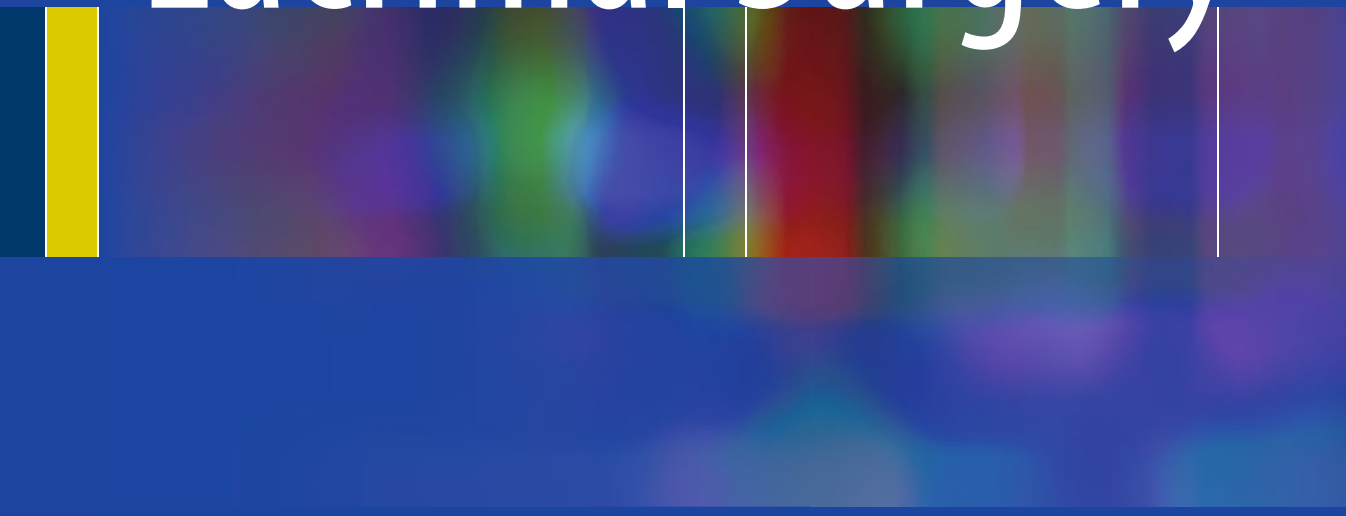
Principles and Practice of Lacrimal Surgery



Mohammad Javed Ali
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Editor
Mohammad Javed Ali, MS, FRCS, FRCGP
Dacryology Service
L.V. Prasad Eye Institute
Hyderabad
India

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Dedicated to my family – Dawood Ali, Qaiser Yasmeen, Farhana Baig, Majid Ali, Rehana Ali, Hafsa Javed, Nabiha Khan, and Jibran Ali

Dedicated to all my mentors and all my patients

Foreword

Over the last 25 years, the lacrimal system has received increasing interest both from the oculoplastic and sinus surgeons. Traditionally, the lacrimal system has been approached through a medial canthal external incision. In the best hands of trained Oculoplastic surgeons, this technique has excellent results. The revival in interest in approaches to the lacrimal system has been driven by the development of the endoscope and increasingly better digital camera systems that allow the anatomy to be both magnified and displayed in crisp detail facilitating delicate and precise surgery. This move in lacrimal surgery mirrors the general surgical move from incisions to minimally invasive surgery with the endoscope playing the central role in this surgical evolvement. The interest in the endoscopic techniques has increased especially among oculoplastic surgeons, as the results with this technique are now at least equivocal and in some publications better than the traditional external techniques.

This book provides an extraordinarily comprehensive reference, starting with historical perspectives, anatomy, and assessment and then going through the many and varied external approaches before moving to an extensive guide on the endoscopic approaches. Finally, an overview of quality of life in lacrimal disorders is provided. The list of contributors is impressive as is their expertise in the chapters which they provide. Worthy additions to the text are a number of chapters on controversial topics in lacrimal surgery, such as the role of mitomycin C, whether the lacrimal system should be routinely intubated after DCR surgery, and the management of common canaliculus strictures.

This text is wide ranging and extensive and covers established knowledge, new ideas, and controversies presented by high-quality contributors with insight and experience and as recognized experts in the field. This book would be a worthy addition to the library of any surgeon interested in lacrimal surgery, allowing them to delve quickly into chapters for valuable insights as well as having it as a major reference text resource. This book is the most valuable contribution to our literature, and the editor and contributing authors are to be congratulated.

Adelaide, SA, Australia — Peter-John Wormald

Prologue

Lacrimal Surgery: Glorious Past, Exciting Present Era, and the Audacity of Hope for a Brilliant Future

> Do not fear to be eccentric in opinion, for every opinion now accepted was once eccentric. – Bertrand Russell (1872–1970)

The evolution of lacrimal disorders and their management amply exemplifies the above stated quote of the twentieth-century British philosopher Bertrand Russell. Lacrimal surgeries has been a subject of discussion in antiquity with the earliest documented reference being a lacrimal sac incision in the "Code of Hammurabi" in 2250 BC [1]. The past which appears glorious today had once travelled through many rough terrains in ancient times nurtured by the Egyptians (Ebers Papyrus – 1500 BC), the Greeks (Hippocrates and Celcus – 25 BC), and the Romans (Galen – 200 AD) [1, 2]. The Arabians chipped in between with their contributions from Ibn Sina and Al Razi in the medieval times. The Modern Dacryology was given impetus with the hallmark anatomical works of Giovanni Morgagni (1682–1771) and Johann Zinn (1727–1759) and equally by the influential lacrimal treatises by Percival Pott (1714–1788) and Johann Schmidt (1759–1809) [3].

"Men love to wonder and that is the seed of science," said the famous nineteenth-century American poet Ralph Waldo Emerson. Lacrimal surgeries have undergone a sea change in the last two centuries. The original Woolhouse technique (1724) of dacryocystectomy underwent numerous changes in techniques and approaches to the present age but with progressively lesser indications. The external dacryocystorhinostomy (DCR) had a steeper evolution for obvious reasons from the times when Addeo Toti (1904) first described it to the current-day practice with various incisions and lacrimal sac implants [4, 5]. With the introduction of rigid endoscopy and better view, endonasal dacryocystorhinostomy showed a steep resurgence into the practice (McDonough –1989) [6], more than a century after its original description (Caldwell – 1893) [7] failed to gain wider acceptance. Endocanalicular laser DCR, however, till the present date has failed to gain widespread acceptance despite numerous modifications since its introduction to dacryology by Levin and Stormogipson in 1992 [8, 9]. Likewise was the journey of trans-conjunctival DCR (CDCR), which evolved into endoscopic and lesser invasive approaches along with numerous Jones tube modifications [10, 11]. Balloon dacryoplasty

has evolved mostly in terms of indications rather than instrumentation or techniques [12, 13].

The present era of lacrimal practice is exciting and, at the same time, challenging. State-of-the-art equipment and mechanisms, including high-definition endoscopic systems, diagnostic and therapeutic dacryoendoscopy, and higher resolution yet safer imaging, are increasingly contributing toward our understanding of the disorders as well as developing minimally invasive surgical options. Many debates today are centered on the approaches to a DCR, ostium size, mitomycin C, and intubation. The recent most meta-analyses have been able to shed much needed light into these areas highlighting their clinical implications [14, 15]. The PEDIG studies have helped greatly in the management of congenital nasolacrimal duct obstructions in terms of clinical decision making and outcomes [16, 17]. There is an increasing focus on canalicular and nasolacrimal duct recanalizations under dacryoendoscopic guidance in an effort to avoid a DCR [18]. Although this mode appears promising, skepticism is very well justified at this stage. The present era is also seeing many attempts to standardize the nomenclatures [19], drug dosage [20], introduction of newer terminologies [21], and paradigm shifts in the understanding of lacrimal anatomy [22, 23]. The armamentarium of a lacrimal surgeon today is more well equipped than any other time, and this very fact brings in more responsibility on us than any other time, to take this forward in every possible way into the future!

The audacity of hope and optimism points toward a brighter future for the patients of tomorrow with lacrimal disorders. However, despite some of the advances highlighted, we still have a long way to go in our understanding and treatment of lacrimal disorders. This would require work on two different fronts with concurrent amalgamation. The first front should be science related, and let the second be related to the surgeon. On the science frontier, the need of the hour is to demystify the etiopathogenesis of lacrimal disorders, primarily that of primary acquired nasolacrimal duct obstruction, or PANDO. It would be inappropriate to continue managing lacrimal disorders mechanically without simultaneous efforts to unravel the elusive etiopathogenesis. The key to this, I believe, lies with the basic sciences. Embryonic studies to look for regulatory proteins influencing lacrimal primordium and sub-adjacent mesenchyme of surface ectoderm during Carnegie stages of development may hold promising clues to understanding of congenital lacrimal disorders. Cytochemical analysis for inflammatory mediators in tears of patients with PANDO and, if the culprits are zeroed in on, the search to pharmacologically block them or their receptors in the lacrimal system may have prophylactic value early on in the disease. Lacrimal immunology work on lacrimal drainage-associated lymphoid tissue (LDALT), its derangements [24], and how differently it behaves from the rest of the immune system should be carried forward to its logical conclusions, as this may have great bearing on our understanding of lacrimal physiology. Other avenues of potential research in the near future include lacrimal system stem cell characterization on similar lines as that of lacrimal gland [25], drug-coated stents, and electron microscopic inter- and intracellular changes in lacrimal disorders.

On the second front, the lacrimal surgeon should not only focus on evidence-based practice but also constantly endeavor to explore avenues to generate evidence. The research potential needs to be unlocked, and academic institutes should strive toward protecting and rearing the endangered species of "clinician-scientists" rather than pure clinicians. The need of the hour is also to cross-specialize where it matters! The lacrimal drainage system has a long course within the nasal cavity, and it is obvious that a good lacrimal work cannot be done without a good anatomical and surgical knowledge of the nose. Although the resurgence of EENT (eye, ear, nose, and throat) specialists may not be desirable due to explosion in the knowledge and vast nature of each subject, the benefits of limited cross-specialization cannot be overemphasized. Cross-specialization also opens up the surgeon to at least some ideas of one specialty that when appropriately extrapolated to the other may have beneficial results. Basic sciences are the key to the future; hence, a very good understanding of the fundamentals of the lacrimal system up to the molecular level would greatly help the lacrimal surgeon in dealing with the disorders both in the lab and the clinic. Efforts should be made on the part of the lacrimal surgeon to perform focused clinical and research work with an emphasis on translational values. The challenge of the future is to set audacious goals and strive hard to achieve them. "We" as lacrimal surgeons need to remind ourselves frequently of our equally important responsibility to advance medicine and hand it over in a better shape to the next generation and probably beyond them. Are we doing enough on these fronts? If not, let us change that from today!

> There is a single light of science, and to brighten it anywhere is to brighten it everywhere. — Isaac Asimov (1920–1992)

Hyderabad, India Mohammad Javed Ali, MS, FRCS, FRCGP

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Contents

Contributors

Mohammad Javed Ali, MS, FRCS, FRCGP Dacryology Service, L.V. Prasad Eye Institute, Hyderabad, India

Peter-John Wormald, FRACS Department of Otolaryngology, Head Neck Surgery, University of Adelaide, Adelaide, SA, Australia

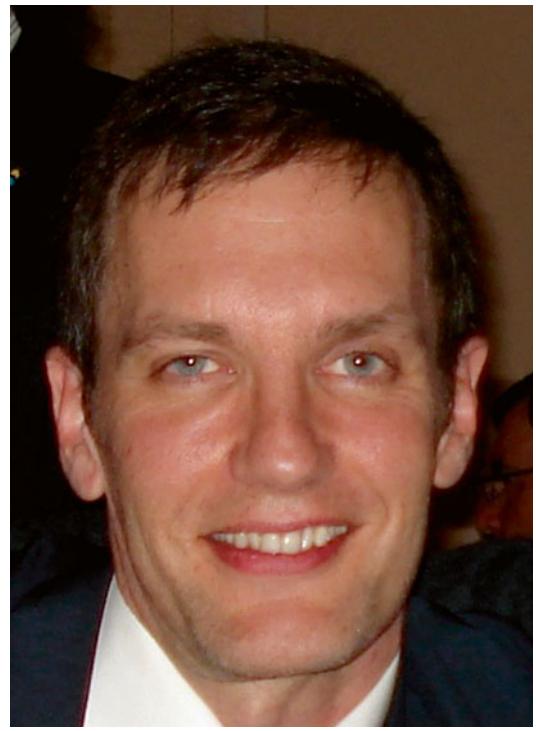
Joseph Brunworth, MD Department of Otolaryngology, University of Adelaide, Adelaide, SA, Australia

Kelvin Kam-Lung Chong, MD Ophthalmic Plastics Surgery, Chinese University of Hong Kong, Sha Tin, New Territories, Hong Kong

Natasha Choudhury, FRCS (ORL-HNS) Department of Otolaryngology, Charing Cross Hospital, London, UK

Sima Das, MS Ophthalmic Plastics Sugery, Schroff Eye Hospital, Delhi, India

Tarjani Vivek Dave, DNB, FLVPEI Ophthalmic Plastics Surgery,
L.V. Prasad Eye Institute, Hyderabad, India



Peter J. Dolman, MD, FRCSC Ophthalmic Plastics Surgery, University of British Columbia, Vancouver, BC, Canada

Yi-fan Feng, MD, PhD Department of Ophthalmology, Zhongshan Hospital and Fudan University, Shanghai, China

Edwin C. Figueira, FRANZCO Ophthalmic Plastics Surgery, Royal Adelaide Hospital, Adelaide, SA, Australia

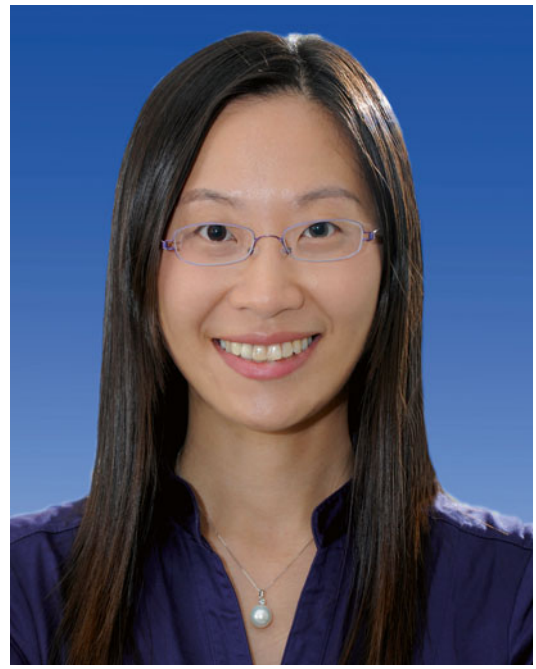
Vinod Gauba, FRCS Ophthalmic Plastics Surgery, Imperial Healthcare Institute, Dubai, UAE

Raoul Paolo D. Henson, MD Ophthalmic Plastics Surgery, Makati Medical Center, Makati City, Philippines

Hirohiko Kakizaki, MD, PhD Department of Ophthalmology, Aichi Medical University, Aichi, Japan

Saurabh Kamal, MD Ophthalmic Plastics Surgery, L.V. Prasad Eye Institute, Hyderabad, India

Pelin Kaynak, MD Ophthalmic Plastics Surgery, Beyoglu Eye Research and Training Hospital, Istanbul, Turkey



Emmy Lee, FRCS Department of Ophthalmology, Chinese University of Hong Kong, Shatin, New Territories, Hong Kong

Andre Litwin, FRCS Oculoplastic Surgery, Queen Victoria NHS Trust, London, UK

Simon N. Madge, FRCOphth Department of Ophthalmology, Wye Valley Trust, NHS, Hereford, UK

Samir Mahapatra, MS Ophthalmic Plastics Surgery, L.V. Prasad Eye Institute, Vishakapatnam, India

Lakshmi Mahesh, MS Department of Ophthalmology, Manipal Hospital, Bangalore, India

Raman Malhotra, FRCS Oculoplastic Surgery, Cadogan Clinic and Queen Victorial NHS Trust, London, UK

Marcus M. Marcet, MD Department of Ophthalmology, University of Hong Kong, Cyberport, Hong Kong

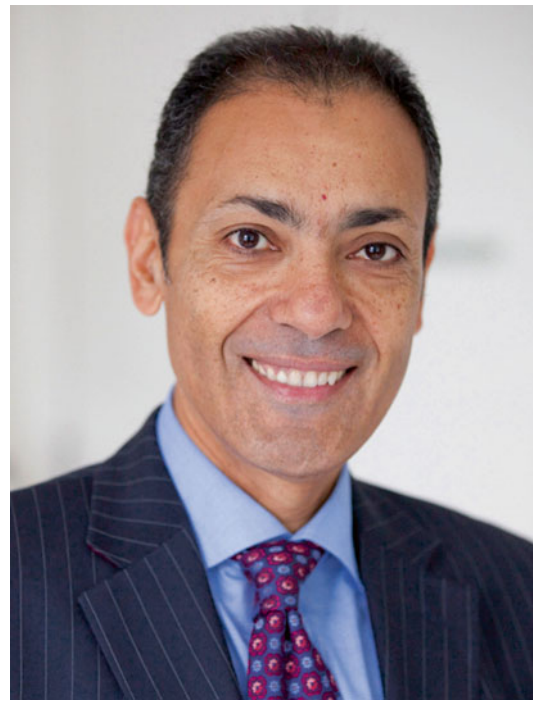
Noelle S. Matta, CO, CRC, COT Department of Pediatric Ophthalmology, Family Eye Group, Lancaster, PA, USA

Milind N. Naik, MD Ophthalmic Plastics Surgery, L.V.Prasad Eye Institute, Hyderabad, India

Alkis James Psaltis, FRACS Department of Otolaryngology, Head Neck Surgery, University of Adelaide, Adelaide, SA, Australia

Qasim Qasem, MD Pediatric Ophthalmology, Imperial Healthcare Institute, Dubai, UAE

Suryasnata Rath, MS, FRCS Ophthalmic Plastics Surgery, L.V. Prasad Eye Institute, Bhubaneswar, India



Hesham Saleh, FRCS, FRCS (ORL-HNS) Department of Otolaryngology, Charing Cross Hospital and Imperial College, London, UK

Dinesh Selva, FRANZCO Ophthalmology and Visual Sciences, University of Adelaide, Adelaide, SA, Australia

David I. Silbert, MD, FAAP Department of Pediatric Ophthalmology, Family Eye Group, Lancaster, PA, USA

Gangadhara Sundar, DO, FRCSEd, FAMS Orbit and Oculofacial Surgery, National University of Singapore, Singapore, Singapore

Aditi Watve, MD Ophthalmic Plastics Surgery, L.V. Prasad Eye Institute, Hyderabad, India

Hunter Yuen, MRCS Department of Ophthalmology, Chinese University of Hong Kong, Shatin, New Territories, Hong Kong

Andrea Zarkovic, FRANZCO Department of Ophthalmology, Wye Valley Trust, NHS, Hereford, UK

Lacrimal Disorders and Surgery: Historical Perspectives

1

Mohammad Javed Ali

Introduction

The evolution of lacrimal surgeries and the understanding of lacrimal disorders has been an amazing journey! From times immemorial, lacrimal disorders have continued to intrigue mankind and pose significant challenges. Tough problems have fortunately met tougher wise men at the right time and the science continued to evolve at a rapid pace. The spectrum of events in this journey can be captured in two wise quotations, one of Sir Isaac Newton (1642–1727) who lauded the culture of each contributor building a higher platform for the subsequent one to fly higher; and of Sir Rudolph Virchow (1821–1905), who not long ago expressed his pain at the diminishing number of students who learn from history in subsequent generations.

> If I have seen further, it is by standing on the shoulders of ye giants. (Sir Isaac Newton).

> It is one of the worst aspects of our present development that historical knowledge diminishes with each generation of students. (Sir Rudolph Virchow).

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute,
Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

Ancient Dacryology

The earliest documented reference to any Ophthalmic plastic surgery is that of an incision to an infected lacrimal sac in the Code of Hammurabi (2250 BC) (Fig. 1.1). The ancient Egyptians document lacrimal sac infections in the Ebers Papyrus (1500 BC) (Fig. 1.2) and recommended a mixture of antimony, wood powder, myrrh, and dried honey, rubbed into the eyes for four days! [1] Hippocrates (460 BC–377 BC) (Fig. 1.3) believed that watery eyes set in an old age and if it turns thicker (discharge), recommended a dried juice of white grapes mixed with copper sulfate [1].

The Greeks made significant contributions in the early days. Most diseases of the lacrimal system were referred to as "fistules." Celcus (25 BC–50 AD) advocated cautery and burning of the system to cure "fistules"! [2] Claude Galen (129–200 AD), a century after Celcus, advocated the use of hot iron to achieve charring of the "fistules" and hence a cure! He believed that puncta evacuates as well as secretes into the eye! [2] However, the most remarkable contribution of Galen (Fig. 1.4) has been his description of causes of epiphora. He documented as follows [2]

> A canal goes from the eyes to the palate and empties there the secretion formed in the eye. Watering may have three causes; either this canal is blocked, or the secretion is excessive or a scar at the nasal canthus. The latter most is incurable.

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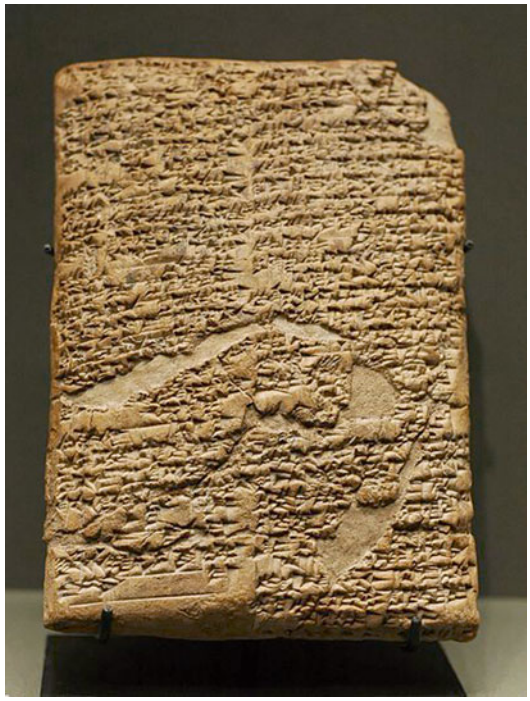

Fig. 1.1 Code of Hammurabi (2250 BC)

Fig. 1.2 Ebers Papyrus (1500 BC)

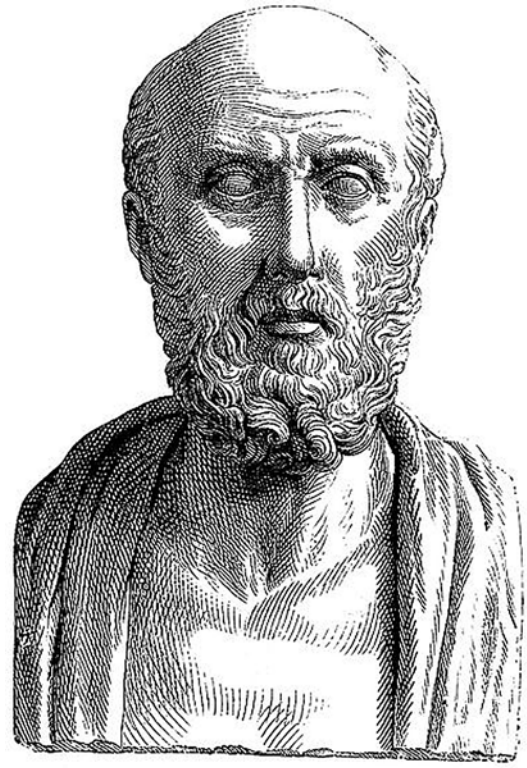

Fig. 1.3 Hippocrates (460–377 BC)

Fig. 1.4 Claude Galen (129–200 AD)

Fig. 1.5 Avicenna (980–1037 AD)

Fig. 1.6 George Ernst Stahl (1660–1734)

Medieval Times and Renaissance

The medieval times as well as the Renaissance were unfortunately a bit laid back as far as the scientific progress related to lacrimal system was concerned. The Arabians chipped in with Rhazes (854–925 AD) evaluating the lacrimal passage further down into the nose and later Avicenna (980–1037 AD) (Fig. 1.5) advocating application of Mongo bean pastes for lacrimal fistulas. Leonardo da Vinci's (1453–1519) and later William Harvey's (1578–1657) embryologic work were notable during these times.

Modern Dacryology

Major Contributors of Early Days

George Ernst Stahl (1660–1734)

Stahl was a German physician (Fig. 1.6), who established nasolacrimal duct obstruction as a cause of dacryocystitis. He also suggested probing using a violin thread!

Dominique Anel (1679–1730)

Anel was a French Surgeon and among the earliest to device a probe and a syringe (Anel's Probes and Syringes) and became famous in 1713 after he treated the Duchess of Savoy for lacrimal fistule in a period of 10 days! [3, 4]

Giovanni Battista Morgagni (1682–1771)

Morgagni was an Italian anatomist (Fig. 1.7) and among the earliest to give a description of lacrimal drainage system. He concluded that there were no valves in this system and the flow was bidirectional! He published his account in the treatise "Adversaria Anatomica Omnia" in 1718.

Lorenz Heister (1683–1758)

Heister was the first to classify lacrimal disorders in 1753. He divided the disorders into four chapters namely: A tearing eye, tumefaction of the lacrimal system, an ulcer of the lacrimal system, and lacrimal fistule. The treatise published in 1753 was named "Chirurgische Wahrnemungen" [5].

Fig. 1.7 Giovanni Battista Morgagni (1682–1771)

John Louis Petit (1664–1741)

Petit explained the flow of tears in the lacrimal system and devised a grooved probe for exploration [6].

Sir William Bowman (1816–1892)

Sir Bowman was an English anatomist and surgeon (Fig. 1.8) and his contributions to lacrimal surgery are many. He described Bowman's probes in 1851, punctoplasty in 1853, and canaliculotomy in 1857 [7].

Joseph Hasner (1819–1892)

Hasner was an Austrian Ophthalmologist who contributed immensely toward lacrimal physiology, mechanics of flow of tears, and devised surgical procedures for treatment of lacrimal fistules. The distal most valve of the lacrimal drainage pathway is named after him.

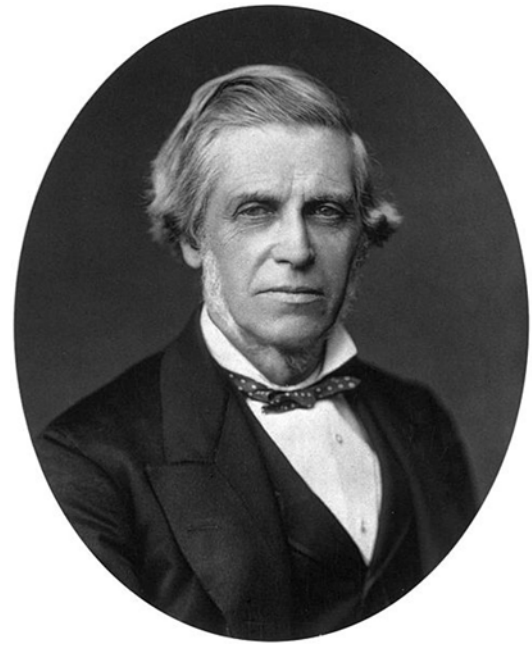

Fig. 1.8 Sir William Bowman (1816–1892)

Influencial Treatise That Paved the Way Early on

Descriptio Anatomica Oculi Humani

This treatise was published in Gottingen in 1755 by the famous German anatomist Johann Gottfried Zinn (1727–1759) (Fig. 1.9). He was among the earliest to describe complete anatomical course of the lacrimal drainage pathway.

Observations on That Disorder of Corner of the Eye Commonly Called Fistula Lacrimalis

Published by Percival Pott (1714–1788), an English surgeon (Fig. 1.10) and one of the founders of orthopedics, this work of his was one of the earliest texts on lacrimal disorders.

Fig. 1.9 Johann Gottfried Zinn (1727–1759)

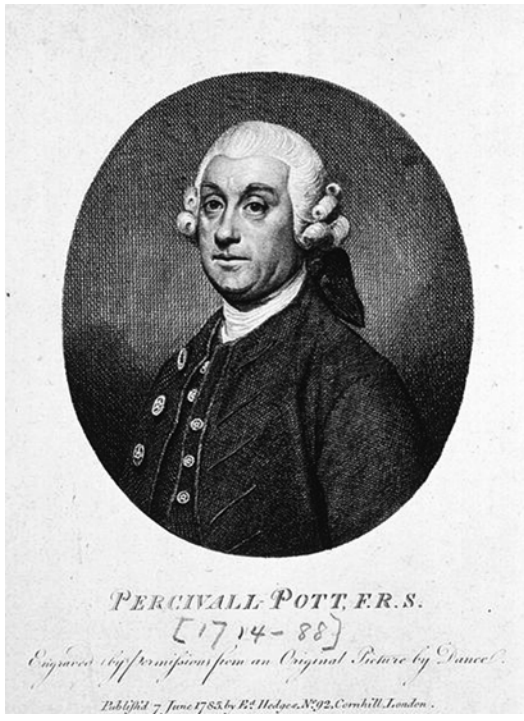

Fig. 1.10 Percival Pott (1714–1788)

Chirurgische Wahrnemungen

This treatise was published in 1753 by Lorenz Heister (1683–1758) and was the first to classify lacrimal disorders into four separate subdivisions. Some of the surgical instruments and their design he published are legendary (Fig. 1.11).

Organic Lacrimalis Pretiumque Externum Oculi Humanos Description Anatomica

This treatise was published in 1797 in Leipzig by Johann Christian Rosenmüller (1771–1820) (Fig. 1.12). In comparison to Zinn's work, this was very specific treatise only on lacrimal system with advance anatomical details.

Comprehensive Text on Lacrimal Disorders

Johann Adam Schmidt (1759–1809) was the first to bring out an influential treatise on lacrimal system in German and was published on copper plates!

History of Dacryocystectomy (DCT)

The earliest ways of dealing with lacrimal sac infections have been to burn or char it down with help of molten lead or iron [1, 2], which is practically destroying the lacrimal sac. The first refined way of surgical dacryocystectomy can be traced back to John Thomas Woolhouse in 1724 [8]. Johannes Platner (1694–1747) practiced Woolhouse's technique and described DCT with trephination of lacrimal sac and cautery [8]. Most of these surgeries were incomplete and obviously unintentional because of incomplete knowledge of anatomical details. The modern DCT was described by Rudolph Berlin (1833–1897) (Fig. 1.13) in 1868 and he documented [8, 9] as follows:

> Dacryocystectomy is the principal operation against incurable epiphora. It is the main protection against corneal abscess and purulent infections against cataract.

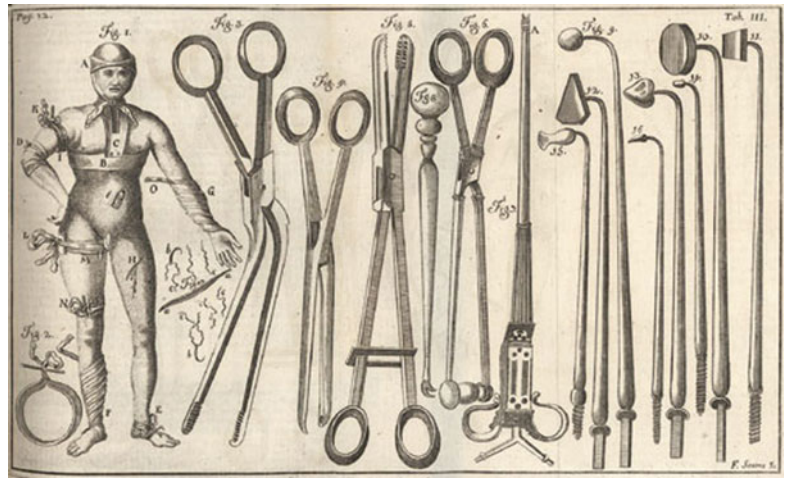

Fig. 1.11 Surgical instruments of Lorenz Hiester (1683–1758)

Fig. 1.12 Johann Christian Rosenmüller (1771–1820)

Fig. 1.13 Rudolph Berlin (1833–1897)

Although not much progress has been made in surgical advancement of dacryocystectomy, its indications have become limited but much more refined today [10].

History of Dacryocystorhinostomy (DCR)

Dacryocystorhinostomy is among those surgeries, whose fascinating history is paralleled by only a few in medicine. It has tremendously evolved in techniques, instrumentation, and above all the approaches! The earliest attempts to create a communications can be traced back to John Thomas Woolhouse (1650–1734), who described extirpation of sac, perforation of lacrimal bone, and insertion of drains made of gold, silver, or lead. Antonio Scarpa (1752–1832), an Italian anatomist (Fig. 1.14), designed a lead nail, slit the lacrimal sac, and introduced it in a 50-year-old woman, who died in 4 days following surgery [11], possibly because of tetanus or septicemia! Around the same time Dupuytren (1777–1835) designed a gold tubule for similar purpose but the patient had

Fig. 1.14 Antonio Scarpa (1752–1832)

a palatal perforation and suffocation [11]. Laguier attempted to drain the sac into maxillary antrum in 1830 [12, 13].

Endonasal DCR was first conceptualized by Caldwell in 1893 [13, 14]. John West in 1914 modified this technique by creating a bony window within lacrimal and maxillary bone to clear the area of lacrimal sac and nasolacrimal duct into the middle meatus [13, 15]. Rice first introduced the concept of endoscopic endonasal DCR in cadavers in 1988 and showed its feasibility as a good alternative to an external DCR [16]. McDonogh and Meiring in 1989 introduced endoscopic endonasal DCR in patients [17] and since then there was no looking back for the endoscopic approach! The techniques have refined and newer adjunctive technologies have evolved since 1989. Powered and mechanical endoscopic DCR was described by Peter-John Wormald in 2002 [18].

External DCR was described by Italian rhinologist Addeo Toti in 1904 with a 35-mm incision where both the medial wall of the sac as well as nasal mucosa were excised [19]. Significant change to this procedure happened soon in 1920 when Dupuy-Dutemps and Bourguet introduced creation of lacrimal sac and nasal mucosal flaps with suturing to create an epithelium lined fistula [20]. Very few modifications have happened since then for example by Viers in 1969 [21] and Iliff in 1971 [22].

Other approaches for a DCR mostly evolved much later [23]. Bruce Massaro in 1990 introduced endoscopic laser-assisted DCR using Argon-blue laser in cadavers [24]. Shortly thereafter in 1992, Levin and Stormogipson introduced endocanalicular laser-assisted DCR in cadavers [25] and later Silkiss introduced it in patients in 1992 [26]. Subsequently various different types of lasers have been used for the bone removal [27, 28]. Endoscopic radiofrequency-assisted DCR as a different technique was introduced by Reynaldo Javate in 1995 [29]. Ultrasonic DCR was first performed by Krasnov in 1971 [30] and reintroduced in 2005 by Sivak-Callcott [31] and has subsequently generated some interest. A 9-mm balloon DCR was pioneered by David Silbert. [32]

Conjunctivodacryocystorhinostomy (CDCR) was introduced by Von Hoffman in 1904 by opening the lacrimal sac and suturing it to conjunctiva without a stent [33]. Lester Jones described CDCR with Pyrex Jones tubes in 1962 [34]. Subsequently various stents and their modifications as well as buccal mucosa and vein grafts were used [35].

History of Other Lacrimal Surgeries

Interventional radiological procedures for nasolacrimal duct dilatation were described by Hanafee and Dayton in 1978 using the sialography cannulas and fluoroscopic guidance [36]. Dacryoendoscopy was introduced by Junemann in 1975 [37]. Becker and Berry introduced balloon dacryoplasty in 1989 [38] and in the same year Busse conceptualized microdrill dacryoplasty [39]. Canalicular obstructions beyond proximal canaliculi are usually managed by trephination, and modern canalicular trephines were introduced by Hampson Sisler in 1990 [40].

In conclusion, it is very important to know the depths of history, at least in the area of one's expertise and this helps greatly in innovating further and advancing medicine. The take home message can be summarized in the words of Dr Paul Litcher, the President of the American

Academy of Ophthalmology in its centennial year, who said:

> Ophthalmic History must be taught in our residency programmes and a must read for all Ophthalmologists as too few of our students revere history and the lessons it can provide.

Note The photographs used are courtesy of Wikipedia

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Embryology of the Lacrimal Drainage System

2

Mohammad Javed Ali and Hirohiko Kakizaki

Introduction

The understanding of lacrimal embryology is very crucial to the understanding of lacrimal anatomy and its subsequent surgical applications. In addition, numerous congenital anomalies of the lacrimal system and their appropriate management largely depend on a sound knowledge of evolution. A thorough insight of lacrimal embryology is essential for advancing this science in terms of fundamental reasoning and developing minimally invasive interventions.

The human embryonic period generally covers the first 8 weeks postovulation, after which the embryo is called the "fetus" [1]. The moment when an embryo transforms into a fetus is not clearly determined, though [2] main parts of the human body are formed simultaneously during the embryonic period, and the lacrimal system is roughly completed by the first 10 weeks postovulation [2]. The structure itself does not change largely after that. The lacrimal drainage system can be broadly divided into embryonic and fetal developments for a lucid understanding.

M. Javed Ali, MS, FRCS, FRCGP (✉)
Dacryology Service, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 500034, India

H. Kakizaki, MD, PhD
Department of Ophthalmology, Aichi Medical University, Aichi, Japan

Lacrimal Drainage System Development During Embryogenesis

The lacrimal passages develop along the line of cleft between the maxillary process and the lateral nasal process. From its inception, the maxillary process grows much rapidly in comparison with the lateral nasal process and subsequently overlaps the paraxial region around the eye, leading to formation of a fold of ectoderm between the processes (Fig. 2.1) [1, 2].

Embryonic development is estimated with the help of Carnegie stages [3]. Carnegie stages have been named after Carnegie Institute of Washington, which began collecting and classifying embryos in the early 1900s. The Carnegie stages divide the human embryonic period to 23 stages [3]. Criteria beyond morphological features include range of age in days, number of somites present, and embryonic crown rump lengths (CRL) [3].

The development of the lacrimal system begins at Carnegie Stage 16 (CRL: 11 mm), when an epithelial thickening of the lacrimal groove forms the lacrimal lamina [4]. At Carnegie Stage 19 (CRL: 17 mm), the lacrimal lamina separates from the surface ectoderm and forms the lacrimal cord [4]. The lateral extreme of the cord closest to the surface ectoderm bifurcates, thus giving rise to the canaliculi (Fig. 2.2) [4]. At Carnegie Stage 20 (CRL: 19–21 mm), the lacrimal cord is arranged lateral to the nasal capsule and finally lateral and inferior to the inferior meatal lamina [4].

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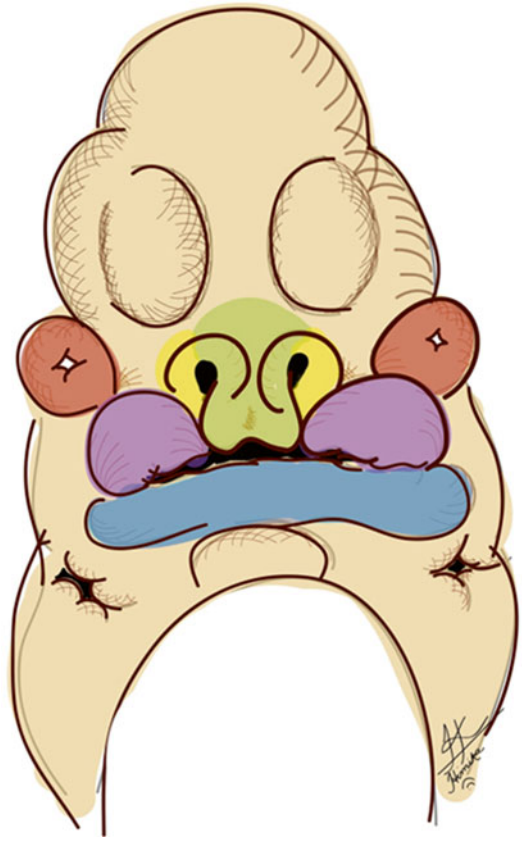

Fig. 2.1 Schematic diagram showing the development of lacrimal system between the maxillary and fronto-nasal process (Photo Courtesy: Dr Himika Gupta)

At Carnegie Stage 22 (CRL: 26 mm), the proximal portion of the lacrimal system is perfectly differentiated, although it does not have a lumen as yet. The surrounding mesenchyme starts condensing [4]. The cells of the lacrimal cord condense at its periphery but are more loosely organized as we explore the interiors toward the future lumen [4]. At the end of the embryonic period (Carnegie Stage 23, CRL: 27–28 mm), morphology of the lacrimal system is well developed [4]. The lateral portion of the lacrimal system is clearly differentiated into the superior and inferior lacrimal canaliculus proximally and the lacrimal sac distally [4]. The canaliculi are close to the conjunctiva [5]. The medial portion of the lacrimal cord continues caudal and lateral to the inferior meatal lamina although the epithelia have not yet joined [4].

Lacrimal System Development During Fetal Period

From the 10th week (CRL: 48–55 mm), various significant changes occur such as canalization of the lacrimal cord and development of the surrounding tissues (Fig. 2.3) [4, 5]. Canalization occurs at the same time throughout the nasolacrimal

Fig. 2.2 Schematic diagram showing the outbudding of solid canaliculi from the lacrimal cord (Photo Courtesy: Dr Himika Gupta)

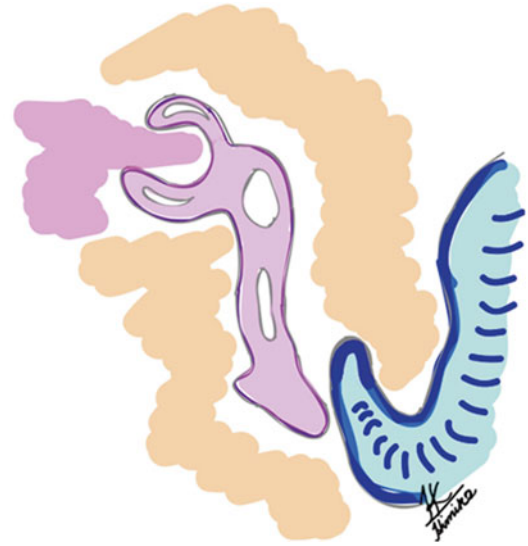

Fig. 2.3 Schematic diagram showing the process of canalization (Photo Courtesy: Dr Himika Gupta)

apparatus [5]. The canalicular epithelium comes in contact with the palpebral conjunctival epithelium and both epithelia form a continuous epithelial lamina [4]. The caudal extreme of the lacrimal duct and the inferior meatal lamina makes contact and the latter begins to cavitate [1, 2, 4]. Central cells toward the lumen possibly undergo apoptosis and subsequently degenerate and shed off leaving a clear lumen behind. Muscular fibers of the Horner's muscle are observed to surround the lacrimal canaliculi and mesenchymal tissue is interposed between the canaliculi and the muscle fibers [1, 2, 4, 5]. During the 12th week of development, reabsorption of the inferior meatal lamina is clearly visible (CRL: 74 mm). After the 13th week of development (CRL: around 85–90 mm), the surrounding tissues of the lacrimal apparatus such as ligament and tendon are clearly formed [4].

Although the canalicular lumina become patent by the 4th month after gestation, the lacrimal puncta do not open onto the eyelid margins until the eyelids separate during the 7th month [1, 2]. However, the lower end of the duct is often separated from the inferior meatus at birth by a membrane constituted by the apposed mucosal linings of the lower ductal end and the nasal fossa. Only in 30 % is the lowermost end patent at birth [1, 2]. An obstruction at this site balloons out later into the inferior meatus and its opening mostly occurs after birth [1, 2].

Clinco-Embryological Correlations

Position of the Puncta

The inferior punctum lies 0.5–1.0 mm more temporally than the superior one, so that they do not superimpose during eyelid closure [1, 2]. This anatomy has embryological explanations and results because of a relative rapid growth of the maxilla compared to that of the frontal bone [1, 2]. The lacrimal caruncle has been shown to be in close relation to the lower eyelid developmentally and its supero-temporal margin smoothly continues in level with the lower eyelid margin [6], and hence is a reasonable guide to lead to and judge a normal punctal position.

Ectopic Canaliculus and Caruncle

The lacrimal caruncle contains sebaceous glands and hairs and an ectopic canaliculus occasionally opens to the caruncle [7]. The reason for this is the common developmental origin of lower eyelid and the caruncle (Fig. 2.4) [1, 2, 6].

Punctal Agenesis

The basic etiopathogenesis of punctal agenesis is likely to be failure of canaliculi outbudding from the upper end of the solid lacrimal cord in an embryo of 18–24 mm (Fig. 2.5) [1, 2]. Punctal

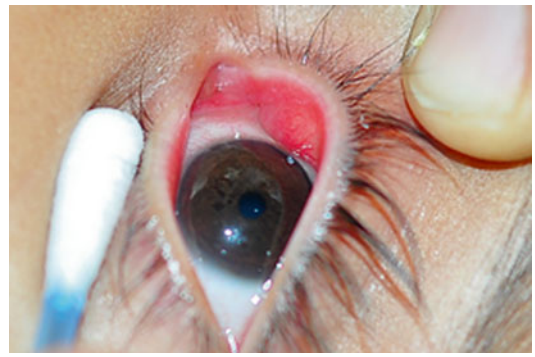

Fig. 2.4 Ectopic canalicular opening near caruncle

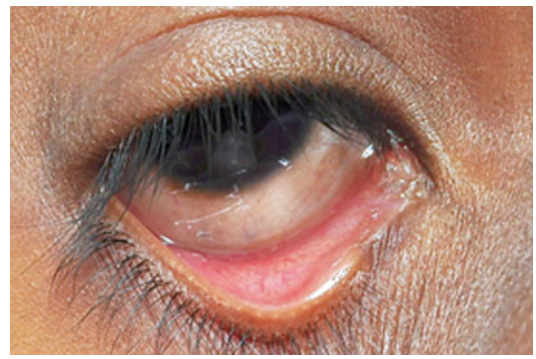

Fig. 2.5 Lower punctal agenesis associated canalicular agenesis. Note the atrophy of area over the lower canaliculus

Fig. 2.6 Incomplete punctal canalization of external membrane variety (IPC-EM)

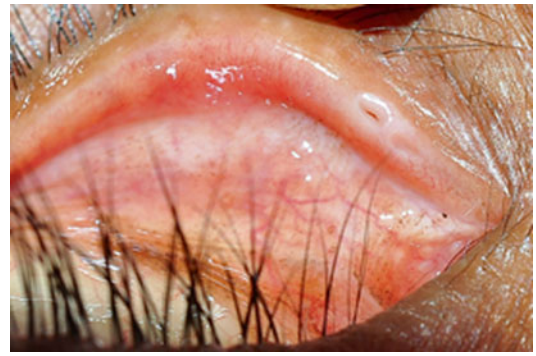

Fig. 2.7 Supernumerary puncta

agenesis has important associated ocular and systemic associations. Lyons et al. [8] found 23 % of their cases ($n=57$) to have ocular abnormalities like lacrimal fistula, blepharitis, distichiasis, eyelid tags, absence of caruncle, and divergent strabismus. Punctal agenesis has well-known association with systemic syndromes like ectodermal dysplasia [1, 9], Hay-Wells [9], and Levy-Hollister syndromes [10].

Incomplete Punctal Canalization (IPC)

Incomplete punctal canalization is a term that refers to a form of punctal dysgenesis with membranes (Fig. 2.6) [11]. The pathogenesis of punctal membranes is unknown but is believed to either represent failed dehiscence of epithelium overlying the normally formed canaliculi or failure of canalization of the most proximal part of lacrimal apparatus. This dysgenesis is not found to have any systemic association although associated lacrimal system anomalies like canalicular stenosis and congenital nasolacrimal duct obstruction are reported [11].

Canalicular Agenesis

This results from failure of outpouching of epithelial buds from the upper end of lacrimal cord or abrupt halt in migration toward eyelids immediately following outpouching. Canalicular agenesis is associated with punctal agenesis (Fig. 2.5) [12].

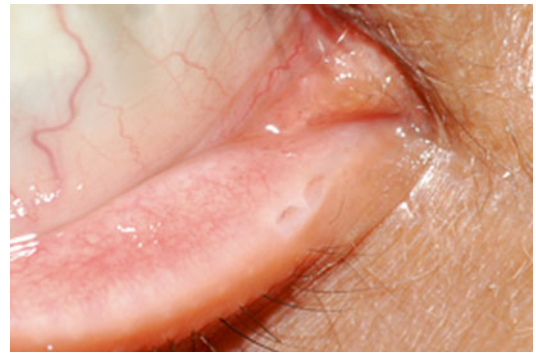

Fig. 2.8 Supernumerary or double puncta in this case

Supernumerary Puncta and Canaliculi

These may result from multiple epithelial buds developing from the upper end of lacrimal cord in a 18–24 mm embryo (Figs. 2.7 and 2.8) [12]. Wicherkiewicz estimated the incidence of supernumerary puncta and canaliculi to be 1 in 60,000 [13]. These are known to be associated with lacrimal fistula and lacrimal sac diverticulum. Systemic associations known are Down's syndrome and preauricular sinus [14].

Canalicular Wall Dysgenesis

Canalicular wall dysgenesis and its eight subtypes have been recently described (Fig. 2.9). Its etiopathogenesis is unknown but is believed to represent dysregulation of mesenchymal condensation

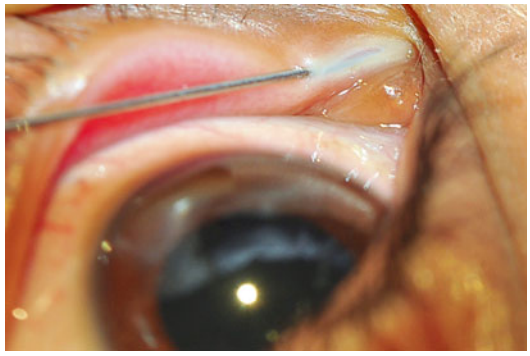

Fig. 2.9 Single canalicular wall dysgenesis (Hypoplasia type)

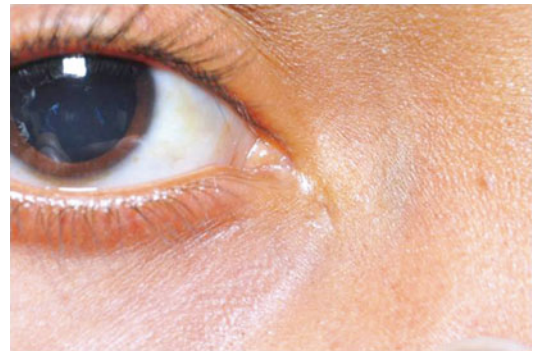

Fig. 2.11 A classical congenital fistula

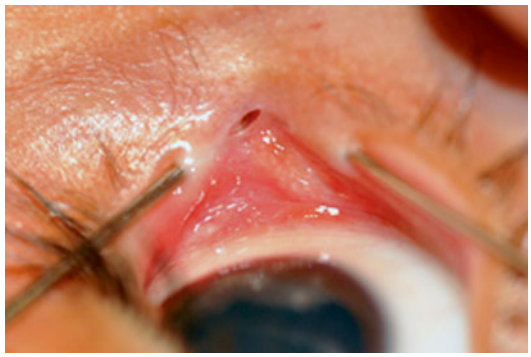

Fig. 2.10 Lacrimal sac fistula

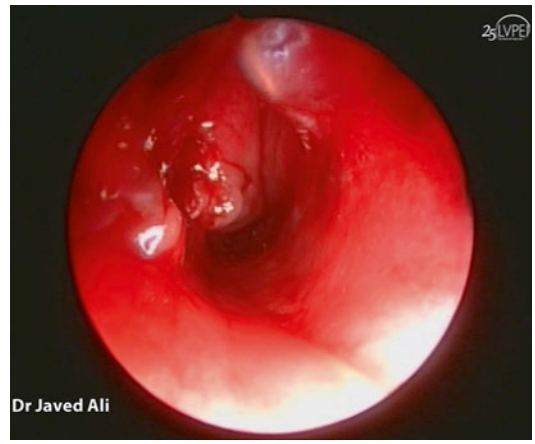

Fig. 2.12 Endoscopic view of a buried probe

around the canalicular primordium and its contiguity with the subadjacent mesenchyme of the surface ectoderm during Carnegie Stage 19 of embryonic development [15].

Lacrimal Anlage Duct or Lacrimal Fistula

Lacrimal fistula is an accessory or an anlage duct communicating with the skin on one side and the canaliculus, lacrimal sac, or nasolacrimal duct on the other (Figs. 2.10 and 2.11). These result from abnormal embryological development at the optic end of the naso-optic fissure, whereby there are additional outbudding from the embryonic lacrimal epithelial cord or an epithelial core is not completely separated from the surface ectoderm. Autosomal dominant inheritance pattern has been reported for congenital lacrimal fistulas [16].

Nasolacrimal Duct Variations in Congenital Nasolacrimal Duct Obstruction

1. Nasolacrimal duct does not open into inferior meatus and may end abruptly onto the vault of the meatus or get buried in the lateral wall (Fig. 2.12) [17].
2. Nasolacrimal duct ending blindly into the inferior turbinate.
3. Nasolacrimal duct ending blindly into the medial maxillary sinus wall.
4. Nasolacrimal duct ending in a bony, noncanalized nasolacrimal canal.
5. Absence of nasolacrimal duct [17]

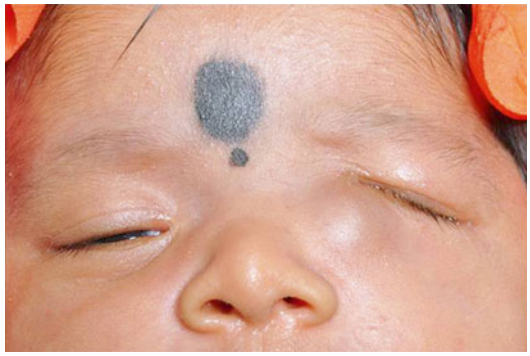

Fig. 2.13 Congenital dacryocele

Fig. 2.14 Right lacrimal sac diverticula presenting as mucocele

Congenital Dacryocele

The pathogenesis in dacryocele is believed to be persistent noncanalization of the lower end of nasolacrimal duct (NLD) along with a functional obstruction at the valve of Rosenmüller [18]. This is thought to cause sufficient pressure to dilate the entire sac (Fig. 2.13) and in many cases the nasolacrimal duct, leading to an intranasal cyst.

Lacrimal Sac Diverticula

Lacrimal diverticulas are cystic outpouchings, mostly communicating with the lacrimal sac [19]. An abnormal cellular cord stem from the lacrimal sac region during embryogenesis could contribute to diverticula. The infero-lateral wall of the sac is a common area for the diverticula, since resistance to any expansion is least in this region as compared to other walls which have support of the periosteum and orbicularis. Diagnosis is usually by a plain dacryocystography (DCG) or by a CT or MR-DCG and excision is performed with specific techniques for symptomatic cases (Figs. 2.14 and 2.15) [19, 20].

Congenital Absence of Lacrimal Valves

Absence or defective development of the lacrimal valves may result in few uncommon conditions. Absence of the valves in the nasolacrimal duct

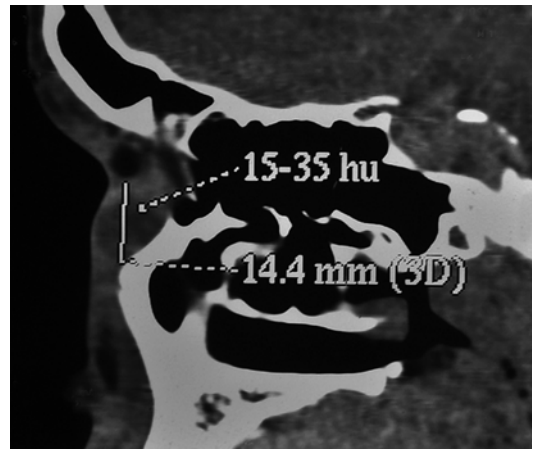

Fig. 2.15 CT scan, sagittal reconstruction showing the diverticula

may result in pneumatoceles of the sac secondary to retrograde passage of air. Absence of valve of Rosenmüller along with Hasners may result in passage of air from the nose onto the ocular surface [17].

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3 Anatomy, Physiology, and Immunology of the Lacrimal System

Hirohiko Kakizaki

Introduction

Lacrimal surgery is performed to reconstruct an appropriate lacrimal drainage and its success depends on how much the anatomy is understood. We describe here the anatomy and physiology of the lacrimal system, and also refer to its embryology and immunology.

Anatomy of the Lacrimal Punctum

The lacrimal punctum lies on a small fibrous mound, called the "lacrimal papilla" (Fig. 3.1). Diameter of its opening is 0.2–0.3 mm and directs somewhat posteriorly toward the lacrimal lake [1–6]. The puncta are round or oval in youth but often collapses into fish-mouth or slit configuration with age [6]. The inferior punctum lies 0.5–1.0 mm more temporally than the superior one, because the maxillary process in embryonic life grows faster than the lateral nasal process [1, 2]. The inner epithelium is nonkeratinized stratified squamous epithelium [7, 8]. No meibomian glands exist medial to the papillae, and most medial meibomian orifices are situated at 0.5–1.0 mm lateral to the puncta [6].

H. Kakizaki, MD, PhD
Department of Ophthalmology,
Aichi Medical University, Aichi, Japan
e-mail: cosme_geka@yahoo.com.jp

Anatomy of the Lacrimal Canaliculus

The lacrimal canaliculus is divided into the vertical and horizontal portions [1, 2, 6]. Its transitional part occasionally dilates to form an irregular dilated cavity or ampulla (Fig. 3.2) [6]. The length of the vertical portion is 2 mm and that of the horizontal part is 10 mm [6]. The medial most 2 mm of the horizontal portion mostly forms the common duct or canaliculus [5, 9], and more than half of this part runs in the wall of the sac. The punctum and vertical canaliculus are encircled by a similar hard fibrous tissue. This fibrous tissue in the vertical canaliculus contains skeletal muscle fibers, called the muscle of Riolan (Fig. 3.1) [10]. The epithelium of the canaliculus is a nonkeratinized stratified squamous epithelium, similar to the punctum (Fig. 3.3) [10]. As the canalicular wall contains much elastic fibers (Fig. 3.4), its diameter can be changed to enlarge or shrink as needed. Although the diameter of the canaliculus is usually 0.3–0.6 mm [1, 8], it can be expanded to over 1.0 mm. The temporal 4/5 part is directed posteronasally and surrounded by the Horner's muscle, occasionally called the lacrimal part of the orbicularis oculi muscle (Fig. 3.5) [8]. In the nasal 1/5 part, the Horner's muscle directs posteriorly away from the canaliculus (Fig. 3.5) [8]. Although the canaliculus usually directs anteronasally after separation from the Horner's muscle (Fig. 3.5), it occasionally directs posteronasally in cases with proptosis (Fig. 3.6) [8]. The superior canaliculus

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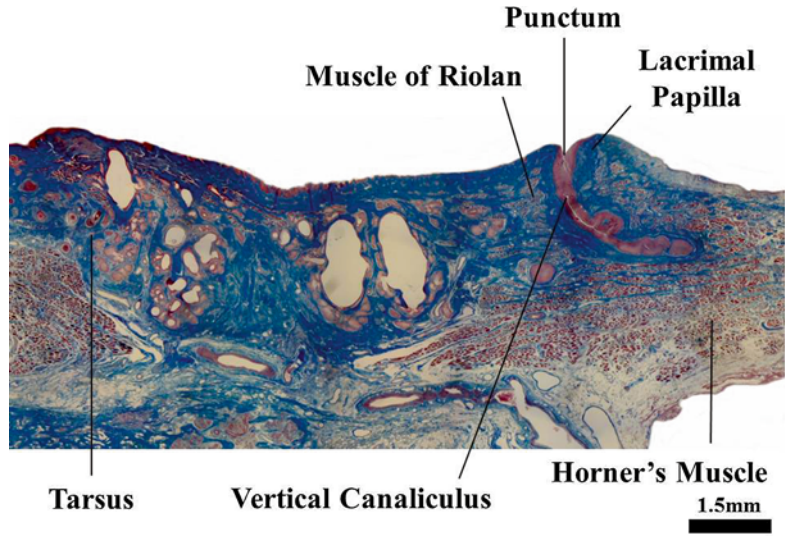

Fig. 3.1 Anatomy of the lacrimal punctum and its surrounding tissues. This section is performed parallel to the tarsal plate (Masson's trichrome stain)

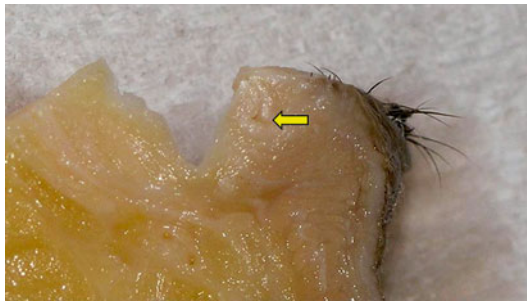

Fig. 3.2 Gross anatomy of the ampulla of a lacrimal caruncle. A left lower eyelid sagittally incised. *Yellow arrow* – ampulla

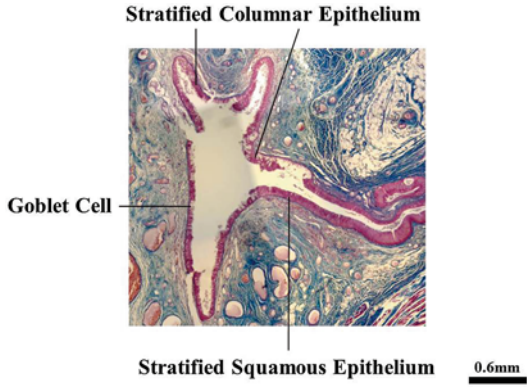

Fig. 3.3 Epithelia of the lacrimal caruncle and the sac. The canaliculus shows a nonkeratinized stratified squamous epithelium and goblet cells in part. This specimen demonstrates the stratified columnar epithelium extending to the canaliculus (Masson's trichrome stain)

courses, in general, almost straight to the internal common ostium, but the inferior canaliculus changes the course superiorly before joining the superior canaliculus. The course of the inferior canaliculus to be independently emptying into the sac has not been known so far.

Anatomy of the Common Lacrimal Canaliculus

More than 95 % of the upper and lower canaliculi join to become the common canaliculus to reach the common internal ostium [5, 11]. The canaliculi empty into the sinus of Maier (Fig. 3.7) and those independently pouring into the sac are <2 % [11]. Sinus of Maier needs further elaboration. The common internal ostium is the part where the common canaliculus pours to the sac. However, the common canalicular cavity does not simply connect with the sac lumen. A laterally bulged portion of the sac, called the sinus of Maier, is occasionally formed around the common internal ostium and some canaliculi empty to this portion (Fig. 3.7) [11]. An expanded common canaliculus can also be called the sinus of Maier (Fig. 3.4) [11].

The common canaliculus has a nonkeratinized stratified squamous epithelium. However, the

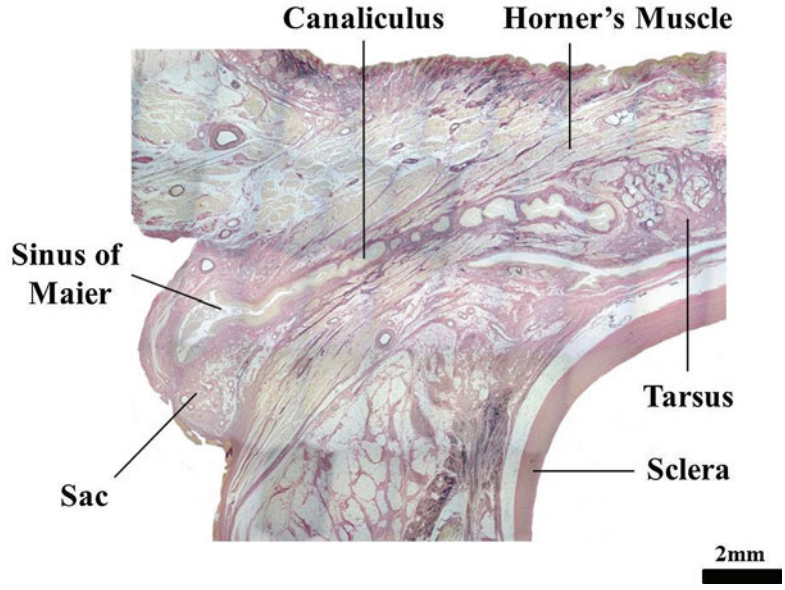

Fig. 3.4 Elastic fibers of a canalicular wall. This specimen contains a lot of elastic fibers in the canalicular wall. A sinus of Maier is shown here, into which the canalicular part is expanded (Elastica van Gieson stain)

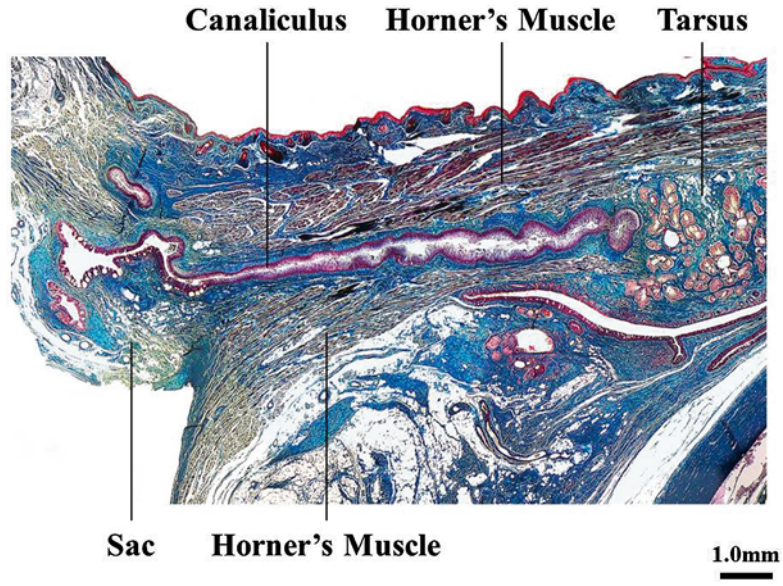

Fig. 3.5 Relationship between the lacrimal canaliculus and the Horner's muscle (Masson's trichrome stain)

transitional area with the stratified columnar epithelium of the sac with some goblet cells is occasionally seen in the common canaliculus (Fig. 3.3) [8]. To the contrary, the stratified squamous epithelium of the common canaliculus sometimes extends to the sac lumen (Fig. 3.8) [8].

A protuberance (fold) is shown, although only a half of cases [9], at the junction between the common canaliculus and the sac [12]. This structure is called the valve of Rosenmüller [5, 6]. The common internal ostium largely opens by temporal traction of the Horner's muscle during eye closing, but there is a nasal movement of the ostium as well [13]. Therefore, the part around the common internal ostium needs a structure dealing with this nasal movement and this may be the real reason for a valvular presence in this region. The sinus of Maier could have also been evolved for the same reason.

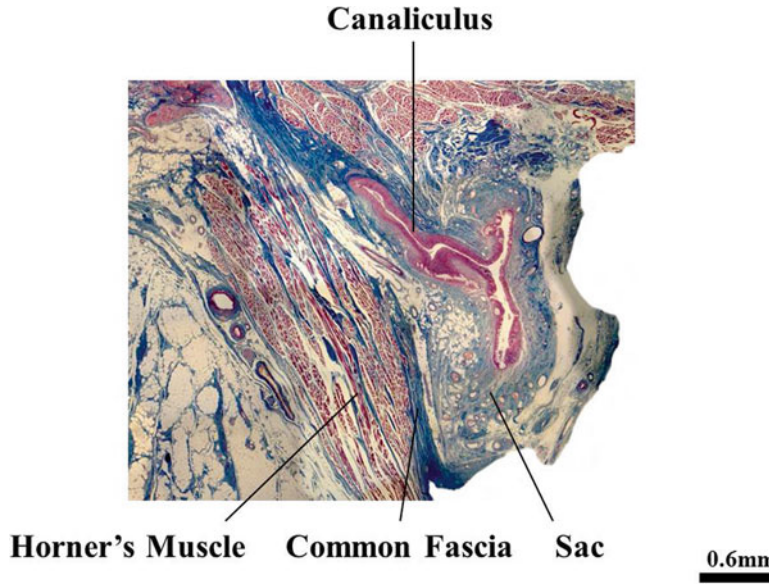

Fig. 3.6 Connection of common lacrimal canaliculus to sac. A common canaliculus occasionally empties into a sac from superiorly. A common fascia is seen between the sac and the Horner's muscle (Masson's trichrome stain)

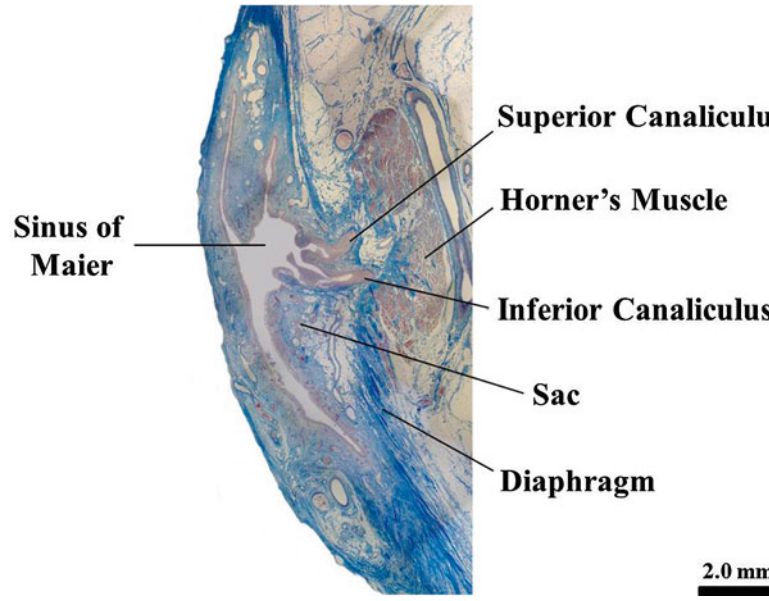

Fig. 3.7 A sinus of Maier, in which a part of sac is expanded. The superior and inferior canaliculi separately empty into the sinus of Maier (Masson's trichrome stain)

Anatomy of the Lacrimal Sac and Its Fossa

The lacrimal sac and the nasolacrimal duct are a continuous structure [14]. The part within the lacrimal sac fossa is called as the "sac," and the part inferior to the superior opening of the nasolacrimal canal is the "nasolacrimal duct." [14] The part of the sac superior to the medial canthal tendon (MCT) is called the fundus, with its vertical length of 3–5 mm [14]. The body of the sac, inferior to the MCT, is about 10 mm in length. The epithelium of the sac is a stratified columnar epithelium (Figs. 3.3, 3.6, and 3.8) [15] and contains goblet cells, cilia, and serous glands [16]. The epithelial surface shows microvilli [17, 18]. Although the sac wall is constituted with a cavernous structure, it is fairly thin and less

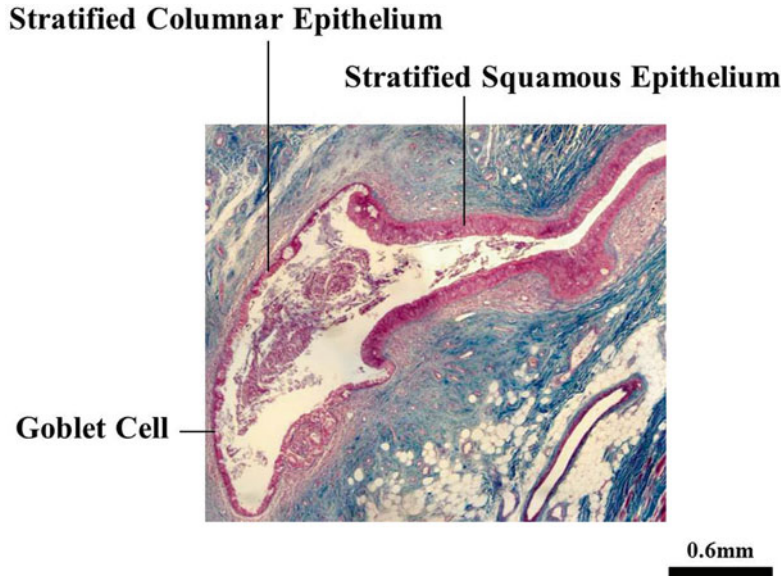

Fig. 3.8 Connection of common lacrimal canaliculus to sac. A stratified squamous epithelium in a canaliculus occasionally extends into a sac (Masson's trichrome stain)

developed than that of the nasolacrimal duct [16, 19]. The lateral aspect of the sac wall is covered by a fascia, and its posterior portion is a common fascia with the Horner's muscle (Fig. 3.6), which is called the "lacrimal diaphragm" [14].

The lacrimal sac fossa comprises of the anterior frontal process of the maxillary bone and the posterior lacrimal bone [9]. There are ridges anteriorly and posteriorly, which are called the anterior or posterior lacrimal crest, respectively (Fig. 3.9) [5]. The suture between the maxilla and the lacrimal bone is situated in various ways, and some take its site close to the posterior lacrimal crest. A process is formed between the inferior portion of the posterior lacrimal crest and the orbital face of the maxilla, which is called the hamular process (Fig. 3.10) [6]. A groove is shown nasal to the anterior lacrimal crest which is called the sutura notha [5], sutura longitudinalis imperfecta [6], or pseudo-suture [20]. It is not considered as a true suture but a vessel groove formed by a branch of the inferior orbital artery [9].

The superoinferior length of the lacrimal sac fossa is 12–15 mm, anteroposterior 4–9 mm, and the width 2–3 mm (Figs. 3.9 and 3.10) [9]. The lacrimal sac fossa shows shorter anteroposterior length superiorly [21, 22]. As the lacrimal sac fossa opens temporally, the sac lumen is usually large enough. The long axis of the fossa inclines

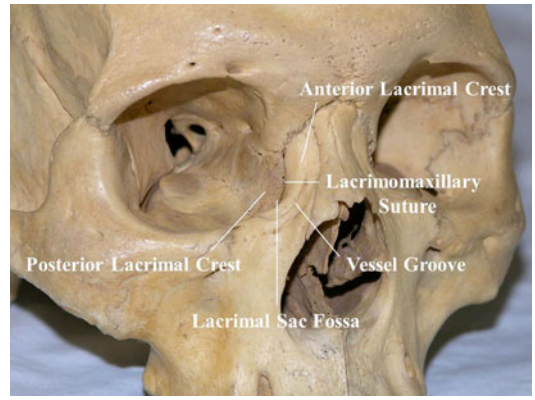

Fig. 3.9 Anatomy of lacrimal sac fossa and its surrounding tissues

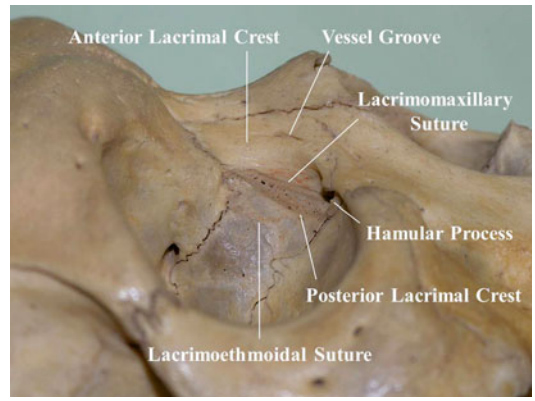

Fig. 3.10 A right lacrimal sac fossa, seen from temporally

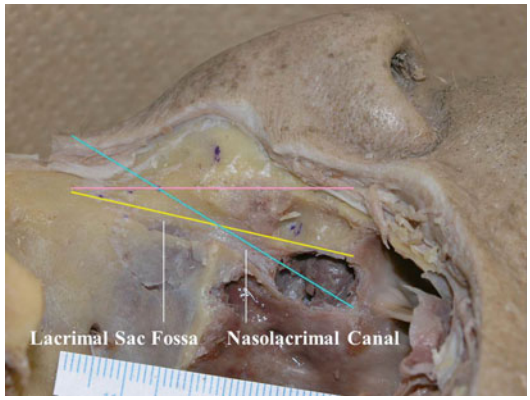

Fig. 3.11 A posterior inclination of lacrimal sac fossa and nasolacrimal canal. The nasolacrimal canal inclines more posteriorly than the lacrimal sac fossa. *Line Pink*: base line, *Line Yellow*: long axis of lacrimal sac fossa, *Line Blue*: long axis of nasolacrimal canal

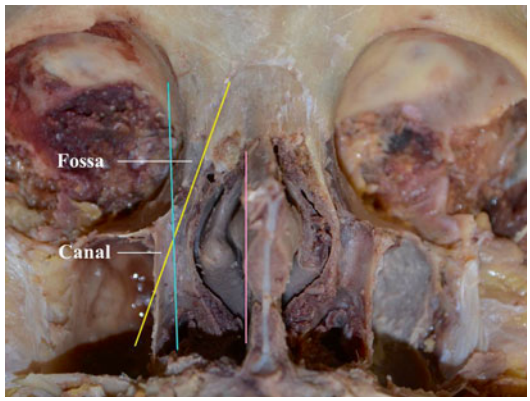

Fig. 3.12 A horizontal inclination of lacrimal sac fossa and nasolacrimal canal. Lacrimal sac fossa goes temporally without exception. Nasolacrimal canal is mostly parallel to the vertical base line. *Line Pink*: base line, *Line Yellow*: long axis of lacrimal sac fossa, *Line Blue*: long axis of nasolacrimal canal

about 10° poteriorly [23] (Fig. 3.11) and directs about 10° temporally [24] (Fig. 3.12). The angle range of the long axis of the fossa is 0–20° posteriorly [23] and 1–30° temporally [24].

Clinical Correlations

1. The orbit is defined as the part posterior to the orbital septum [9]. The lacrimal apparatus is not an orbital tissue as it is located anterior to the orbital septum. However, according to vicinity with the eyelid as an extra-septal tissue, the lacrimal system is closely related to the eyelid and relies on the eyelid movement for pump functions of the lacrimal drainage. Since the function of the lacrimal apparatus is highly specialized, it is defined as the "lacrimal system" with an independent identity of its own.
2. When an acute dacryocystitis extends around the sac, the inflammation goes toward the eyelid because of the above reason. In an advancing stage, it occasionally goes into the orbital space, since the barriers are not strong enough.
3. The lacrimal bone is too thin with its thickness around 0.1 mm [5]. Therefore, in both external and endonasal dacryocystorhinostomy, an osteotomy is made from the lacrimal bone. In cases of a lacrimo-maxillary suture being situated close to the posterior lacrimal crest, a surgeon occasionally feels difficulty to perform the osteotomy. In an external dacryocystorhinostomy, initial osteotomy sometimes begins at the part around the sutura notha [21]. It is better, however, not to extend the osteotomy toward the ethmoid sinus to prevent bleeding from the ethmoid mucosa.
4. In an endonasal dacryocystorhinostomy, relationship between the lacrimal sac fossa and the base of the middle turbinate is vital (Fig. 3.13). The base of the middle turbinate, called the "axilla," often corresponds to the lacrimal sac fossa (Fig. 3.14) [15], although there are exceptions. A high sac position is defined as the sac situating superior to the

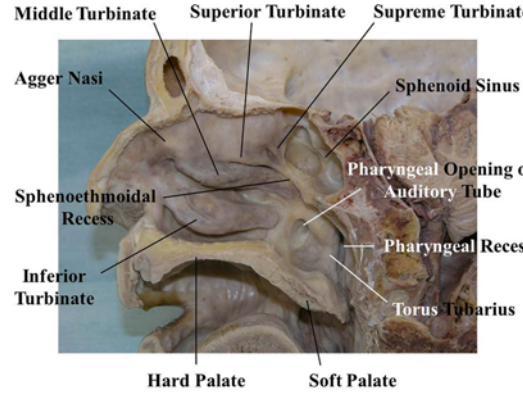

Fig. 3.13 Overview of a lateral nasal wall

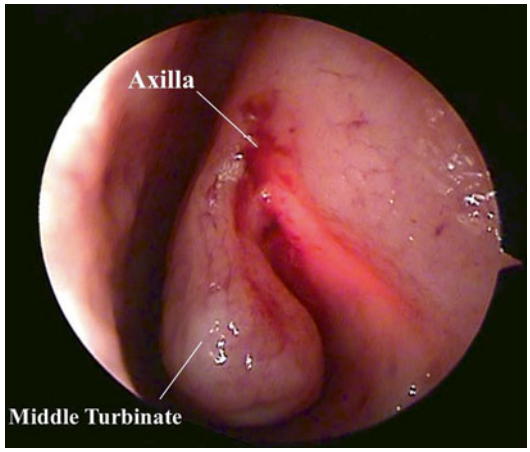

Fig. 3.14 Relationship between lacrimal sac fossa and axilla. A light is seen through the bone

axilla, and a low sac is a position inferior to the axilla [15]. This relative position between the lacrimal sac fossa and the axilla is confirmed with a preoperative CT or intraoperative light pipe inserted from a punctum (Fig. 3.14). A light cannot be occasionally seen in cases with thick frontal process of the maxilla, posterior location of the lacrimomaxillary suture, cases with high sac position, or cases with anterior protrusion of the ethmoid air cells with wide distance between the lacrimal bone and the lateral wall of the nasal cavity.

5. Endoscopic clinical anatomy reveals that the posterior portion of the lacrimal bone is covered in considerable cases by the uncinate process forming the most anterior part of the ethmoid air cells [25]. The inferoposterior part of the lacrimal bone tends to be covered largerly [25]. A small protuberance called the agger nasi is seen over the lacrimal sac fossa (Fig. 3.13) [25]. Aerated agger nasi (agger nasi cell) can often reach the lacrimal sac fossa [25].
6. The uncinate process is, as its name, a bony process with a "hook" (Fig. 3.15) [15, 26]. This hook part is situated at a considerable depth corresponding to the posterior hiatus semilunaris. As the tail of the uncinate process faces anteriorly, we cannot easily see the "hook" part around the lacrimal sac fossa [26].

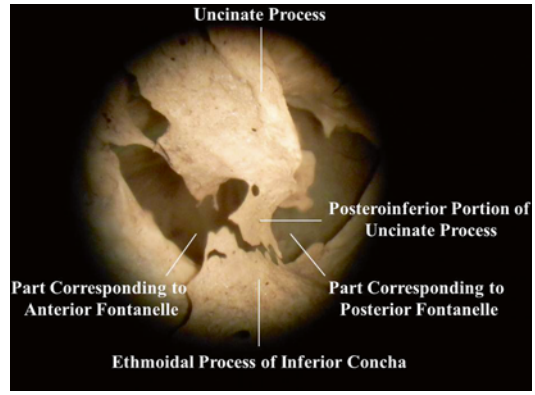

Fig. 3.15 Tip of a right uncinate process. The hook part directs posteriorly

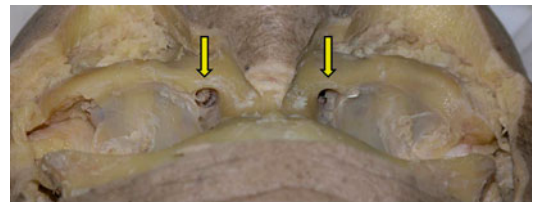

Fig. 3.16 Superior view of the opening of nasolacrimal canal (*Yellow arrows*)

Anatomy of the Nasolacrimal Duct (NLD) and Canal

The lacrimal sac and the nasolacrimal duct are a continuous tissue, and anatomically speaking, the "nasolacrimal duct" (mucosal portion) is the part inferior to the superior opening of the nasolacrimal canal (bony portion) [14]. The nasolacrimal canal is formed by the lacrimal bone superonasally, the inferior turbinate bone inferonasally, and the maxillary bone temporally [5]. The superior opening is about 6 mm in diameter and, in general, is an ellipse with a little longer horizontally (Fig. 3.16). The supero-inferior length of the canal is fairly short, about 12 mm [14] (Fig. 3.12). Although the longitudinal axis of the canal directs about 20° posteriorly [23] (Fig. 3.11), it directs almost vertically in most cases [24]. The nasolacrimal canal empties into the superior part of the inferior meatus (Fig. 3.12).

The angle range of the long axis of the nasolacrimal canal is 3–40° posteriorly [23]. The frontal

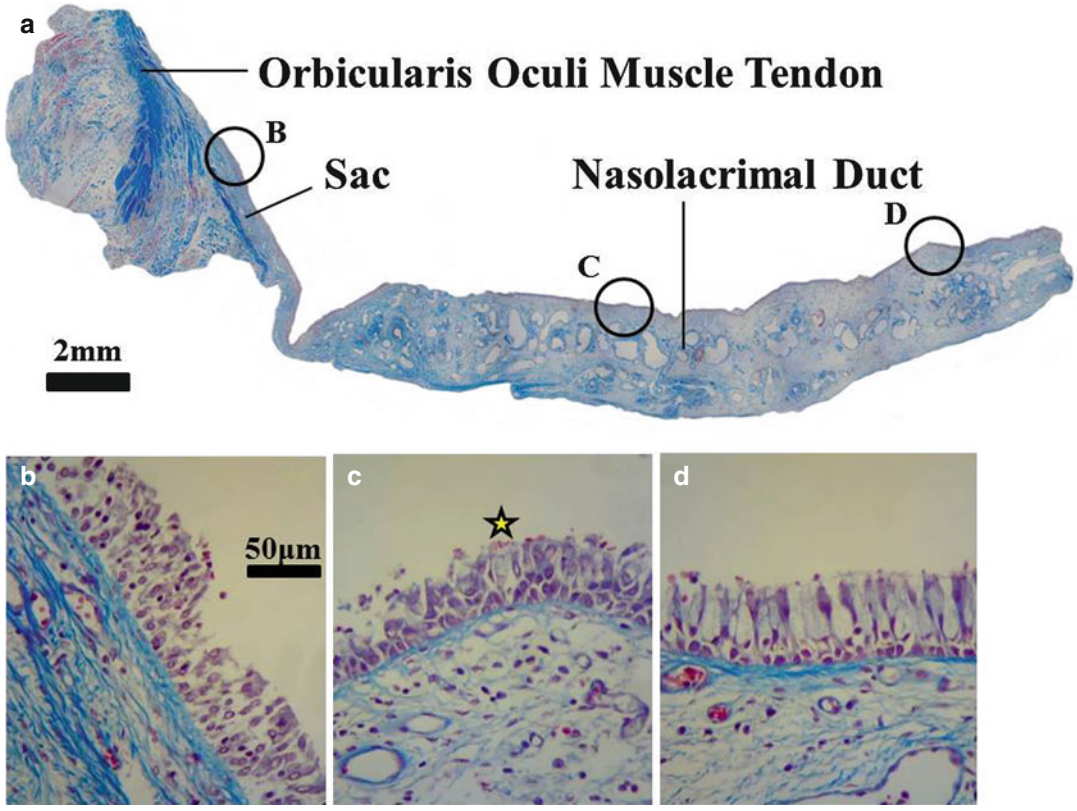

Fig. 3.17 A vertical slice from lacrimal sac to nasolacrimal duct. The **b–d** are enlarged photos in each part of the **a**. (**b**) Sac epithelium, (**c**) superior nasolacrimal duct epithelium, (**d**) inferior nasolacrimal duct epithelium. Numbers of goblet cells are increasing as we proceed inferiorly. The **b** does not show a goblet cell, but the Figs. 3.3, 3.5, 3.6, and 3.8, similarly showing lacrimal sac, demonstrate goblet cells. The **b–d** are the same scale. The *asterisk* in the (**c**) indicates the goblet cell (Masson's trichrome stain)

view shows the angle range from 12 ° nasally to 11° temporally and mostly directs vertically around 0° [24]. Although a general consensus of the canal course is "temporal," occasionally cases with medial course have been noted.

