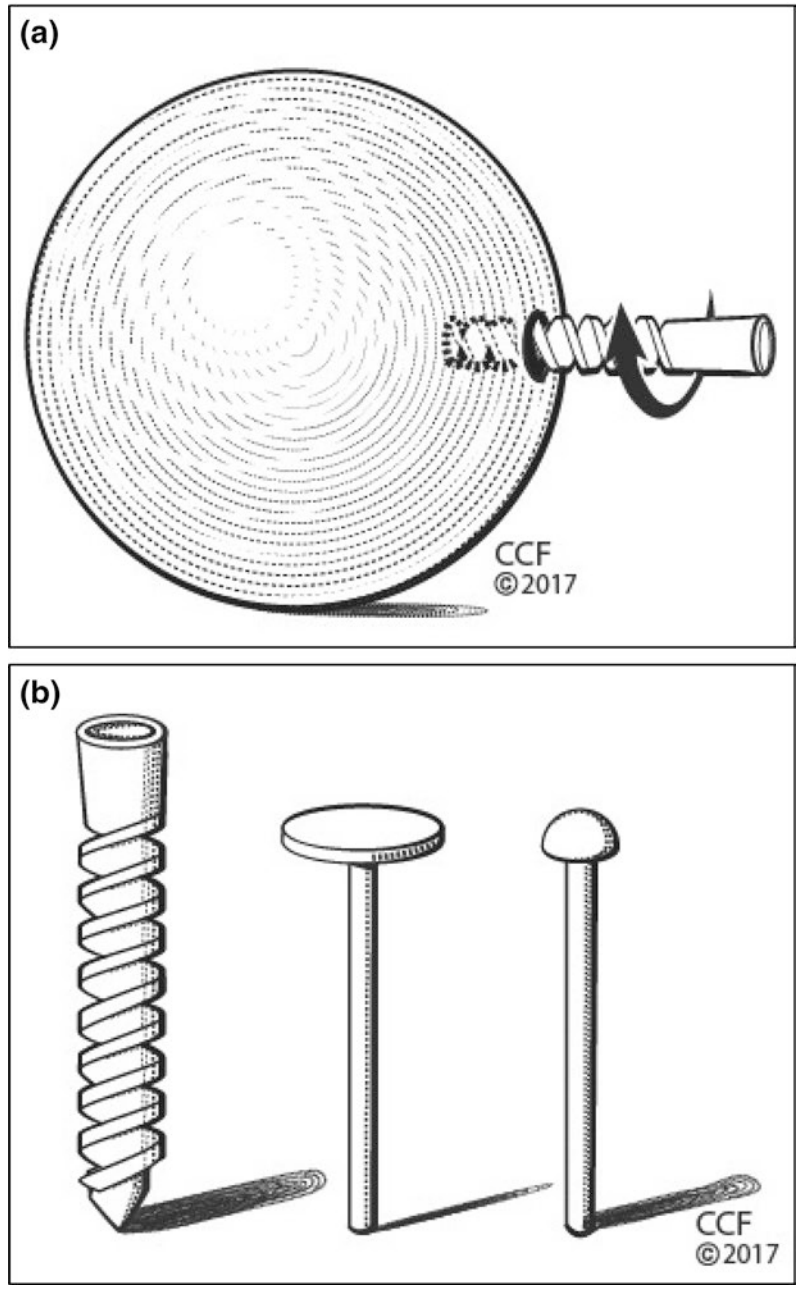

Fig. 12 **a** Insertion of motility sleeve into hydroxyapatite implant. **b** Motility sleeve, flat peg (temporary), round peg (permanent)

cauterized and the underlying hydroxyapatite implant is exposed. The implant is then drilled with a 3-mm cutting drill bit on an electric drill to a depth of 10–11 mm. The hole is irrigated with balanced salt solution to remove any debris.

A sleeve (e.g., polycarbonate, polymethylmethacrylate, titanium) and 2 pegs (one temporary flat head and one permanent round head) are required for the pegging of a hydroxyapatite implant (Fig. 12a, b). The sleeve is screwed

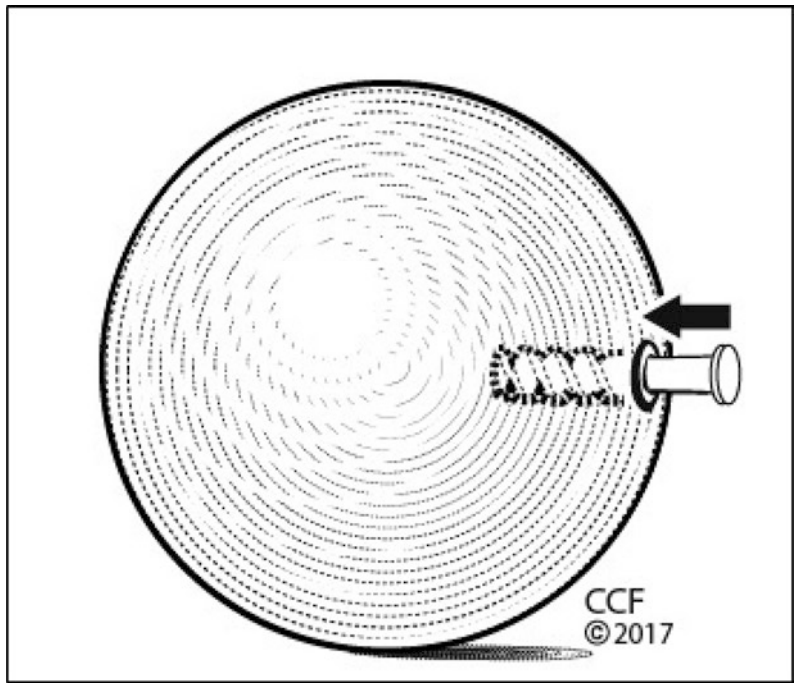

Fig. 13 Insertion of temporary flat peg into sleeve

into the drill hole until the collar of the sleeve is flush with the surface of the conjunctiva. The swelling that injection of local anesthetic creates should be taken into account. The shaft of the peg fits within the sleeve. The flat head of the peg should lie flat against the conjunctiva (Fig. 13). Titanium is generally more biocompatible and better tolerated by the human tissues than other materials.

Three to six weeks after placement of the temporary flat head peg., it is replaced with a permanent round head peg. The ocularist designs the posterior surface of the prosthesis to follow the contour of the permanent peg forming a "ball and socket" joint for better motility.

With a porous polyethylene implant, pegging steps are carried out in the same manner as for porous HA implant. A pilot hole is created in the predetermined location on the implant using a hand drill supplied by the manufacturer. The hole is irrigated to remove any residual PPE debris.

The motility coupling post (MCP) is screwed directly into the pilot hole with the screwdriver that the manufacturer provides. A sleeve is not required. When anchoring the MCP, it is important not to catch any of the surrounding tissue and drag it into the pilot hole. The head of the post should be positioned to protrude 2–4 mm above the anterior surface of the implant (Fig. 14).

The conformer containing the central "marking hole" is then placed back into the socket to ensure that the MCP is positioned in the central hole. Subsequently, the patient is sent to the ocularist in 2–3 weeks for modification of their prosthesis to "couple" it with the MCP.

Complications of Pegging a Porous Implant

Any exposed piece of hardware such as a motility peg that is protruding from the surface of intact conjunctiva and is hidden behind a socket foreign body such as the prosthesis can be associated with significant complications.

Pegging an HA implant can be associated with developing discharge, pyogenic granulomas, peg

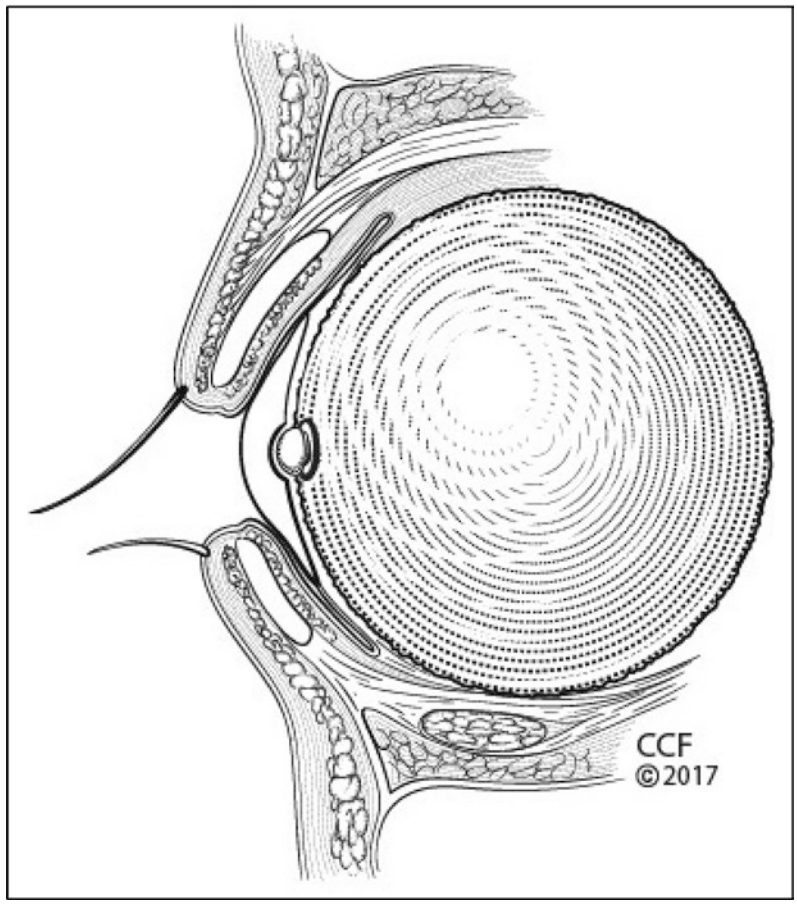

Fig. 14 Permanent round peg in porous implant with modified prosthesis (ball and socket)

falling out of its sleeve, poor transfer of movement, audible clicking, conjunctiva overgrowing peg, poor-fitting HA sleeve, part of HA sleeve shaft visible, peg drilled on an angle, hydroxyapatite visible around peg hole, peg drilled off-center, popping peg, and excess movement of peg. The most significant complication of pegging a HA implant is implant infection, which may necessitate the removal of the implant.