The nasolacrimal canal does not have a constant diameter throughout its length: some shows narrower and others larger [27]. Two thirds to 3/4 of cases show the narrowest part at the superior opening, but the others have found the narrowest portion at 3.5–5.5 mm from the superior opening [27]. These narrowings may have a bearing on the etiopathogenesis of primary acquired nasolacrimal duct obstructions (PANDO) [27].

Epithelium of the NLD is a stratified columnar epithelium, similar to the lacrimal sac, and contains goblet cells and serous glands [15]. In general, the goblet cells are distributed more inferiorly, but several specimens have also demonstrated considerable number of goblet cells throughout (Figs. 3.17, 3.18, and 3.19). Although the cavernous structure is shown similar to the lacrimal sac, it is much more developed than the sac [16, 19] (Figs. 3.17 and 3.18). The wall is more thickened inferiorly and most show a funnel shape lumen (Fig. 3.20). Cilia are similar to the nasal mucosal cells [18]. The microvilli on the epithelial surface contribute to reabsorption of the lacrimal fluid [17, 18].

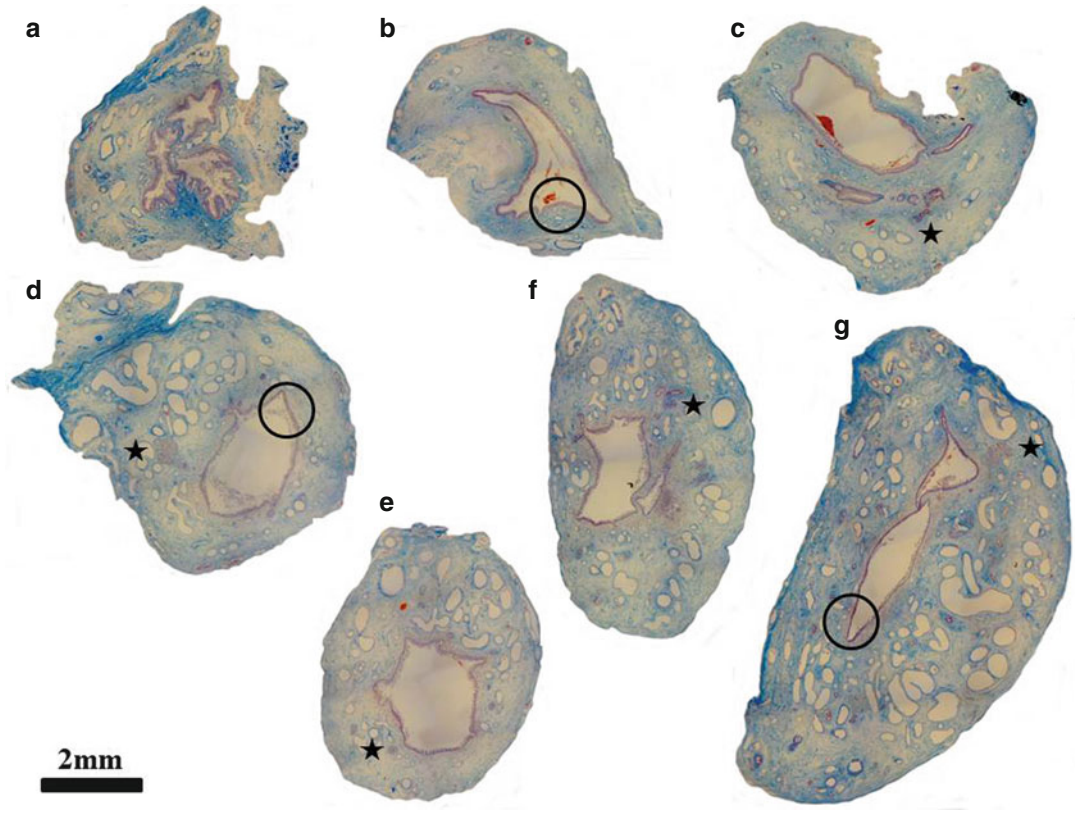

Fig. 3.18 Continuous left horizontal slices from lacrimal sac to nasolacrimal duct. The sections are made every 3 mm. The wall is more thickened as we proceed inferiorly with developing cavernous structure. Serous glands (★) are seen from the **c**–**g**. *Superior*: anterior direction, *Left*: temporal direction. (**a**) Part of connection of canaliculus and sac. (**b**) Sac, (**c**) part of junction of sac and nasolacrimal duct, (**d**–**g**) nasolacrimal duct (Masson's trichrome stain)

The NLD occasionally shows folds called as valves of Krause [27]. In addition, septa are sometimes seen in the nasolacrimal duct or the sac [28]. The nasolacrimal duct mostly continues for several millimeters beneath the nasal mucosa after leaving its osseous channel [19, 28–30]. This part has a valve called the valve of Hasner [27]. The total length of the nasolacrimal duct is 15–18 mm and it is longer than its bony canal. The shape of the NLD opening into inferior meatus shows 4 types: wide-open type (12 %), valve-like type (8 %), sleeve-like type (14 %), and adhesive type (66 %), although these were studied in patients with functional epiphora [30]. These openings are situated around 30–35 mm posterior to the lateral margin of the nare [6].

Clinical Correlation

Although the lacrimal sac and the NLD are a continuous structure, and the basic structure is same, their compositions, such as number of goblet cells, development of the cavernous structure, and thickness of the wall, are considerably different. In the lacrimal system, roles are shared between these two portions: the lacrimal sac sucks the tear supported by the lacrimal drainage system and the NLD reabsorbs them. This feature is similar to the intestinal canal, which shows a long continuous structure but has different function in each portion.

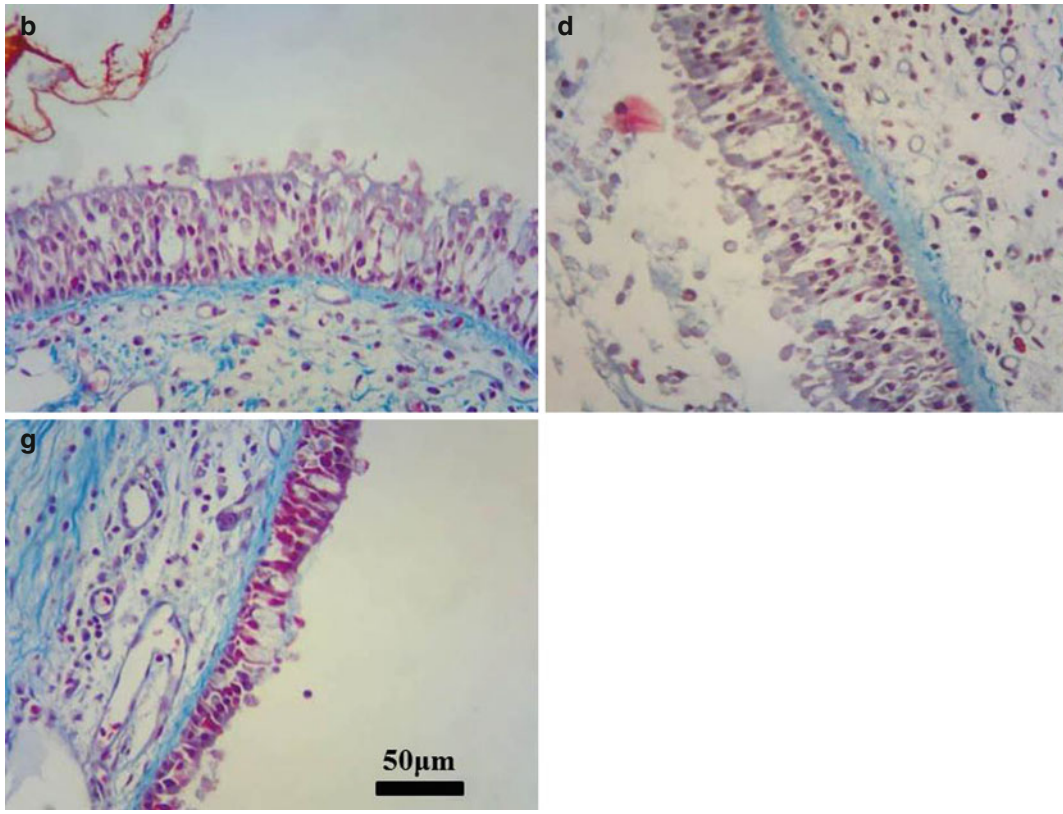

Fig. 3.19 The **b**, **d**, and **g** are enlarged photos in each part of Fig. 3.18. A lot of goblet cells are shown from the sac level. The **b**, **d**, and **g** are the same scale (Masson's trichrome stain)

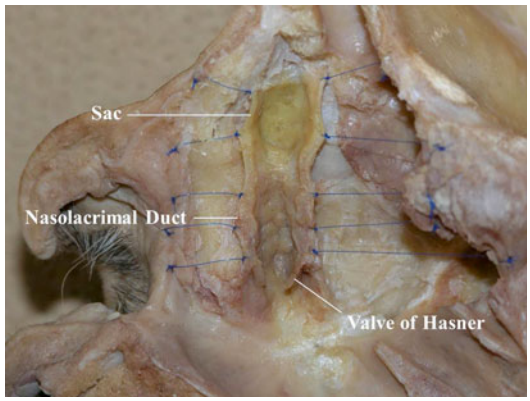

Fig. 3.20 A development view of a sac and a nasolacrimal duct. The sac and the nasolacrimal duct are contiguous. The wall is thin in the sac and more thickened with going inferiorly in the nasolacrimal duct. A valve of Hasner is shown below the inferior opening of the nasolacrimal canal. Several protuberances shown in the nasolacrimal duct are called the valves of Krause

Mechanism of the Lacrimal Drainage

Physiological Relationship of Lacrimal Punctum, Lake, and Caruncle

The lacrimal caruncle derives embryologically from the lower eyelid [1], and its lateral margin smoothly continues to the lower eyelid margin [2]. As this lateral margin of the caruncle directs inferolaterally, the lower punctum is situated more temporally than the upper punctum [2]. The lacrimal lake is formed adjacent to the caruncle, where the lacrimal papilla faces it in general. This is the normal relationship of the punctum, lake, and caruncle. Although the plica semilunaris is formed more temporally to the lacrimal lake, this buffers an imbalance of an ocular and a palpebral movement. When the trinity of the

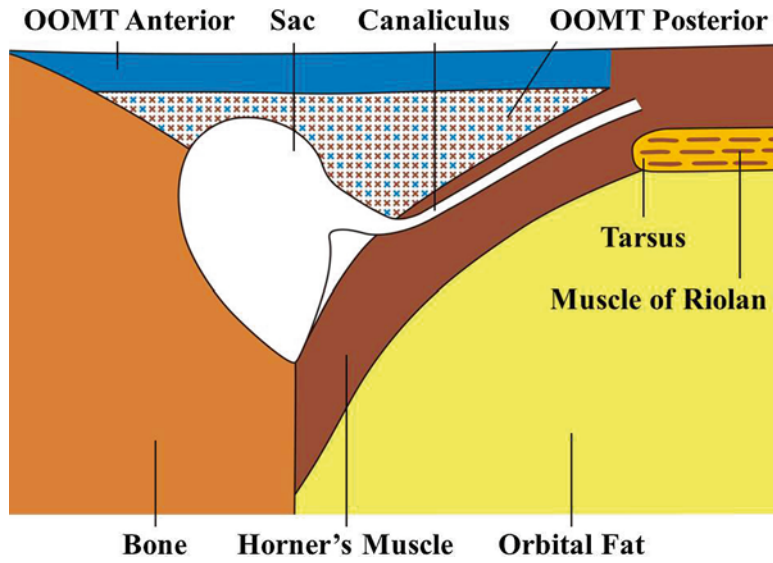

Fig. 3.21 A figure of lacrimal canaliculus and upper part of sac during eye closing. *OOMT Anterior*: orbicularis oculi muscle tendon anterior lamella. *OOMT Posterior*: orbicularis oculi muscle tendon posterior lamella

punctum, lake, and caruncle is in disproportion, that is to say, when the lacrimal papilla does not face the lacrimal lake, an epiphora may occur.

Lacrimal Drainage System of the Canaliculus

The lateral 4/5 of the lacrimal canaliculus is encircled by the Horner's muscle but not the medial 1/5 (Fig. 3.5). The canalicular drainage is easily understood by dividing the canaliculus into two parts with relation to the Horner's muscle.

During the eye closing, the Horner's muscle contracts and the temporal 4/5 part of the canaliculus is pressed and closed (Fig. 3.21). The nasal 1/5 part is pulled posteriorly and opens. In this situation, the Horner's muscle moves posteronasally toward the origin of this muscle (posterior lacrimal crest), and this movement begins from the temporal side with shortening of the canalicular length [31]. Therefore, the lacrimal fluid is effectively transported from temporal to nasal sides, finally reaching the lacrimal sac cavity [31]. During the eye opening, as the Horner's muscle relaxes, the temporal 4/5 part of the canaliculus is expanded and the nasal 1/5 part is pressed and closed via the Horner's muscle and the connective tissues (Fig. 3.22). This canalicular closure is not perfect, though. In this phase, as the whole canaliculus moves anterotemporally and is elongated, the canaliculus can pool more lacrimal fluid in it.

An aspiration from the punctum relies on a capillary phenomenon and/or negative pressure in the canalicular lumen [31]. As stated before, the protuberance on the common internal ostium is thought to be formed to buffer the movement of the common internal ostium. The sinus of Maier may be a similar buffering structure because it is notably seen in eye closing with the Horner's muscle traction. This protuberance has been argued in relation to regurgitation. However, it is difficult to judge this structure formed for prevention of tear regurgitation because almost all patients who underwent dacryocystorhinostomy feel air reflux to the eye during sneezing.

The medial most 1 mm of the common canaliculus runs in the wall of the sac (Figs. 3.3, 3.5, 3.6, and 3.8). As the sac wall is constituted by cavernous structure [32], its thickness could be regulated by an autonomic innervation [16]. If the intra-sac canaliculus receives an autonomic regulation, then in a sympathetic dominant state, as the sac mucosa shrinks, the intra-sac canaliculus is enlarged and shortened, resulting in more

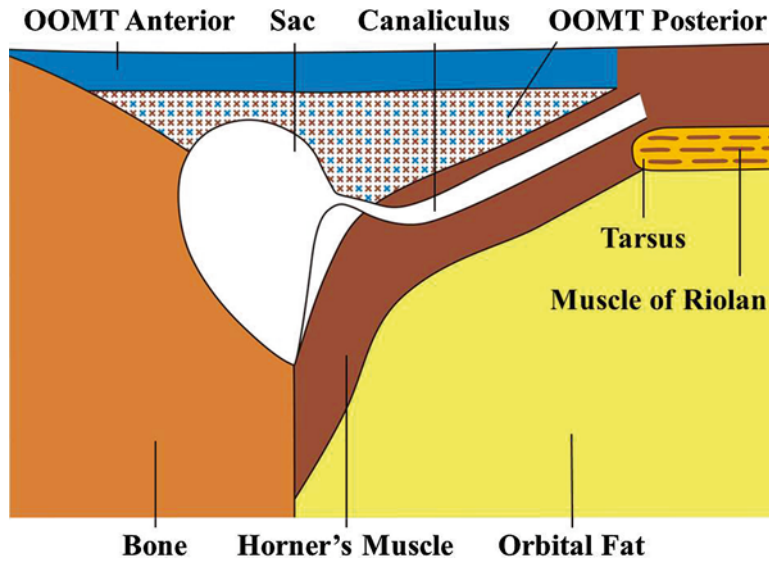

Fig. 3.22 A figure of lacrimal canaliculus and upper part of sac in eye opening. *OOMT Anterior*: orbicularis oculi muscle tendon anterior lamella. *OOMT Posterior*: orbicularis oculi muscle tendon posterior lamella

drainage. To the contrary, in a parasympathetic dominant state, as the sac mucosa is thickened, the intra-sac canaliculus is pressed but elongated, resulting in less drainage. However, as its length is only 1 mm and the cavernous structure of the sac is less developed than that of the nasolacrimal duct, it is unclear whether the above phenomenon occurs.

Lacrimal Drainage System of the Lacrimal Sac

The lacrimal drainage system of the sac, just like canaliculi can be easily understood if it is divided into two parts with relation to the Horner's muscle [9]. In addition, as the fundus of the sac has a special lacrimal drainage system, it is explained in another clause.

The upper part of the sac is directly affected by the Horner's muscle movement. During eye closing (when the Horner's muscle contracts), as the Horner's muscle moves away from the sac, the sac expands temporally (Fig. 3.21). During the eye opening (when the Horner's muscle relax), as the Horner's muscle moves toward the original position and pushes the sac nasally, the sac shrinks with an additional help of its elasticity (Fig. 3.22).

The lower lateral half of the sac is covered only by the lower eyelid capsulopalpebral fascia (CPF). During eye closure, as the CPF takes no tension and the orbicularis oculi muscle pushes the orbital tissues posteriorly, the lower lateral half of the sac is pushed nasally with the tensionless CPF. At the same time, shrinkage of the lower eyelid orbicularis oculi muscle pushes the anterior surface of the sac posteriorly. During eye opening, the CPF is pulled temporally with the lower lateral half of the sac under decreased orbital pressure. Then, the lower eyelid orbicularis oculi muscle is in less tension, resulting in a forward movement of the anterior sac surface.

As the fundus of the sac has an orbicularis attachment, this part is expanded superiorly during eye closure or during an orbicularis oculi muscle contraction [33]. The orbicularis oculi muscle attached to the fundus is opposed by the medial horn of the levator aponeurosis and relaxes during eye opening to an appropriate muscle length to prepare for the next contraction. As the superoanterior surface of the sac is mostly covered by the orbicularis oculi muscle and a force from the orbicularis contraction being applied only horizontally, an effect to the sac can be ignored. The sac movement stated earlier does not directly correspond with the tear movement [34]. With several times blinking, pooled fluid in the sac flows inferiorly as a cluster.

Krehbiel Flow

The Krehbiel flow is a special type of lacrimal fluid drainage [35, 36]. This is a phenomenon in which a lacrimal fluid aspiration from the lacus lacrimalis into the punctum continues for a considerable period during eye opening (without blinking). Although all the cases do not show this phenomenon, 25 % of the lacrimal passage with 45° posterior inclination demonstrates it [35]. According to Prof. Ohashi and Dr. Yamaguchi in Ehime University (Japan), a velocity and a volume of the Krehbiel flow changes with various eye positions (personal communication). The Krehbiel flow is believed to occur by a lower intra-sac pressure against a canalicular pressure, namely by a pressure gradient from the canaliculus to the sac [35, 36]. To decrease the intra-sac pressure, the sac and the nasolacrimal duct cavities need to be occluded to a certain extent, and the fluid and air need to be absorbed.

Prerequisites or Factors Favoring Krehbiel Flow

1. Long valve of Hasner is necessary for making one-way valve function [6].
2. The lower nasolacrimal duct should be funnel-like with narrower lumen inferiorly, which should be able to functionally obstruct when needed.
3. The fluid and air need to be absorbed by the well-developed cavernous structure of the sac and the nasolacrimal duct.
4. In the upper stream, the canaliculus needs to be filled with fluid by continuous tear aspiration with much less air in the lumen.

Clinical Observations on Krehbiel Flow

1. When a person takes a lying position or lower head position, duration of the Krehbiel flow gets shorter or nil [35]. That is to say, an effect by the gravity is only additional.
2. After dacryocystorhinostomy, as the nasal cavity pressure is relatively higher than the preoperative intra-sac pressure, the pressure gradient from the canaliculus to the sac is lost, resulting in no Krehbiel flow [35, 36].
3. A case with air in the nasolacrimal duct as shown by a CT does not demonstrate the Krehbiel flow (observational finding). Although the common internal ostium is pressed and occluded when the Horner's muscle relax [8], this closure is not perfect with a little opening. This probably contributes to the simultaneous occurrence of the Krehbiel flow and contribution to tear drainage.

Lacrimal Drainage System of the Nasolacrimal Duct

The nasolacrimal duct does not perform an active lacrimal drainage, but contributes by making the flow smoother and by the way of tear reabsorption. As the cavernous tissue in the sac and the nasolacrimal duct have collagen fascicules, elastic and reticular fibers, which are helically arranged from superiorly to inferiorly [32], this complex architecture cooperates with the dynamic lacrimal drainage and the gravity, and help drain the fluid effectively toward the nasal cavity [32].

Mechanism of the Lacrimal Fluid Reabsorption

Tissue Anatomy in Relation to Lacrimal Fluid Reabsorption

The lumens of the sac and the nasolacrimal duct are covered by the stratified columnar epithelium with microvilli [15, 18]. This anatomy enlarges the surface area of the lumen and is advantageous for the lacrimal fluid reabsorption [17]. A lot of vessels exists in the subepithelial tissue, in which one barrier artery and two types of veins (throttle and capacitance veins) comprise the cavernous structure [17]. (Figs. 3.17 and 3.18) This cavernous tissue of the lower nasolacrimal duct continues with that of the inferior meatus [32]. The vessel area of the cavernous tissue is smaller in the sac and larger in the nasolacrimal duct with increasing density as we move inferiorly. More inferior the area, more advantageous for tear reabsorption (Figs. 3.17 and 3.18). As the nasolacrimal duct is embedded in the canal, a change

in the lumen width most likely results from a change in thickness of the duct wall rather than a change of the outer diameter [16, 19]. This anatomy creates a larger resistance of the tear drainage, which is also advantageous for tear reabsorption (Fig. 3.20).

Autonomic Regulation of the Lacrimal Fluid Reabsorption

The subepithelial tissue of the lacrimal sac and the nasolacrimal duct contains a lot of nerves [17], in which the autonomic nerves regulate mucosal thickness [32]. As the nasolacrimal duct is encircled by bone, the mucosal thickness and the lumen diameter are in inverse proportion. That is to say, in a parasympathetic dominant state, the mucosa is thickened but the lumen gets smaller. At this time, as the drainage resistance becomes higher, the lacrimal fluid flows slower but effect of the tear reabsorption gets increased. To the contrary, in a sympathetic dominant state, because of thinning of the mucosa and enlargement of the lumen, the drainage resistance becomes smaller, the lacrimal fluid flows faster, the tear drainage faster but the reabsorption gets lesser.

When a tear secretion is accelerated from the lacrimal gland, for example, by contact of ocular surface with a foreign body, that is to say, when the lacrimal fluid drainage needs to be blocked to wash off the foreign body, the autonomic regulation inclines to a parasympathetic dominant [16]. Then, an arterial flow increases but a drainage from the throttle vein decreases with more blood pooling in the capacitance vein. Therefore, the walls of the sac and the nasolacrimal duct are thickened [17] and the lumen diameter gets smaller, which result in lesser flow but more effective tear reabsorption. On the other hand, when the ocular surface needs to be drier like a situation of fight and flight, the sympathetic system predominates, the arterial flow decreases, drainage from the throttle vein increases with less blood pooling in the capacitance vein. Therefore, the walls of the sac and the nasolacrimal duct are thinned [17] and the lumen diameter gets larger, resulting in acceleration of the tear drainage and keeping the ocular surface relatively drier for clearer vision for fight or flight!

Immune Mechanism of the Lacrimal Apparatus

Immune Mechanism in Lacrimal Fluid or Tears

The lacrimal fluid contains numerous antimicrobial like lactoferrin, lysosome, immunoglobulins, etc., and these block proliferation of pathogens by their bactericidal effects [37].

Defense Mechanism from Pathogens on Anatomical Structures

Antigens coming via the ocular surface are dealt with lacrimal fluid and various immune systems on the ocular surface. However, the lacrimal tract also needs to protect itself from a retrograde infection from the nasal cavity.

The notable is the existence of the nasolacrimal duct running beneath the nasal mucosa after leaving the osseous channel. Although all the cases do not show this kind of duct [19, 30], invasion of pathogens may be considerably prevented mechanically by this structure. With cooperation from the dynamic lacrimal drainage and gravity, collagen fascicules, elastic and reticular fibers helically arranged from superiorly to inferiorly in the cavernous tissue of the sac and the nasolacrimal duct [32], all contributing effectively to drain the immune-rich lacrimal fluid inferiorly, resulting in defense against pathogens [38]. However, this mechanism works in a situation with thinned walls of the sac and nasolacrimal duct. It is hard to apply this theory to a situation with thickened walls of the sac and the nasolacrimal duct. Then, a mucous defense is vital for pathogen blocking [38]. The cilia also contributes to form a one-way flow from superiorly to inferiorly to prevent pathogens [13].

Mucous Defense Against Pathogens

Density of the goblet cells increases as we descend toward inferior parts of lacrimal drainage system (Figs. 3.17, 3.18, and 3.19). That is to say, more inferior area can secrete more mucus. When the walls of the sac and the nasolacrimal duct are thick and gaining an appropriate tear velocity to exclude pathogens gets difficult, the mucus can make a functional plug at the lower site of the duct and prevent pathogens from invading retrograde from the nasal cavity. As the mucus contains lactoferrin, lysosome, and immunoglobulins, similar to the lacrimal fluid, defense against pathogens can be performed synergistically [38].

The mucus is secreted by the goblet cells in the epithelium [38] and prevents pathogens from adhering to the epithelium [38]. This adhesion block is performed by simple covering on the epithelium and besieging adhesive agents constituted by glycoproteins and/or glycolipids expressed on the surface of pathogens or toxins [38].

However, as some pathogens have enzymes which can dissolve the mucus, the pathogen can easily adhere to the epithelium in this situation [38]. In addition, as the degradation products become nutrients for the pathogens, proliferation of the pathogens is accelerated then [15]. Therefore, only a mucus defense is insufficient for pathogens, and humoral and cellular immunities are necessary [38, 39].

Humoral and Cellular Immunity

The lacrimal tract contains a mucosa-associated lymphoid tissue (MALT) which is related to an antigen recognition and immune response [39]. This tissue carries the main immune system. The lymphocytes and plasma cells constituting the MALT are sparsely distributed mainly in the lamina propria mucosae but some in the epithelium. This tissue is thin in the canaliculi, but thick in the sac and the nasolacrimal duct.

The lymphatic follicles in the lacrimal mucosae are, in general, primary without a germinal center, but some show secondary follicle with germinal centers. As the germinal center emerges when lymphocytes with antigen stimulation proliferate actively, an ability of antigen recognition and other immune responses is weak in the lacrimal MALT. However, proliferation and differentiation of the IgA secreting plasma cells do not simply depend on obvious follicles.

The main source of the humoral immunity in the lacrimal tract is the secretory IgA. IgM and IgG, although much less volume than the secretory IgA, are also related to the lacrimal humoral immunity. The immunoglobulin covers the mucosal surface, prevents pathogens from adhering to the epithelium, and makes them inactive, resulting in protection from the pathogens. In addition, the immunoglobulins accelerate opsonization, a process by which bacteria are altered so that they are more readily and more efficiently engulfed by the phagocytes. As the immunoglobulins in the lacrimal tract need to cover the broad mucosal surface, a secretory mechanism which does not depend on the germinal centers carries an important role against the pathogens. Ali et al. [40] have shown that the lacrimal drainage-associated lymphoid tissue (LDALT) is altered in cases of chronic dacryocystitis and discussed both the cellular and humoral derangements that occur. Further studies on these could provide insights into LDALT and greater immunological understandings and possibly immune factors influencing lacrimal systems in health and disease.

Most lymphocytes in the lacrimal tract are T cells [41]. Although volume of the B cells is less than that of the T cells, B cells occasionally form lymphatic follicles. T cells show CD8 positive cells that are inhibitory and cytotoxic. Macrophages exist as well, distributed in the lamina propria mucosae but occasionally in the epithelium. Although the cellular immunity in the lacrimal tract shows less weight than the humoral immunity, the presence of MHC class II positive cells reflects its active role in the capture and presentation of antigens.

Conclusion

The anatomy, physiology, and immunology of the lacrimal apparatus have been described in detail. With advances in nasal endoscopic and dacryoendoscopic techniques, treatment for lacrimal diseases is rapidly advancing. I would like the readers to get back again to basics and to review the findings presented here. I believe that this enables the readers to easily understand the pathological backgrounds of each entity and to choose and perform more appropriate treatment for every lacrimal disease.

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Paradigm Shifts in the Lacrimal Anatomy

4

Hirohiko Kakizaki

Introduction

Anatomical knowledge in the lacrimal drainage system is rapidly advancing year by year. This topic would need a separate update, hence I picked up two representative topics which have been believed to be gold standard, but now needs to be revised based on the recent evidence and hence the need for a paradigm shift here! The first part of this chapter deals with valvular system and second with the medical canthal tendon.

The Valvular Structures in the Lacrimal Passage

The lacrimal excretory passage has been believed to have several valves such as Rosenmüller, Hasner, Bochdalek, Folta, Krause, spiral valve of Hyrtl, and Taillefer (Fig. 4.1) [1, 2]. These have been thought to play an important role in the lacrimal drainage [1, 2]. However, a perfect one-way valve structure like one in the heart or vein has not been convincingly demonstrated in the lacrimal excretory passage [3]. The lacrimal valves are only mucosal folds or protuberances [1, 2]. In spite of these understandings, the true entities and functional values of the so-called valves of Rosenmüller and Hasner have not been correctly understood so far.

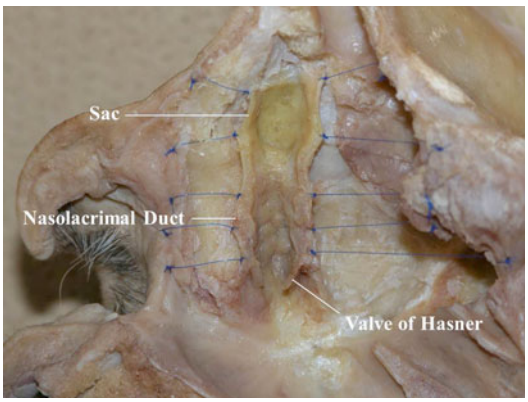

Fig. 4.1 The lacrimal drainage system has numerous mucosal folds or valves across its length

The Valve of Rosenmüller

The so-called valve of Rosenmüller [4, 5] is situated, although only in a half of cases [6], at the junction between the common canaliculus and the sac [7]. This structure is not a valve, in truth, but only a mucosal fold. A valve-like mechanism here is contributed and functionally structured by movement of the common lacrimal canaliculus in blinking, which originates from contraction and relaxation by Horner's muscle [8]. The internal canalicular orifice largely opens by a temporal traction of Horner's muscle during eye closing but moves nasally during an eye opening [8].

H. Kakizaki, MD, PhD
Department of Ophthalmology,
Aichi Medical University, Aichi, Japan
e-mail: cosme_geka@yahoo.com.jp

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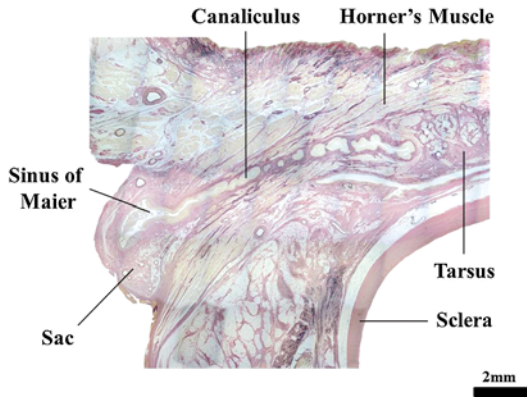

Fig. 4.2 A sinus of Maier is shown here, into which the canalicular part is expanded (Elastica van Gieson stain)

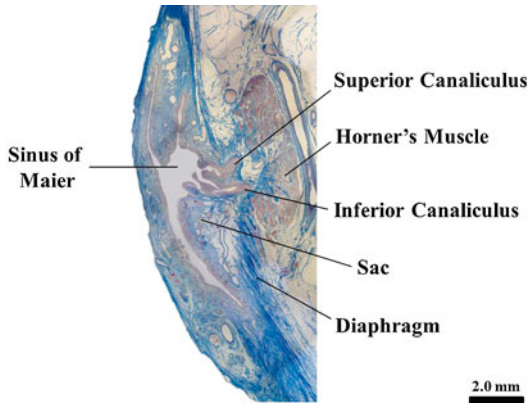

Fig. 4.3 A sinus of Maier, in which a part of sac is expanded. The superior and inferior canaliculi separately empty into the sinus of Maier (Masson's trichrome stain)

The diverticulum, called the sinus of Maier [1, 2], is obvious, especially during eyelid closure, in which folds or membranes are not shown (Figs. 4.2 and 4.3). These folds or membranes only reflect a mucosal spare in the closed state of the internal canalicular orifice, allowing for expansion of the diverticulum. As the lacrimal sac comprises a cavernous structure [9, 10] and may not withstand dynamic movements during repetitive blinking, such a buffering structure may be necessary. Therefore, the movement of the internal canalicular orifice may not directly contribute to lacrimal drainage or antiregurgitation, but protects the sac against repetitive blinking.

Studies for the valve of Rosenmüller have been mostly performed using cadavers. Although cadavers usually have closed eyelids, their Horner's muscle tone was completely lost [11], which is similar to an eyelid in the opening state with closing of the internal canalicular orifice. This situation may show folds or membranes at the internal canalicular orifice. Cadaveric studies would evaluate only one aspect of the above process. Live patients enable us to observe opening and closing of the internal canalicular orifice. The valve of Rosenmüller may thus be a phantom anatomy.

The Valve of Hasner

The so-called valve of Hasner is only the terminal soft tissue component of the lacrimal excretory passage [12]. An imperforate valve will result in epiphora and signs of congenital nasolacrimal duct obstruction [12]. This soft tissue is situated at the meatal opening of the nasolacrimal duct (NLD), several millimeters inferiorly after NLD's exit from the bony lacrimal canal [13, 14]. This soft tissue has been thought to prevent air current or fluid from within the nose being drawn up into the lacrimal duct.

The shape of this terminal soft tissue shows four types: wide-open type (12 %), valve-like type (8 %), sleeve-like type (14 %), and adhesive type (66 %) [14]. Judging from these variations, the wide open type at least should demonstrate regurgitation of air current or fluid [12]. Bert (quoted by Aubaret) [1, 2] found that colored fluids injected in the nose escaped from the lacrimal puncta only 3 times in 18 experiments, whereas direct injections into the duct invariably appeared at these points, showing that the terminal soft tissue of the lacrimal excretory passage usually shows valve-like mechanism but not always. Although Bert's study has been reported more than 100 years ago, it has been under surgeons' recognition.

Anatomy of the Medial Canthal Tendon (MCT)

History of the MCT Anatomy

The medial canthus is a complex anatomical region and the most striking entity here is the

medial canthal tendon (MCT) [15–19]. The MCT was earlier known as the "medial canthal ligament" [20]. In view of inadequate information, some considered it to be a ligament, but others saw it simply as a large adhesion to the periosteum of the frontal process of maxilla [20].

A different opinion about the medial canthal region was published in 1970s by Lester T. Jones, who was the first to reconsider this classical anatomy. Jones and his colleague reported that the medial canthal ligament was not a ligament, but rather a tendon of the orbicularis oculi muscle (OOM) [17].

The classical teaching about MCT is its two limbs, i.e., the anterior and posterior [18, 21]. The anterior limb, which is stronger than the posterior limb [22], was thought to be situated in front of the lacrimal sac and connected to the anterior lacrimal crest and the medial aspect of the tarsal plate [18]. Ritleng et al. also stated that the anterior part of the medial canthal ligament was actually the tendon of the pretarsal OOM [3] and suggested to call it as the "medial palpebral tendon" [18]. Yamamoto et al. proposed that the MCT comprised an aggregate of muscle fibers from the orbital area of the OOM, as well as the tendon from the tarsal area [16].

Many anatomists worked on the anatomy of the MCT, however we revisited the anterior limb to include two lamellae, i.e., the anterior and posterior [23]. The anterior lamella is the tendon of the pretarsal part of the OOM [23]. The posterior lamella is the musculotendinous junction of the preseptal and orbital parts of the OOM [23]. The anterior limb continues to the pretarsal OOM without insertion into the tarsal plate [24].

The classical teaching with regards to the posterior limb is its attachment to the posterior lacrimal crest and tarsal plate and Horner's being related to its posterior surface (Fig. 4.4) [18]. However, true fixation of the nasal aspect of the tarsal plate is performed by Horner's muscle and the medial rectus capsulopalpebral fascia (mrCPF) [24] and not by the posterior limb of the MCT. Most researchers considered this posterior limb as a relative subsidiary structure, compared with the anterior limb [22, 25, 26], although some thought the posterior limb to have the same tough fibrous consistency as the anterior limb [27].

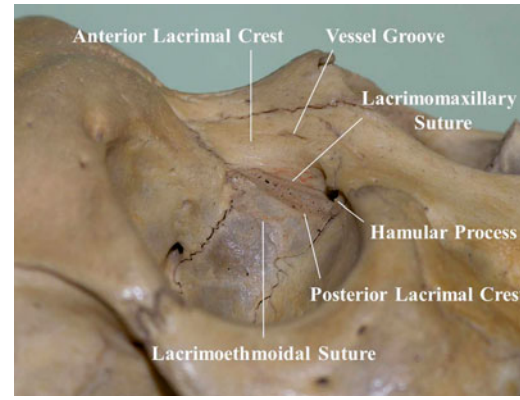

Fig. 4.4 Important bony landmarks in medial canthal anatomy

The Truth of the Posterior Limb of the MCT

The classical anatomical teaching has been that the medial canthus is supported by the anterior and posterior limbs of the MCT and the Horner's muscle. The posterior limb of the medial canthal ligament, as a deep or reflected part arising from the main ligament [18, 25], was thought to be merely a thin fascial expansion [28] or simply a thin and weak structure to assist the anterior limb [26]. The posterior limb of the MCT was thought to be attached behind the lacrimal sac and contiguous with the lacrimal fascia, and thus helped to support the upper part of the lacrimal sac [25].

Some anatomist regarded the posterior limb of the MCT as Horner's muscle [22]. Ritleng et al. stated that Horner's muscle was a separate structure from the posterior limb of the MCT, and that the structure corresponding to the posterior limb was not a tendon, but Horner's muscle [18]. Adenis et al. reported that the posterior component of the MCT was more delicate and had more of a dynamic structure than the anterior portion, and Horner's muscle comprised the posterior portion of the MCT [22]. Shinohara et al. reported that the posterior connective tissue fibers of the MCT were interwoven with fibers of the lacrimal fascia and extended to the common lacrimal canaliculus and to the bifurcation of Horner's muscle [29].

Our group revisited the anatomy of the posterior limb of the MCT as recently as 2012 but failed to detect it in any of the studied specimens,

irrespective of race [30, 31]. Instead, a thick fibrous lacrimal diaphragm [32], namely, the common fascia between the lacrimal sac and Horner's muscle, was noted around the posterior lacrimal crest, which appeared to be continuous with Horner's muscle fascia and was indistinguishable from the muscle's tendon [30, 31]. This thick, fibrous diaphragm, similar to Horner's muscle tendon, may have been regarded mistakenly as the posterior limb of the MCT [30].

Way Forward: The Modified Tarsal Fixation Model

To better study, understand, and standardize the anatomical exploration of medical canthus, we believe the modified tarsal fixation model is the way forward. Horner's muscle and the mrCPF are key to understand the modified tarsal fixation model of the medial canthus [24]. Horner's muscle, the lacrimal part of the OOM, originates from the posterior lacrimal crest and inserts to the medial aspect of the tarsal plate in the eyelid margin and to the pretarsal OOM in others [18, 21, 24, 31]. The mrCPF is a fibrous structure, which originates from the pulley of the medial rectus muscle around the globe equator, and inserts to the medial tarsal aspect, the lacrimal caruncle, and the medial orbital wall via the medial check ligament [24, 33]. The mrCPF contains many smooth muscle fibers as well [24]. The main function of the mrCPF is connecting the medial rectus muscle and the medial aspect of the tarsal plate as the "medial eyelid retractor" during eye movement [24, 33].

Horner's muscle supports the medial side of the tarsal plate, in the area close to the eyelid margins and not by the mrCPF as was earlier believed [24]. At this level, no tendon or ligament supports the tarsal plate [24]. In the area away from the eyelid margin, the tarsal plate is supported by the mrCPF. The tarsal plate is not supported here by a tendon or a ligament [24]. The medial aspect of the tarsal plate is not, therefore, supported by the anterior or posterior limb of the MCT, but rather by Horner's muscle and the mrCPF. The anterior limb of the MCT only influences medial canthal fixation via the pretarsal OOM located on the tarsal plate [24].

Conclusion

Anatomy in the lacrimal drainage system is fast showing a "paradigm shift" on many aspects. This has led to many concepts being revisited and anatomical dogmas being questioned. Since most of these paradigm shifts have clinical implications, we therefore need to update our anatomical knowledge to catch up and be at the forefront!

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The Sinonasal Anatomy: Endoscopic Lacrimal and Orbital Perspectives

5

Hirohiko Kakizaki

Introduction

Basic knowledge of the sinonasal anatomy is required to safely perform lacrimal and orbital surgeries. We reviewed the anatomy of the nasal cavity (overview, nasal septum, lateral nasal wall including the lacrimal passage, inferior turbinate and meatus, middle turbinate and meatus, and superior and supreme turbinates and meatuses), ethmoid sinus (overview, agger nasi, uncinate process, fontanelle, ethmoid bulla, hiatus semilunaris, ethmoid infundibulum, and ostiomeatal complex), and sphenoid sinus.

Anatomy of the Nasal Cavity

Overview of the Nasal Cavity

The nares or nostrils are the two openings into the nasal cavity [1]. The nasal septum divides the nasal cavity into two sides [2]. The vestibule is the anterior, skin-lined portion containing nasal hairs (Fig. 5.1a) [1]. The junction of the skin and nasal mucosa occurs at a variable distance inside the nose and is usually clearly discernible by different colors between the skin and mucosa (Fig. 5.1a) [1]. The web-like structure at this junction corresponds to the base of the ala nasi (Fig. 5.1b–d).

The choanae, the round, larger posterior nares, are the spaces representing the posterior limits of the nasal cavities and divide the nose from the superior epipharynx (Fig. 5.2a, b). The choanae are clearly visible from the front using nasal endoscopy (Fig. 5.2a). The floor of the nasal cavity is bordered by the hard and soft palates (Fig. 5.3) [1].

The lateral wall of the nose is a complex structure [1]. There are three or four paired nasal turbinates with a corresponding meatus under each turbinate (Fig. 5.4) [1]. The most important paranasal structures are concentrated in the middle meatus, and the nasolacrimal duct empties into the inferior meatus [1–3].

The effect of the nasal conchae and meatuses on the inspired airstream sets the parameters for nasal breathing and treatment of air before it is directed down into the lungs [4]. The turbulent airflow caused by the conchae adds to the perceived resistance of nasal airflow and the sensation of adequate breathing [4]. Turbulent airflow allows for the wafting of molecules to the sensory cells of the olfactory system, aiding the senses of taste and smell [4].

The external proportions of the nose are expected to influence the internal anatomy, and thus cause differences in nasal physiology. Populations adapted to cold and dry environments tend to have large, protruding external noses,

H. Kakizaki, MD, PhD
Department of Ophthalmology,
Aichi Medical University, Aichi, Japan
e-mail: cosme_geka@yahoo.com.jp

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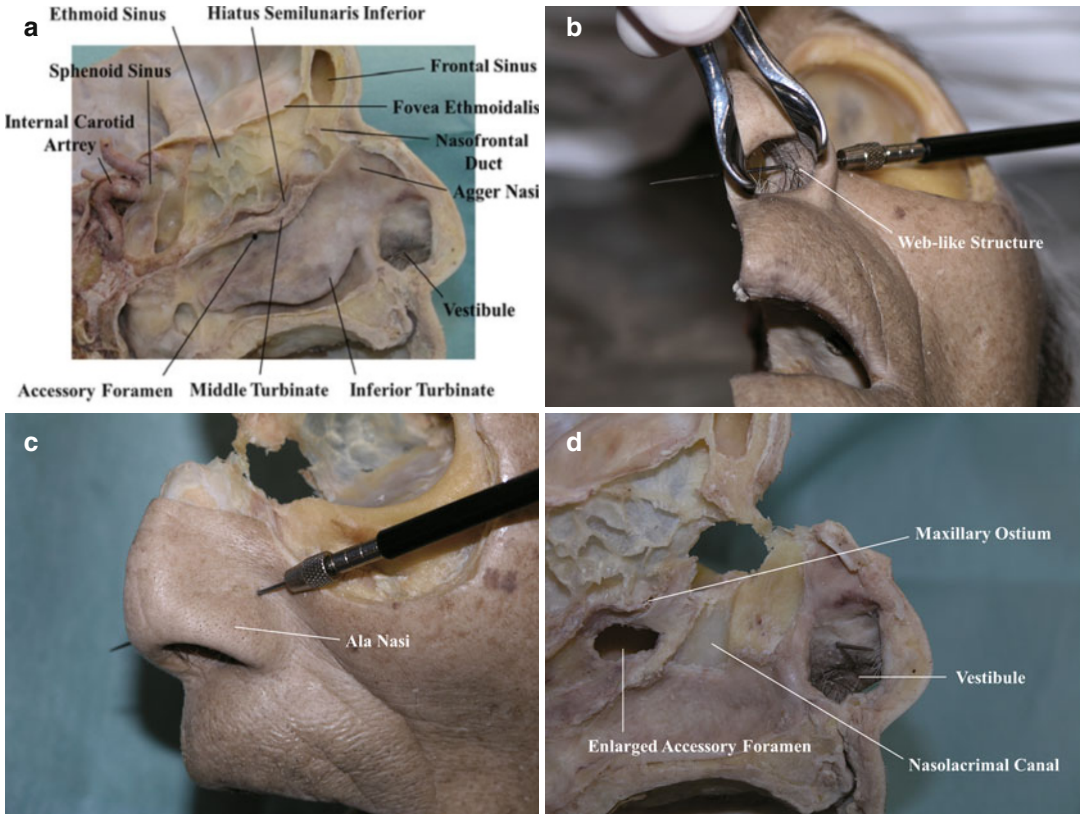


Fig. 5.1 (**a**) Anterior nasal space, lateral nasal space, and ethmoid and frontal sinuses. The middle turbinate is removed. (cadaver, 89-year-old male). (**b**) Web-like structure seen from the inferior aspect. (cadaver, 89-year-old male). (**c**) Pin piercing the base of the ala nasi. (cadaver, 89-year-old male). (**d**) Pin emerged at the superior border of the nasal vestibule. The nasolacrimal canal is directed posteriorly. (cadaver, 89-year-old male)

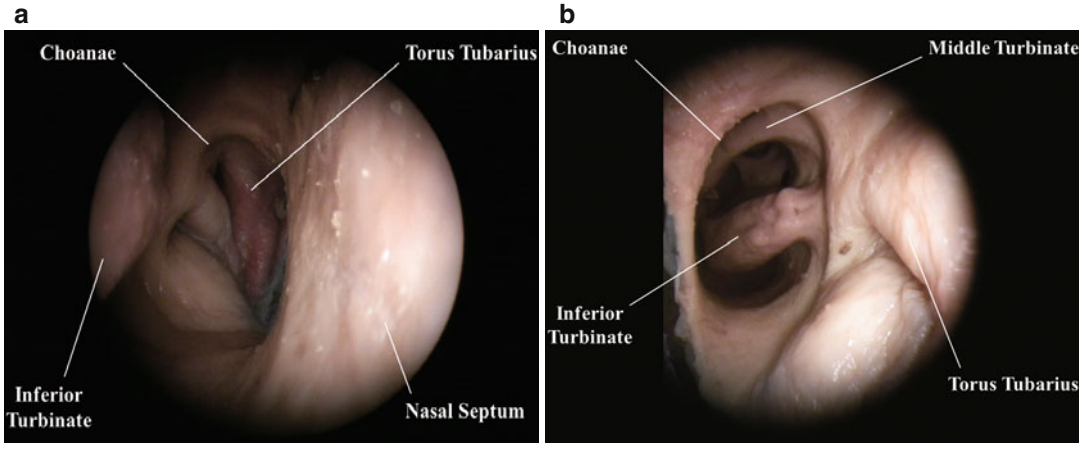


Fig. 5.2 (**a**) Appearance of the choanae seen from the front. (cadaver, 97-year-old female). (**b**) Appearance of the choanae seen from the back. (cadaver, 97-year-old female)

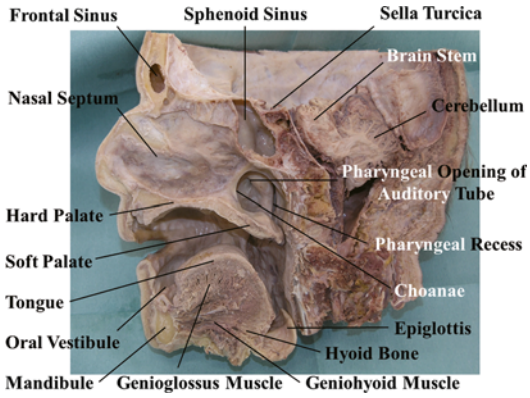


Fig. 5.3 Appearance of the facial half including the nasal septum. (cadaver, 89-year-old male)

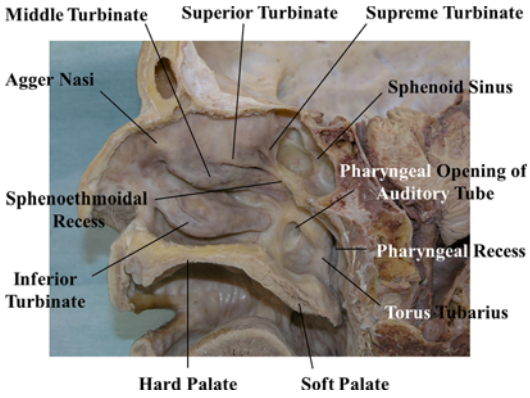


Fig. 5.4 Appearance of the lateral nasal wall with surrounding structures. (cadaver, 89-year-old male)

downwardly directed nostrils, and narrower skeletal nasal apertures [5]. These characteristics are thought to induce turbulence of nasal airflow, thereby maximizing filtration, heat, and humidification of air within the nasal passages [5–7]. Conversely, those with smaller, flatter external noses, more anteriorly directed nares, and shorter piriform apertures are better adapted to hot, humid environments. Because much of the energy required for breathing is expended in the nasal passages, a broader, flatter nasal structure favors less turbulent airflow, which is physiologically more economical because of the lower nasal airway resistance. In the platyrrhine nose, inspiratory airstreams passing through more horizontally

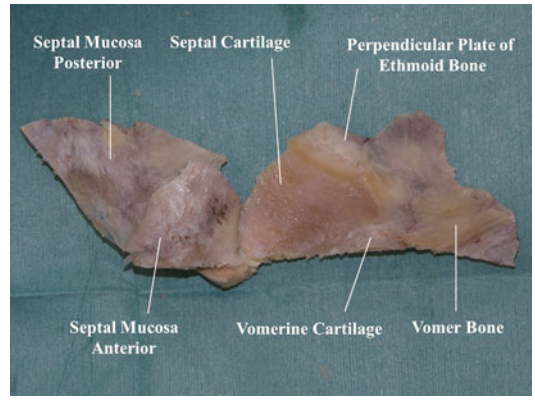


Fig. 5.5 Appearance of the nasal septum and mucosa. The septal mucosa has been placed inside out. (cadaver, 89-year-old male)

placed nostrils are directed toward the inferior portion of the nasal chamber to condition very warm air, and the region anterior to the turbinates typically plays a lesser role in black than in white individuals [5, 8].

Nasal Septum

The nasal septum comprises cartilage anteriorly (quadrilateral/septal cartilage) and bone posteriorly (vertical plate of the ethmoid bone posterosuperiorly and vomer bone posteroinferiorly) (Fig. 5.5) [1]. A membranous columella that divides the nares is present in the anteroinferior area [9], and the vomerine cartilage occupies the posteroinferior area [10]. The nasal septum divides the nasal cavity into two portions and forms most of the nasal bridge [2].

Although the vertical plate of the ethmoid bone and the nasal septum comprise hyaline cartilage in neonates, the vomer is already a bone [10]. From 1 or 2 months after birth, the hyaline cartilage begins to ossify posteriorly and forms the vertical plate of the ethmoid bone [10]. The nasal septum begins to grow rapidly from puberty and raises the external nose [10]. With its growth, the cartilage occasionally bends, forming protuberances and spurs at the junction with the vomer

[3, 10]. Approximately 90 % of adults show variable extents of septal bending that is directed both anteroposteriorly and transversely [3]. The nasal septum and bone continue to grow until the end of puberty [10]. The posterior edge of the cartilage grows posteriorly from puberty, resulting in formation of the sphenoid or vomerine processes [10].

The septal mucosa is thickest centrally in the superoinferior direction with a tendency to be thicker anteriorly in the anteroposterior direction (Fig. 5.5) [10]. The mucosa of the olfactory cleavage is comparatively thin [10]. Kiesselbach's area, a common site of nasal bleeding, is situated in the anteroinferior part of the septal mucosa [10].

Clinical Correlations

1. Nasal septal surgery should be performed after puberty because removal of the septal cartilage before puberty may prevent growth of the external nose [10]. For the same reason, it should be avoided or a minimal focal septoplasty should be done, if greatly needed in pediatric DCR.
2. Excessive removal of the anteriorly located septal cartilage occasionally causes ptosis of the nasal tip [10]. A saddle nose may occur by overharvesting the septal cartilage in the dorsum nasi [10]. Therefore, a 5- to 10-mm width of the dorsum nasi tissue should not to be removed. Incision of the nasal septum is usually performed 10 mm from the anterior tip of the septal cartilage, which approximately corresponds to the mucocutaneous junction. Incision of the cartilage is started approximately 3-mm posterior from the mucosal incision [3].
3. Endonasal dacryocystorhinostomy (DCR) occasionally requires a septoplasty, particularly if a Jones bypass tube is planned for insertion, because its aftercare requires easy endonasal access [2].

Lateral Nasal Wall

Lacrimal Passage

The anterior lacrimal crest, ridge, or maxillary line is formed by the underlying frontal process of the maxilla and corresponds to the anterior surface of the nasolacrimal duct [2].

The maxillary line is a curvilinear mucosal eminence projecting from the anterior middle turbinate attachment superiorly and extending inferiorly along the lateral nasal wall to the dorsum of the inferior turbinate (Fig. 5.6a, b) [11]. It corresponds intranasally to the junction of the maxilla and uncinate process and extranasally to the suture between the maxilla and lacrimal bone within the lacrimal fossa [11, 12]. A line drawn through the midpoint of the maxillary line is just inferior to the lacrimal sac–duct junction [11]. The thickness and proportion of the maxillary bone in the lacrimal sac fossa increases as the level increases from lower to upper [13]. When the height and length of the nasal bone are small, the frontal process of the maxilla is thick in the lacrimal fossa [13]. In this respect, Asians tend to have a thicker maxillary frontal process than that of Caucasians [13].

The lacrimal bone, which has a mean thickness of 0.057 [14] to 0.106 mm [15], is located posterior to the maxillary line. The lacrimal bone is also situated just anterior to the middle third of the uncinate process, which has an average length and width of 7.2 and 2.5 mm, respectively [14].

The nasolacrimal canal, which has an average length of 12 mm and drains into the inferior meatus (Figs. 5.1d and 5.6b) [9], originates at the base of the lacrimal fossa and is formed by the maxillary bone laterally and inferior turbinate bones medially [9]. The average width of the superior opening of the canal is 4.5–5.7 mm transversely [16–18] and 6.5–6.9 mm anteroposteriorly [17, 18]. The canal courses posteroinferiorly at an average of 12–27° (Fig. 5.1d) [17, 19–21] and almost parallel to the sagittal plane (Fig. 5.6c) [22]. However, in approximately half of individuals, the canal is directed inward against the sagittal line irrespective of the outward course of the lacrimal fossa [22, 23].

The nasolacrimal duct opening is present on the lateral nasal wall in the inferior meatus (Fig. 5.6b) [2]. The bony opening is most commonly located high up in the inferior meatus [2]. A duct orifice is present at this site in only about 10 % of individuals [24]. In most cases, a certain length of the mucosal duct extends anteroinferiorly from there

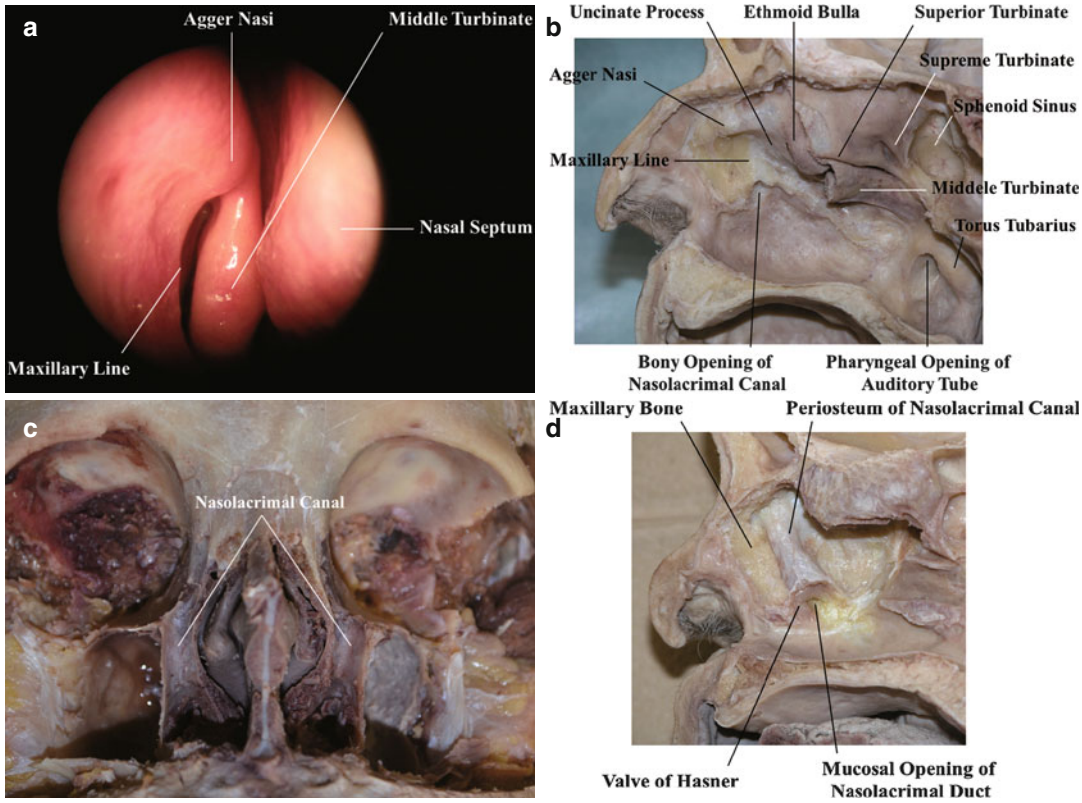


Fig. 5.6 (**a**) Maxillary line, agger nasi, and middle turbinate. (34-year-old female). (**b**). Appearance of the lateral nasal wall. The inferior turbinate and half of the middle and superior turbinates are removed. The bony opening of the nasolacrimal canal is seen. (cadaver, 89-year-old male). (**c**) The nasolacrimal canal courses almost parallel to the sagittal plane. (cadaver, 70-year-old male). (**d**) Certain length of mucosal duct, termed the valve of Hasner, extends from the bony opening of the nasolacrimal canal. (cadaver, 97-year-old female)

[24] and reaches approximately 1 cm posterior to the anterior tip of the inferior turbinate (Fig. 5.6d) [2]. This mucosal duct is often called the valve of Hasner [2]. The shape of the opening varies considerably from round to slit like or may simply be a pit or fold [2, 24].

The relationship between the lacrimal sac and lateral nasal wall is variable; the sac may be relatively high, normal, or low compared with the adjacent anterior nasal space (Fig. 5.7a, b) [2]. This may simply reflect differently sized nasal spaces and mid-face bony development [2]. Anterior ethmoid air cells are usually found between the lacrimal fossa and lateral nasal wall in most subjects [2]. These air cells are more common in the posterior superior lacrimal fossa [2].

The anterior end of the middle turbinate has been thought to be a constant anatomical landmark of the lacrimal sac [2, 25, 26]. However, whether this structure can serve as a useful landmark of the lacrimal sac fossa in the vertical or anteroposterior position is unclear [27]. Up to 20 % of the lacrimal sac was reported to be situated above the axilla of the middle turbinate [28, 29]. However, another study suggested that a large part of the lacrimal sac fossa was above the axilla of the middle turbinate [30–32]. In an Asian study, the axilla of the middle turbinate was attached to the lacrimal sac fossa in more than 90 % of cases and located above the lacrimal sac fossa in 4 % [13]. A wide positional variation was shown in relation to the lacrimal sac fossa.

The horizontal position of the axilla of the middle turbinate in Asians differs from that of Caucasians. A Caucasian study [33] demonstrated that in 53.2 % of cases, the axilla of the middle turbinate was located within the lacrimal sac fossa in contrast to the conventional notion

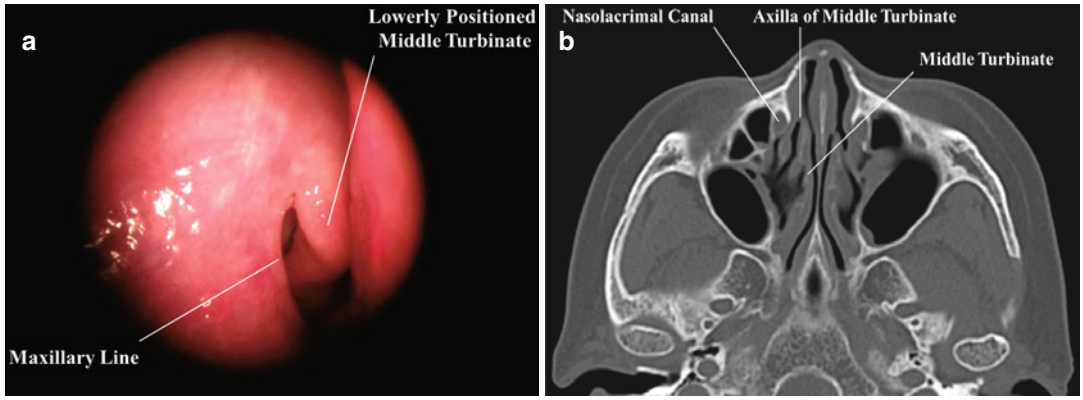


Fig. 5.7 (**a**, **b**) Relationship between the lacrimal sac and the middle turbinate is variable. These figures show high sac positions. (61-year-old female)

that the axilla of the middle turbinate is posterior to the lacrimal sac fossa. In an Asian study [13], the axilla of the middle turbinate was located posterior to the posterior lacrimal crest in only 2 % of cases.

More than 90 % of Caucasian specimens demonstrate the uncinate process extending beyond the posterior lacrimal crest [34]. However, in Asians, 100 % of the uncinate process reportedly attaches to the lacrimal fossa [13]. The ethmoid air cells are positioned more anteriorly in Asians than in Caucasians [13]. The anterior insertion of the uncinate process is oblique; the uncinate process generally attaches to the lacrimal bone at the lower level, becomes anterior to the maxillary bone–lacrimal bone at the middle level, and then joins the middle turbinate at the upper level [13]. The uncinate process is also helpful when approaching the lower portion of the lacrimal sac fossa [13].

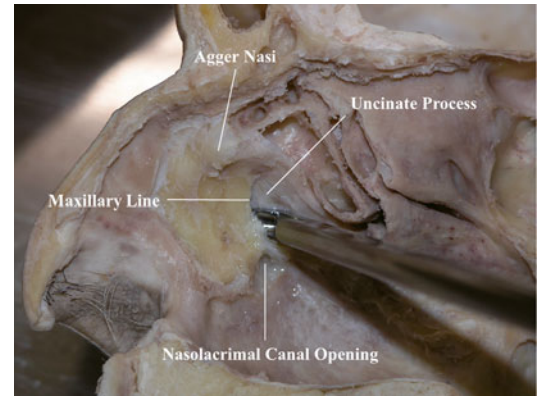


Fig. 5.8 Osteotomy during an endonasal dacryocystorhinostomy can be easily started at the lower portion of the lacrimal sac fossa, in which the lacrimal bone constitutes the lacrimal sac fossa in the highest proportion and the frontal process of the maxilla is thinnest. For ease of understanding, the rongeur is inserted into the nasolacrimal canal. (cadaver, 89-year-old male)

Clinical Correlations

(a) The lacrimal bone is very thin [14, 15] and easily penetrated for entrance into the nasal cavity during endonasal DCR [2]. In patients with a maxillary bone dominant fossa, the thicker bone makes it more difficult to create the osteotomy [2]. Special surgical techniques and instruments, such as a surgical drills or ultrasound aspirators, must be equipped for patients with a thick maxillary frontal process to expose the upper portion of the lacrimal sac fossa [13, 26]. In this respect, DCR for Caucasian patients with a thinner maxillary frontal process [13] may not require the use of such instruments.

(b) Osteotomy can be easily started at the lower portion of the lacrimal sac fossa, in which the lacrimal bone constitutes the lacrimal fossa in the highest proportion and the frontal process of the maxilla is thinnest (Fig. 5.8) [13].

(c) The uncinate process, which mostly extends beyond the posterior lacrimal crest, is an important factor to consider when creating an

osteotomy during DCR [25, 34]. However, the sac and duct usually lie immediately anteriorly and laterally to the uncinate process, which does not need to be disturbed during surgery [2]. This notion is mostly applied to Caucasians, but not to Asians. Because the anterior ethmoid air cells always extend to the posterior lacrimal crest in Asians [2], an uncinectomy is recommended to clearly expose the lacrimal sac fossa to create a sufficient ostium.

(d) The nasolacrimal canal opening (bony opening) is located in the ceiling of the inferior meatus [2]. However, the nasolacrimal mucosal orifice empties fairly anteriorly [24]. Therefore, a specific technique is needed to clearly observe this mucosal orifice, such as preexamination fluorescein staining or putting the inferior turbinate aside.

(e) Because of variability in the relationship between the lacrimal sac and lateral nasal wall [2], and because of the thick maxillary frontal process in patients with a low nasal bridge [13], the precise position of the lacrimal sac is best to be confirmed by a transcanalicular illumination device during endonasal DCR [13]. The structures intervening between the lacrimal sac fossa and nasal cavity must be defined by moving the light device up and down and back and forth [13]. Diffuse light is expected in cases with an anteriorly displaced uncinate process or large agger nasi cell [13].

(f) Most Asians may sometimes need a partial middle turbinectomy for creation of a sufficient ostium because most of the posterior lacrimal crest is covered by the axilla of the middle turbinate [13].

(g) As described in the "Ethmoid Infundibulum" section, bone exposure after mucosal resection induces granulation [3]. Although anterior and posterior mucosal flaps are created during external DCR, bone in the upper and lower portions of the osteotomy is still exposed. These parts are at risk of granulation formation. Although the use of mitomycin C [35] or a stent [36] may prevent granulation to some extent, covering the whole osteotomy margin with the mucosal flap without bone exposure leads to a decreased risk of granulation.

Inferior Turbinate and Meatus

The inferior turbinate is the largest turbinate and occupies the lower third of the lateral nasal wall (Fig. 5.4) [2]. It arises from the medial wall of the maxillary sinus; the other turbinates arise from the ethmoid bone [9]. Its anterior tip is located 1.5–2.0 cm inside the nasal space in adults [2]. Its medial surface is usually concave, and its lateral surface is usually convex [2]. The inferior turbinate is covered by thick vascular mucosa, which often results in hypertrophy [2]. The nasolacrimal canal opening is located on the lateral nasal wall in the inferior meatus (Fig. 5.6b) [2].

The size of the meatus under each turbinate may be large or small, corresponding to the size of the bone making up the turbinate and varying with the state of mucosal and vascular engorgement of the overlying epithelium [1]. These anatomic and mucosal factors can dramatically influence the structures draining into each meatus [1].

Middle Turbinate and Meatus

The middle turbinate is part of the ethmoid bone (Fig. 5.4) [2]. When this turbinate is enlarged by air cells, it is called the "concha bullosa" (Fig. 5.9) [2] or sometimes the "interlamellar cell" [3]. The concha bullosa is classified into three types: pneumatization of the vertical lamella (lamellar type), pneumatization of the

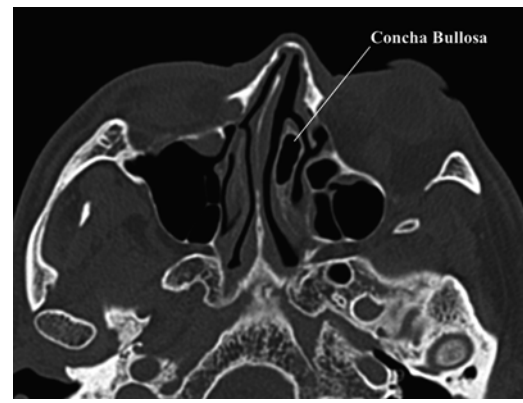


Fig. 5.9 Concha bullosa. (43-year-old male)

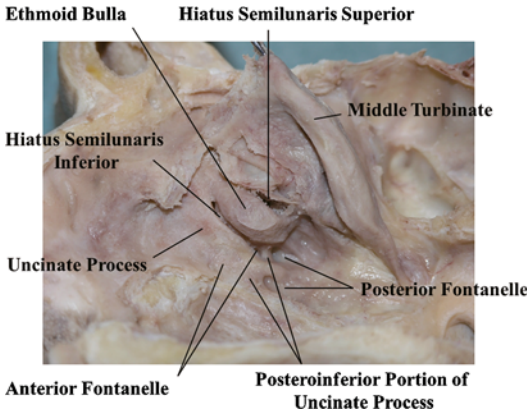


Fig. 5.10 Appearance of the middle meatus. This contains the uncinate process, hiatus semilunaris with the infundibulum, and ethmoid bulla and receives drainage from the frontal, anterior ethmoid, and maxillary sinuses. The posterior portion of the uncinate process divides the fontanelle into anterior and posterior parts. (cadaver, 89-year-old male)

inferior bulbous portion (bulbous type), and pneumatization of the entire turbinate (extensive type) [37, 38]. These air cells usually originate from the agger nasi [2]. Normally, its lateral wall is convex and its medial wall is concave. It protects the middle meatus and its important physiological structures [2].

The middle meatus contains the uncinate process, hiatus semilunaris with the infundibulum, and ethmoid bulla [2] and receives drainage from the frontal, anterior ethmoid, and maxillary sinuses (Fig. 5.10) [9]. This area is important pathophysiologically because it forms part of the ostiomeatal complex [2]. The detailed anatomy of this structure is described later [2].

The middle meatus divides the paranasal sinuses into anterior and posterior portions [3]. The anterior paranasal sinuses are the general term for the paranasal sinuses emptying into the middle meatus and comprise the frontal, anterior ethmoid, and maxillary sinuses [3]. The posterior paranasal sinuses are located posterior to the middle turbinate, the opening of which is around the ceiling of the posterior nasal cavity [3]. The posterior paranasal sinuses are constituted by the posterior ethmoid cells emptying into the superior meatus and the sphenoid sinus with its orifice

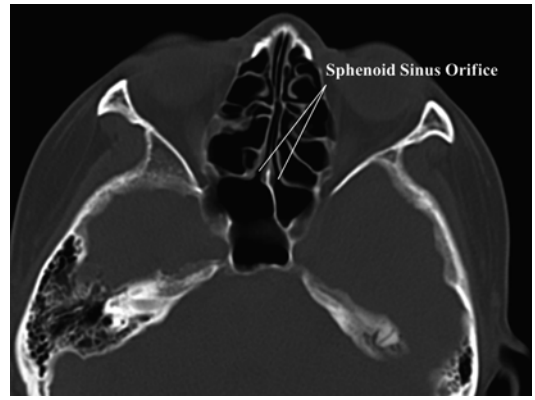


Fig. 5.11 Sphenoid sinus orifices. (38-year-old female)

opening to the sphenoethmoidal recess (Fig. 5.11) [3]. Conditions such as sinusitis are usually sectioned such as anterior or posterior types [3].

Superior and Supreme Turbinates and Meatuses

These structures and spaces are usually small and insignificant in size compared with the other two turbinates (Fig. 5.4) [1]. These turbinates originate from the ethmoid bone. The superior turbinate has the common attachment of the middle turbinate to the skull base [39]. The supreme turbinate may be found in up to 65 % of specimens [9]. The air cells forming the posterior ethmoid sinus drain into the superior meatus with two or three ducts and occasionally into the supreme meatus [1, 40]. The olfactory neuroepithelium, which is centered principally on the area of the cribriform plate, extends to the superior turbinate and superior part of the middle turbinate to varying degrees [41].

Anatomy of Ethmoid Sinus

Overview of the Ethmoid Sinus

The ethmoid air cells are cavities comprising various sizes of honeycomb-like air cells (Fig. 5.1a) [3, 42]. The superior border is the comparatively flat roof of the ethmoid, the lateral border is the lamina papyracea, and the medial

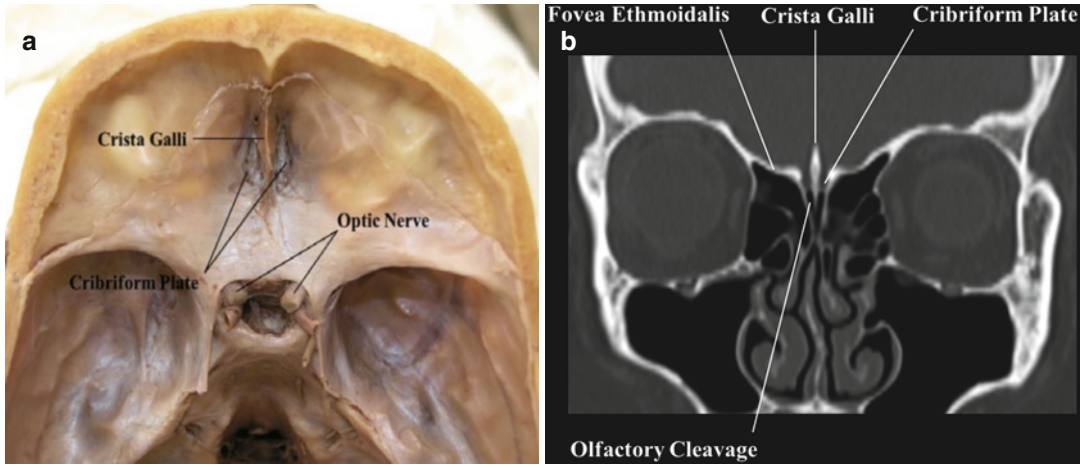


Fig. 5.12 (**a**) Appearance of the skull base with special features of the cribriform plate, crista galli, and optic nerve. (cadaver, 81-year-old male). (**b**) Cribriform plate separates the nose from the anterior cranial fossa. The cribriform plates are often located lower than the fovea ethmoidalis. (42-year-old male)

border is the lateral wall of the middle and superior meatuses and middle turbinate [3, 42]. The space is narrower anteriorly and becomes larger posteriorly, finally reaching the anterior wall of the sphenoid sinus (Fig. 5.11) [3, 42].

The cribriform plate is not a part of the ethmoid sinus, but is located medial to the attachment of the middle turbinate, separating the nose from the anterior cranial fossa (Fig. 5.12a) [1]. The two cribriform plates are separated from each other by the crista galli, and both plates lie posterior to the posterior table of the frontal sinus [1]. Each cribriform plate measures approximately 2 cm from anterior to posterior and 0.5 cm from medial to lateral [1]. The olfactory nerve endings traverse small openings in each cribriform plate to reach the olfactory bulb [1]. The narrow nasal cavity inferior to the cribriform plate is the olfactory cleavage [42]. The cribriform plates are often located lower than the roof of the ethmoid sinus, called the fovea ethmoidalis (Fig. 5.12b) [42].

Although the inside of the ethmoid sinus is complexly divided into many cells, there are several partitions dividing the sinus from anterior to posterior [3]. These are called the "basal lamellae" or "ground lamellae" [3]. When this is used in a singular form, it represents the "third basal lamella" [3]. Because the term "ground lamella" is not cited in Nomina Anatomica, the term "basal lamellae" is mainly used at present [3].

The basal lamellae of the ethmoid sinus are walls connecting the lateral nasal wall and the lamina papyracea [3]. However, only the third basal lamella clearly reaches the lamina papyracea from the lateral nasal wall [3]. Whether most of the other basal lamellae reach the lamina papyracea cannot be confirmed because of their complex structure [3]. Therefore, they are termed the "incomplete basal lamellae" [3].

The ethmoid sinus generally shows five basal lamellae that are numbered from anterior to posterior (Fig. 5.13) [3]. The first basal lamella continues to the uncinate process. The second generally originates from the anterior wall of the ethmoid bulla, occasionally including the whole ethmoid bulla with its posterior wall [43]. The third is the largest and most obvious lamella and hangs the middle turbinate [3]. This third basal lamella clearly divides the ethmoid sinus into anterior and posterior portions [3]. The fourth supports the superior turbinate, and the fifth originates at the supreme turbinate [3]. The central portion of the middle turbinate is all hung by the third basal lamella, but the anterior and posterior edges attach to the lateral nasal wall [3].

The three-dimensional positional relationship between the middle meatus and third basal lamella is similar to the relationship between the body of a pigeon and its half-opened wing when its body is regarded as the lamina papyracea [3]. That is to say, the portion of the body close to the half-opened wing is the third basal lamella, and the wing inferiorly hanging from that site is the suspended middle turbinate [3].

Haller cells (Fig. 5.14a) and Onodi cells (Fig. 5.14b) are known as special cells [3]. Haller cells, also called infraorbital cells, extend beneath the orbit and often narrow the ostiomeatal complex [3]. Onodi cells develop from the lateral wall of the ethmoid sinus and are specifically named when the optic canal protuberates into this sinus [3].

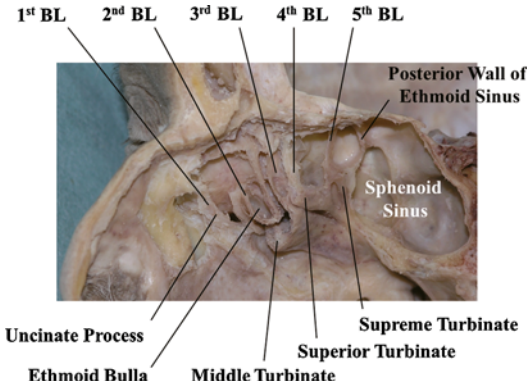


Fig. 5.13 Five basal lamellae of the ethmoid sinus. *BL* basal lamella. (cadaver, 89-year-old male)

Clinical Correlations

(a) Knowledge of the anatomy described herein is vital for the performance of endoscopic sinus surgery and endoscopic orbital surgeries such as orbitotomies or orbital and optic nerve decompression.

(b) Mucoceles and sinusitis in Onodi cells occasionally cause optic neuropathy because the optic nerve often runs close to the small cavities of Onodi cell [44–46]. Imaging studies are vital to detect these lesions, and endoscopic sinus surgery and antibiotic administration are effective treatments [44–46]. When operating in the vicinity of Onodi cells, optic nerve injury must be prevented [3].

Agger Nasi

The agger nasi is a mound situated above the axilla of the middle turbinate (Fig. 5.4). It is a remnant of the first ethmoturbinal region and is a pneumatized portion of the most anterior part of the ethmoid cell (Figs. 5.6b and 5.15a). The ascending portion of the first ethmoturbinal regresses as the agger nasi, and the descending portion remains as the uncinate process [12]. The agger nasi can lie within the lacrimal fossa, between the lacrimal bone and the nasofrontal fossa [2, 42]. It is present in 78–100 % of cases [13, 47]. When the axilla of the middle turbinate is situated lower, the agger nasi is also positioned

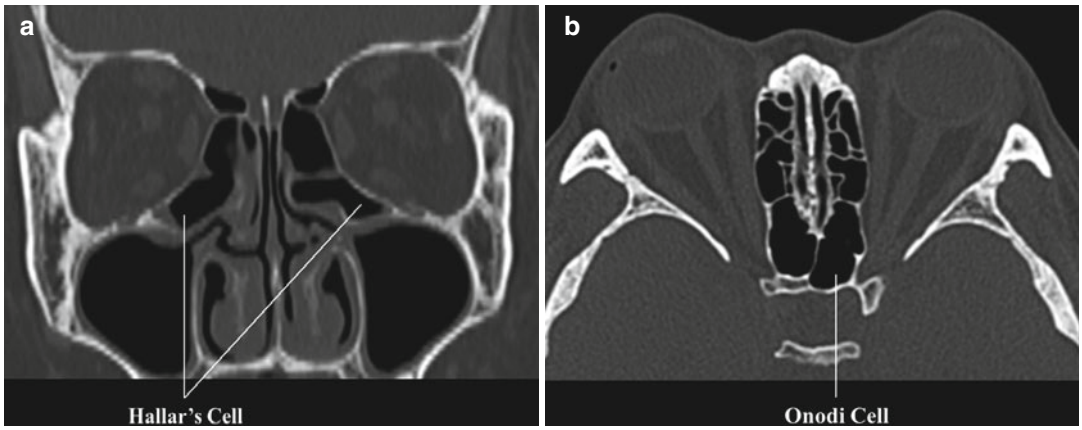


Fig. 5.14 (**a**) Haller cell. (49-year-old male). (**b**) Onodi cell. (52-year-old female)

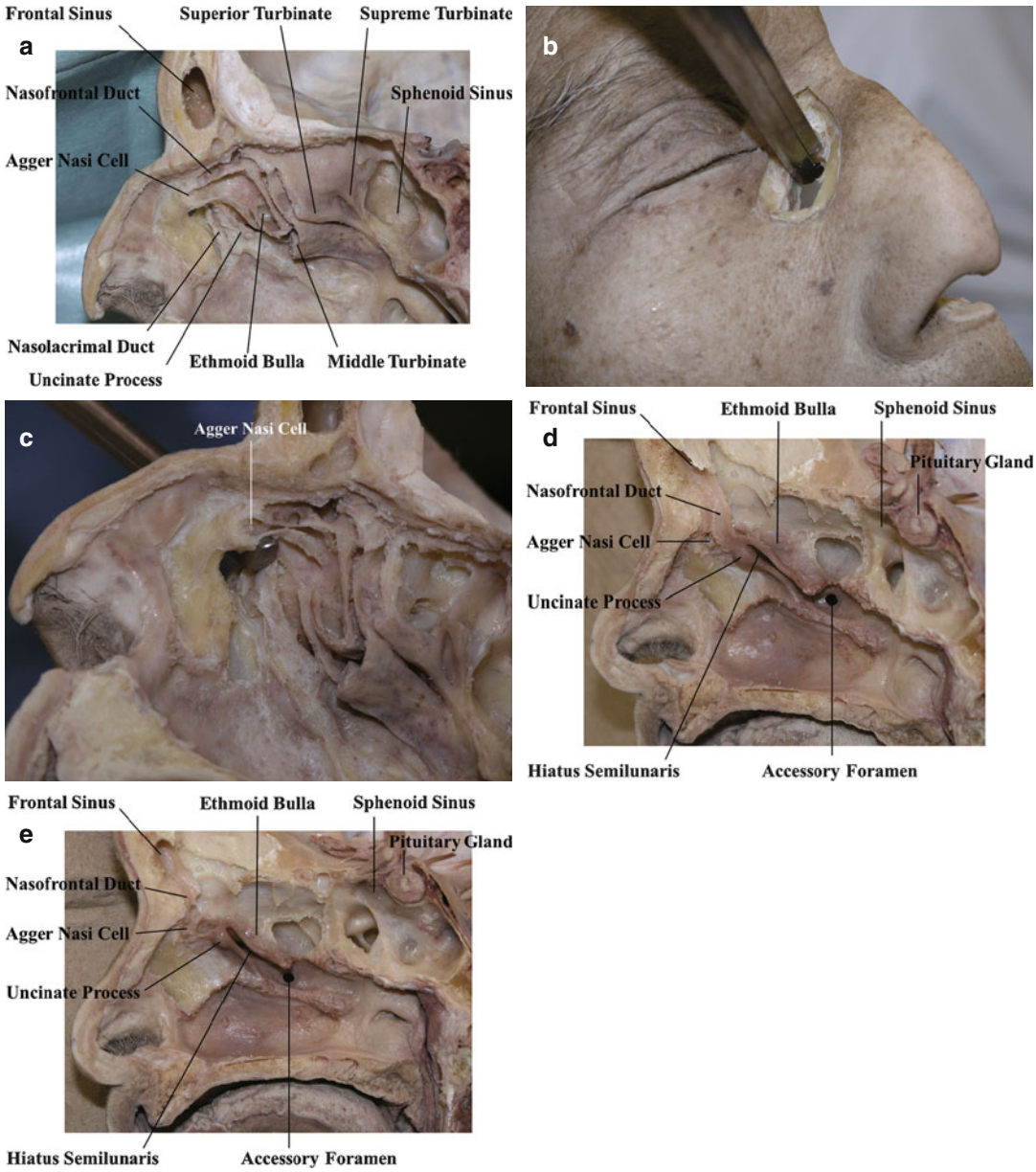
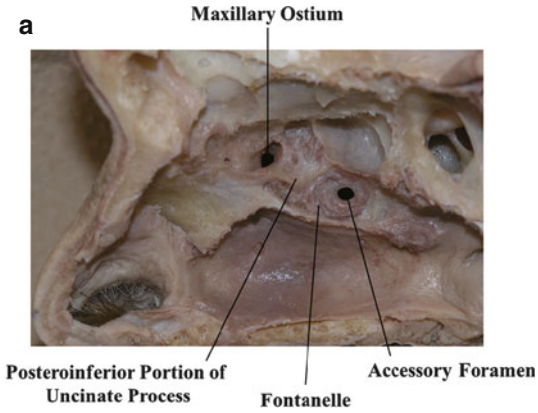


Fig. 5.15 (**a**) Agger nasi cell is a pneumatized part of the most anterior portion of the ethmoid air cell. (cadaver, 89-year-old male). (**b**, **c**) When the axilla of the middle turbinate is located lower than the lacrimal sac fossa, the agger nasi cell must be removed during dacryocystorhinostomy. (cadaver, 89-year-old male). (**d**) The agger nasi cell is situated in front of the nasofrontal duct. Accessory foramen is shown. The inferior and middle turbinates are removed. (cadaver, 97-year-old female). (**e**) Removing the lower part of the nasolacrimal duct, the agger nasi cell is situated is shown behind the nasofrontal duct. The maxillary ostium is shown through the hiatus semilunaris. (cadaver, 97-year-old female)

lower, with tendency to be adjacent to the lacrimal sac fossa [13]. This type is present in one-third to one-half of lacrimal sac fossas [13, 48]. The agger nasi cell is medially, superiorly, and inferiorly bound by the uncinate process [12]. Its anterior wall is the frontal process of the maxilla, and its lateral wall is the lacrimal bone [12]. Posterior pneumatization of the agger nasi cell



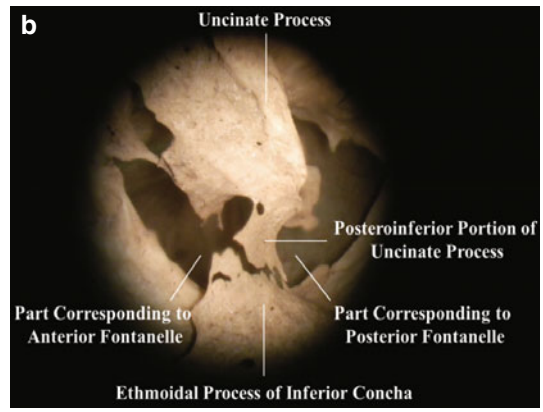


Fig. 5.16 (**a**) The hook part is covered by the fontanelle and located too posteroinferiorly. This figure shows a posteroinferior portion of the uncinate process with upward bending with attachment to only the lower portion of the ethmoid bulla. Accessory foramen opens at the fontanelle. The maxillary ostium is shown in front of the posteroinferior portion of the uncinate process. (97-year-old female). (**b**) The posteroinferior portion of the uncinate process comprises a plate of a cortical bone with no cells. (dry skull of unknown nationality, sex, and age)

pushes the posterosuperior attachment of the uncinate process backward to the lamina papyracea to form the terminal recess [12].

Clinical Correlation

(a) If the axilla of the middle turbinate is located lower than the lacrimal sac fossa, the agger nasi cell must be removed during DCR (Fig. 5.15b, c) [13].
(b) Because there is a close relationship between the agger nasi and the uncinate process, it is important to examine and analyze these structures as one unit.
(c) When confirmation of the frontonasal duct is difficult, removal of the agger nasi helps to detect it (Fig. 5.15d, e) [42]. In addition, the agger nasi cell is a key to understanding the anatomy of the frontal recess [49]. The frontal recess originally indicated a part of the ethmoid cells extending the frontal bone and clinically indicates a part of the anterior ethmoid cells around the frontonasal canal.

Uncinate Process

The uncinate process is a wing-like or boomerang-like structure covering the ethmoid infundibulum in the anterior part of the middle meatus (Fig. 5.10) [2, 42]. "Uncinate" is Latin for "hook" and refers to the shape of a thin leaf of bone lying almost parallel to the lateral nasal wall [2]. The hook part is covered by the fontanelle and located too posteroinferiorly (Fig. 5.16a) to see its shape [50, 51]. It comprises a plate of a cortical bone with no cells (Fig. 5.16b) [42].

The inferior border of the uncinate process is curvilinear and directed anterosuperiorly [48]. An anteriorly attached uncinate process covering at least 50 % of the lacrimal fossa is present in 63 % of individuals [48] and can be expected to totally obstruct the access to the lacrimal sac fossa [13]. Fifty percent of the uncinate process reaches anterior to the frontal process of the maxilla, and 40 % articulates on the lacrimal bone [52–54].

The uncinate process is divided into eight patterns based on the shape or articulation pattern of its posteroinferior portion: [50, 51] articulation only to the inferior concha (42 %); articulation to the inferior concha inferiorly with simultaneous attachment to the lower portion of the bulla ethmoidalis superiorly (24 %); a small or absent anterior fontanelle because of attachment of the lower margin of the posteroinferior portion of the uncinate process to the inferior concha in close proximity (11 %); attachment only to fibrous tissues without any bony attachment to

the landmarks of the fontanelle such as the inferior concha, the perpendicular plate of the palatine bone, or the lower portion of the bulla ethmoidalis (10 %); articulation to the perpendicular plate of the palatine bone (5 %); complete ossification over the location of the posterior fontanelle (4 %); upward bending and attachment to only the lower portion of the bulla ethmoidalis (3 %); and simultaneous articulation to the lower portion of the bulla ethmoidalis, perpendicular process of the palatine bone, and inferior concha (1 %).

The superior attachment of the uncinate process is divided into three major variants: attachment to the lamina papyracea laterally, to the skull base centrally, and to the middle turbinate medially [12]. The single superior attachment of the uncinate process to the lamina papyracea shows the highest prevalence (33 %), followed by that to the skull base (10 %) [12]. Other specimens show more than one superior attachment (57 %) either to the lamina papyracea and skull base (31 %) or to the lamina papyracea and middle turbinate (21 %) [12]. Taken together, the uncinate process attaches to the lamina papyracea in 86 % of cases [12]. This rate of 86 % is close to the prevalence of the agger nasi cell (78–100 %) [12]. The two close rates indicate that most of the upper part of the uncinate process extends backward and laterally to further connect the agger nasi cell with the terminal recess [12]. The cells between the uncinate process and the lamina papyracea in the posterosuperior portion comprise the "terminal recess." [3, 12]

The site of attachment of the uncinate process determines the frontal sinus drainage pathway [42]. When the uncinate process attaches to the lamina papyracea inferolateral to the frontonasal fossa, the frontonasal duct drains into the nasal cavity, and when the uncinate process attaches to the roof of the ethmoid bone or middle turbinate medial to the nasofrontal fossa, the nasofrontal duct drains into the ethmoid infundibulum [42]. The frontal sinus empties via the nasofrontal duct into the nasal cavity in 86 % of cases and into the ethmoid infundibulum in 14 % [12, 42]. Because the nasofrontal duct threads the ethmoid cells, it is not actually a simple duct, but an irregular passway [3].

Fontanelle

The fontanelle, the membranous part of the maxillary sinus, must be described in relation to the uncinate process (Figs. 5.10 and 5.16a) [42]. The boundaries of the fontanelle were recently well described [50]. The anterior boundary is the lacrimal bone, and the posterior boundary is the perpendicular plate of the palatine bone [50]. The superior boundary comprises the orbital floor in the anterior one-fifth, the lower horizontal portion of the bulla ethmoidalis in the middle section, and the horizontal portion of the basal lamella of the middle turbinate in the last one-fifth [50]. Therefore, the superior margin of the fontanelle corresponds to the inferior margin of the orbital floor [42]. The inferior boundary is the superior border of the inferior turbinate [50]. In most cases, the posteroinferior portion of the uncinate process crosses the anterior portion of the fontanelle and is attached to the ethmoid process of the inferior concha [50]. The fontanelle is usually divided into anteroinferior and posterosuperior parts by the posteroinferior portion of the uncinate process (Fig. 5.10) [3, 50, 51].

The fontanelle shows three major shapes when observed from the medial to lateral aspects: triangular, pencil-like, and oval [50]. In the triangular type, the posterior height is higher than the anterior height, whereas the anterior and posterior heights of the pencil-like type are almost identical [50]. The pencil-like type has an anterior end that is similar in shape to the blunt tip of a pencil [50]. In the oval type, the midportion of the fontanelle is the highest, with less anterior and posterior height. [50] The triangular type is the most common (57.3 %), followed by the pencil-like type (25 %) and oval type (20 %) [51]. In one study, the anteroposterior length of the whole fontanelle was 18.1 ± 3.8 mm (mean ± SD), and the greatest height of the whole fontanelle was 9.2 ± 2.2 mm [50].

Clinical Correlation

It is important to know the anatomical landmarks of the fontanelle, since this is utilized as a landmark in sphenopalatine artery (SPA) ligation. The SPA ligation is one of the last resorts in the

management of recalcitrant epistaxis and this is an important tool in the armamentarium of any nasal endoscopic surgeon.

Ethmoid Bulla

The ethmoid bulla is a thin-walled bony prominence representing the largest and most consistent air cell of the anterior ethmoid complex, like a bleb on the lamina papyracea (Figs. 5.10 and 5.17a) [2]. The orifice of this cell is located at a cavity in the back side facing the third basal lamella [3] called the lateral recess or retrobulbar recess (Fig. 5.17b, c) [3, 55]. When no air cell exists in the ethmoid bulla, it is termed the torus ethmoidalis or torus lateralis [3]. The part forming a dome in the roof of the anterior ethmoid cells is called the fovea ethmoidalis and is part of the skull base formed by the frontal bone [3].

The ethmoid bulla is classified into three types based on its development [56]. The simple bulla is a single cavity with one opening, generally to the hiatus semilunaris [56]. The compound bulla has two or three separate compartments that communicate with the hiatus semilunaris [56]. The complex bulla also has two or three compartments, each of which communicates with the hiatus

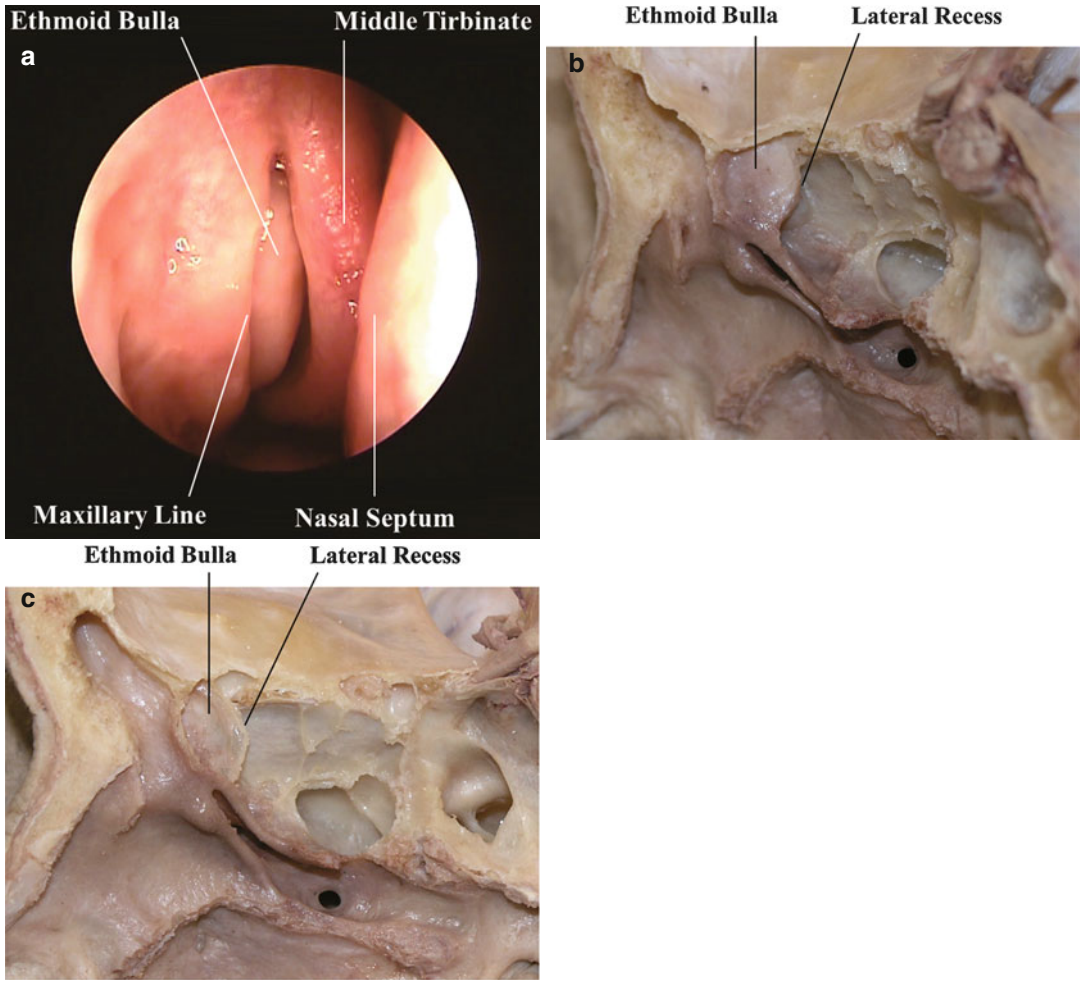


Fig. 5.17 (**a**) Ethmoid bulla occasionally bulges anteriorly (67-year-old female). (**b**) The lateral recess of the ethmoid bull is a cavity in the posterolateral side facing the third basal lamella. (cadaver, 97-year-old female). (**c**) The lateral recess of the ethmoid bulla. The medial aspect of the ethmoid bulla is removed. (cadaver, 97-year-old female)

semilunaris, ethmoid infundibulum, or superior meatus [56]. In individuals with compound and complex bullae, there is no communication between the compartments [56]. About 50, 25, and 25 % of ethmoid bullae are simple, compound, and complex bullae, respectively [56].

Hiatus Semilunaris

The superior posterior free margin borders of the uncinate process create the hiatus semilunaris with the ethmoid bulla (Figs. 5.10 and 5.15d, e), which is an important crescent-shaped cleft leading to the infundibulum and into which the frontal, anterior ethmoid, and maxillary sinuses drain [2]. In general, the cleft situated anteroinferior to the ethmoid bulla is known as the hiatus semilunaris. This is typically 1–2 mm wide, but can be up to 3 mm wide [57]. The posterosuperior cleft to the ethmoid bulla is occasionally called the hiatus semilunaris superior [3]. In this situation, the general hiatus semilunaris is called the hiatus semilunaris inferior [3]. The hiatus semilunaris superior is continuous with the lateral recess of the ethmoid bulla and third basal lamella (Fig. 5.17b, c) [3, 58]. Including the ethmoid infundibulum, the hiatus semilunaris is not a term describing a structure or a tissue, but a space encircled by tissues [3].

Ethmoid Infundibulum

The ethmoid infundibulum is a funnel-shaped space bordered medially by the hiatus semilunaris and laterally by the lamina papyracea (Figs. 5.1a, 5.9, and 5.14a) [2]. The maxillary sinus ostium is found at the floor and lateral aspect of the infundibulum, where is usually hidden by the uncinate process and cannot be observed by nasal endoscopy (Figs. 5.15d, e and 5.16a) [2, 42]. The ostium of the maxillary sinus lies in an approximate vertical line to the anterior ethmoid foramen [10]. In most specimens, the position of the maxillary ostium is situated on the second and half quarter of the anterior surface of the ethmoid bulla [59] with a 7- to 11-mm length and 2- to 6-mm width [60]. The average distance from the maxillary ostium to the nasolacrimal canal is 5.5 mm [59]. Ten to fifty percent of specimens show more than one accessory ostium opening at the anterior, posterior, or both fontanelles (Figs. 5.1a, 5.15d, e, and 5.16a) [3, 59, 61]. These accessory ostia can be observed by nasal endoscopy [3].

The anterior and posterior ethmoid air cells show several openings, respectively [3]. The ethmoid infundibular area is important pathophysiologically because it forms part of the ostiomeatal complex [2].

Clinical Correlations

(a) Silent sinus syndrome, also called imploding antrum syndrome [62], is a rare disorder characterized by unilateral or bilateral enophthalmos and hypoglobus caused by an alteration of the orbital architecture due to maxillary sinus collapse with chronic hypoventilation [62–64]. Its basic pathology involves negative maxillary antral pressure because of obstruction of the ethmoid infundibulum, which generates negative pressure over time [65]. This entity is idiopathic, occurs postoperatively following bony decompression for Graves' orbitopathy [66], or develops after facial trauma, especially orbital floor fracture [65]. The conditions after surgery and radiotherapy for sinonasal malignancy are excluded [64, 67]. Frontal silent sinus syndrome was recently reported as well [68].

(b) Bone exposure after mucosal resection induces granulation [3]. In medial orbital wall decompression, mucosal removal [69] may not cause granulation because the escaped orbital contents occupy the space. However, after surgery for smooth ventilation against sinusitis, mucosal removal may increase granulation to an extent that negates the surgical purpose [3]. In this kind of surgery, the intact mucosa must therefore be preserved as much as possible [3].

Ostiomeatal Complex

The ostiomeatal complex is also called the ostiomeatal unit [3]. This complex is considered to be a unified apparatus comprising the anterior

ethmoid sinus openings and their passages [3]. It is a functional and conceptual unit containing the openings and passages of the frontal, anterior ethmoid, and maxillary sinuses [3]. Therefore, the ostiomeatal complex is not an anatomical term [3], but corresponds to the middle meatus, anterior ethmoid sinus, and orifices of each paranasal sinus emptying around them. Specifically, the ostiomeatal complex contains the agger nasi cells, frontal sinus orifice, nasofrontal duct, natural ostium of the maxillary sinus, ethmoid infundibulum, hiatus semilunaris, and middle meatus [3].

Ventilation and drainage of the frontal, ethmoid, and maxillary sinuses largely depend on the state of the ostiomeatal complex [3]. Functional deficiency of the ostiomeatal complex is mainly caused by anatomical disorders, obstructive lesions, and functional changes [3]. Anatomical disorders involve the concha bullosa, paradoxical middle nasal turbinate, paradoxical uncinate process, septal deviation, and distention of agger nasi cells and Haller cells [3]. Cilial disorders are enumerated as functional disorders [3]. These disorders do not always result in disorders of the ostiomeatal complex [3]

Anatomy of the Sphenoid Sinuses

The sphenoid sinuses are located at the most posterior part of all the paranasal sinuses (Figs. 5.1a, 5.3, 5.4, and 5.11) [42] and within the body of the sphenoid bone. They vary greatly in size and shape [1, 34]. The length from the nostril to the anterior wall of the sinus is about 7 cm [42]. They are commonly deep in their anteroposterior dimensions [1, 34]. Laterally, they may extend into various parts of the sphenoid bone, including the greater and lesser wings, pterygoid processes, and lateral pterygoid plates [1, 34]. The midline septum usually divides the two sinuses unequally (Fig. 5.11) [1, 34].

The sphenoid ostia are located superiorly and medially on the anterior wall and drain into the sphenoethmoidal recess [1, 34], the highest point of which is about the center between the choanae and the roof of the nasal cavity [42]. From an endoscopic viewpoint, the sphenoid ostium is located, in most cases, medial to the posterior part of the superior turbinate [40, 70, 71]. The lateral one-half to two-thirds of the anterior wall of the sphenoid sinus abuts against the posterior ethmoid air cells and is called the pars ethmoidalis [1, 34, 35]. The medial one-third to one-half faces the posterosuperior nasal cavity between the superior turbinate and the nasal septum and is called the pars nasalis [42].

The sphenoid sinuses have several important relationships with surrounding structures (Figs. 5.1a, 5.3, 5.4, and 5.15a) [1, 34]. The brain stem (pons, basilar artery) lies posterior to the ethmoid sinus (Figs. 5.3 and 5.4) [1, 34]. The optic chiasm and pituitary gland lie superior to the sinus, and the pituitary gland commonly bulges into the superior wall (Figs. 5.3, 5.4 and 5.15d, e) [1, 34]. The optic nerves, carotid artery, and cavernous sinus are important lateral relationships (Figs. 5.1a and 5.12a) [1, 34]. The nasopharynx is inferior to the sphenoid sinus (Figs. 5.3 and 5.4) [1, 34].

Clinical Tips

(a) When the sphenoid sinus is pneumatized to a large extent, only a thin wall of bone and mucoperiosteum separate it from the surrounding tissue [34]. In such a situation, serious cases of sphenoid sinusitis may compromise the optic nerve [34].

(b) Invasive fungal sphenoiditis is an ophthalmic emergency. Fungal elements penetrate the sinus mucosa, submucosa, blood vessels, or bone in invasive sphenoiditis [72], often causing an orbital apex syndrome and further extending to the meninges, cavernous sinus, and cavernous carotid artery [73]. Early treatment including aggressive surgical debridement and antimycotic drugs is essential to preserve vision and life [73].

(c) An injury to the head, especially to the brow, may result in an optic canal fracture [74, 75]. Causes of vision loss include bone fracture or tissue swelling within the optic canal that compresses the optic nerve or a bone fragment penetrating into the optic nerve [76]. Optic nerve decompression via the sphenoid sinus may result in vision improvement in

patients with light perception [76]. On the other hand, this procedure may not be indicated for patients with no light perception who have a lateral wall fracture of the optic canal or a bone fragment penetrating the optic nerve [76].

Conclusion

The sinonasal anatomy was illustrated in detail with the use of cadaver specimens, CT, and nasal endoscopic figures. Although each lacrimal or orbital surgery requires different portions of the knowledge presented in this chapter, we believe that these surgeries can be performed safely and with confidence endoscopically by understanding each surgical field as a part of the whole.

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Evaluation of Epiphora

6

Sima Das

Epiphora or watering is one of the most common symptoms of any ocular pathology. Though most cases of watering are due to nonpatency in the lacrimal outflow pathway, others like eyelid and adnexal disorders, corneal and ocular surface pathology can also manifest as watering. In this context, it is important to distinguish between the terms epiphora and pseudoepiphora or hyperlacrimation [1, 2]. True epiphora refers to watering due to obstruction in the lacrimal outflow pathway, while hyerlacrimation refers to excessive watering due to reflex irritation of the corneal and conjunctival surface as in cases of dry eye, corneal abrasion, corneal foreign body, etc. (Fig. 6.1a–f). It is also important to differentiate between anatomical and functional lacrimal pathway obstruction. Anatomical obstruction refers to any structural pathology in the lacrimal outflow pathway which hinders tear drainage. Conditions like punctal and canalicular stenosis and block, nasolacrimal duct obstruction (NLDO), etc., are the causes of anatomical obstruction. In functional dysfunction, the lacrimal outflow pathway is normal anatomically with a patent syringing. However, there is a failure of the lacrimal pump mechanisms which could be due to pathology outside the lacrimal pathway like punctal ectropion, eyelid laxity, or due to problems in the lacrimal pump mechanism itself as in cases of facial palsy. Hence, a detailed and comprehensive evaluation is needed to identify the cause of watering and initiate appropriate management. The goal of the evaluation is to differentiate true epiphora from hyperlacrimation, differentiate obstructive cause of epiphora from nonobstructive cause, and find the site of obstruction in cases of obstructive epiphora. The evaluation can be divided into history taking, local examination, lacrimal system vital signs, ancillary investigations, and nasal evaluation.

History

A detailed history will provide a clue to the appropriate diagnosis in most cases of watering. This is especially important in children where tests like irrigation and probing which are usual part of evaluation in adult patients may not be possible. History should be taken from the patient or the primary care giver in case of a child and should include details about the onset, frequency, type, intermittency, laterality of the symptoms, any previous treatment, etc. Epiphora due to congenital nasolacrimal duct obstruction (CNLDO) will be present since shortly after birth. CNLDO is usually caused by imperforate valve of Hasner and the symptom of watering is mostly constant in these patients [3]. Symptoms of watering which starts a few months after birth may not be due

S. Das, MS
Ophthalmic Plastics Surgery,
Schroff Eye Hospital, Delhi, India
e-mail: contactsima@gmail.com

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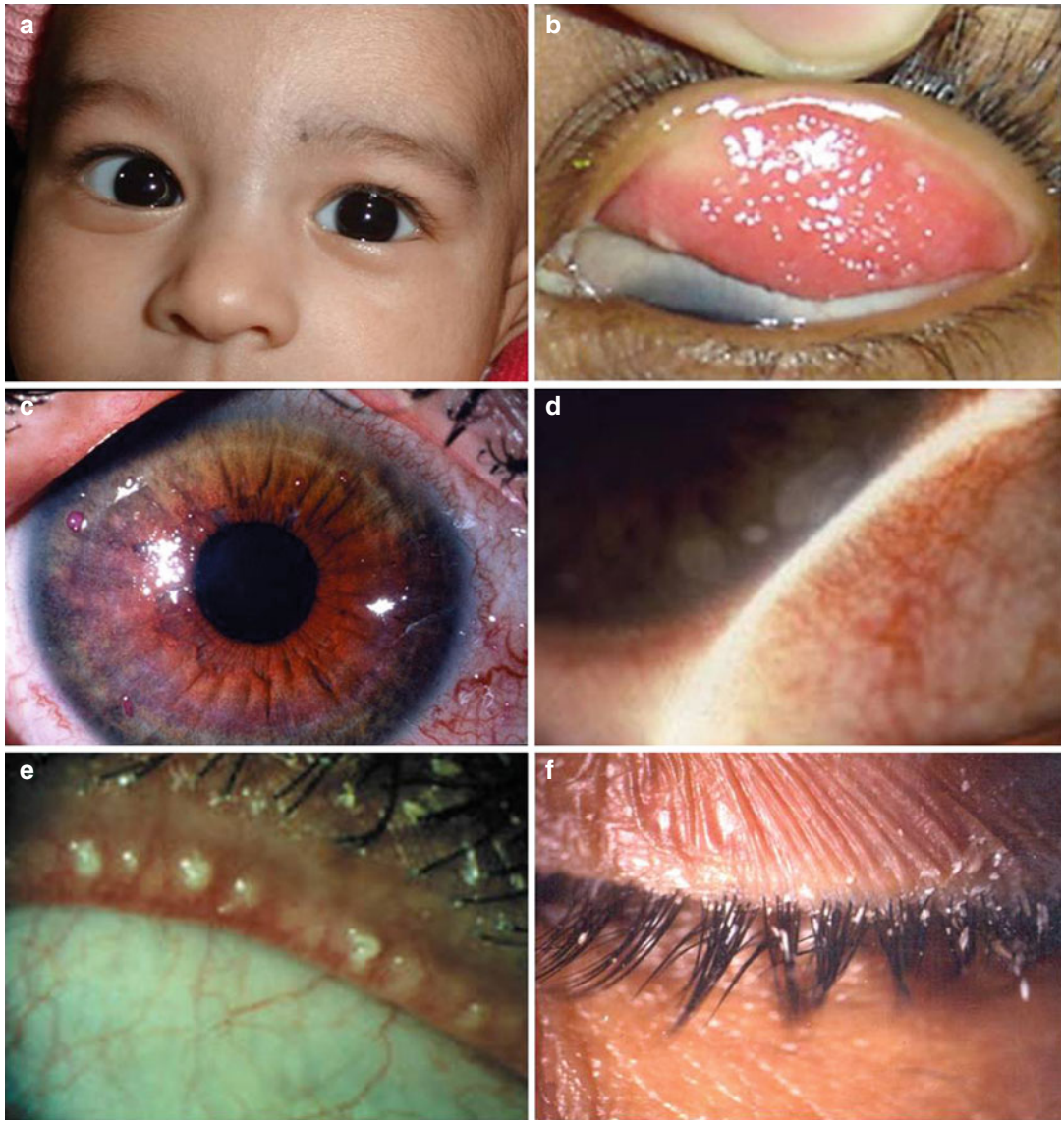


Fig. 6.1 Common causes of hypersecretion or reflex watering. Congenital entropion in a child (**a**), Conjunctival papillae in a case of allergic conjunctivitis (**b**), Dry eye with corneal filaments causing reflex hypersecretion (**c**), Marginal keratitis as the cause of epiphora in cases with blepharitis (**d**), Severe meibomitis and blepharitis causing watering due to tear film disturbance (**e**, **f**)

to CNLDO and warrants further evaluation to determine the cause. Epiphora due to complete nasolacrimal duct obstruction (NLDO) is usually continuous with associated intermittent mucoid or purulent discharge. History of intermittency with exacerbation during episodes of upper respiratory tract infection points toward a partial obstruction or nasolacrimal duct stenosis. History of bluish swelling in lacrimal sac area present since early days of life is suggestive of amniontocele and an underlying NLDO. History suggestive of acute dacryocystitis in a child with CNLDO should

also be elicited as it might warrant an early probing. Associated history of systemic conditions like Crouzon and Treacher Collins syndrome should also be noted as these syndromes can have associated bilateral NLDO and more likely to have complex NLDO. Symptoms of photophobia with history of watering should raise suspicion of associated corneal or ocular surface problem or eyelid conditions like entropion or lid margin keratinization as seen in cases of Stevens–Johnson syndrome. Congenital glaucoma is a vision threatening condition and can manifest initially with watering and photophobia [4]. Epiphora due to anatomical obstruction in the nasolacrimal duct or canaliculi is more likely to be unilateral while bilateral watering especially if associated with history of itching and seasonal exacerbation more likely points toward a reflex cause of watering like allergic conjunctivitis.

History of trauma to the ocular adnexa or nose should be elicited as injury to the punctum or canaliculus can give rise to watering and naso-orbito-ethmoidal fracture can cause acquired NLDO [5].

History of previous medical therapy should also be elicited, especially use of topical anti-glaucoma and antiviral medications as these can cause punctual scarring and stenosis [6]. Occasionally a history of antineoplastic drugs like Paclitaxel and 5-Fluorouracil may similarly give a clue toward possible punctal and canalicular stenosis. History of nasal symptoms and previous nasal surgery like sinus surgery can provide a clue to the cause of watering. Any history of previous surgical intervention for epiphora like previous sac surgery, probing or incision, and drainage for lacrimal abscess should be elicited as it has a bearing on the management decision.

External Examination

External examination should begin with inspection of the face and periorbital region (Figs. 6.2a–d and 6.3a–f). Position of the eyelids, punctum, gross nasal deformity, and facial symmetry should be looked for. Presence of any swelling or mass in the lacrimal sac area should be noted.

Severe entropion and trichiasis with lashes rubbing on the ocular surface can cause reflex watering. Ectropion due to facial palsy can affect the lacrimal pump mechanism and thus cause epiphora. Ectropion and eyelid laxity can also cause epiphora by causing lagophthalmos and displacement of the punctum from the tear lake thereby decreasing the tear outflow. Horizontal laxity of the eyelid can be checked by doing the pinch test where the lower eyelid is pinched at the center and pulled away from the globe [1, 2]. More than 6 mm distance between the pinched eyelid and cornea indicates a lax eyelid which can cause epiphora due to disturbed tear flow. The tone of the orbicularis muscle is tested by doing the snapback test where the lower eyelid is pulled away from the globe, released, and the speed with which the eyelid goes back to its normal position is assessed. When the orbicularis tone is good, the eyelid snaps back immediately and quickly to its normal position. In cases of decreased orbicularis tone as in cases of facial palsy the eyelid moves slowly or sometimes after a blink to its actual position. Such cases can have associated weakness of the lacrimal pump function and can manifest as epiphora. Poor orbicularis tone can also cause watering by disturbing the tear flow along the lower eyelid.

Any eyelid retraction or lagophthalmos as seen in cases of thyroid eye disease and facial palsy can cause reflex hypersecretion due to corneal or conjunctival exposure [7, 8]. In addition, in thyroid eye disease, the tear outflow facility is also disturbed due to a caruncular swelling or disturbance of canalicular function.

Anterior insertion of the medial canthal tendon is seen in patients with Centurion syndrome [9]. This clinical condition is usually detected in the older children and has a spectrum of facial and ocular findings including steep nasal bridge, anterior insertion of medial canthal tendon, punctal ectropion, punctal stenosis, lagophthalmos, etc. Presentation is usually with an unexplained epiphora. Treatment is required in symptomatic patients and is usually done by a medial canthoplasty with or without punctoplasty.

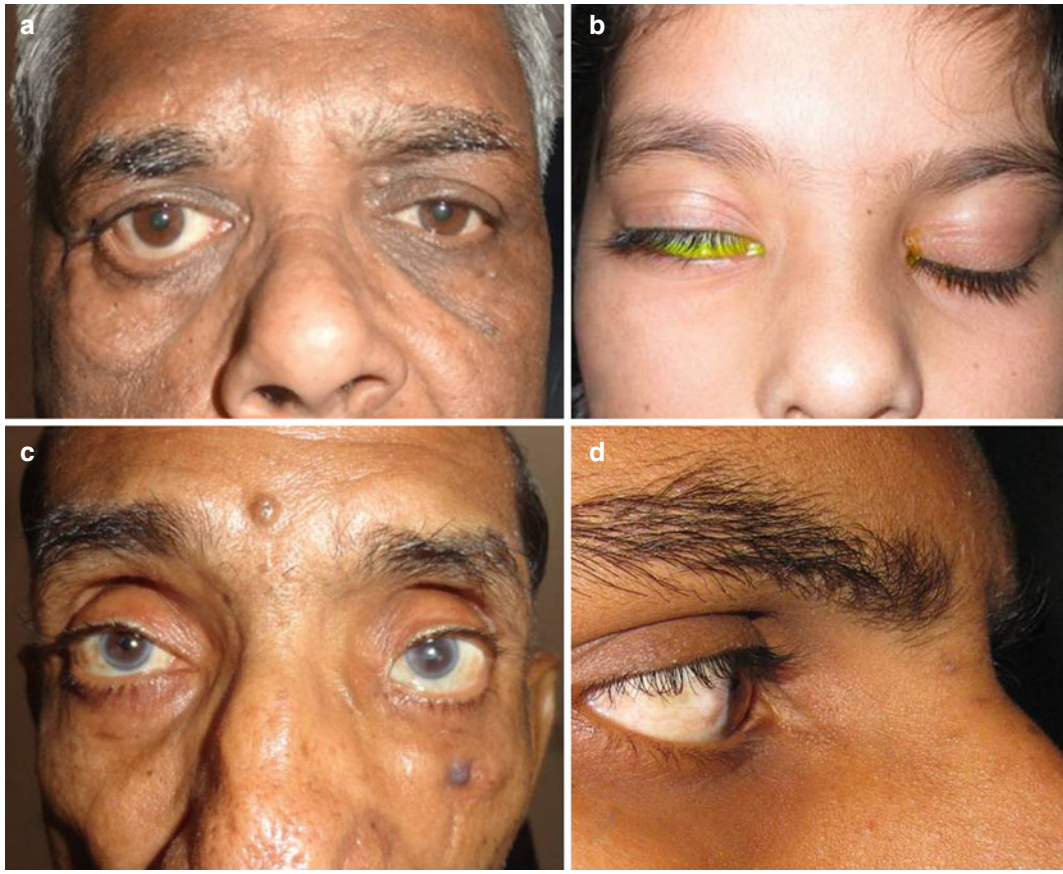


Fig. 6.2 Inspection findings of the adnexa and periocular area. Epiphora in a patient with lower eyelid laxity and ectropion in a patient with long-standing right-sided facial palsy (**a**). Lagophthalmos due to right facial palsy causing epiphora due to lacrimal pump dysfunction. Note the increased tear meniscus height on right side (**b**). Rounding of the medial canthus and unilateral telecanthus in a patient with history of trauma and poorly repaired eyelid laceration resulting in a bicanalicular block and cosmetic blemish (**c**). Steep nasal bridge and anterior insertion of the medial canthal tendon in young patient with Centurion syndrome (**d**)

Inspection of the medial canthal area can also reveal swelling below the canthus suggestive of a lacrimal mucocele [1, 2]. Mucocele of the sac rarely extends above the level of medial canthal tendon and extension of the swelling above the level of canthus might indicate a malignant sac swelling or mass lesion arising from the surrounding structures like nasal cavity or ethmoid sinus. Swelling arising from ethmoid sinus or nasal cavity can cause secondary NLDO and can extend to the medial orbit causing unilateral telecanthus which if present points to an underlying sinonasal pathology. Presence of any skin scar from previous surgery or fistulae in the medial canthal area should be noted. Congenital lacrimal fistulae are located inferolateral to the canthus and are usually single [10]. Acquired lacrimal fistulae following trauma or a granulomatous sac infection can be situated above or below the canthus and can be multiple.

Palpation of the lacrimal sac area might reveal the presence of mucocele or occasionally lacrimal sac masses (Fig. 6.4a, b). Pressure over the lacrimal sac can cause mucopurulent material to regurgitate through the punctum confirming a diagnosis of chronic dacryocystitis or lacrimal mucocele [1, 2]. If pressure regurgitation over the lacrimal sac (ROPLAS) is positive, note is made of the type of the regurgitated material (watery, mucoid, mucopurulent, blood stained) and whether it is coming from the same or opposite punctum. To avoid false

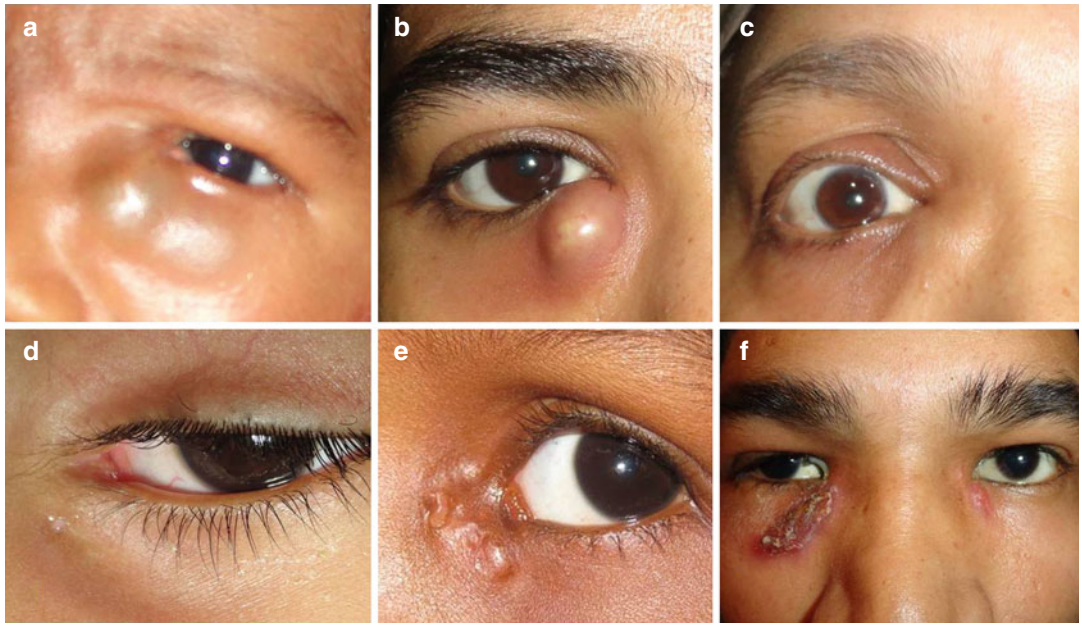


Fig. 6.3 Examination findings of the lacrimal sac and medial canthal area. Bluish, tense cystic swelling below the level of medial canthus in a newborn suggestive of dacryocele (**a**). Acute dacryocystitis with lacrimal abscess in a patient with nasolacrimal duct obstruction. Note the overlying skin erythema and edema (**b**). Chronic dacryocystitis with lacrimal mucocele (**c**). Congenital lacrimal fistulae located just inferolateral to the medial canthus (**d**). Acquired lacrimal fistulae following spontaneously drained lacrimal abscess. Note scarring of the surrounding skin (**e**). Bilateral chronic dacryocystitis with multiple fistulae formation and skin ulceration following spontaneously drained lacrimal abscess in a patient with lacrimal sac tuberculosis (**f**)

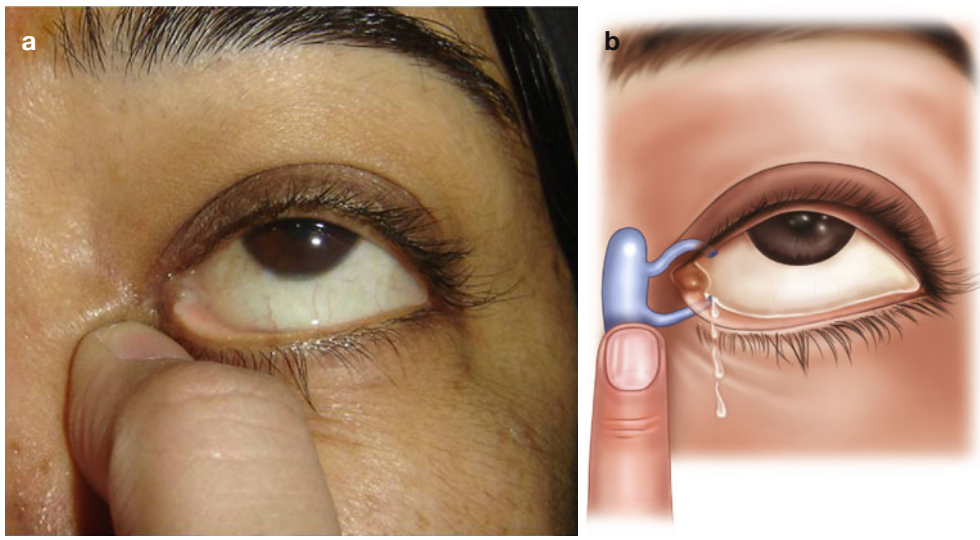


Fig. 6.4 ROPLAS test. Eliciting the ROPLAS test by pressing upon the lacrimal sac in the lacrimal fossa. Regurgitation of fluid from same or opposite punctum is noted (**a**). Schematic diagram showing ROPLAS test (**b**)

negative results, it is important to apply pressure over the lacrimal sac in the lacrimal fossa in a slightly backward and upward direction. A positive regurgitation test is a confirmatory test for chronic dacryocystitis with NLDO and no further diagnostic testing is usually necessary in these cases. Interpretation of ROPLAS test results is given in Table 6.1.

Table 6.1 Interpretation of ROPLAS findings

ROPLAS test finding	Interpretation
Clear, mucoid, or mucopurulent regurgitation on pressure over the sac	Nasolacrimal duct obstruction
Regurgitation test positive with blood tinged fluid	Rule out dacryolith or lacrimal sac tumor
No regurgitation of fluid through the punctum while pressing over a distended sac and the sac remains dilated	Encysted mucocele
No regurgitation of fluid through the punctum while pressing over a distended sac but the sac empties into the nose	Atonic sac or internal fistulae

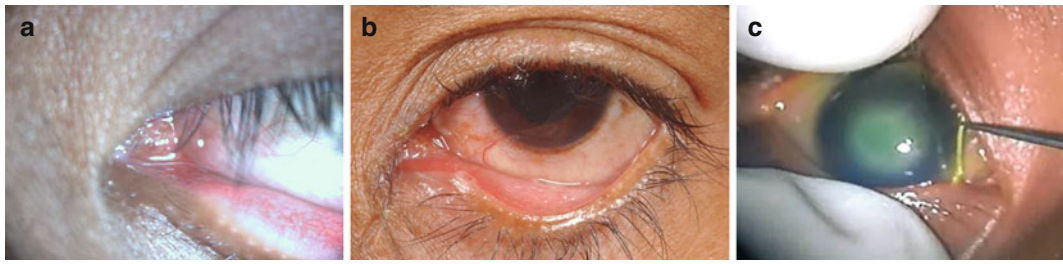


Fig. 6.5 Slit lamp evaluation of the punctum and adnexa. A case of punctal agenesis (**a**). Canaliculitis causing epiphora and discharge, Note the erythema, edema, and pouting of the lower punctum (**b**). Canaliculitis and secondary keratitis caused by a parasitic worm blocking the canaliculus and punctum (**c**)

A detailed slit lamp evaluation is also must in cases of watering (Fig. 6.5a–c). Size, site, and position of the punctum should be noted to rule out any stenosis or agenesis of the punctum. The normal position of the punctum is at the summit of the lacrimal papilla facing the tear lake. Eversion of the punctum out of the tear lake can occur due to eyelid laxity or loss of eyelid tone as in cases of facial palsy. A red, swollen, pouting punctum can be a sign of canaliculitis. The diagnosis of canaliculitis is can additionally be confirmed by expressing out concretions through the punctum by applying pressure with cotton bud. Blepharitis and meibomitis can also be detected on slit lamp examination which can cause watering due to disturbance of the tear film layer. Blepharitis can also be associated with marginal keratitis and can cause reflex watering. Watering in cases of allergic conjunctivitis will have associated conjunctival papillae and follicles on slit lamp examination. Presence of punctate corneal staining due to corneal exposure and xerosis can cause reflex watering in patients with lagophthalmos. Height of the marginal tear meniscus is noted by staining the tear film with fluorescein dye (Fig. 6.6). Increased tear meniscus height is seen in cases of obstructive and functional epiphora and a decreased meniscus height if associated with other signs like corneal filaments, ocular surface inflammation, and punctate staining, and low Schirmer values can indicate a dry eye disease.

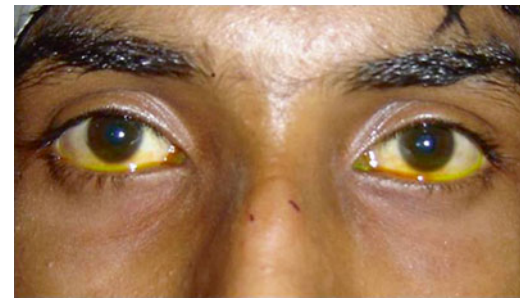


Fig. 6.6 Fluorescein dye disappearance test. Positive test showing retention of the dye in the cul de sac after 5 min

Diagnostic Clinical Tests

Diagnostic tests in cases of watery eyes include both excretory and secretory tests [2]. The excretory tests check for the anatomical patency and function of the lacrimal outflow pathway, whereas

the secretory tests check for any evidence of dry eye which can cause reflex hypersecretion. The anatomical patency of the lacrimal outflow pathway is tested by lacrimal irrigation, diagnostic probing, and dacryocystography.

Lacrimal Irrigation

Lacrimal irrigation is an anatomical test which checks for the patency of the nasolacrimal duct (NLD) [11]. This is not a physiological test as passage of the fluid through the NLD in case of irrigation occurs at a higher hydrostatic pressure than in normal physiological condition. A stenosis of the NLD might hinder the outflow of tears in normal physiological condition and can cause epiphora while the system might still seem patent on irrigation as fluid is pushed at a higher hydrostatic pressure during irrigation which might be able to overcome the area of stenosis. On contrary, in cases of atonic sac, there is a dysfunction of the pump mechanism of the lacrimal sac and although the irrigation is patent free, these patients usually complain of epiphora. Hence, the results of the lacrimal irrigation must always be interpreted in conjunction with clinical evaluation and physiological tests.

Following are the steps for performing lacrimal irrigation (Fig. 6.7a–f):

- The conjunctiva is anesthetized with 2 % paracaine eye drops. Lacrimal irrigation can be performed with the patient reclining or lying down position. Appropriate sized lacrimal cannula is selected for performing the irrigation. For adult patients, a 15° smoothly curved cannula or a straight cannula of 24G or 25G size fitted to a two syringe filled with sterile water or normal saline is appropriate.
- Diagnostic irrigation is preferably done through the upper punctum as it aids in intrasac irrigation.
- Patient is advised to look down and the medial eyelid is gently pulled up (for upper lid) and down (for lower lid) to evert the

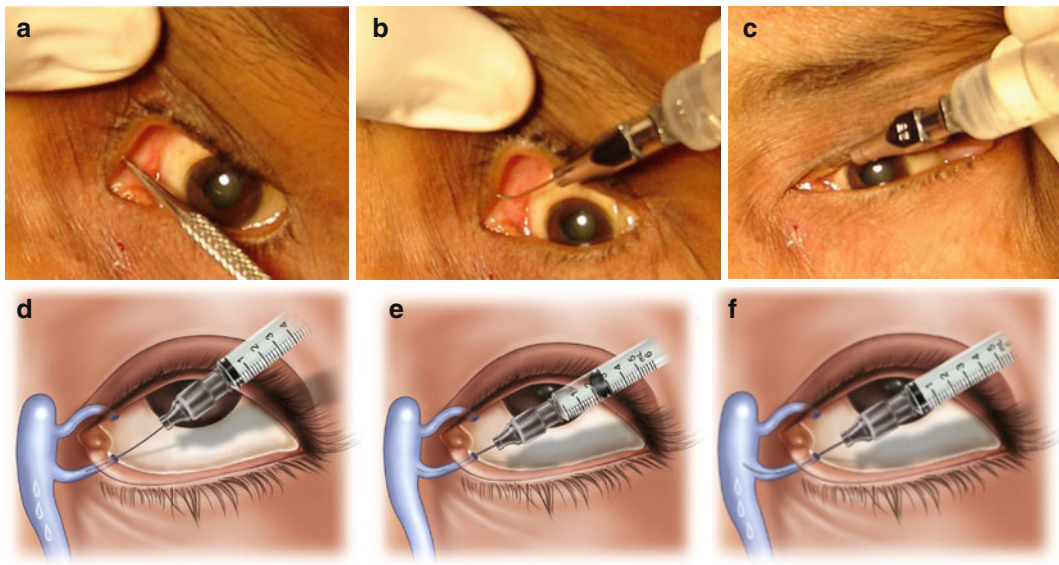


Fig. 6.7 Lacrimal irrigation procedure. Dilatation of punctum with the Nettleship's punctum dilator (**a**). The lacrimal canula inserted into the canaliculus first vertically (**b**) and then in a horizontal direction. Note the lateral traction is given to the eyelid to straighten the canaliculi before the horizontal pass (**c**). Schematic diagram showing intracanalicular irrigation. A very little amount is irrigated to dilate the lacrimal passage to avoid the risk of mucosal trauma (**d**). Intrasac irrigation is the desired goal for better interpretation unless there is a canalicular obstruction (**e**, **f**)

punctum. The upper punctum is dilated using a Nettelship punctum dilator. The lacrimal cannula attached to the syringe is inserted into the punctum vertically and then horizontally to reach the horizontal canaliculus. A gentle lateral traction is maintained on the eyelid while inserting the cannula to straighten the canaliculus. The cannula is advanced into the horizontal canaliculus and a small amount of fluid is gently pushed slowly (intracanalicular irrigation). This is primarily to dilate the incoming lacrimal pathway and thus aids in avoiding inadvertent canalicular wall touch. The cannula is advanced into the sac and irrigation is performed. Note is made whether fluid passes to the nasal cavity immediately, after a delay or if there is regurgitation of fluid from the same or opposite punctum. In case of fluid regurgitation, note is made of the type of the fluid regurgitating and associated swelling of the sac. In case of obstruction in the upper canaliculus or punctum, irrigation is repeated through the lower punctum. If any stenosis is noted in the canaliculus while doing irrigation, attempt is made to gently advance the cannula beyond the area of stenosis into the lacrimal sac before irrigation (intrasac irrigation). No attempts should be made to overcome any stenosis forcefully. Any resistance to passage of fluid while doing irrigation along with swelling in the medial canthal area and patient reporting severe pain indicates a possible false passage formation.

Interpretation of Lacrimal Irrigation

Interpretation of lacrimal irrigation should be done in conjunction with diagnostic probing and other tests. Conclusions about the anatomical patency of lacrimal pathway at various levels can be arrived at based on irrigation findings which are listed in Table 6.2.

Diagnostic Probing

Probing is indicated if irrigation reveals an obstruction in the lacrimal outflow system. It is done to confirm the site of the blockage (Fig. 6.8a–c). Probing is done using the Bowmans lacrimal probe. After installing topical anesthetic, one of the punctum is dilated and appropriate sized lacrimal probe is passed following the direction of the canaliculi and advanced gently till it reaches a stop. The interpretations of probing findings are described as either hard stop or soft stop.

Hard Stop (Fig. 6.9a)

When the probe is advanced into the sac to touch the medial wall of the sac and underlying bone, a hard stop is encountered. Hard stop indicates that the probe has gone beyond the common canaliculus into the lumen of the sac and presence of a hard

Table 6.2 Interpretation of lacrimal irrigation findings

Irrigation finding	Interpretation
Regurgitation of clear fluid from the opposite punctum	Indicates an obstruction in the common canaliculi, lacrimal sac, or nasolacrimal duct. Further diagnostic probing is needed to differentiate common canalicular block from more distal obstruction.
Mucoid or mucopurulent regurgitation from the opposite punctum after some delay with dilatation of the sac	Nasolacrimal duct obstruction
Immediate regurgitation of clear fluid through same punctum while performing irrigation through one of the punctum	Individual canalicular block
Regurgitation of mucoid or mucopurulent material through lower punctum only while doing irrigation from lower punctum with a hard stop	Nasolacrimal duct block associated with upper canalicular block
Patent irrigation with sac dilatation and residual stasis in patient complaining of epiphora	Atonic sac
Patent irrigation with regurgitation of some clear or mucoid fluid	Partial NLDO

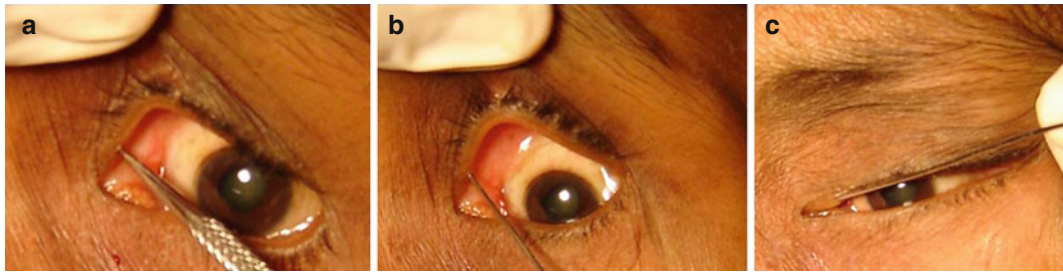


Fig. 6.8 Technique of lacrimal probing. Dilatation of the punctum (**a**). Appropriate sized Bowman's lacrimal probe inserted into the canaliculi first vertically (**b**) and then in a horizontal direction. Note the lateral traction is given to the eyelid to straighten the canaliculi before the horizontal pass (**c**)

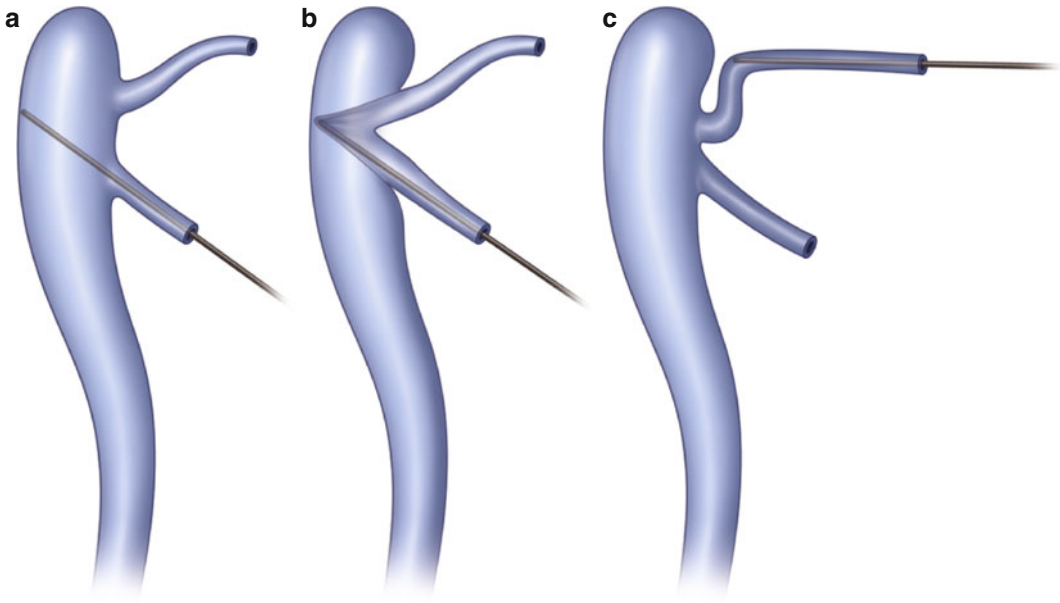


Fig. 6.9 Interpretation of lacrimal probing. Hard stop is felt when the probe hits the medial wall of the sac and underlying bone (**a**). Soft stop is felt when the probe drags the lateral wall of the sac toward the medial wall in cases of canalicular obstructions (**b**). False positive soft stop can be felt if adequate lateral traction is not given on the eyelid to straighten the canaliculi while passing the probe through it and the probe drags the roof or floor of the canaliculi against the sac (**c**)

stop on probing in patients whose irrigation finding reveals clear fluid regurgitation from opposite punctum rules out the diagnosis of common canalicular block and confirms diagnosis of NLD block.

Soft Stop (Fig. 6.9b, c)

In cases of common canalicular or individual canalicular block, a soft stop is encountered. Here the probe stops at site of the blockage near the canaliculus and presses the lateral wall of the sac giving a spongy feel which is known as soft stop. In addition to soft stop, movement of the medial canthus is also noted while doing probing. In canalicular block, the probe pushes the soft tissue of the canaliculus medially toward the sac which causes the medial canthus to move, whereas in cases of hard stop, the probe enters the lumen of the sac and hence no movement of the canthus is noted. In case of canalicular block, the length of the probe which can be passed through the punctum is measured as it helps in deciding on the surgical management [12, 13].

While performing probing, it is important to give a gentle lateral traction on the eyelid to straighten the canaliculus and make the insertion of the canaliculus to the sac as perpendicular as possible. A false soft stop can sometimes be felt if there is a kink at the junction of sac and common canaliculus and the probe instead of passing through common canalicular opening pushes the roof of the canaliculus against the lateral wall of sac giving a false spongy feel.

Fluorescein Dye Disappearance Test (Fig. 6.6)

Fluorescence dye disappearance test is a physiological test for checking the function of the lacrimal outflow pathway with a high specificity of 94.8 % and positive predictive value of 93.5 % [14, 15]. It is a noninvasive test and is extremely useful in children with complaint of watering who are not suitable for other diagnostic office procedures like irrigation and probing. A positive test indicates dysfunction in the lacrimal outflow pathway. However, this test cannot differentiate a functional from anatomical obstruction and cannot pinpoint the site of the block in cases of anatomical obstruction. This is a good screening test and patients with a positive test need further evaluation with other tests like irrigation and probing.

A drop of 2 % fluorescein is placed in the nonanesthetized conjunctival cul de sac inferiorly and after 5 min residual fluorescein is looked for in the tear film using a cobalt blue filter. The tear film should not be wiped or the eye should not be rubbed during this period. Normally, the fluorescein should drain into the nose within 5 min, any persistence of fluorescein beyond this period indicates an obstruction in the outflow pathway and a positive test result. The height of the stained tear filmed can also be measured using the slit lamp or scale and results of the test are graded on scale from 0 to 3, Grade 0 and 1 indicating no or a very thin fluorescein marginal tear strip and a negative test and Grade 2 and 3 a positive test. In cases of large mucocele or lacrimal sac diverticula, there can be pooling of the dye into the sac and fluorescein dye test can give false negative result giving the impression of a patent system. This should be kept in mind while interpreting the test result in cases with hugely distended sac. Similarly, functional endoscopic dye test (FEDT) is performed following a dacryocystorhinostomy to assess the anatomical and functional clearance of the dye using an endoscope.

Imaging of the Lacrimal System

Radiological investigations for evaluation of the lacrimal system are rarely indicated in selected cases where other anatomical and physiological tests cannot provide a conclusive diagnosis (Fig. 6.10a–f). Imaging of the lacrimal system includes dacryocystography (DCG), nuclear lacrimal scintigraphy, and CT-DCG and MR_DCG scan [16]. Dacryocystography is a radiological test where radiopaque dye is injected through the lacrimal punctum and the passage of dye through the canaliculi, sac, and NLD is captured on images [16, 17]. It outlines the lacrimal outflow system and the area of blockage can be picked up on the images. DCG is indicated in patients with failed lacrimal surgery to determine the extent of the sac remnant and in patients with suspected lacrimal sac diverticula, dacryoliths, or lacrimal sac tumors. While DCG is an anatomical test and is performed to visualize the site of the obstruction, scintigraphy is a physiological test and is useful in determining the site of delay in the tear outflow in patients with a functional epiphora [18]. C T-DCG and MR-DCG are structural investigations and are mainly indicated to rule out any secondary causes of obstruction of the sac or NLD like tumor, trauma, sinus disease, etc. [16]. Details of these modalities will be dealt with in Chap. 10.

Nasal Endoscopy

Examination of the nasal cavity and nasal endoscopy are important part of evaluation of any patient with lacrimal outflow pathway obstruction [19]. Anterior rhinoscopy with nasal speculum might not be able to provide a complete information about any underlying nasal pathology and an endoscopic evaluation is a must to diagnose pathologies if any. Nasal endoscopy can detect conditions like deviated nasal septum, hypertrophied turbinate, or any anatomical

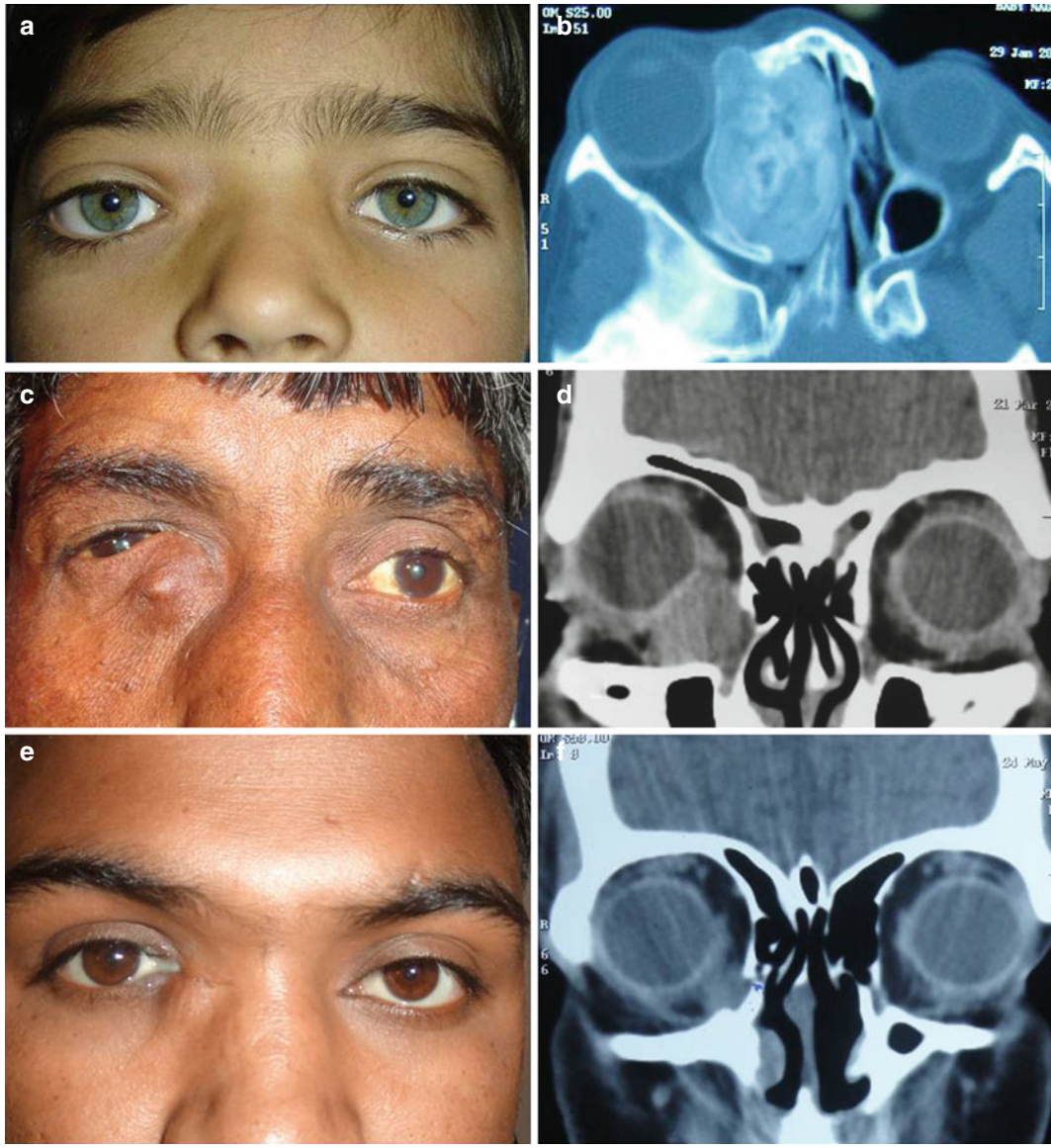
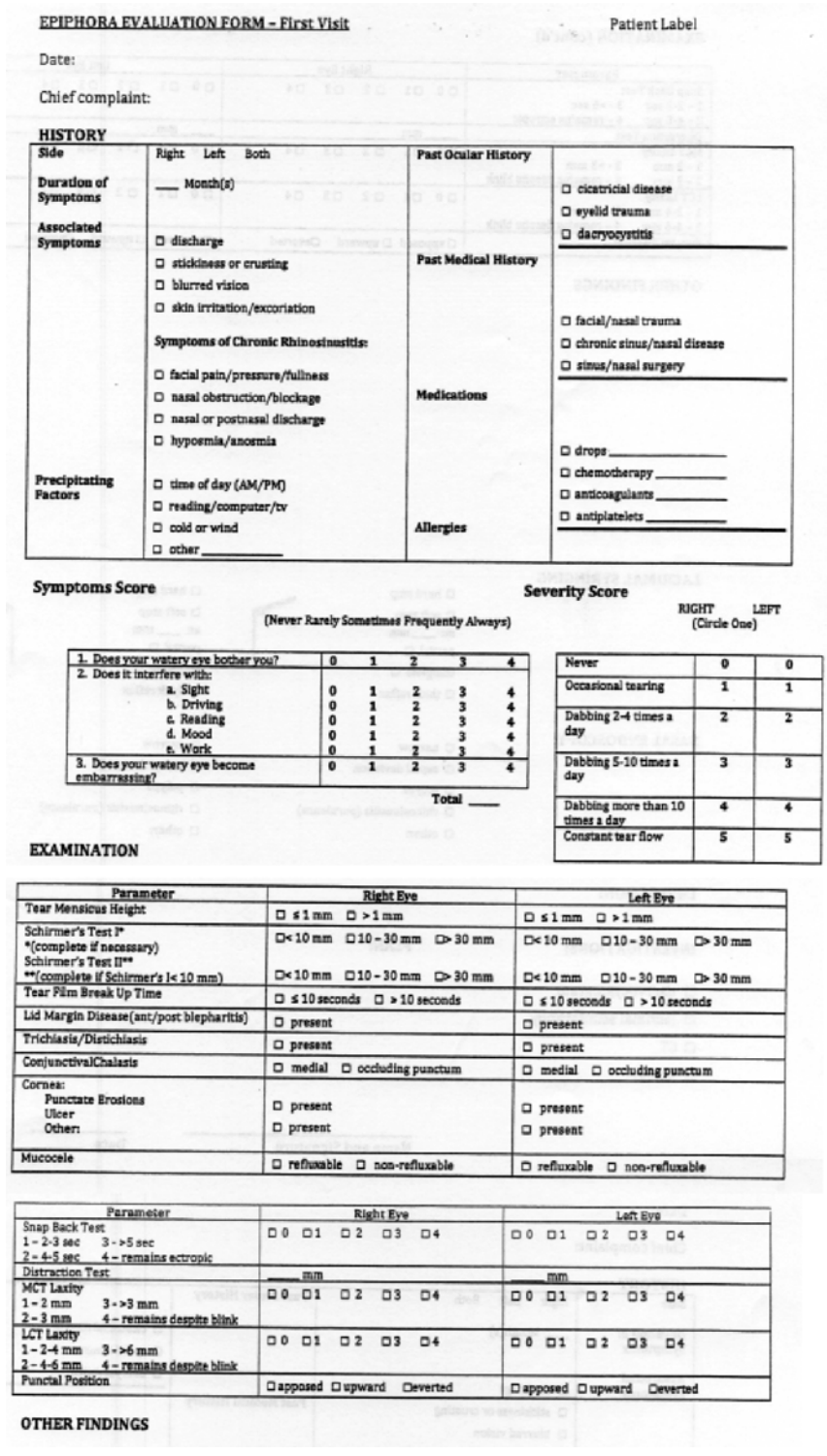


Fig. 6.10 Imaging findings in patients with epiphora. Young child with unilateral telecanthus complaining of watering from right eye (**a**). CT scan revealed an ethmoid sinus mass (fibrous dysplasia) extending to nasal cavity causing secondary NLD obstruction (**b**). Adult patient with distended lacrimal sac and partially patent irrigation (**c**). CT scan revealed lacrimal sac mass, later confirmed to be a benign fibrous histiocytoma (**d**). Right-sided chronic dacryocystitis with mucocele following facial trauma (**e**). CT scan showing fracture of the ethmoid bone near the upper end of NLD (**f**)

abnormality which might be having a bearing on the surgical decision making [20, 21]. Tumors and granulomatous infection and inflammations of the nasal cavity can cause nasolacrimal duct obstruction which can be detected by nasal endoscopy. It is of utmost value in assessing the etiology of failed DCRs. Endoscopic nasal examination is also essential in postoperative care following a dacryocystorhinostomy (DCR) to look for the site and status of the ostium, internal common opening movements, and functional endoscopic dye test. The details of nasal endoscopy will be discussed in the subsequent (Chaps. 7 and 8).

Table 6.3 A comprehensive epiphora evaluation sheet in Professor PJ Wormald's practice at Adelaide, Australia



EPIPHORA EVALUATION FORM – First Visit

Patient Label

Date:

Chief complaint:

HISTORY

Side	Right Left Both	**Past Ocular History**	
Duration of Symptoms	___ Month(s)		☐ cicatricial disease ☐ eyelid trauma ☐ dacryocystitis
Associated Symptoms	☐ discharge ☐ stickiness or crusting ☐ blurred vision ☐ skin irritation/excoriation	**Past Medical History**	
	Symptoms of Chronic Rhinosinusitis: ☐ facial pain/pressure/fullness ☐ nasal obstruction/blockage ☐ nasal or postnasal discharge ☐ hyposmia/anosmia		☐ facial/nasal trauma ☐ chronic sinus/nasal disease ☐ sinus/nasal surgery
		Medications	☐ drops _____ ☐ chemotherapy _____ ☐ anticoagulants _____ ☐ antiplatelets _____
Precipitating Factors	☐ time of day (AM/PM) ☐ reading/computer/tv ☐ cold or wind ☐ other _____	**Allergies**	

Symptoms Score

(Never Rarely Sometimes Frequently Always)

1. Does your watery eye bother you?	0	1	2	3	4
2. Does it interfere with:					
a. Sight	0	1	2	3	4
b. Driving	0	1	2	3	4
c. Reading	0	1	2	3	4
d. Mood	0	1	2	3	4
e. Work	0	1	2	3	4
3. Does your watery eye become embarrassing?	0	1	2	3	4

Total ____

Severity Score

	RIGHT	LEFT (Circle One)
Never	0	0
Occasional tearing	1	1
Dabbing 2-4 times a day	2	2
Dabbing 5-10 times a day	3	3
Dabbing more than 10 times a day	4	4
Constant tear flow	5	5

EXAMINATION

Parameter	Right Eye	Left Eye
Tear Mensicus Height	☐ ≤ 1 mm ☐ > 1 mm	☐ ≤ 1 mm ☐ > 1 mm
Schirmer's Test I* *(complete if necessary) Schirmer's Test II** **(complete if Schirmer's I< 10 mm)	☐< 10 mm ☐ 10 – 30 mm ☐> 30 mm ☐< 10 mm ☐ 10 – 30 mm ☐> 30 mm	☐< 10 mm ☐ 10 – 30 mm ☐> 30 mm ☐< 10 mm ☐ 10 – 30 mm ☐> 30 mm
Tear Film Break Up Time	☐ ≤ 10 seconds ☐ > 10 seconds	☐ ≤ 10 seconds ☐ > 10 seconds
Lid Margin Disease(ant/post blepharitis)	☐ present	☐ present
Trichiasis/Distichiasis	☐ present	☐ present
Conjunctival Chalasis	☐ medial ☐ occluding punctum	☐ medial ☐ occluding punctum
Cornea: Punctate Erosions Ulcer Other:	 ☐ present ☐ present	 ☐ present ☐ present
Mucocele	☐ refluxable ☐ non-refluxable	☐ refluxable ☐ non-refluxable

Parameter	Right Eye	Left Eye
Snap Back Test 1 – 2-3 sec 3 – >5 sec 2 – 4-5 sec 4 – remains ectropic	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4
Distraction Test	___ mm	___ mm
MCT Laxity 1 – 2 mm 3 – >3 mm 2 – 3 mm 4 – remains despite blink	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4
LCT Laxity 1 – 2-4 mm 3 – >6 mm 2 – 4-6 mm 4 – remains despite blink	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4
Punctal Position	☐ apposed ☐ upward ☐ everted	☐ apposed ☐ upward ☐ everted

OTHER FINDINGS

Secretory Tests

Secretory tests check for any evidence of dry eye to rule out any reflex cause of watering. Schirmers test, tear film breakup time, and Rose Bengal staining are the commonly performed secretory tests. These tests provide information about the quantity of tear production and quality of precorneal tear film and are part of the diagnostic workup for patients with suspected dry eye disease as the cause of watering. Schirmers tests are commonly performed office test for dry eye evaluation. In Schrimers I test, a Whatmann filter paper of 35×5 mm dimension is folded 5 mm from the tip and placed at the inferior conjunctival fornix laterally and the amount of wetting of the filter paper strip is noted. This checks for both basal and reflex secretion from the main and accessory lacrimal glands. The same test performed after anesthetizing the conjunctiva measures only the basal secretion from the accessory lacrimal glands. Schirmers II test measures only reflex secretion and is performed by placing the filter paper strip in the anesthetized conjunctiva and stimulating secretion from the main lacrimal gland by placing a cotton applicator on nasal mucosa which stimulates the trigeminal nerve. Tear film breakup time is a function of the mucin layer of tear film. Normal breakup time is 10–15 s and values less than 10 s indicate a mucin deficiency dry eye disease.

Conclusion

Watering is a common complaint and can be due to hypersecretion or due to obstruction in the lacrimal outflow pathway. The goal of evaluation of a patient with watering is to differentiate the two and to find out the cause and site of obstruction in cases with lacrimal outflow pathway problem. A detailed clinical history, local examination of the adnexal structures, and lacrimal sac area coupled with diagnostic tests like lacrimal irrigation, probing, fluorescein dye disappearance test will clinch the diagnosis in most patients (Table 6.3). Ancillary investigations like dacryocystography, lacrimal scintigraphy, and imaging are required in selected patients to determine the underlying cause of watering. The management decision for epiphora depends on the underlying cause, type, and level of the blockage in cases of anatomical obstruction, any previous surgery and age of the patient that would be dealt with in subsequent chapters.

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Setup for Nasal Endoscopy and Endoscopic Surgery

7

Hesham Saleh and Natasha Choudhury

Introduction

Nasal examination should be obligatory in any patient who is being considered for lacrimal surgery. Preoperative assessment should include nasal endoscopy to allow evaluation of any concurrent intranasal pathology or anatomical variations. Furthermore, lacrimal surgery itself is now widely practiced via an endoscopic approach and therefore Ophthalmologists performing lacrimal surgery should familiarize themselves with the use of nasal endoscopes.

Nasal Endoscopes

The use of rigid nasal endoscopes (Hopkins telescopes) is now standard practice for clinical examination of the nose as it provides a detailed, magnified, high-quality view of the nose and sinus passages. Nasal endoscopes are available in a variety of different sizes and angulations. Standard nasal endoscopes are available in 2.7- and 4-mm caliber thickness (Fig. 7.1), with varying viewing angles ranging from 0° to 120°, which are used for both clinical examination and operative procedures. The most suitable endoscope to use during a clinic examination is a 30° 2.7-mm diameter Hopkins endoscope. The 30° angled allows for a panoramic view of the nasal cavity and the smaller diameter is best used to avoid inflicting any discomfort to the patient. Intraoperatively however, the wider 4-mm nasal endoscopes are preferred as they offer better illumination and view through the wider caliber telescope. For most purposes it is sufficient to use either 0° or 30° endoscopes for operative procedures. The 0° endoscope offers a straight-line view and is the easiest to use. It is often possible to perform a full dacryocystorhinostomy using

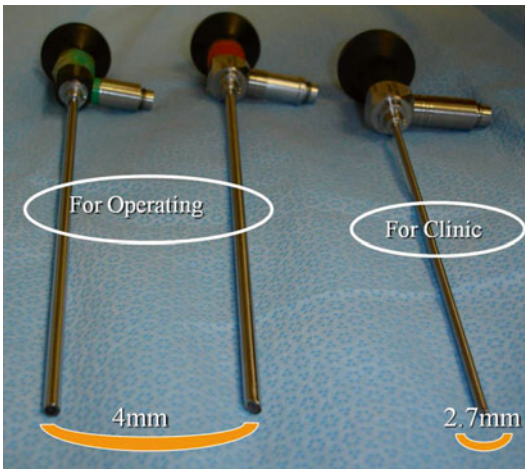

Fig. 7.1 Nasal endoscopes; from left to right 4-mm 0°, 4-mm 30°, and 2.7-mm 30°endoscopes

H. Saleh, FRCS, FRCS (ORL-HNS) (✉)
Department of Otolaryngology, Charing Cross Hospital and Imperial College, London, UK
e-mail: hesham.saleh@btinternet.com

N. Choudhury, FRCS (ORL-HNS)
Department of Otolaryngology, Charing Cross Hospital, London, UK

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this endoscope. In some cases however, a 30° endoscope is necessary for better visualization of the lateral nasal wall when the anatomy dictates.

Adjunct Equipment

In addition to the selected endoscope, a good halogen or xenon light source is essential for the best possible optics while using the endoscopes. This also requires good quality fiber-optic cables to connect with light source. Handheld light sources that can connect to Hopkins endoscopes are available, but a light cable and a separate light source are preferable and easier to use.

Outpatient Setup for Nasal Endoscopy

Before starting nasal endoscopy, the patient's nose should be prepared by applying topical local anesthetic with decongestant. Our preference is to use two sprays of cophenylcaine spray (5 % lignocaine with 0.5 % phenylephrine) into each nasal cavity (Fig. 7.2), which should be left for at least 5 min before attempting any instrumentation, to allow sufficient time for the anesthetic and vasoconstrictive effect. The patient should then be positioned appropriately, either sitting upright facing the examiner or lying down, with head elevation of about 45°, and turned toward the examiner who should be on the patient's right side. Diagnostic nasal endoscopy in the clinic can then be performed with a 2.7-mm, 30° nasal endoscope, using a three pass technique. The endoscope should be held in the right hand and supported between the thumb and index finger of the left hand, to avoid any sudden movements. With each pass, the condition of the nasal mucosa and anatomical structures are examined, as well as carefully noting of any anatomical variations or intranasal pathology.

Setup for Endoscopic Surgery

Endoscopic lacrimal surgery is almost always performed between two surgeons including an Ophthalmologist and rhinologist. A full complement of all nasal endoscopes, as well as sinus and ophthalmology instruments should be available [1, 2]. The endoscope needs to be connected to a light cable and high-quality light source, as well as a camera and large viewing stack (Fig. 7.3) which can be seen by both sets of surgeons and theatre scrub nurse. The operating surgeon should be positioned on to the right side of the patient with the assisting surgeon adjacent to them. Good interaction between the two surgeons is essential to facilitate the surgery, for example in guiding the light probe to demonstrate the extent of bone removal required for adequate exposure of the lacrimal sac and also in supporting the sac while the other surgeon is opening it. The scrub nurse and instrument tray should be positioned on the opposite side of the patient, and the anesthetist needs to be away from the operating head end (Fig. 7.4a, b).

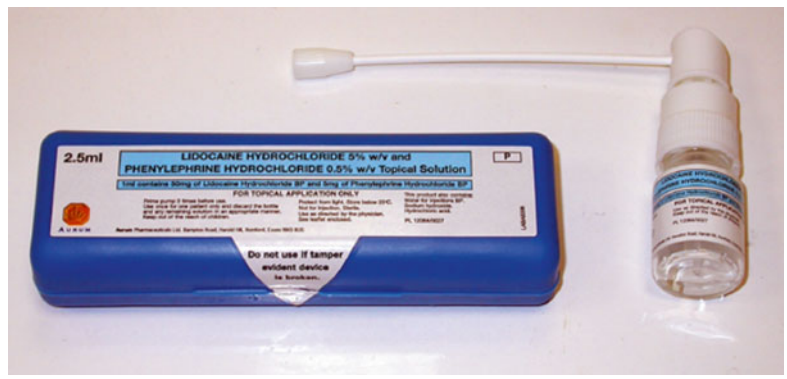

Fig. 7.2 Co-phenylcaine (5 % lignocaine with 0.5 % phenylephrine)

Before commencing endoscopic surgery, the patient's nose should be prepared in the anesthetic room, following induction of anesthesia.

Fig. 7.3 Stack system with High Definition screen, connected to camera and endoscope

Any one of the variety of different nasal preparations which permit decongestion via their vasoconstrictive effect can be used, including Moffat's solution (2 ml of 10 % cocaine, 1 m of 1:1,000 adrenaline, and 2 ml of sodium bicarbonate), oxymetazoline nasal drops, or co-phenylcaine spray, depending on local availability and personal preference. After its application, the patient can be positioned for surgery in the reverse Trendelenburg position, with 30° head elevation. Where possible, hypotensive anesthesia should be maintained throughout the surgery to minimize intraoperative bleeding.

For endoscopic surgery, the wider caliber 4-mm endoscopes are used throughout. Initially, the 4-mm, 0° nasal endoscope should be used to inspect each nasal cavity and apply topical adrenaline (1 in 1,000) on merocel patties or ribbon gauze, within the middle meatus, for at least 5 min. Following that a standard dental syringe is used to inject 1 ml of 1:80,000 adrenaline and lignocaine 2 % into the area of the planned mucosal flap for further decongestion and to facilitate dissection (Fig. 7.5). Once the nose is adequately decongested, the surgery can commence. Endoscopic surgery is performed mainly with the 4-mm, 0° endoscope but can be changed to the 4-mm, 30° endoscope for a better-angled view of the lateral nasal wall.

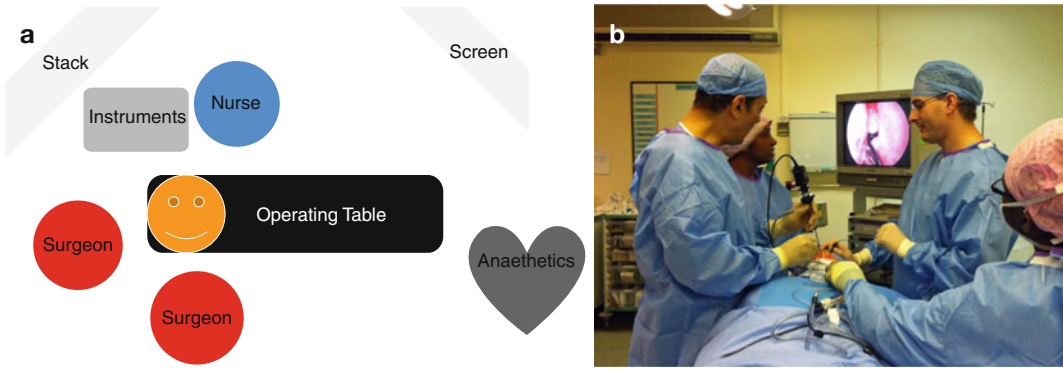

Fig. 7.4 (**a**) A schematic representation of the intraoperative setup for endoscopic surgery. A second screen at the foot of the table is included for better visualization by the second surgeon. (**b**) A photograph of the operating team during an endoscopic dacryocystorhinostomy. In this setting, an assistant surgeon is seen holding the lacrimal light probe and the operating surgeons are at the right side of the patient

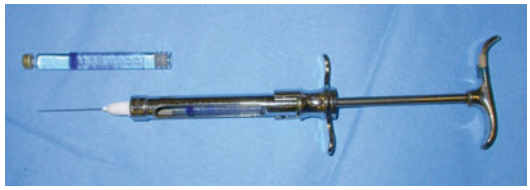

Fig. 7.5 A dental syringe with 1:80,000 adrenaline and 2 % lignocaine cartilages

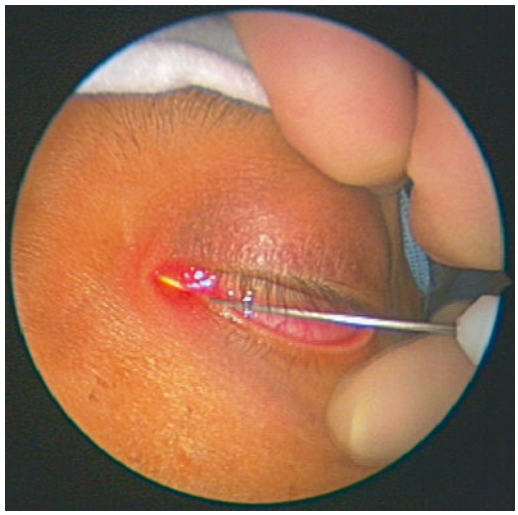

Fig. 7.6 A fiber-optic light probe is being inserted into the lower canaliculus

Surgical Instruments

For transnasal endoscopic lacrimal surgery, a limited functional endoscopic sinus surgery set as well as ophthalmic set is required for all the necessary instruments. These should include a fiber-optic light probe to guide to the position of the lacrimal sac (Fig. 7.6), a 15 blade on a long, slim handle to provide adequate length for access within the nose (Fig. 7.7), a Freer's elevator for elevating the mucosal flap (Fig. 7.8), a straight and 45° upturned Blakesley forceps for grasping bony and mucosal fragments (Figs. 7.9 and 7.10), a microdebrider with a 4-mm Trucut blade (Fig. 7.11) for mucosal trimming, a 2.5-mm diamond burr (Fig. 7.12) for bone removal, a standard sinus suction (Fig. 7.13), a keratome for opening the lacrimal sac (Fig. 7.14), and silicone lacrimal tubes if intubation is planned (Fig. 7.15).