There are less complications associated with pegging a PPE implant than an HA implant, which is attributed to the implant having no sleeve and the motility post is screwed directly into the implant. As with any imbedded surface foreign body, inflammatory conjunctival granulomas may form at the base of the peg, which can lead to dead spaces behind the prosthesis, and result in fluid collection, and serve as a source of infection. Pyogenic granulomas can enlarge in size and displace the prosthesis. These granulomas can be locally excised but can often regrow. Peg removal is sometimes the only option for preventing regrowth. Most oculoplastic surgeons, and even Stryker Corporation, manufacturer of the Medpor porous polyethylene orbital implant, no longer supports implant pegging.

The surgeon must weigh the risks of these potential complications against the benefits of increased motility of the prosthesis and whether the enhanced motility is a true overall benefit to each individual patient.

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Orbital Implants and Prosthesis: Ocularist Perspective

Kuldeep Raizada and Deepa Raizada

Eye Removal Surgery

Ocular tumors (mostly choroidal melanoma and retinoblasoma), disfigured or painful blind eye, staphylomatous eye, ocular infections need eye removal surgery in the form of enucleation or evisceration (Fig. 1a–f). An adequate size orbital implant is placed during surgery wherever indicated. These are often considered as a last option where the eyeball cannot be salvaged.

The main objective from this point is aimed at providing optimal cosmesis and maintain a healthy socket.

Orbital Implants

Enucleation or evisceration can be performed without placement of an orbital implant, but this will result in suboptimal cosmetic outcome. An orbital implant replaces the lost volume in evisceratedor enucleated globe, impart motility to the prosthesis, supports surrounding structures and thus maintain cosmetic symmetry with the fellow eye.

It is crucial to place an optimum size implant. Placement of smaller or a larger implant has its own implications. Smaller implants tend to migrate and does not solve the purpose of adequate volume replacement. Larger implant interferes with the aesthetics and tension on the conjunctival wound that could result in wound gap and implant extrusion. Ideally, 65–70% of the volume should be replaced by implant and remaining 30–35% with the prosthesis. Generally, a 16–18 mm implant is used in infants, 18–20 mm in older children, and 20–22 mm in adults. The recent introduction of non-spherical (conical or egg-shaped) implants has made it possible to increase the volume of the implant without the need to increase its anterior curvature. In cases of evisceration, this requires posterior sclerotomy to accommodate the increased volume in the orbit without increasing the anterior curvature of the implant.

Implant Material

Various types of orbital implants are available (Table 1).

PMMA and silicone are the most common nonintegrated implants used as they are not expensive, well tolerated and accepted without

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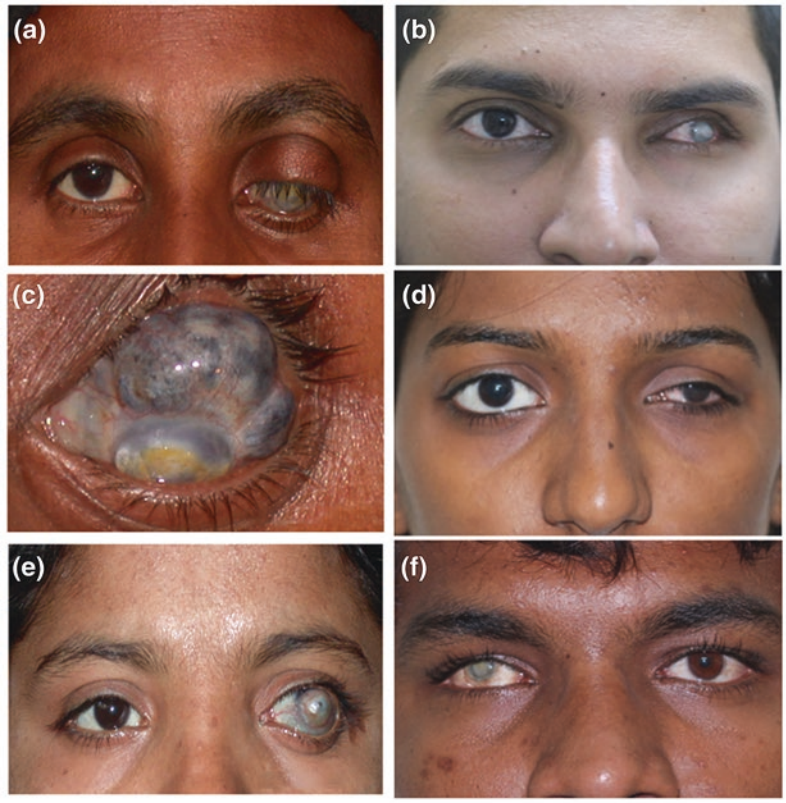

Fig. 1 **a** shows Left Staphylomatous eye with significance ptosis and eye lid deformity. **b** Left Phthisis eye with calcification. **c** Shows thinning of uveal tissue over upper sclera. **d** Painful Atrophic blind eye. **e** Left Eye buphthalmic painful blind eye. **f** Right Phthisis bulbi with Clear cornea

Table 1 Classification of Orbital Implants

Type	Definition	Example
Non-integrated	No direct or indirect integration of the synthetic implant with the orbital structures or with the prosthesis	PMMA or Silicone spheres
Semi-integrated	Indirect (mechanical) integration of the synthetic implant with the orbital structures but not with the prosthesis	Allen implant
Integrated	Indirect (mechanical) integration of the synthetic implant with the orbital structures and with the prosthesis	Cutler's implant
Bio-integrated	Direct (biological) integration of a natural or a synthetic implant with the orbital structures with or without integration with the prosthesis	Hydroxyapatite, Porus polyethylene, Aluminium oxide
Biogenic	An autograft or allograft of a natural tissue with direct (biological) integration with orbital structures but not with the prosthesis	Dermis-fat graft Cancellous bone

any significant complications. Silicone is less prone to migration because a layer of fibrous tissue sequestrates it. Better implant centration and prosthesis motility is noted when wrapping these implant in sclera and attaching the extraocular muscles to it.

Synthetic semi-integrated and integrated implants have been used in the past and are no

longer used. Biointegrated implants such as hydroxyapatite and porous polyethelene are porous materials, which allows blood vessels to grow through the poses and thus biologically integrates with the orbital tissue. These are expensive options as compared to nonintegrated implants. Since they have a rough surface, the implant is wrapped before placing into the orbit in cases of enucleation. These include hydroxyapatite, bioceramic implants made from aluminium oxide and porous polyethylene with 400-micron large pores. These implants allows fibrovascular ingrowth. A new material formed by a combination of porous polyethylene with Bioglass seems to provide improved vascularity (Fig. 2).

Pegging

Pegging was a procedure where the bioinegrated implant was surgically drilled in the center and a motility coupling post (usually made of titanium) was placed into the hole. A custom-made prosthesis designed to fit over the coupling post forms a ball-and-socket joint, thus enhancing motility with the prosthesis. It was carried out usually after 6 months of implant placement ensuring vascularization of implant. MRI with surface coil can be used to assess implant vascularization.

Complications of implant exposure and infection is a concern associated with pegging, therefore it is rarely performed now.

Surgical Aspects of Importance to the Ocularist

The choice of the implant, the implant size, its placement, gentle tissue handling, attention to creation of fornices with adequate conjunctival lining, proper upper and lower eyelid positioning and correction of any laxity are all important

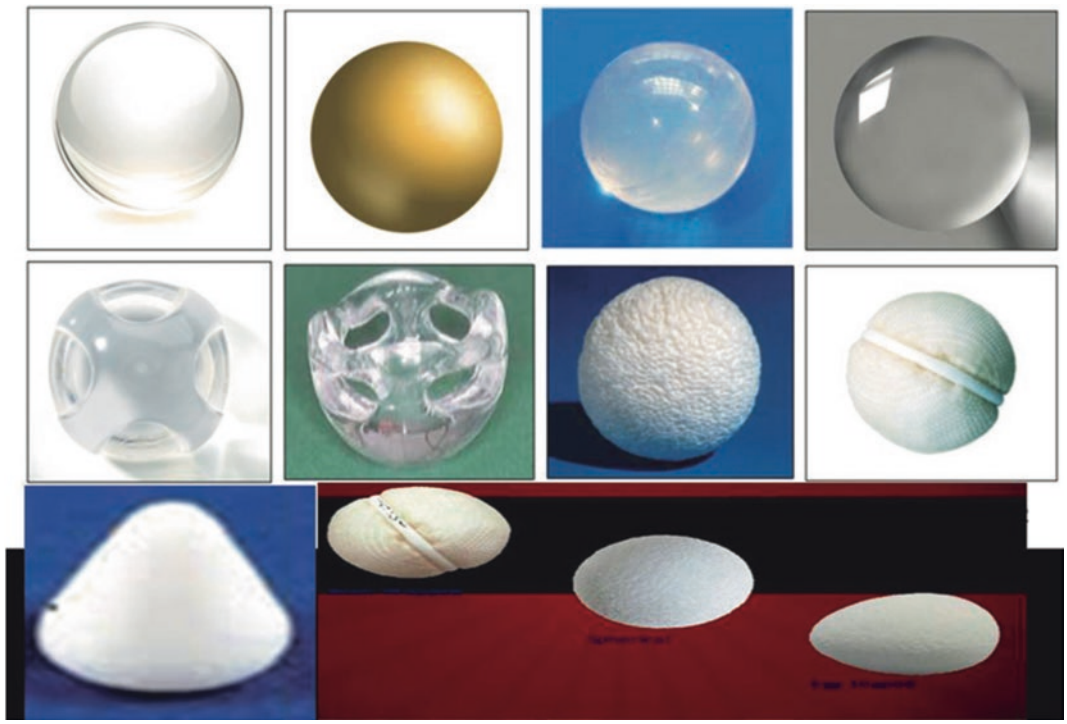

Fig. 2 The implant in the upper left is a hollow glass ball, as first used by Mules in 1884. Also shown are implants of gold, silicone, and acrylic in various shapes. Below implants are Castroviejo, Allen Implant, Hydroxyapettite implant, Biocermic Implant and the new conical porous implants