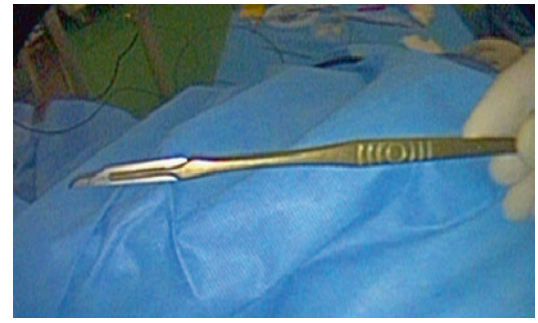

Fig. 7.7 A 15 Blade armed onto a long, slim handle slim to provide adequate length for access within the nose

Fig. 7.8 A Freer's elevator which can be used to elevate mucosal flap

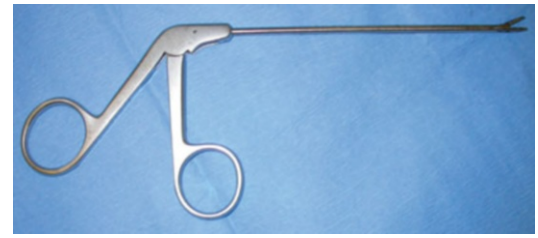

Fig. 7.9 Straight Blakesley forceps

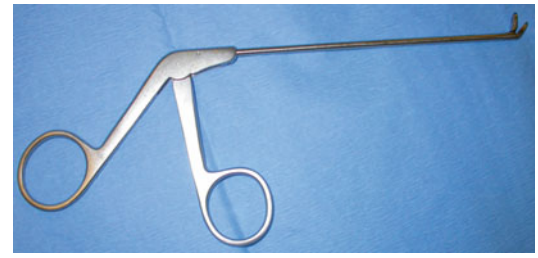

Fig. 7.10 A 45° upturned Blakesley forceps

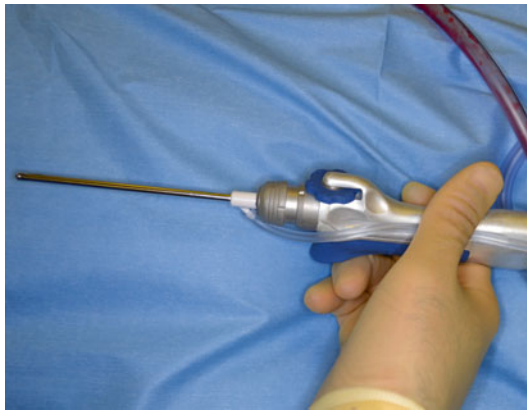

Fig. 7.11 A microdebrider handle attached to a straight 4-mm Trucut blade

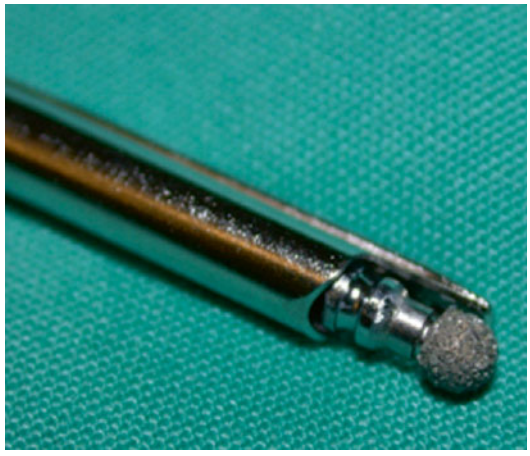

Fig. 7.12 A 2.5-mm diamond burr

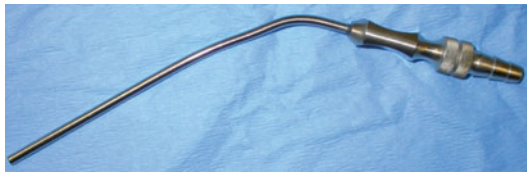

Fig. 7.13 A metal Fergusson suction

Fig. 7.14 A keratome blade

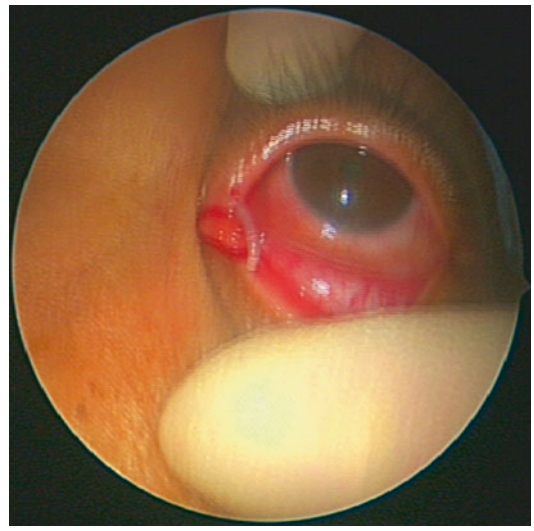

Fig. 7.15 Silicone intubation

Conclusion

Nasal endoscopy is a key technique that should be mastered by anyone practicing lacrimal surgery. It is vital as part of the preoperative assessment to evaluate for any coexisting nasal pathology or anatomical abnormalities that may impede surgical access. It also now forms the cornerstone for an endoscopic approach for lacrimal surgery and should therefore be familiarized by Ophthalmologists who are interested in this area of surgery. A number of practical tips and considerations for the setup of nasal endoscopy, both in the clinic and operating theater, have been highlighted here within to facilitate its practice.

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Nasal Endoscopic Evaluation

8

Hesham Saleh and Natasha Choudhury

Introduction

Dacryocystorhinostomy via an endoscopic approach is now widely favored and considered to result in comparable outcomes to similar surgery via an external approach. Such surgery is usually done jointly between Ophthalmologists and otolaryngologists. If endoscopic surgery is to be considered, patients should have a complete preoperative assessment to facilitate surgical planning. Clearly, patients with lacrimal obstruction require a comprehensive ophthalmologic assessment to confirm the diagnosis. However, in addition nasal examination should be considered obligatory in such patients, for evaluation of any concurrent intranasal pathology or anatomical variations, and therefore Ophthalmologists practicing lacrimal surgery should familiarize themselves with the use of the nasal endoscopes. Examination with a nasal speculum and headlight provides only a limited view of the anterior nasal passages, and therefore rigid nasal endoscopy should be performed as part of the standard preoperative assessment.

H. Saleh, FRCS, FRCS (ORL-HNS) (✉)
Department of Otolaryngology, Charing Cross Hospital and Imperial College, London, UK
e-mail: hesham.saleh@btinternet.com

N. Choudhury, FRCS (ORL-HNS)
Department of Otolaryngology, Charing Cross Hospital, London, UK

Nasal Endoscopes

The advent of nasal endoscopes (Hopkins telescopes) has revolutionized clinical examination of the nose in providing a magnified, high-quality view of the nose and sinus passages. A variety of nasal endoscopes are available in different sizes and angulations. Standard nasal endoscopes are available in 2.7- and 4-mm caliber thickness (Fig. 8.1). Each size is also available with different viewing angles, including 0°, 30°, 45°, and 70°, to facilitate a complete view of the lateral nasal wall. The 2.7-mm endoscope is typically used for diagnostic nasal endoscopy in the outpatient clinic and also in children. For diagnostic

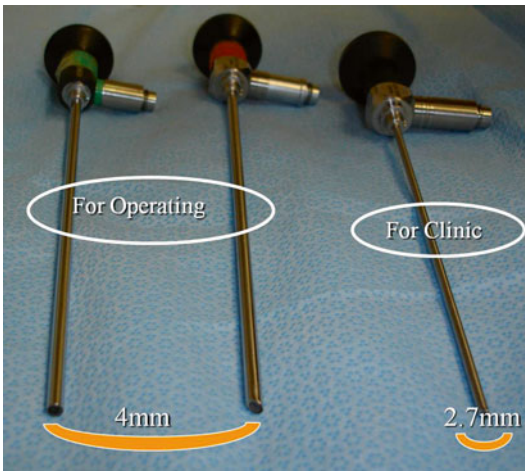

Fig. 8.1 Nasal endoscopes; from left to right 0° 4-mm, 30° 4-mm, and 30° 2.7-mm endoscopes

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nasal endoscopy, we prefer to use the 2.7-mm, 30° nasal endoscope, which provides adequate angulations to include a view the lateral nasal wall. Intraoperatively however, the wider 4-mm nasal endoscopes are preferred as they offer better illumination and view through the wider caliber telescope. Both the 4-mm, 0° and 30° endoscopes should be made available for optimum visualization of the surgical field. In addition to the selected endoscope, a high-quality light source and light cable are required as well as suction equipment to clear any secretions and provide the optimum view.

Technique

Prior to nasal endoscopy, the nose is inspected for any visible abnormalities, such as structural deviations, using a head light (Fig. 8.2). For nasal endoscopy, the patient's nose should be prepared by applying a topical local anesthetic with a decongestant to anesthetize the nasal cavity before the procedure. Our preference is to use two sprays of co-phenylcaine spray (5 % lignocaine with 0.5 % phenylephrine) into each nasal cavity (Fig. 8.3), which should be left for at least 5 min before attempting any instrumentation, to allow sufficient time for the anesthetic and vasoconstrictive effect. The patient can be examined in either a sitting position, facing the examiner or if preferred lying down, then the examiner would be on his/her right side. Diagnostic nasal endoscopy can then be performed with a 2.7-mm, 30° nasal endoscope, using a three pass technique. The endoscope should be held with the right hand and supported between the thumb and index finger of the left hand to avoid any sudden movements (Fig. 8.4). With each pass, the condition of the nasal mucosa and normal anatomical structures are examined, as well as carefully noting of any anatomical variations or intranasal pathology.

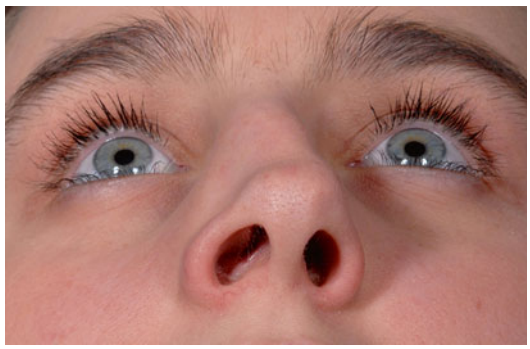

Fig. 8.2 Severe right side deviation of the nasal septum with deviation of the external nasal structure to the left side

During the first pass, the endoscope is introduced along the floor of the nasal cavity, between the inferior turbinate and the septum, toward the choana. This first pass allows examination of the inferior part of the nasal cavity including the inferior meatus where the nasolacrimal duct drains, and the nasal septum, as well as the nasopharynx and Eustachian tube openings. The endoscope is then withdrawn and gently reinserted for the second pass between the middle and inferior turbinate to examine the middle meatus. It is during the second pass that the lateral nasal wall is inspected including the maxillary line and attachment of the middle turbinate (Fig. 8.5). For the third pass, the endoscope should be gently maneuvered medial and poste-

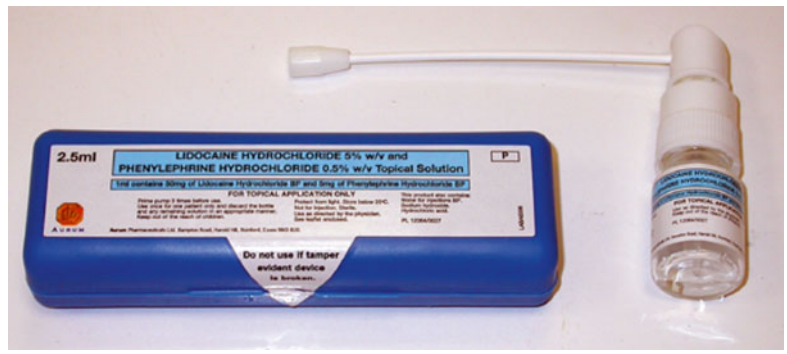

Fig. 8.3 Co-phenylcaine (5 % lignocaine with 0.5 % phenylephrine)

Fig. 8.4 Nasal endoscopy in the sitting position. Note the support of the endoscope between the index finger and thumb

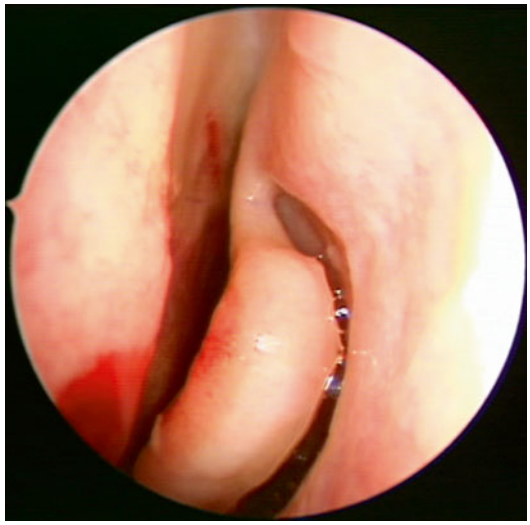

Fig. 8.5 An endoscopic view of the left middle meatus during second pass

rior to the middle turbinate to examine the sphenoethmoid recess where the posterior ethmoid and sphenoid sinus drain.

Clinical Findings

A wide spectrum of anatomical variations and pathologies may be noted while examining the nasal cavity with endoscopy. Careful assessment is essential to help plan any endoscopic lacrimal surgery, and in particular, anatomical variations that may impede access during such surgery need

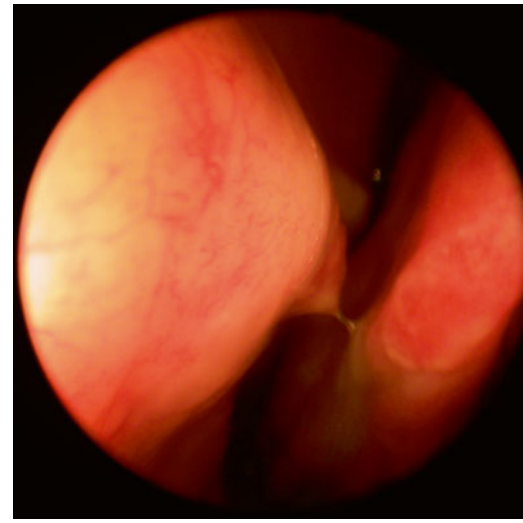

Fig. 8.6 Endoscopic view of the left nasal cavity showing a significant deviation of the nasal septum to the left resulting in a limited view of the middle turbinate

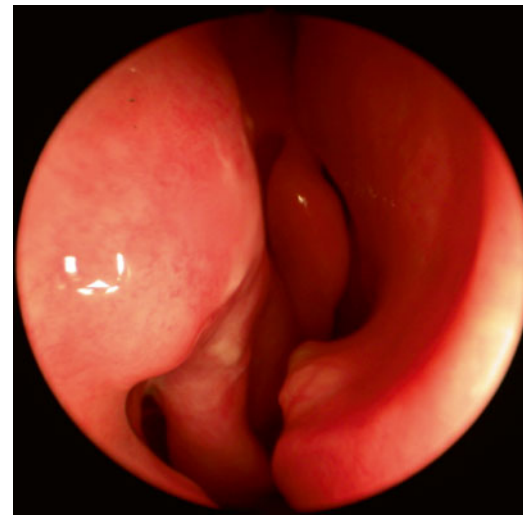

Fig. 8.7 Endoscopic view of the right nasal cavity showing a right inferior septal spur

specific consideration. Significant anterosuperior septal deviations (Fig. 8.6) or septal spurs (Fig. 8.7) may limit access of the endoscope or additional instruments for surgery, and in such cases, endoscopic septoplasty may need to be performed in order to create adequate space for safe instrumentation. Indeed, Tsirbas and Wormald quoted a 46 % rate of concomitant septoplasty, in their original landmark paper in lacrimal surgery

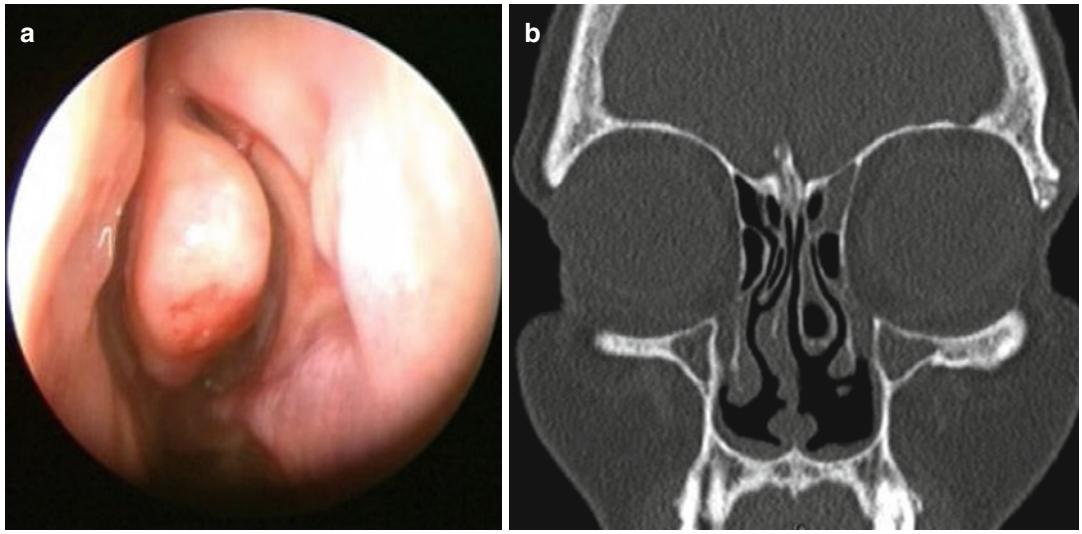

Fig. 8.8 (**a**) Endoscopic view of the left nasal cavity showing a concha bullosa of the left middle turbinate. (**b**) Corresponding CT scan of the sinuses in the coronal plane illustrating the left concha bullosa

describing endonasal dacryocystorhinostomy [1], thereby highlighting the need to carefully assess septal alignment during the preoperative nasal examination. In our experience, endoscopic septoplasty for such localized deviations is required in about 30 % of patients. For more severe septal deviations where the airway is significantly obstructed, a formal septoplasty may be required (Fig. 8.7). Another important anatomical variant is large concha bullosa of the middle turbinate (pneumatized middle turbinate) (Fig. 8.8a, b), which may also impede surgical access and therefore require adjuvant endoscopic reduction.

Alternatively, clinical examination may reveal intranasal pathologies that may require preoperative treatment. For example, significant rhinitis (Fig. 8.9) may result in marked inflammation in the nasal mucosa causing edema around the orifice of the nasolacrimal duct, resulting in epiphora. Any signs of rhinitis should be treated medically in the first instance, which may in itself reduce the symptoms of epiphora, and avoid the need for surgery [2, 3]. Other sinonasal pathologies, including chronic sinus infection [4], chronic sinusitis [5] (Fig. 8.10), or granulomatous disease [6, 7] (Fig. 8.11), should also be evaluated for and treated medically in the first instance. In one study, Kallman et al. identified an 87 % prevalence of one or more radiological

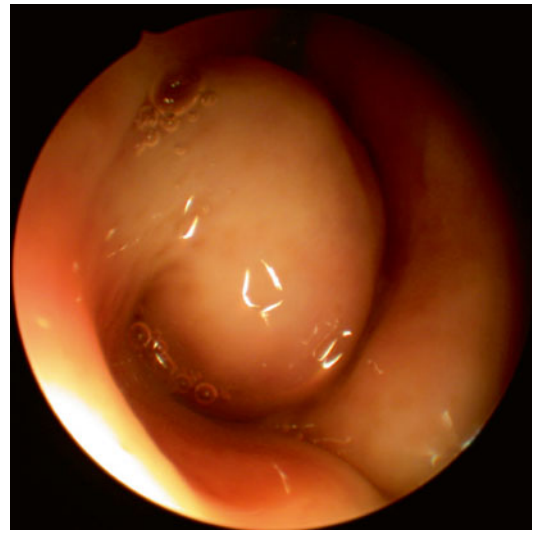

Fig. 8.9 Endoscopic view of the right nasal cavity showing an enlarged, hypertrophic inferior turbinate with marked rhinitis

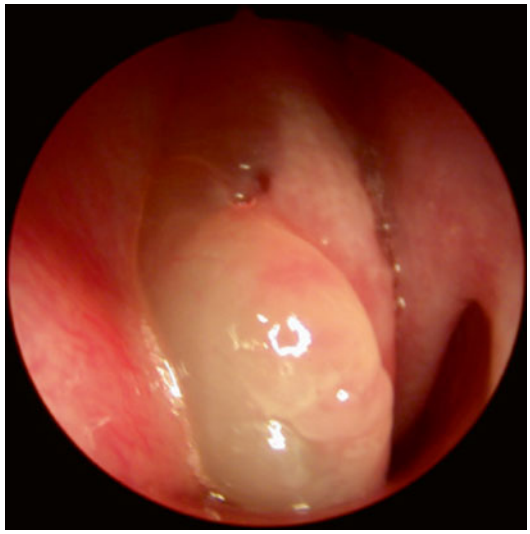

Fig. 8.10 Endoscopic view of the left nasal cavity showing obstructive nasal polyps

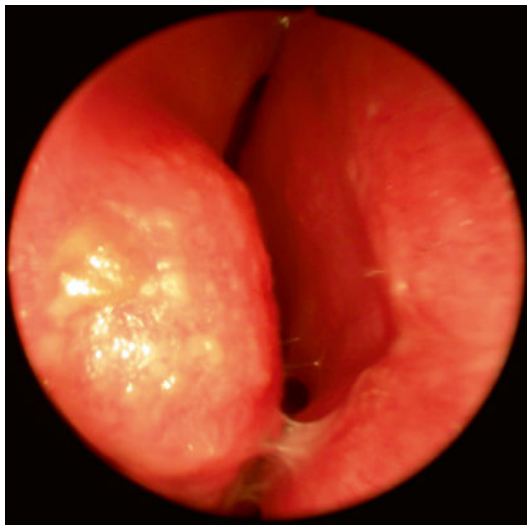

Fig. 8.11 An endoscopic view of the left nasal cavity in a patient with sarcoidosis. Note the inflammation, crusting, and severe edema

finding of sinus disease or rhinological abnormality in patients with acquired nasolacrimal duct obstruction [8], thereby highlighting the importance of nasal endoscopic evaluation for concomitant nasal and sinus disease in this group of patients.

Conclusion

Mastering nasal endoscopy is essential for any surgeon performing lacrimal surgery. Following the structure mentioned above, the surgeon will gradually attain experience and skill to recognize most encountered pathologies.

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Dacryoendoscopic Examination of the Lacrimal System

9

Mohammad Javed Ali

Introduction

Dacryoendoscopy is a procedure utilizing microendoscopic techniques to visualize the entire lacrimal system from the puncta to the inferior meatus [1–10]. It is gaining firm ground and increasing popularity for expanding indications in lacrimal disorders, thus having many diagnostic and potential therapeutic implications [1–10]. Till the late 1990s, the microendoscopic systems were not well developed; however, with the advancement in other specialties like endoscopic retrograde cholangiopancreatography (ERCP), numerous microendoscopes with a good image quality were designed. Dacryoendoscopes used in the past include the Junemann probe and the VITROPTIC. Additional channels were added for example for laser delivery of KTP-YAG or Erbium-YAG laser for laser dacryoplasty and micropunches for sample collection. The author performs it using a 0.6-mm microendoscope (Karl Storz, Tuttlingen, Germany), which was adapted and partly modified from the original sialoendoscope. This chapter discusses the instruments, indications, techniques, and findings of a normal dacryoendoscopic examination.

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute,
Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

Instruments and Techniques

1. Dacryoendoscope
2. 1-ml syringe with saline
3. Camera head
4. Endoscopic viewing system
5. Antifog solutions (ex diluted chlorhexidine)

The dacryoendoscope has a thin, rigid fiber endoscope and a side port on the hand piece (Figs. 9.1 and 9.2). The rigid fiber endoscope is attached to the eyepiece through a fiber-optic cable (Fig. 9.1). The eyepiece of the dacryoendoscope is connected to the camera head and secured. The camera head is then connected to the endoscopic viewing system (Fig. 9.3), the tip of the scope is gently cleaned with antifog solution and image quality is assessed.

Dacryoendoscopy can be performed in an anterograde or a retrograde manner. In the anterograde, evaluation sequence starts at the

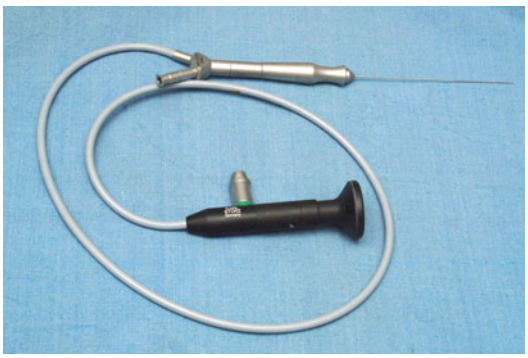

Fig. 9.1 A dacryoendoscope

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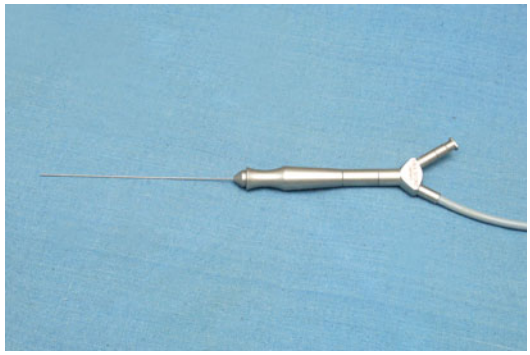

Fig. 9.2 Closer view of the side port

Fig. 9.4 Punctal dilatation

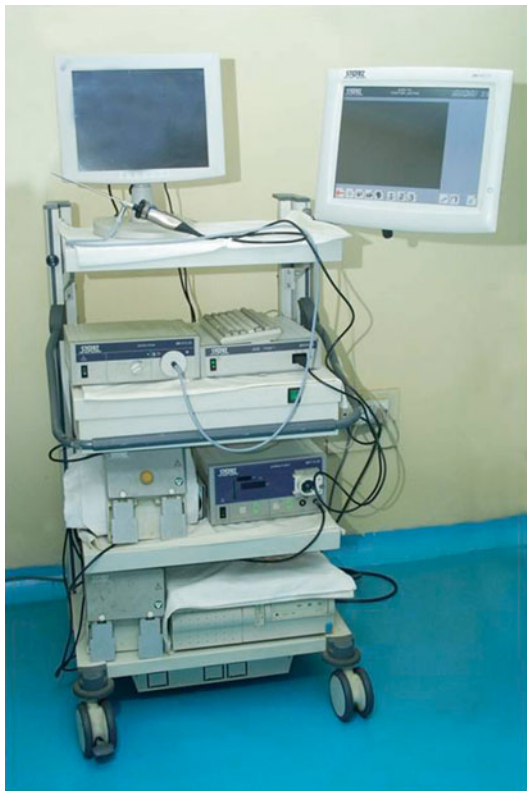

Fig. 9.3 Endoscopic viewing system

Fig. 9.5 Canalicular pass of the dacryoendoscope

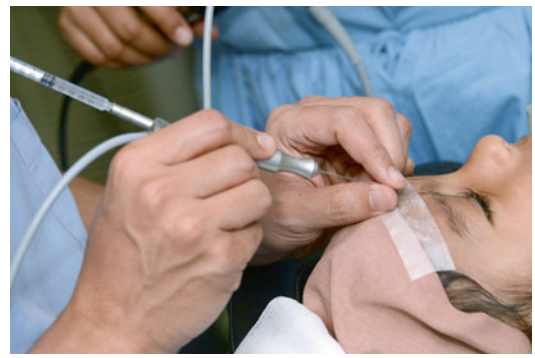

Fig. 9.6 Vertical pass of the dacryoendoscope. Note the saline syringe to side port

puncta and subsequently the canaliculus, lacrimal sac, and the nasolacrimal ducts are studied. This is technically demanding and bumping into the mucosal walls is not uncommon especially for the beginners. In the retrograde technique, the punctum is dilated with a Nettleship's punctum dilator (Fig. 9.4), the dacryoendoscope is gently passed into the horizontal canaliculus from the upper punctum on an outstretched eyelid (Fig. 9.5) and gently turned 90° just as in probing and descends down till the inferior meatus (Fig. 9.6). Now the scope is gently retracted back very slowly to study each part of the lacrimal drainage system. Gentle forward and backward movements are continued all

through to help evaluate the system thoroughly. The retrograde technique is much easier in technical terms. It is important to know that illumination may need to vary in different parts of the lacrimal system. For example, the illumination needs to be more while examining the interiors of lacrimal sac as compared to the nasolacrimal duct or canaliculi.

Indications

The indications for which dacryoendoscopy is gaining popularity are as follows [1–10], but by no means this list is exhaustive or complete.

1. Acquired internal punctal stenosis
2. Incomplete punctal canalizations (IPC) [11]
3. Canalicular explorations following IPC membranotomy
4. Canalicular wall dysgenesis (CWD) [12]
5. Canalicular stenosis
6. Patchy or multifocal canalicular strictures
7. Partial and complete canalicular obstructions
8. Dacryoendoscopic guided canalicular trephination
9. Laser dacryoplasty
10. Microdrill canaliculoplasty
11. Balloon canaliculoplasty
12. Confirmation of complete canalicular recanalizations
13. Assessment of the mucosal folds across the lacrimal system
14. Lacrimal sac inflammations
15. Focal and suspicious mucosal elevations ± guided punch biopsy
16. Residual lacrimal sac septum
17. Lacrimal sac diverticula
18. Chronic dacryocystitis to assess intrasac synechiae
19. Lacrimal sac entrapments following bony trauma
20. Dacryocele
21. Lacrimal drainage system tumors
22. Assessment of unusual types of sac discharges
23. Assessment of foreign bodies and migrated punctal plugs
24. Dacryolithiasis—assessment and guided removal
25. Assessment of lacrimal fistulas
26. Etiopathogenesis of congenital nasolacrimal duct obstructions
27. Functional nasolacrimal duct obstructions (to rule out anatomical issues)
28. Dacryoendoscopic-guided probing
29. Assessment of false passage
30. Buried probes
31. Assessment of etiopathogenesis of primary acquired nasolacrimal duct obstruction (PANDO)

Normal Dacryoendoscopy

Canaliculus

The normal canaliculus has a narrow lumen, which progressively constricts toward the distal segment. The mucosa classically appears white to whitish pink unless there is an inflammation (Fig. 9.7). The walls of the canaliculus are homogenous and smooth (Fig. 9.7). The canaliculus can be arbitrarily divided into four walls: anterior, posterior, roof, and floor and findings of each can be described separately (Fig. 9.8). The change of angulations from canaliculus to common canaliculi and at entry into lacrimal sac should be kept in mind, especially in anterograde technique. Valvular folds (elevated mucosal folds) may be seen at these junctions (Fig. 9.9) and occasionally one may be able to capture the valve of Rosenmuller.

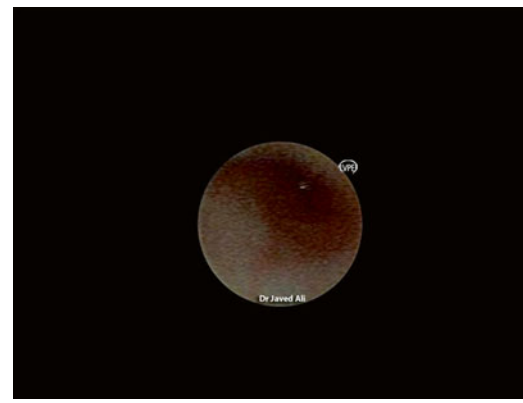

Fig. 9.7 A normal canaliculus

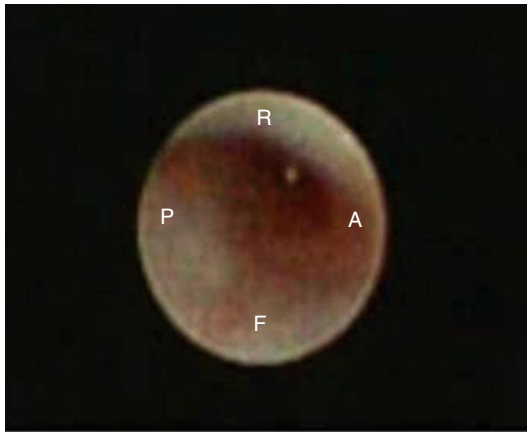

Fig. 9.8 Walls of a normal canaliculus. *A* anterior, *P* posterior, *R* roof, *F* floor

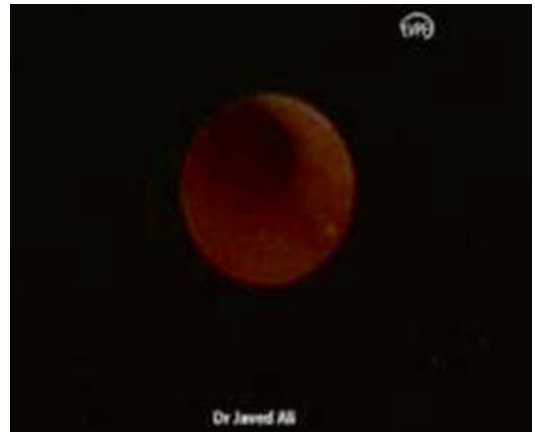

Fig. 9.10 Normal lacrimal sac

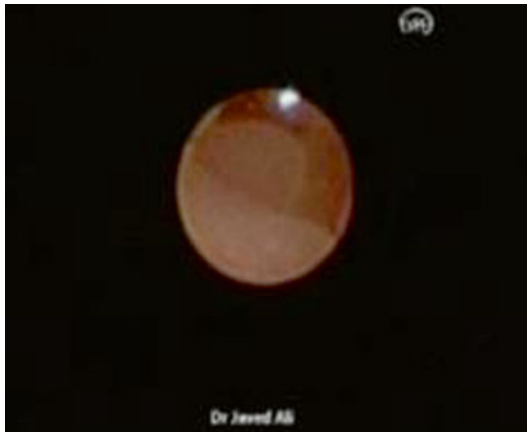

Fig. 9.9 Dacryoendoscopic view (DEN) showing valves

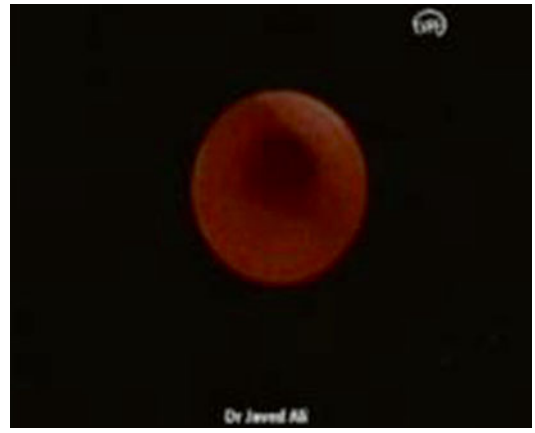

Fig. 9.11 Sac-duct junction

Lacrimal Sac

As the dacryoendoscope enters the lacrimal sac, the lumen is noted to become very wide (Fig. 9.10). The illumination usually appears to become dull and may need to be increased for clearer images. The mucosa of lacrimal sac is pinkish to pinkish-red. The mucosal folds are sparse and less elevated on the walls as against the elevated mucosal folds noted in the common canaliculus or at canalicular-sac junction. The play for scope is more here, but occasionally undue touch to the walls may cause bleeding. Mucus secretions on the wall and lumen may be noticed and can be gently washed away with saline from the side port. As the scope descends down, the lumen is found to narrow down significantly at one point, the sac-duct junction and may be guarded by mucosal valves (Fig. 9.11).

Nasolacrimal Duct

The nasolacrimal duct begins soon after the sac-duct junction as described earlier. The lumen is narrow and the mucosa is reddish in color (Fig. 9.12). The walls usually are flat with no elevated mucosal folds (Fig. 9.12). Occasionally a peripheral rim of residual Hasner's valve may be noticed. The end of nasolacrimal duct can be assessed by the change to intense red appearance of nasal mucosa and the enormously wide cavity.

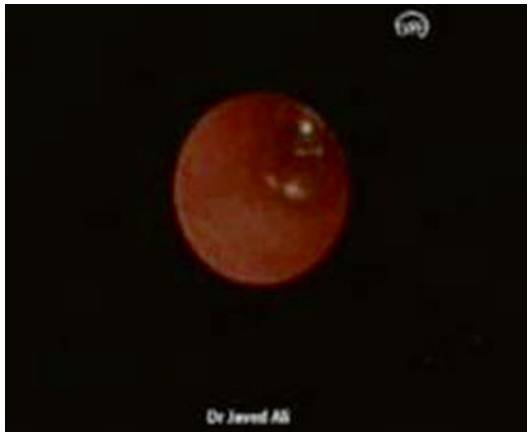

Fig. 9.12 Nasolacrimal duct

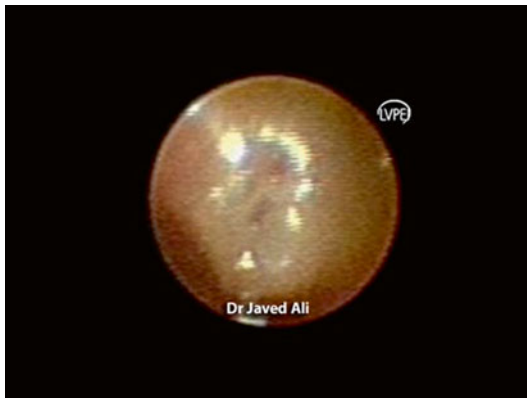

Fig. 9.13 Acquired internal punctal stenosis

Common Pathologies on Dacryoendoscopy

The list of indications for dacryoendoscopy described earlier in the chapter elucidates a host of lacrimal drainage system disorders that can be diagnosed and managed under guidance. Diagnosis of a few common pathologies should be learnt and include acquired internal punctal stenosis (Fig. 9.13), canalicular stenosis (Fig. 9.14), partial and complete canalicular obstructions (Figs. 9.15 and 9.16), and mucosal inflammations (Fig. 9.17).

Advantages of Dacryoendoscopy

Direct visualization of the lacrimal drainage system and pathologies obviates the need for many

Fig. 9.14 Canalicular stenosis

Fig. 9.15 Partial canalicular obstruction

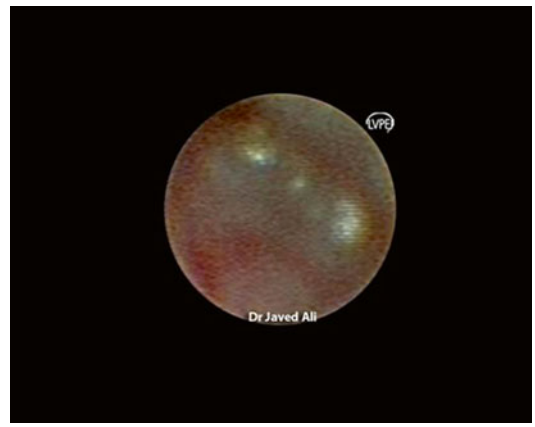

Fig. 9.16 Complete canalicular obstruction

cumbersome investigations in most of the cases. Many therapeutic procedures as mentioned in the indications can be accurately performed under

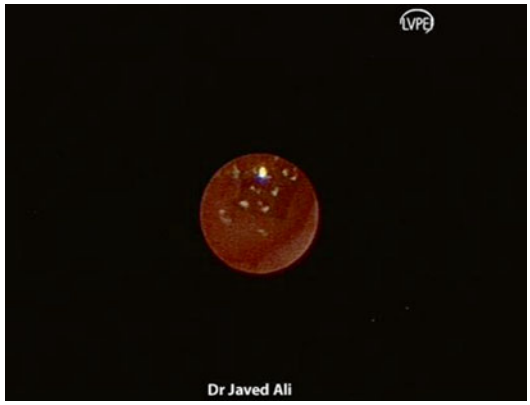

Fig. 9.17 Mucosal inflammation

dacryoendoscopic guidance and hence prevent false passages. The biggest advantage that this guidance gives is in terms of visualizing what we are doing rather than blind interventions. It also helps in better understanding of the disorders which will ultimately translate to better patient care.

Difficulties with Dacryoendoscopy

Procuring dacryoendoscopy is limited in the developing world because of the cost issues, but the author believes that increased usage would indirectly enhance affordability. The learning curve can be steep initially as with any new modality but once on track, the procedure takes very less time. For the same reason, it is advised that this learning be done under supervision since, occasionally damage to the lacrimal system may occur if one is not careful. Not able to get good images can be frustrating initially and sometimes even the best of hands may not be able to visualize and capture good images. However, following reasonable practice, the use of dacryoendoscopy contributes significantly in the diagnosis and management of lacrimal disorders.

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Imaging Modalities for Lacrimal Disorders

10

Lakshmi Mahesh and Mohammad Javed Ali

Introduction

Disorders of the lacrimal system are not uncommon. The spectrum of disease varies from congenital absence or aberrant anlage to acquired stenosis and obstructions of adult onset. Primary acquired nasolacrimal duct obstruction with associated infection is relatively common, whereas certain other disorders such as primary sac and duct tumors are very rare. Radiologic evaluation of the lacrimal system has evolved over the past decades to include a variety of studies ranging from plain dacryocystography (Fig. 10.1) to digital subtraction dacryocystography (DCG), nuclear medicine isotope studies (dacryoscintigraphy (DSG)), lacrimal ultrasonography (USG), computed tomography (CT), combined CT-DCG, and magnetic resonance imaging DCG (MR-DCG) [1]. Technological advances and enhanced imaging processing has allowed development of techniques that provide three-dimensional visualization of the nasolacrimal duct system.

L. Mahesh, MS (✉)
Department of Ophthalmology,
Manipal Hospital, Bangalore, India
e-mail: lakshmimahesh1@gmail.com

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute,
Banjara Hills, Hyderabad 500034, India

Digital Subtraction Dacryocystography (DS-DCG)

DS-DCG was first described by Galloway et al. in 1984 [2]. DCG is a useful modality to study the anatomical abnormalities of the lacrimal system such as stenosis, obstructions, diverticula, and to detect dacryolithiasis [2–6]. Digital subtraction dacryocystography is currently the most favored among conventional X-ray techniques. As the name reflects, this technique can subtract background images and noises to give a clear contrast-filled lacrimal image for study (Figs. 10.2 and 10.3). Its other advantages include reduced radiation exposure as compared to conventional techniques, ability to digitally manipulate the image contrast and brightness (Figs. 10.4 and 10.5), and cinematic view helping with understanding the flow dynamics.

The technique is performed after cannulating the canalicular system and gently injecting 1 ml of contrast material (Lipiodol, Omnipaque or Gadobutrol) [4]. As the dye is injected, the frames are obtained at a rate of 1 s each. Since the entire lacrimal system would typically fill up in 10 s, frames are obtained for similar duration. During the injection stage, apart from the anteroposterior images, both oblique frontal projections and off-lateral views are captures to yield a better delineation (Figs. 10.6, 10.7, and 10.8). DS-DCG have been reported to not only be useful in detecting presaccal from postsaccal stenosis but also in evaluating results of a dacryocystorhinostomy [5].

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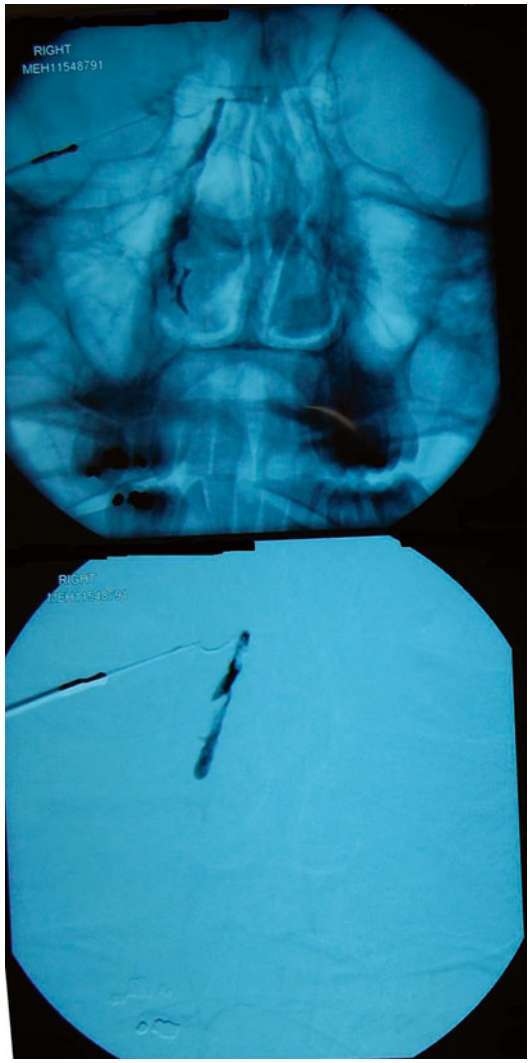

Fig. 10.1 Plain DCG in a trauma setting showing a right distal nasolacrimal duct obstruction (Photo courtesy: Gangadhar Sundar, Singapore)

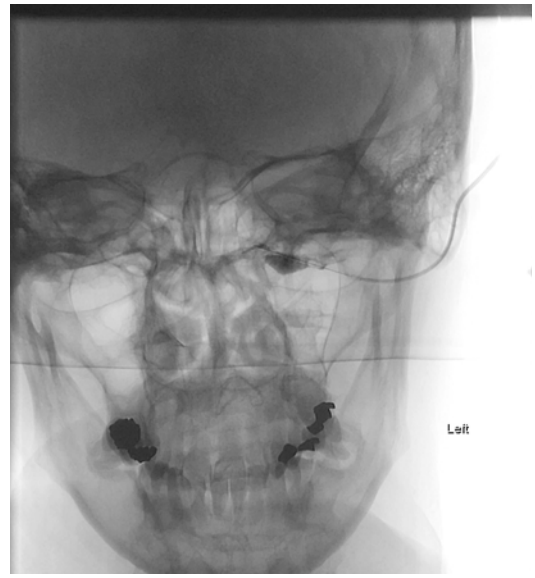

Fig. 10.2 Plain DCG before digital subtraction

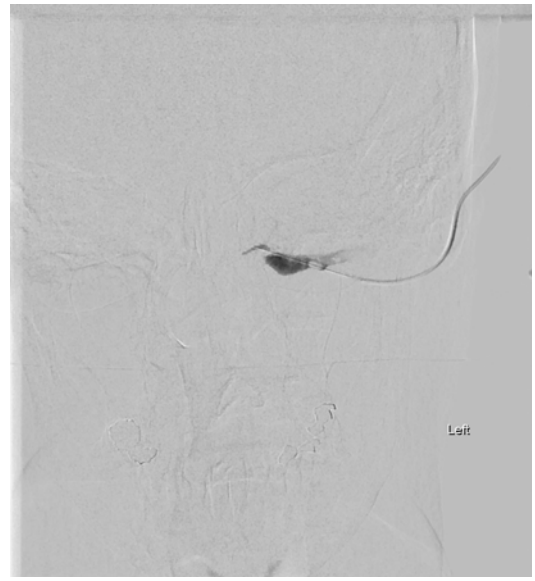

Fig. 10.3 DCG after digital subtraction of the same patient as in Fig. 10.2

Dacryoscintigraphy (DSG)

Rossomondo et al. first described the radionucleotide evaluation of lacrimal system in 1972 [7]. The advances in nuclear medicine has made dacryoscintigraphy a fairly safe and easy method for assessing the flow dynamics and other physiological aspects of lacrimal system [6–9]. It has a complementary role to anatomic studies and can be useful in evaluating pediatric epiphora, partial obstructions, and functional nasolacrimal duct obstructions (Figs. 10.9, 10.10, and 10.11). The test is performed by instilling 10 μl of Technetium 99 pertechnetate into the conjunctival cul-de-sac and tracing the dye through the lacrimal system using a pinhole-collimated gamma camera. Patients are instructed to blink normally and images are acquired in real time up to 30 min. The study end point is the detection of radionucleotide dye in the nasal cavity. In a typical normal DSG, visualization of canaliculi and sac occurs before 30 s and with passage into the nasal

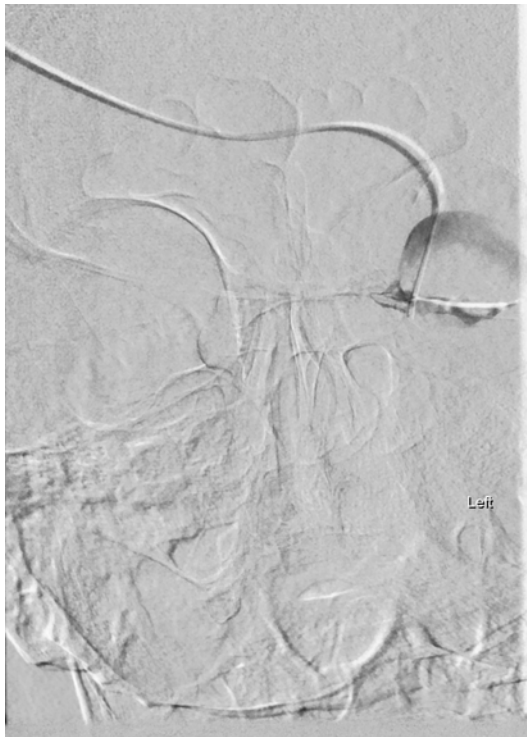

Fig. 10.4 Digitally subtracted image with a cannula in left lacrimal system (Photo courtesy: Alkis Psaltis, Adelaide)

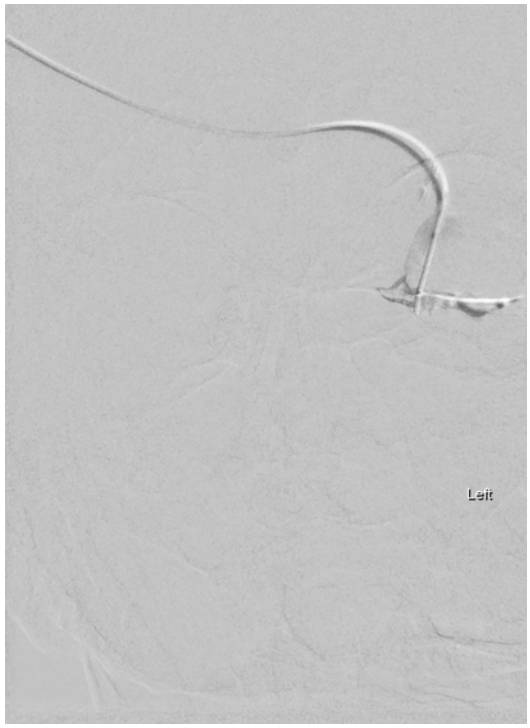

Fig. 10.5 Image contrast and brightness manipulation of the same patient as in Fig. 10.4 for better lacrimal delineation (Photo courtesy: Alkis Psaltis, Adelaide)

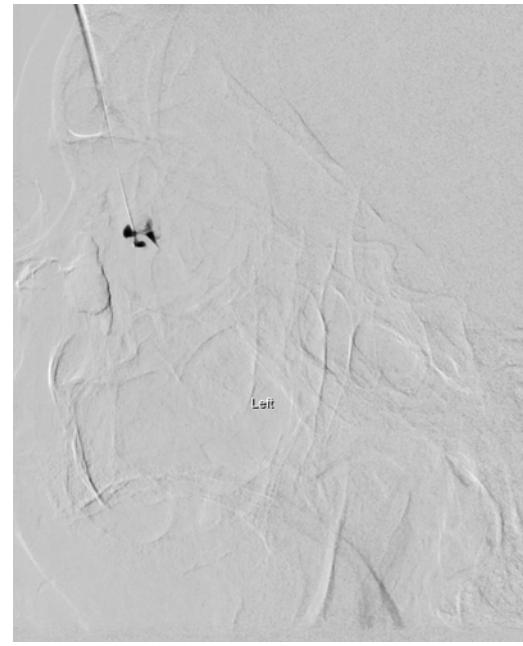

Fig. 10.6 Lateral view of DS-DCG showing canalicular filling with dye (Photo courtesy: Alkis Psaltis, Adelaide)

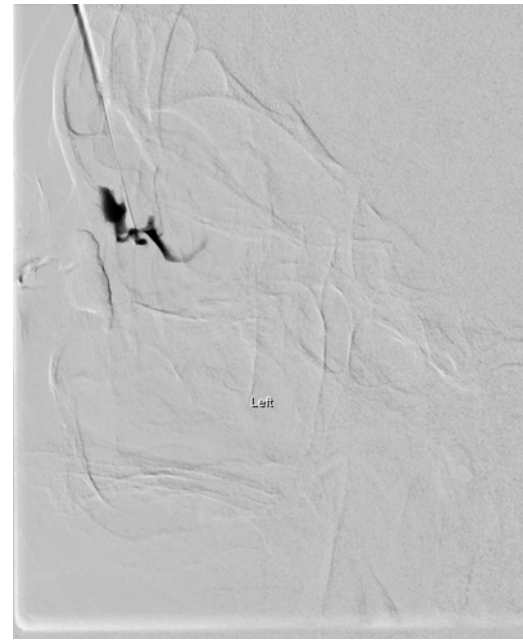

Fig. 10.7 Sequential DCG of same patient as in Fig. 10.6, showing early sac filling (Photo courtesy: Alkis Psaltis, Adelaide)

cavity in 10–20 min (Fig. 10.9). Areas of interest can be marked on the DSG images and quantity of tracer and times taken can be plotted on the time-activity scales. For example if the system is obstructed at a point, the time-activity slope there would be flat. Disadvantages of DSG include poor anatomical details, poor resolution, and variable transit times throughout the lacrimal system [6–9].

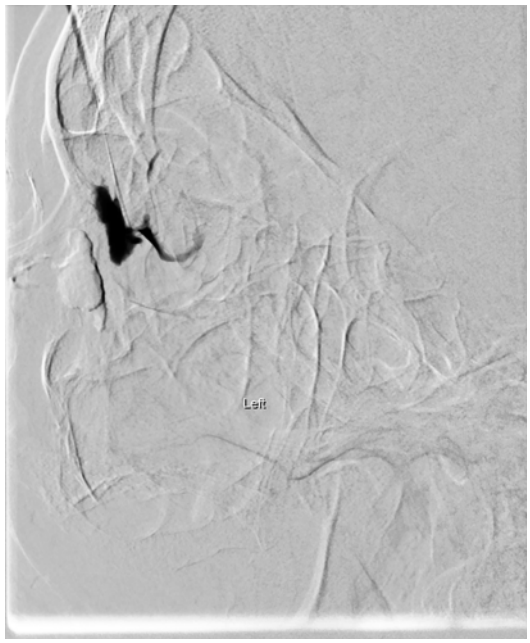

Fig. 10.8 Sequential DCG of same patient as in Figs. 10.6 and 10.7, showing complete filling of the sac but obstruction at the sac-duct junction (Photo courtesy: Alkis Psaltis, Adelaide)

Ultrasonography (USG)

Lacrimal ultrasonography was first described by Oksala in 1959 [10]. Using the B-scan mode, gross lacrimal anomalies such as diverticula, abscess, and dacryolithiasis could be identified [10, 11]. The normal lacrimal system appears as echo-free tubular structures as compared to a completely filled sac with an echogenic stone or tumor. The advantages of USG are easy technique, can be performed in an outpatient setting, and no radiation exposure. The disadvantages of USG include lack of anatomical details and inability to accurately localize abnormalities. However, with increasing technological improvements, there is a resurgence of interest in lacrimal USG. Determining the DCR ostium size and features in the postoperative period by serial ultrasonic measurements have been reported; however with the advent of endoscopes, a simple outpatient examination with a variety of measuring tools has been favored over a USG [12]. Anatomical and physiological utility of USG biomicroscopy have also been reported to be effec-

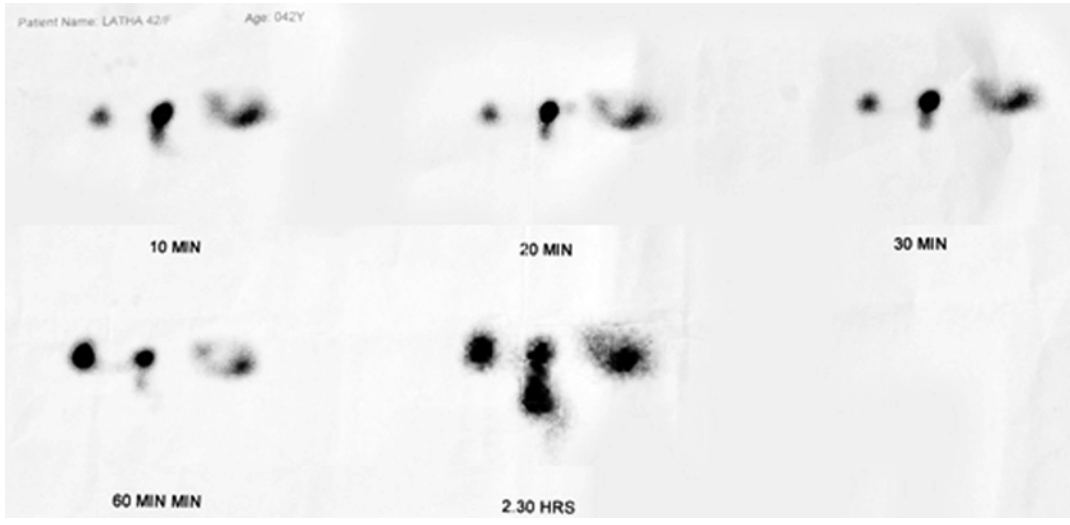

Fig. 10.9 Dacryoscintigraphy showing a normal right lacrimal system and a left distal canalicular obstruction

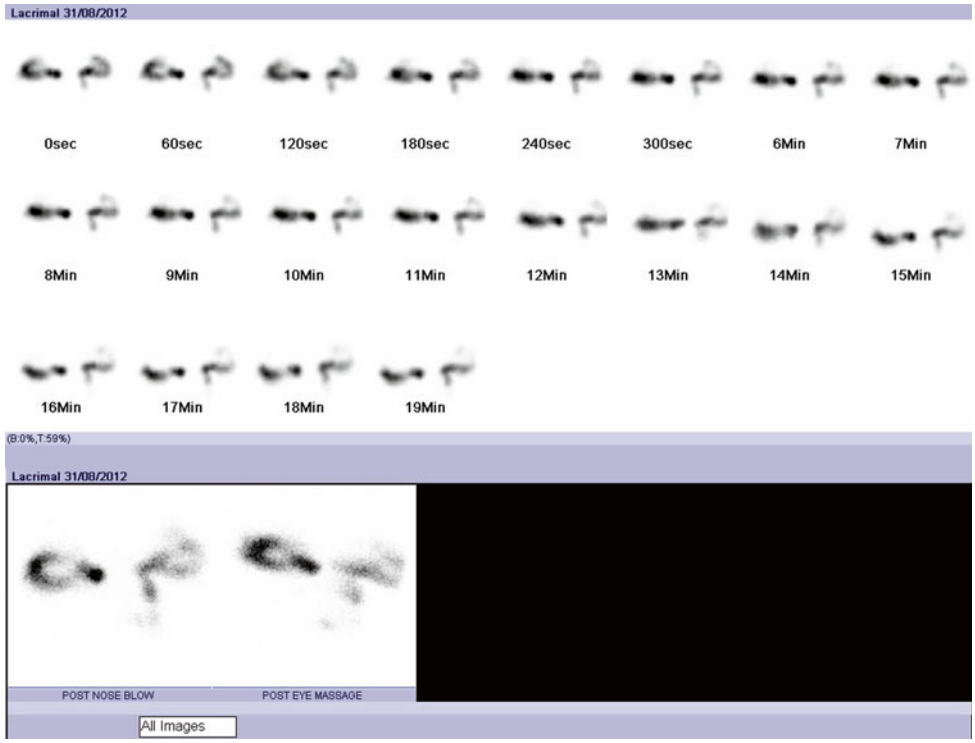

Fig. 10.10 Dacryoscintigraphy showing a right presaccal and a left postsaccal obstructions

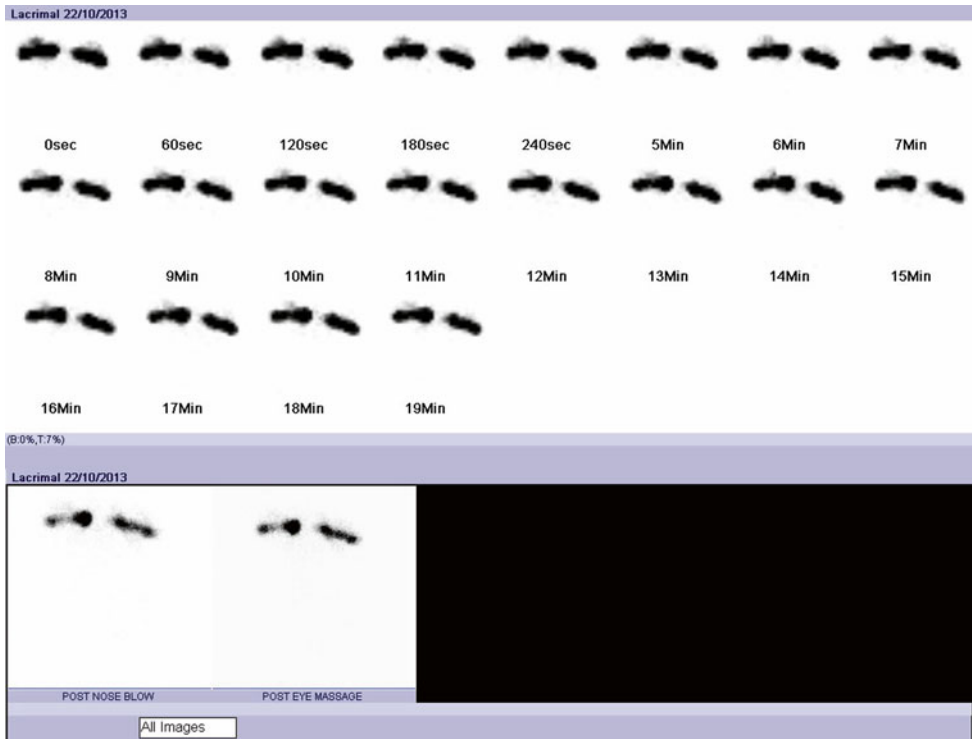

Fig. 10.11 Dacryoscintigraphy showing bilateral presaccal obstructions (Photo courtesy: Alkis Psaltis, Adelaide)

tive in examining the entire lacrimal drainage system as well as demonstrating the lacrimal sac turbulent flow but has not gained popularity as a clinical tool [11, 13].

Computed Tomography-Dacryocystography (CT-DCG)

Freitag et al. [14] first described CT-DCG in 2002. CT-DCG is an excellent tool for delineating the bony structures around the lacrimal system in bony windows and to some extent soft tissue study of lacrimal system [1, 15–17]. Technique employed can be either by dye instillation (drop method) or cannulation technique. The drop method is particularly useful in children and in patients unable to cooperate for irrigation. Serial coronal and axial images (2 mm slices) of the lacrimal area should be requested. Its advantages are listed in Table 10.1. By using modern spiral CT techniques with contrast material, high-resolution thin sections of the system are obtained (Figs. 10.12, 10.13, 10.14, and 10.15). Shorter acquisition time and three-dimensional (3D) reconstruction (Fig. 10.16) offer very good imaging and patient compliance.

This procedure is contraindicated in pregnancy and in those with history of Iodine allergy. Children and uncooperative patients can have sedation for the procedure. Radiological acquisition is performed soon after the dye is irrigated through the respective canaliculi.

Table 10.1 Indications for lacrimal imaging

Mid face trauma	Failed DCR-status of the ostium-size, patency etc.,
Medial canthal masses	
Previous lacrimal (failed DCR)/sino nasal surgery	Patients uncooperative to clinical evaluation
Anatomical variations	Uncertainty as to the cause of epiphora

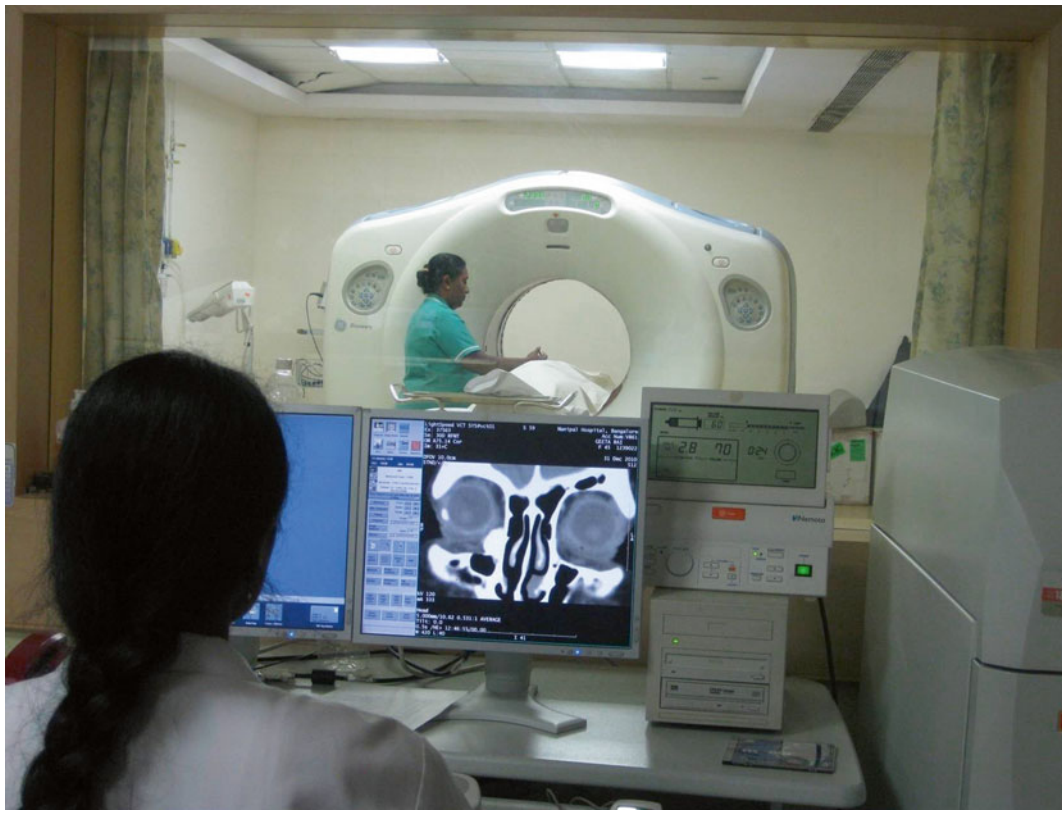

Fig. 10.12 A CT-DCG procedure in action

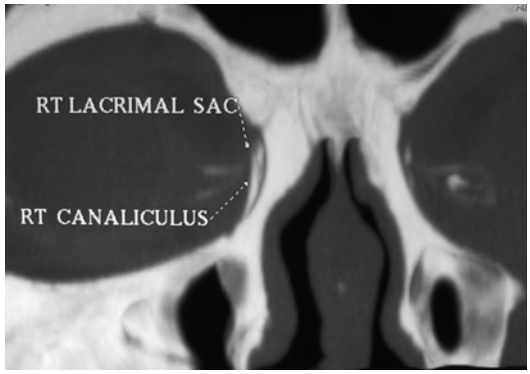

Fig. 10.13 CT-DCG, coronal image showing the dye within the canaliculi and lacrimal sac

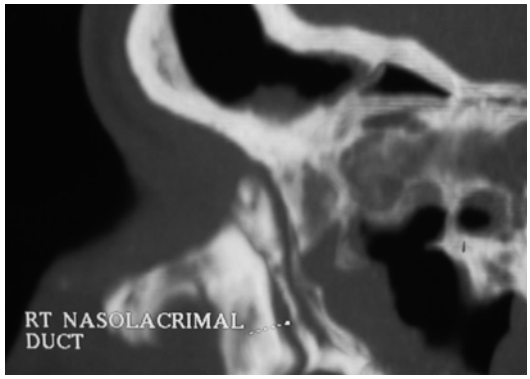

Fig. 10.14 CT-DCG, sagittal reconstruction showing the sac emptying into the nasolacrimal duct

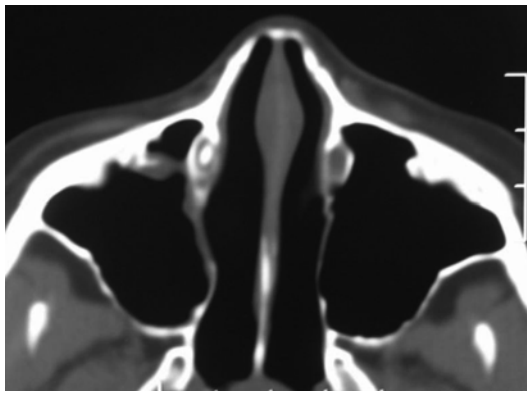

Fig. 10.15 CT-DCG, axial image, showing presence of dye in the right nasolacrimal duct, while it is absent on the left side, indicating obstruction

CT-DCG plays a useful role in the evaluation of the patient with tearing when an anatomic abnormality is suspected and is particularly helpful for surgical planning. In axial scans through the lower orbit, the lacrimal sac fossa appears as a depression in the anteromedial wall. In successively lower sections, the duct appears as a round to oval defect in the frontal process of the maxillary bone at the anteromedial corner of the antrum (Fig. 10.15). In absence of contrast, the duct may be filled with air or fluid. As the duct is traced inferiorly, it can be seen to open beneath the inferior turbinate. Cross sections of the system are seen in coronal reformatted images because the line of section is oriented downward and obliquely backward. Parasagittal reformatted images will reveal the entire length of the system in longitudinal section (Fig. 10.14). This view is indispensable in picking up the exact level of the obstruction [15–17]. In trauma cases, it offers additional benefits of more exact localization of the lacrimal drainage system fractures, bone displacements, location of previously placed miniplates, wires or sheets used in fracture repair, etc. (Figs. 10.17 and 10.18) [15].

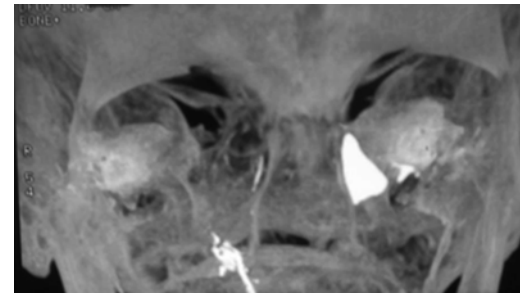

Fig. 10.16 Virtual rendered image showing pooling of dye on the left side indicating an obstruction. Note the dye in the right nasal cavity indicating a patent right system

In our unpublished series of 39 patients who underwent CT-DCG, 23 were males and 16 females. The age ranged from 6 to 78 years. All the cases were performed at a single center by the first author (LM) who performed the irrigation of the dye while the patient underwent the scan. There were two pediatric patients in the study who cooperated for the same under topical anesthesia. In majority of the cases, the initial plain scan was avoided to minimize exposure to radiation. The total procedure time takes about 10–15 min. The dye (water soluble Iodine based

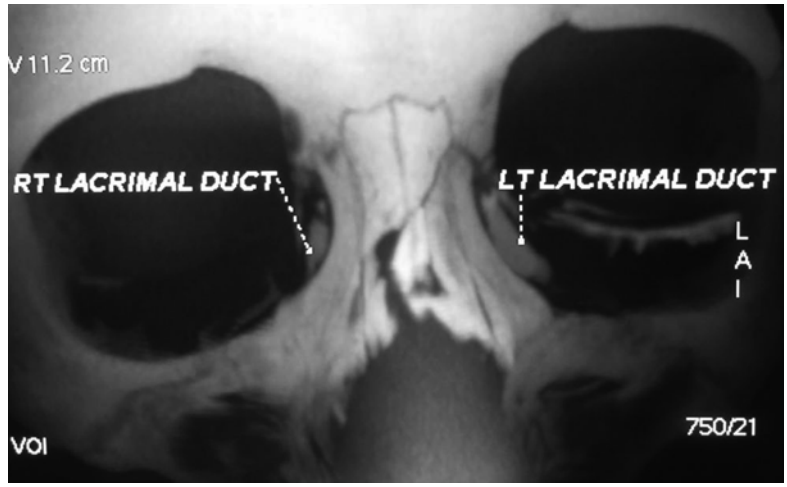

Fig. 10.17 CT-DCG in a trauma setting showing accumulation of the dye in the left lacrimal sac indicating an obstruction below in a case of nasoorbitoethmoid fractures

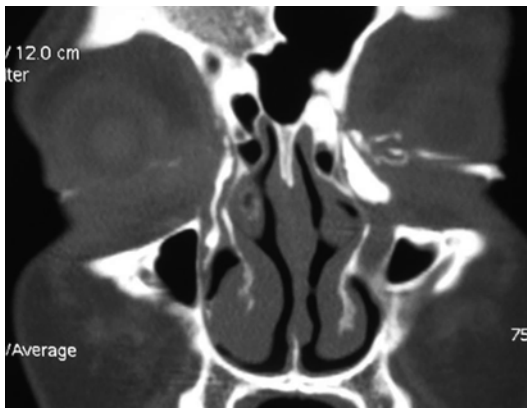

Fig. 10.18 CT-DCG of the same patient as in Fig. 10.17, showing a patent right system and an obstructed left lacrimal system

Table 10.2 Advantages of CT-DCG

Assessment of the anatomical variations
Assess immediate bony confines
3D lacrimal fossa evaluation
Evaluation of orbit and facial skeleton
Evaluates paranasal sinus contributions

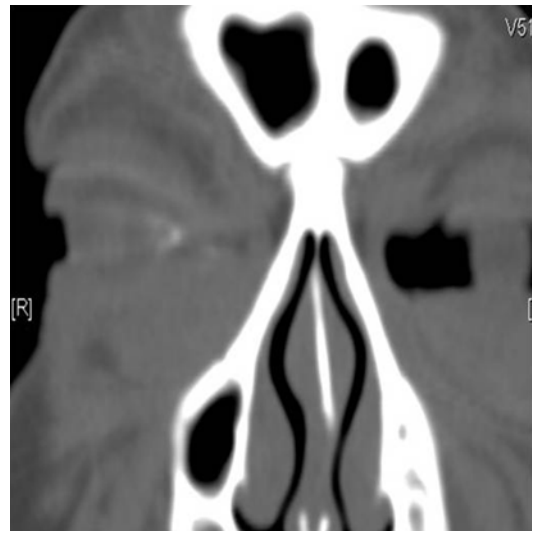

Fig. 10.19 CT-DCG, coronal image, showing a mass in the inferomedial orbit. Note the presence of dye in the canaliculi

dye—Omnipaque, Ioversol) containing 300-mg Iodine/ml was diluted either in 1:1 or 1:5 concentrations. This was loaded into a 2-cc disposable syringe with a lacrimal cannula (26 gauge) and after application of topical anesthetic, cannulation was carried out to inject the dye into the system. Simultaneous evaluation of the other side was also carried out for comparison. Seven patients had bilateral disease with partial or total obstruction of the system on the other side. The rest of the patients had unilateral disease. No untoward effect or allergy to the dye was noted in any case.

The indications for CT-DCG are listed in Table 10.2. Traumatic obstructions are a major indication in which displacement of the sac and its precise location could be ascertained. This was especially helpful in cases where there was persisting dacryocystitis following maxillofacial repair and medial canthal masses (Figs. 10.19 and 10.20) [15]. CT-DCG is very helpful to note

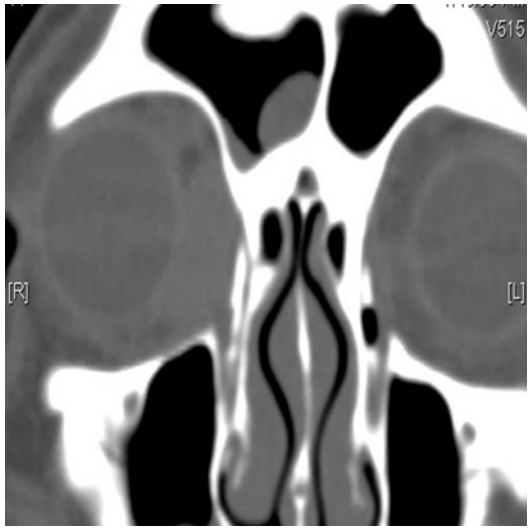

Fig. 10.20 CT-DCG, coronal image of the same patient as in Fig. 10.19, showing the lacrimal sac and nasolacrimal filling, indicating that the mass is not arising from lacrimal sac

the involvement of the sac in tumors initially and also for noting the features posttreatment such as irradiation where further reconstruction along with epiphora management is contemplated. Unusual features such as diverticulum of sac, canalicular pouch along with foreign bodies could be picked up. Tracking of the fistulous tract is also feasible [15–17]. In an unpublished series by first author (LM), 20 patients underwent surgery after the imaging procedure. In all patients who underwent subsequent surgery the findings on CT-DCG correlated well with the intraoperative findings. Seventeen patients had features of associated sinus disease, which could be picked up very well as imaging of the paranasal sinuses could be done simultaneously. These patients were also treated for the sinusitis. At present, CT-DCG is an invaluable tool in the diagnosis and management of complex lacrimal duct obstructions.

Magnetic Resonance Imaging Dacryocystography (MR-DCG)

MR-DCG was first described by Goldberg et al. in 1993 [18]. MR-DCG is a very useful lacrimal imaging modality that offers a superior soft tissue delineation and can differentiate lacrimal system fluid signals from surrounding tissues [18–22]. Table 10.3 lists the advantages of MR-DCG. However, the disadvantages are long acquisition times, lack of bony details and higher costs as compared to others. The technique can be performed similar to that of CT-DCG; however, the contrast used in 0.5 % gadolinium meglumine. T1-weighted images with fat suppression in any plane desired are acquired between 5 and 10 min following the contrast instillation, but not later since the dye is not retained beyond 20 min. Although the anatomical delineation is excellent, it superiority over CT-DCG for anatomical abnormalities in lacrimal system has not been established [20]. MR-DCG is preferred for congenital dacryocystoceles but with the advent of endoscopic examinations, this can well be avoided in favor of a less cumbersome and outpatient procedure. The half-Fourier single shot technique of HASTE using fast sequence of T2-weighted images and dynamic MR studies have been found useful for functional studies of lacrimal system but has not gained wide clinical acceptance [21, 22].

Table 10.3 Advantages of MR-DCG

High tissue contrast
Better soft tissue delineation
Imaging in any obliquity desired
Clear identification of fluid signals
No ionizing radiations
Noninvasive contrasts

Conclusion

There is no single gold-standard imaging modality among the battery of techniques described in this chapter. Each modality has its own niche and unique set of advantages and contributes significantly in its own way. Regardless of the radiologic studies requested, good communication between the clinician and the radiologist with reference to the patient's symptoms, examination findings and possible diagnosis is helpful to ensure that the maximum amount of useful information is obtained in every study.

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Disorders of the Upper Lacrimal System

11

Mohammad Javed Ali

Introduction

Proximal lacrimal outflow disorders are sparsely documented in the literature [1–9]. Disorders of the upper lacrimal system pose much more challenges in terms of management as compared to the lower system. These disorders can be broadly classified as congenital or acquired. In order to simplify this topic, we will broadly discuss it under the following three headings:

A. Disorders of the puncta
B. Disorders of the canaliculi
C. Lacrimal fistula

Before we dwell into the details of each of the disorders, a thorough knowledge and understanding of the upper lacrimal system embryology is of imperative value. The embryonic origin of lacrimal passages is along the line of the cleft between the lateral nasal process and the maxillary process of the embryonic face (Fig. 11.1) [6]. After the cleft obliterates, a solid epithelial rod appears in the embryo of 9.5 mm length and then completely separates from the surface in an embryo of 15 mm. The canaliculi are formed by budding of the upper end of this solid cord in an embryo of 18–24 mm (Fig. 11.2) [9]. The process of canalization begins in a 35 mm embryo by the disintegration or apoptosis of the central cells (Fig. 11.3). The entire canaliculus is canalized except near the puncta which opens onto the lid

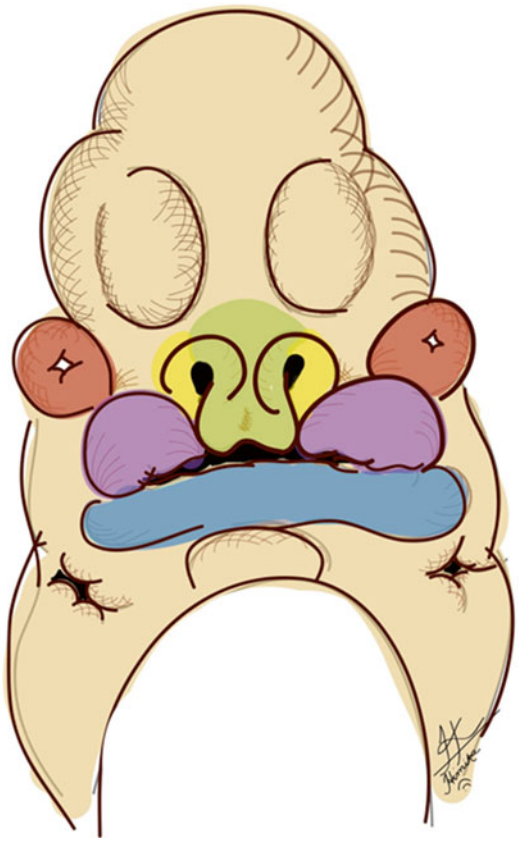

Fig. 11.1 Schematic diagram showing the development of lacrimal system between the maxillary and frontonasal process (Photo Courtesy: Dr. Himika Gupta)

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

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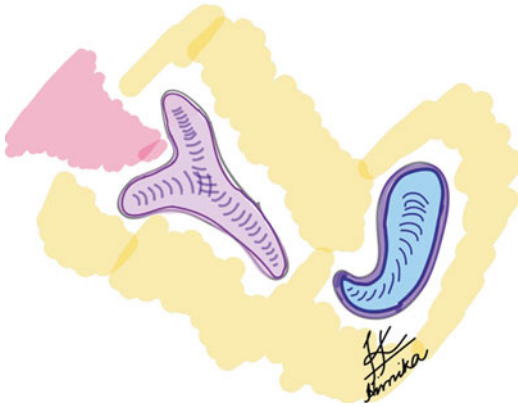

Fig. 11.2 Schematic diagram showing the out-budding of solid canaliculi from the lacrimal rod (Photo Courtesy: Dr. Himika Gupta)

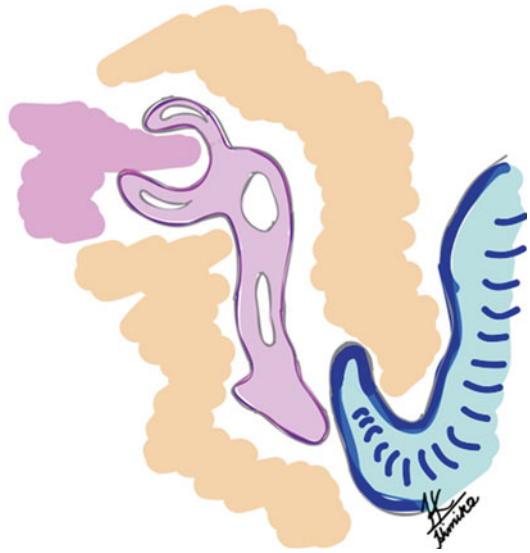

Fig. 11.3 Schematic diagram showing the process of canalization (Photo Courtesy: Dr. Himika Gupta)

surface when the embryo is 130 mm, before the separation of the eyelids at 7th month of intrauterine life [3, 4, 6, 9].

Disorders of the Punctum

The punctum is the entrance to the lacrimal outflow system and, hence, is of sacrosanct value in terms of disease recognition and its subsequent management. The spectrum of punctal disorders is wide and varies from a mild stenosis to punctal agenesis. Table 11.1 outlines the proposed classification of punctal disorders, which we believe will help in better understanding and building standardized protocols. Certain disorders like punctal and canalicular trauma would be discussed in Chapters 16 and 15 "Lacrimal System Trauma" and canaliculitis in Chapter "Infections of the Lacrimal System."

Table 11.1 Proposed classification of punctal disorders

A. Primary punctal disorders
1. Punctal agenesis
2. Incomplete punctal canalization
3. Punctal stenosis
4. Supernumerary puncta
5. Ectopic punctum
B. Secondary punctal disorders
1. Peripunctal disorders
2. Punctal trauma
3. Punctal ectropion
4. Iatrogenic punctal disorders
5. Contiguous punctal involvement in systemic disorders

Punctal Agenesis

Proximal lacrimal outflow dysgenesis involving the punctum and canaliculus is a sparsely documented entity in the literature [1–12]. The term punctal atresia has been used interchangeably with punctal agenesis as well as for a spectrum of punctal disorders varying from a fine membrane in the punctum to its absence itself [1–11]. It is important therefore to clearly differentiate punctal agenesis from other congenital punctal disorders.

The basic etiopathogenesis of punctal agenesis is likely to be failure of canaliculi out-budding from the upper end of the solid lacrimal cord in an embryo of 18–24 mm (Fig. 11.2) [9]. It is very rare to have intact canaliculi with a punctal agenesis [13, 14]. Welham and Hughes reported 89 % ($n = 19$) of the patients with punctal agenesis to have concomitant canalicular agenesis [15].

The diagnosis of punctal agenesis should include a careful history and examination. History of epiphora and other symptoms may be variable depending upon the agenesis of single or both puncta of the eye. Patients with a single

punctum missing may have mild epiphora. Severe epiphora usually indicates an associated nasolacrimal duct obstruction. Associated redness and discharge are also seen. In contrast, patients with both puncta missing have universal epiphora but are usually not very symptomatic and do not have redness or discharge. Lyons et al. [3] in their series reported 78 % of the eyes with single punctum missing ($n=41$) presented with epiphora and 22 % presented with medial canthal swelling and features of dacryocystitis. As against this, 100 % of the eyes with both puncta missing ($n=53$) presented with epiphora, but none had any discharge or dacryocystitis. Clinical examination by slit lamp would show absence of the punctal papilla, absence of any transilluminant membrane, absence of any dimple in the area of the punctum, and occasionally the presence of eyelashes medial to the punctum in the pars lacrimalis area of eyelids (Figs. 11.4 and 11.5).

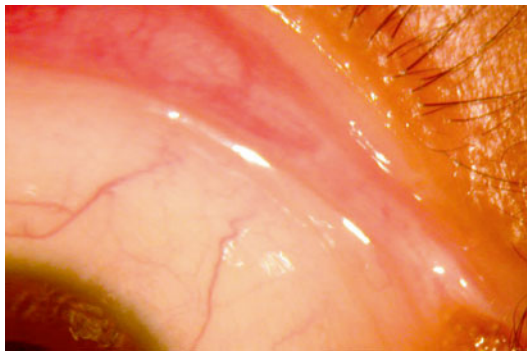

Fig. 11.4 Clinical photograph showing a lower punctum agenesis. Note the cilia in the pars lacrimalis portion of the eyelid

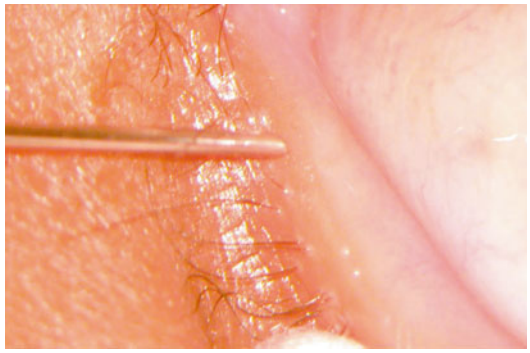

Fig. 11.5 Upper punctal agenesis. Note the absence of punctal papilla

Punctal agenesis has important ocular and systemic associations. Lyons et al. [3] found 23 % of their cases ($n=57$) to have ocular abnormalities like lacrimal fistula, blepharitis, distichiasis, eyelid tags, absence of caruncle, and divergent strabismus. Punctal agenesis has a well-known association with systemic syndromes like ectodermal dysplasia [1, 6], Hay-Wells [1], and Levy-Hollister syndromes [8]. In addition it has been found that patients with both puncta missing showed intraoperative anatomical variations like aplasia of the lacrimal crests, sac hypoplasia, and large anterior ethmoidal air cells [3].

Management of punctal agenesis is challenging. Patients who have a single punctum missing and are asymptomatic may be observed without any intervention. However, probing is warranted in those who have associated nasolacrimal duct obstruction and most would do well. Failure of probing is an indication for a dacryocystorhinostomy with a Mini-Monoka tube. Lyons et al. [3] performed probing in 24 % ($n=41$) of the eyes with a single punctum missing, DCR in 31 %, and DCR with Lester Jones tubes in 17 % of these patients. Patients with both punctum missing but with minimal symptoms can be observed. For those with severe symptoms, we prefer to manage using an endoscopic placement of Lester Jones tube (Fig. 11.6) or Gladstone-Putterman tube without an actual dacryocystorhinostomy (Fig. 11.7) [16]. However, there are many techniques described for Jones tube insertion in these patients, and individual surgeon preferences are based on what suits them best [17–21]. We do not advocate any retrograde approach or cutting down of the canaliculus or canaliculotomy, since these are cumbersome procedures and the results in the literature are not very encouraging [3, 13, 14].

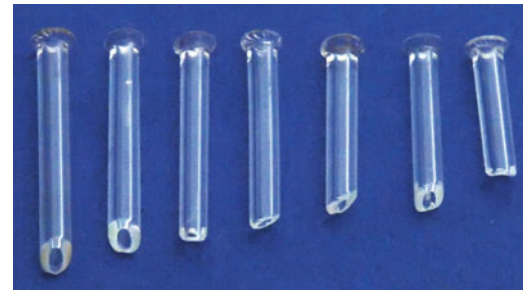

Fig. 11.6 Lester Jones tubes

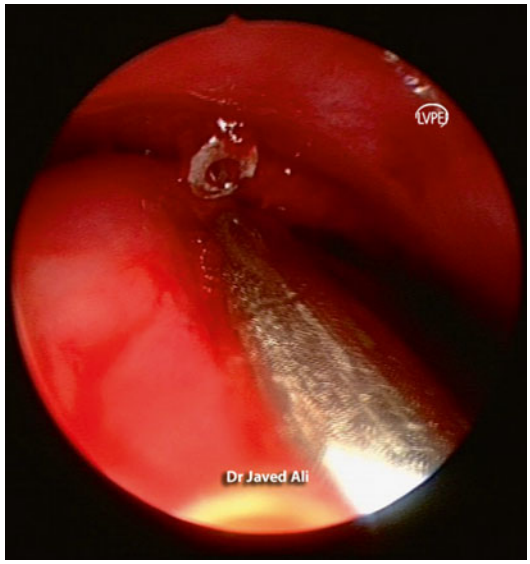

Fig. 11.7 Endoscopic view following CDCR with Lester Jones tube

Incomplete Punctal Canalization (IPC)

Incomplete punctal canalization is a term that refers to a form of punctal dysgenesis with membranes. The term was first described by Ali et al. [22], who studied 55 such dysgenetic puncta. The pathogenesis of punctal membranes is unknown but is believed to either represent failed dehiscence of the epithelium overlying the normally formed canaliculi or failure of canalization of the most proximal part of the lacrimal apparatus. This dysgenesis is not found to have any systemic association although associated lacrimal system anomalies like canalicular stenosis and congenital nasolacrimal duct obstruction are reported [22]. Patients typically present in the first decade with symptoms of epiphora since birth or infancy. Clinical examination reveals punctal membranes which could be external or internal. The external membrane (EM) variety, which is also called IPC-EM, typically covers the external surface of the puncta and hides it beneath, giving a false impression of punctal agenesis (Fig. 11.8). The internal membrane (IM) variety, which is also called IPC-IM, typically demonstrates blurred punctal margins but, just at

Fig. 11.8 Clinical photograph showing IPC-EM variety. Note how closely it mimics punctal agenesis

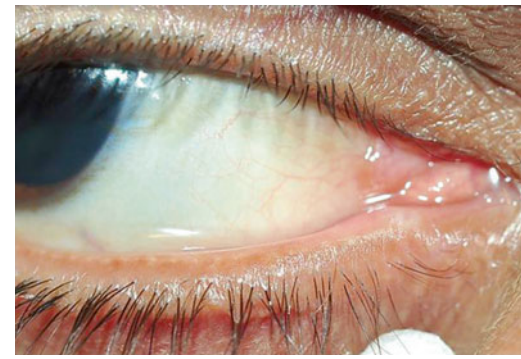

Fig. 11.9 IPC-IM variety. Note that the blurred punctal margins can still be made out

the entry into the puncta, covers it entirely with a membrane. The membranes usually appear translucent (Fig. 11.9). Clinical diagnosis is based on a high degree of suspicion of a slight avascular dimple at the site of the puncta, and the membrane tends to stand out as a translucent structure from the surroundings if indirect illumination is used with the help of a slit lamp and a thin slit beam is placed perpendicular and adjacent to the punctum.

Ali et al. [22] found that external membranes (EM) over the puncta were noted in 86.4 % and internal punctal membranes (IM) in 13.6 % of their patients. The punctal membranes on histopathological examination uniformly were fibrovascular membranes without any signs of inflammation.

Management of IPC is usually simple. A membranotomy using a slow taper punctum dilator is almost always helpful. Once the membrane is overcome, the surgeon would find a normal

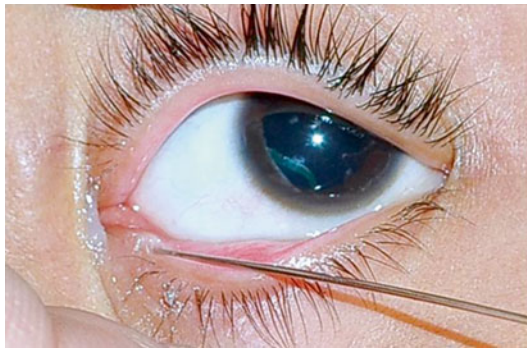

Fig. 11.10 IPC: following membranotomy, the canaliculus was found to be normal

punctum beneath, and usually the canaliculi and the rest of the lacrimal outflow are found to be normal (Fig. 11.10). Intubation is helpful for the rarely associated canalicular stenosis; however, the authors do not advocate the use of routine intubation following membranotomy, since the diameter of the punctum is fairly large following the procedure and does not tend toward restenosis later on. With a simple membranotomy and occasional adjunctive procedures, the anatomical patency was found to be 100 %, and the relief from symptoms was seen in 91 % (20/22) of the patients [22].

Punctal Stenosis

Punctal stenosis is not an uncommon disorder of the punctum. It is an important cause of epiphora and accounted for 8 % of all patients presenting with epiphora in a tertiary care Oculoplastics practice [23]. Table 11.2 enlists the frequent causes of punctal stenosis [2, 12, 24–26]. The pathogenesis is still elusive, but it is important to remember in this regard that the punctum being the entry point for tears is exposed to all the possible soluble irritants that an ocular surface encounters. The widely believed hypothesis that has been supported by histological studies [27] is a common mechanism involving inflammation leading to fibrosis and subsequent stenosis.

In order to facilitate uniform protocols of management, Kashkouli et al. [12, 25] proposed

Table 11.2 Common causes of punctal stenosis

1. Involutional or age related
2. Conjunctivitis (HSV, HPV, chlamydial)
3. Eyelid infections
4. Topical medication toxicity (timolol, latanoprost)
5. Systemic medications (5-fluorouracil, paclitaxel)
6. Lid malpositions
7. Trauma (thermal)
8. Chronic cicatricial disorders (Steven-Johnson syndrome)
9. Peripunctal tumors
10. Systemic disorders (porphyrias, acrodermatitis)
11. Radiotherapy

Table 11.3 Grades of punctal stenosis

Grade 0 – punctal agenesis
Grade 1 – incomplete punctal canalization (IPC-EM and IPC-IM)
Grade 2 – recognizable but less than normal
Grade 3 – normal, round punctum (admits 26G canula)
Grade 4 – slit punctum <2 mm in size

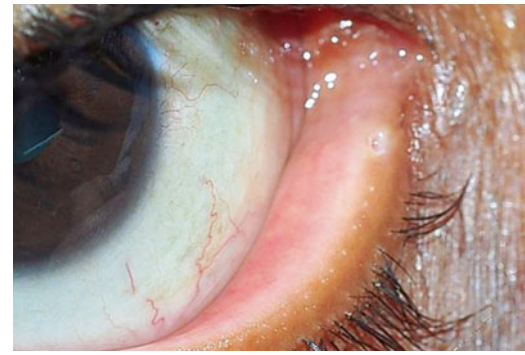

Fig. 11.11 A normal round punctum

a grading system for the puncta based on its size and shape. Table 11.3 enlists the different grades of punctal stenosis as published by Kashkouli with slight modifications, which our group believes are important. Figure 11.11 represents a normal round punctum, whereas Figs. 11.12 and 11.13 represent punctal stenosis.

There are no uniform acceptable guidelines for the management of punctal stenosis. Several modalities described in the literature include punctal dilatation, one-snip punctoplasty, two-snip punctoplasty, three-snip punctoplasty, rectangular three-snip punctoplasty, four-snip

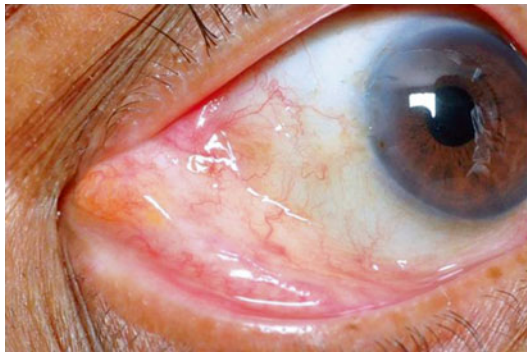

Fig. 11.12 Clinical photograph showing lower punctal stenosis

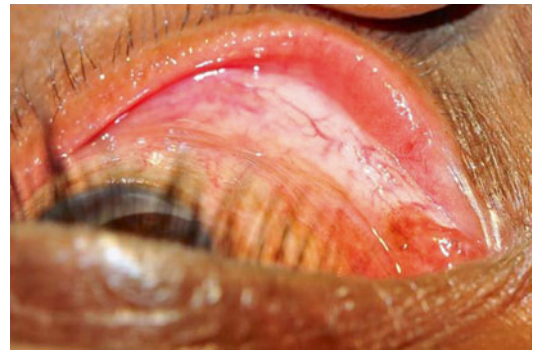

Fig. 11.14 One-snip punctoplasty

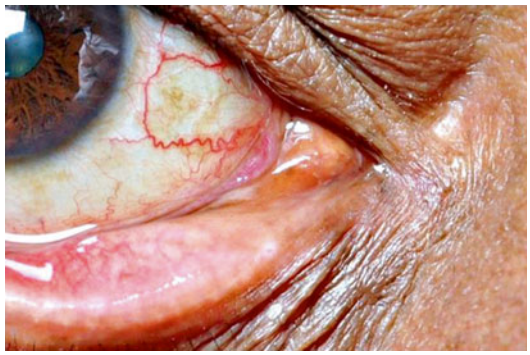

Fig. 11.13 Grade 2 punctal stenosis

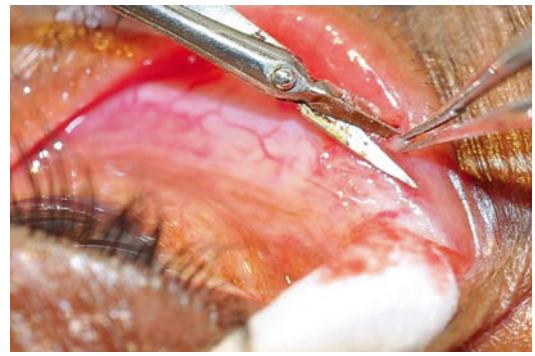

Fig. 11.15 The second snip in punctoplasty

punctoplasty, punctal punching with Kelly or Reiss punch, punctoplasty with mitomycin C, and inserting perforated punctal plugs, self-retaining bicanalicular stents, or Mini-Monoka [28–34]. It is important to note that there is an increasing evidence in the literature about the benefits of Mini-Monoka as a noninvasive modality of managing punctal stenosis, and the author anticipates this to be one of the most acceptable modality in the near future. Mathew and Olver [28] reported punctal dilatation and placement of Mini-Monoka without any surgical snips as a simple yet effective procedure. Hussain et al. [29] in a very large series of 123 eyes showed Mini-Monokas to be effective in relieving epiphora in 82 % of the eyes at 6 weeks. Konuk et al. [30] showed a long-term success rate of 84 % with the use of perforated punctal plugs in their series of 44 procedures with a follow-up of 19 ± 13.4 months.

Punctoplasty

The earliest description of one-snip punctoplasty was by Bowman in 1853, later modified by Jones in 1962 [24, 25]. One-snip punctoplasty involves a single vertical cut on the conjunctival side of the punctum and vertical canaliculus till the ampulla (Fig. 11.14). Kashkouli et al. [25] combined a 2 mm horizontal one-snip punctoplasty starting from the ampulla, parallel to the lid margin, with additional Mini-Monoka insertion and reported a 77.4 % success ($n=53$) at a mean follow-up of 18.5 months. In two-snip punctoplasty, after the vertical cut-like one-snip procedure, the second snip starts from the end of the first incision as a 2 mm horizontal cut and involves the ampulla (Fig. 11.15). Two-snip procedures are not very popular.

Three-snip procedures were described by Thomas in 1951. The modern three-snip punctoplasty can be triangular or rectangular in

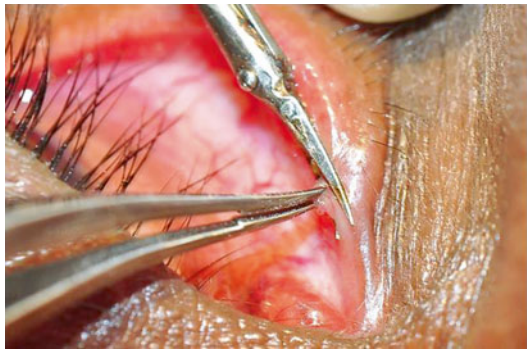

Fig. 11.16 The third snip in punctoplasty

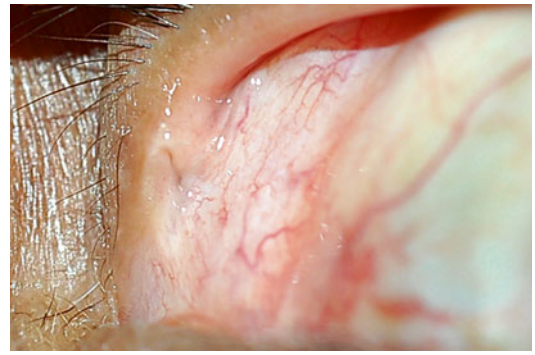

Fig. 11.17 Cicatrization following punctoplasty

shape. The triangular three-snip punctoplasty is a more traditional way which is like a two-snip punctoplasty with an additional excision of the base (Fig. 11.16). This means that there is one cut in the vertical canaliculus, one cut in the horizontal canaliculus, and one cut at the base. In contrast to this, the rectangular three-snip procedure has two vertical cuts on either side of the vertical canaliculus with one cut at the base. Caesar and McNab [24] documented a success rate of 92 % with a three-snip procedure ($n=53$). Chak and Irvine [32] compared 49 triangular three-snip with 59 rectangular three-snip procedures and found that the recurrence rates were not significantly different between both groups. However, postoperatively the patients who underwent triangular three snips were more symptomatic (16.9 %) compared to those with rectangular three snips (10.2 %). This can be partly explained because of lack of a cut in the horizontal canaliculus with rectangular three snips, hence avoiding greater injury to the lacrimal pump.

Cicatrization following punctoplasty due to wound healing is a major cause of restenosis, which is much more difficult to manage than the primary stenosis (Fig. 11.17). Fraser et al. [35] advocated the use of re-dilatation with punctum dilator for early cicatrization following a three-snip punctoplasty. However, the study was retrospective, and a clear benefit was not demonstrated. Ma'luf et al. [34] compared two groups of patients undergoing punctoplasty with and without the use of adjunctive mitomycin C (0.5 mg/ml). They found that the restenosis and cicatrization were seen in 19 % ($n=26$) of patients where MMC was not used as compared to 0 % ($n=25$) in cases where MMC was used ($p<0.02$).

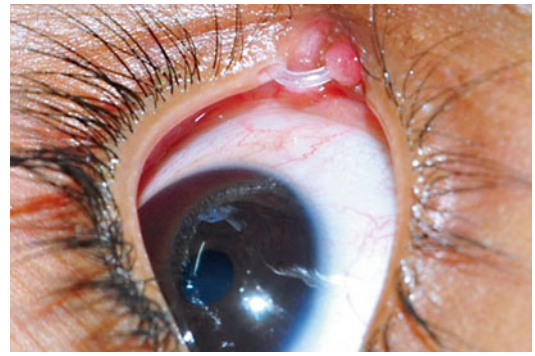

Fig. 11.18 Peripunctal granuloma

Peripunctal Disorders

Peripunctal disorders refer to those which involve the punctum as well as encircle it all around. Numerous lesions can have a peripunctal location like a peripunctal granuloma secondary to a foreign body or stent (Fig. 11.18), nevus (Fig. 11.19), papilloma, hemangioma, basal cell carcinoma (Fig. 11.20), neurofibroma, and a peripunctal abscess. The management of these lesions can be very challenging since excision will surely mean loss of the puncta and proximal canaliculus. Lesions that are benign and not showing a growth may be observed. Nevi may have to be followed up closely specially in elderly patients. A simple clinical tip would be

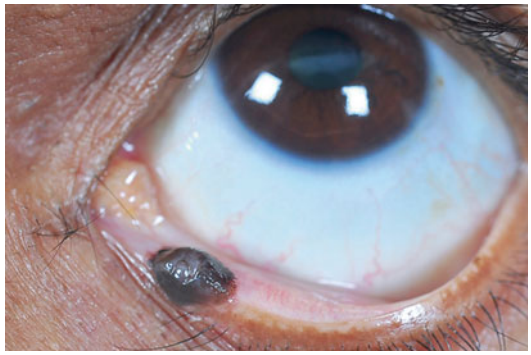

Fig. 11.19 Peripunctal nevus

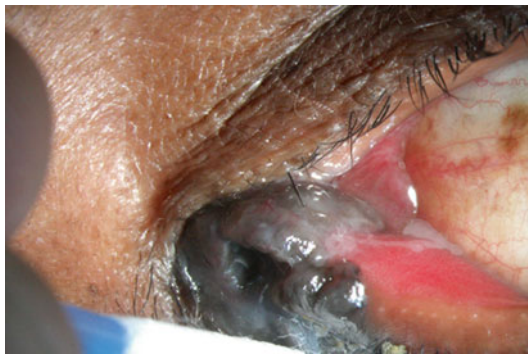

Fig. 11.20 Peripunctal basal cell carcinoma

to assess the patency of the puncta with a probe. Obstruction in a previously patent puncta should be viewed with a high suspicion. Occasionally hemangiomas may have a similar lesion, and careful use of steroids or propranolol (if associated with extensive hemangioma) may be helpful in preserving the punctal integrity. In all lesions where excision becomes mandatory, all attempts must be made for preserving as much canaliculi as possible as well as stenting the passages for lacrimal reconstruction.

Disorders of the Canaliculi

There are wide varieties of congenital and acquired canalicular disorders. These include canalicular wall dysgenesis, canaliculitis, and post-traumatic canalicular fistulas. The latter two will be discussed in the chapters on lacrimal infections (Chap. 15) and trauma (Chap. 16), respectively.

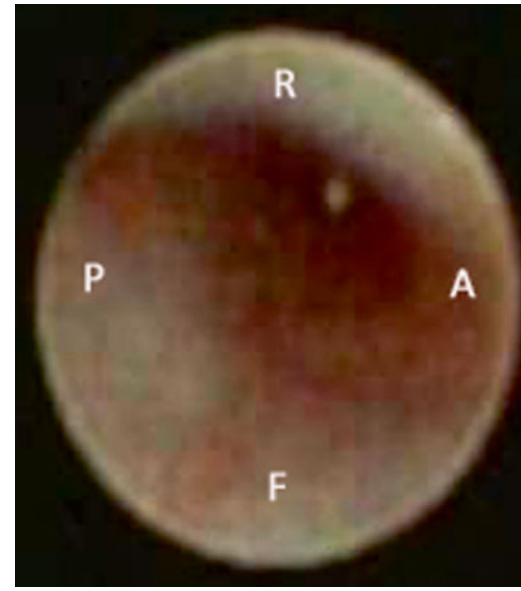

Fig. 11.21 Arbitrary division of canaliculus into four walls, a dacryoendoscopic view. *A*-anterior, *P*-posterior, *R*-roof, *F*-floor

Canalicular Wall Dysgenesis (CWD)

Proximal lacrimal outflow dysgenesis involving the punctum and canaliculus is a sparsely documented entity in the literature [1–9]. Ali et al. [36] introduced the term canalicular wall dysgenesis and its eight subtypes of aplasia and hypoplasia. The same group also introduced an arbitrary division of a canaliculus into four walls, namely, roof, floor, anterior wall, and a posterior wall toward the conjunctiva (Fig. 11.21). The roof is that wall of the canaliculus which is near and parallel to the lid margin, and the posterior wall is parallel to the palpebral conjunctiva.

The etiopathogenesis of canalicular wall dysgenesis is unknown, but three possibilities have been proposed. First, it could represent dysregulation of mesenchymal condensation around the canalicular primordium and its contiguity with the sub-adjacent mesenchyme of the surface ectoderm during Carnegie stage 19 of embryonic development. Second, when the canaliculi are well differentiated but without a lumen (Carnegie stage 22), the cells in the center of the future lumen are loosely arranged as compared to dense and tight arrangement near the walls. Changes in

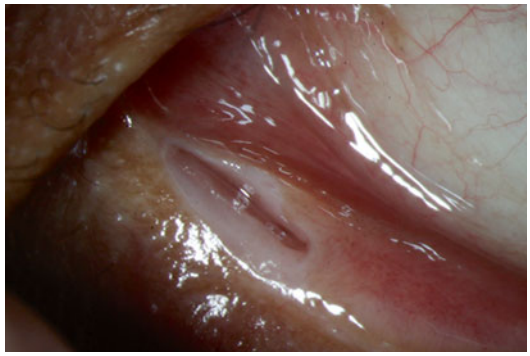

Fig. 11.22 Single canalicular wall aplasia

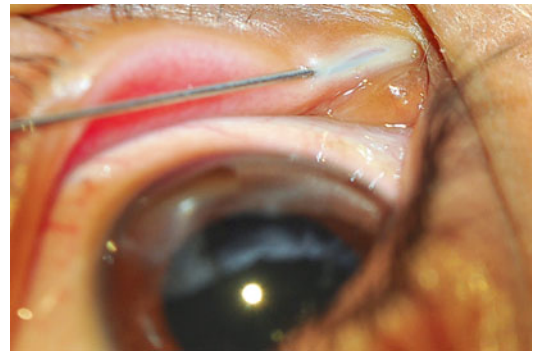

Fig. 11.23 Single canalicular wall hypoplasia

this arrangement can lead to focal or diffuse wall dysgenesis. Third, during the early fetal weeks (10–12 weeks of gestation), the canalicular epithelium interacts and becomes contiguous with the conjunctival epithelium. Interference with this mechanism or dehiscence of the epithelium overlying the maturing canaliculi could result in wall dysgenesis. Future well-planned embryonic morphogenetic studies using embryonic specimens are needed to verify these possibilities.

The diagnosis of single canalicular wall dysgenesis (SCWD) is made on slit lamp biomicroscopy. The term isolated refers to involvement of a single wall of the canaliculus. The typical finding in cases of aplasia, which is called single canalicular wall aplasia (SCWA), includes an obvious defect in the canalicular wall, which is a complete dehiscence (Fig. 11.22). This defect can be further classified as focal if it involves a part of the canaliculi (Fig. 11.22) or diffuse if the defect extends along the entire length of the canaliculi. This canalicular wall dehiscence may mimic a post-traumatic slit canaliculus. The points in favor of SCWA would be a negative history, a larger dehiscence with smoother walls, and no other obvious signs of associated trauma. If the roof is aplastic, one would notice the whitish mucosal lining of the canaliculi on the remaining three walls by slit lamp biomicroscopy with high magnification (Fig. 11.22). The other variant of SCWD is hypoplasia, which is called single canalicular wall hypoplasia (SCWH), and requires a high degree of suspicion for the clinical diagnosis. The most obvious finding in SCWH is thinning of the wall, most noticeable if we place a probe in the canaliculus (Fig. 11.23). The surface of the probe becomes more obvious and is easily visualized in the areas of hypoplasia. A comparison with a probe in normal canaliculi helps us understand this difference. Unlike aplasia, the mucosal lining of the remaining walls cannot be easily noticed in hypoplasia because there is just a thinning of a wall and no defect. As for SCWA, the hypoplastic component can be focal or diffuse (Fig. 11.23).

Table 11.4 Proposed classification of canalicular wall dysgenesis (CWD)

Canalicular wall dysgenesis: proposed classification
A. Single canalicular wall dysgenesis (SCWD)
1. Single canalicular wall hypoplasia (SCWH)
(a) Focal
(b) Diffuse
2. Single canalicular wall aplasia (SCWA)
(a) Focal
(b) Diffuse
B. Multiple canalicular wall dysgenesis (MCWD)
1. Multiple canalicular wall hypoplasia (MCWH)
(a) Focal
(b) Diffuse
2. Multiple canalicular wall aplasia (MCWA)
(a) Focal
(b) Diffuse

When more than one wall of the canaliculus is affected, the term multiple canalicular wall dysgenesis (MCWD) is used and is further classified into aplastic and hypoplastic components (Table 11.4). The diagnosis of multiple canalicular

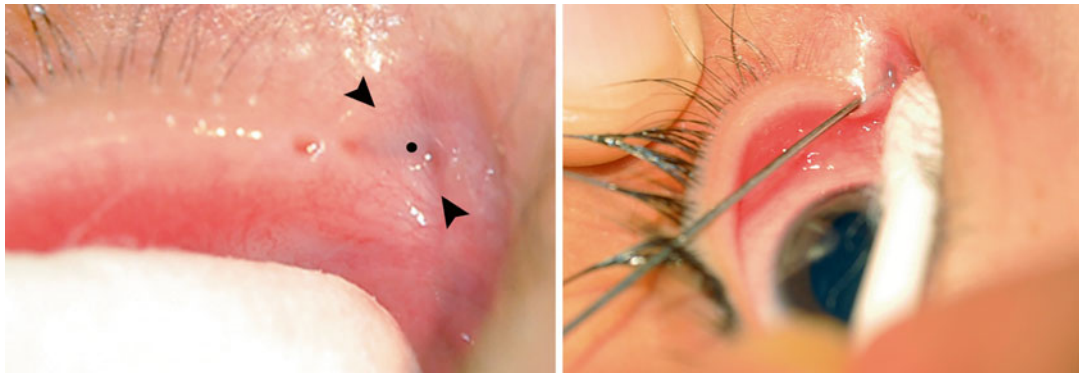

Fig. 11.24 Multiple canalicular wall aplasia (*left panel*), note the defective anterior and posterior walls (*arrowheads*) and floor (*dot*) and multiple canalicular wall hypoplasia (*right panel*)

wall aplasia (MCWA) and hypoplasia (MCWH) would follow similar principles with subtle differences. In cases of MCWA, apart from the obvious defect as noted in isolated walls, one would notice the whitish mucosal lining of the canaliculi only on the remaining one or two walls by slit lamp biomicroscopy with high magnification (Fig. 11.24, *left panel*). However, MCWH may pose diagnostic challenges, and the clinical feature that gives a clue to anterior or posterior wall involvement would be the increasing circumference of the probe that becomes noticeable in front or behind the roof and wall assessment by probe tilt test (Fig. 11.24, *right panel*). In this test, under biomicroscopic guidance, once the probe is gently advanced into the canaliculus in the area of dysgenesis, a gentle tilt is attempted toward the roof of the canaliculus. This tilt along with the presence of probe helps the examiner to assess the thinning and status of both the anterior and posterior walls (Fig. 11.24, *right panel*). However, the floor assessment is difficult with this test. Multiple canalicular wall dysgenesis can further be subclassified as focal or diffuse based on the extent of canalicular wall involvement.

In their study, Ali et al. [36] found that SCWD involving only the roof was the most common feature noted in 71.4 and 28.5 % patients who had three-wall involvements. Canalicular wall hypoplasia was most common and seen in 57.1 %, whereas canalicular wall aplasia was noted in 42.8 %. Associated lacrimal anomalies were seen in all patients and included supernumerary puncta, incomplete punctal canalization of the external membrane variety (IPC-EM), punctal stenosis, congenital nasolacrimal duct obstruction (CNLDO), and punctal agenesis. Systemic anomalies were noted in 28.5 % (2/7) of the patients and included right hemiparesis with left cerebral hypoplasia and delayed milestones.

Dysgenetic canaliculi may have long-term profound effect in terms of its clinical and psychosocial implications. All these patients present with epiphora, where complete cure is desired but is a challenging goal. Almost all patients have associated lacrimal system anomalies, which, if addressed effectively, will go a long way in helping improve the overall quality of life. Accordingly, ipsilateral punctal stenosis, punctal agenesis, CNLDO, and IPC-EM when addressed appropriately result in satisfied patients and parents. It is also prudent to keep few points in mind while irrigating or treating associated lacrimal anomalies in cases of canalicular wall dysgenesis especially hypoplasia. During irrigation or probing, be very gentle and mindful of the canaliculus anatomy and course. Any quick or aggressive misdirection may lead to rupture of the thinned walls and worsen the epiphora. This care is especially required when rotating the probe 90° for probing the nasolacrimal duct. On the other hand, in aplasia, there is a propensity to engage the edge of the residual wall during irrigation or probing, leading to an extended tear. The baseline is that CWD merits careful evaluation and even more careful interventions.

Lacrimal Fistula

Lacrimal fistula is an accessory or an anlage duct communicating with the skin on one side and the canaliculus, lacrimal sac, or nasolacrimal duct on the other [37–40]. The incidence of congenital lacrimal fistulas has been reported to be 1 in 2000, but this could be a referral bias [3]. These result from abnormal embryological development at the optic end of the naso-optic fissure, whereby there is additional out-budding from the embryonic lacrimal epithelial cord in an embryo of 18–24 mm (Fig. 11.2) [6, 37]. The external opening can be on the skin below the punctum, lid margin, or medial end of the lower lid crease. Almost all of these are external, but occasionally an internal fistula may be present between the lacrimal system and the nasal cavity and fortunately do not cause any obstructions.

The embryonic etiopathogenesis is unclear even after three centuries following its first description by Rasor in 1675 [41]. Jones and Wobig [42] proposed that lacrimal fistulas develop secondary to failure of lacrimal anlage to involute and its subsequent canalization. Others have implicated amniotic bands or inflammation as the causes, but these theories have not gained wider acceptance. Harman [43] proposed that lacrimal fistulas represent rudimentary lacrimal sinus. Welham and Bergin [38] proposed the more accepted theory of fistula being an extra canaliculus based on their histopathological analysis. Another interesting dimension to this is the reports of lacrimal fistula presenting in an autosomal dominant inheritance pattern in up to four generations, its presence in twins and in first cousins, and its association with fistulas elsewhere in the body [38, 40, 42].

Lacrimal fistulas can be congenital or acquired following trauma or surgical interventions. There might be associated epiphora or discharge from the fistula (Fig. 11.25). Occasionally the surrounding skin may get excoriated. Congenital fistula is usually small with a well-defined opening, classically present 1–2 mm inferomedial to medial canthus (Fig. 11.26). In contrast, the acquired fistulas may be irregular, large with surrounding scarring, and without any probable location (Fig. 11.27). A lacrimal probe can be passed through the fistula to assess its depth and possible internal communicating structure (Fig. 11.27). Few decades earlier, a radiological test called the three-point test was popular to differentiate congenital and acquired varieties,

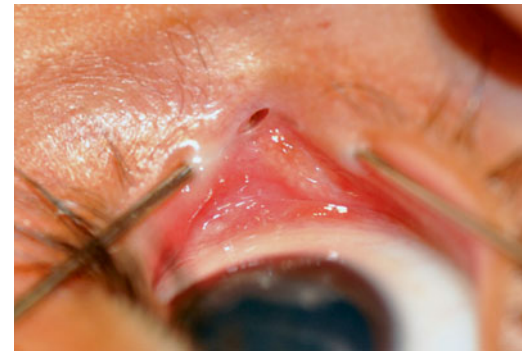

Fig. 11.25 Congenital lacrimal fistula with epiphora

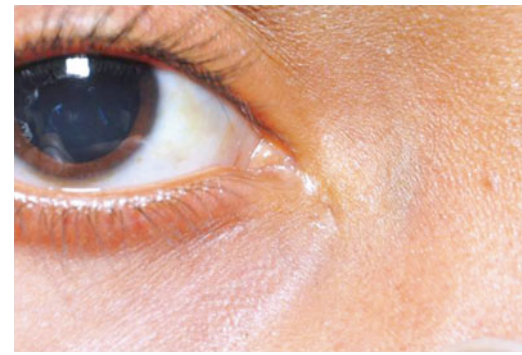

Fig. 11.26 Congenital lacrimal fistula

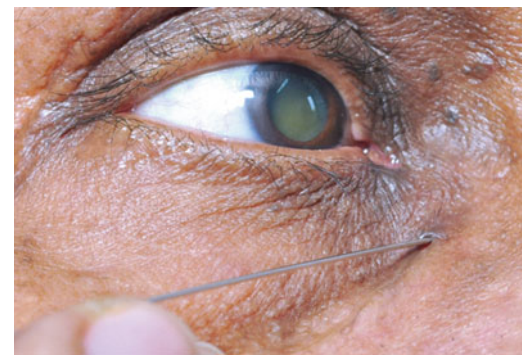

Fig. 11.27 An acquired lacrimal fistula

whereby three lacrimal probes are passed (one from upper and lower punctum each and one from the fistula) and assessed. All the three probes would meet in a congenital but not in acquired fistulas. However, the procedure is cumbersome with unspecified benefits.

In a large clinicopathologic study of 22 surgical patients with lacrimal fistula, Welham and Bergin found [38] that 15 of the 22 originated from the common canaliculus and 4 from the lacrimal sac giving an impetus to the theory of lacrimal fistula being an extra canaliculus.

The management of lacrimal fistulas is case dependent. All patients should undergo lacrimal system irrigation to assess the patency of the lacrimal system. In cases of associated congenital nasolacrimal duct obstruction, the patient should undergo a probing along with a simple excision of the fistulous tract (fistulectomy). We recommend the closed excision technique of fistulectomy as described by Sullivan et al. [40] and found it to be very useful in preventing recurrences. In this technique, a Bowman's probe is placed in the fistula to assess its extent. With the probe in place, an elliptical incision is taken in the skin around the fistula. The fistulous tract is then traced to its origin by gentle dissection. An 8-0 Vicryl is placed and tightened in a purse-string manner at the base of the fistula followed by excision of the tract. The skin is closed vertically with 6-0 Vicryl sutures.

In patients with failed probing or in adults, fistulectomy can be performed along with a dacryocystorhinostomy with or without intubation (based on canalicular manipulation) for associated nasolacrimal duct obstructions. In light of the published literature, we do not advocate repeated probings or cautery of the fistula, since this may potentially damage the normal underlying canaliculus.

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Congenital Nasolacrimal Duct Obstruction

12

Saurabh Kamal, Mohammad Javed Ali, Vinod Gauba, and Qasim Qasem

Introduction

Congenital nasolacrimal duct obstruction (CNLDO) is a common cause of epiphora in children with incidence of symptoms ranging from 1.2 to 30 % [1, 2]. However the incidence of anatomic nasolacrimal duct obstruction seen in stillborn is much higher at around 73 %. It is believed that respiratory efforts, crying, and sucking create negative pressure within the nose which helps to break the membrane present at the nasolacrimal duct (NLD) opening. This spontaneous perforation usually occurs by 3–4 weeks of age, but if it fails, manifestations of CNLDO are seen [3]. Management of CNLDO is principally guided by natural history of the disease and high spontaneous remission rate by 1 year of age [2]. The standard of care now for non-resolving cases is endoscopic-assisted probing with or without intubation. There is an increasing role of dacryoendoscopy and simultaneous correction of associated intranasal abnormalities [4, 5].

S. Kamal, MD
Ophthalmic Plastics Surgery,
L.V. Prasad Eye Institute, Hyderabad, India

M. Javed Ali, MS, FRCS, FRCGP (✉)
Dacryology Service, L.V. Prasad Eye Institute,
Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

V. Gauba, FRCS
Ophthalmic Plastics Surgery,
Imperial Healthcare Institute, Dubai, UAE

Q. Qasem, MD
Pediatric Ophthalmology,
Imperial Healthcare Institute, Dubai, UAE

Embryology

There are 23 Carnegie stages which covers the 8-week postovulatory stage of the human embryo [6]. Each stage characterizes the morphological development of the embryo. Development of the lacrimal excretory system begins at Carnegie stage 16 when the lacrimal groove is formed between the maxillary and external nasal processes which thicken to form the lacrimal lamina. At Carnegie stage 18, the lacrimal lamina bifurcates at extreme medial end to form the primordium of the lacrimal canaliculi (Fig. 12.1) [6]. At Carnegie stage 19, the lacrimal lamina separates from the surface ectoderm to form the lacrimal cord, the medial end of which bifurcates to form two canaliculi. At Carnegie stage 23, the medial end of the lacrimal cord differentiates into canaliculi, and the other end continues caudally and laterally to the inferior meatal lamina (thickened epithelium of inferior and lateral part of the nasal cavity). At 10 weeks of fetal stage, three significant changes occur: first is the appearance of a lumen in the lacrimal system; second, the epithelium of the canaliculi makes contact with the epithelium of the conjunctiva and forms a continuous lamina; and, third, cavitations start near the caudal end of the lacrimal cord and inferior meatal

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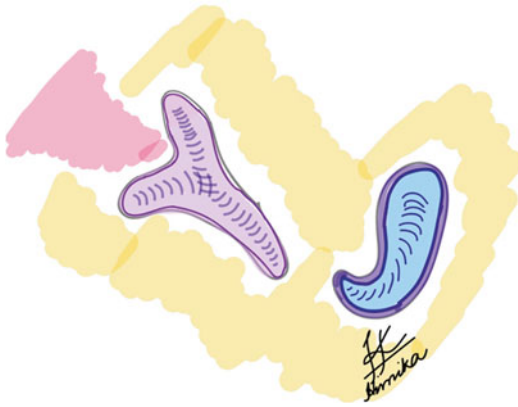

Fig. 12.1 Schematic diagram showing the outbudding of solid canaliculi from the lacrimal cord (Photo Courtesy: Dr. Himika Gupta)

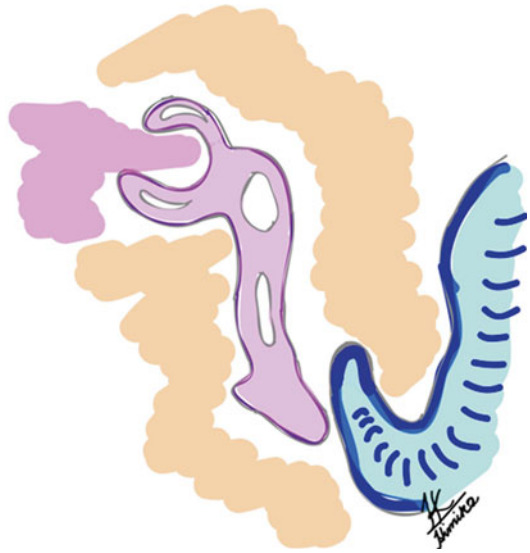

Fig. 12.2 Schematic diagram showing the process of canalization (Photo Courtesy: Dr. Himika Gupta)

lamina (Fig. 12.2). At the 7th month, the puncta opens when the two eyelids start to separate. At the caudal end where the lacrimal cord and inferior meatal lamina are present, apoptosis of cells to form a luminal passage occurs but varies from 6 months intrauterine to several weeks or months after birth [7].

Therefore development of the lacrimal sac and nasolacrimal duct occurs earlier than the canaliculi, but the caudal end of the nasolacrimal duct is the last to canalize [7]. This explains why

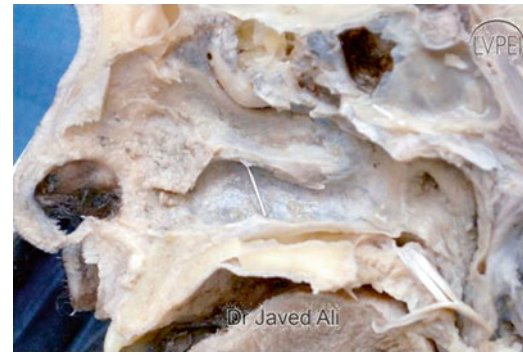

Fig. 12.3 Cadaver midsagittal head section showing the lateral wall and the probe entry into the inferior meatus

pathology in CNLDO is mostly present at the distal end, where the NLD normally opens into the inferior meatus (Fig. 12.3).

CNLDO: Types and Variations

A number of variations of CNLDO were described way back in 1976 by Jones and Wobig [8]. These variations are seen in the lower end of the NLD, and the most common one described is the duct that fails to open through the nasal mucosa and stops at the vault of the anterior end of the inferior nasal meatus (Fig. 12.4a–f). The other variations include the NLD extending lateral to the nasal mucosa, extending up to the floor, complete absence of the duct or the impacted anterior end of the inferior turbinate, etc. (Fig. 12.4a–f).

Kushner first described the types of CNLDO into simple and complex based on intraoperative findings during probing [9]. In cases of simple obstruction, there is lack of resistance in passing the probe through the NLD until a point of membranous obstruction can be perforated. Simple obstruction also includes cases of canalicular valves, where resistance is encountered while bypassing them although there may not be true obstruction. Complicated obstruction can be those associated with any of the variations described earlier like a buried probe, a bony obstruction, nondevelopment of nasolacrimal duct, NLD opening into the inferior turbinate, and anlages.

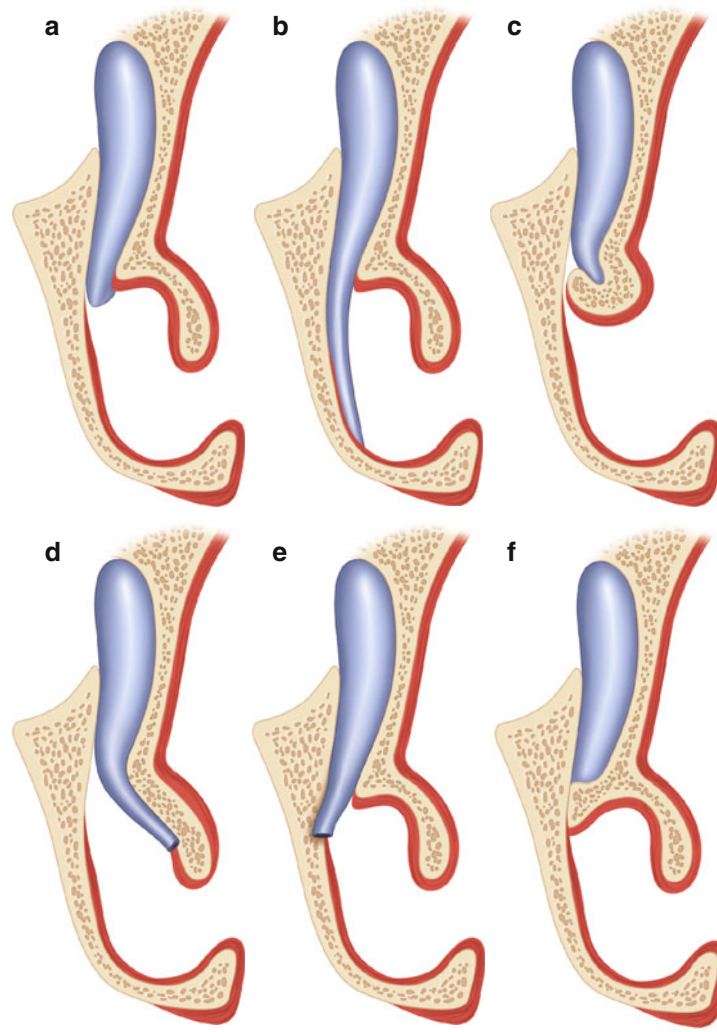

Fig. 12.4 Schematic diagram showing various CNLDO variations: nasolacrimal duct (NLD) entering at vault of the inferior meatus (**a**). NLD extending up to the floor lying lateral to the nasal mucosa or a buried probe (**b**). NLD obstruction caused by impacted anterior end of the inferior turbinate (**c**). NLD ending in the anterior end of the inferior turbinate (**d**). NLD ending blindly into the maxillary wall (**e**). Complete absence of NLD (**f**) (*blue* lacrimal sac and NLD, *yellow* lateral wall of nose, *orange* inferior turbinate)

Clinical Features

The characteristic triad includes watering, discharge, and matting of eyelashes. In 95 % of cases, the onset of epiphora is within the first month of age [2]. The condition can be unilateral or bilateral. Symptoms may worsen with occurrence of upper respiratory tract infection. Other signs include increased tear meniscus height, positive fluorescein dye disappearance test (FDDT), and regurgitation on pressure over the lacrimal sac (ROPLAS). A spectrum of presentation can rarely include acute dacryocystitis, dacryocele, mucopyocele, and preseptal and orbital cellulitis (Fig. 12.5a–f).

Dacryocystoceles or simply dacryoceles are bluish cystic lacrimal sac swelling typically present below the medial canthal tendon, filled with secretions from epithelial lining and tears (Figs. 12.5b and 12.6). It is an uncommon manifestation of CNLDO occurring in 1 in 3,900 live births [8]. Nasolacrimal duct obstruction when combined with either functional obstruction of the proximal lacrimal system or common canaliculus leads to accumulation of secretions in the lacrimal sac. This leads to distortion of the

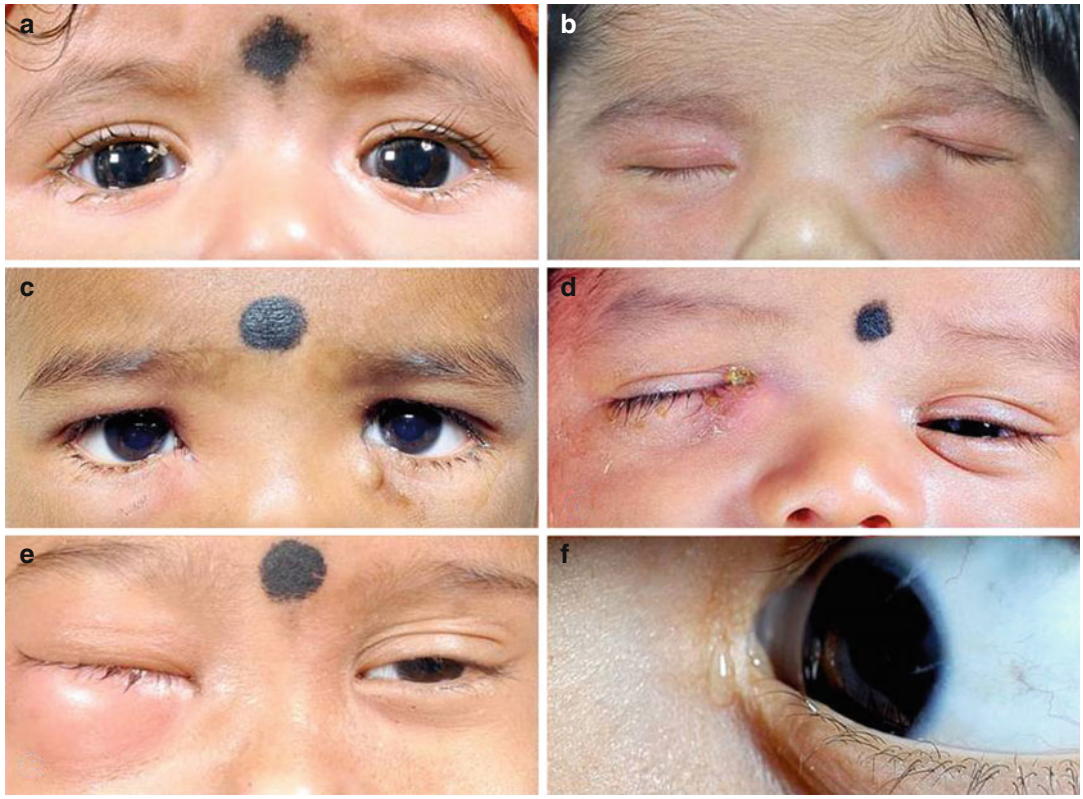

Fig. 12.5 Clinical spectrum of CNLDO: typical manifestation with increased tear meniscus, discharge, and matting of eyelashes (**a**). Left dacryocele (**b**). Bilateral CNLDO presenting with right-sided acute dacryocystitis and left-sided mucocele (**c**). Superadded infection of right-sided dacryocele (**d**). Infected dacryocele complicating into orbital cellulitis (**e**). Congenital lacrimal fistula at typical location near the medial canthus (**f**)

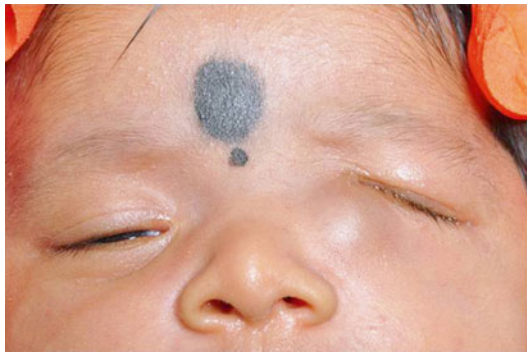

Fig. 12.6 Left congenital dacryocele

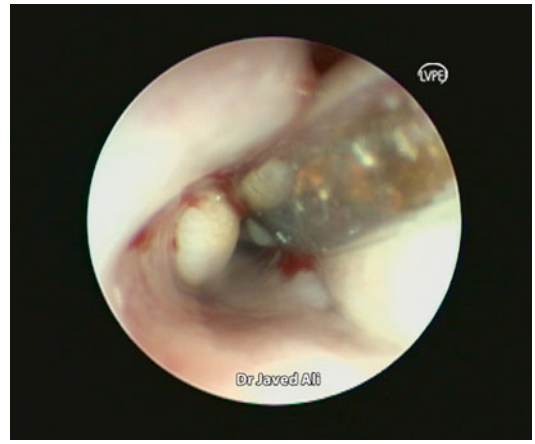

Fig. 12.7 Endoscopic view of an intranasal cyst

common canaliculus and creates a ball-valve mechanism at the valve of Rosenmuller which allows ingress of tears into the sac but interferes with egress [10]. Dacryocystocele can be bilateral in 25 % of cases and can complicate into superadded infection and respiratory distress [5, 11]. Associated intranasal cyst (Fig. 12.7) can be small or large (if >50 of the nasal cavity) and,

if large, can cause respiratory insufficiency because infants are nasal breathers, which can be life-threatening in cases of bilateral pathology [11]. Infection can lead to preseptal cellulitis, orbital cellulitis, and sepsis, therefore indicating early management of this condition. In the absence of intranasal cysts, dacryocele can be managed conservatively, and success rate achieved with sac compression alone was 76 % in one of the series [12]. In non-resolving cases and associated intranasal cyst, it is preferable to marsupialize the intranasal cyst early. Ali et al. [13] defined and classified the intranasal cysts as small and large and described a new technique of cruciate marsupialization for large intranasal cysts with good results on long-term follow-up.

Lacrimal fistula (anlage duct) is seen in 1 in 2,000 births [14]. It can cause epiphora (seen from the fistulous opening), discharge, dermatitis, and ascending infection causing acute or chronic dacryocystitis (Figs. 12.5f and 12.8). There are many theories postulating its formation; the most accepted one is that lacrimal fistula is an aberrant canaliculus which often originates from a common canaliculus or canaliculus and lined by a nonkeratinized stratified squamous epithelium resembling a canaliculus [14, 15]. Other associated lacrimal anomalies include CNLDO, absent canaliculus, supernumerary/absent punctum, and total agenesis of the lacrimal system [16]. A careful fistulectomy is performed when the lacrimal system is patent, but in cases of CNLDO, the authors prefer probing first and to wait for 6 months for a spontaneous closure of the fistula secondary to no flow. However if fistula persists, a fistulectomy can be performed.

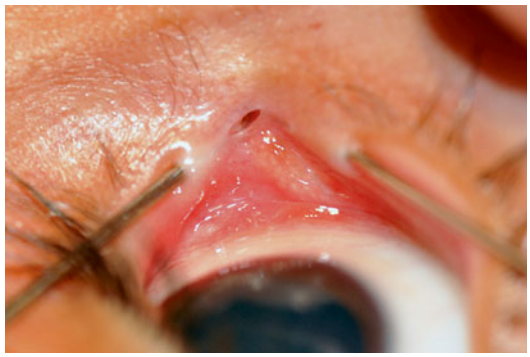

Fig. 12.8 Lacrimal fistula

Syndromes and Craniofacial Abnormalities Associated with CNLDO

Syndromic associations include Down's syndrome (trisomy 21), Crouzon syndrome, Treacher Collins syndrome, Klinefelter syndrome, and Rubinstein-Taybi syndrome [14]. Associated craniofacial abnormalities include: cleft lip/palate, facial cleft, hypertelorism, bifid uvula, hemifacial microsomia, preauricular skin appendages, deformed external ears, and laryngeal stenosis (Fig. 12.9) [16].

Natural History

A thorough knowledge and understanding of the natural history of CNLDO is a must for making a decision regarding the management as well as explaining the prognosis to the parents. In the landmark study by MacEwen and Young published in 1991, a large cohort of 1,019 eyes of infants were observed to determine the incidence and natural history of epiphora during the first year of life [2]. In 95 % of cases, the onset of epiphora was within the first month of age and thereafter 3 % in the second month and less than 1 % in the third and fourth months of age. Spontaneous resolution was observed throughout the year from the first month, and by 1 year of age, overall spontaneous resolution rate was 96 %. The authors also provided the probability of spontaneous resolution, i.e., the percentage of infants at each month, who on follow-up, resolved before age 12 months. Table 12.1 reflects the rounded up figures, making it easy to remember. This study provided the evidence that the probing should ideally be delayed until 1 year of age but did not provided the optimum age at which probing should be considered.

In subsequent study by the same researchers on CNLDO during the second year of life, it was noted that at 15 months of age, probing is superior to "no treatment" with statistical difference, but at the age of 24 months, there was no statistical

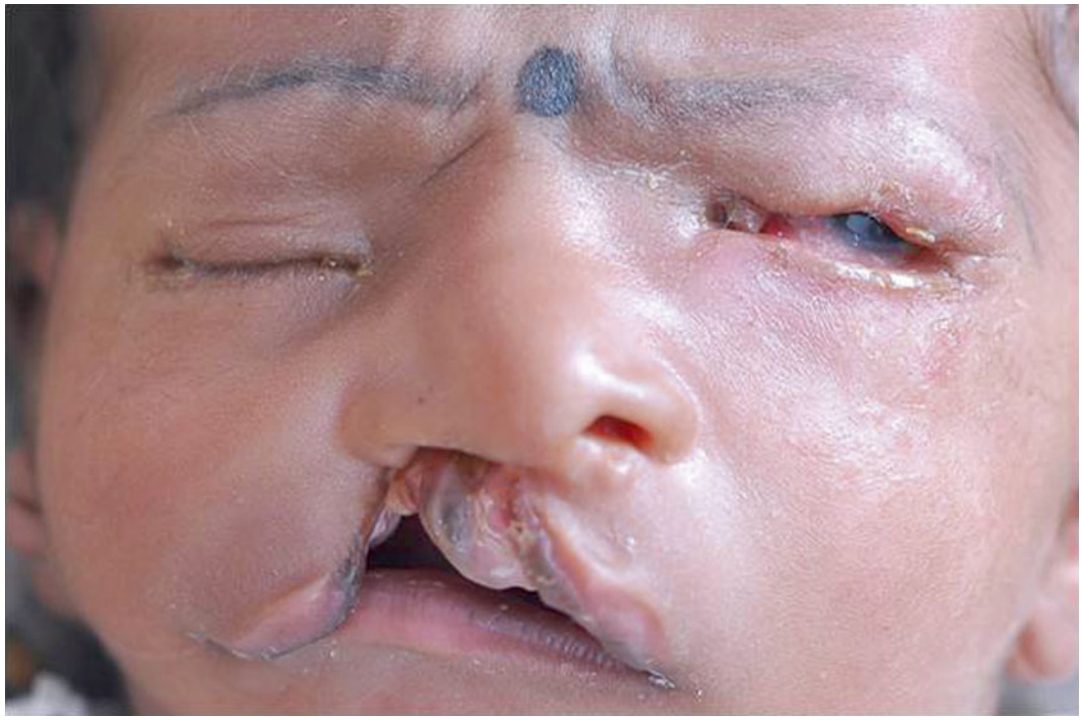

Fig. 12.9 Syndromic association with CNLDO

Table 12.1 Predicting the probability of spontaneous resolution of CNLDO by 1 year of age at various months of presentation [2] (Numbers rounded for easy memory!)

Age (month)	Spontaneous resolution probability (%)
1	95
2	95
3	90
4	85
5	80
6	75
7	65
8	50
9	35
10	25
11	5
12	0

difference between the two groups (74 % resolution in the probing group versus 60 % in the observation group) [17]. Spontaneous resolution remains a common occurrence during the second year of life with about 50 % rate (among the residuals) between 13 and 18 months and 23 % between 19 and 24 months of age. Appropriate time of probing recommended was 18 months of age if there are no signs of resolution.

Paediatric Eye Disease Investigator Group (PEDIG) studied the resolution of CNLDO with 6-month observation for infants presenting between 6 and <10 months old [18]. In this age group, more than half of the eyes (~66 %) resolved.

Treatment

The most common outcome of CNLDO is the spontaneous resolution without the surgical intervention. Topical antibiotics are needed when there is purulent discharge and conjunctivitis or associated acute dacryocystitis. However, some surgeons prefer antibiotics more so for their additional anti-inflammatory actions as well. Various treatment options in CNLDO are conservative with compression over the lacrimal sac area, probing, intubation, balloon catheter dilation,

endoscopic-assisted correction of associated nasal abnormalities, and, as a last resort for recalcitrant cases, an endoscopic or external dacryocystorhinostomy (DCR).

Conservative with Compression Over the Lacrimal Sac Area

Hydrostatic pressure over the lacrimal sac area was described by Criggler in 1923. The aim was to increase the intraluminal pressure and direct it downward (by compressing the common canaliculus) to rupture the membrane (Hasner valve) at the lower end of the NLD (Fig. 12.10a, b). The success rate observed in various studies ranged from 30 to 93 % [16] being the maximum when done early in life and as compared to older age group. Other factors for success include a correct technique of sac compression and compliance. It appears that sac compression essentially causes earlier resolution of CNLDO symptoms when compared to natural history. In clinics, the correct method of sac compression should be demonstrated to the parents or caregivers and encouraged to perform the technique under clinician supervision. Depending upon the treating physician, sac compression can be continued till age of 9–12 months, and if symptoms persist, probing is advised.

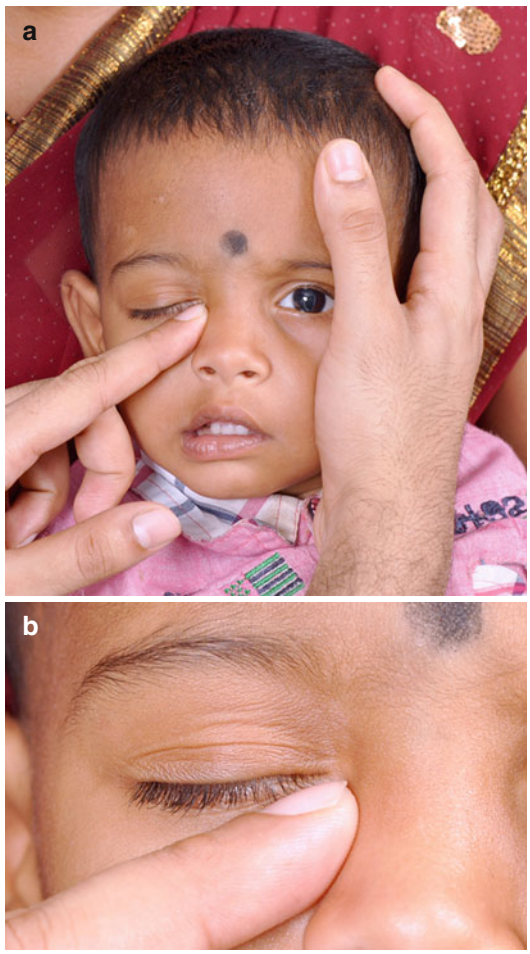

Fig. 12.10 (**a**) Technique of Crigler's lacrimal sac compression. (**b**) Closer view of the exact technique

Method of Sac Compression

Parents should be instructed to wash hands and use the index finger for sac compression. Pressure should be directly applied over the lacrimal sac area, just on the inside of the anterior lacrimal crest, below the medial canthal tendon and without compressing the bone or eye. Usual frequency advised is ten times/session with 4 sessions per day (Fig. 12.10a, b).

Probing: Early Office-Based Versus Late Probing Under General Anesthesia

Probing is indicated if symptoms and signs of CNLDO persist despite lacrimal sac compression. Age at which probing is indicated is debated in literature but is usually after 6 months of age [19]. Early probing usually done between 6 and 9 months of age is an office procedure practiced by some which avoids general anesthesia and is done under topical anesthesia and restraint. Late probing after 9–12 months of age is done under general anesthesia and is technically easier. Adopting early office probing would result in probing approximately two-thirds of infants in whom obstruction would spontaneously resolve on follow-up of 6 months [20]. Early probing for 6 to <10 months of age group has a success rate of 92 % compared to 82 % with late probing when done after 6 months of observation [20].

PEDIG concluded that although CNLDO resolves spontaneously in two-thirds of cases presenting between 6 and <10 months of age group, early office-based probing is effective and cost-saving when compared to late probing with an added advantage of 3 months of fewer symptoms. But the treatment decision rests entirely upon the parents and physician weighing the risk/benefit ratio. The authors of this chapter prefer to avoid office-based probing because it causes undue stress on infants and parents. A more controlled irrigation and probing under general anesthesia also allows a more detailed evaluation of the lacrimal system as well as diagnosing and treating suspected nasal pathology with an aid of an endoscope.

Method of Probing

Probing is a technique of passing a predetermined diameter-rigid probe into the lacrimal system with an aim of overcoming the obstruction at the lower end of the nasolacrimal duct. The instrumentation is simple (Fig. 12.11). It is preferred to pass the probe through the upper punctum because it is more in continuation with the lacrimal sac and gives an easier entry and a less traumatic 90° turn. The nasal mucosa is decongested with 0.025 % oxymetazoline. The upper punctum is first gently dilated with a Nettleship punctum dilator (Fig. 12.12). Although the choice of probe depends on the surgeon, a general guideline is useful (Table 12.2). It is also important to know what kind of probe is being

Fig. 12.11 Instrumentation for a probing

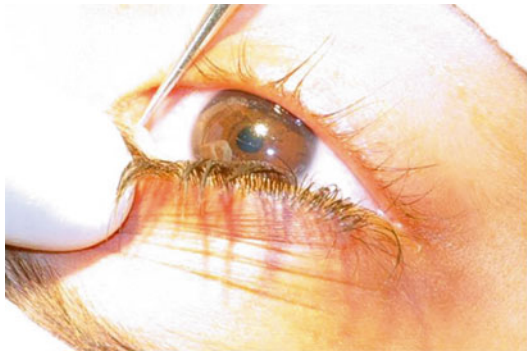

Fig. 12.12 Punctal dilatation

Table 12.2 Broad guidelines used by author for choosing the size of probe

Age	Bowman's probe size
Neonate	# 00
Infants	# 0
1–4 years	# 1
4 years	# 1 or # 2

Table 12.3 Comparison of Bowman's and Clarke's probes with respect to size number and diameter

Bowman's size	Bowman's diameter (mm)	Clarke's size	Clarke's diameter (mm)
# 0000	0.7	# 00	0.6
# 000	0.8	# 0	0.7
# 00	0.9	# 1	0.8
# 0	1	# 2	0.9
# 1	1.1	# 3	1.0
# 2	1.2	# 4	1.1

used, Bowman's or Clarke's or any other, since they may vary in diameter although the number may be the same (Table 12.3). A smear of lubrication onto the probe in a form of ointment or jelly can be less traumatic (Fig. 12.13). Probe of appropriate size is then passed gently, first directed along the vertical canaliculus and then bending it gently at the ampulla, without any force and then along the horizontal canaliculus with simultaneous outward stretching of the

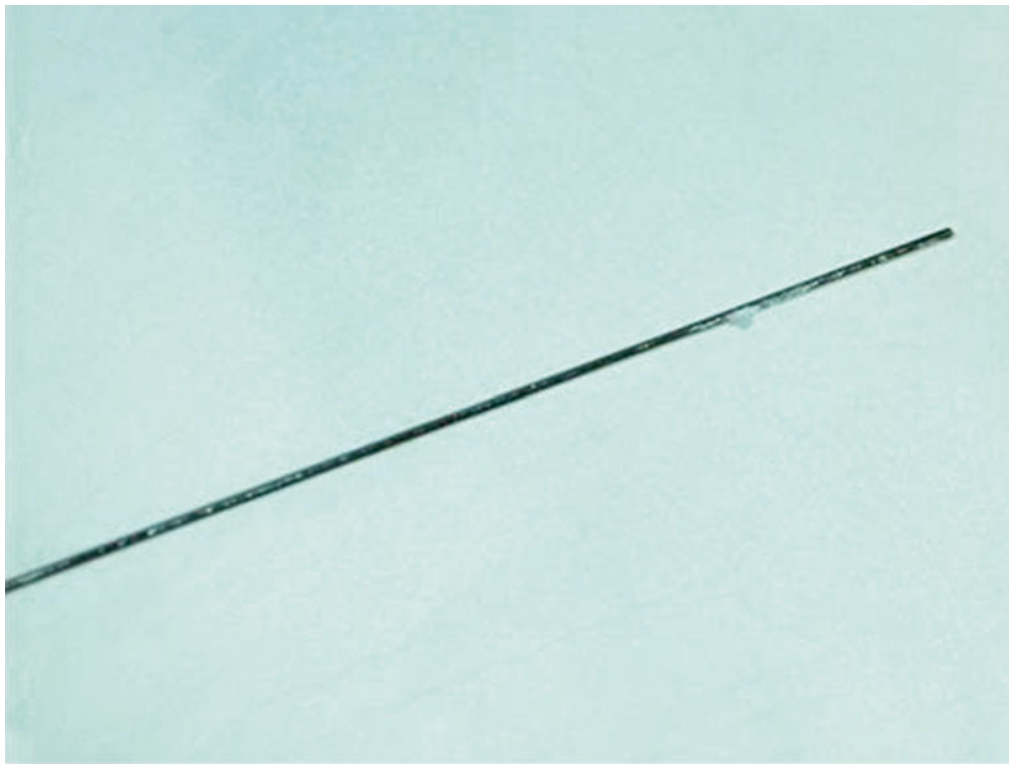

Fig. 12.13 Probe smeared with ointment for lubrication

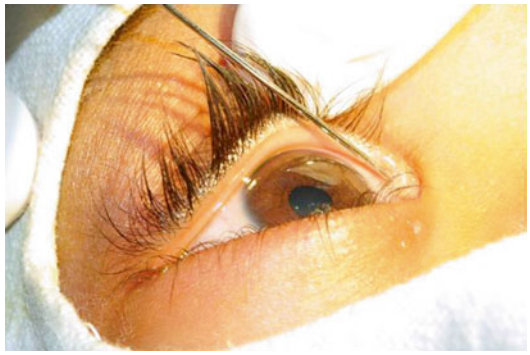

Fig. 12.14 Probe in upper canaliculus on an outstretched eyelid

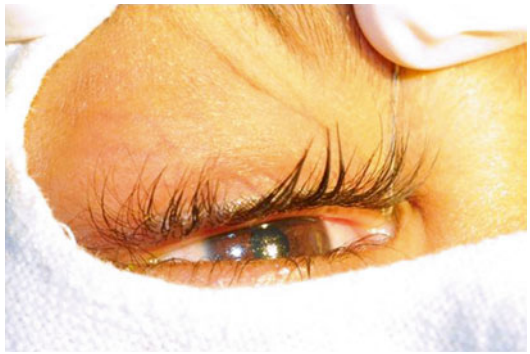

Fig. 12.15 Probe vertically oriented and flat on the trochlea

upper lid (Fig. 12.14). Once the probe enters the sac and touches its medial wall, a hard stop is felt. The probe is then withdrawn by 1 mm and then gently turned 90° to lie flat on the forehead in line with the trochlea (Fig. 12.15). The probe is then gently advanced into the lacrimal sac and nasolacrimal duct. It is important to know that the NLD is most course downward, backward, and laterally. No undue movements or force should be applied to avoid any false passage. Membranous obstruction at the lower end of the nasolacrimal duct can be overcome with a give way of resistance without application of much force. Probe should be pushed just for a few millimeters further so as to avoid injury to the floor of the nose and subsequently the palate. Presence of probe at the NLD opening can be confirmed by a metal to metal touch by placing a spatula in

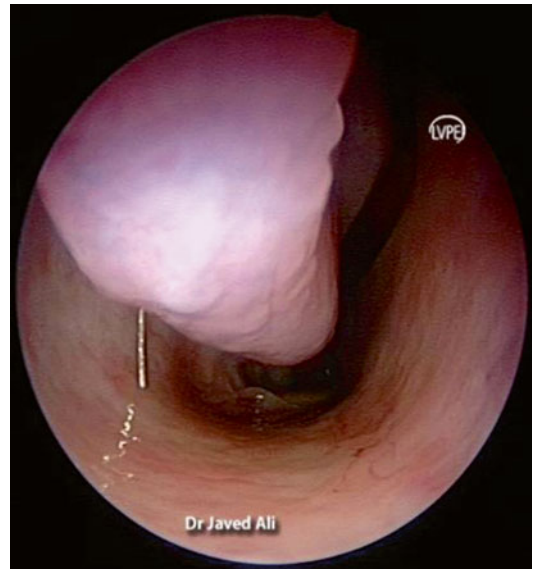

Fig. 12.16 Endoscopic view of the probe in the inferior meatus

the inferior meatus at the NLD opening. Patency can be confirmed with irrigation using fluorescein-stained saline. However the authors routinely perform an endoscopic-guided probing in all their patients (Fig. 12.16).

Probing in Older Age Group

Probing can also be used as a primary treatment for children <36 months of age, where success rate of 78–93 % can be achieved [21, 22]. For older children, success rate is even less [22, 23]. Studies on older children between 25 and 60 months have shown failure rates as high as 28 %. The prevalence of complex obstruction in children between 49 and 60 months was 43 % with a success rate of only 33 % on probing.

Factors Affecting the Success of Probing

Various studies have studied the factors affecting the outcome of probing. Those associated with higher failure rate include: age >36 months, bilateral affection, failed conservative treatment, failed earlier probing, dilated lacrimal sac, intraoperative firm obstruction, inability to pass 0000 probe, proximal obstructions, and physiologic causes [4, 20, 22].

Balloon Catheter Dilation (BCD)

BCD is usually indicated for cases with previous failed probing, but some surgeons use it as a primary modality. When used as primary treatment, success rate achieved for age 12–24 months was 82 % and for age 24–48 months was 75 % [24]. Other indications include: previous failed probing, failed intubation, complex CNLDO, CNLDO with syndromic association, and older age group [25].

Method of BCD

The usual balloon size used is 2 mm for children <30 months of age and 3 mm for >30 months of age [25]. The nasal mucosa is decongested. The upper punctum is dilated, and probing is done to confirm the type of block. Obstruction is overcome and probe is confirmed in the inferior meatus. The desired-size balloon is lubricated with viscoelastic and passed in the lacrimal system. There are two markings on the balloon: 10 and 15 mm. Balloon catheter is passed till 15 mm mark reaches the punctum. Two cycles of balloon inflation and deflation are performed: first cycle of 8 atm pressure for 90 s and second cycle of 8 atm pressure for 60 s (Fig. 12.17). Probe is then withdrawn till the 10 mm mark and similar two cycles are repeated. Patency is confirmed with fluorescein-stained saline. (Detailed technique and outcomes can be read in Chap. 31 on balloon dacryoplasty.)

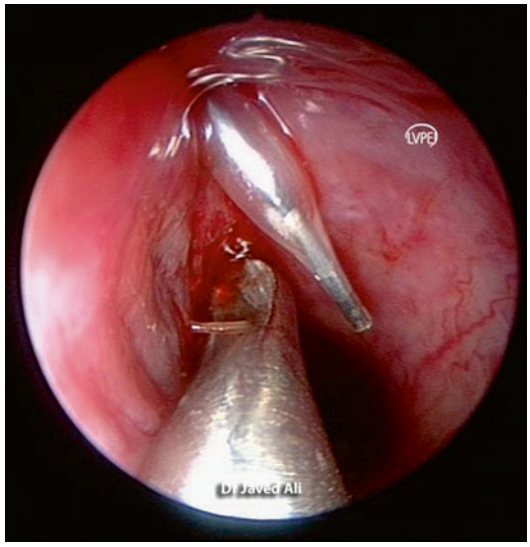

Fig. 12.17 Endoscopic view of balloon dilatation of NLD

Silicone Intubation (SI)

SI is indicated for cases with previous failed probing and complex CNLDO and can also be used as primary treatment modality. When used as primary treatment, the success rate reported for age <12 months is 95 %, for 12–24 months is 92 %, and for 24–45 months is 84 % [26]. Results with monocanalicular intubation (with Mini-Monoka) and bicanalicular SI are comparable. Advantage of monocanalicular stent is the easy removal under topical anesthesia in clinic without the need of sedation or general anesthesia. Common monocanalicular stents used are either Mini-Monoka or Monoka-Crawford and that for bicanalicular is Crawford silicone stent (Figs. 12.18, 12.19 and 12.20).

Timing of SI removal in CNLDO is controversial. While the PEDIG study aimed to retain the SI for a period of 2–5 months, other studies have noted higher success rates with early (6 weeks) as well as late (≥6 months) removal of stent [26].

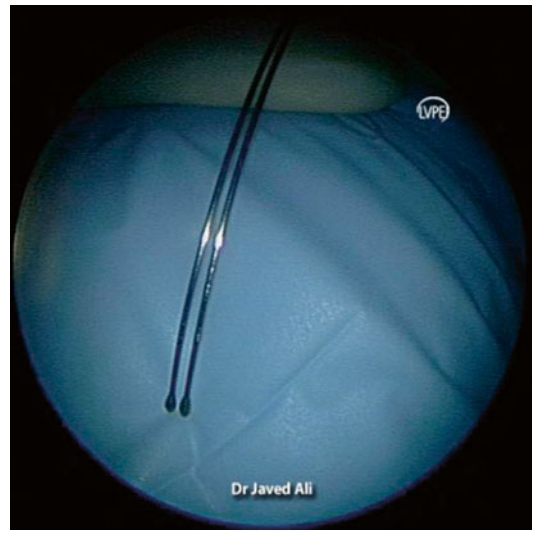

Fig. 12.18 Crawford bicanalicular intubation

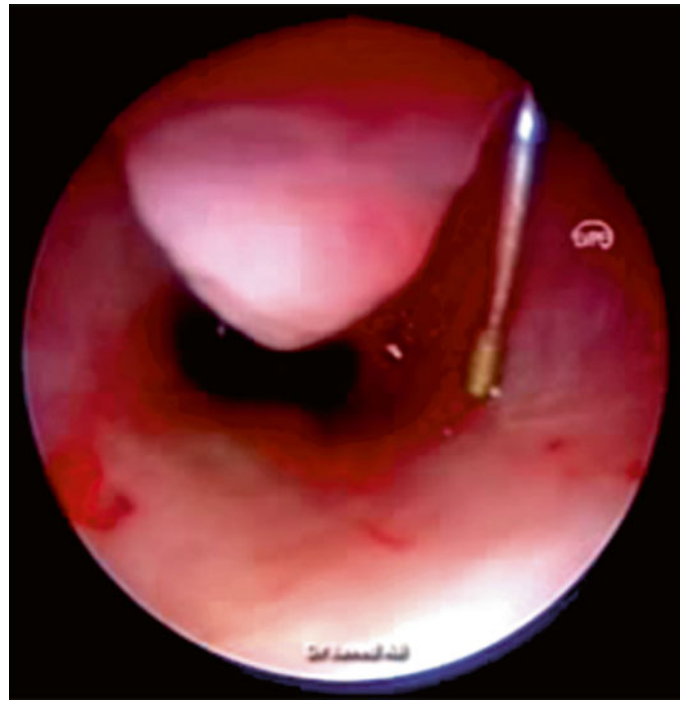

Fig. 12.19 Crawford bodkin in the inferior meatus before retrieval

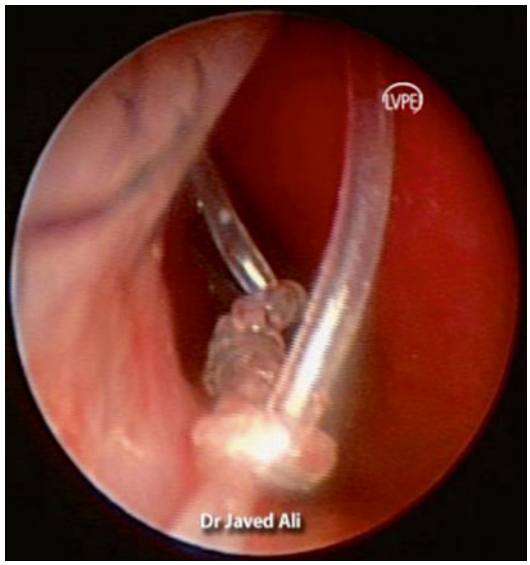

Fig. 12.20 Silicone tube secured in the inferior meatus

Complications are rare but can occur and include epistaxis, inferior turbinate and floor injury, punctal cheesewiring, corneal abrasion, migration of tube, and pyogenic granuloma.

Persistent CNLDO (Failed Probing)

Persistent CNLDO is defined as recurrence of symptoms of CNLDO after primary probing, usually occurring within 6 weeks. Apart from the various factors associated with increased failure (as stated above), complex CNLDO comprises the bulk of this category. Frequency of complex CNLDO cases increases with increasing age with 2.2–3.6 % incidence in <24 months of age but 20–57 % incidence in age group 24–60 months [27].

All cases of persistent CNLDO should have a careful nasal examination to rule out nasal causes. Other causes of persistent symptoms include punctal stenosis, canalicular obstruction, upper nasolacrimal duct obstruction, and physiological obstruction [4]. Their recognition is important during repeat procedure and should be appropriately addressed.

Options for treatment include repeat probing with intubation, balloon catheter dilation, or intubation alone. PEDIG invested these treatment modalities and noted a success rate of 56 % for repeat probing, 77 % for BCD, and 84 % for intubation [28, 29]. But these studies excluded

the patients of Down's syndrome and other syndromic associations, where the success can be still lower.

Nasal Endoscopy

Recently there has been increasing use of endoscopic-assisted probing for CNLDO. Endoscopy allows direct visualization of the probe and inferior nasolacrimal duct opening, helps avoid and detect false passage if any (Fig. 12.21), allows direct visualization of fluorescein during fluorescein endoscopic dye test (FEDT), and aids in diagnosing NLD variations, performing inferior turbinate medialization, and most importantly recognizing and treating intranasal abnormalities. Endoscopy is especially useful for cases with complex and persistent CNLDO. Intranasal abnormalities include nasal cyst in cases of dacryocele (Fig. 12.7) and distal NLD cyst in cases of long-standing mucocele and buried probe (Fig. 12.22) [5].

Inferior Turbinate (IT) Medialization

We prefer the term medialization to infracture, since we do not advocate it. Medialization is for a better view in a more lateralized IT. Historical teaching to perform it in cases where it is impacted around the opening of NLD does not appear to hold more ground today, since IT impactions are rare and lateralized ITs are more often labeled as impacted. Endoscopic guidance gives a better control, allows direct visualization of the inferior meatus, and helps avoid damage to the intrameatal portion of the NLD (Fig. 12.23) [12].

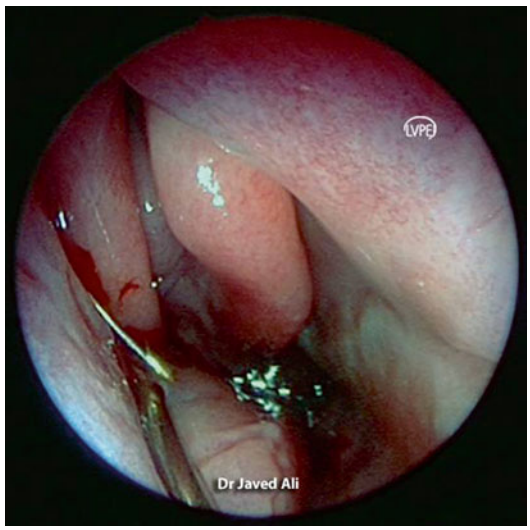

Fig. 12.21 Endoscopic view of a false passage

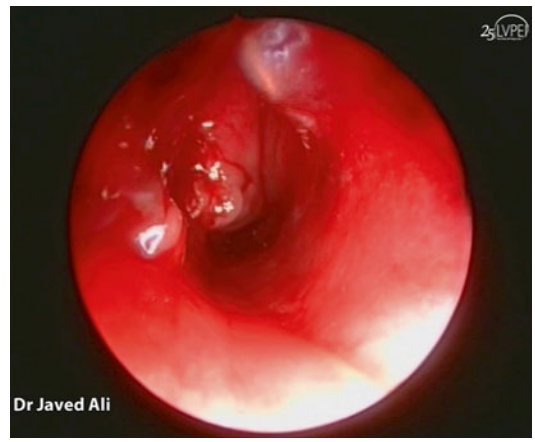

Fig. 12.22 Buried probe

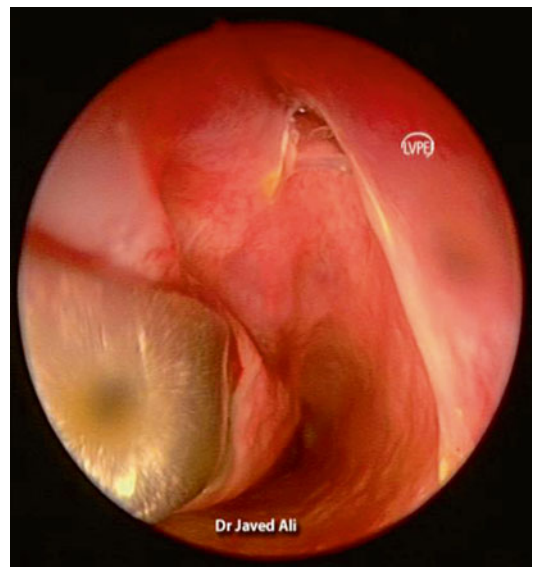

Fig. 12.23 Inferior turbinate medialization

Dacryoendoscopy

Dacryoendoscopy is a procedure utilizing micro-endoscopic techniques to visualize the entire lacrimal system from the puncta to the inferior meatus [30, 31]. It is gaining firm ground and increasing popularity for expanding indications in lacrimal disorders, thus having many diagnostic and therapeutic implications. It is a very useful tool to assess the NLD in children with persistent CNLDO. Accurate assessment on the type of inflammation, locations of fibrotic tissues (Fig. 12.24), and recanalization of the NLD can be performed. Although it appears to be a very promising modality of the management for complex CNLDO, skepticism at this stage is justified in the absence of long-term results. For details of this technique and indications, please refer to the Chap. 9 on dacryoendoscopy and Chap. 32 on NLD recanalization.

Dacryocystorhinostomy (DCR)

DCR is indicated in persistent CNLDO cases which fail to resolve with repeated probing/BCD/intubation and endoscopic evaluation and treatment of nasal abnormality. Both external and endoscopic approaches are feasible and have good success rates. Endoscopic DCR may be difficult for the beginners because of the variable anatomy and narrow confines, but success rate can be comparable to external approach [32].

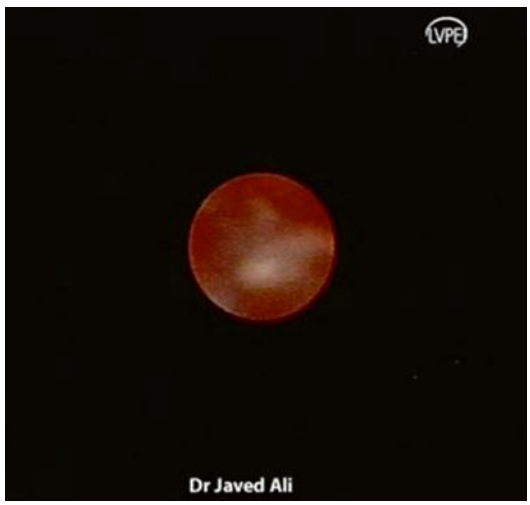

Fig. 12.24 Dacryoendoscopic photo showing focal thick fibrotic tissue in NLD

Conclusion

Congenital nasolacrimal duct obstruction is a common cause of epiphora in children. Most of the cases either resolve spontaneously or can be managed conservatively with lacrimal sac compression. Persistent, complex CNLDO and older age children will usually require balloon catheter dilation or intubation and endoscopy to rule out intranasal abnormalities. Cases of dacryocele should be managed early with endoscopic approach when associated with intranasal cyst. With the advent of dacryoendoscopic-guided probing, fewer number of children would need dacryocystorhinostomy.

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13 Primary Acquired Nasolacrimal Duct Obstruction (PANDO) and Secondary Acquired Lacrimal Duct Obstructions (SALDO)

Saurabh Kamal and Mohammad Javed Ali

Introduction

Epiphora resulting from nasolacrimal duct obstruction (NLDO) is common and accounts for about one-third of cases [1]. Symptomatic acquired NLDO has an average annual incidence rate of 30.47 per 100,000 [2]. It is commonly encountered in Ophthalmic clinics especially Ophthalmic plastics and Dacryology clinics. NLDO can be classified as either primary acquired nasolacrimal duct obstruction (PANDO) when it is idiopathic or secondary acquired lacrimal duct obstructions (SALDO) when it is secondary to various etiologies [3, 4]. The term PANDO was given by Linberg and McCormick in 1986 [4]. They described a female preponderance, a usual onset of epiphora after the age of 40 years, subsequent development of associated symptoms, and signs of chronic or acute dacryocystitis, which constitute the clinical syndrome of primary acquired nasolacrimal duct obstruction (PANDO) [4].

S. Kamal, MD
Ophthalmic Plastics Surgery,
L.V. Prasad Eye Institute, Hyderabad, India

M. Javed Ali, MS, FRCS, FRCGP (✉)
Dacryology Service, L.V. Prasad Eye Institute,
Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

PANDO

Pathophysiology of PANDO

The epithelial lining of the lacrimal sac and nasolacrimal duct (NLD) is formed by pseudostratified columnar epithelium with intraepithelial goblet cells. Beneath the epithelium, there is loose connective tissue containing many lymphocytes and a rich vascular plexus called cavernous body which is presumed to regulate the tear outflow [5].

The first landmark study on the pathophysiology of PANDO was published in 1986 by Linberg and McCormick who described a surgical technique of performing biopsy from the nasolacrimal duct (NLD) to elucidate the disease pathology [4]. They biopsied the NLD during routine external dacryocystorhinostomy (DCR) in 16 patients. They observed narrowing of the NLD lumen with inflammatory infiltrates, edema and dense fibrosis of periductal tissues, and prominent vascular plexus with intimal proliferation and muscular hypertrophy. They classified NLD specimens into three types: active inflammatory, intermediate, and fibrotic. Early in the course of the disease, they noted the presence of active inflammation and infiltrate which antedates the onset of infection leading to stenosis of the NLD. These cases have functional obstruction whereby there is absence of mucopurulent reflux on the pressure over the lacrimal sac and irrigation of the lacrimal system is patent. This stage is

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followed by the fibrotic stage where initially there is focal resolution of the inflammatory process with patchy replacement of the duct by fibrosis, and over the years (>2 years), there is complete fibrous obliteration of the duct. Their findings provided the basis that probing or stenting in cases of PANDO is unlikely to produce a patent duct except for partial obstructions, where stents can apparently maintain the tract and prevent complete obstruction of the NLD [4].