parts of the surgical planning and execution. Two-thirds of the lost volume of an eyeball should ideally be replaced by an implant and no more than one-third of the volume by the prosthesis. To that end, accurate sizing of orbital implants is of paramount importance. In most adult sockets, a 20 or 22 mm implant is likely adequate. In children, at least a 16 mm implant is placed. The implant should be centered. After an enucleation, careful suturing of the extraocular muscles, around the implant is important. The technique of inserting uncovered porous implants creates adhesions to the implant along the track of the muscles and also adhesions of the orbital fat: this makes subsequent removal of the implant, should the need arise, very traumatic. In cases undergoing evisceration, the aim should be to remove the contents of the globe with posterior sclerotomies to allow the placement of the appropriately sized implant with proper anterior overlapping closure of the sclera and tenons and conjunctival closure without tension. When implants are covered with sclera, there is no advantage to using porous implants over non-porous implants. When smooth implants have the extraocular muscles imbricated in front of the implant, it increases the risk of supero-temporal dislocation of the implant over time. To help decrease the risk of displacement and improve motility, implants can be covered with sclera with the extraocular muscles sutured to the sclera. In patients who have sustained trauma, the lacrimal system should be evaluated for obstruction (Fig. 3a–i).

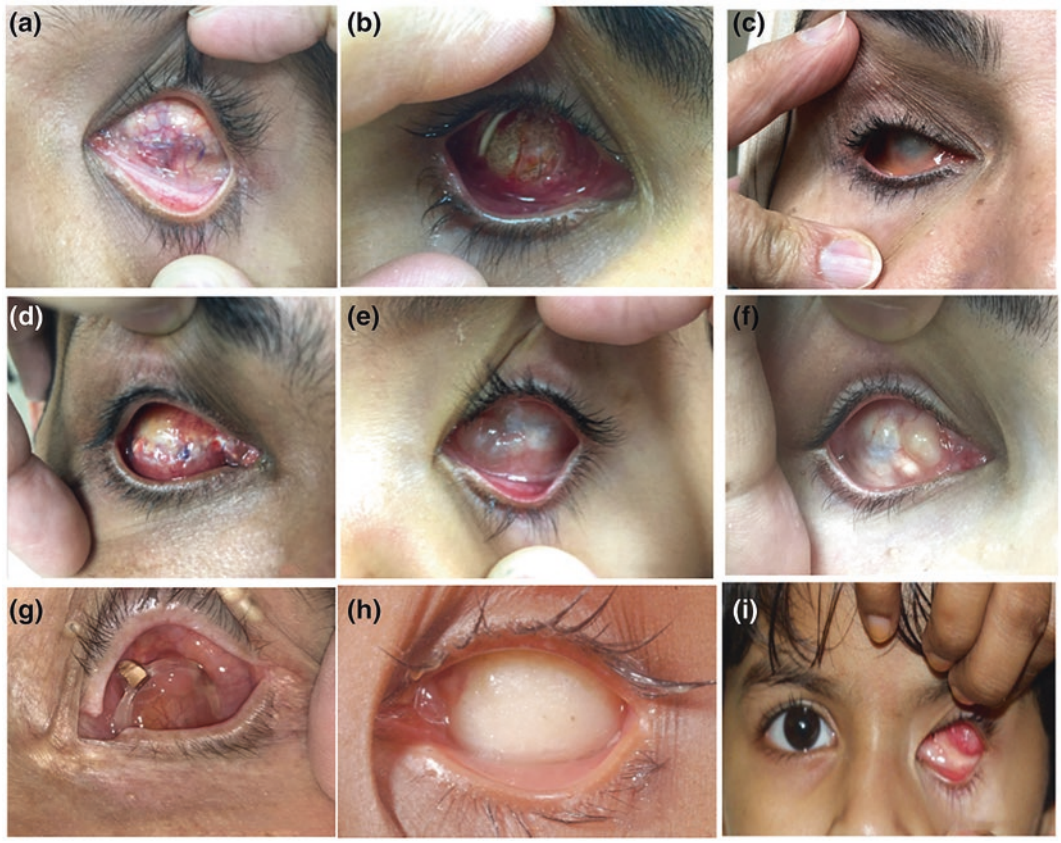

Fig. 3 **a** Shows loose suture post evisceration with Orbital implant. **b** Shows Exposed bio ceramic Implant. **c** Very Deep seated implant. **d** Shows early exposure of sclera within the loose suture. **e** Shows Conjunctival Cyst post-surgery. f Conjunctival medially Cyst post-surgery, long term. g Socket shows exposure of allen implant. **h** Socket Shows Exposure of Porous Polyethelne implant. i Socket shows migration of Orbital Implant, Laterally

Referral to the Ocularist

When is referring patients to the ocularist necessary ?

- A pre-surgical visit to the ocularist should be arranged if possible.
- A preoperative photograph of the face and the two eyes is useful for the ocularist to know what the appearance of the eye was prior to surgery. Photographs from years past may be useful when there is an evolving and changing disease process or in the presence of anophthalmos or microphthalmos.
- The aim should be to fit the patient with a prosthetic eye within six to eight weeks of surgery. The ocularist should be familiar with a systematic approach to examining the socket before a prosthesis is made and during subsequent visits.
- A detailed history of the patient, including prior irradiation, other surgeries, and exact diagnosis should be conveyed to the ocularist.
- A detailed operative report should be submitted to the ocularist, including details of the implant type and size, what it was covered with, muscle attachments (to insertion points, imbrication, etc), details of any fornix reconstruction or eyelid reconstruction and presence of any tarsorrhaphy.
- An outline of future care of the patient: will the patient need irradiation or other surgical intervention following the fitting of the prosthesis?

Materials Used in Fabrication of Eye Prosthesis

For over 300 years, glass was the preferred prosthetic material used. Owing to difficulty in molding and because of its fragility, glass is used rarely today.

Most modern ocular protheses are made using poly methyl methacrylate (PMMA). The material is inert in nature and is easy to mold, making it the material of choice. Silicone is no longer used in fabricating the ocular prosthesis due to water absorption and hydrophobic nature of the material. However, silicone is used for making facial prostheses following exentration as it is non-reactive, molds easily and can be used to match skin texture and color.

Fabrication of an Ocular Prosthesis

The following steps are involved in the fabrication of an ocular prosthesis

1. Examination by the ocularist. Even though an attempt is made to make a prosthesis six to eight weeks after surgery, it is first important to examine the socket to assess the healing, presence of sutures, fornices, lid position, chemosis, pain, cysts, scarring, and also to assess the surrounding structures.
2. Taking an impression: Patients are often anxious about the first step of taking an impression. The patient should be reassured that taking an impression is not uncomfortable. The normal contralateral eye is kept open with fixation on a predetermined point. The impression is taken with the patient sitting on a chair: a topical anesthetic is instilled and the molding material known as alginate (usually hydrophilic colloid) is prepared with a spatula in a rubber bowl. The mixture is placed in a syringe. The molding shell (which is also called an impression tray) is placed on the socket with the patient looking down so that the shell is first inserted under the upper eyelid, followed by the lower eyelid. With the eyes then in primary gaze, the syringe is attached to the shell and the molding material is injected gently. The molding mixture fills the socket with the impression material and sets (gels) in about two minutes with the consistency of a hard-boiled egg. With the upper and lower eyelids gently retracted the shell handle is rocked side-to-side and removed from the socket. The impression is then immersed in water.
3. Molding the impression into the wax model: half a cup of distilled water is taken and mixed thoroughly with one spoonful of

alginate. This paste is then poured in a plastic cup and into the rear surface of the impression. The alginate hardens in 2–3 minutes. The alginate mold is cut along the lines drawn on the impression tray. The carving wax is heated in a steel bowl till it becomes liquid. The molten wax is poured into the alginate mold and allowed to harden. An exact replica of the socket impression is now created (Fig. 4).

4. Centration of the iris: centration of the iris and marking the corneal plane is essential to achieve symmetry of the two eyes. Various methods are used to achieve this symmetry.
   a. **Using the interpupillary distance (IPD)**: Once the wax model has been made, wax solvent is used to smooth the surface. This wax model is inserted in the patient's socket. After making it symmetrical with respect to its position and plane, the interpupillary distance is marked with a nontoxic marker.
   b. **Using Hirschberg's test**: In absence of gross asymmetry of the orbit, the base for the ocular prosthesis can be made in white acrylic and inserted into the socket. The light reflex is kept at the center of the model.
   c. **Using iris corneal buttons**: This is the most difficult of the various methods described. However this gives the best cosmetic result. The iris button is inserted in the wax model using the carving wax and hot metal spatula and symmetry is achieved by trial and error.
   d. **Using the Peg**: The 18 mm stem frees up a hand to mark the center of the iris.
   e. **Freehand drawing**: On the white acrylic base, based on the ocularist's judgment, a circle is marked in the center corresponding to the fellow eye.
5. Fabrication of the iris and pupil to match the fellow eye: Once the wax model is finished, a two-piece mold in the dental stone is prepared (Fig. 5a–c). There are several ways to create an iris corneal component to integrate into an eye prosthesis (Fig. 6a–f).
   a. **Iris Corneal Disc System**: This is two-piece system where the iris disc (sized