Further insight into the pathophysiology of PANDO was given by Paulsen et al. [5] who postulated the pathogenic concept of PANDO and role of ectopic nasal epithelial cells in the NLD. Their findings suggested that either descending or ascending inflammation from the nose results initially in malfunctioning of the cavernous body, reactive hyperemia, edema of mucous membrane, and temporary occlusion of the NLD. This results in repeated attacks of dacryocystitis with permanent structural changes setting in such as loss of goblet cells, epithelial damage and fibrosis of helical connective tissues, and loss of specialized blood vessels of the cavernous body [6]. These changes are thought to affect the tear outflow mechanism and starting up a vicious cycle [7]. In addition they explained that the functional obstruction initially results from edema of the mucous membrane, and later with advanced structural changes, there is loss of functioning segment and tear transport.

There is an increased number of pathogenic microbes which can be seen in an obstructed lacrimal duct. Whether these organisms are primarily the cause of inflammation or secondarily colonize the duct remains obscure [6, 8].

The current focus is on understanding the mucosa-associated lymphoid tissue (MALT) associated with the lacrimal sac and duct. Lacrimal drainage-associated lymphoid tissue (LDALT) and tear duct-related lymphoid tissue (TALT) have been identified and studied recently [9, 10]. These lymphoid tissues are thought to modulate immune responses, and their derangements can have possible implications on the etiopathogenesis of PANDO. Changes that have been noted in LDALT in cases of dacryocystitis include: diffuse infiltrate lymphoid pattern (81 %), distinct lymphoid follicles (28 %), increase in the goblet cells (82 %), dilated lymphatics (94 %), proliferating blood vessels (99 %), thickened epithelium (54.5 %), and stromal fibrosis (88 %) [9]. TALT have been observed to be absent in cases of NLDO, probably related to the lack of antigen exposure in the obstructed duct or replacement of lymphoid tissue by scarring [10]. Alternatively, it can be thought that the presence of TALT may have a protective effect against the development of lacrimal duct stenosis [9].

Predisposing and Associated Factors

(a) Age: PANDO occurs more frequently in middle-aged and elderly population and is usually noted in the age group above 40 years [4, 11, 12].
(b) Race and sex: Increased prevalence is noted in females and whites. This can be explained due to their longer and narrower canal as compared to males and blacks [11, 12]. However whether this NLD canal size difference really contributes to PANDO is not established.
(c) Previous infections: History of previous infectious conjunctivitis or rhinitis (nonspecific, viral, or bacterial) before the onset of NLDO has been noted to be a predisposing factor [13].
(d) Swimming pool exposure could be associated with the development of PANDO. Chlorinated compound can cause inflammation, oxidative stress, and hyperpermeability in the respiratory mucosa and nasolacrimal duct [13]. However, this is at present a belief and not satisfactorily established.
(e) Other associations noted with PANDO are ischemic heart disease, glaucoma, allergic conjunctivitis, dry eye, antiglaucoma medication (timolol maleate), and allergic rhinitis [14]. A relationship between gastroesophageal reflux disease and rhinopharyngitis and rhinosinusitis has been noted, and some also believe that it can cause direct and indirect (autonomic nervous system) hyperemia and edema of the NLD [15].

(f) Nasal factors noted to be associated with PANDO are concha bullosa, inferior turbinate hypertrophy, osteomeatal complex disease, and maxillary sinusitis [4].

Clinical Features

A detailed history and examination in most of the cases can distinguish between PANDO and SALDO. History should elicit secondary causes like trauma, sinus disease, sinus surgery, and systemic diseases such as tuberculosis and sarcoidosis. History of previous acute dacryocystitis should be recorded. Classically the lacrimal sac swelling/mucocele (in PANDO) is noted below the medial palpebral ligament (MPL). Symptoms of nasolacrimal duct obstruction may include epiphora, discharge, irritation, and blurred vision due to tear accumulation in the conjunctival cul-de-sac. Lacrimal pump function abnormality which can be age related or associated with facial nerve palsy should be kept in mind. A detailed comprehensive evaluation as described in "Evaluation of Epiphora" must be carried out.

Obstruction of the nasolacrimal duct can be associated with chronic or acute dacryocystitis, lacrimal mucocele, fistula, and lacrimal abscess and even may complicate into orbital cellulitis and cavernous sinus thrombosis. The stasis of tear and secretions within the sac can lead to buildup of bacterial load which causes chronic dacryocystitis. Chronic dacryocystitis can be classified into three types: catarrhal dacryocystitis, lacrimal mucocele, and chronic suppurative form [16]. Catarrhal dacryocystitis is characterized by constant and persistent epiphora and angular conjunctivitis. Lacrimal mucocele is a cystic swelling which results from the accumulation of secretions which causes dilation of the sac and collapse of the valve of Rosenmuller. This creates a ball-valve mechanism which initially allows ingress of fluid but limits egress of fluid leading to the formation of lacrimal mucocele [17]. Absence of reflux of discharge from the sac into the conjunctival fornix can decrease conjunctival irritation and thus epiphora. The clinical picture in chronic suppurative dacryocystitis consists of increased epiphora and discharge and formation of pyocele (inflamed sac filled with pus) [16].

Acute inflammation can result leading to acute dacryocystitis. Acute dacryocystitis [18] is defined as "A medical urgency which is clinically characterized by rapid onset of pain, erythema and swelling, classically below the medial canthal tendon with or without pre-existing epiphora mainly resulting from the acute infection of the lacrimal sac and perisac tissues." Clinical presentation includes swelling, pain, and erythema over the lacrimal sac area. Complications seen in advanced cases can be orbital cellulitis, orbital abscess, superior ophthalmic vein thrombosis, cavernous sinus thrombosis, meningitis, and visual loss. But these complications are rare due to various barriers such as the orbital septum, medial canthal tendon, Horner's muscle, and Jones muscle [18]. Causes of non-resolving acute dacryocystitis and progression to lacrimal sac abscess include virulent organism, antibiotic resistance, and persistent inflammation [18]. About 2 % of cases have no response, and in 6 % of cases, there may be relapse of acute dacryocystitis. Lacrimal abscess can be a presenting feature in one-fourth of acute dacryocystitis cases, and cutaneous fistula formation is noted in about 6 % of cases secondary to spontaneous rupture or after incision and drainage [18]. The most common microorganisms isolated in such cases are gram-positive cocci (*Staphylococcus aureus, Staphylococcus pneumoniae*) followed by gram-negative bacilli (*Haemophilus influenzae*) [19].

Indications for Treatment

Indications for treatment of PANDO vary and depend upon patient symptoms, their interest, stage of dacryocystitis, and also need for an intraocular surgery in some patients. Acute dacryocystitis is an emergency and requires immediate medical or surgical treatment. Treatment for chronic dacryocystitis is usually elective, but early surgical intervention may be needed for cases with ophthalmic infections and/or those requiring ocular surgery.

Patient-related factors which determine the need for surgery are impact on the quality of life due to blurred vision, irritation or skin eczema, social embarrassment due to epiphora [20], frequency of dapping, and presence of discharge or matting of eyelashes in the morning.

Management

The medical management of acute infections has been described in the Chap. 15. The various surgical modalities, minimally invasive therapies, and various approaches in literature for both partial and complete PANDO have been described subsequently in this text individually and in great detail.

SALDO

Secondary acquired lacrimal duct obstructions or SALDO is a term described by Bartley in 1992 to define all the secondary causes of lacrimal obstructions [3]. It essentially means that the specific cause of obstructions could be zeroed in on, and therapies targeting the cause may result in relief from obstructions. Bartley et al. [21, 22] classified five categories of secondary obstructions, namely, infectious, inflammatory, traumatic, mechanical, and neoplastic with numerous etiologies for each category.

Infectious SALDO

The infections can involve any site of the lacrimal system and may present as punctal abscess, canaliculitis, dacryocystitis, and isolated NLD infections. Etiological factors can be bacterial, viral, fungal, or rarely parasitic (Figs. 13.1, 13.2, and 13.3). Treatment is based upon the location and organism involved. The Chap. 15 provides illustrated details on this subject.

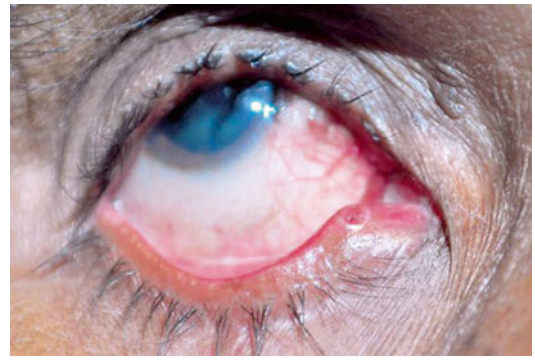

Fig. 13.1 Infective canaliculitis: an example of an infectious SALDO

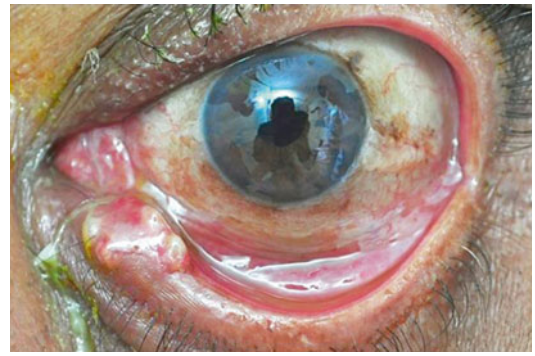

Fig. 13.2 Punctal and canalicular abscess

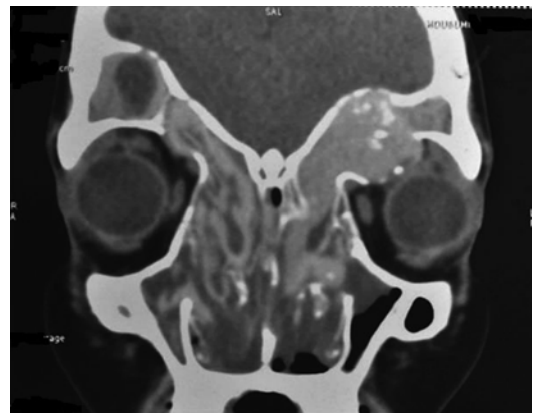

Fig. 13.3 CT scan, coronal plane showing extensive pansinus and lacrimal involvement by aspergillosis

Inflammatory SALDO

Inflammatory SALDO can include endogenous etiologies like Stevens-Johnson syndrome, cicatricial pemphigoid, sarcoidosis, and Wegener's granulomatosis (Figs. 13.4 and 13.5). Exogenous etiologies include burns, allergies, use of eye drops like antiviral, radiotherapy, and certain chemotherapeutic agents like 5-fluorouracil and paclitaxel (Figs. 13.6 and 13.7). All the etiologies

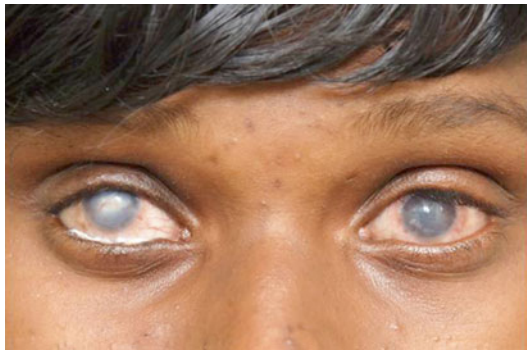

Fig. 13.4 Stevens-Johnson syndrome: an example of inflammatory SALDO

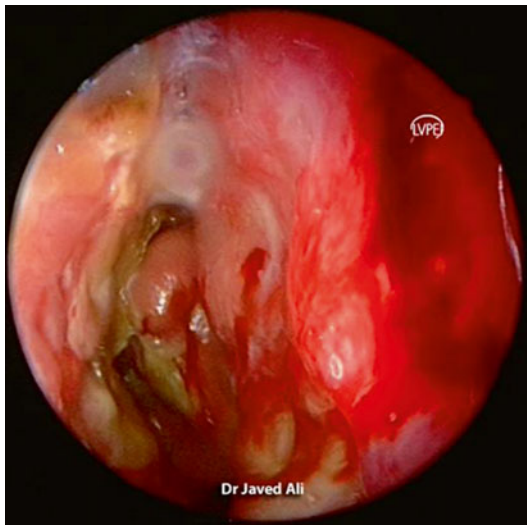

Fig. 13.5 Endoscopic view of a nasal cavity extensively involved with Wegener's granulomatosis

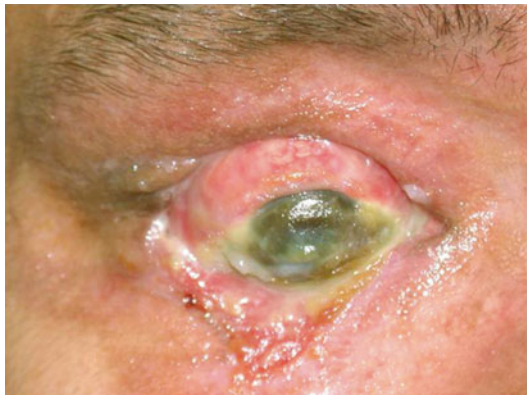

Fig. 13.6 Loss of eyelids and proximal lacrimal system in a case of chemical burns

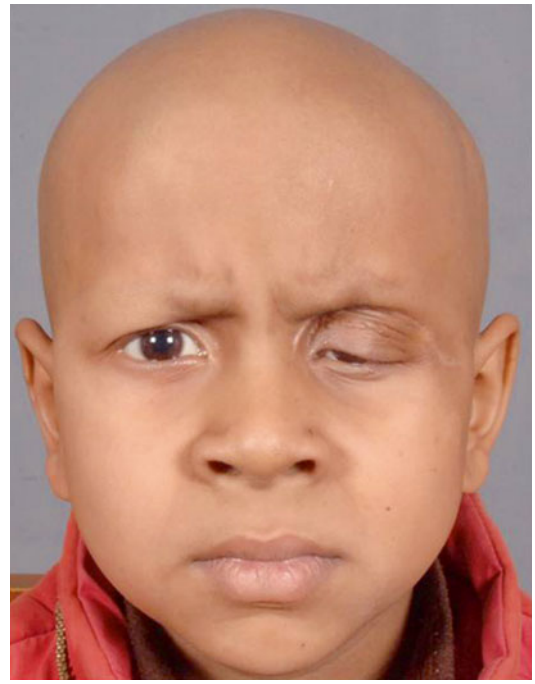

Fig. 13.7 Radiotherapy-induced SALDO

whether endogenous or exogenous result in response by lacrimal tissues by progressive fibrosis and ultimately result in an obstruction. Instituting measures early on in the inflammatory phase by removing or minimizing the inciting agent, topical and systemic steroids, and recanalization procedures in later phases help in reducing the morbidity associated with epiphora.

Traumatic SALDO

Traumatic SALDO is a distinct entity that includes iatrogenic and accidental trauma. Iatrogenic etiologies include probing, intubation, punctal plugs, and sinus surgeries (Figs. 13.8 and 13.9). Accidental traumas involve SALDO secondary to either a soft tissue trauma or a bony trauma. Among the soft tissue injuries, canalicular tears are the most common (Figs. 13.10 and 13.11), and among the bony injuries, specific naso-orbito-ethmoid fractures are known to cause nasolacrimal entrapment and damage (Figs. 13.12 and 13.13) [23]. The specifics of diagnosis and treatment are mentioned in detail in the Chap. 16.

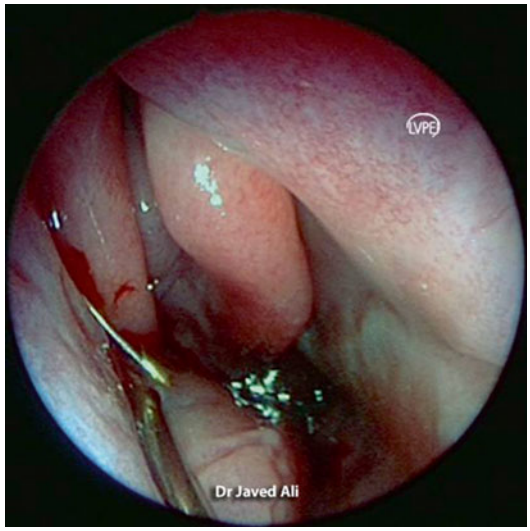

Fig. 13.8 Endoscopic photograph of an iatrogenic SALDO caused by producing a false passage during probing

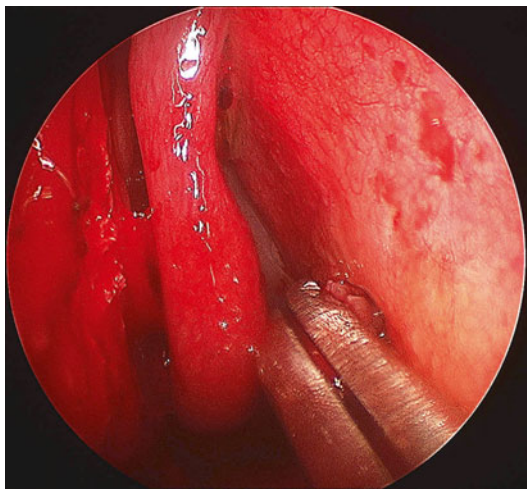

Fig. 13.9 Endoscopic photograph showing horizontal uncinectomy during a sinus surgery. This step has the most potential for causing a traumatic SALDO involving the nasolacrimal duct

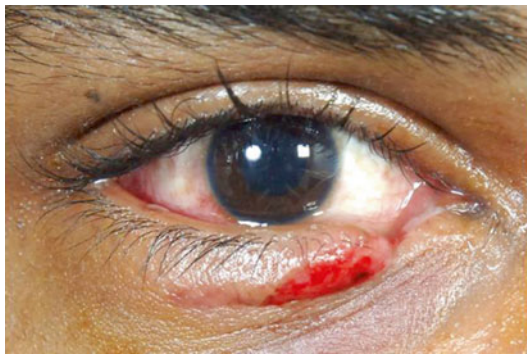

Fig. 13.10 A lower lid canalicular tear

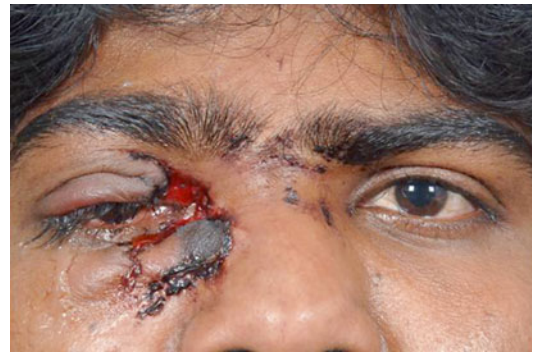

Fig. 13.11 Extensive periocular lacerations involving the lacrimal system

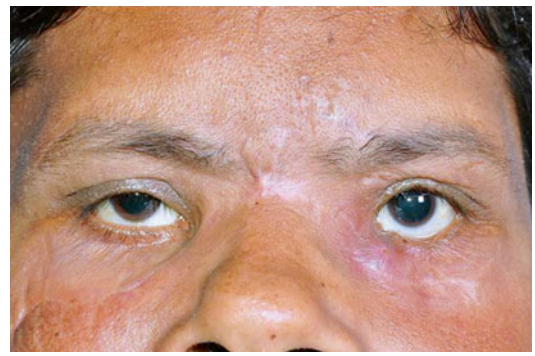

Fig. 13.12 Left acute dacryocystitis with a fistula in a case of naso-orbito-ethmoid fracture. Note the past scars of maxillofacial repair

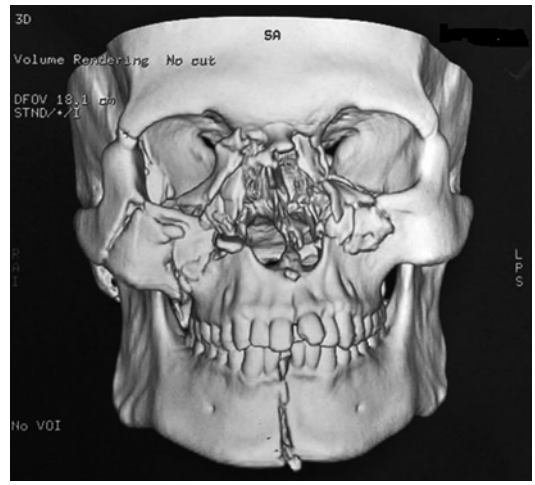

Fig. 13.13 3D reconstructed, volume-rendered CT scan of facial skeleton showing an extensive NOE fracture along with bony lacrimal involvement

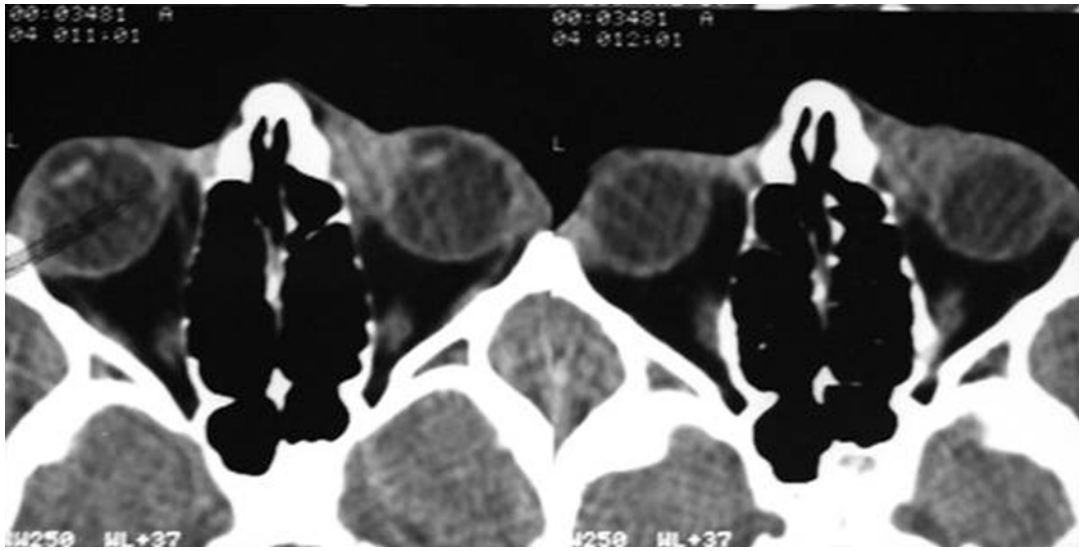

Fig. 13.14 CT scan axial image showing left lacrimal sac enlargement with dacryolithiasis

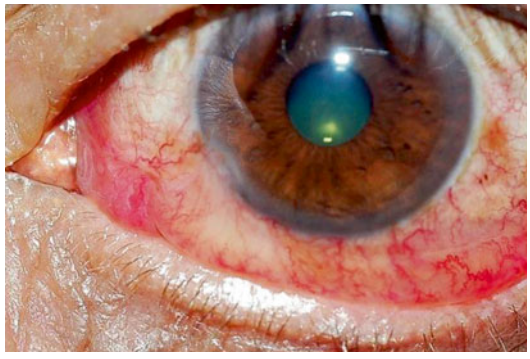

Fig. 13.15 Mechanical SALDO caused by redundant and inflamed conjunctiva obstructing the punctum

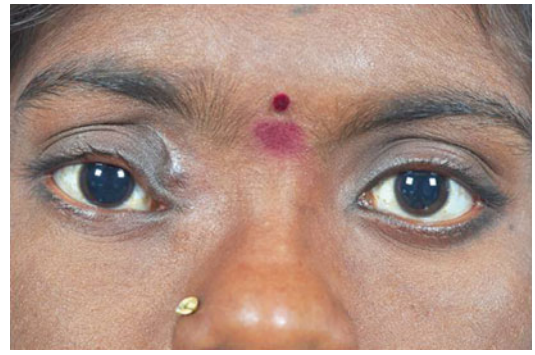

Fig. 13.16 Mechanical SALDO caused by an ethmoid mucocele. Note the unilateral telecanthus

Mechanical SALDO

The term mechanical refers to a lacrimal passage physically obstructed anywhere along its entire course by specific agents. These could be endogenous factors like dacryoliths (Fig. 13.14) and migrated punctal plugs or exogenous factors like conjunctivochalasis (Fig. 13.15), sinus mucocele (Fig. 13.16), or caruncular masses (Fig. 13.17). Treatment consists of removing the inciting agent like punctal plugs and excision of caruncular mass or redundant conjunctiva.

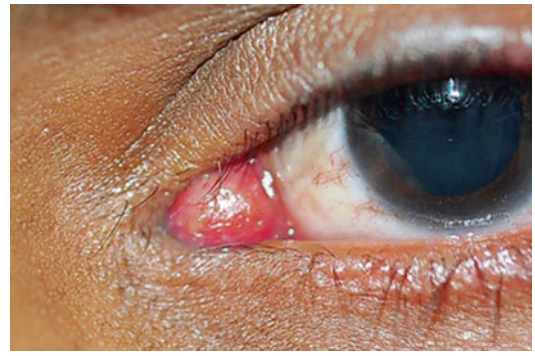

Fig. 13.17 Mechanical SALDO secondary to punctal obstruction by a caruncular mass

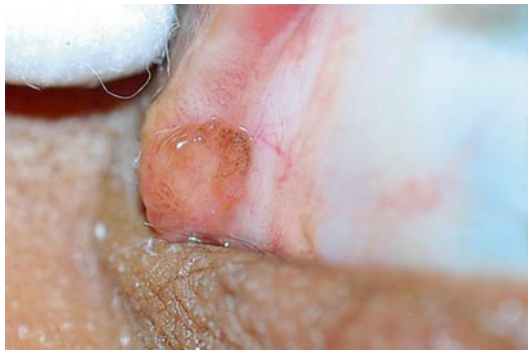

Fig. 13.18 Papilloma involving the proximal lacrimal system

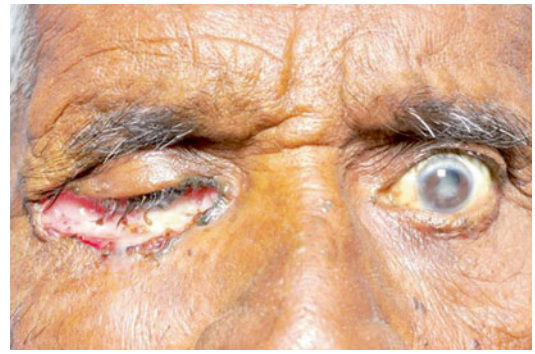

Fig. 13.20 Neoplastic SALDO secondary to a basal cell carcinoma

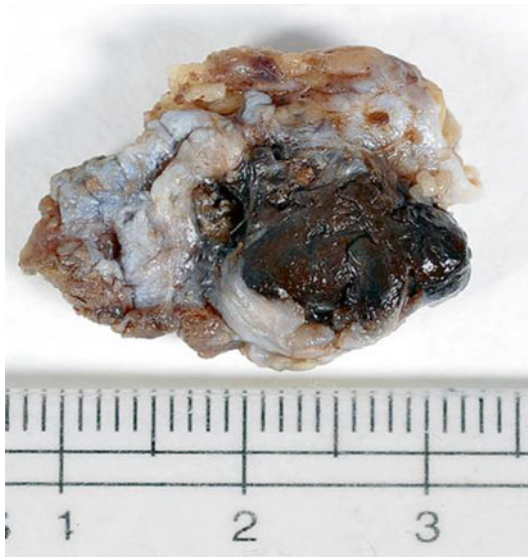

Fig. 13.19 Malignant melanoma of the lacrimal sac following an extended dacryocystectomy

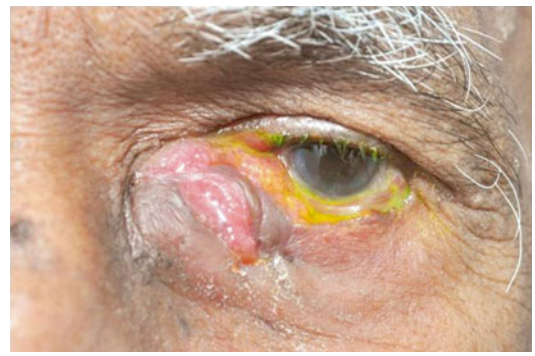

Fig. 13.21 Neoplastic SALDO secondary to a squamous cell carcinoma

Neoplastic SALDO

SALDO can occur from primary neoplasms arising from the lacrimal system like papillomas, squamous cell carcinomas, lymphoma, and melanoma (Figs. 13.18 and 13.19). Lacrimal obstructions can also occur as a result of secondary involvement by many tumors that may develop in adjacent tissues, for example, basal cell carcinoma, squamous cell carcinoma, adenoid cystic carcinoma, leukemia, and lymphomas (Figs. 13.20 and 13.21). Rarely SALDO can result from metastasis from breast carcinoma, malignant melanoma, and prostate carcinoma. The Chap. 33 in this text enlists all the malignancies and modes of their management.

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Functional Obstructions of the Lacrimal System

14

Mohammad Javed Ali

Introduction

Functional obstructions of lacrimal drainage systems are an underdiagnosed entity. Epiphora in the presence of a patent lacrimal pathway and absence of alternative etiology could be the simplest description. Nomenclature has been confusing since functional issues of the lacrimal system have been poorly defined. Terms used include functional block, physiologic dysfunction, and functional acquired epiphora; however, the most common terminology used is functional nasolacrimal duct obstruction (FNLDO) [1–5]. Few authors have defined FNLDO to also include partial obstructions [5] but would be misleading since there is an anatomical issue rather than a functional one. Functional epiphora can be an alternate and probably a better term [1]. It is of utmost importance to rule out other causes of epiphora before labeling a case as functional. Functional issues can be of the upper or lower lacrimal system. Altered outflow dynamics without anatomical narrowing in the upper system is known to occur in older patients (mean age 57–64 years) with a high incidence of bilaterality (86 %) [6, 7]. These findings in upper system dysfunctions supports the theory of decreasing efficiency of the lacrimal pump secondary to weakening of the orbicularis oculi with increasing age as suggested by Jones in 1957 [8] and later supported by Worst in 1971 [9]. In addition, the lower system dysfunctions also occur more frequently in younger patients. This chapter aims to describe the clinical examinations, investigations, management, and outcomes of functional epiphora.

Clinical Examination

A careful history of epiphora with emphasis on preceding and subsequent events must be noted. Relevant ocular history, periocular surgical events, and drug (chemotherapy) history are important. Functional epiphora is a diagnosis of exclusion, and hence, a careful slit-lamp examination should be done to rule out a number of potential causes of epiphora like ocular surface disorders, lacrimal gland hypersecretion, eyelid malpositions, eyelid laxities, puncta-globe incongruities, punctal stenosis, conjunctivochalasis, dry eyes, and lagophthalmos. Clinical examination should be tailored towards suspects like tear breakup time and Schirmer's test for dry eyes and hypersecretion. Nasal endoscopy can occasionally reveal nasal causes of functional epiphora like rhinitis (Fig. 14.1) [10].

Irrigation and probing should be carefully performed as elucidated in the Chap. 6, to be very sure that there is no anatomical problem (Figs. 14.2 and 14.3). Functional dye disappearance test (FDDT) is also a very reliable adjunctive

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute,
Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

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clinical test (Fig. 14.4) to support the diagnosis and must be performed as part of the standard protocol in all cases of functional epiphora (please refer to the Chap. 6) [11, 12]. A survey conducted in Southwest United Kingdom to study the assessment practice by ophthalmologists in cases of FNLDO showed gross variations. Only 41 % used FDDT as an assessment tool and only 51 % performed irrigation themselves. They pointed out that the incomplete assessment resulted in inadequate management and recommended FDDT in all patients, irrigation by experienced staff, and additional use of radiological investigations [12].

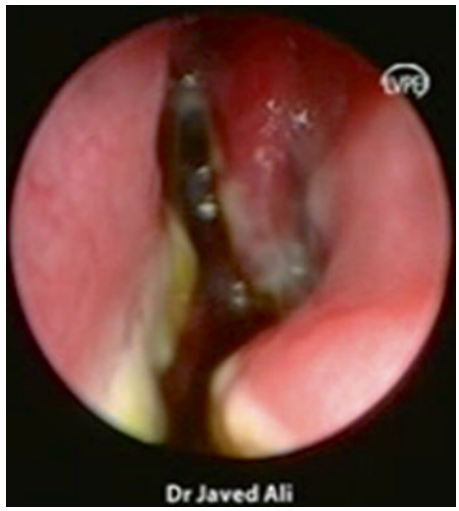

Fig. 14.1 Endoscopic view in acute rhinitis

Investigations

Dacryocystography (DCG) has been used to exclude areas of narrowing or stenosis, and if the lacrimal system is patent, dacryoscintigraphy (DCS) is use to define the level of outflow delay [1, 13]. Wearne et al. [14] studied the feasibility of DCG and DCS in patients with FNLDO and showed that when used together, they have a high sensitivity of 98 %. Montanara et al. [3] described outflow difficulties of contrast medium without anatomical narrowing as characteristic features on DCG. Hurwitz and Welham [6] divided the functional abnormalities radiologically at two levels: upper part (orbicularis, puncta, canaliculi) and lower part (sac, duct, inferior meatus). Chan et al. [1] further refined these as those with pre-sac and post-sac delay. Francis et al. [15] showed

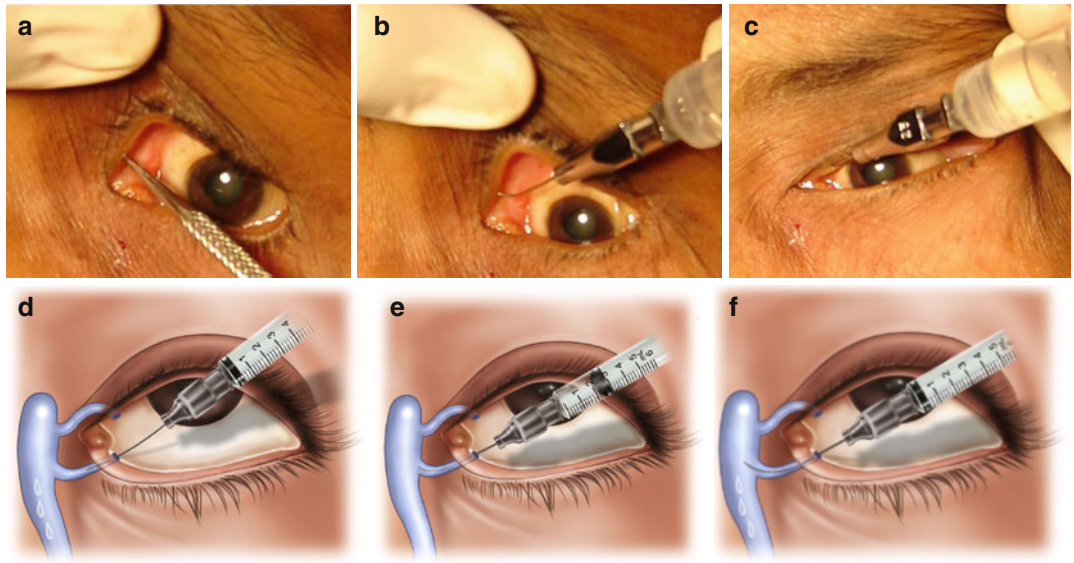

Fig. 14.2 Lacrimal irrigation procedure. Dilatation of punctum with the Nettleship's punctum dilator (**a**). The lacrimal canula inserted into the canaliculus first vertically (**b**) and then in a horizontal direction. Note the lateral traction is given to the eyelid to straighten the canaliculi before the horizontal pass (**c**). Schematic diagram showing intracanalicular irrigation. A very little amount is irrigated to dilate the lacrimal passage to avoid the risk of mucosal trauma (**d**). Intrasac irrigation is the desired goal for better interpretation unless there is a canalicular obstruction (**e**, **f**) (Photo courtesy of Dr. Sima Das)

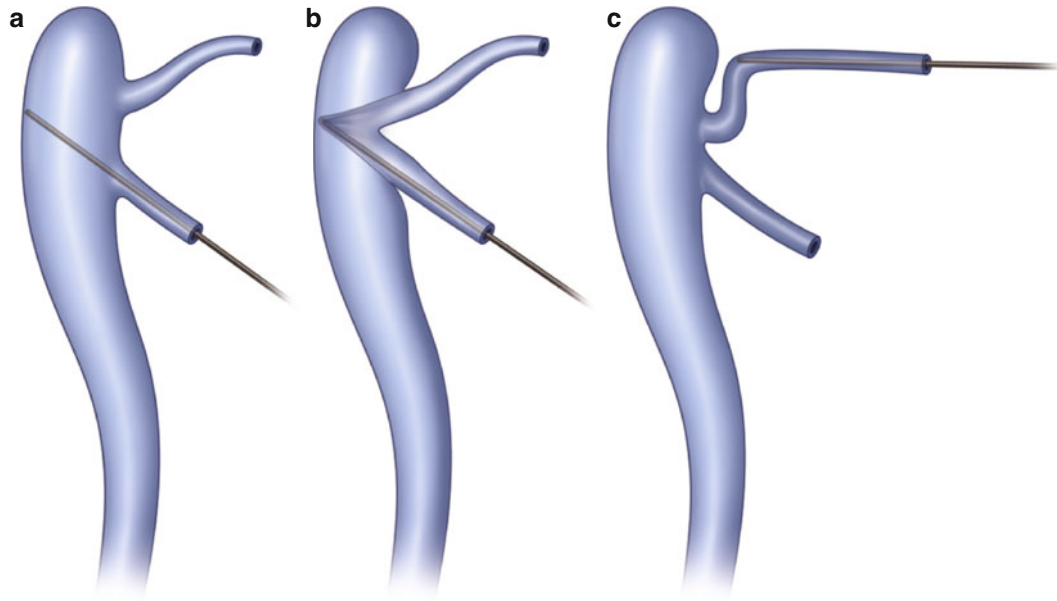

Fig. 14.3 Interpretation of lacrimal probing. Hard stop is felt when the probe hits the medial wall of the sac and underlying bone (**a**). Soft stop is felt when the probe drags the lateral wall of the sac toward the medial wall in cases of canalicular obstructions (**b**). False positive soft stop can be felt if adequate lateral traction is not given on the eyelid to straighten the canaliculi while passing the probe through it and the probe drags the roof or floor of the canaliculi against the sac (**c**) (Photo courtesy of Dr. Sima Das)

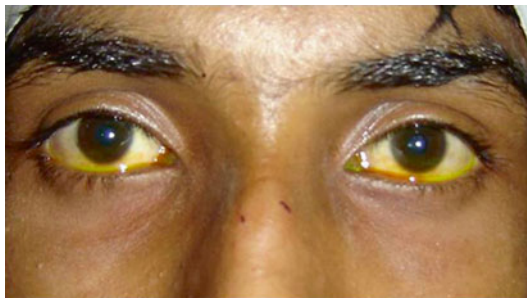

Fig. 14.4 Bilaterally retained dye in FDDT (Photo courtesy of Dr. Sima Das)

increased tear meniscus height in FNLDO using videoreflective dacryomeniscometry but found no statistical difference was noted when compared with PANDO, making it a nonspecific diagnostic tool.

The author of this chapter believes that with the advent of dacryoendoscopy, it would be easier to identify any anatomical narrowing or stenosis. Since the management does not differ markedly, exclusion of anatomical abnormalities with demonstrable patent lacrimal passage should be sufficient for a diagnosis in a routine practice.

Management

The management of functional epiphora is controversial, and no consensus has evolved over the last six decades since its first description in 1955 [2]. One of the fundamental reason for this is the variations in terminologies exclusion criteria and management. Do these patients really need treatment? Evidence suggests in the affirmative. Cheung et al. [7] conducted a detailed study on 33 FNLDO patients and studied their symptoms in relation to the vision, reading, driving, moods, work, and embarrassment. All these parameters were affected specifically vision, reading, and embarrassment, resulting in lower quality of life. Overall symptom scores significantly reduced after dacryocystorhinostomy (DCR) from a mean preoperative score of 3.50 (SD = 2.07) to 2.0 (SD = 1.65) in the postoperative period ($p < 0.05$).

Lacrimal pump failures with severe symptoms can be candidates for a conjunctivodacryocystorhinostomy, or CDCR, with Jones tubes [16]. These tubes have also shown to benefit persistent epiphora following a patent DCR [16, 17]. There

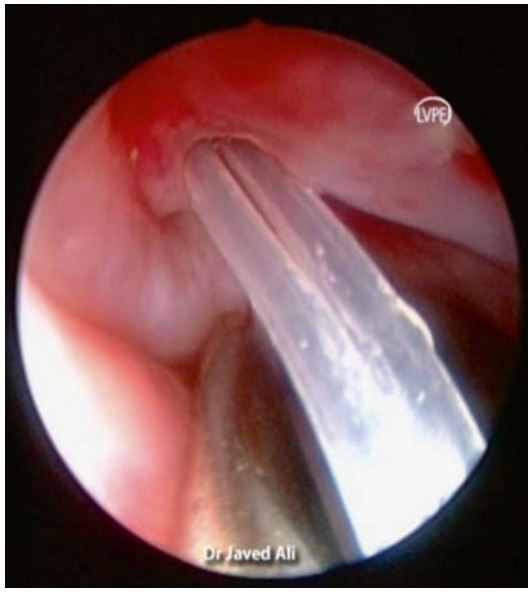

Fig. 14.5 Endoscopic view of a silicone tube dilating the nasolacrimal duct

is an increasing evidence of benefits of silicone intubation (SI) in FNLDO patients [4, 18, 19]. Moscato et al. [4] studied 44 eyes of 30 patients diagnosed with FNLDO, who underwent SI for a mean duration of 4 (±4.1) months. They were followed for a mean of 2.6 (±2.0) years from the time of intubation. The overall success for resolution of symptoms was seen in 77 %. Extrapolating the data showed success at 50 % between 5 and 6 years. They concluded that SI has good long-term success in cases of FNLDO.

Multiple mechanisms have been postulated to explain the benefit seen with SI in FNLDO [4, 20, 21]. Stent placement increases the volume and hence reduces resistance to outflow. Poiseuille's law states that resistance to flow is inversely proportional to the fourth power of the radius. Hence, by increasing the diameter of the lumen, the stents reduce resistance to flow (Fig. 14.5). In addition, Moscato et al. [4] proposed the riverbed phenomenon where an increased outflow following reduced resistance helps to maintain the enlarged passage. In addition, the stents may straighten up acute curves impeding outflow as well as help tear outflow by capillary action.

There is good evidence in literature that supports the beneficial effects of DCR in FNLDO patients. Both external DCR (Ex-DCR) and endoscopic DCR (En-DCR) have shown good results. However, these results should be interpreted with caution since few studies did not take into account a strict criteria not to include NLD stenosis, but did demonstrate preoperative patency. The success rates in those with strict criteria ranged from 54 to 84 % [17, 22] and in those without from 50 to 94 % [23–26]. Cho et al. [27] performed a comparative trial between SI ($n = 108$), En-DCR ($n = 32$), and Ex-DCR ($n = 13$) in FNLDO patients. At 6 months' follow-up, complete resolution of symptoms was achieved in 68.5 % of SI, 81.3 % of En-DCR, and 53.9 % of Ex-DCR. However, these results need to be interpreted with caution because of grossly variable number in each group and variable SI duration and SI confounding effects in DCRs.

In conclusion, functional epiphora is a distinct entity with characteristic clinical features, specific investigative modalities for diagnosis, and good outcomes upon management. However, gold-standard diagnostic criteria are unknown, and further work needs to focus on this as well as standardization of nomenclatures for a better understanding that would translate to better patient management.

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Infections of the Lacrimal Drainage System

15

Aditi Watve and Mohammad Javed Ali

The canaliculi and the lacrimal sac are the regions of the lacrimal drainage system, which are prone to infections. In this chapter, we would focus on infective canaliculitis and dacryocystitis.

Canaliculitis

It is an infection of the canalicular part of the lacrimal drainage system (Fig. 15.1) [1].

Epidemiology

It accounts for only 2 % of all patients with lacrimal diseases [2]. Canaliculitis affects the lower eyelid more than the upper eyelid and women more than men [3]. This female preponderance is thought to be partly due to physiological or hormonal changes during menopause, which may cause decreased tear production and reduced protection against infections [4]. Furthermore, makeup and cosmetics may occlude the canaliculus and promote bacterial growth, predisposing to canaliculitis [5].

A. Watve, MD
Ophthalmic Plastics Surgery,
L.V. Prasad Eye Institute, Hyderabad, India

M. Javed Ali, MS, FRCS, FRCGP (✉)
Dacryology Service, L.V. Prasad Eye Institute,
Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

Etiology

Most of the cases are idiopathic in nature. Few rare predisposing factors include diverticulum or obstruction of the canaliculus which promote anaerobic bacterial growth secondary to stasis of tear and use of cosmetics.

Microbiological Profile

Most published case series report *Actinomyces* and *Nocardia* species, prominent among them being *Actinomyces israelii* (Fig. 15.2) and *Nocardia asteroides* as the common pathogenic organisms [6–16]. There are only isolated case reports of canaliculitis due to other various other organisms like *Mycobacterium chelonae*, *Lactococcus lactis*, *Eikenella corrodens*, *Enterobacter cloa-*

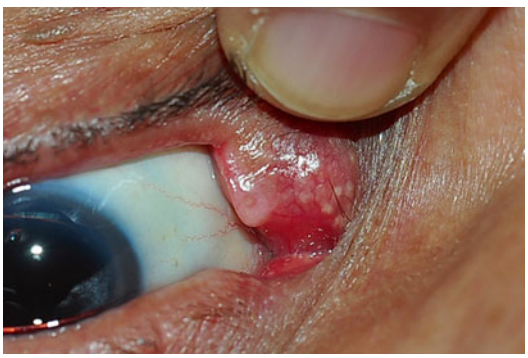

Fig. 15.1 Clinical presentation of canaliculitis

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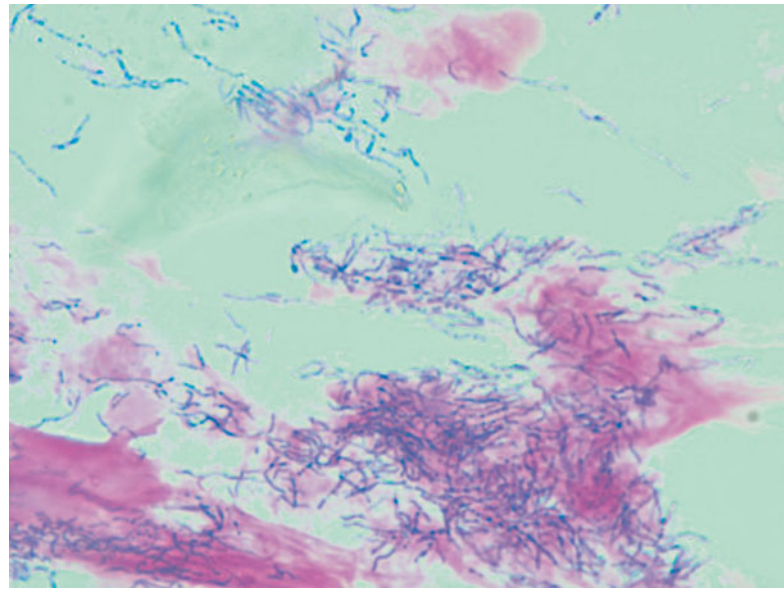

Fig. 15.2 Microbiological smear of *Actinomyces*

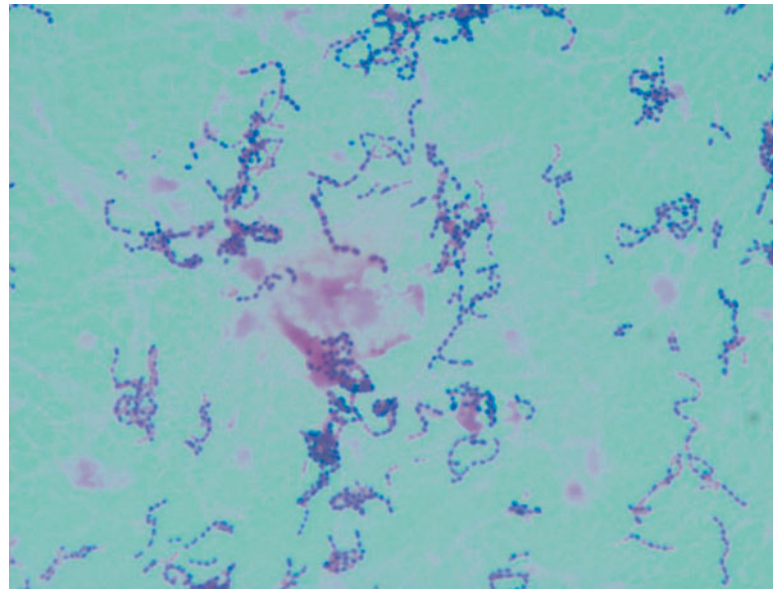

Fig. 15.3 Gram-positive organisms on a smear

cae, *Fusobacterium*, and *Kocuria rosea*; viruses like *Herpes simplex;* and fungal organisms like *Malassezia pachydermatis and Candida albicans* [17–25]. However, in one of the largest studies in literature from the author's institution, the culture-positive rates were 91 % with *Staphylococcus* species being the most common isolate (39 %) (Fig. 15.3) followed by *Streptococcus* species (29 %) and *Actinomyces* (10 %) [3].

Clinical Presentation

Common presenting symptoms include epiphora, swelling of the eyelid, pain, and redness (Fig. 15.1). Kaliki et al. [3] in a very large series showed epiphora as the most common symptom (85 %) followed by swelling of the canalicular portion of the eyelid (32 %) and pain in 27 % of the cases. Rarely patient may even be asymptomatic [3].

On clinical examination, typical signs of canaliculitis include thickening of the canalicular portion of the eyelid margin (72 %), expressible punctal discharge (36 %), and pouting erythematous punctum (34 %) (Fig. 15.1) or rarely a firm, non-tender nodule in the punctal and canalicular region [3].

Diagnosis

Although canalicular imaging by dacryocystography and ultrasound biomicroscopy has been described for diagnosis and documentation of canaliculitis, a thorough clinical examination is sufficient for the diagnosis in most cases [26, 27].

The rarity of this disease may be attributed to the high rate of missed and delayed diagnosis. Furthermore, it may have atypical presentations, leading to additional difficulties in diagnosis [4, 28–30]. Canaliculitis can be misdiagnosed as chronic conjunctivitis, chalazion, hordeolum internum, or chronic dacryocystitis, causing a further delay in the initiation of effective treatment [3, 4, 31–33].

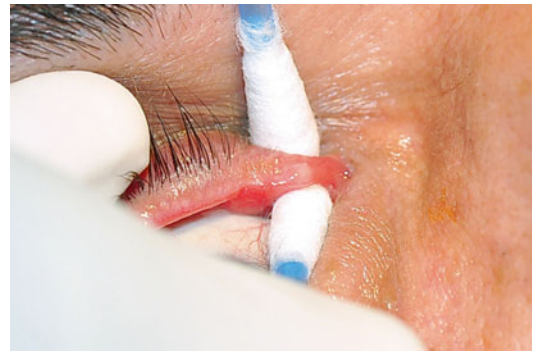

Fig. 15.4 Early phase of milking canalicular contents

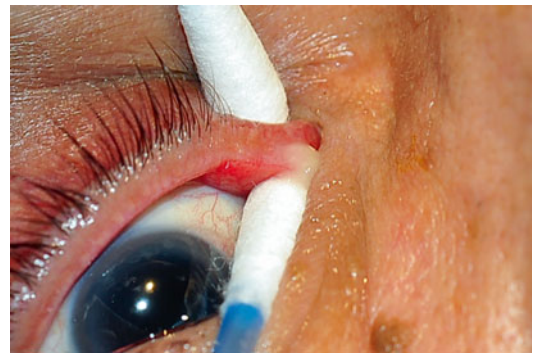

Fig. 15.5 Late phase of canalicular milking

Management

Various modalities of treatment have been described for canaliculitis [2–33]. Conservative measures include oral and topical antibiotics, punctal dilatation, and canalicular expression or canalicular irrigation with antibiotics [6–8]. Surgical measures include punctoplasty and canalicular curettage, canaliculotomy with canalicular curettage, and canaliculostomy [2, 3, 10–33].

However, with any of the modality of treatment, it is important to send the material for a meticulous microbiological examination.

Conservative Medical Therapy

Initially, punctal dilatation with expression of canalicular discharge is performed under strict aseptic precautions under topical anesthesia. After instilling a drop of 0.5 % proparacaine hydrochloride in the conjunctival cul-de-sac, dilatation of the punctum is performed with Nettleship punctum dilator and manual expression of canalicular contents by a milking movement toward the punctum (Fig. 15.4). Mechanical expression is repeated (Fig. 15.5) until no further contents are expressed. The expressed contents are collected on a sterile cotton-tipped applicator and sent for microbiological workup. Broad-spectrum antibiotics can be started as dictated by regional isolates and their sensitivity, followed by specific antibiotics guided by patient-specific isolates. Conservative treatment in one of the largest series has shown to be effective in 59 % of the patients with a high rate or recurrence [3].

Surgical Treatment

Surgical modalities include punctoplasty alone or in conjunction with canalicular curettage, per-

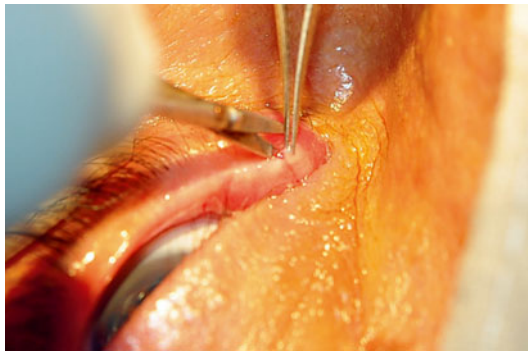

Fig. 15.6 Punctoplasty

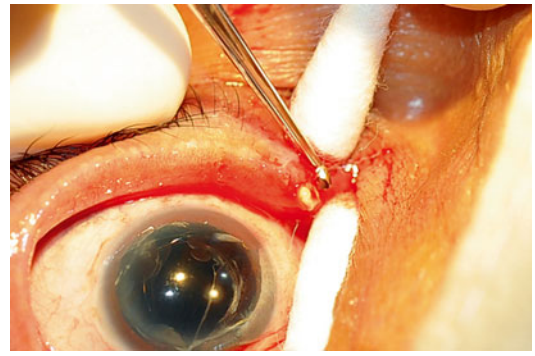

Fig. 15.9 Pouting of concretions following canaliculotomy

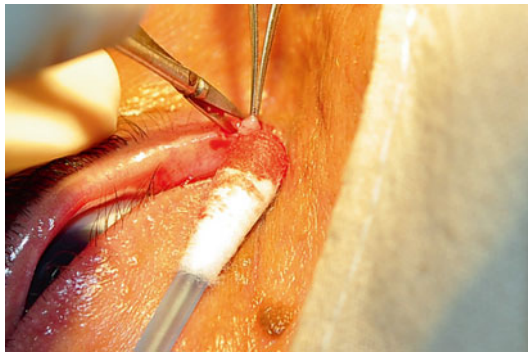

Fig. 15.7 Completed punctoplasty

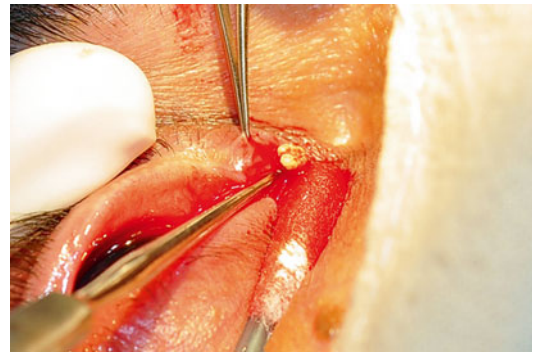

Fig. 15.10 Canalicular curettage

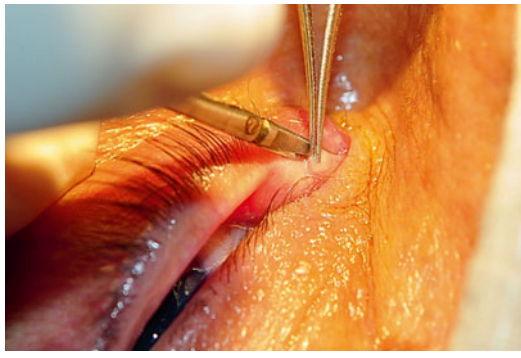

Fig. 15.8 Canaliculotomy

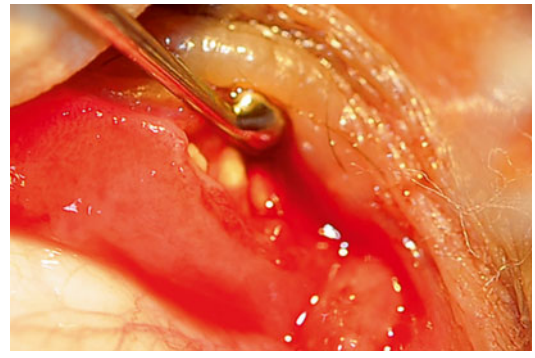

Fig. 15.11 Remnant concretions in the ampulla and proximal canalicular floor

formed under strict aseptic precautions, under local infiltrative anesthesia with 2 % lignocaine hydrochloride. A 3-snip punctoplasty or the surgeon-preferred punctoplasty is performed with a small, straight Vannas scissors (Figs. 15.6 and 15.7). To this, a small canaliculotomy can be added (Fig. 15.8), and a 1-mm chalazion curette is used to curette out the granular material, concretions, or mucoid debris (Figs. 15.9 and 15.10). It is a good practice to evaluate the walls of the ampulla, since concretions have a tendency to stack up and accumulate there (Fig. 15.11). The curettage is repeated until there are no further

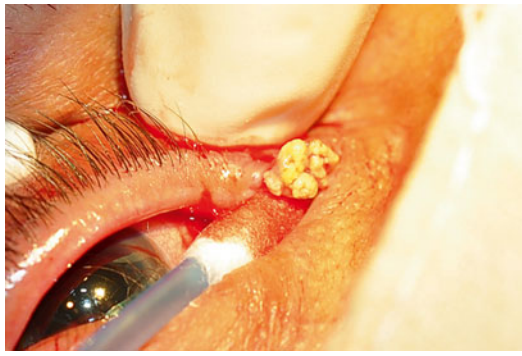

Fig. 15.12 Complete expression of concretions

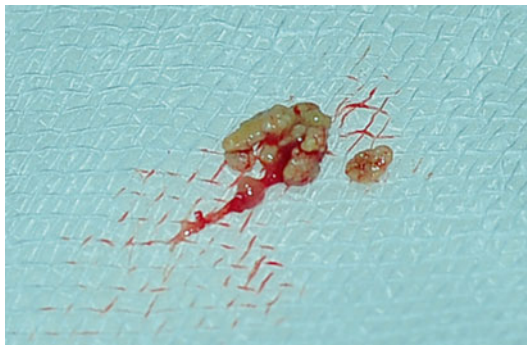

Fig. 15.13 Canalicular concretions on a sterile surface

contents (Fig. 15.12). It is of utmost importance to avoid any damage to canalicular mucosa during this procedure. The curetted material is collected on a sterile surface (Fig. 15.13) or cotton-tipped applicator and sent for microbiological culture and sensitivity.

Following any of the two interventions, the patient is prescribed a broad-spectrum antibiotic eye drop (e.g., 0.3 % ciprofloxacin four times per day) and is subsequently altered according to the results of the microbiology culture and sensitivity report.

Conservative treatment with topical antibiotics is associated with a high recurrence rate as high as 41 % [3, 4]. Canalicular curettage after canaliculotomy or punctoplasty carries a high resolution rate and is the procedure of choice [2–4, 10, 31, 33]. Occasionally a repeat procedure may be required to manage recurrences. However, canaliculotomy can result in canalicular luminal narrowing or scarring, lacrimal pump dysfunction, and canalicular fistula formation [6, 31, 33]. In contrast, curettage through the punctum is a less invasive procedure and preserves the lacrimal pump function [31, 33].

In conclusion, a high index of suspicion is needed for the diagnosis of canaliculitis. The microbiological profile of canaliculitis seems to be evolving with staphylococcus emerging as the most common isolated species in Southeast Asia. Punctal dilatation with canalicular expression, though is effective in few patients, is more commonly associated with persistence of the disease. Punctoplasty with canalicular curettage is more efficacious with high success rates. In recurrent and persistent cases, conservative treatment is best avoided, and canalicular curettage should be done in all such cases to achieve a complete resolution.

Acute Dacryocystitis

Dacryocystitis is inflammation of the lacrimal sac which can be chronic or can present as an acute condition due to secondary infection of the stagnant tear secretions [34, 35]. Dacryocystitis is generally due to obstruction of the nasolacrimal duct, which can be congenital or acquired. However, it is uncommon to have acute dacryocystitis associated with congenital nasolacrimal duct obstructions. Rarely a dacryopyocele may be the presenting feature. Details of these infections have been dealt with in the Chap. 12.

In this section, we shall discuss acute infective dacryocystitis.

Definition

Acute dacryocystitis can be defined as “a medical urgency which is clinically characterized by rapid onset of pain, erythema and swelling, classically below the medial canthal tendon with or without preexisting epiphora mainly resulting from the acute infection of the lacrimal sac and perisac tissues” [34] (Fig. 15.14).

Epidemiology

Epidemiology of acute dacryocystitis is not very well known. It constitutes 2.4 % of all lacrimal disorders with a female preponderance (2:1), usually noted in the 3rd–5th decade, although it can affect any age and is predominantly unilateral (91.6 %) [34].

Microbiological Profile

Although many microbiological studies are available for chronic dacryocystitis, very few looked at the acute ones [36–38]. The microbiologic spectrum of acute dacryocystitis in 21 patients found gram-positive organisms to be the most common with *Staphylococcus aureus* as the most common organism isolated from cultures [36]. In contrast, Razavi et al. [37] concluded that there are significant differences in the isolates between acute dacryocystitis and chronic dacryocystitis, although the study did not show much difference and the sample size of acute cases was only 12 patients. In the largest study on microbiological profile of lacrimal abscess ($n=100$) [38], gram-positive cocci (GPC) were the most common isolates (56 %) followed by gram-negative bacilli (GNB) (30 %) (Figs. 15.15 and 15.16) and gram-positive bacilli (3 %). Among the gram-positive cocci, the most common isolates were *Staphylococcus aureus*, *Streptococcus pneumoniae*, and *Streptococcus pyogenes*. *Haemophilus influenza*, *Escherichia coli*, and *Pseudomonas aeruginosa* were the common gram-negative bacilli [38]. Occasionally rare organisms like *Cardiobacterium hominis* had been implicated in the pathogenesis of acute dacryocystitis [39].

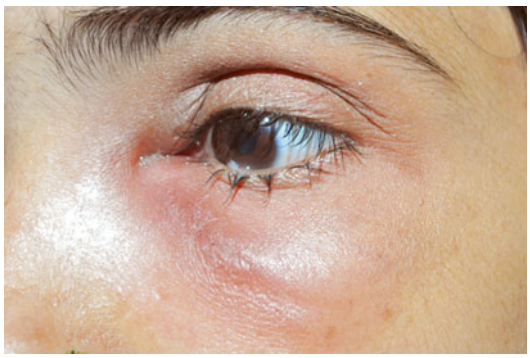

Fig. 15.14 Clinical presentation of acute dacryocystitis

Clinical Presentation

There is a varied spectrum of its clinical presentations ranging from tenderness and erythema of the overlying tissues to a frank lacrimal

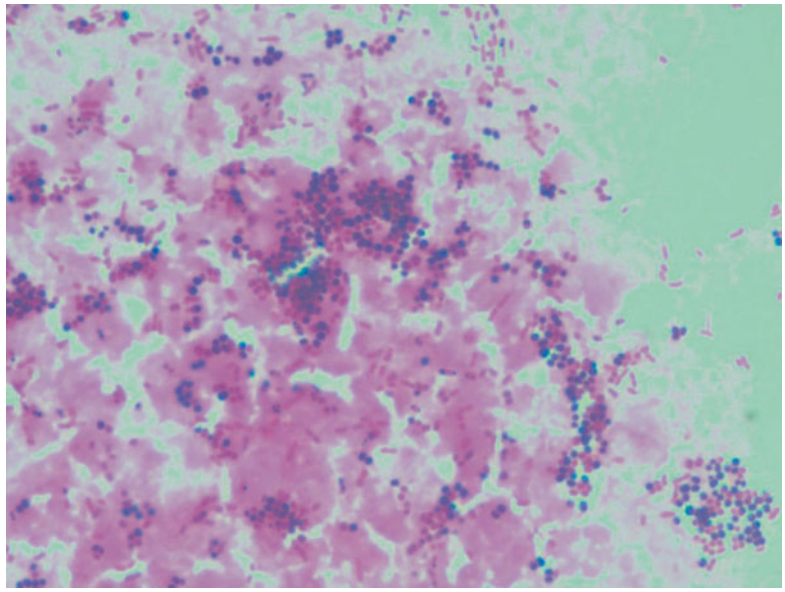

Fig. 15.15 Mixed infection with GPC and GNB

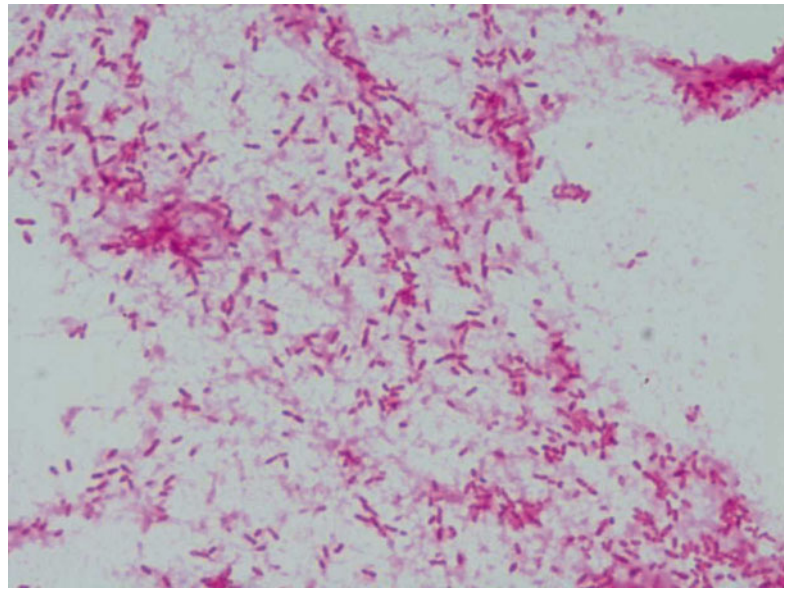

Fig. 15.16 GNB on a smear

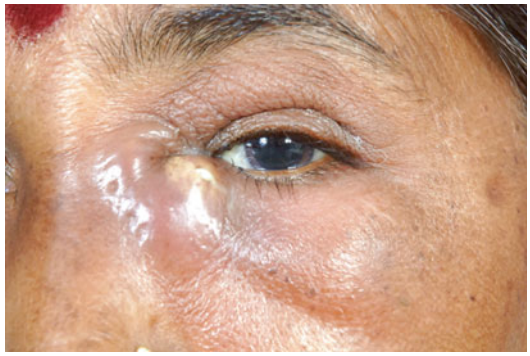

Fig. 15.17 Acute dacryocystitis with lacrimal abscess

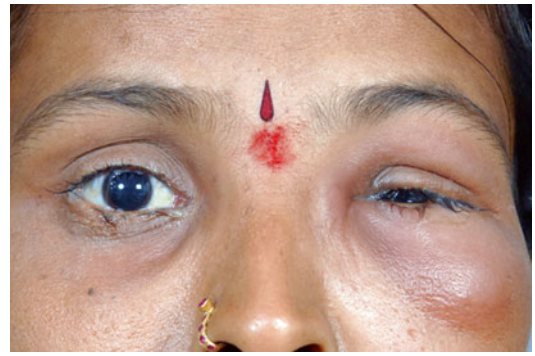

Fig. 15.18 Acute dacryocystitis with orbital cellulitis

abscess [34–45]. Generally, patients present with pain and swelling in the lacrimal sac area with a tender induration below the medial canthal tendon, epiphora with or without a palpable distended lacrimal sac, and regurgitation of purulent material from the puncta (Fig. 15.14) [34–45]. In the largest series on acute dacryocystitis ($n=347$), swelling in the lacrimal sac region was noted in 84 with 83 % of patients complaining of pain. Erythema and redness were noted in 48 %, discharge in 40 %, lacrimal abscess in 23 % (Fig. 15.17), orbital cellulitis in 3 % (Fig. 15.18), and constitutional symptoms like fever in 6 % of patients [34]. Occasionally lacrimal fistula may be the presenting feature secondary to spontaneous drainage of lacrimal abscess (Fig. 15.19) [34].

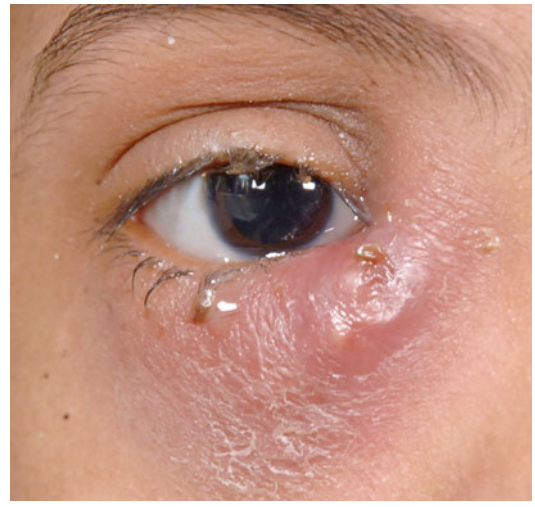

Fig. 15.19 Acute dacryocystitis with lacrimal fistula

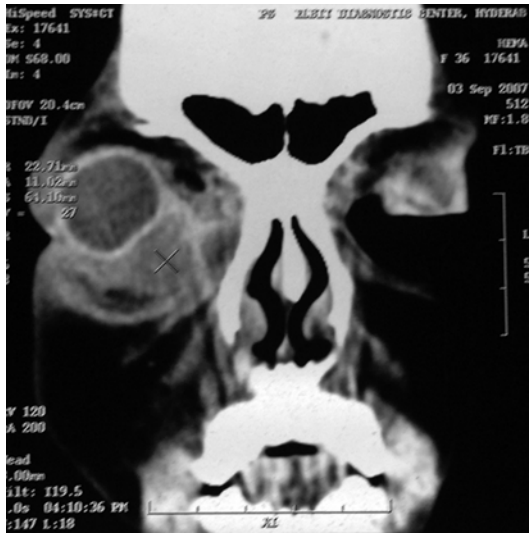

Fig. 15.20 Coronal CT photograph of the right orbital abscess associated with acute dacryocystitis

Orbital cellulitis following acute dacryocystitis is not common owing to numerous barriers that limit spread of an infection like the orbital septum, medial canthal ligaments, Horner's muscle, and Jones muscle [34, 44]. Breach of these barriers would provide the infection an unhindered access to the orbital tissues.

More advanced presentations in the form of orbital cellulitis with orbital abscess (Fig. 15.20), necrotizing fasciitis, superior ophthalmic vein thrombosis, cavernous sinus thrombosis, meningitis, and total vision loss have also been reported [34, 41–45].

Management

Conservative Medical Therapy

Acute dacryocystitis is a very painful condition which resolves slowly with systemic antibiotics [34–45]. *Conservative management* includes warm compresses, systemic antibiotics, and anti-inflammatory drugs. In a large series ($n=347$), only 4 % required an inpatient management, and the rest were treated on a day care basis [34]. All attempts should be made to control the acute attack medically. In a large series from Southeast Asia, gram-positive isolates were susceptible to penicillins and cephalosporins and most of the gram-negative isolates to quinolones [38]. Appropriate antibiotic should be chosen based on the common regional isolates and their sensitivity profiles. The mean time to resolution is around 7–10 days, and 6 % relapsed before a definite surgical therapy could be performed, mostly due to delays in seeking treatment or long waiting period [34, 38].

Causes of nonresolving acute dacryocystitis include the following:

- Progression to lacrimal sac abscess
- Virulent organism
- Antibiotic resistance
- Persistent aggressive inflammation

Disadvantages of continuous conservative management in suboptimal response are as follows:

- Prolonged/recurrent infection leading to orbital cellulitis and cavernous sinus thrombosis
- Adverse effect of antibiotic due to prolong and repeated usage
- Cutaneous scar/fistula – most commonly in patients with spontaneous rupture of abscess
- Failure of surgery due to scarring and granulation in the lacrimal sac

Surgical Management

The surgical modalities include drainage of lacrimal or orbital abscess and dacryocystorhinostomy (DCR) after resolution of acute infection [34–45].

The results of external DCR are quite good when done by an appropriate method. In the largest reported DCRs following resolution of acute attack ($n=264$), 70 % required bicanalicular intubation [34]. At 1-year follow-up after removal of stents, anatomical success was achieved in 94.3 % and functional success in 93.5 % of the patients. Of the 15 failures, who underwent a revision external DCR with MMC and intubation, 73 % reported anatomical success [34]. Endoscopic dacryocystorhinostomy in acute dacryocystitis is gaining wider acceptance as a promising modality of management [46, 47]. It can be a good option not only following resolution of acute phase, but could have potential use

in an acute clinical setting of cases which either do not resolve or show suboptimal response following medical management. More data and longer follow-up of these patients are required to validate the usefulness of endoscopic DCR in acute dacryocystitis.

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Lacrimal Trauma and Its Management

16

Gangadhara Sundar

Introduction

> Laughter and tears are both responses to frustration and exhaustion. I myself prefer to laugh, since there is less cleaning up to do afterward. ~Kurt Vonnegut

Injury of the lacrimal drainage apparatus, usually in the form of canalicular lacerations, are relatively common in periorbital and facial trauma [1, 2]. This is most frequently encountered in otherwise young healthy males, although it may be seen in young children, the women, and the elderly. Less frequently encountered is injury of the nasolacrimal duct, usually in midfacial and naso-orbit-ethmoid (NOE) fractures [3]. The incidence of lacrimal system injuries has been reported to vary from 7 to 20 % depending upon the mechanism of the injury and reporting [2]. Failure to recognize and manage lacrimal injuries is one of the common complications of eyelid/midfacial injuries. I shall herewith outline the predisposing factors and evaluation of the patient and discuss details of principles and mechanisms of management including long-term follow-up.

G. Sundar, DO, FRCSEd, FAMS
Orbit and Oculofacial Surgery,
National University of Singapore, Singapore, Singapore
e-mail: gsundar1@yahoo.com

Etiopathogenesis

While most injuries arise from mechanical trauma, from either direct or indirect injuries, including avulsions, other forms of trauma include thermal (industrial or domestic fires), chemical (industrial or domestic vitriolage), drug induced (chemotherapeutic agents: 5-fluorouracil, paclitaxel, docetaxel, etc.), and radiation trauma (external beam radiation for head and neck tumors), including beta irradiation (in the past, for pterygium surgery) (Table 16.1) [4, 5]. Canalicular lacerations in children may result either from broken spectacle lenses (Fig. 16.1), from blouse hooks (developing nations), or not infrequently from animal bites (dogs) [6, 7]. Most young adults are affected either as blunt high-impact injuries (industrial, motor vehicle accident, assaults) when they are usually associated with varying degrees of naso-orbital-ethmoid (NOE) fractures (Fig. 16.2) [3]. In general, the lower canaliculus is more likely to be injured either related to the location or the ability to be avulsed by hooks and similar objects. Fractures of the midface (NOE, Le Fort II and III) also may involve the lacrimal sac fossa and nasolacrimal duct resulting in bony and occasionally soft tissue nasolacrimal duct disruption [3]. While most patients remain asymptomatic, late obstructions of the canaliculus or nasolacrimal duct are not uncommon and quite challenging to manage as well [3].

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Table 16.1 Etiology of lacrimal drainage system trauma (Wulc and Arterberry [4], Jordan et al. [5])

1. Mechanical
(a) Penetrating
(i) Direct: lacerations from sharp objects
(ii) Indirect: lacerations from high-impact blunt objects: punch, hard balls and objects, blunt weapons, etc.
(b) Avulsions
2. Thermal
3. Chemical
(a) Vitriolage and domestic or industrial accidents
(b) Chemotherapeutic agents: 5-FU, paclitaxel, docetaxel, etc.
4. Radiation
(a) External beam radiotherapy, IMRT
(b) Beta irradiation (historical)
5. Iatrogenic: multifactorial:
(a) Accidental:
(i) Mechanical (direct (cuts) or indirect (avulsions – aggressive retraction during orbital surgery), false passage, mucosa tear with traumatic probing)
(ii) Thermal (electrocautery, lasers, etc.)
(iii) Chemical (3 b)
(iv) Radiation (4a, b)
(b) Intentional, e.g., punctal or canalicular thermal cautery or surgical closure for dry eye management

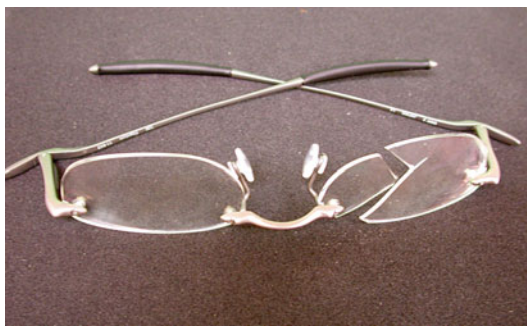

Fig. 16.1 Broken glasses in lacrimal trauma

Classification

Lacrimal system trauma may be classified based on anatomical structures involved or the mechanisms of injury. Based on the anatomic structures, it is further classified as bony or soft tissue trauma. Injuries may involve the lacrimal puncta

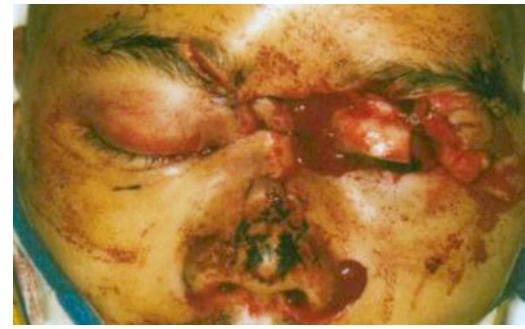

Fig. 16.2 Eyelid and canthal lacerations with underlying NOE fracture

at the eyelid margins; the vertical or more commonly the horizontal component of the canaliculi, usually the lower or the common canaliculus (most frequent); the lacrimal sac; and lastly the bony nasolacrimal canal and nasolacrimal duct (second most frequent). Table 16.1 reflects Wulc and Jordan's classification of lacrimal drainage system trauma [4, 5].

Clinical Features

As stated above, the frequency of involvement of the lacrimal drainage apparatus structures from most frequent to least frequent is as follows: canaliculus (lower, upper, and bicanalicular), nasolacrimal duct, lacrimal sac, and finally lacrimal puncta.

Most patients are diagnosed based on a high degree of suspicion [8–13]. The general principle of eyelid lacerations is that all eyelid lacerations medial to the puncta involve the canaliculus (canaliculi) until proven otherwise (Fig. 16.3). Thus, the onus is upon the trauma physician or Ophthalmologist to diagnose and plan the management accordingly. Likewise, in all patients with facio-maxillary trauma, an evaluation of the CT scan for evidence of bony nasolacrimal duct disruption (Figs. 16.4, 16.5, and 16.6) should prompt the Ophthalmologist to consider lacrimal irrigation to confirm patency of the drainage system, either immediately before facial fracture repair or after reduction of the NOE fragments but before plating of the involved bones. In the acutely traumatized patient, tearing and fluorescein dye

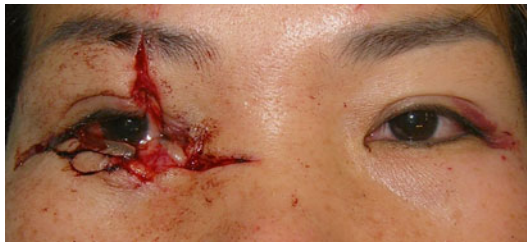

Fig. 16.3 Upper and lower eyelid with medical canthal lacerations

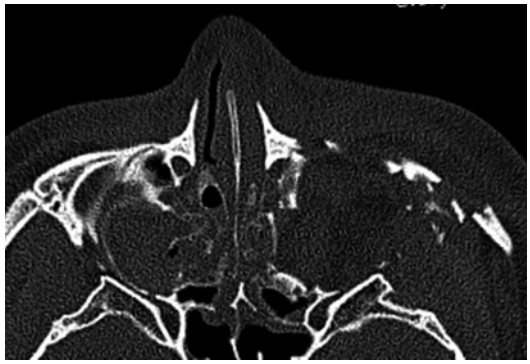

Fig. 16.4 CT scan, axial cut, and bony window, showing a left bony NLD fracture

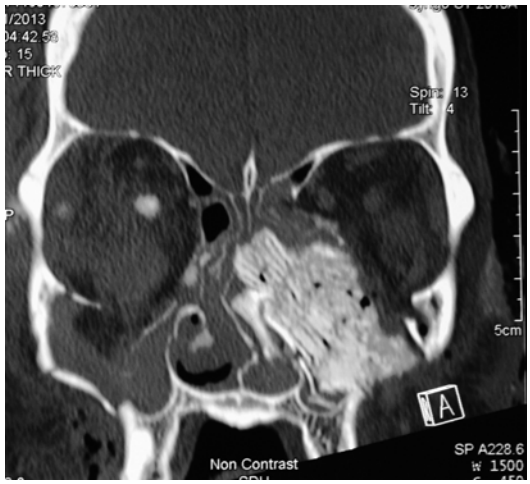

Fig. 16.5 CT scan and coronal cut showing bony and soft tissue NLD disruption following a blast injury

disappearance test are generally unhelpful and unreliable owing to the false-positive results from edema resulting in drainage dysfunction [8–13].

After stabilization of the patient to rule out poly trauma, intracranial injury, cervical spine stabilization, and underlying globe injury, a preliminary examination of the medial upper and lower eyelids under magnification/slit lamp and medial canthal region without infiltrative anesthesia is recommended, partly to confirm the diagnosis and also to help identify distal cut end of the canaliculus. Gentle probing under topical anesthesia is usually well tolerated (Fig. 16.7). The classic clinical "calamari ring" sign (Fig. 16.8), a white collagenous ring surrounded by bloodstained soft tissue, is obvious once local hemostasis is secured with ice packs and analgesia prior to examination. This

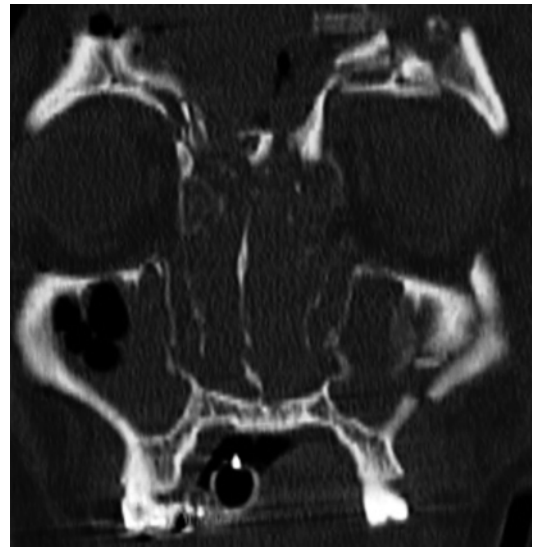

Fig. 16.6 CT scan, coronal cut, and bony window, showing bilateral bony NLD fracture

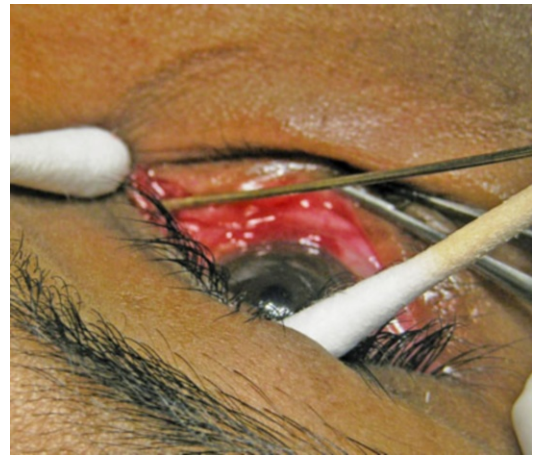

Fig. 16.7 Probing the distal cut end

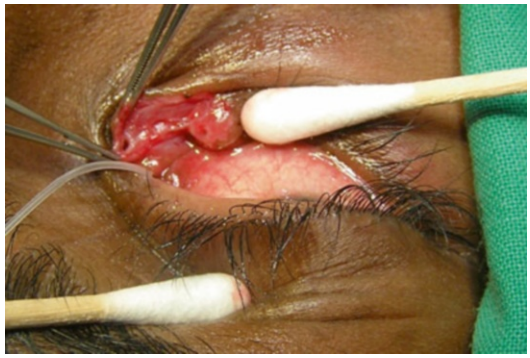

Fig. 16.8 Calamari sign

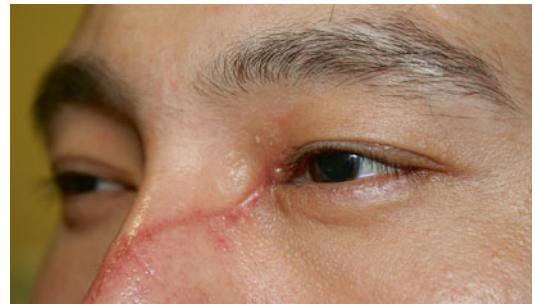

Fig. 16.9 Acute dacryocystitis following NOE fracture

helps counsel patients accordingly and plan treatment. Inexperienced Ophthalmologists may also diagnose a canalicular laceration upon lacrimal irrigation through the puncta (upper and lower separately) when extravasations of the irrigant fluid are visualized, prompting an exploration in the operating room under either local or general anesthesia.

Nasolacrimal duct injuries may be either bony duct fractures alone with intact soft tissue duct or obvious disruption of both (Figs. 16.2, 16.5, and 16.6) [3, 14–18]. Following a radiological examination of fine-cut CT from the lacrimal sac fossa down to the inferior turbinate, lacrimal irrigation may be attempted on the operating table after nasal decongestion to confirm the same. Direct visualization of fluorescein either under the inferior meatus or site of disruption is usually aided by a rigid nasal endoscope.

A late diagnosis of disruption of the lacrimal system is made on an asymptomatic patient based on the clinical history, positive fluorescein dye disappearance test, or lacrimal irrigation and probing under topical anesthesia (Fig. 16.7) to confirm the presence of either a soft stop (canalicular obstruction) or hard stop (nasolacrimal duct obstruction). Symptomatic patients often present with wet, teary eye with or without epiphora (overflow) with the constant need to wipe their tears to clear their vision. A Bowman probe or straight lacrimal cannula usually helps confirm the extent and location of the canalicular obstruction. Regurgitation of either clear fluid or mucus with a hard stop usually helps confirm a nasolacrimal duct obstruction. Occasionally mucocele or acute dacryocystitis may be noted late in the course (Fig. 16.9). Not infrequently an obvious scar involving the eyelid margin medial to the punctum and medial canthal area and lateral displacement of the upper or lower puncta are telltale signs of canalicular obstruction.

Diagnostic Evaluation

Apart from clinical examination either at the bedside or at the slit lamp, the following investigations may be indicated based on the presentation. As mentioned earlier, review of CT scans of the face (fine cuts) for evidence of NOE fracture, disruption of the lacrimal sac fossa, and bony nasolacrimal duct down to the inferior meatus is warranted, emphasizing the need for a CT with three-dimensional reconstruction of the whole face in most orbital fractures [3, 14–18]. MRI is contraindicated in the acutely traumatized patient unless magnetizable foreign bodies have been ruled out, for example, gunshot pellets (Fig. 16.10). A CT scan is also useful in patients presenting late with tearing with or without discharge to diagnose the underlying bony deformities including diastasis, nonhealing fractures, and hyperostosis or not infrequently to confirm the location of the metallic plates and screws (Fig. 16.11) which may confound lacrimal bypass surgery. Rarely, a DCG or a CT dacryocystography (CT-DCG) may also be indicated to confirm the site of obstruction and alternative drainage path as well (Fig. 16.12).

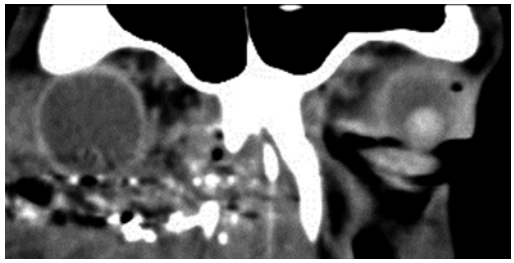

Fig. 16.10 CT scan and coronal cut showing numerous gun pellets and disruption of NLD

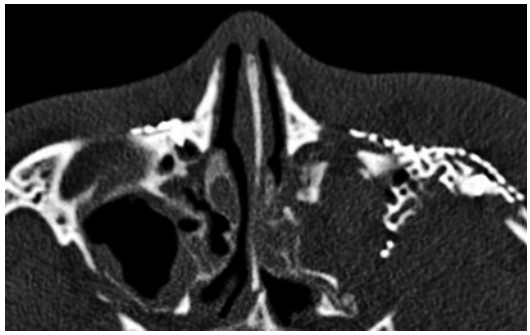

Fig. 16.11 CT scan, axial cut, and bony window, showing titanium screws near NLD

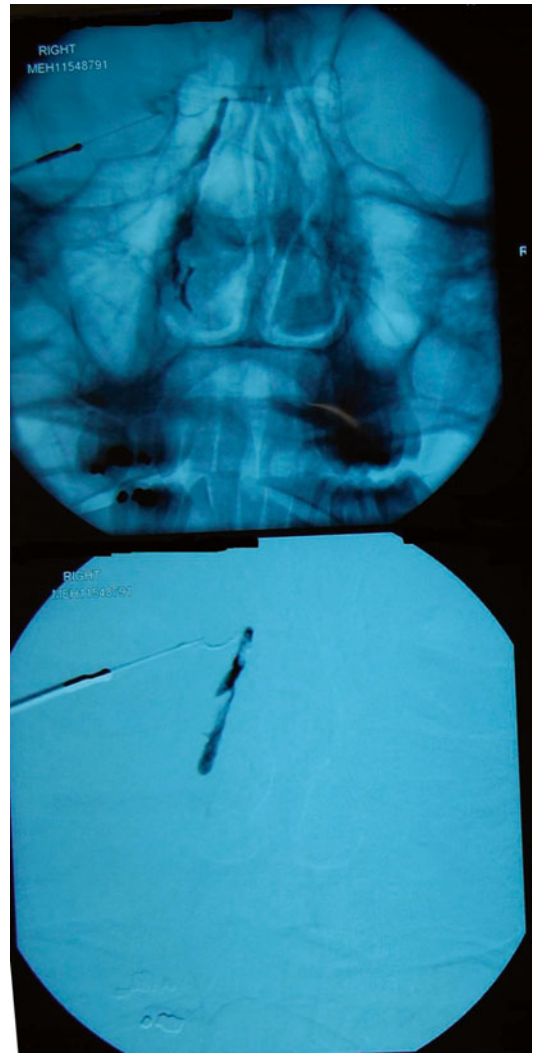

Fig. 16.12 DCG showing a right distal NLD obstruction

Management

Canalicular Lacerations

The driving principle behind managing canalicular lacerations is that wound healing by primary intention (early primary repair) is always better than secondary intention or late repair [8–13]. While in the past the indication for intervention of a monocanalicular laceration was controversial, it is now well recognized by most orbito-facial surgeons that all canalicular lacerations warrant primary repair, whether they are upper or lower. Canalicular laceration repairs are not true emergencies and may be optimally performed in a controlled environment within 24–48 h, although on rare occasions a successful repair may be done as late as 4–5 days. Adequate anesthesia, magnification, and illumination are essential. Most patients with bicanalicular injury (Figs. 16.13 and 16.14) or avulsion injuries (Fig. 16.15) require bicanalicular intubation and thus better performed under general anesthesia. Local anesthetic infiltration

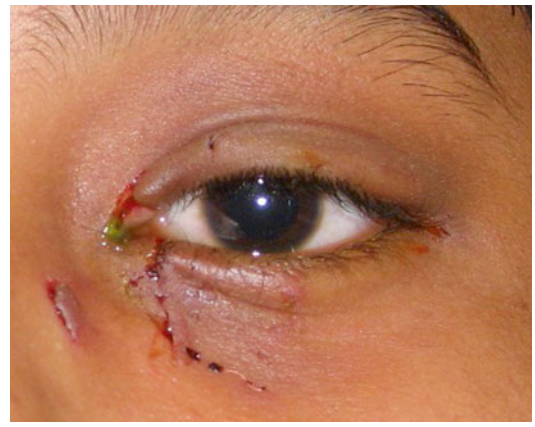

Fig. 16.13 Bicanalicular laceration

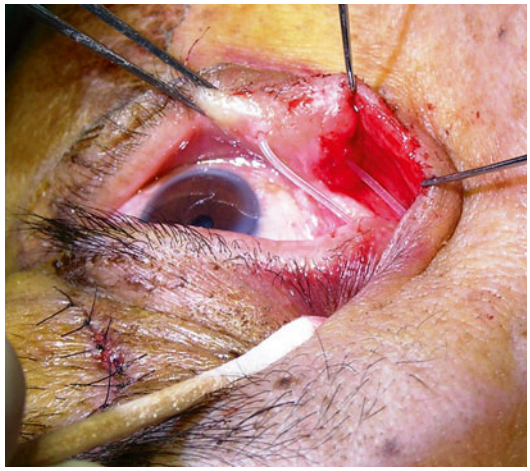

Fig. 16.14 Upper and lower canalicular injury being repaired

Fig. 16.15 Avulsion injury. It is important to rule out underlying fractures

in the medial canthal area may distort or disrupt surgical anatomy and may interfere with identification and repair. It may be considered only in simple direct canalicular lacerations or when general anesthetic is either contraindicated or unavailable. Magnification may be either with surgical operating loupes or the operating microscope. The author prefers the operating loupes as they are versatile and adaptable to eyelid, lacrimal, orbital, and facial reconstruction with angulated viewing when necessary, especially in the medial canthal area or within the nasal cavity. The ENT or neurosurgical microscope is often more useful than a vertically oriented ophthalmological microscope for the same reason. Illumination may be either in the form of "headlights" or from the operating microscope.

Intubation Systems in Lacrimal Trauma

The intubation systems in lacrimal trauma can be broadly divided into bicanalicular and monocanalicular ones. The advantages and disadvantages of each are summarized in Table 16.2.

Bicanalicular Intubation Systems

The following intubation systems are currently available and used based on availability and surgeons' preference:

Table 16.2 Comparison of bicanalicular and monocanalicular stents

	Advantages	Disadvantages
Bicanalicular stent	Familiarity of surgeon	Requirement for general anesthesia
	Ease of use	Potential injury to unaffected canaliculus
	Ready availability	Removal requires training/experience
	Less expensive	
	Medical canthal approximation	
	Bicanalicular repair possible	
	Prolapsed tube does not result in tube/stent loss	
	For intubating the lower lacrimal system	
Monocanalicular stent	Simpler to use	Poor medial canthal approximation
	Can be performed under local anesthesia	Poor anchoring with large, dilated puncta
	Easy removal	Easily removed and lost when not secure
	Performed even in patients with single punctum/canaliculus	More expensive

Crawford bicanalicular intubation system with olive tip and Crawford hook (Fig. 16.16)
Ritleng bicanalicular intubation system with hook (Fig. 16.17)
Large diameter STENTube (Fig. 16.18)
Others: Quickert-Dryden tube, Guibor tube, and Jackson intubation systems
Beyer's modified pigtail probe: This has a French eye at the tip (as opposed to the fishhook-ended Worst pigtail probe that is not recommended) (Fig. 16.19)
Two separate monocanalicular stents: Mini-Monoka or Crawford-Monoka [19]

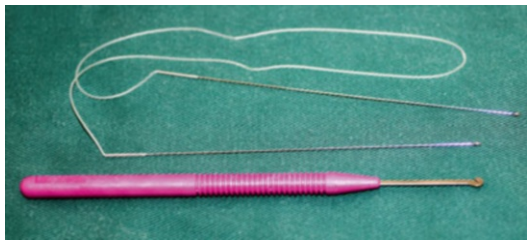

Fig. 16.16 Crawford stents with retrieval device

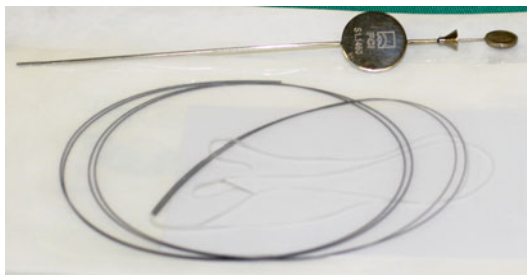

Fig. 16.17 Ritleng intubation

Monocanalicular Intubation Systems

Historical (Veirs rods, modified Venflon catheters, etc.): Generally not recommended
Monocanalicular stents: Monoka, Mini-Monoka, and Crawford-Monoka (Fig. 16.20)

Steps in the Surgical Management of Lacrimal Canalicular Lacerations

1. Stabilization of the medical status of patients and evaluation for serious vital organ injury (life, brain, eye, etc.).
2. Optimization and fitness for anesthesia, general anesthesia if possible.
3. Apply ice packs to the medial canthal area to minimize bleeding and edema and pain relief as well.
4. Nasal decongestion is preferable.
5. Attempts should be made overall to minimize iatrogenic trauma, dissection, and cautery and to prevent any further disruption of the medial canthal area.
6. *Tips to identify cut end of canaliculus:* In most cases, direct visualization under magnification, illumination, and gentle retraction of the wound with approximation of the lateral eyelid margin to the medial canthal area will guide the surgeon towards localizing the cut end of the canaliculus (Fig. 16.21). The "calamari ring" sign (Fig. 16.8) is a very reliable clinical sign in most patients, better seen several hours after the initial injury when active bleeding has stopped. As the lacrimal punctum is the narrowest part of the drainage system, the canaliculi are usually

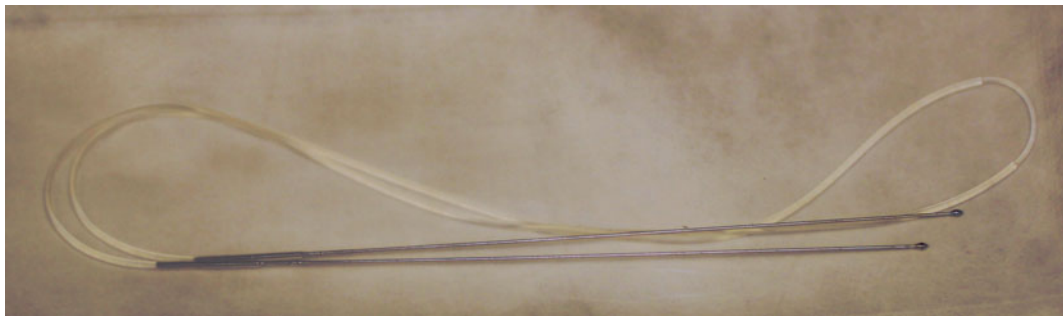

Fig. 16.18 Large diameter StenTube

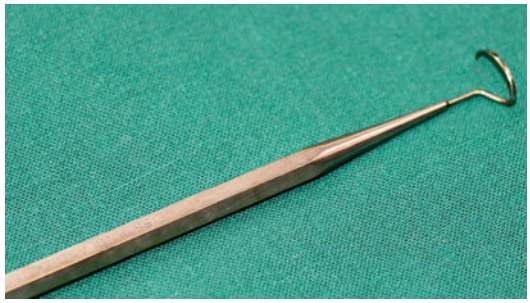

Fig. 16.19 Pigtail probe

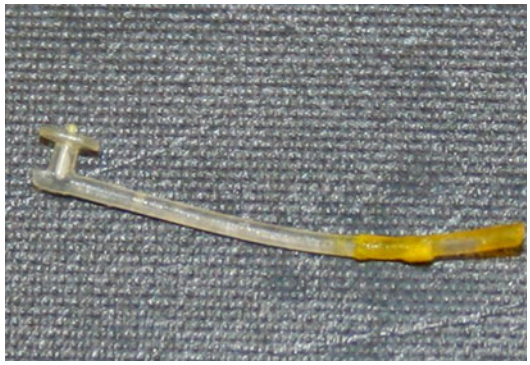

Fig. 16.20 Mini-Monoka stent

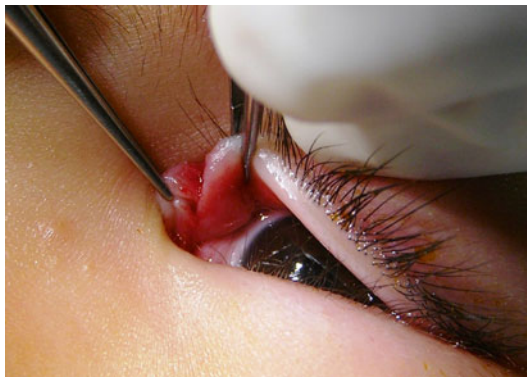

Fig. 16.21 Approximation of eyelid margins in efforts to locate canalicular cut ends

large and easily visible to the experienced surgeon unless the primary team has traumatized them by performing cautery or surgery in that region. Once identified, a Bowman probe is gently passed into its lumen to confirm a "hard stop."

Pigtail probe: Alternative technique includes the use of a nontraumatic pigtail probe (Fig. 16.19) through the other punctum,

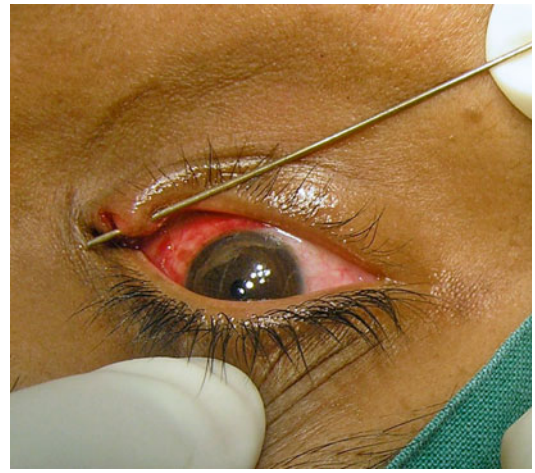

Fig. 16.22 Probing the proximal canaliculus

canaliculus, and proximal common canaliculus [20, 21]. It is to be remembered that common canaliculus may not be present in all the cases as in some the canaliculi enter the sac independently and thus make this technique unfeasible [12]. Even in experienced hands the pigtail probe is sometimes difficult to use to help identify the cut end and more importantly may cause iatrogenic injury to the lacrimal system. Thus, this technique is indicated in patients where general anesthesia is not possible and intubation of the upper lacrimal system alone is desired. It is not advisable in inexperienced hands and involvement of the lower lacrimal system.

Injecting viscoelastic "milk," air, fluorescein, methylene blue, etc. has also been reported but often not used owing to the variability of results and dense staining of the entire wound with the latter. The author believes that the cut ends of the canaliculus can almost always be identified, the only exception being severe blast injuries of the medial canthal region and face.

7. Once the cut end is identified, probing is performed gently to ascertain the patency of the tract (Fig. 16.22) followed by cannulation of the upper and lower canalicular system delivered endonasally from the inferior meatus either by tactile retrieval or preferably by direct visualization (Figs. 16.23 and 16.24).

Fig. 16.23 Bicanalicular intubation being retrieved from the nose

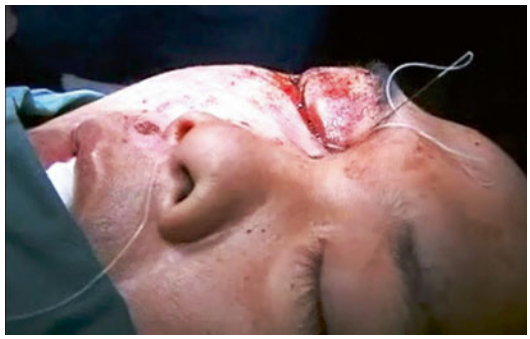

Fig. 16.24 Bicanalicular intubation in lacrimal trauma

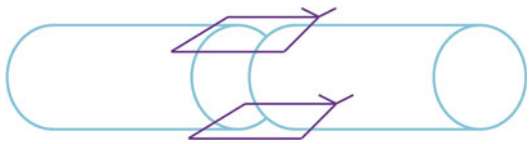

Fig. 16.25 Pericanalicular horizontal mattress sutures

8. The medial canthal tendon is gently approximated with 4–0 Vicryl sutures to ensure better approximation of the cut ends of the canaliculus. One of the various techniques of pericanalicular suturing may be employed. The author prefers a double horizontal pericanalicular mattress suture (Fig. 16.25), a modification of the "single-stitch" technique with delayed absorbable sutures (PDS) (6-0 for proximal and 5-0 for distal) followed by tightening of the medial canthus before repairing the eyelid margin using the standard technique [13]. Better approximation is facilitated by gentle traction on the bicanalicular stents while tying the pericanalicular suture knots, a distinct advantage over monocanalicular and annular ring intubation.

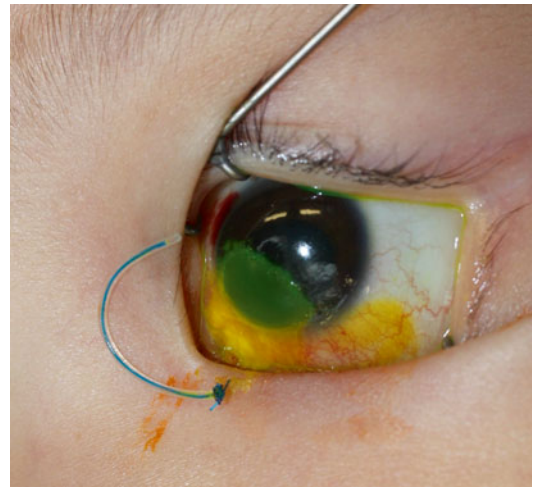

Fig. 16.26 Annular ring intubation with corneal abrasion

9. Securing the silicone stents: Most bicanalicular stents are secured, under gentle traction, below the inferior meatus. A small secure knot is essential if removal of the tube is to be performed by rotation of the knot through the canaliculi and puncta in the office under topical anesthesia. This is possible even in young children in an outpatient office setting without sedation or anesthesia. When multiple knots are placed, the tube may be removed only though the nasal cavity either by nasal speculum examination or nasal endoscopy, thus precluding the procedure in the office in children and uncooperative adults.

   When annular ring intubation is performed, the Prolene or nylon suture is tied within the lumen of the silicone stent and rotated into the lacrimal sac (Figs. 16.26 and 16.27).

   When Mini-Monoka or Crawford-Monoka stents are used, the nubbin at the proximal end secures its position at the vertical part of the canaliculus and the tip lying flat against the eyelid margin.
10. *Duration of stenting:* In general, while the wound healing occurs by primary intention, pericanalicular wound continues to mature and wound contraction continues for a few

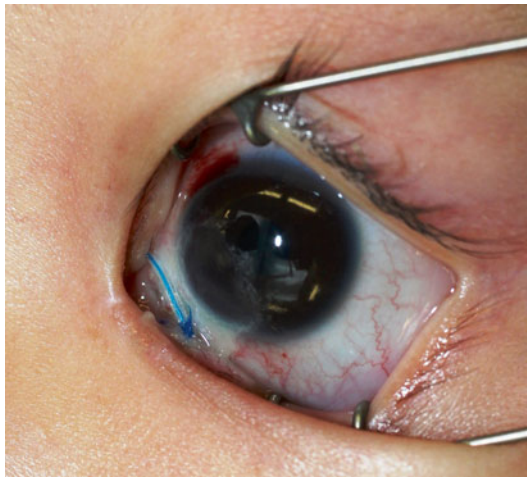

Fig. 16.27 Annular ring intubation with corneal abrasion

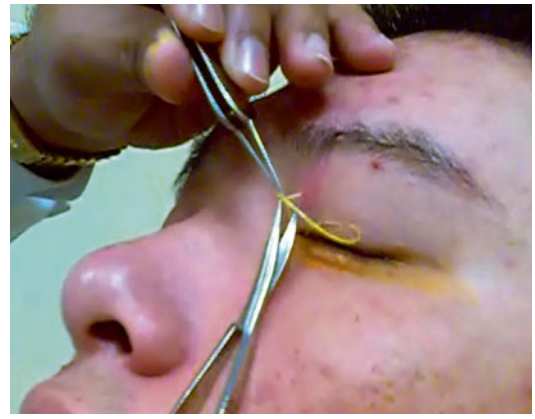

Fig. 16.28 Transocular stent removal

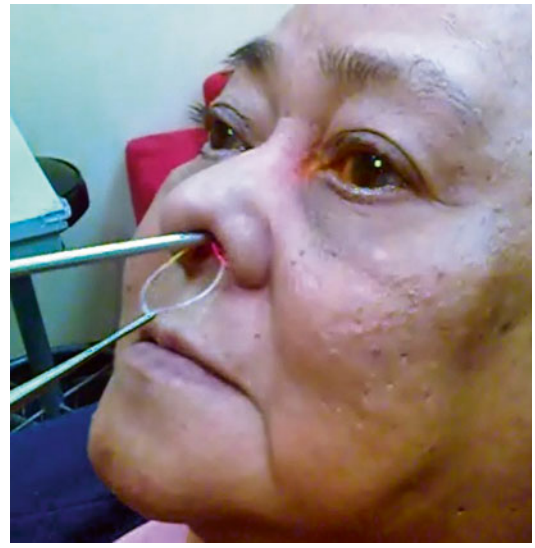

Fig. 16.29 Transnasal stent removal

months. For this reason, the author generally leaves both monocanalicular and bicanalicular stents for up to 3 months unless the patient is very symptomatic or accidentally pulls the tube out.

11. *Postoperative management:* Most patients will require a tapering antibiotic-steroid eye drop in the initial 3–4 weeks postoperatively. Intraocular pressure may need monitoring for steroid response. Nasal decongestion may be prescribed for the first few weeks. Topical antibiotic cream is indicated for eyelid lacerations and continued for a week after suture removal. Systemic antibiotics are indicated based on the nature of the injury, e.g., animal bite, human bite, surgical knife, or industrial equipment.
12. *Silicone stent removal:* The author's preferred technique when no knots are placed is to simply pull the stent through the canaliculus not involved by the laceration (Fig. 16.28). When multiple knots are placed, the distal end is first visualized after nasal decongestion below the inferior meatus, the visualized loop cut at the medial canthal area and the nasal ends of the tube removed under direct visualization (Fig. 16.29). Annual ring extubation is performed by rotating the suture knot into the medial canthal area and then cut and the silicone-suture segment removed under topical anesthesia. Monoka stents are usually removed under direct visualization and topical anesthesia by removing it just like a punctal plug.
13. A fluorescein dye disappearance test with confirmation of fluorescein on nasal endoscopy and if necessary gentle probing and irrigation through the repaired canaliculus may be performed to confirm functional and anatomical patency (Fig. 16.30).
14. *Follow-up:* The author reviews the patient 6 weeks, 3 , 6 months, and then annually for 2–3 years when possible.

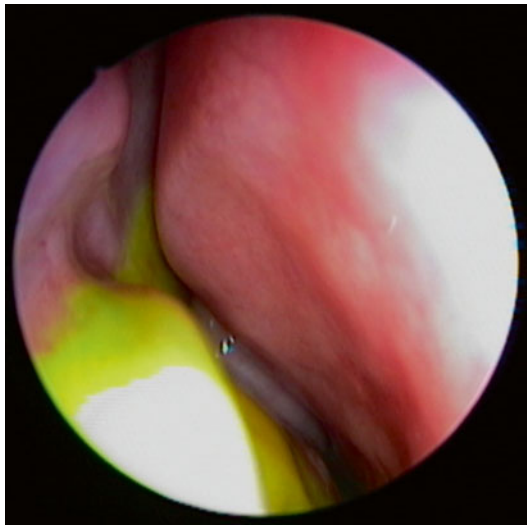

Fig. 16.30 Fluorescein dye test

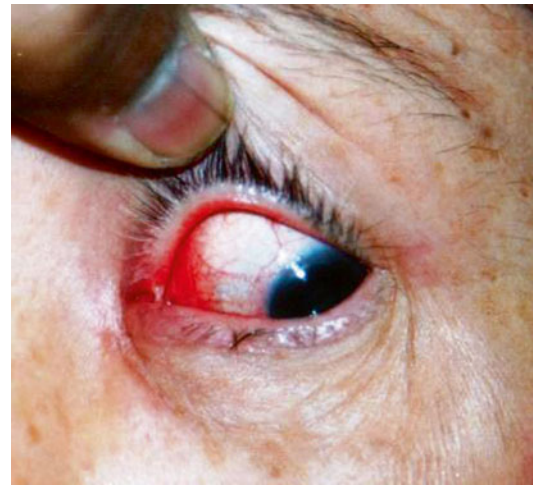

Fig. 16.31 Early pyogenic granuloma secondary to intubation

15. *Management of epiphora post-intubation:* Epiphora post-intubation may be related to the following reasons:
    (a) Edema in the perioperative period, which usually resolves within a few days.
    (b) Tearing secondary to the occlusion of the luminal cavity especially with large diameter stents that usually resolve after removal of the tube.
    (c) Persistent tearing and discharge in patients with a tight canaliculus (hypertrophic scarring, wound contraction, or healing by secondary intention). These may not resolve even upon removal of the tube and may warrant secondary procedures including balloon canaliculoplasty, canaliculo-DCR, or even conjunctivo-DCR when indicated.
16. *Management of tube-related complications:*
    (a) Prolapsed bicanalicular stents may be successfully reposited either by gentle repositioning into the lacrimal sac by reinsertion or through the nasal cavity and securing the knot. On rare occasions, if either of the above is not possible, the stent may have been removed (if more than several weeks post injury) or re-stented under local or general anesthesia (if early on) as indicated. Cheese wiring of puncta, canaliculi, and pyogenic granuloma (Fig. 16.31) may occur either because of a stiff, poor medical grade silicone, or tightly secured stents. In such cases early removal of the stents may be indicated to prevent migration of the stent in the lacrimal sac and prevent a dacryocystitis.

Nasolacrimal Duct Injuries

Bony fractures of the nasolacrimal duct are seen in 7–15 % of all facial traumas, and a small proportion of that result in soft tissue duct injury (Figs. 16.4, 16.5, and 16.6). Most authorities prefer a wait-and-watch approach and consider a dacryocystorhinostomy or conjunctivo-DCR at a later stage [3, 14–18]. While infrequently, performing a DCR or C-DCR in these patients is fraught with complications including high rates of failure, postoperative morbidity of chronic dacryocystitis, hyperostosis of the lacrimal sac fossa/bony nasolacrimal duct, and interference with surgery by the orbital/midfacial reconstruction plates/screws possibly warranting removal of the hardware prior to the DCR itself. Such situations may propel the surgeon to consider primary repair or intubation of the nasolacrimal duct.

In the author's extensive practice of orbital and midfacial trauma, all patients have evaluation of the bony and soft tissue ducts. When clear patency is established and minimal disruption or mobilization of the lacrimal fragments is expected, conservative management is a practice. In gross disruption of the lacrimal sac fossa/lacrimal duct or when major reduction and manipulations are expected, prophylactic bicanalicular intubation with the Crawford tubes is performed atraumatically. The tubes are left loose until all midfacial reconstruction is performed and finally tied below the inferior meatus by the standard technique. The tubes are left in place for 3–6 months before removal. Follow-up is as per canalicular lacerations as mentioned above.

Ali et al. [3] studied the nasolacrimal duct obstructions exclusively in patients with NOE fractures. They found that majority of the fractures were NOE type II (64.2 %) and most were repaired by open reduction and internal fixation prior to lacrimal surgery. The mean duration from trauma to presentation was 19.5 months with all patients having epiphora and half of them presenting additionally with a swelling below the medial canthus. All patients underwent a dacryocystorhinostomy (DCR) with mitomycin C and intubation with a success rate of 92.8 % at 6 months' follow-up after tube removal. In the absence of canalicular injury, DCR appears to be an effective modality of management in such cases, and delayed DCR does not appear to alter the outcomes.

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Primary External Dacryocystorhinostomy

17

Mohammad Javed Ali

Introduction

Dacryocystorhinostomy or DCR is among the common Oculoplastic surgeries performed for managing epiphora due to nasolacrimal duct obstruction [1, 2]. It is a bypass procedure that creates an anastomosis between the lacrimal sac and the nasal mucosa via a bony ostium. It may be performed through an external skin incision or intranasally with or without endoscopic visualization. This chapter will discuss the indications, goals, and simple techniques for a successful outcome of DCR.

Goals

There are two clear goals of DCR procedure. One is to make a large bony ostium into the nose and that remains so. Second is to have a mucosal lined anastomosis. Since both these purposes are equally well served by an external route, it can be one of the approaches with predictable and high success rates.

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute,
Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

Indications

(a) Persistent congenital lacrimal duct obstructions unresponsive to previous therapies
(b) Congenital lacrimal duct obstructions associated with mucocele, dacryocystitis, and fistula
(c) Primary acquired nasolacrimal duct obstructions (PANDO) [3]
(d) Secondary acquired nasolacrimal duct obstructions (SALDO) [4]

Preoperative Requisites

(a) Confirmation of the diagnosis and clinical findings
(b) Hemoglobin levels
(c) Bleeding and clotting times
(d) Blood pressure measurement
(e) Random blood sugars
(f) Additional general anesthesia investigations when required

Steps of the Surgery

Anesthesia

The surgery can be done under general anesthesia or local anesthesia [5]. The latter is the most commonly employed modality. Local anesthesia is given by both infiltration and topical application. For infiltration, 2 % lignocaine with

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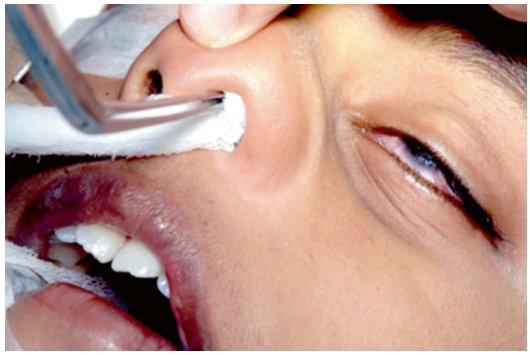

Fig. 17.1 Preoperative nasal packing

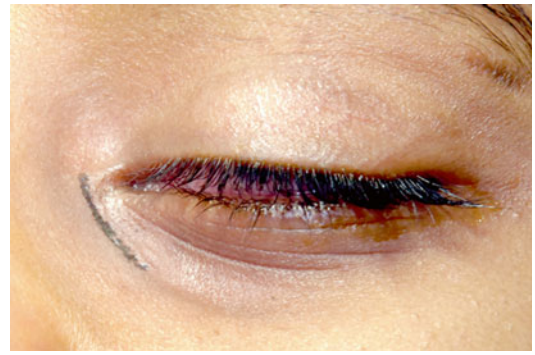

Fig. 17.2 A typical curvilinear incision

0.5 % bupivacaine with or without adrenaline is used. Infratrochlear nerve that supplies the lacrimal apparatus is blocked first. The nondominant hand marks the supraorbital notch, and the needle is inserted into the lateral edge of the medial third of the eyebrow and advanced to just medial to the medial canthus and 2 cc of the drug is injected. The tissues along the anterior lacrimal crest are infiltrated subcutaneously, and the needle enters deeper at about 3 mm medial to the medial canthus, and without withdrawing the needle, the drug is injected into the deeper tissues up to the periosteum both superiorly and inferiorly. A drop of topical proparacaine is placed in the conjunctival cul-de-sac for intraoperative comfort. The nasal mucosa is sprayed with 10 % lignocaine 1–2 puffs followed by packing with 4 % lignocaine and 0.5 % xylometazoline. Alternatively topical lignocaine spray along with topical xylometazoline can be used without packing the nasal cavity. The forceps should guide the medicated cottonoid from the external naris superiorly and backwards so that it reaches the middle meatus, the site of ostium (Fig. 17.1).

Incision

Though various incisions have been described, the authors prefer the commonly used curvilinear incision of about 10–12 mm in length, 3–4 mm from the medial canthus along the anterior lacrimal crest (Fig. 17.2).

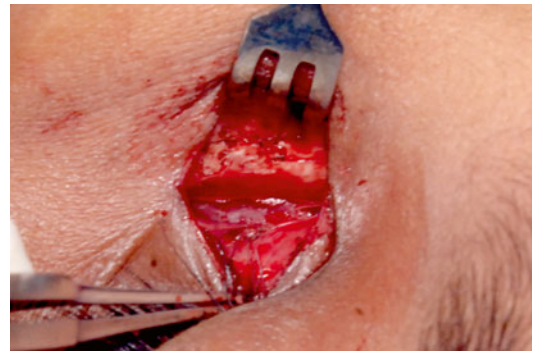

Fig. 17.3 Sac dissected laterally to expose the bony lacrimal fossa

Sac Dissection

Blunt dissection is carried on to reach the periosteum. A freer elevator is used to separate the periosteum from the bone and reflect it laterally along with the lacrimal sac to expose the lacrimal fossa. It is preferable to preserve the medial canthal tendon and dissect only when needed (Fig. 17.3).

Bony Ostium Creation

Once the lacrimal fossa is exposed, bone punching should be started at the junction of the lamina papyracea of the ethmoid and lacrimal bone. The kerrison bone punch should be gently inserted between the bone and the nasal mucosa

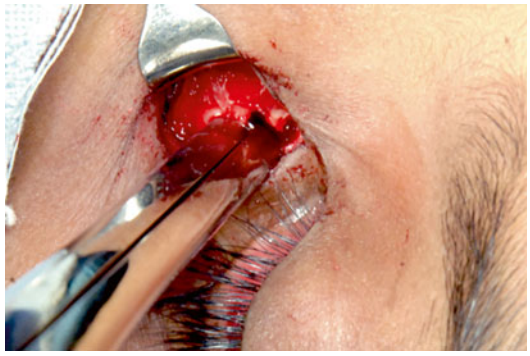

Fig. 17.4 Kerrison punch being used to create a bony ostium

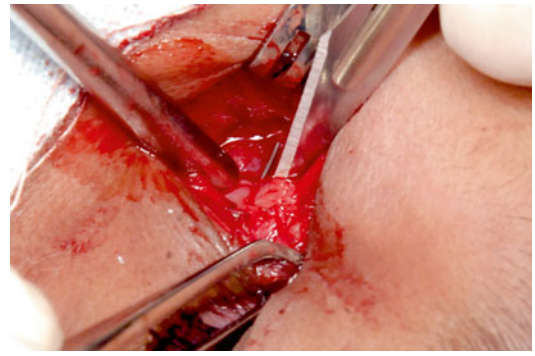

Fig. 17.6 Lacrimal sac incision being taken by a number 11 blade using the probe as a guide

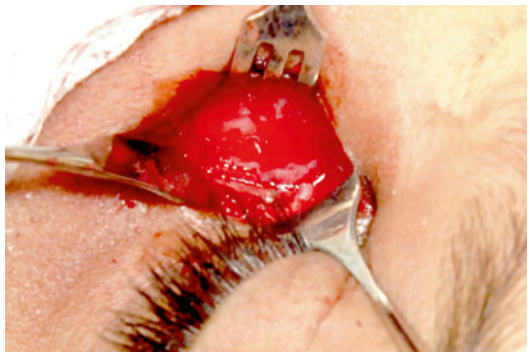

Fig. 17.5 A large bony ostium exposing the nasal mucosa

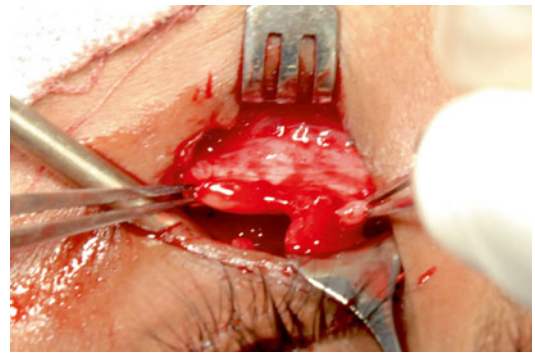

Fig. 17.7 Raising a large nasal mucosal flap

and the ostium sequentially enlarged (Figs. 17.4 and 17.5). The extent of the ostium which the authors follow is:

(a) Anteriorly till the punch cannot be inserted between the bone and the nasal mucosa
(b) Posteriorly till removal of the aerated ethmoid
(c) Superiorly till 5 mm above the common canaliculus
(d) Inferiorly till the nasolacrimal duct is de-roofed

Flap Formation

The first step is to create sac flaps. To do this a Bowman's probe is passed through the lower punctum and bent in such a way to tent the sac as posterior as possible to create a large anterior and small posterior flap. Alternatively, fluorescein-stained viscoelastic can be injected from the upper punctum to dilate the sac and help in creating flaps. Using the probe as guide, an "H"-shaped incision is made with the help of a number 11 or 15 blade right across the sac from the fundus to the nasolacrimal duct. Flaps are raised and the posterior one is cut (Fig. 17.6).

The second step is to fashion the nasal mucosal flaps. With the help of a number 11 blade, incisions are made in the nasal mucosa along the bony ostium except anteriorly to have a hinged flap. The large anterior flap is raised and the posterior small residual flap is cut (Fig. 17.7). Alternatively both the flaps can be sutured, but no significant difference in the success has been noted in doing this either way [6, 7].

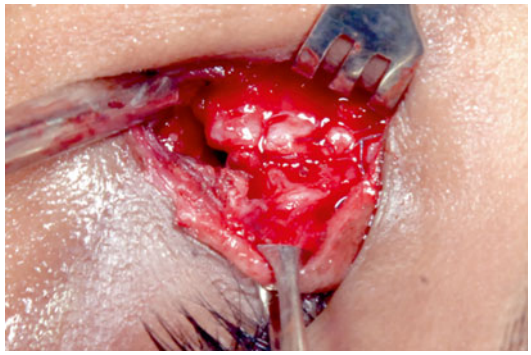

Fig. 17.8 Taut flap anastomosis

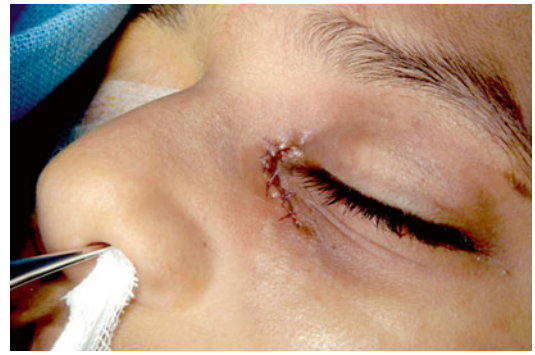

Fig. 17.9 Sutured surgical wound

Flap Anastomosis

It is important to appose the nasal mucosal and sac flaps edge to edge. Excess nasal mucosa can be excised in a controlled manner so as to avoid sagging of the flaps that may compromise the tear drainage later (Fig. 17.8). In case of overriding, the nasal mucosal overriding is preferable or alternatively one can tent the flaps and suture to the overlying orbicularis.

Wound Closure

Once flaps are secured, the orbicularis is sutured back with 6-0 Vicryl followed by the skin with 6-0 silk (Fig. 17.9).

Tips for Hemostasis

(a) Good preoperative assessment to rule out bleeding diathesis
(b) Preoperative blood pressure assessment
(c) Use of adrenaline or oxymetazoline patties along with local anesthetics provided there are no medical contraindications
(d) Good nasal decongestion before beginning
(e) Raising the head end of the table
(f) Avoid known blood vessels
(g) Well-powered suction

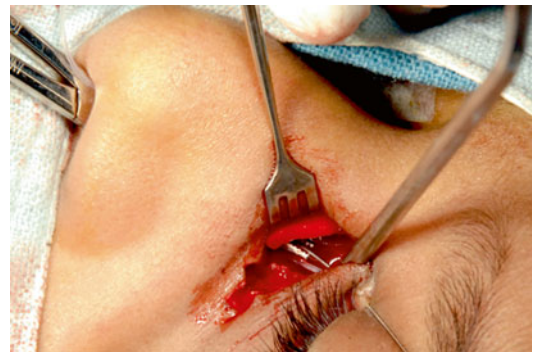

Fig. 17.10 Intubation: upper canaliculi intubated. The bodkins are being retrieved by a transnasal artery forceps

(h) Judicious use of cautery
(i) Keep materials like gel foam or bone wax in the armamentarium

Adjunctive Measures (Use of Mitomycin C and Intubation)

Mitomycin C in a concentration of 0.02 % is used if there are intra-sac synechiae and soft tissue scarring like in failed DCRs and in the presence of a complicated surgery. Intubation is also advisable for similar indications, but in addition, it is also used in the presence of canalicular problems and inadequate flaps [8] (Figs. 17.10, 17.11, and 17.12).

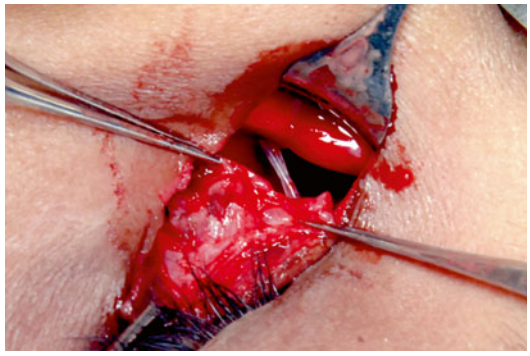

Fig. 17.11 Intubation: tubes in place before flap anastomosis

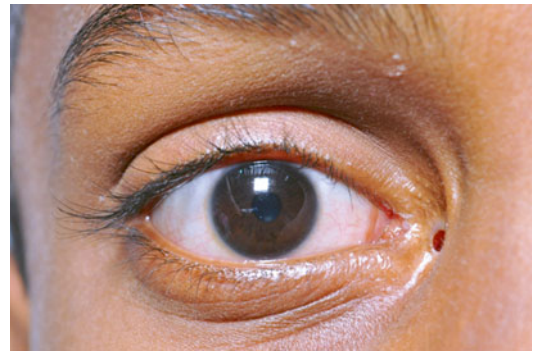

Fig. 17.13 Early wound dehiscence following an external DCR

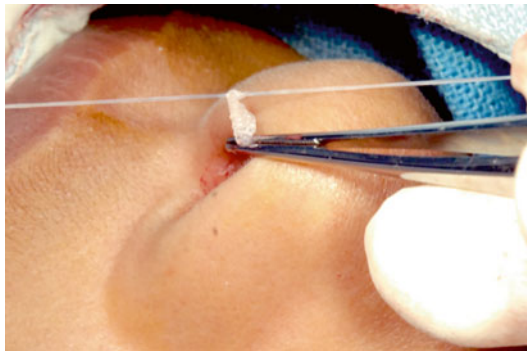

Fig. 17.12 Intubation: tubes being secured in the nose

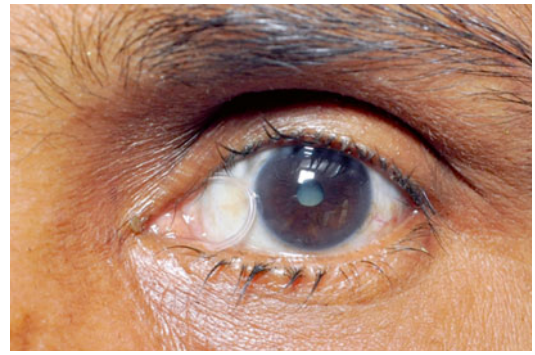

Fig. 17.14 An example of stent prolapse

Immediate Postoperative Steps

Once wound is closed, reassure the patient that the surgery went fine. Nasal packing is optional. When needed, it is important to note that the purpose of this pack is for hemostasis only, so deeper packing like preoperative one should be avoided for it risks damaging the flaps. The patient is placed on oral antibiotics and analgesics.

Follow-Up

After the surgery, the patient is seen on the first postoperative day. The nasal pack if any is gently removed and hemostasis assessed. The wounds are cleaned with 5 % Betadine, and the patient is advised oral antibiotics and analgesics, topical antibiotics and steroids, and nasal decongestants. One week postoperative, the sutures are removed, oral medications discontinued, topical steroids tapered, and nasal medications continued for two more weeks. The patient is reviewed at 6 weeks for stent removal, if any.

Complications

Complications following external DCR surgery can be divided as early (1–4 weeks), intermediate (1–3 months), and late (>3 months) [1–3].

Early complications include wound dehiscence (Fig. 17.13), wound infection, tube displacement (Fig. 17.14), excessive rhinostomy crusting (Fig. 17.15), and intranasal synechiae.

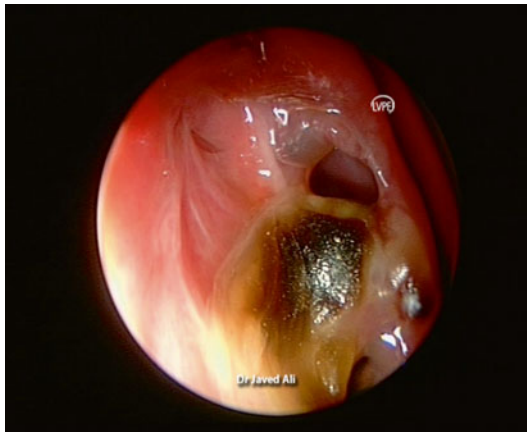

Fig. 17.15 Endoscopic view of rhinostomy scarring

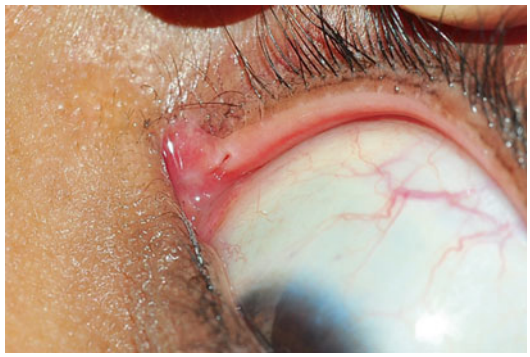

Fig. 17.16 Punctal cheese-wiring

Intermediate complications include granulomas at the rhinostomy site, tube displacements, intranasal synechiae, punctal cheese-wiring (Fig. 17.16), prominent facial scar, and nonfunctional DCR.

Late complications include rhinostomy fibrosis, webbed facial scar, medial canthal distortion, and failed DCR.

Outcomes

A successful DCR is one where there is both anatomical and functional patency. The passage should be patent on irrigation, and the patient should be free of symptoms. The reported success rates of external DCR in literature varies between 85 and 99 % [1–3, 9–11]. These rates were presumed to be much higher as compared to endonasal or transcanalicular, but increasingly literature shows comparable results between both the external and endoscopic approaches [12–15].

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Endoscopic-Guided Single Self-Linking of Stents

18

Mohammad Javed Ali

Introduction

External dacryocystorhinostomy (DCR) is a commonly done surgical procedure for treatment of nasolacrimal duct obstructions. Although the success rates are high, the literature reports the failure rates to range from 1 to 10 % [1, 2]. Among the causes of failure, the most common ones include occlusion of the rhinostomy by either cicatrix, common canalicular obstruction, ostium granuloma, or synechiae [3–5]. The aim of a DCR surgery is therefore twofold, not only to successfully create an ostium but also to take steps to prevent its reclosure. One such step is the use of bicanalicular stents.

With the widespread use of intubation in routine DCR, many problems have been reported in the literature with stents including granuloma formation, nasal irritation, punctal cheese wiring, nasal bleeding, chronic infections, corneal erosions, and displacement [6–10]. Stent prolapse is an important complication with the reported incidence of up to 17 % [10]. This problem of stent displacement is more likely to be prevalent among the pediatric population due to rubbing of the eyes or pulling it out from the medial canthal end (Figs. 18.1 and 18.2). Such events specifically among pediatric patients may warrant premature tube removal and defeat the very purpose of their use. Numerous techniques have been reported in the literature to prevent stent displacements, each with their own sets of advantages and disadvantages [10–14]. The

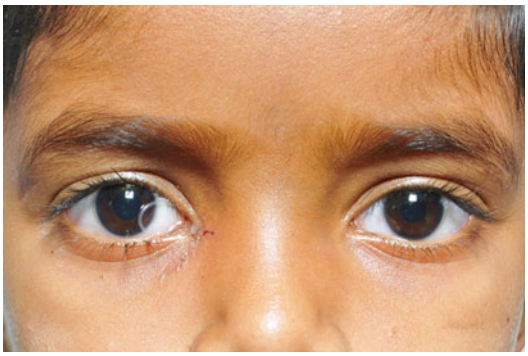

Fig. 18.1 A child with a stent prolapsed

Fig. 18.2 Closer view of a stent prolapse

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute,
Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

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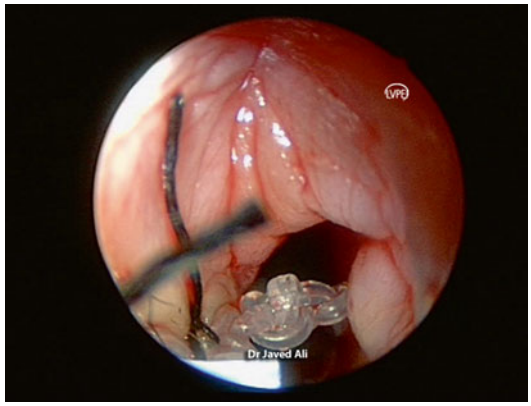

Fig. 18.3 Traditional way of securing the stent at lateral vestibule with a nonabsorbable suture

most common modality is to secure the nasal end of the stent to the lateral vestibule with a nonabsorbable suture (Fig. 18.3). Other techniques include use of Griffith's nasolacrimal catheter, scleral buckling sponges, single-loop stents, silicone sleeves, and aneurysm clips [10–14]. Single self-linking technique was first described by Hui et al. [15] as an effective measure to prevent stent prolapse using both the arms of the Crawford intubation set to cannulate the nasolacrimal duct as well as the internal ostium together. We described for the first time our pleasant experience with endoscopic-guided self-linking stents in pediatric external DCR [16]. We believe that with the help of self-linking stents, not only stent prolapse but also many other complications like nasal irritation, punctal slitting, and corneal erosions can be avoided.

Patient Selection

Careful patient selection is of paramount importance. It is best not to choose patients who underwent a DCR procedure in the past for obvious reason that the nasolacrimal duct in these patients would likely have been violated thereby rendering the nasolacrimal pass unamenable to the self-linking stent. Rarely, those pediatric patients who had persistent complex congenital nasolacrimal duct obstruction with a bony block on probing are not good candidates for self-linked stents since this would as well render the nasolacrimal pass unamenable to the self-linking.

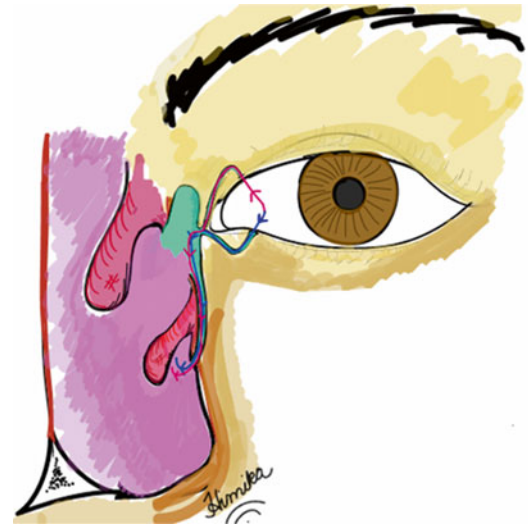

Fig. 18.4 Schematic diagram of the technique showing the nasolacrimal pass of the stent and retrieval at the inferior meatus

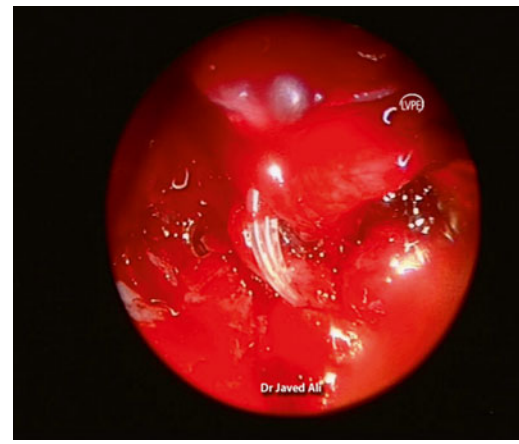

Fig. 18.5 Endoscopic view of the first pass showing the stent coming out of the common canaliculus and entering the nasolacrimal duct

Surgical Technique

Self-linked stents are just one simple additional step for all the surgeons who regularly perform an external DCR (Fig. 18.4). Our surgical technique was the same as described before by Hui et al. [15] except that the surgery was partly done under endoscopic guidance. Following flaps creation in DCR, a Crawford silicone stent (FCI Ophthalmics, MA, USA) is passed through the canaliculi, and then each arm is brought out through the nasolacrimal duct (Fig. 18.5) rather

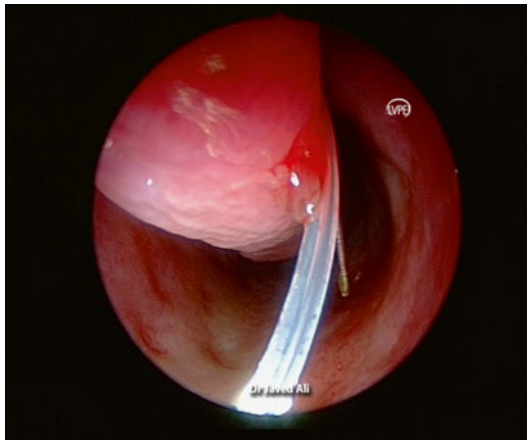

Fig. 18.6 Endoscopic view of one arm of the stent retrieved in the inferior meatus and bodkin of the second arm ready for retrieval

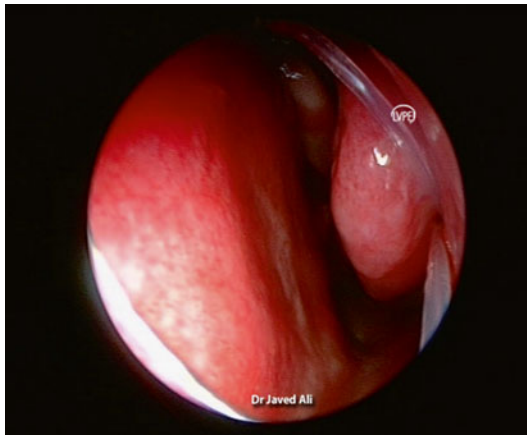

Fig. 18.7 Endoscopic view of the inferior turbinate showing the self-linking of the first arm

than the routine middle meatus. Both the arms of the stent are recovered from the inferior meatus under endoscopic guidance (Figs. 18.6 and 18.7). The bodkins are then passed over the inferior turbinate and redirected towards the middle meatus and the osteotomy under endoscopic guidance (Figs. 18.8 and 18.9) and looped around the proximal portions and tied near the lacrimal sac (Fig. 18.10) thus creating a self-linking stent around the inferior turbinate. At the end of surgery, before closing the wound, an attempt to displace the stent superiorly or inferiorly should be met with resistance (Fig. 18.11). At the same time, it is also important to make sure that there is no undue tightening of the silicone stent since this may lead to punctal cheese wiring.

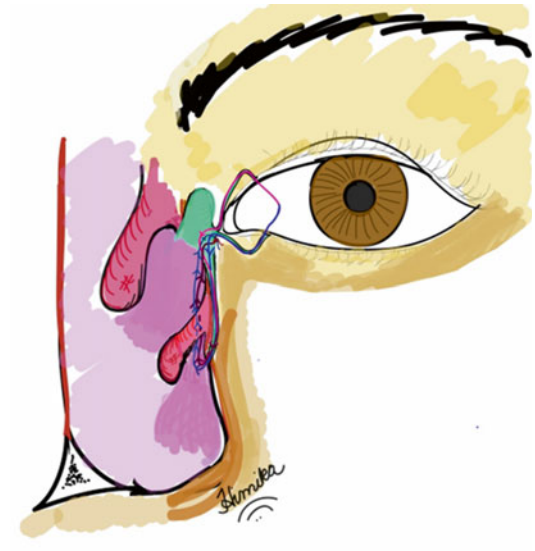

Fig. 18.8 Schematic diagram of the technique depicting redirection of the stent towards the internal nasal ostium and securing around the first pass

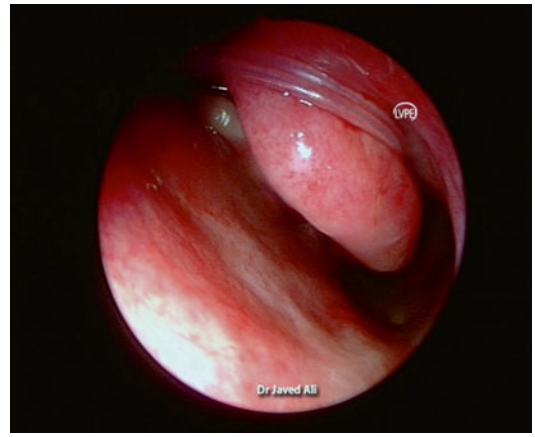

Fig. 18.9 Endoscopic view of the inferior turbinate showing completion of the self-linking

Our Experience

A total of 15 procedures have been carried out till date (11 of these have been analyzed and published earlier) [16]. Following placement of self-linked stents, the removal was done at between 12 and 16 weeks. None of the patients had a stent prolapse during this period. All the stents were removed in the outpatient without the use of general anesthesia with minimal endoscopic guidance. One patient had an ostium granulation tissue around the tube, which was removed and

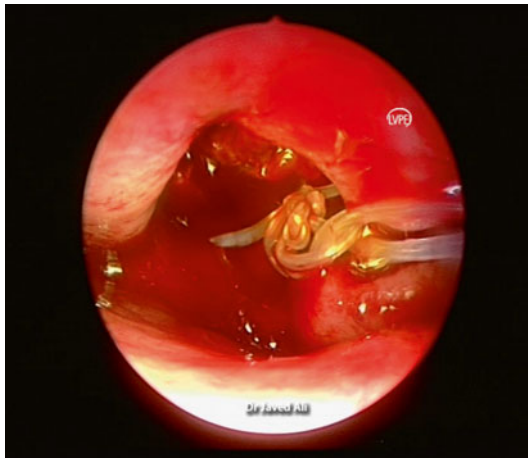

Fig. 18.10 Endoscopic view of the completed loop in front of the lacrimal sac

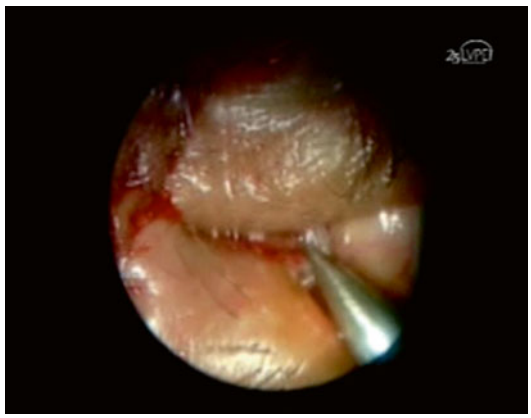

Fig. 18.11 Examination for tube resistance and tension

the patient did well with budesonide nasal spray for a week. The anatomical and functional success rates of DCR were found to be unaffected in our study [16]. We believe from our experience [15] as well as that of Hui et al. [15] that self-linked stents are a very effective measure against stent displacements. In fact at the end of the surgery, any efforts to displace the stent both from the medial canthal end and from the nasal end were met with resistance.

Advantages of Endoscopic Guidance

We advocate the use of endoscopy during this procedure since we found certain advantages in its use. The foremost among these is a better control of the stent at the inferior turbinate which plays the most crucial role in self-linking and retaining the stent (Fig. 18.9). We noticed that on few occasions one arm of the stent may only partially link onto the inferior edge of the turbinate and slips down with rubbing of the nose, thereby hanging beneath the turbinate towards the floor and also creating a downward stress on the entire stent. This may at least theoretically lead to punctal or canalicular slitting. We therefore believe that endoscopic guidance not only prevents such stent slippage at the inferior turbinate but would also be helpful in preventing trauma in the anterior nose during tube retrieval from the inferior meatus and while passing the bodkins up to the internal rhinostomy.

Advantages in Pediatric DCR

Advantages of this procedure in pediatric population include prevention of stent prolapse, prevention of irritation in the nose during sneezing, less amenable to displacement even if pulled, avoiding general anesthesia during removal, reduction in the number of visits in cases of prolapse, better patient cooperation during removal, and of course ease in removal.

Complications

Certain tricky situations include the possibility of negotiating through a blocked nasolacrimal duct for there is a risk of false passage or tightness around the silicone tubing that could lead to tube impaction. We did not encounter this problem of false passage as it was done under visualization from both the entry and exit and thus endoscopic monitoring during this maneuver minimizes such risks. The second problem could be that of punctal cheese wiring if the tube is very tight or it slips and hangs beneath the inferior turbinate. Care should be taken to avoid the tube being too tight by giving some leverage during the second pass near the sac, and the possibility of improper tube pass near the inferior turbinate can be taken care of by endoscopic monitoring and appropriate corrections when

needed. The third possible complication could be granuloma formations near the common internal opening. Routine endoscopic monitoring of our cases did not reveal this but a theoretical possibility does exist.

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Aesthetic External DCR: The Subciliary Approach

19

Milind N. Naik

Introduction

External dacryocystorhinostomy (Ex-DCR) is considered as the gold standard for surgical correction of primary acquired nasolacrimal duct obstruction [1]. It can be performed safely in patients under local anesthesia, with minimal blood loss and economic cost, and has a high success rate of over 90 % in most published series [1, 2]. Despite superior success rate, the inevitable downside of Ex-DCR has been an external skin scar, which has led to the evolution of endonasal and several other nonincisional techniques [3–7]. The success rates with endonasal DCR have been reported to range from 59 to 100 % in various published series with mechanical endonasal DCR being more successful than endolaser DCR [5]. The advantages of endonasal DCR have been reported to be lack of cutaneous scar, less disruption of medial canthal anatomy or lacrimal pump function, decreased operative time, early postoperative rehabilitation, and the ability to simultaneously treat nasal pathologies [6]. However, the disadvantages of the technique include the need for specialized instruments, increased cost, familiarity with nasal anatomy, difficulty in the treatment of canalicular pathologies, need for an expert assistant, and a steep learning curve [6]. Although there have been promising advances in the field of endocanalicular and endonasal DCR surgery, the high success rate of Ex-DCR continues to be confirmed in the literature [8].

In an attempt to avoid an external incision as well as the endonasal approach, two reports have proposed a transconjunctival approach to DCR surgery [9, 10]. In 2003, Adenis and Robert published a series of 11 patients where DCR performed via a retrocaruncular approach yielded 82 % success [9]. Kaynak-Hekimhan and Yilmaz reported a transconjunctival approach to perform scarless DCR in 25 eyes [10]. The authors reported surgical challenges such as orbital fat prolapse and limited access during enlargement of the ostium. The authors needed to convert to external dacryocystorhinostomy in 6 (34 %) patients due to technical difficulties in their initial cases [10].

It is generally agreed that to maximize the success of any DCR, the osteotomy must be large, and the sac mucosa should be anastomosed with the nasal mucosa [11–13]. Moreover, published literature recommends flap formation techniques over the endoscopic approaches [14]. An ideal DCR technique, therefore, would be one that allows a large bony ostium and good mucosal anastomosis without an external scar.

M.N. Naik, MD
Ophthalmic Plastics Surgery,
L.V. Prasad Eye Institute, Hyderbad, India
e-mail: milnaik@gmail.com

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Skin Incisions for External DCR

The Modified Lynch Incision or the Straight Incision

Since the 1920s when Dupuy-Dutemps and Bourguet published their Ex-DCR technique, the surgery has been performed, with slight variations, with the same type of linear vertical incision in the nasal skin medial to the angular vein [15] called the straight or the modified Lynch incision (Fig. 19.1).

The Nasojugal or the Angular Incision

This is a curvilinear incision on the anterior lacrimal crest and is known to allow easy access to the lacrimal sac [16] (Fig. 19.2).

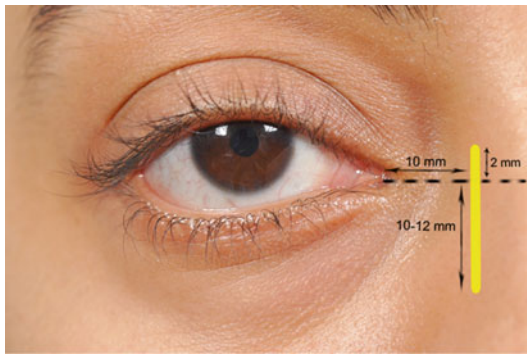

Fig. 19.1 The modified Lynch incision for external dacryorhinostomy

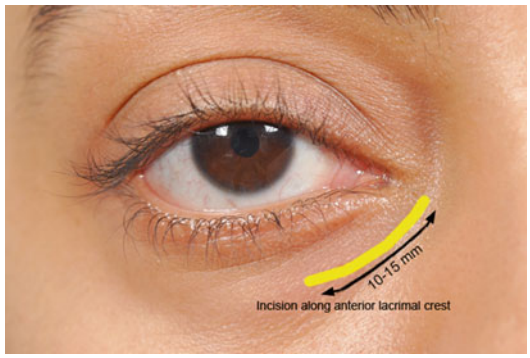

Fig. 19.2 Angular or nasojugal incision for external dacryocystorhinostomy

Incisions on the Lower Eyelid

Harris, in 1989, was the first to demonstrate that external DCR can also be done with a horizontal incision placed on a lower lid crease [17]. This incision extended 10 mm medial to the medial canthus and downward in the first lower eyelid crease. After his first description of this approach in 1989, it was further studied and reported by Putterman [18] in 1994. Putterman also reported a mechanical retraction system. Kim et al. [19] in 2005 used a customized approach where the site of the incision varied. It was either placed in the most prominent wrinkle or in the relaxed skin tension line (4 mm below). Akaishi et al. [20] in 2011 reported good functional and cosmetic outcomes of lower eyelid crease incision. Although there are differences in the location and the extent of incision in all these reports, the common theme is to perform an external dacryocystorhinostomy through an inconspicuous scar.

Harris et al. [17] reported their incision to extend 10 mm medial to the medial canthus and downward in the first lower eyelid crease. Putterman [18] further reported his experience and also introduced the mechanical retraction system. Kim et al. [19] adopted a customized approach where the site of the incision varied. It was placed in either the most prominent wrinkle or relaxed skin tension line (4 mm below). An actual subciliary incision was only used in children without a prominent eyelid crease. The above studies retrospectively analyzed the scars and reported it to be a cosmetically superior approach. The lower eyelid incision within the relaxed skin tension line as reported by Akaishi et al. [20] most closely resembles our approach of the subciliary incision.

The Subciliary Incision

The eyelid subciliary incision is an established approach for several orbital and eyelid procedures and is known to provide excellent cosmesis [21, 22]. We explored the possibility of a subciliary

incision to perform an Ex-DCR and evaluate whether the cosmetic benefits of a subciliary incision can be combined with the high success rate of an Ex-DCR (Fig. 19.3).

Surgical Technique of Subciliary DCR

Surgery is performed under general or local anesthesia as per patient preference. All patients receive local anesthetic infiltration (2 % lignocaine admixed with 1:100,000 adrenaline) along the anterior lacrimal crest and the medial half of pretarsal lower eyelid. The nasal cavity is packed with three cotton-tipped applicators soaked with local anesthetic. A 10–15 mm subciliary incision is placed along the medial half of the lower eyelid, reaching up to the medial canthus (Fig. 19.4a). The incision is placed 1–2 mm below the lashline (subciliary), and not within the eyelid crease. It extends from the punctum medially to the midpupillary line laterally (Fig. 19.4a). Subcutaneous dissection is then carried out inferomedially, to reach the anterior lacrimal crest (Fig. 19.4b). At the level of the anterior lacrimal crest, the orbicularis fibers are gently separated, to expose the periosteum over the anterior lacrimal crest (Fig. 19.4c). The remainder of the surgical procedure is performed like a standard Ex-DCR, including creation of the ostium (Fig. 19.4d, e) and anterior mucosal flaps (Fig. 19.4f, g). Upon completion of the flap anastomosis (Fig. 19.4h), the orbicularis and skin are apposed with interrupted 6-0 polyglactin sutures (Fig. 19.4i).

Routine postoperative wound care and medications are prescribed. Postoperatively, the patients are examined on day 1, 1 week, 6 weeks, 3 months, and thereafter every 3–6 months; 1 day, 1 week, and final postoperative photographs of patients undergoing dacryocystorhinostomy

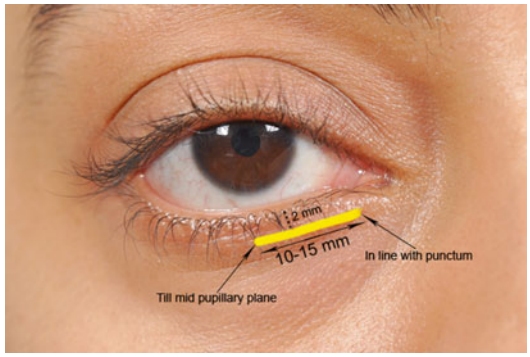

Fig. 19.3 The subciliary incision for external dacryocystorhinostomy

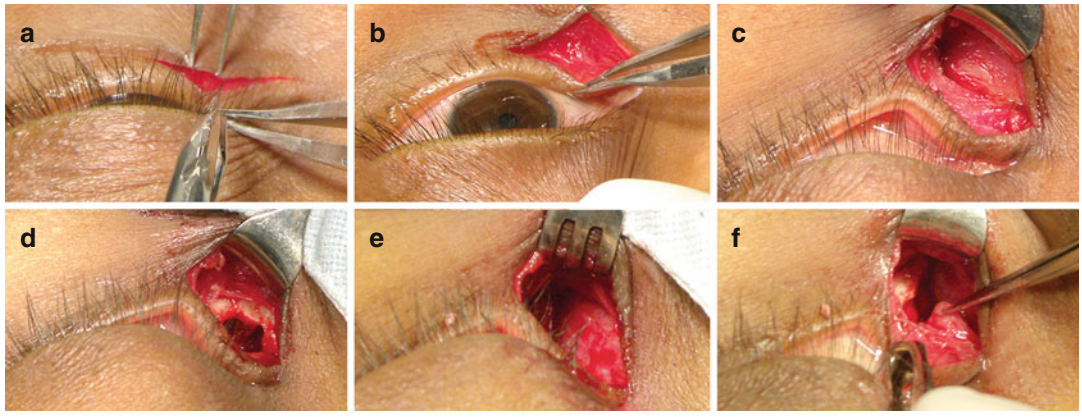

Fig. 19.4 Operative photographs showing the subciliary skin incision (**a**), dissection in the subcutaneous plane to reach the anterior lacrimal crest (**b**), exposing the periosteum over the anterior lacrimal crest (**c**), initiation of the osteotomy after deflecting the sac laterally (**d**), completion of the osteotomy (**e**), construction of the anterior lacrimal sac flap (**f**), construction of the nasal mucosal flap (**g**), suturing the anterior flaps (**h**), and skin closure with interrupted 6.0 polyglactin sutures (**i**)

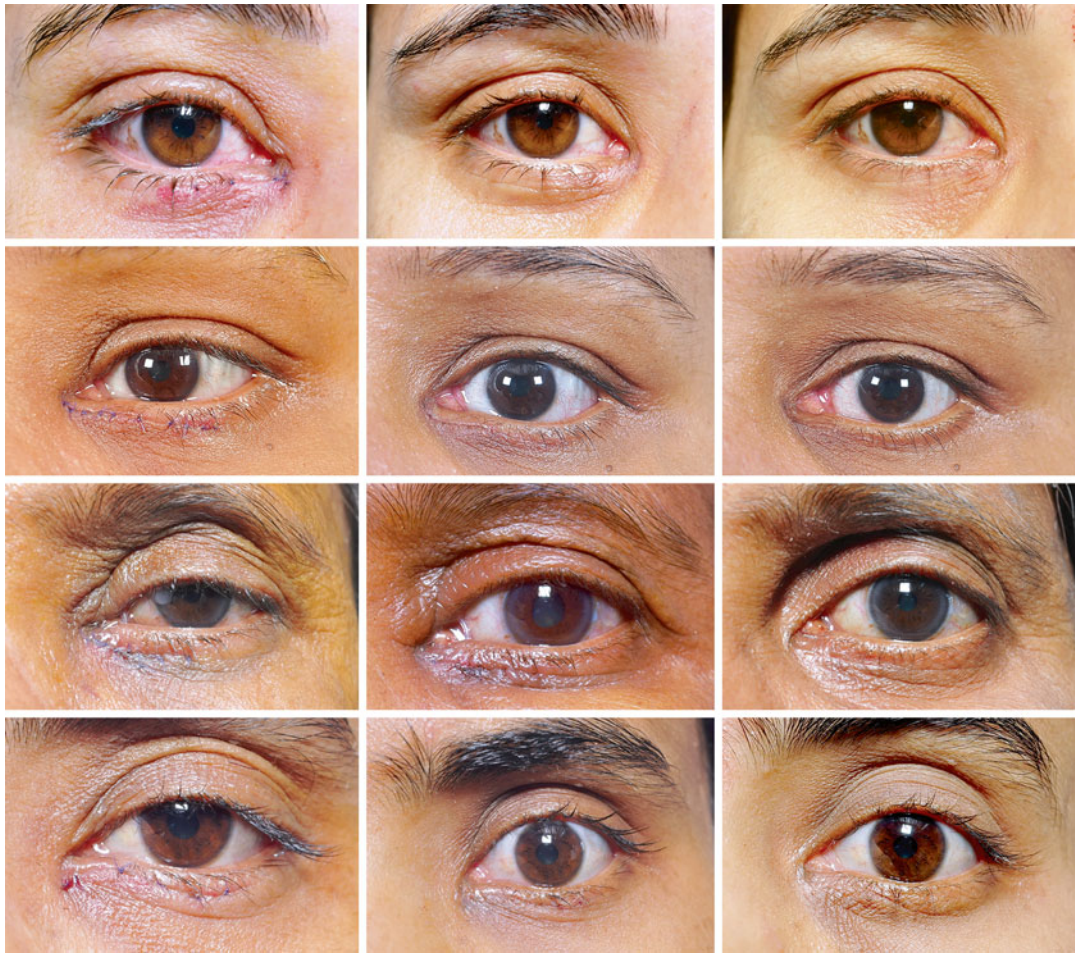

Fig. 19.5 Day 1, week 1, and 6 weeks postoperative photographs of patients undergoing subciliary dacryocystorhinostomy

through the subciliary approach are shown in Fig. 19.5. One patient underwent a bilateral subciliary DCR with good outcomes (Fig. 19.6).

Limitations

Though promising, this surgical approach needs to be adopted with caution. We believe that certain amount of learning curve is involved to attain good aesthetic outcomes with this approach. The amount of wound retraction needed during ostium creation is certainly more than a standard incision Ex-DCR, and hence, gentle tissue handling is required. We did face inadvertent extension (2 mm) of the incision medially in few patients. The subciliary approach is likely to give good results in the hands of an Oculoplastic surgeon who is familiar with subciliary incision for other eyelid or orbital surgeries. A comprehensive Ophthalmologist who performs an occasional Ex-DCR may need some formal training to get the best results with this approach.

We did not have any patient with significant eyelid laxity in our series nor did we include any pediatric patients. We therefore do not know how these eyelids would respond to a subciliary approach in terms of scarring. However,

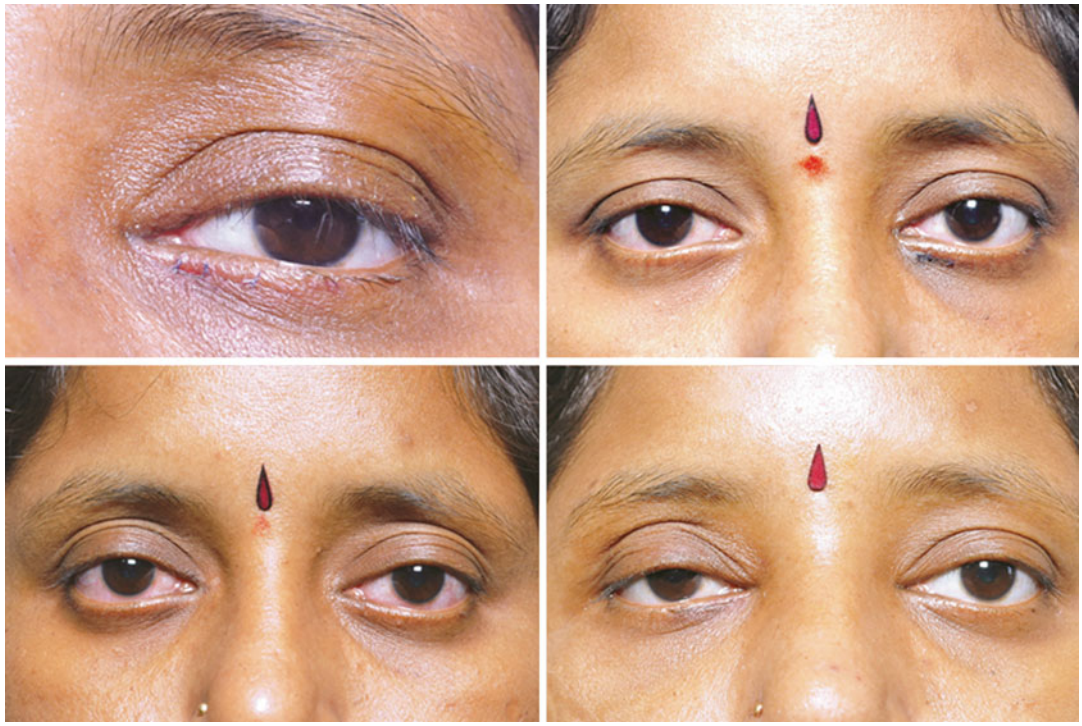

Fig. 19.6 One patient undergoing bilateral subciliary dacryocystorhinostomy (*left* followed by *right*)

extrapolating from the incisions taken for lower eyelid blepharoplasty, one may assume that extremely lax lower eyelids might be very prone to lower eyelid medial ectropion following a subciliary incision.

Conclusions

There is increasing demand on Oculoplastic surgeons from their patients and referring physicians to do endonasal surgery. Young and middle-aged patients are increasingly aware of the endonasal approach and are easily dissuaded by a skin scar. While we wait for endonasal procedures to evolve and achieve comparable success rates, an external approach DCR that can successfully hide the scar is highly desirable. Our technique reports a novel incision approach to Ex-DCR, which has not been reported earlier. The subciliary approach was simply an attempt to combine the best of two worlds, namely, endonasal DCR and Ex-DCR.

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Aesthetic External DCR: The Transconjunctival Approach

20

Pelin Kaynak

Introduction

Primary and secondary nasolacrimal duct obstructions are quite frequently encountered in ophthalmology practice. The traditional surgical approach for managing nasolacrimal duct obstruction (NLDO) is an external dacryocystorhinostomy (Ex-DCR), first described by Toti in 1904 [1]. He gained access to the sac and nasal cavity via a skin incision in the medial canthal region. Dupuy-Dutemps and Bourget later described an Ex-DCR technique where mucosal anastomosis was achieved with suturing of the nasal and saccal flaps [2]. External DCR is still performed in a similar way with minor alterations and high success rates of over 90 % [3–9]. However, external DCR leaves a scar in the medial canthal area.

Endonasal techniques with or without use of lasers and endocanalicular techniques have reported success rates between 60 and 100 %. The results of modern endoscopic DCR are comparable to that of external DCR [10–19]. Use of radiofrequency electrodes [20], powered drills [21], adjunct alkylating agents such as mitomycin C [22], and mechanical endoscopic techniques with flaps [23] contributed to the success. Endoscopic procedures avoid the facial scar, but they necessitate additional surgical equipment and visualization systems.

Retrocaruncular DCR is an uncommon DCR approach aiming to avoid the facial scar as in transconjunctival DCR. Adenis et al. [24] published a series of 11 patients in whom the lacrimal fossa was reached by retrocaruncular approach to perform DCR with 82 % success. This technique avoids a facial scar but may disfigure the caruncular area [24]. Although a familiar area to the Ophthalmologist, to reach the sac via caruncle may not be a common experience. Simpler surgical methods and easy to insert stents are under investigation for high success scarless DCRs [25, 26].

Transconjunctival DCR (TC-DCR) was first performed in 2005 by the author's group, and the results of the first series of 25 patients are published in 2011 [27]. TC-DCR is a scarless external technique where the lacrimal system patency is reestablished via inferomedial transconjunctival approach. This chapter would discuss surgical techniques, complications, and outcomes of TC-DCR.

Surgical Technique

Transconjunctival DCR is performed using conventional external DCR instruments. Rongeurs and/or drills are usually efficient tools for osteotomy. Headlight and surgical loupes are

P. Kaynak, MD
Ophthalmic Plastics Surgery, Beyoglu Eye Research and Training Hospital, Istanbul, Turkey
e-mail: pkaynak@gmail.com

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recommended because of the need for high illumination of the deep surgical area in external DCR. Microscopes can also be used. Surgery can be done under either local anesthesia with or without sedation or general anesthesia.

Preoperative Preparation

The nose is packed with ribbon gauze soaked with 0.05 % xylometazoline and 2 % lidocaine with 1:100,000 adrenaline solution for hemostasis and analgesia. The conjunctival incision site and medial canthal area are infiltrated by approximately 1–4 ml 2 % lidocaine with similar adrenaline concentration. A soft contact lens or a lubricated acrylic corneal protector is placed to protect cornea.

Surgical Steps

The lower eyelid is retracted gently away from the eyeball. Inferomedial vestibular transconjunctival incision of 2–3 cm, similar to medial transconjunctival blepharoplasty incision is performed starting from a point 4–5 mm below the caruncle (Fig. 20.1). The medial fat pad and inferior oblique muscle are exposed and gently retracted laterally to reach the anterior lacrimal crest (Fig. 20.2). Periosteum is incised over the anterior lacrimal crest and reflected medially and laterally. Nasal packing is removed prior to removal of bone. After lacrimal sac is visualized and carefully protected, the frontal process of the maxilla and lacrimal bone are removed either with a drill or rongeurs. Bony rhinostomy site around the sutura in the lacrimal fossa which is approximately 10×10 mm large is created (Fig. 20.3). Attention must be paid not to traumatize the lacrimal sac and nasal mucosa.

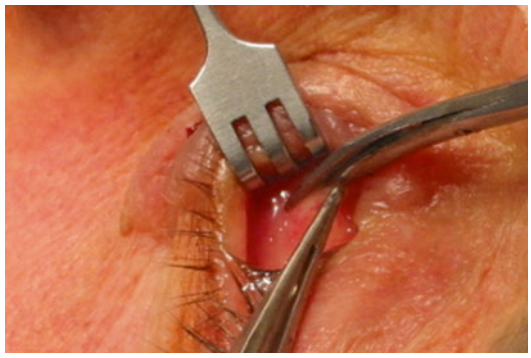

Fig. 20.1 The transconjunctival incision

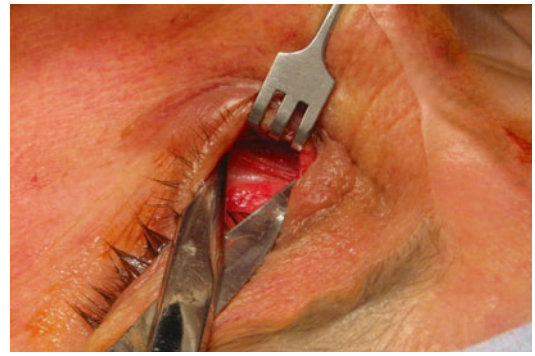

Fig. 20.2 Dissection to access the anterior lacrimal crest

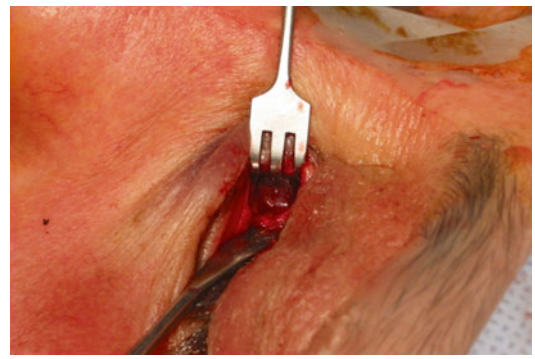

Fig. 20.3 Bony osteotomy

Nasal and saccal mucosae are incised to "H"-shaped flaps, as in external DCR. Full-thickness sac incision and common canalicular patency are checked. The contents of the sac are emptied by irrigation. The nasal and saccal posterior mucosal flaps are best anastomosed with 6–7/0 polyglactin sutures, preferably on a 5/8 curved round needle. When posterior flap apposition is impossible because of either poor manipulation in a deep surgery site or lacerated flaps, it is advised to excise the remnants of posterior flaps. Bicanalicular silicone intubation can be done prior to the anastomosis of the anterior nasal and saccal flaps (Fig. 20.4). Periosteum is

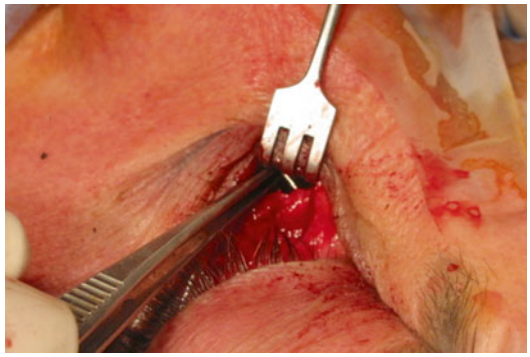

Fig. 20.4 Probe tip in the sac before suturing anterior flaps

Fig. 20.6 Postoperative view: 1st day

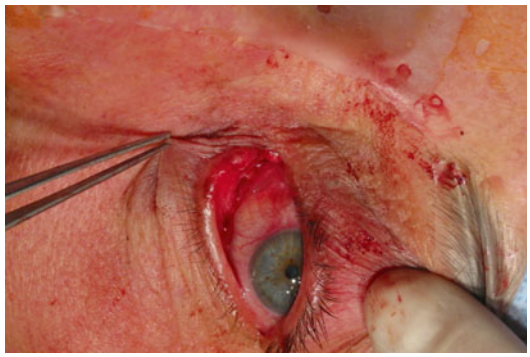

Fig. 20.5 Incision site at the end of surgery

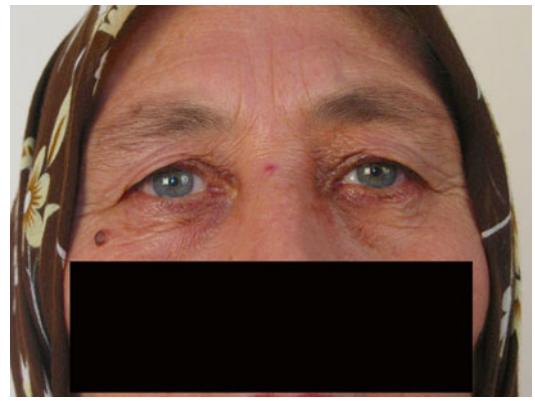

Fig. 20.7 Postoperative view: 2nd week

closed in a fashion to suspend the anterior mucosal wall of the anastomosis. The medial conjunctiva is approximated and sutured with 6-0 polyglactin or may be left unsutured if well apposed (Fig. 20.5).