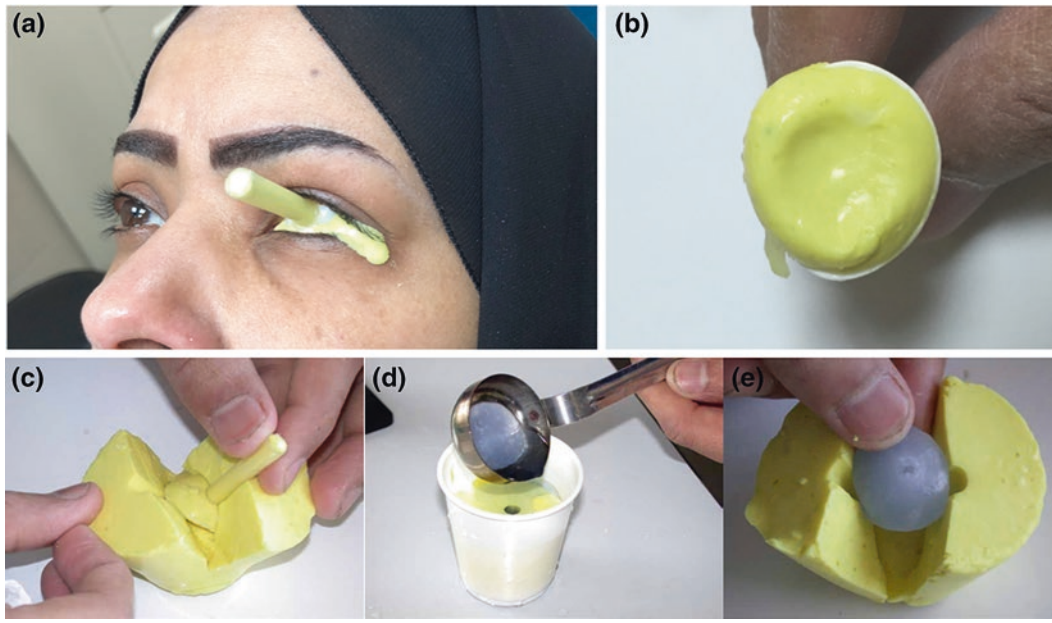

Fig. 4 **a** shows the impression of socket is being taken with impression tray in placed. **b** Shows the picture of impression removed from the socket. **c** Shows the mold is being duplicating with Alginate cast. **d** Shows Wax Is poured, to achieve the imprint in wax shape. **e** Shows wax shaped is achieve

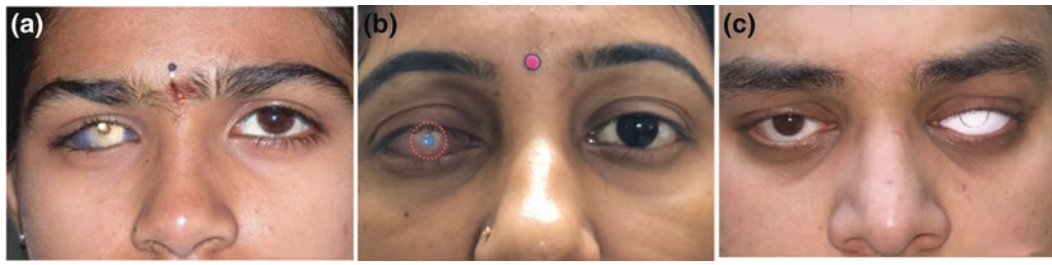

Fig. 5 **a** Shows the centration of Corneal Plane and Position of Iris. **b** Shows using the Plastic Stem and achieving the Corneal Plane and Position of Iris. **c** Shows the Traditional way of Achieving the Corneal Plane and Position of Iris with scribing the iris on scleral Base

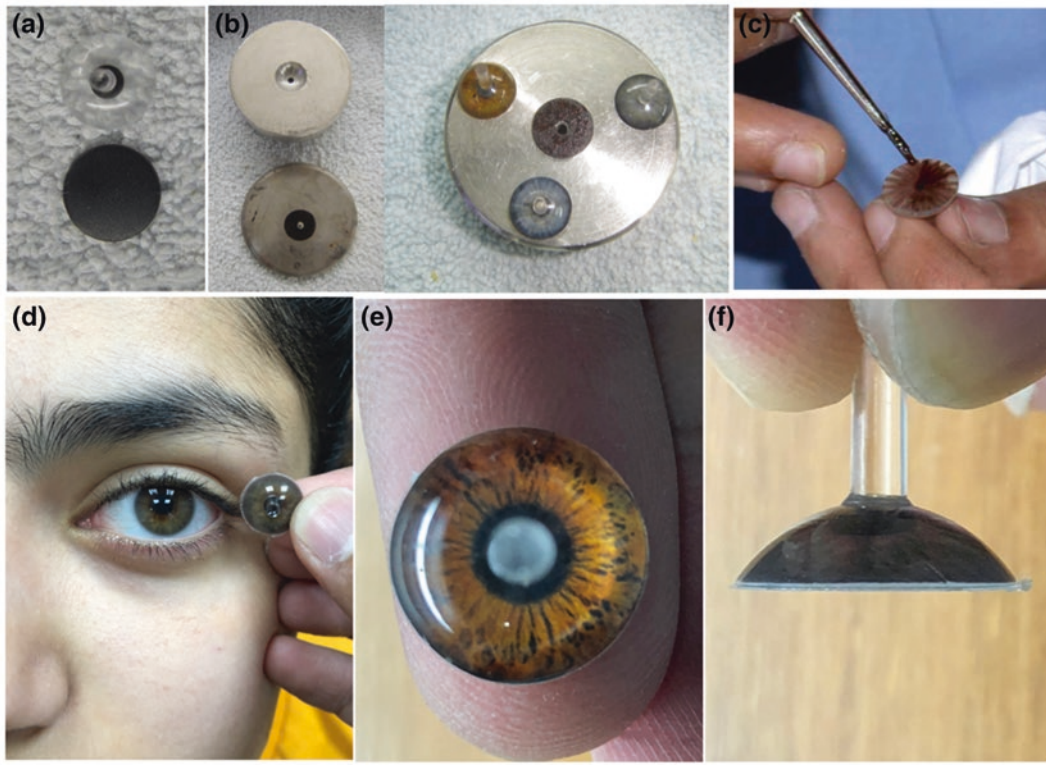

Fig. 6 **a** Shows the corneal iris system, where one can paint on black surface and bind the pre centered cornea over the painted iris disc. **b** shows the Iris is being painted on clear disc and using the mold system, cornea is being molded over painted clear iris disc. **c** Iris is being painted in reverse way over the back surface of cornea button. **d** Shows once the iris is ready, to match ensure coloration which match with fellow eye. **e** Shows a digital Button fabricated. **f** Shows saggital section of iris button in order to achieve the anterior chamber depth

10 mm through 13.5 mm) and cornea button are selected with proper three-dimensional pupil (sizes 2–7 mm). The iris disc is hand painted (1,200–1,500 brush strokes) using dry earth pigment or oil pigments, copying colors of the opposite eye to reproduce anatomy of the stroma and the collarette. The iris is later glued with pre-defined pupil size and corneal button.

b. **Molding in to a metal die**: one can paint over tin foil, and transfer over the corneal mold.
c. **Reverse painting**: those with an artistic eye and knowledge of the anatomy of the iris and also an understanding of colors, can reverse-paint.
d. **Digital iris buttons**: using a high resolution camera, a high definition image of the iris is printed and glued or molded into the iris die.
e. **Colored buttons**: These are pre-defined base colors which can be modified.

6. Preparing the white base: The white base of the PMMA is poured into the molds and cured at 110 degrees and at 4 bar pressure for 25 minutes. Once cured, it is removed from the mold, the edges are trimmed and polished and inserted into the patient's socket (Fig. 7a–d). While doing so we reconfirm the size, plane and angle of the iris in the white base. The corneal button is exposed and the process of tinting is begun. Cotton rayon threads are used to give the appearance of blood vessels (Fig. 8). Dry, finely earth color pigments are used to achieve a close match for the sclera to the opposite eye (Fig. 9). Once it is ensured that the exact color matching has been achieved, the base of the prosthesis is kept in the oven at 85 degrees for 30 min. This cures the colors to saturation levels and prevents any future fading. Once the artwork is completed, the shell is put back into mold and a layer of clear acrylic is polymerized on the front surface, thereby encapsulating the pigmentation and

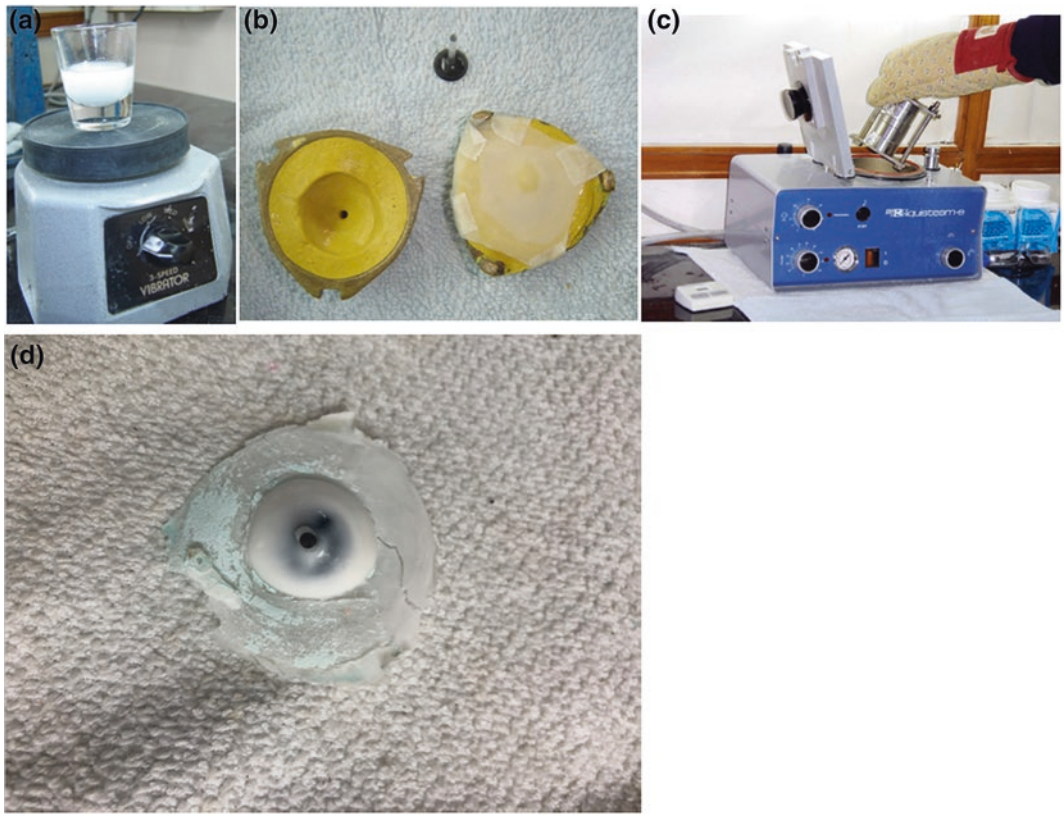

Fig. 7 **a** white scleral powder and Monomer mixed and polymer is ready to be casted in mold, **b** Shows the Die which made with Stone cast, along with iris, back surface is enforced with rubber dam, ensure to have smooth surface and avoid contamination of Scleral polymer. **c** Molds are being taken out from Polymerizing unit. **d** Show he Sclral Shape after taking out from Mold

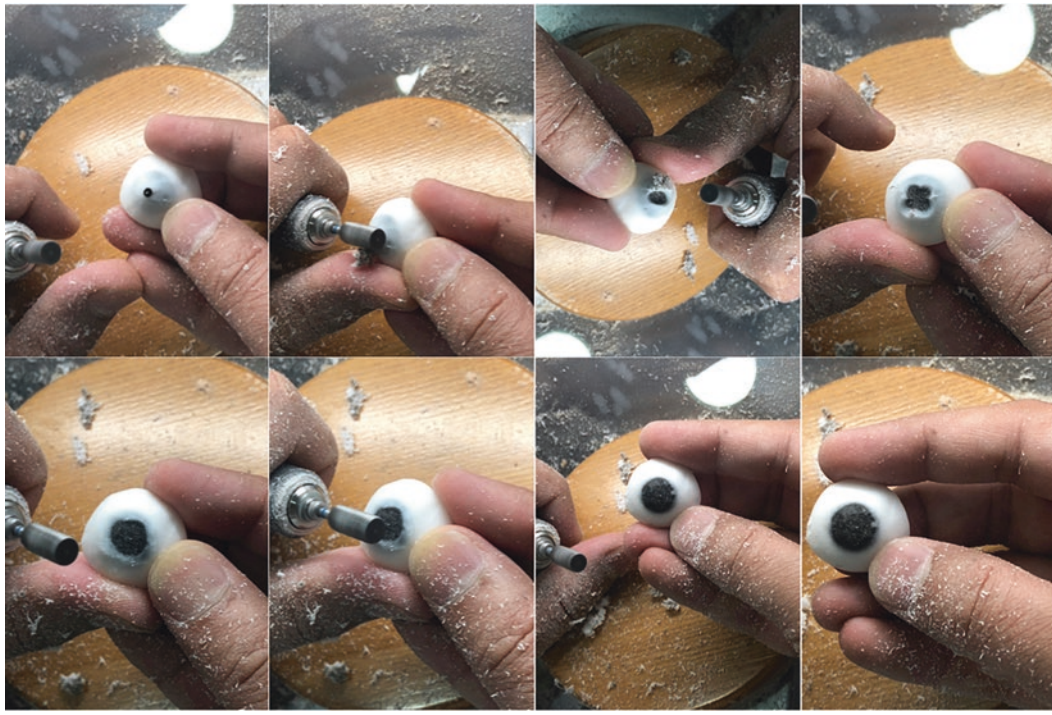

Fig. 8 Shows Various Step in removing the scleral white from anterior surface in order to make a space for painting

adds proper anterior curvature (Fig. 10a–f). This completes the fabrication process. After trimming and polishing (Fig. 11a–f), the final prosthesis may need minor adjustments by removing or adding PMMA in different places, thereby improving lid opening and closure, and correct eyelid malpositions as needed.

7. Final evaluation of the following is performed to assess for comfort, stability, vertical and horizontal position, motility, iris and scleral color, iris position, iris size, pupil size, and anterior and posterior curvature.

Instructions on socket hygiene and prosthetic care are given along with the technique of removal and insertion of the final prosthetic eye.

Gold Standard Eye Prosthesis

The ideal ocular prosthesis there are two main questions that patients raise about their prostheses: "how will it look?" And "will my prosthesis move?" A less common question asked is "will my pupil dilate and constrict?" The appearance is where the fit and the artistry of the ocularist comes in. The antero-posterior thickness should be no more than 7 mm. The prosthesis should be light with minimal pressure being exerted on the orbital tissues. It should have reasonable movement in all fields of gaze and should correct the volume deficit so as to match the appearance of the fellow eye. In the presence of an ideal socket (deep fornices, volume loss less than 4.2 ml, centered orbital implant, quiet, smooth conjunctiva, good lid positions, no sulcus deformity or socket contracture and minimal lagophthalmos), such an ideal prosthesis will fit and look its best (Fig. 12a–c).

Prosthetic Mobility

Prosthetic mobility is a very important concern of patients. It is important to point out to

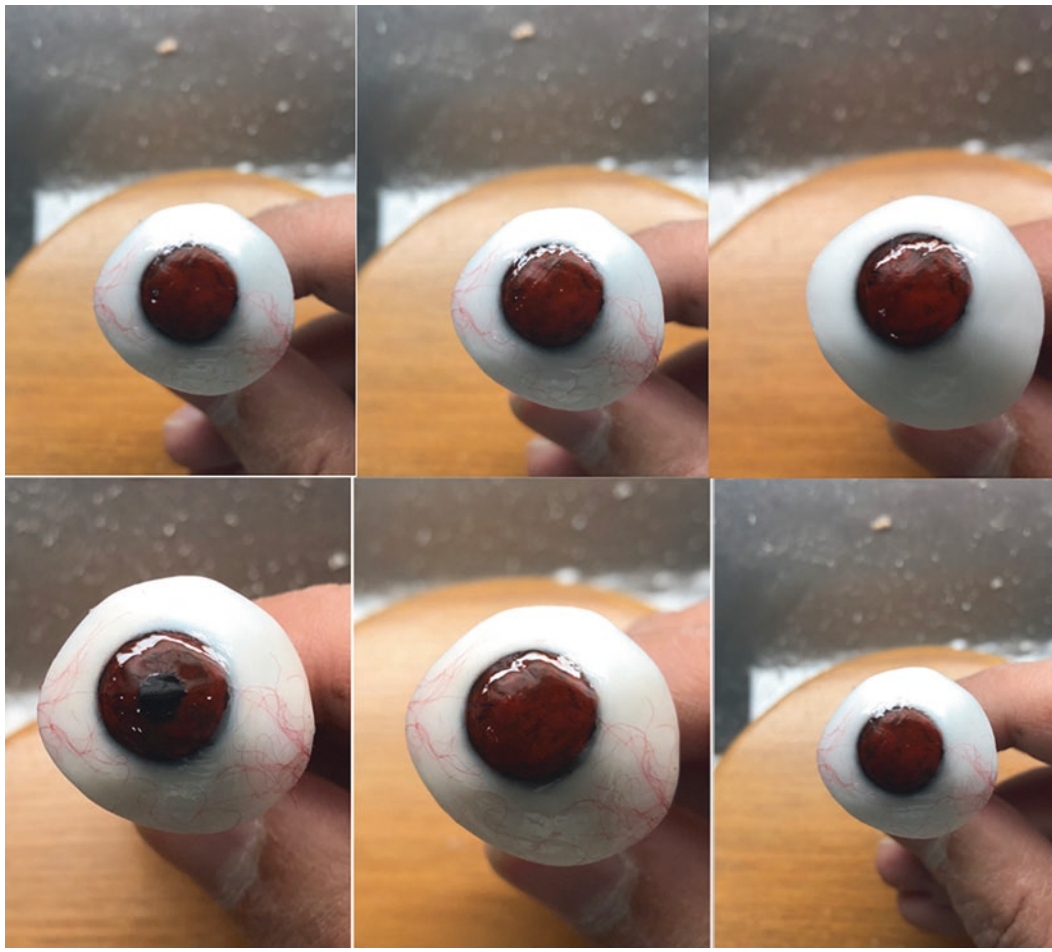

Fig. 9 Shows various stages of tinting the pigmentation

patients that the prosthesis will not move as well as their native eye. Most adults will adapt to move the head rather than the eyes when looking in particular directions, whereas children may not do so. Therefore, most adults will move their eyes within a range of about 30 degrees to the right or left. A well-sized and properly placed (central) implant with attachment of the extraocular muscles will give very satisfactory transmission of movement to the prosthesis. An inferiorly displaced or supero-temporally displaced implant will give suboptimal motility. Pegs are only rarely used now due to problems with exposure and granuloma formation.

Special Considerations in the Fitting of Prostheses

a. In the presence of ptosis, a ptosis crutch can be built upon a prosthesis as has been in use for several decades now. When built upon solid prostheses, this adds weight which is borne by the lower eyelid which invariably leads to lower eyelid laxity over time. This led to the creation of hollow prosthetic devices where two separate pieces are made which are then joined, thereby allowing reduction in the overall weight of the prosthesis by as much as 26%. This type of hollow

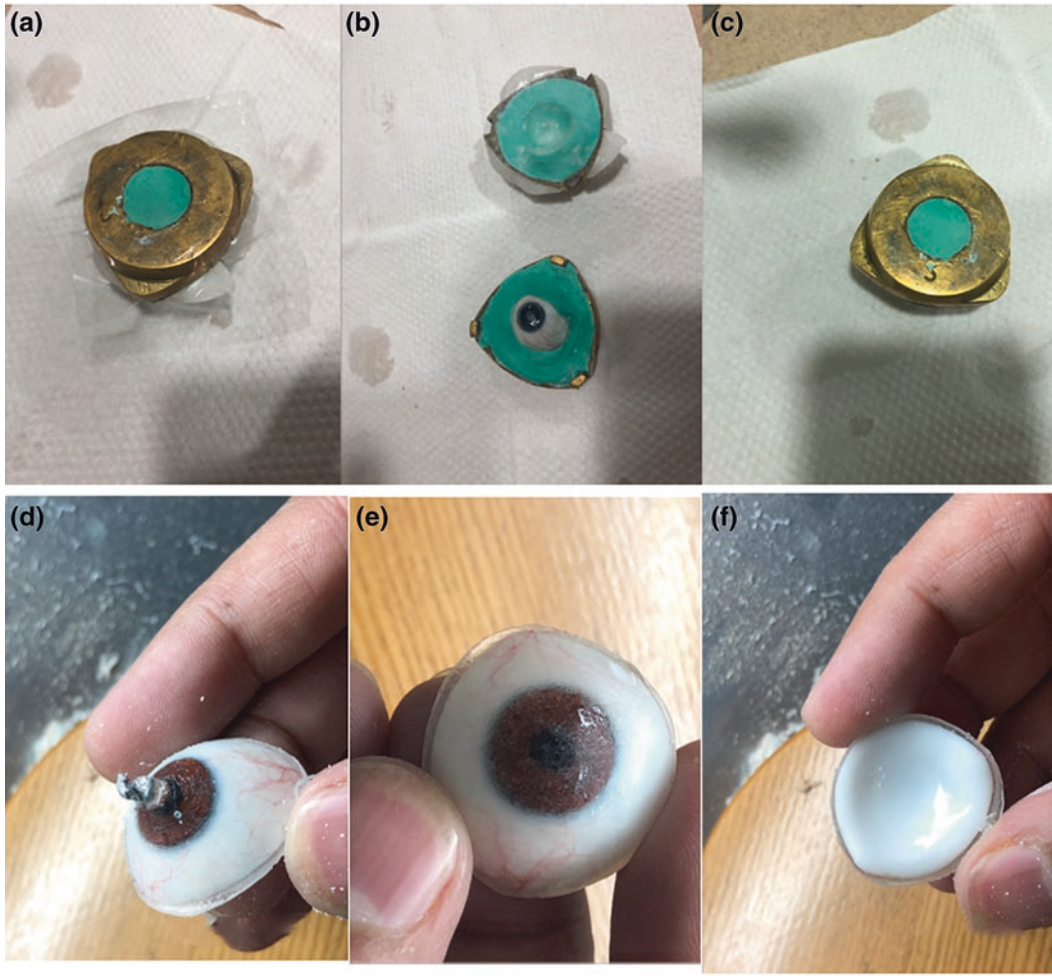

Fig. 10 **a** Shows the clear Polymer is poured and mold is tighten with Clear Plastic Sheet of Densilk. **b** Mold is open and clear den silk is removed. **c** Mold is further closed and polymer is cured in Polymerzing chamber. **d** Shows the unfinished Ocular Prosthesis just after opening mold. **e** Anterior surface is being trimmed. **f** Edged are being trimmed

prostheses cannot be designed when the prosthesis is very thin. However the recent development of using volume displaced technique, where the whole weight is displaced from the lower lid to the upper portion of the prosthesis, made it possible to improve and even help prevent lower lid laxity.

b. Studies have shown that the anophthalmic socket often suffers from deficient tear production. Kelly from Philadelphia designed the self-lubricating ocular prosthesis. This type of prosthesis has a chamber that holds the lubricant, an exit hole and a releasable cap covering the chamber. During a normal blink, lubricant is drawn out of the chamber, thereby lubricating the prosthesis. The chamber can be cleaned with a contact lens solution cleaner and the chamber may be refilled with lubricant. This type of prosthesis is useful in the very dry irradiated anophthalmic sockets and other dry anophthalmic sockets which would have been impossible to tolerate a prosthesis.

c. Advancement of digital technique & improved printing quality which allows the quick fabrication of a prosthesis which could

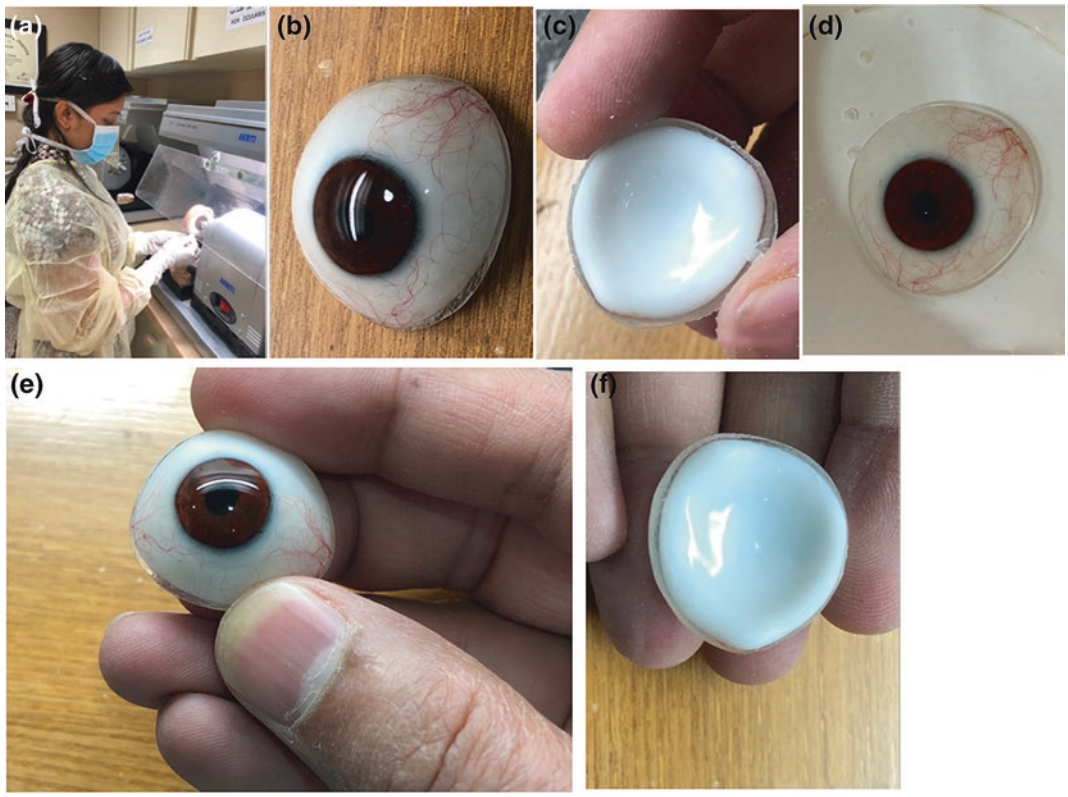

Fig. 11 **a** Polishing of anterior surface and posterior surface is being done on lath machine. **b**, **c**, **d**, **e**, **f** Images shows a uniform Light reflection on anterior surface to shows that polishing is being done uniformly

be used immediately after surgery so the patient does not have to wear a clear conformer. This technique uses photography of the opposite iris with incorporation of a high-resolution print by lamination onto a shell, with the colors used in the process being very stable and very much replicable.

d. In the presence of loss of the upper and/or lower eyelids that cannot be reconstructed, an acrylic eyelid with eyelashes can be made and attached to the prosthesis giving a very acceptable cosmetic results.

Dilatation of the Pupil

Patient with Light color Iris often complains about the fixed pupil size in the prosthesis. Dilating the pupil with various system have been made such as using an LCD crystal display over the top of iris which respond to varying light condition similar to a normal pupil, which is surely advancement an a great advantage to the patient.

Future advances in enucleation and implant will likely focus on better and less expensive implant materials that do not need wrapping,

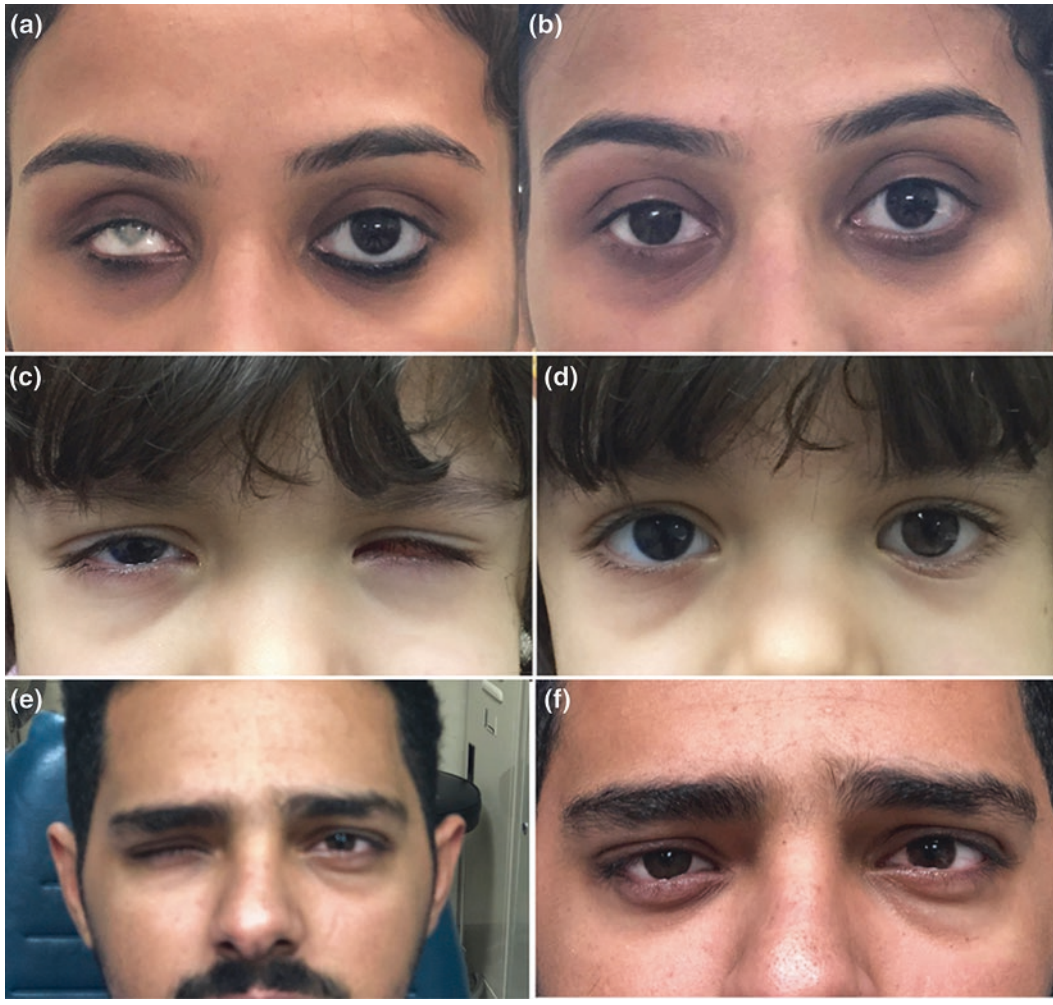

Fig. 12 **a** and **b**, Shows the result post prosthesis in a case of Phthisis Bulbi. **c** and **d** Shows the result post prosthesis in a case Post Enucleation in a child. **e** and **f** Shows the result post prosthesis in a case of Right Evisceration

and provide for easier extraocular muscle attachment, enhanced speed and quality of tissue integration, fewer complications, and preplaced motility peg.

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Orbital Implants

Mrittika Sen and Santosh G. Honavar

Introduction

The removal of an eye is one of the most difficult decisions, both for the doctor and the patient. It has a major impact not only on the physical appearance of a person but is also psychologically overwhelming. Enucleation is indicated for intraocular malignancy, a painful, blind eye or an irreparable eye following severe trauma. Evisceration is preferred for painful, blind eyes secondary to endophthalmitis. Numerous developments have taken place in the field of anophthalmic socket surgery with the aim of improving the appearance of the artificial eye. Orbital implants, placed within the scleral envelope or inside the Tenon's capsule, restore the orbital volume after an evisceration or enucleation respectively. They are important to maintain cosmetic symmetry with the fellow eye and also impart motility to the ocular prosthesis.

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Ideal Implant

A large number of implants are available today. While each of them have their own advantages and disadvantages, an ideal implant is the one which fulfils the following criteria:

- Integration with orbital tissues
- Biocompatible: It should not cause any allergic or inflammatory reaction or rejection
- Non-biodegradable
- Free from complications like infection, extrusion and migration.
- Adequate volume replacement
- Adequate support for prosthesis
- Allow maximum motility with prosthesis
- Stimulate orbital growth
- Readily available, inexpensive and easy to use/implant

None of the currently available implants fulfil all the criteria. In this chapter we provide an overview of the different types of orbital implants, their applications and limitations.

Types of Implants

Implants have been made from a wide variety of materials, ranging from glass, gold and paraffin to more 'natural' materials like ox bone, fat, rubber, silk, rabbit eye or acrylic and wire.

E. A. El Toukhy (ed.), *Oculoplastic Surgery*, https://doi.org/10.1007/978-3-030-36934-7_46

However, few have survived the test of time and have been widely used. A practical classification of orbital implants is shown in chapter "Orbital Implants and Eye Prosthesis".

Non-integrated Implants

Non-integrated implants are smooth with a non-porous surface and do not allow the fibrovascular ingrowth into their inorganic bodies. Silicon and PMMA are the commonly used non-integrated spherical implants. These have no direct connection with the ocular prosthesis but provide motility by surface tension at the conjunctivo-prosthesis interface. They provide good volume replacement. The extraocular muscles are either tied over the implant or sutured to the wrapping material which may be used to cover the implant. The imbrication of extraocular muscles in front of the implant provides some amount of ocular motility. Wrapping of the non-integrated implants helps to decrease the exposure rates in the postoperative period. Non-integrated implants are relatively inexpensive, technically simple to use, well tolerated and have very few complications. Implant migration because of the contraction of the overlying rectus muscle is one of the complications associated with these implants.

1. **Silicone**: It is biologically inert, flexible, easy to handle and inexpensive. When pegging is not planned or discouraged, silicone sphere is a good implant and it offers motility similar to an unpegged porous implant. A wrapped silicone sphere connected to the recti muscles is also preferred in infants and pre-school children and it can be exchanged with a porous implant with pegging once the child is older (>15 years). Even in elderly patients who have difficulty in following up and are therefore poor candidates for pegging, a wrapped silicone sphere can be used. In cases of trauma where the extraocular muscles are unidentifiable, this implant is again useful. Very low extrusion rate (0.84% over a follow up of 10 years) has been described by Nunnery et al. in 1993 using a silicone implant reinforced with autogenous fascia or sclera, and suturing the recti independently to the implant with no case of implant migration. Imbrication of muscles, on the other hand, over a non-porous implant can cause implant migration.
2. **Polymethyl methacrylate (PMMA)**: This implant can be wrapped in donor sclera. It can also be used as both primary and secondary implant. The indications for its use are similar to those for silicone. Recently, It is hypothesized that the weight of the implant is responsible for the implant migration and hollow PMMA implants have been developed. When compared with solid acrylic implants for implant migration using serial CT scans, the results of hollow PMMA implants were comparable.

Quasi-integrated Implants

These have been used in the past and are no longer used.

Bio-integrated Implants

Integrated implant, as the name suggests, allows for the ingrowth of fibrovascular tissue from the anophthalmic socket resulting in true integration of the implant with the orbital tissues. They have a rough, porous surface and can have provision for drilling of 'pegs' or 'posts' to connect them to the ocular prosthesis. The integration makes these implants more resistant to migration and extrusion and pegging of the implants adds to the motility of the prosthesis.

1. **Hydroxyapatite**: First introduced by Perry in 1985, the implant material is made of a complex calcium phosphate salt normally found in human mineralized bone and derived from living corals found deep in the oceans. It is biocompatible, non-biodegradable, non-toxic and non-allergenic. The porous matrix is infiltrated by the orbital fibrovascular tissue. Vascularisation of the implant can be assessed radiographically

with contrast enhanced Magnetic Resonance Imaging (MRI) with surface coil. Implants with grade 3 or 4 vascularisation (equal to or greater than the orbital rim) are considered as adequately vascularized. The assessment of vascularization is essential before drilling a hole for pegging to identify the central avascular zone. Implants with more than 75% vascularization also tend to bleed more during drilling. The extent of vascularization can be influenced by the pore structure and orientation of the pores. Poor vascularization can lead to implant extrusion. The rough surface of the porous implants can cause erosion of the conjunctiva and Tenon's and ultimately cause exposure of the implant. This can be prevented with wrapping the implant with appropriate materials. Various wrapping materials that have been used include donor sclera, autologous fascia lata or synthetic material like Vicryl mesh. Extraocular muscles can be sutured to the wrapping material and thereby impart better motility.

The polymer-coated hydroxyapatite implant is a newer modification that allows the muscles to be attached directly to the implant without the need for a wrapping material. The implant has a polymer coating made of smooth, inorganic material without the risk of infectious diseases related to the use of donor tissues. The implant can also be easily placed in the orbit without any tissue adhesion. The anterior surface of the implant has an amber-pink colour polymer that resorbs over 18 months and the posterior surface is coated with purple-blue polymer that resorbs over 6 weeks. The faster dissolution of the posterior polymer allows early fibrous ingrowth through the posterior aspect of the implant, thereby protecting against infection and extrusion. The slow dissolution of the anterior coating prevents erosion of Tenon's and conjunctiva. The implant preparation is done under sterile aseptic conditions using cautery, before implantation. A single opening is made in the posterior part to allow vascular ingrowth and 4 windows are made anteriorly to allow each of the rectus muscles to be pulled through them and secure them to suture holes also made in the anterior portion.

The most common complications associated with hydroxyapatite implants are exposure and infection. Implant exposure is related more to the surgical implantation technique and wrapping material used rather than the implant material itself. Various studies have reported an exposure rate of 3–7.6%. Proper implant sizing and meticulous wound closure can minimize the risk of implant exposure. Other complications include late exposure following conjunctival thinning and erosion, orbital hemorrhage, socket discharge, pyogenic granuloma formation and persistent pain in the socket. The brittle and spiculated nature of the material precludes direct suturing of the extraocular muscles to the implant and also makes insertion into the socket difficult. The various limitations elucidated above, coupled with the higher cost of the implant, as well as the added cost of the wrapping material, drilling and peg placement, has made it, in the recent years, less popular. Synthetic hydroxyapatite implant costs nearly half of that of coralline hydroxyapatite. However, the complication and limitation profile of the synthetic hydroxyapatite implant remains similar to that of the coralline implant.

2. **Porous polyethylene**: This is an integrated implant that allows fibrovascular ingrowth. But the surface of this implant is smoother than hydroxyapatite. This allows easier implantation with minimal tissue drag and direct suturing of the muscles to their surface. The technique of saline impregnation may accelerate fibrovascular growth. There is no need for a wrapping material and this brings down the cost. The smoother surface also causes less irritation of the overlying conjunctiva thereby reducing the rate of late exposure. It is available in spherical, egg, conical and mounded shapes.

Porous polyethylene implant is not free from complications. Exposure rate varies from 3.7 to 21.6%. Infection and extrusion have also been reported. A recent technique of covering

only the anterior surface of the implant with 10–12 mm diameter of donor or autologous sclera (scleral cap technique) can provide an additional barrier to minimize the risk of implant exposure as shown in Fig. 1. It also does not impede fibrovascular ingrowth, which can happen with the conventional method of wrapping the implant with one large posterior window and four anterior windows for recti. A new material formed by the combination of porous polyethylene and bioglass provides improved vascularity.

3. **Bioceramic**: The chemical constituent is aluminium oxide and it is similar to other porous implants in its physical properties. It is strong, easy to manufacture and less expensive as compared to other synthetic implants. Exposure rate reported is similar.

Porous implants are preferred in adults but avoided in children because they require implant substitution with larger sized implants to stimulate adequate orbital growth. The ASOPRS survey done in 1995 and 2002 has shown a shift in trend from the use of hydroxyapatite to porous polyethylene. In the survey done in 2005, it was also observed that most surgeons did not wrap the implants (59.8%) or use a motility peg (91.8%).

Wrapping of Porous Implants

Various materials like donor sclera, bovine pericardium, autologous tissue like fascia lata and synthetic material like polyglactin mesh have been used for wrapping the orbital implants prior to their placement into the orbit.

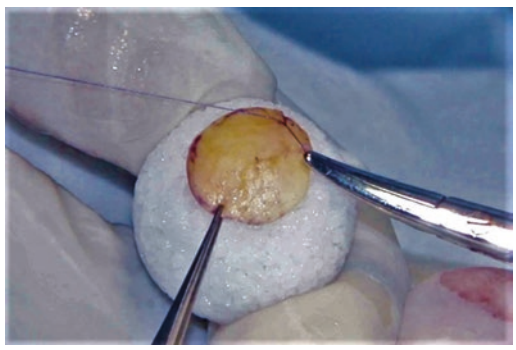

Fig. 1 Porous polyethylene implant with a 12-mm diameter scleral cap sutured on to its anterior surface

(a) **Donor sclera**: Freshly frozen donor sclera has been the most popular and successful wrapping material for orbital implants over the years. It is readily available and easy to use, can be sutured to the implant with 4-0 or 5-0 non-absorbable sutures. Other processed donor tissues like human pericardium, fascia lata, dura mater and bovine pericardium have been less commonly used due to the high cost.

(b) **Autologous tissue**: These include fascia lata, temporalis fascia, auricularis muscle complex, pericardium, pericranium. The main advantage is that they vascularise rapidly and there is no risk of a foreign body response. However, they require an additional procedure at another site, with prolonged surgical and recovery times. Scarring at the donor site is a concern, especially in cases with fascia lata. Autologous sclera can also be used if enucleation is done for an indication other than a suspected tumour.

(c) **Synthetic mesh**: Vicryl (polyglactin 910) is the most common synthetic material used for wrapping implants. The advantages of synthetic mesh lies in the ease of insertion and attachment of extraocular muscles. It has a multitude of holes to allow good vascularisation. Also, it eliminates the risk of disease transmission and the need for a second surgical procedure for donor tissue, thus bringing down postoperative morbidity. It is easily available, non-antigenic and inexpensive. Another material that has been explored for wrapping implants is Gore-Tex (polytetrafluorothylene).

Wrapping materials make the insertion of implants with rough surfaces easier by reducing the tissue drag and provide volume augmentation (adds 1–1.5 mm to implant diameter); it provides a barrier over the spiculated surface of the implant, though the role of wrapping in reducing implant exposure is debatable. It allows for the precise fixation of the extraocular

muscles over the implant surface and is said to improve the implant motility with smooth movement of the prosthesis. However, wrapping increases the cost of the procedure and there is a theoretical risk of disease transmission when donor tissue is used.

Pegging of Porous Implants

It is a surgical procedure where a hole is drilled into the anterior surface of a porous implant and a polymeric or a metal peg is inserted into this hole which articulates with the prosthesis. Pegging allows for coupling of the orbital implant with the prosthesis, thereby increasing the motility of the artificial eye and hence the overall cosmetic appearance of the patient. Though pegging provides definite improvement in prosthesis motility, it is not widely practiced by many surgeons due to the satisfactory results obtained without pegging. Pegging is done after adequate vascularisation of the porous implant which can be confirmed on contrast enhanced MRI. Fibrovascular ingrowth may occur at different rates in different individuals and an avascular area of the implant may predispose to implant extrusion. Pegging of hydroxyapatite implant can be performed as early as 6 months after the initial surgery. Titanium peg systems are currently preferred as it is biocompatible and better tolerated by soft tissues than the polycarbonate pegs used earlier. A titanium peg (called the "motility coupling post") preplaced in a porous polyethylene implant is a newer concept. The motility coupling post is placed at the time of surgery and is simply exteriorized after 4–6 months, thus eliminating a second procedure of implant drilling.

Though pegging is thought to provide better prosthesis motility, there is not much evidence comparing the motility of pegged versus non-pegged prosthesis. This, coupled with the fact that pegging increases the cost of the procedure considerably, there is a need for repeat surgical procedure and the complications associated with peg like extrusion, infection, granuloma formation, many surgeons do not prefer pegging of the implant. Also, not every patient is a suitable candidate for peg placement. Small children and adults over 65 years or patients with chronic debilitating illness or collagen vascular disease who might not be compliant with follow up and not take adequate care of the peg, are not suitable candidates for peg placement.

Biogenic Implants

Though dermis fat graft is often not considered as a conventional orbital implant, it is an excellent material for implantation in pediatric anophthalmic sockets and fulfills most of the criteria of an ideal implant (Fig. 2). It is a composite biogenic implant, providing volume augmentation, as well as causing expansion of the socket. The extraocular muscles can be sutured to the graft, providing some amount of motility. It is specifically advantageous in children as it can grow with the age of the child, thus allowing for bony socket expansion. Since it an autologous material, chances of infection and exposure

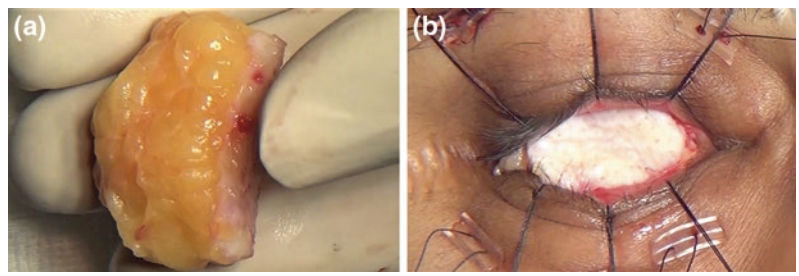

Fig. 2 Dermis Fat Graft for reconstruction of an anophthalmic socket. **a** Graft harvested from gluteal region. **b** Graft being sutured into the socket with fornix formation sutures in place

are minimal. It is also preferred in reconstruction of irradiated socket where the vascularity is compromised and there is a higher possibility of extrusion of alloplastic implant. However, fat atrophy can cause late volume loss in adults implanted with dermis fat graft. Socket discharge and hair growth on the surface of the graft are other problems sometimes associated with dermis fat grafts.

Implant Size

Proper implant sizing is crucial. Implant that provides about 65–70% of volume replacement is ideal, the remaining 35–30% being contributed by the prosthesis. Kaltreider et al. in 2000 noted that the average volume of an enucleated specimen was 7.9 ml and with an implant of 16–18 mm size, a volume deficit of 1.5–2.5 ml remains.

A smaller implant has a higher tendency to displace or migrate and develop superior sulcus deformity. A larger implant is known to improve both cosmesis and motility. However, an inappropriately large implant may produce tension on the conjunctival wound and result in wound gape and implant exposure. Implant sizing has mostly been empirical and is often decided in the operating room. Generally, a 16–18 mm implant is used in infants, 18–20 mm in older children, and 20–22 mm in adults. There are implant sizers that may help gauge the appropriate size. A better technique is to use the axial length of the fellow eye (axial length in −2 mm = implant diameter in mm) to choose the implant size. One should remember to deduct an additional 2-mm from the axial length if the implant is traditionally wrapped but not when the scleral cap technique is used.

Implant Selection

The search for an ideal orbital implant is still ongoing and there is little consensus regarding orbital implant material and design among surgeons. Most surgeons have their own preference about spherical versus shaped implant, integrated versus non- integrated, wrapped versus unwrapped implant. The implant selection is determined by the nature of injury, clinical history of patient, age, experience/opinion of surgeon, cost and whether pegging is planned or not.

The clinical practice followed among ophthalmologists in UK was reported by Viswanathan et al. in 2007. 55% used porous implants, 57% used wrapped implants after enucleation, 20% used salvaged autogenous sclera, 28% used donor sclera and 42% used Vicryl or mersilene mesh. Motility pegs were used only by 7%. The Ophthalmic Technology Assessments by the American Academy of Ophthalmology was prepared after assessing the literature published between 2003 and 2017 to compare the motility and complication rates of porous and non porous implants after enucleation. The literature showed that porous implants are preferred by majority of the surgeons. Incidence of major complications like implant extrusion and infection was found to be low in both groups. Rates of exposure and extrusion were also comparable, with extrusion rates ranging from 0–7% for non porous implants and 0–1.3% for porous implants. There was no motility advantage seen with unpegged porous implants over non porous spheres.

There are special considerations in patients who undergo enucleation for intraocular tumors:

1. The implant should be able to tolerate adjuvant radiotherapy, if indicated, postoperatively;

2. The implant should not impede radiological evaluation for local tumor recurrence.

A PMMA implant is the specific implant of choice in patients being enucleated for intraocular tumors. A porous implant in this situation would have compromised vascularity following radiotherapy, and thus a higher incidence of complications.

Conclusion

The search for the ideal implant has led to the development of many ingenious types and designs of implants. Bioactive glass-based orbital implants which can induce angiogenesis and fibrovascularization by releasing specific ions are a leap into the future. Specific properties can be added to these implants like coating the surface with silver-doped layer which can have antibacterial effect or grafting of biomolecules or drugs to elicit therapeutic effects.

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E. A. El Toukhy (ed.), *Oculoplastic Surgery,* https://doi.org/10.1007/978-3-030-36934-7