The surgeon may choose to convert the surgery to conventional external DCR with skin approach, whenever an adequate size bony ostium could not be created to expose the nasal mucosa to complete the DCR via transconjunctival route. Agger nasi cell may prevent access to the nasal cavity, and other posterior ethmoidal cells may be entered instead.

Postoperative Care

Eye patching for 4 h with sterile antibiotic and corticosteroid ointment after surgery is safe and comfortable for the patient. The eyes are opened early on surgery day to check for hemorrhage. It is advised to keep the patient in supine position and apply ice compresses in the first 24 h. Topical and systemic antibiotics are prescribed for the 1st week, and nasal and ocular steroids and nasal saline spray are continued for 3 weeks after surgery. Patients are also advised not to blow the nose during the 1st week.

Figures 20.6, 20.7, and 20.8 show the typical postoperative course of a patient who had transconjunctival DCR for treatment of PANDO. We suggest to follow up the patients on the 1st day, after 1 week, and 1, 3, and 6 months afterwards. During the follow-up, the incision site is examined and the patency of the new rhinostomy is assessed by a dye test or irrigation if required. Silicone tubes are mostly removed at 4 weeks.

Fig. 20.8 Postoperative view of incision site: 2nd week

Table 20.1 Advantages of TC-DCR

1. Avoids facial scar
2. Minimal trauma to medial canthal structures
3. Preserved lacrimal pump
4. Enables flap anastomosis
5. Surgery with basic DCR equipment
6. No need for endoscopy and laser assistance

Outcomes

The success rate of transconjunctival DCR is over 90 % which is comparable to the success of external DCR [27]. It is easy to convert the surgery to external DCR when needed. In the author's series of 25 patients, 76 % of the eyes could be successfully operated using TC-DCR and among these, epiphora resolved completely in 94.7 % eyes [27]. In the remaining 24 %, the DCRs needed to be completed via with cutaneous approach because of fat prolapse hindering adequate osteotomy. Ethmoidal cells were entered in 12.5 % of the eyes. Although Becker reported 92.5 % success in patients who underwent external DCRs without flaps [7], general surgical principles advocate the endothelium-lined smooth tract for the long-term patency of the anastomosis and the drainage of tears. High success rate of transconjunctival DCR can be attributed to the successful flap anastomosis.

Table 20.1 summarizes the advantages of TC-DCR. Surgical difficulties and disadvantages of TC-DCR are listed in Table 20.2.

Table 20.2 Difficulties and disadvantages of TC-DCR

1. Difficult visualization of deeper planes
2. Difficult access to the sac and lacrimal fossa
3. Tight lower eyelids are prone to injury
4. Manipulation and maneuvering difficulties (Ethmoid cell entry, agger nasi cell, orbital fat prolapse)
5. Longer procedure time
6. Variable learning curve

Disadvantages

The higher rate of conversion to external DCR (24 %) especially during the learning curve appears to be the major disadvantage of TC-DCR technique. [27] It is occasionally difficult to reach the nasal mucosa and suture the flaps in the deep surgical planes. In our series of the first 25 cases of transconjunctival DCR, incidence of converting to cutaneous approach external DCR to complete surgery (technical failure) decreased from 38.5 % (first 13 eyes) to 8 % (last 12 eyes) in the second half of the patient group [27]. This result may point towards a learning curve, but the decrease in this conversion as we gain experience is noticeable.

Complications

Orbital fat prolapsed was commonly encountered while performing transconjunctival DCR, which is considered to be one of the important reasons for DCR failure according to Welham et al. [28]. In presence of this complication, manipulation of bony and soft tissues is difficult, and undue trauma to the fat tissue may end up with retroseptal hemorrhage. Fat prolapse, whenever encountered, should be retracted from the site, and the periosteum should be closed meticulously after rhinostomy and flap suturing to prevent fat tissue incarceration in the rhinostomy site.

Anteriorly located ethmoidal air cells can occasionally confuse the surgeon. Talks and Hopkinson reported that the ostium was opened via the standard lacrimal fissure in only 46 % of DCRs [29]. Ethmoidal cells beyond the agger nasi might occasionally be violated.

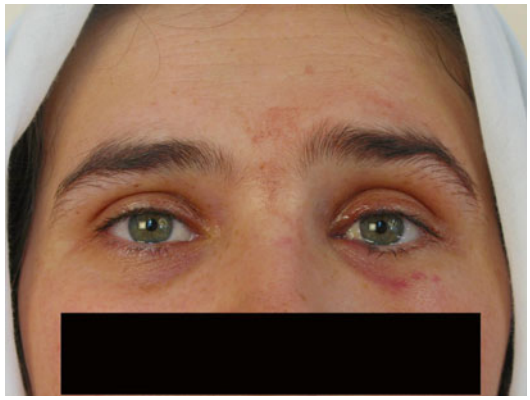

Fig. 20.9 Repaired accidental lower eyelid laceration during TC-DCR

Table 20.3 Complications of transconjunctival DCR

1. Retroseptal hemorrhage
2. Orbital fat prolapse
3. Entry to ethmoid cells
4. Inferior oblique muscle injury
5. Granuloma formation at the incision site
6. Eyelid laceration

Occasionally the ethmoidal sinus entrance might be a hindrance in fashioning the appropriate rhinostomy site in transconjunctival DCR, although it does not mandate conversion to an external DCR.

Eyelid laceration due to excessive traction for better visualization of the surgical site is possible and should be meticulously sutured. It would be wise to choose patients with good eyelid elasticity and not to exert too much force for traction of the lower eyelid for surgical site exposure. Figure 20.9 exemplifies a patient with a repaired eyelid laceration due to excessive traction during TC-DCR.

Possible complications of transconjunctival DCR are listed in Table 20.3.

Comparing Transconjunctival and Retrocaruncular Routes for DCR

Transcaruncular DCR series of 11 cases, by Adenis et al. in 2003, is the most similar approach to transconjunctival technique presented in ophthalmology literature [24]. Both surgical techniques avoid facial scarring, minimize trauma to the medial canthal tendon-Horner's muscle complex, allow anastomosis of mucosal flaps, and can be performed with conventional surgical instruments.

The major difference between retrocaruncular approach and the transconjunctival DCR is the site of incision. The incision is hidden in the medial conjunctival fornix in transconjunctival DCR, avoiding the medial canthal scar. The retrocaruncular entry is adjacent to the globe, and the incision is reported to heal without scarring in their series. However, this incision is visible and carries the possibility of a conjunctival scar adjacent to the caruncle. The medial vestibular transconjunctival incision heals with negligible scarring. In case of a scar or a granuloma formation, it is hidden completely by the lower eyelid.

Another difference between these techniques is the site of the rhinostomy. Adenis et al. create the rhinostomy posterior to the medial canthal ligament, while in TC-DCR, medial canthal ligament makes the superior border of the rhinostomy [24]. More inferior localization of rhinostomy did not decrease the success rate of transconjunctival DCR but is likely to improve the drainage owing to additional factor of gravity.

Less surgical trauma to the tissues around the medial canthal ligament which contributes to the pump mechanism may be another factor of higher success of TC-DCR.

Conclusion

The transconjunctival dacryocystorhinostomy is a useful technique in treating patients with epiphora due to NLDO, with high success rates comparable to external and endoscopic DCR techniques. There are technical difficulties while performing this surgery, but transconjunctival DCR offers the surgeon and the patient a scarless surgery option in the presence of solely the conventional DCR equipment. It does not leave a facial scar and can be performed without endoscope and laser assistance.

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Primary Endoscopic Dacryocystorhinostomy

21

Kelvin Kam-Lung Chong

Introduction

Endoscopic endonasal dacryocystorhinostomy (EEDCR), which was first described in the late 1980s [1], has gained considerable popularity in the recent two decades with the advent of the rigid fiber-optic endoscope and its use in paranasal sinus surgery. It avoids a facial incision, disruption of the medial canthal tendon, injury to the terminal branch of facial nerve, or a full thickness (skin to mucosa) ring contracture over the osteotomy site, all of which may lead to secondary lacrimal pump failure despite anatomical patency. Endoscopic DCR is not contraindicated during active dacryocystitis (minimal risk of fistula formation), presumably allowing faster healing process, and is perceivably less traumatic compared to external DCR. Recent published series of EEDCR reported higher success rates up to 95 % as compared to prior studies [2]. This likely reflects an increased experience with endoscopic instrumentation and anatomy among lacrimal surgeons and an improved understanding and control of postoperative mucosal healing [3]. The key to successful EEDCR relies on atraumatic creation of a large osteotomy [3] with adequate superior bony clearance, complete marsupialization of the lacrimal sac [4], maximal preservation of the nasal and lacrimal sac mucosa with close approximation of the mucosal edges [2, 5], as well as regular endoscopic monitoring of ostial healing during the early postoperative period.

There are multiple surgical variations in performing endonasal DCR including use of endoscope (versus direct visualization using headlight and/or endoilluminator), preservation of mucosal flaps (versus excision), powered instruments (versus cold steel), suturing/gluing of the mucosal flaps, use of mitomycin C, intubation, triamcinolone, and absorbable (gelfoam, Merogel) or non-absorbable (Merocel, ribbon gauze) packings. These variations are based on surgeon's preferences rather than strong evidence in favor of one over the other.

Surgical Technique

Preparation and Anesthesia

EEDCR may be performed under either general anesthesia or local anesthesia. Two percent xylocaine with 1:200,000 adrenaline can be used for regional transcaruncle, infratrochlear, and infraorbital nerve block. The operation is performed with a video camera system attached to a rigid 4-mm endoscope. With the patient in supine position, the patient's head should be slightly elevated and neck slightly extended so as to facilitate

K.K.-L. Chong, MD
Ophthalmic Plastics Surgery, Chinese University of Hong Kong, Sha Tin, New Territories, Hong Kong
e-mail: chongkamlung@gmail.com

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superior osteotomy using the rongeurs. Nasal packing using ribbon gauze soaked in cocaine or alpha-adrenergic type of vasoconstricting solution is placed along the middle meatal area and lateral nasal wall to decongest the nasal mucosa. Xylometazoline and oxymetazoline are commonly used sympathomimetics for decongestion. 0.05 % concentration is used in adults and 0.025 % in pediatric patients. Using a 0° nasal endoscope for visualization, the mucosa of the lateral nasal wall above and below the level of the axilla of middle turbinate can be further infiltrated with 2 % xylocaine with 1:80,000 adrenaline before incision.

Endoscopic Landmarks

The most useful endonasal landmark to identify the lacrimal sac is the axilla of the middle turbinate (Fig. 21.1). An endoilluminator probe may be used to visualize the lacrimal sac through the canaliculus and advance into the lacrimal sac. The fundus of the lacrimal sac usually extends above the level of the axilla of middle turbinate [6]. The maxillary line is an important landmark in endoscopic dacryocystorhinostomy. It is the curvilinear ridge on the lateral nasal wall that runs from the axilla of middle turbinate to the root of the inferior turbinate. It is the suture line formed by the thick maxillary bone anteriorly and the thin lacrimal bones posteriorly. The lacrimal sac often extends posteriorly behind the maxillary line beneath the middle turbinate. Exposure of the posterior half of the lacrimal sac requires removal of the thin lacrimal bone behind the maxillary line and occasionally a part of the uncinate process inferiorly. Exposure of the anterior half of the lacrimal sac requires removal of the thick frontal process of maxilla. The inferior end of the lacrimal sac tapers as the sac-duct junction when it enters the nasolacrimal canal, formed by the maxillary, lacrimal, and inferior turbinate bones.

Fashioning the Nasal Mucosa Flaps

A crescent or sickle knife or a radio frequency device is used to make the incision over the lateral nasal mucosa down to the periosteum in front of the maxillary line (Fig. 21.2). The first vertical incision is made around 10 mm anterior to the maxillary line with a length of about two-thirds of the vertical height of the middle turbinate starting from the level slightly above the axilla of middle turbinate. A horizontal incision is then made at right angle at the inferior end of the vertical incision until reaching the maxillary line. The upper horizontal incision can be completed with the knife or a pair of Westcott scissors starting from the top of the vertical line over and cut beyond the axilla of the middle turbinate (Fig. 21.3). A Freer periosteal elevator is then used to elevate the mucoperiosteal flap and folded

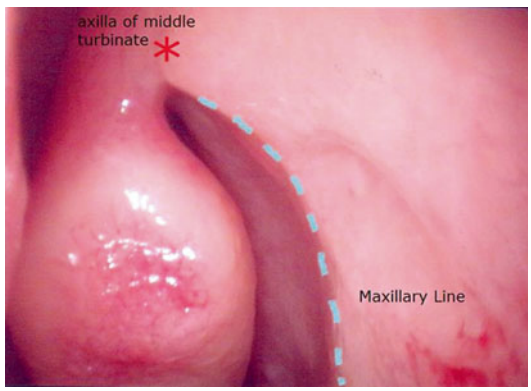

Fig. 21.1 * denotes the axilla of middle turbinate. The important maxillary line is represented by the *blue dashed line*

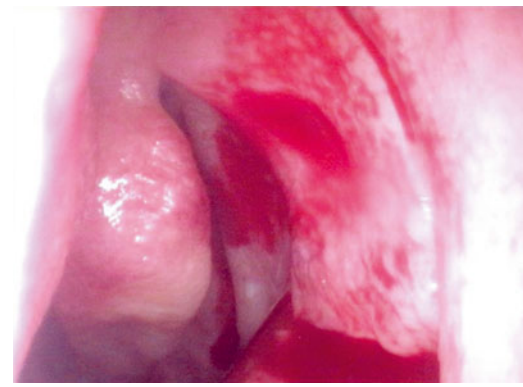

Fig. 21.2 An L-shape incision is made over the lateral nasal mucosa in front of the maxillary line

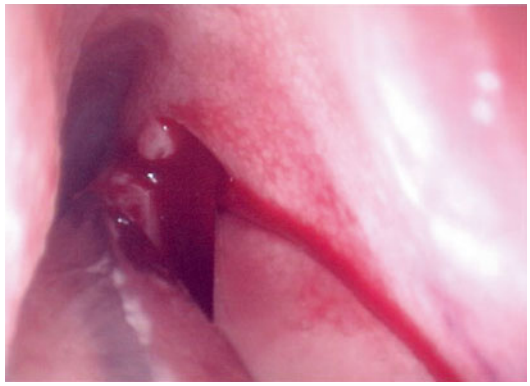

Fig. 21.3 Superior horizontal incision of the nasal mucosal flap using Westcott scissors

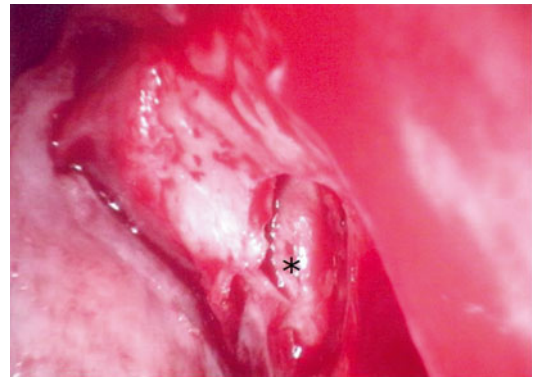

Fig. 21.5 Removal of maxillary bone exposed the inferior half of the lacrimal sac. * denotes the lacrimal sac

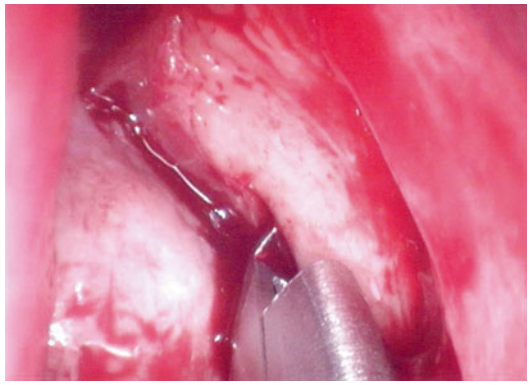

Fig. 21.4 Kerrison Ronguer is used to engage and remove the maxillary bone starting from the maxillary line

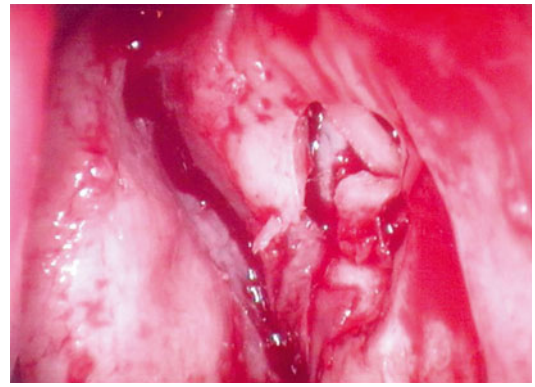

Fig. 21.6 Bone removal is continued anteriorly and superiorly

around the middle turbinate to keep it out of the operating field. Alternatively, an anteriorly based nasal mucosal flap can be created in a similar fashion but usually required sutures to retract anteriorly during osteotomy. An anteriorly based flap may allow better mucosal coverage of bare bone at the end of the osteotomy procedure.

Osteotomy

A Kerrison Rongeur or forward-biting Hajek-Koeffler punch is used to enlarge and remove the hard bone of the frontal process of the maxilla, starting from the maxillary line (Fig. 21.4). Removal of the maxillary bone should expose the inferior half of the lacrimal sac (Fig. 21.5). Bone removal is continued anteriorly and as far superiorly as possible (Fig. 21.6). The thin lacrimal bone at the posterior half of the lacrimal sac is elevated with Freer elevator and removed using a pair of Takahashi forceps (Figs. 21.7 and 21.8). An osteotomy of at least 15 mm in vertical length is usually required to expose the lacrimal sac from fundus to sac-duct junction. All bones over the lacrimal sac fundus and common canaliculus opening should be removed.

Boundaries of the Ostium

Superoanteriorly, the orbicularis oculi muscle is often exposed (Fig. 21.9). Superoposteriorly, the agger nasi air cells or operculum of the middle

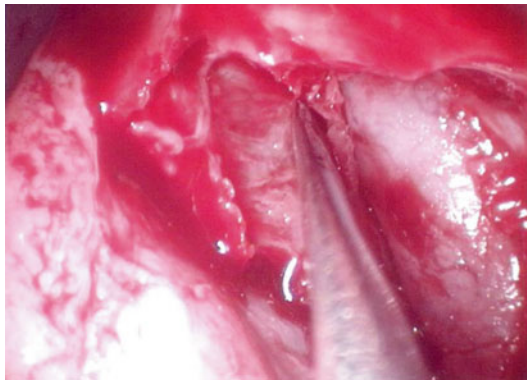

Fig. 21.7 The thin lacrimal bone at the posterior half of the lacrimal sac is elevated with Freer elevator

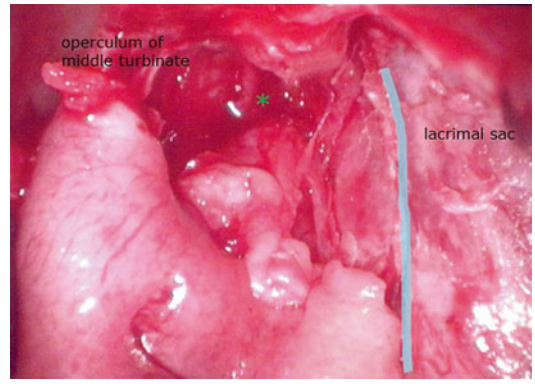

Fig. 21.10 Superoposterior to the unopened lacrimal sac is the operculum of middle turbinate and the opened agger nasi air cell (*). *Blue line* represents the lacrimal sac

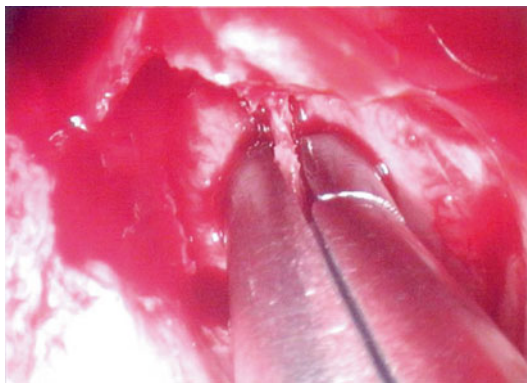

Fig. 21.8 The lacrimal bone being removed using Takahashi forceps

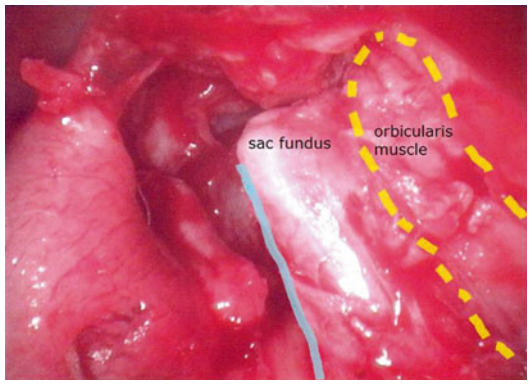

Fig. 21.9 A large osteotomy is required to expose the lacrimal sac fundus. Superoanterior to the unopened lacrimal sac (*blue solid line*), exposed orbicularis muscle is represented by the *yellow dashed line*

turbinate is entered to ensure full fundus exposure (Fig. 21.10). Posteriorly, a limited anterior ethmodiectomy may be required and part of the medial periorbita can get exposed. This allows maximal superior bone removal without using powered instruments and posterior lacrimal sac flap to lie flat. Lacrimal sac fundus is reached when orbicularis muscle is also exposed superiorly. Alternately, one can use special punches like the Malhotra punch, powered drills, or piezoelectric energy to perform a superior osteotomy. Inferior boundary of the osteotomy is the nasolacrimal duct, which is noted after the canal is de-roofed.

Fashioning Lacrimal Sac Flaps

The position of the internal punctum can be verified using a Bowman probe, passing through the lacrimal canaliculus into the lacrimal sac and tenting the medial sac wall. With the Bowman probe passed horizontally tenting the medial wall of the lacrimal sac, at least 2 mm space should be left between the tented lacrimal probe tip and the superior edge of the osteotomy.

Once tenting the medial wall of the lacrimal sac is achieved (Fig. 21.11), a crescent or sickle knife is used to make a vertical incision along the entire length of the lacrimal sac from the fundus down to the nasolacrimal duct (Fig. 21.12). An "I"- or "Y"- shaped incision is then com-

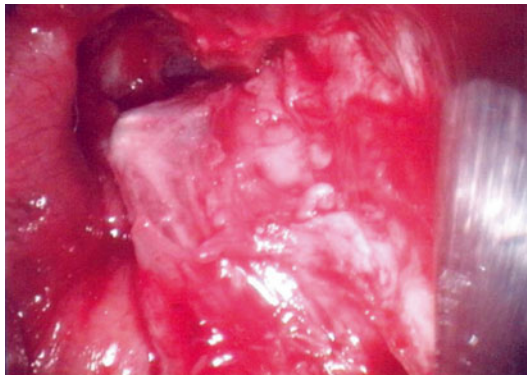

Fig. 21.11 Bowman probes are inserted through the upper and lower canaliculi into the lacrimal sac, tenting the medial wall of the lacrimal sac on the posterior aspect

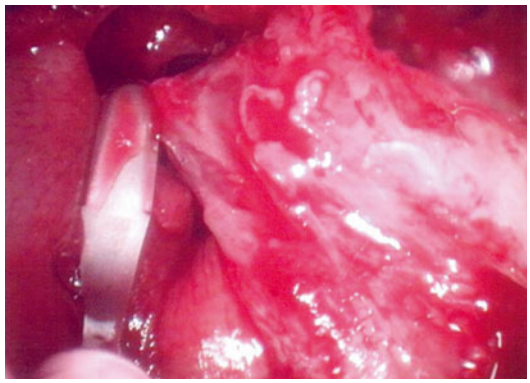

Fig. 21.12 Crescent knife is used to make a vertical incision along the length of the lacrimal sac from the sac fundus down to the sac-duct junction

pleted with upper and lower horizontal releasing cuts at the top and the bottom using Westcott scissors or crescent knife (Fig. 21.13). The lacrimal sac is then completely marsupialized and both the anterior and posterior sac flaps are laid open and flat on the lateral nasal wall (Fig. 21.14).

Irrigation using the fluorescein-stained saline confirms the patency of the common internal punctum intraoperatively (Fig. 21.15).

Edge-to-Edge Mucosal Apposition

Once both the nasal mucosal and lacrimal sacs are fashioned, an edge-to-edge approximation is performed so as to achieve healing by primary

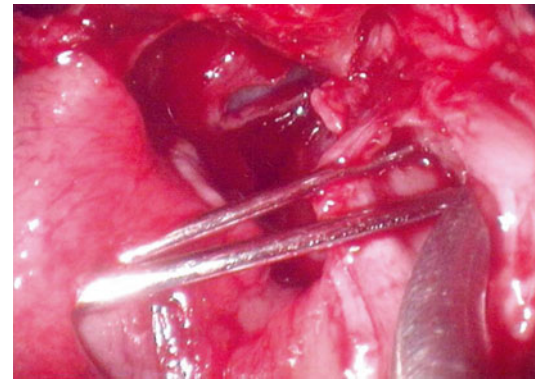

Fig. 21.13 An "I" incision is completed with upper and lower horizontal releasing incision at the top and the bottom of the vertical incision using Westcott scissors or crescent knife

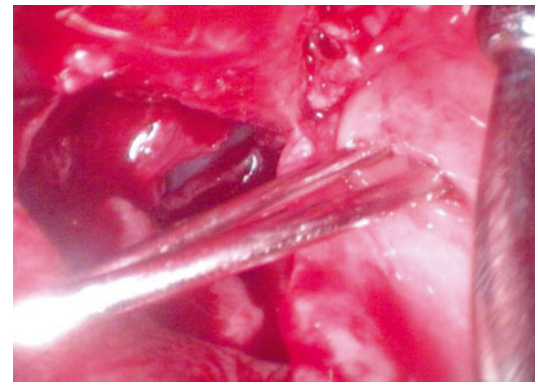

Fig. 21.14 The lacrimal sac was completely marsupialized and both the anterior and posterior sac flap were laid open and remained flat on the lateral nasal wall

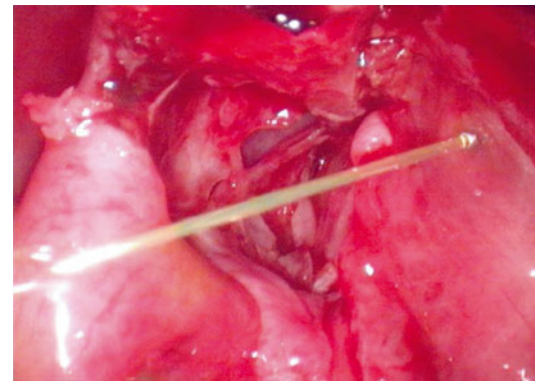

Fig. 21.15 Internal ostium is identified with the fluorescein flushing through

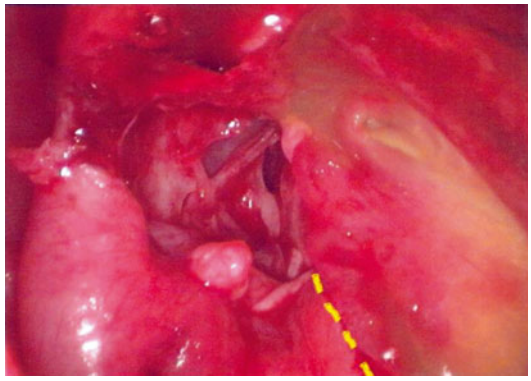

Fig. 21.16 The nasal mucosal flap was repositioned back and approximated the posterior edge of the marsupialized lacrimal sac flap (*yellow line*)

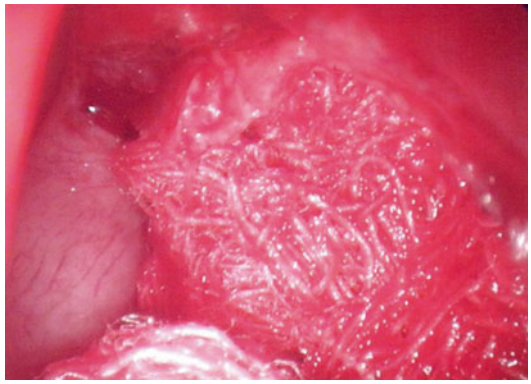

Fig. 21.17 Intraoperative nasal packing with ribbon gauze to achieve hemostasis

intention. A maxillary ostium seeker probe is useful to spread open the lacrimal sac flaps thereby avoiding excessive sharp dissection within the sac, particularly around the internal ostium. The nasal mucosal flap can then be trimmed in the center and edges are repositioned back and approximate the posterior edge of the marsupialized lacrimal sac flap (Fig. 21.16).

Hemostasis

Hemostasis is achieved intraoperatively with nasal packing (Fig. 21.17), medicated patties, cold saline irrigation, head-up position, or bipolar cautery of the bleeding mucosal edges. Small piece of surgical (absorbable hemostat, oxidized cellulose polymer) gauze can be left at the end of the surgery to maintain hemostasis. A point to remember is nasal packing after the surgery should never interfere with the flaps.

Adjunctive Modalities

Bicanalicular silicone intubation is thought to prevent sealing of the edges of the lacrimal sac and impede fibrous closure during healing [7]. It may not be necessary in most primary acquired nasolacrimal duct obstruction (PANDO) cases as our study has shown that bicanalicular intubation did not improve the final outcome at 12-month follow-up [8]. However, silicone tubes may be beneficial in cases of canalicular obstruction, poor flaps, or in revision DCR cases particularly in those with a fibrotic and scarred sac. If bicanalicular silicone intubation is used, the stents are passed through both superior and inferior canaliculi and the silicone tube ends can be tied together on themselves or with suture fixation to the nasal ala or with the use of Ligar clips to prevent tube prolapse. Tension on the stent should be avoided to prevent gradual cheese wiring and slitting of the lacrimal punctae. The silicone tubes are removed at around 4–8 weeks postoperatively based on the surgeon's preference and when mucosal healing is complete. A longer period of intubation may be chosen in cases of canalicular obstruction when scarring around the canalicular opening is more difficult to control, but evidence is lacking.

Mitomycin-C is an alkylating agent that inhibits fibroblast proliferation. This pharmacological adjuvant is used by many endoscopic lacrimal surgeons to minimize cicatrix formation and maintain ostial patency. Evidence for or against it is lacking in primary cases but appears to be helpful in revision cases. The author's unpublished data also have not shown any significant advantage in terms of postoperative granulation tissue formation or the final outcome, as long as a large osteotomy is created with flap marsupialized. When needed, the authors use it as 0.04 % solution, soaked in dental roll applied topically over the opened lacrimal sac for 5 min. However

upcoming evidence with the help of basic science studies suggests that 0.02 % for 3 min may be adequate to prevent cellular proliferation of the fibroblasts [9].

A piece of absorbable packing, for example, gelfoam is sometimes used to keep the flaps in place and triamcinolone solution can be added which may decrease inflammatory response during mucosal healing [2]. Packing with ribbon gauze to tamponade the marsupialized lacrimal sac in the first few days postoperatively is another option favored by the author but systemic antibiotics should be given to avoid infection. The author noticed slight increase in postoperative granulation tissue when gelfoam is used.

Postoperative Management

Postoperatively, broad-spectrum oral antibiotics, nasal steroid spray, and steroid-antibiotic eyedrops are prescribed. Patients are instructed to perform nasal douching to remove crusts and improve mucosal healing. The authors adopted a relatively frequent (every 2 weeks) postoperative follow-up with endoscopic monitoring of ostial healing and removal of "ostial-threatening" granulation tissue and found that most granulation tissue formed at around 6 weeks postoperatively. The follow-up of the patient is based upon the presence of silicone stents and the need for frequent follow-up, if any.

Outcomes

A meta-analysis comparing external and endoscopic DCRs (355 studies included) found that mechanical endoscopic DCR had comparable rates of success with external DCR [10]. The scarring, infection, and bleeding were much less in an endoscopic DCR [10]. With equal success rates and better cosmesis, endoscopic DCR is gaining wide popularity.

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Ultrasonic Endoscopic Dacryocystorhinostomy

22

Mohammad Javed Ali

Introduction

Endoscopic endonasal dacryocystorhinostomy has gained a considerable popularity in the recent two decades with the advent of the rigid fiber-optic endoscope [1, 2]. There are numerous advantages of endoscopic dacryocystorhinostomy (DCR) which include no facial incision, no disruption of the medial canthal tendon, no disruption of the lacrimal pump, less trauma, and feasibility in acute dacryocystitis [1, 2]. Recent published meta-analysis have revealed comparable results with external DCR with lesser risks of infection and bleeding [3]. With increasing understanding, it is clear that among others two major goals for a successful endoscopic DCR are creating large osteotomy and as minimally traumatic as possible. Both of these can be easily achieved with an ultrasonic osteotomy.

Ultrasonic DCR was first performed by Krasnov in 1971 [4] and reintroduced in 2005 by Sivak-Callcott et al. [5]. This is a technique where piezoelectric or ultrasonic waves in the range of 20–30 kHz are used to cut mineralized tissues only, thus sparing the soft tissues. This technology has been successfully used in neurosurgery, otology, and craniofacial procedures [6–8].

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

The advantage of safety in crucial areas made its adaptation for orbital and lacrimal surgeries natural. This chapter will elucidate the instrumentation, principles, techniques, and results of ultrasonic DCR.

Instruments and Setup

The author uses Synthes Piezoelectric System (Synthes GmbH, Oberdorf, Germany), which consists of a main device or console, foot pedal, handpiece, and various tips for cutting bone and bone substitutes.

Console

The console is the main control unit, which has two ends like ears; these are irrigation pumps, one on each side (Fig. 22.1). There are two cable connectors in the front for two handpiece attachment simultaneously (Fig. 22.1). The center of console houses a LCD touch screen with various functions and controls like the irrigation flow, LED light option on handpiece, and flush and operating programs from D1 to D4 (Figs. 22.1 and 22.2).

Each of this can have a range from 1 to 5 (low power to high power). D1 is the most powerful setting used for very dense and thick bones whereas D4 is used for very thin bones and soft tissue detachments (Fig. 22.2).

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Fig. 22.1 The piezoelectric console

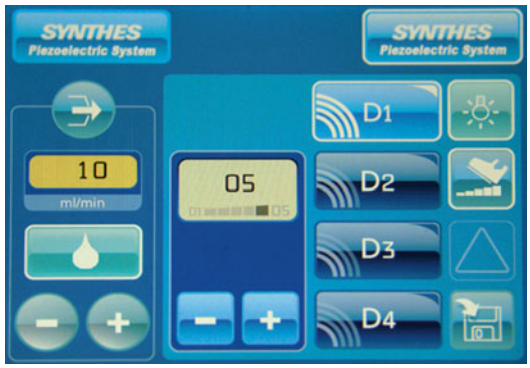

Fig. 22.2 Control panel on the console

Pump House

The pump house (one on each side of console) is designed to accommodate peristaltic cassettes and irrigation tubing (Fig. 22.3). They generate flow from 10 to 120 ml/min with an interval of 10 ml/min and a flush rate of 120 ml/min. The other end of tubing is attached to the handpiece.

Handpiece

The handpiece houses an opening at its front for accommodating various tips for different functions (Fig. 22.4). Once the tips are placed, they are secured in a clockwise turning manner using the flat or the torque wrenches (Fig. 22.5).

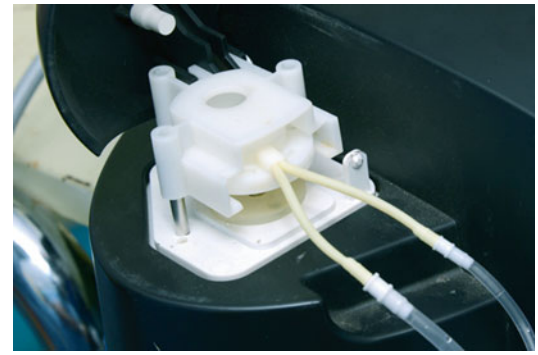

Fig. 22.3 The pump housing

Fig. 22.4 The piezo handpiece

Fig. 22.5 Wrench used to secure the tip

The circumference of this opening has six LED lights for providing visualization in deep cavities (Fig. 22.6). At the rear end is a cable that is attached to the front panel of console. There is also a small metal pipe to which the irrigation tube is attached.

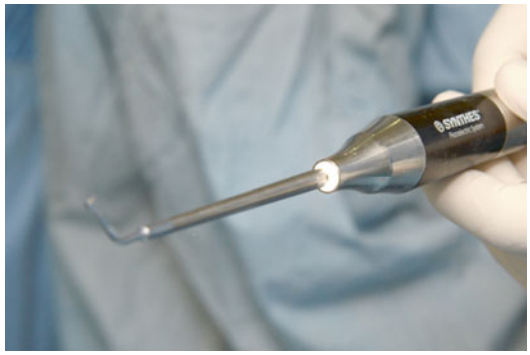

Fig. 22.6 Handpiece with LED light

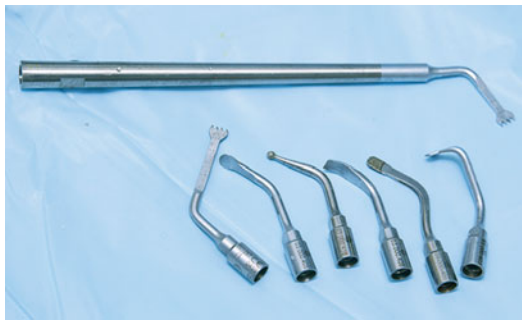

Fig. 22.7 Various cutting tips

Cutting Tips

There are numerous cutting tips but can be grouped into four as saw tips, diamond tips, scalpel tips, and decorticating tips (Fig. 22.7). The diamond and saw tips are mostly used in endoscopic DCR.

Foot Pedal

The foot pedal has all the controls as that of the console and helps the surgeon to work in a sterile environment, without much dependency on the assistants (Fig. 22.8).

Principle

The machine uses an alternate current to cause vibrations, contractions, and expansion of the piezoelectric element or quartz particle. These

Fig. 22.8 The control panel on foot pedal

cause generation of micro vibrations which in turn cause inserts to vibrate linearly between 60 and 210 μm. The piezo element thus generates ultrasonic vibrations, which are transmitted to the cutting tips, causing fragmentation of the target bone by acoustic and Jack-Hammer effects.

Advantages in Endoscopic DCR

- Easy osteotomy
- Easy superior osteoplasty
- Minimal heat/no necrosis
- Minimizes bleeding
- Safe for sac and soft tissues
- Enhanced visualization (LED)
- Quicker surgery
- Low surgeon fatigue
- Superior histological healing
- Good for beginners

Surgical Technique

Preparation and Anesthesia

Ultrasonic- or piezoelectric-assisted DCR may be performed under either general anesthesia or local anesthesia. The author prefers general anesthesia. The middle turbinate, axilla, and adjacent lateral wall are infiltrated with 2 % xylocaine with 1:60,000 adrenaline (Fig. 22.9) and followed by nasal packing with ribbon gauze or

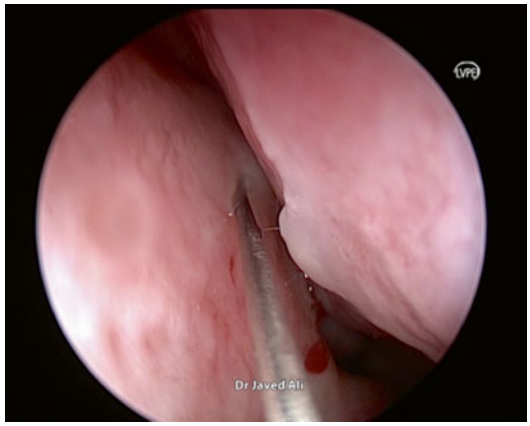

Fig. 22.9 Infiltration anesthesia

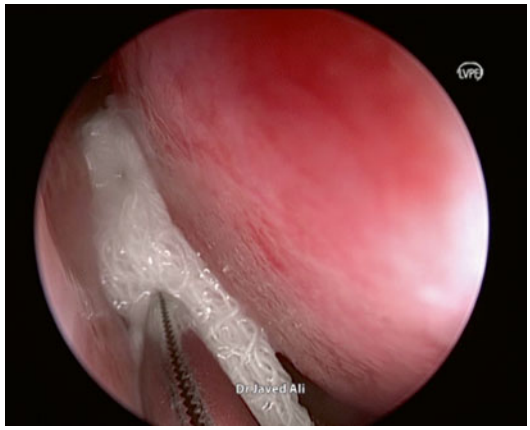

Fig. 22.10 Nasal decongestive packing

preferably neurosurgical patties (Fig. 22.10). The patties are medicated with 0.05 % (adults) or 0.025 % (pediatric) xylometazoline. It is best to leave the patties for at least 8–10 min for good decongestion. With the patient in supine position, the patient's head should be slightly elevated and neck slightly extended so as to facilitate superior osteotomy.

Fashioning the Nasal Mucosa Flaps

A no 15 blade or sickle knife or a radio-frequency device (Fig. 22.11) is used to make the incision over the lateral nasal mucosa down to the periosteum in front of the maxillary line (Fig. 22.12). The first horizontal incision of

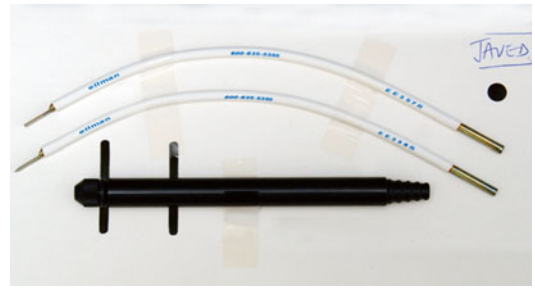

Fig. 22.11 Endoscopic malleable radio-frequency probes

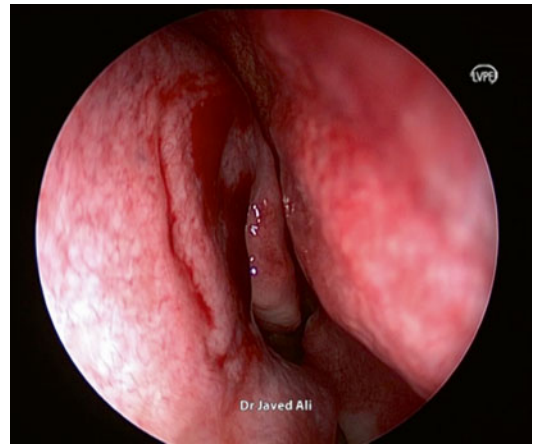

Fig. 22.12 Outline of the nasal mucosal incision

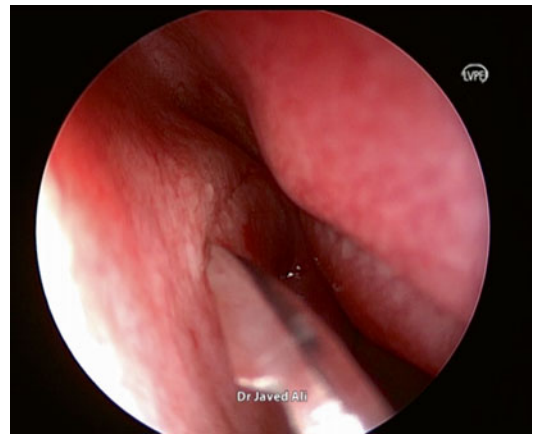

Fig. 22.13 Horizontal incision

12–15 mm length is made 10 mm above the axilla of the middle turbinate (Fig. 22.13). The vertical incision begins from the anterior end of the horizontal incision and ends at about two-thirds of

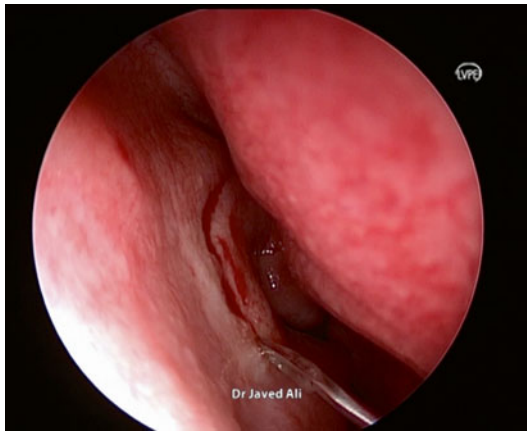

Fig. 22.14 Vertical incision

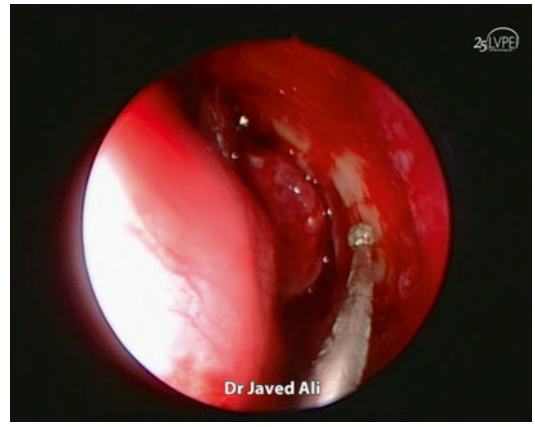

Fig. 22.16 Ultrasonic probe position

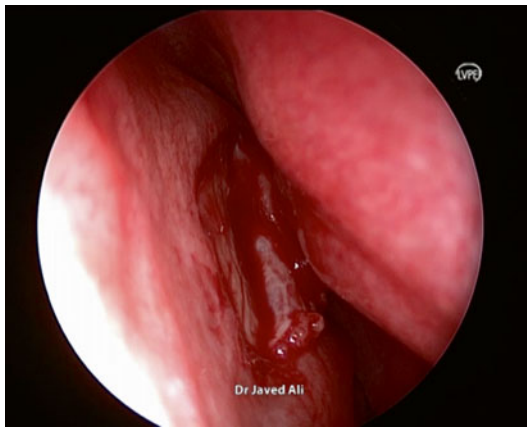

Fig. 22.15 Mucoperiostial flap elevation

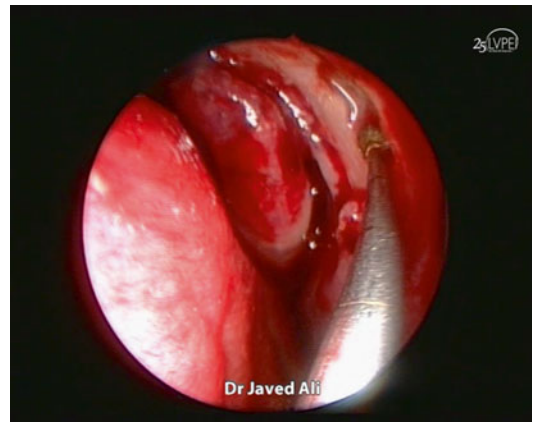

Fig. 22.17 Trench creation

the vertical height of the middle turbinate (Fig. 22.14). A horizontal incision is then made at right angle at the inferior end of the vertical incision until the maxillary line is reached, short of uncinate process. A Freer periosteal elevator is then used to elevate the mucoperiosteal flap, baring the underlying bone (Fig. 22.15) and is then tucked around the axilla of middle turbinate to keep it out of the operating field.

Osteotomy

A diamond cutting tip at a flow rate of 30 ml/min with D2 program with power of 5 is used to begin the osteotomy from the inferior end of the maxillary line. Place the diamond tip perpendicular to the target bone (Fig. 22.16) and start emulsifying the bone in a brush-stroke movement. Only a slight pressure can be used but force is never needed. A trench is initially created (Fig. 22.17) and subsequently deepened by slight back and forth movement in line with the initial cut, till entire bone is emulsified, exposing the underlying nasolacrimal duct (Fig. 22.18). The osteotomy is then created anteriorly and posteriorly. Simultaneous suction would help in clearing the emulsified debris. The extent of osteotomy anteriorly and posteriorly should be 2 mm beyond complete exposure of the lacrimal sac. One would realize that the cutting tip does not work if it touches the lacrimal sac or surrounding soft tis-

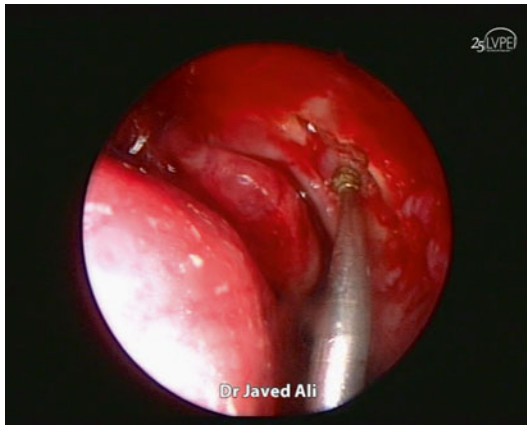

Fig. 22.18 Osteotomy completed in one area. Note the lacrimal sac underneath

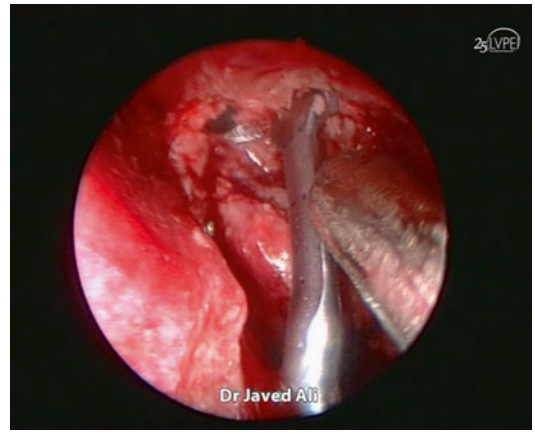

Fig. 22.20 Superior osteotomy with saw tip. Note the opened agger nasi

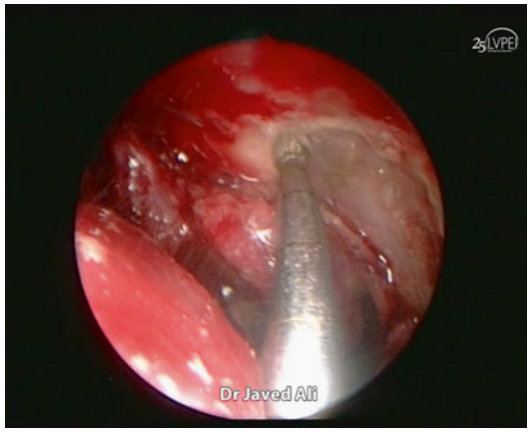

Fig. 22.19 Superior osteotomy with diamond tip

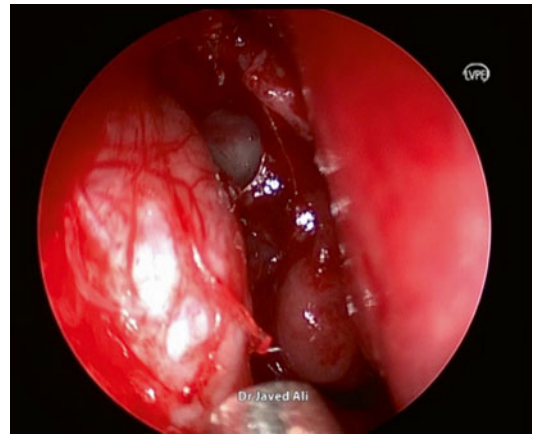

Fig. 22.21 Lacrimal sac filled with fluorescien viscoelastic

sues (Fig. 22.18). Once the superior part of the ostium is reached, a flow rate of 40–50 ml/min with D1 program with power of 5 is used since the bone is very thick here (Fig. 22.19). Occasionally, a long right- or left-sided cutting saw tip may be used (Fig. 22.20) but care should be taken while using it since they are sharp. All bones over the lacrimal sac fundus and common canaliculus opening should be removed. Superoanteriorly, the osteotomy should extend till orbicularis oculi muscle is just exposed and superoposteriorly, the agger nasi air cells or operculum of the middle turbinate is entered to ensure full fundus exposure (Fig. 22.20).

Fashioning Lacrimal Sac Flaps

The author prefers filling the lacrimal sac with fluorescein-stained viscoelastic since this not only dilates the lacrimal canaliculi and sac (Fig. 22.21) but also protects the lateral wall of sac and internal common opening from inadvertent trauma. The Bowman probe is passed through the upper canaliculus and is held horizontally tenting the medial wall of the lacrimal sac (Fig. 22.22).

A crescent or DCR spear knife is used to make a vertical incision along the entire length of the lacrimal sac from the fundus down to the naso-

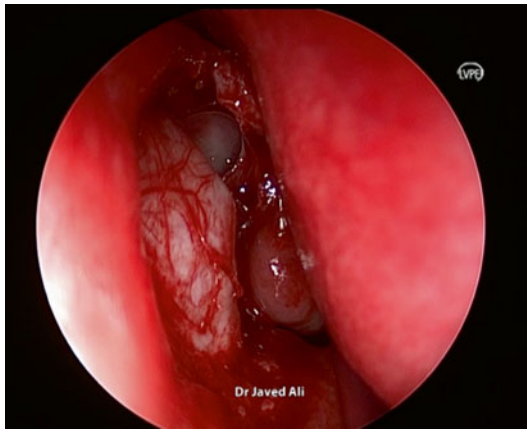

Fig. 22.22 Tenting of medial wall of lacrimal sac by a probe

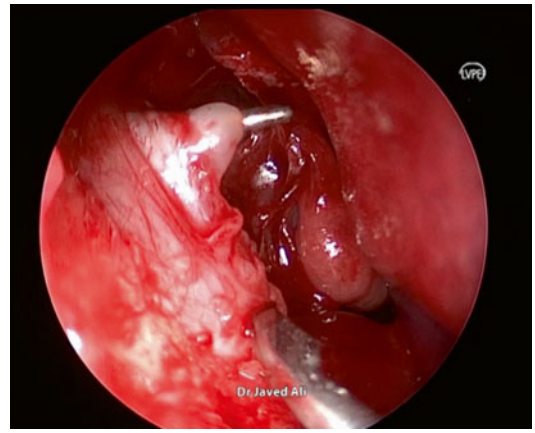

Fig. 22.24 Horizontal lacrimal sac incision

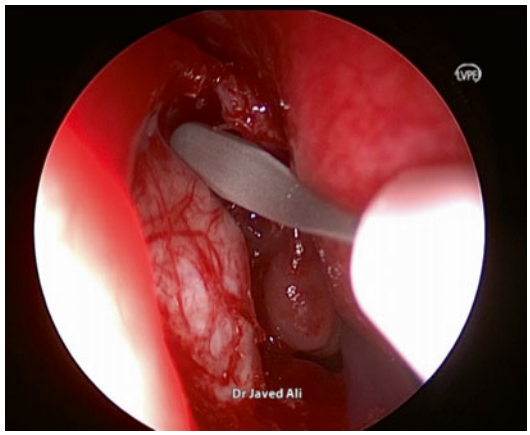

Fig. 22.23 Vertical lacrimal sac incision

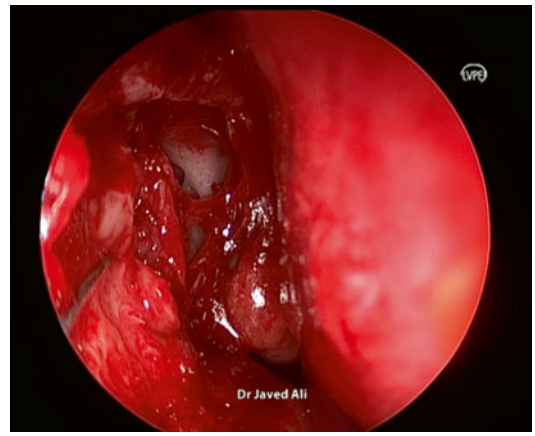

Fig. 22.25 Complete sac marsupialization

lacrimal duct (Fig. 22.23). An "I" or "Y"-shaped incision is then completed with upper and lower horizontal releasing cuts at the top and the bottom using a sickle or spear knife (Fig. 22.24). The lacrimal sac is then completely marsupialized and both the anterior and posterior sac flaps are laid open and flat like an open book on the lateral nasal wall (Fig. 22.25).

Edge-to-Edge Mucosal Apposition

Once both the nasal mucosal and lacrimal sacs are fashioned, an edge-to-edge approximation is performed so as to achieve healing by primary intention. A ball probe is useful to spread open the lacrimal sac flaps. No bare bone should be left behind since that may incite granulation tissue. The anterior flap should be in contact with the anterior cut end of the nasal mucosa whereas the posterior flap should lie back flat in apposition with the agger nasi mucosa (Fig. 22.26).

Hemostasis

A correctly done endoscopic DCR rarely would have hemostasis issues! When needed, it can be

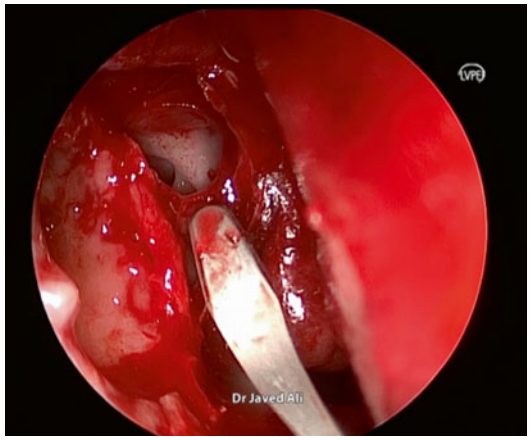

Fig. 22.26 Edge-to-edge mucosal approximation. Crescent points toward posterior lacrimal flap and agger nasi mucosa approximation

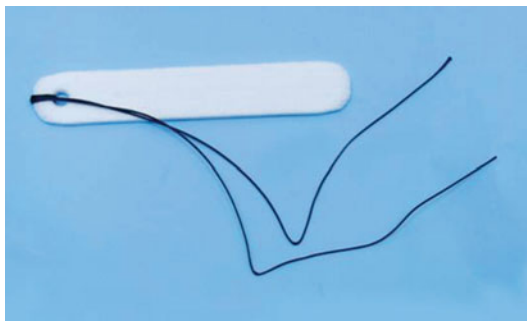

Fig. 22.27 Merocel pack

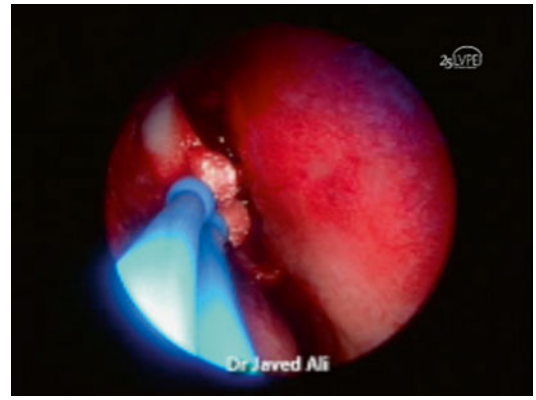

Fig. 22.28 Mitomycin application on Merocel sponges

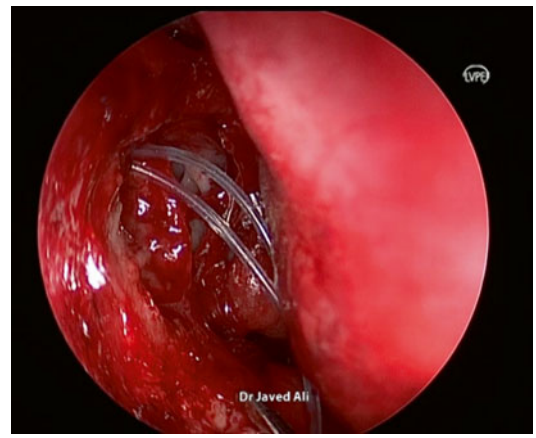

Fig. 22.29 Bicanalicular intubation

achieved with Merocel nasal packing (Fig. 22.27), cold saline irrigation, head-up position, or judicious bipolar cautery of the bleeding mucosal edges. Small piece of surgical (absorbable hemostat, oxidized cellulose polymer) gauze can be left at the end of the surgery to maintain hemostasis.

Adjunctive Modalities

The use of silicone intubation and mitomycin C (MMC) is controversial without concrete proof of benefit or harm. For their endoscopic DCRs, the author prefers using intubation for 4 weeks and circumostial MMC as per protocols described in literature (Figs. 22.28 and 22.29) [9, 10].

Postoperative Management

Postoperatively, broad-spectrum oral antibiotics, nasal steroid spray, and steroid-antibiotic eye drops are prescribed. Patients are instructed to perform nasal douching to remove crusts and improve mucosal healing. The follow-up of the patient is at 4 weeks for stent removal and further follow-up only if needed.

Outcomes

In view of this being among newer procedures, very few studies have looked into the outcomes [5, 11–14]. Studies have found piezoelectric

assistance to be quick and respectful to surrounding tissues [12–15]. The largest series by Murchinson et al. [11], which studied 59 DCRs of 49 patients, found it to be comparable to microdrill endoscopic DCRs in success. No complications related to ultrasonic emulsification were noted in their series. Salami et al. [13] in their 20 cases found this technique to be successful in all their patients and noted no granulation or synechiae at the ostium. In another comparative study between burr and piezoelectric osteotomy, the histological bone healing was found to be superior with piezo assistance [15]. The bone healing was more rapid and primarily composed of bone rather than fibrovascular tissues. The author in his unpublished data has found that the surgery was quicker with much less bleeding and less ostium scarring postoperatively. Because of the safety profile with the surrounding soft tissues, it could well be the technique of choice with the beginners in endoscopic surgery!

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Non-endoscopic Endonasal Dacryocystorhinostomy

23

Suryasnata Rath, Samir Mahapatra, and Peter J. Dolman

Introduction

Caldwell [1] and Toti [2], respectively, described the endonasal and external approaches to dacryocystorhinostomy (DCR) [1, 2]. Because of difficulty in visualizing the nasal cavity, the endonasal approach fell out of favor, and for the next 100 years, a slightly modified external approach remained the treatment of choice for Primary Acquired Nasolacrimal Duct Obstructions (PANDO). Interest in endonasal DCR saw resurgence around 1990 with the availability of rigid and fiber-optic imaging systems. Despite these advancements, identification of the precise site for DCR remained a concern, because of the possibility of injury to adjacent orbital and intracranial tissues. In 1990, Bruce Massaro introduced the concept of transilluminating the lacrimal sac with a vitrectomy light pipe [3]. Over the last two decades, the technique and technology in endonasal DCR has evolved to make this an effective, scarless option in the treatment of NLDO with several authors reporting success rates (≥90 %) equivalent to that of external DCR [4–6].

The main advantages of endonasal DCR include the absence of a visible scar, minimal postoperative morbidity, faster recovery, and comparable success rates to that of external DCR [4, 6, 7]. We describe in this chapter the technique of non-LASER, non-endoscopic endonasal DCR (NEN-DCR) which retains the benefits of an endonasal approach while alleviating the need for expensive video-endoscope or laser systems.

Indications

1. Primary acquired NLDO (PANDO)
2. Acute dacryocystitis with lacrimal abscess
3. Revision in failed external or endonasal DCR
4. NLDO with associated nasal pathology
5. Posttraumatic secondary acquired nasolacrimal duct obstruction (SANDO)
6. Persistent congenital NLDO (CNLDO)

NEN-DCR is usually not preferred in certain complex conditions which are as follows:

1. Suspected lacrimal sac neoplasm
2. Severe midfacial trauma with hyperostosis around the lacrimal sac and nasolacrimal duct
3. Lacrimal sac diverticulae/fistulae extending to eyelid skin
4. Thick bones causing difficulty in initiating osteotomy
5. Down's syndrome

S. Rath, MS, FRCS (✉)
Ophthalmic Plastics Surgery,
L.V. Prasad Eye Institute, Bhubaneswar, India
e-mail: drsuryasnata@gmail.com

S. Mahapatra, MS
Ophthalmic Plastics Surgery,
L.V. Prasad Eye Institute, Vishakapatnam, India

P.J. Dolman, MD, FRCSC
Ophthalmic Plastics Surgery, University of British Columbia, Vancouver, BC, Canada

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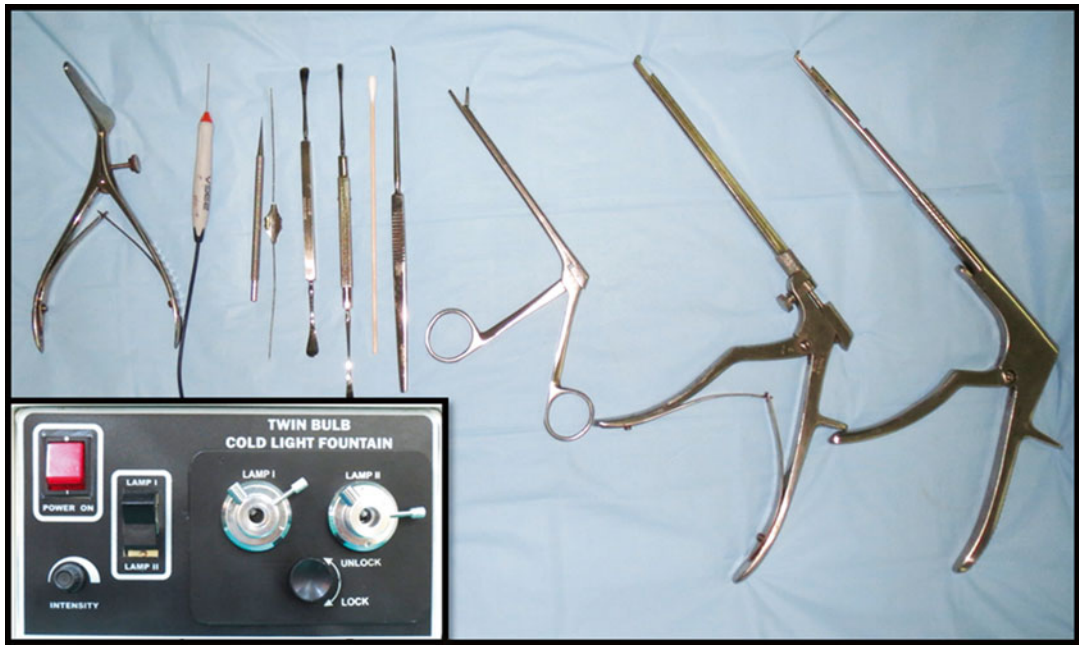

Fig. 23.1 Instrumentation for NEN-DCR

Surgical Technique

Instruments Used for the Technique Include (Fig. 23.1)

1. Endoilluminator and 23G Vitrectomy retinal light pipe
2. Long- (5 cm) bladed nasal speculum with self-lock
3. Myringotomy sickle knife
4. Freer's or Cottle's periosteal elevator
5. Straight Weil-Blakesley ethmoid forceps
6. 2 and 3 mm right-angled Kerrison-Ruggles ronguer
7. Suction apparatus with canula

Technique

Endonasal dacryocystorhinostomy can be performed under general or local anesthesia. An area of 10 mm^2 anterior to the attachment of the middle turbinate on the lateral nasal wall is infiltrated with 2 % lidocaine with epinephrine (1 in 200,000) till mucosal blanching is evident. The nasal cavity is decongested for 5 min with a nasal pack soaked in 0.05 % oxymetazoline nasal drops. The surgeon positions himself on the contralateral side, that is, on the right side of the patient to do a left endonasal dacryocystorhinostomy. After punctal dilatation with a Nettleship dilator, a 23G vitrectomy light pipe is gently introduced (Fig. 23.2a, b) through the upper canaliculus until a hard stop is felt. A self-locking nasal speculum with 5 cm long blades is then introduced into the nasal cavity with the blades of the retractor placed vertically in the nostril and locked in a dilated position with the length of the speculum draped across the face, allowing self-retraction. The transillumination effect of the sac can be easily seen in the lateral nasal wall. A myringotomy sickle knife is used to incise the lateral nasal mucosa (Fig. 23.2c, d) showing maximal transillumination effect. The incision for the mucosal flap is begun 8 mm above the insertion of the middle turbinate and is then carried out vertically or in a curvilinear fashion down to the bone. A Freer's or Cottle's periosteal

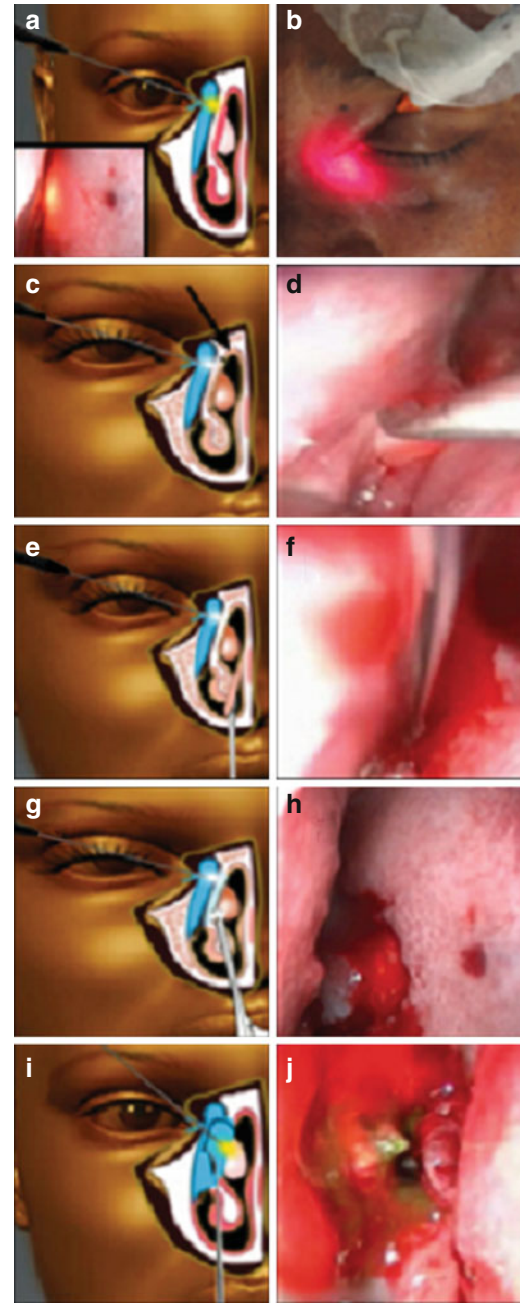

Fig. 23.2 (**a–j**): (**a**) Transillumination of the lacrimal sac with the vitrectomy light pipe touching the medial wall of the lacrimal sac. Inset shows the glow in the medial wall of the nasal cavity. (**b**) Oblique positioning of the light pipe through the upper canaliculus with the lacrimal sac transillumination as seen externally. (**c**, **d**) Incision on the lateral nasal wall with a myringotomy sickle knife. (**e**, **f**) The nasal mucosal flap is removed with Weil-Blakesley forceps. (**g**) Kerrison rongeur is used for enlarging the bony ostium. (**h**) The lateral nasal wall shows a bony ostium with the pale lacrimal sac mucosa showing through the ostium. (**i**) The lacrimal sac is tented with the light pipe and a myringotomy sickle knife is used to incise the lacrimal sac. (**j**) The marsupialized lacrimal sac shows a free flow of fluorescein-stained saline into the nasal cavity

elevator is used to elevate the incised nasal mucosa and expose the frontal process of the maxilla and its articulation with the lacrimal bone. The posteriorly hinged nasal mucosal flap is excised (Fig. 23.2e, f) with Weil-Blakesley forceps. Once the lacrimal fossa is exposed, the thin lacrimal bone is elevated off the posterior half of the lower lacrimal sac up to the insertion of the uncinate process. With the use of a 3 mm forward-biting straight Kerrison ronguers (Fig. 23.2g, h), the thick bone of the frontal process of the maxilla is sequentially removed. The osteotomy is gradually enlarged superiorly so that the light pipe held horizontally can easily be seen tenting

the lacrimal sac from within the nasal cavity, confirming that bone has been removed to the level of the common internal punctum. Any residual bone that appears dark against the bright red transillumination of the lacrimal sac needs to be meticulously removed. Finally the medial wall of the lacrimal sac is incised (Fig. 23.2i) with a myringotomy sickle knife while the lacrimal sac is tented by a light pipe and a large posteriorly hinged lacrimal mucosal flap is created. The overhanging edge of the lacrimal mucosal flap is trimmed with Blakesley forceps to create a marsupialized sac. Irrigation (Fig. 23.2j) is done to check for the patency of the drainage system. Bicanalicular silicone tubes are introduced through the canaliculi, retrieved and secured by two square knots in the nasal cavity. A prospective randomized trial currently underway by one of the authors (PJD) appears to show that the lacrimal stents may be an unnecessary step.

The patients are followed at 3 months after surgery and are asked to return subsequently if their symptoms return. At each visit, the patient is specifically asked about epiphora and syringing of the lacrimal passage is done. Tubes are usually removed after 6–8 weeks of surgery and/or earlier if there is spontaneous extrusion.

Outcomes

In a large comparative series of 354 patients reported by Dolman in 2003, complete success was achieved in 89.1 % (179/201) of NEN-DCR's compared to 90.2 % (138/153) of traditional external DCRs [4]. Among patients who underwent further revision NEN-DCR, 90 % achieved success and complete relief from symptoms in the above series of patients [4]. In 2009, Razavi et al. [8] reported combined symptomatic and anatomic patency in 96 % patients in a series of 99 NEN-DCRs performed in 95 patients. They achieved favorable outcome in 51/53(96 %) patients with chronic NLDO, 31/32(96 %) patients with acute/subacute dacryocystitis, 13/14(93 %) revision surgeries [8]. The above studies clearly show that NEN-DCR has outcomes comparable to external DCR [4, 8].

Ophthalmologists often prefer external over endonasal DCR owing to nonfamiliarity with the nasal anatomy and longer learning curve in the endonasal approach. Preechawai [9] studied the learning curve of NEN-DCR in 75 DCRs which were performed by the author who had no prior training in nasal endoscopy and by residents under his supervision. The functional success rate in their study was 74.7 % and anatomical patency was 92 % [9]. Onerci et al. [10] observed that success of endoscopic DCR could range from 94 % in the hands of experienced surgeons to 58 % in inexperienced hands. The above studies go to show that endoscopic DCR has a longer learning curve than NEN-DCR [9, 10]. The simpler instrumentation and lacrimal sac transillumination acting as a guide in NEN-DCR may be responsible for easier learning of the technique (Table 23.1).

Complications

NEN-DCR is a relatively safe procedure with few serious complications reported [4, 8, 9]. Unlike external DCR, the average intraoperative bleeding is minimal (≤12 ml) in NEN-DCR [8]. More serious complications include orbital fat prolapse and medial rectus incarceration [4]. In an endonasal approach, most sharp instruments point toward the orbit [9]. It is important to remember that the posterior landmark to the lacrimal sac is the uncinate process of the ethmoid bone and therefore surgical manipulations must be restricted to the area anterior to this landmark [5].

Mild postoperative epistaxis is common [9]. The most common complication of NEN-DCR is failure in 5–10 % [8]. The varied patterns of failure described are cicatrization at the ostium, synechiae between ostium and middle turbinate and/or nasal septum, and granuloma formation within the ostium [4, 8]. Canalicular obstruction, orbital and subcutaneous emphysema, conjunctival fistula formation, and retrobulbar hemorrhage, as well as transient medial rectus paresis are other rare postoperative complications reported after endonasal DCR [10]. Tube-related complications include punctal erosion, granuloma formation, and spontaneous extrusion [8].

Table 23.1 Comparison of endoscopic endolaser DCR and non-laser non-endoscopic DCR

	Endonasal DCR assisted by endoscope/LASER	Non-LASER non-endoscopic DCR
Equipment	Complex instruments like Endoscope and LASER units a prerequisite; LASER protective shields for safety required	Simple instruments – Halogen/LED light source and endoilluminator 23G/20G required
Technique	Steeper learning curve: familiarity with the nasal anatomy [10]	Easier to learn; [9] lacrimal sac transillumination makes procedure easier for a novice surgeon
Frequent follow-ups	Required for nasal lavage in endolaser DCR especially after LASER	Not required as less damage to nasal mucosa
Portability of instruments	Difficult to transport bulky equipment; often done at large multispeciality hospitals	Simpler equipment can be easily transported; suited for remote clinics and in developing regions
Operation cost	High; maintenance of LASER, endoscope sterile sleeves for instruments, anti-fog solution, increased OR time for setup of equipment	Affordable

Conclusion

NEN-DCR is a safe and effective procedure in the treatment of PANDO. Transillumination of the lacrimal sac makes learning easier for even a novice surgeon. It can be performed without expensive instrumentation and therefore may be particularly suited for the developing regions of the world.

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Primary Endocanalicular Laser Dacryocystorhinostomy

24

Raoul Paolo D. Henson

Introduction

External Dacryocystorhinostomy (Ex-DCR) is the current gold standard in the treatment of primary acquired nasolacrimal duct obstruction (PANDO). Description of a transcanalicular DCR was first published in 1963 by Jack [1]. In recent years endoscopes have been modified and are now able to visualize the canaliculus, sac, and duct. Similarly, lasers have evolved and are smaller, portable with thinner diameter fiber optics, and can be inserted through small orifices like the canaliculus. All these advances in endoscopy and laser technology led to the discovery of endocanalicular laser dacryocystorhinostomy (ECLDCR). Levin and Silkiss were the first ones to describe this laser technique using cadavers in 1992 [2, 3]. Micahalos et al. also followed suit with cadaveric studies with ECLDCR in 1995 [4]. Christenbury was the first to perform ECLDCR in patients using an argon laser [5, 6]. Since then, numerous clinical articles have been published using ECLDCR with varying success rates at 47–97 % [5–30].

In ECLDCR, a laser fiber optic is inserted in the punctum, passed through the canaliculus, and finally into the lacrimal sac. A standard-diameter nasal endoscope is used to visualize the laser glow from the nasal side (Fig. 24.1). Then the laser fiber optic is utilized to puncture into the nasal cavity thereby creating an osteotomy. Since there is no marsupialization of the lacrimal sac with the nasal mucosa, the patency of the otium is of utmost importance in ECLDCR. The surgical success of a primary ECLDCR will depend on proper patient selection, thorough preoperative

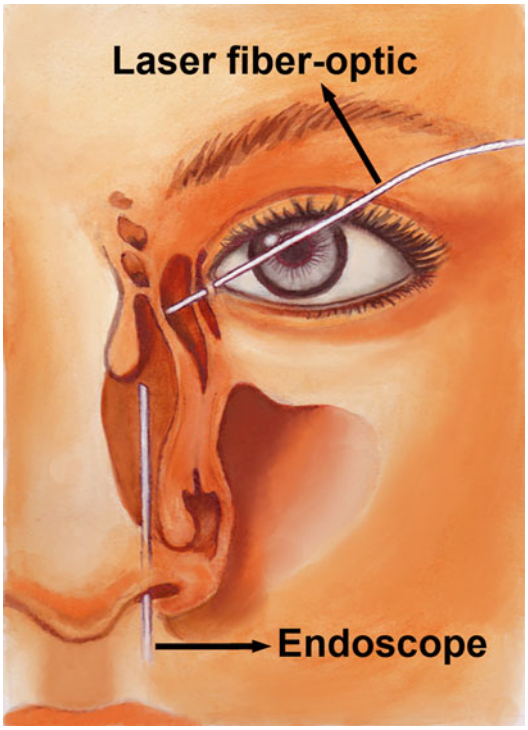

Fig. 24.1 Schematic overview of ECLDCR (Photo courtesy: Josie Henson, Philippines)

R.P.D. Henson, MD
Ophthalmic Plastics Surgery, Makati Medical Center, Makati City, Philippines
e-mail: Henson_raoul@yahoo.com.ph

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nasal endoscopy, appropriate laser machine, good technique, and appropriate timing of adjuvant therapy (Mitomycin-C) [19, 20, 24, 28].

Patient Selection

Proper screening tests should confirm the diagnosis of primary acquired NLDO. Only patients with chronic epiphora without infection and discharge (dacryostenosis) can undergo ECLDCR. Patients with a history of acute dacryocystitis and mucocoele formation are not good candidates [32]. These conditions should preferably be treated with the external or endonasal approach. This procedure is also contraindicated in patients with suspected dacryolithiasis, neoplasm, and NLDO secondary to sarcoidosis or Wegener's granulomatosis [7, 13, 16]. Table 24.1 summarizes the oculolacrimal contraindications for ECLDCR.

Proper antibiotic treatment and thorough lacrimal irrigation should be initially done to remove the purulent material before ECLDCR. Nasal endoscopy should be a routine practice for preoperative evaluation before ECLDCR. This will give the surgeon an overview of what to expect before the surgery. The two most important nasal structures to look out for are the septum and the middle turbinate. Severe septal deviation is a relative contraindication; therefore, a septoplasty if one is competent or a referral to an ENT surgeon is warranted before proceeding to ECLDCR. An enlarged middle turbinate can be partially resected to expose the surgical area [24, 34]. Patients who have undergone previous nasal surgery (functional endosocopic sinus surgery–FESS, polypectomy, etc.) are not good candidates for ECLDCR [20, 25]. Patients who also had naso-orbital trauma involving the lacrimal system are undesirable for this type of surgery [20, 25]. Table 24.2 summarizes the nasal contraindications for ECLDCR.

Table 24.1 Oculo-lacrimal contraindications of primary ECLDCR

1. Acute dacryocystitis
2. Chronic dacryocystitis with mucopurulent discharge
3. Mucocoele
4. Lacrimal fistula
5. Suspected dacryolithiasis
6. NLDO secondary to Sarcoidosis or Wegener's graulomatosis
7. Previous lacrimal surgery
8. Lacrimal tumors

Diode Laser and Setup

The ideal laser in ECLDCR must produce enough power to allow the surgeon to create an adequate osteotomy without inducing damage to surrounding tissues [17, 30]. Different types of lasers have been applied in ECLDCR. These are the Argon laser, the Holmium (Ho): Yttrium Aluminum Garnet (YAG) laser, Neodymium (Nd): YAG laser, Potassium Titanyl phosphate (KTP): YAG laser, Erbium (Er): YAG laser, and the diode laser [6–30] (Table 24.3). In recent years, the diode laser (Fig. 24.2) has been gaining popularity due to a number of advantages.

Diode lasers are designed for multispecialty application in minimally invasive surgery (ophthalmology, otorhinolaryngology, and urology), open surgery (obstetrics and gynecology), interstitial laser therapy, and vascular applications (dermatology and vascular surgery) [5]. Therefore, from a financial perspective a single diode laser in a hospital setting can be shared by surgical specialties. Operating at a wavelength of 810–980 nm in the near-infrared portion of the spectrum, this laser induces excellent hemostasis due to its high absorption in melanin and hemoglobin. It is compact, portable, and can fit neatly into any doctor's clinic or operating suite. Due to its portability, it can be easily transported from one clinic to another or between hospitals. Setting

Table 24.2 Nasal contraindications of primary ECLDCR

1. Previous nasal surgery (e.g., functional endoscopic sinus surgery)
2. Extensive nasal polyposis
3. Severe allergic rhinitis
4. Atrophic rhinitis
5. Naso–orbito–ethmoid facial fractures involving the nasolacrimal canal
6. Nasal malignancy

Table 24.3 Different types of lasers in ECLDCR

Laser	Wavelength (nm)	Power (W)	Fiber size (um)	Comments
Diode	810–980	0.5–60	400–1,000	Good cutting effect Good hemostasis Good coagulation Less collateral damage
Nd: YAG	1,064	3–10	600	Good cutting ability More collateral damage
KTP	532	10	300	Good cutting effect Good coagulation Need protective wear
Er:YAG	2,940	0.1–0.4	350–425	Good bone ablation Poor coagulation Okay for canaliculoplasty
Ho:YAG	2,140	2.5–20	300–1,000	Adequate coagulation Soft tissue ablation Easily penetrates bone

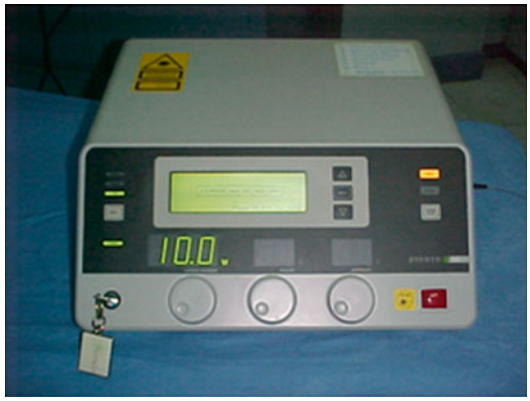

Fig. 24.2 Diode laser (DIOMED, Cambridge, United Kingdom)

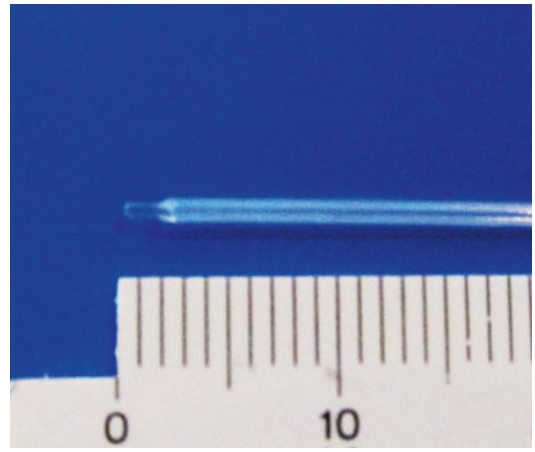

Fig. 24.3 Laser fiber optic (600 um)

up this laser is also simple and easy. All diode lasers run from a standard electrical wall socket and are ready for use within seconds. The menu-driven user interface is simple and it gives immediate access to treatment options with continuous, pulsed or repeat-pulse mode. There is also minimal maintenance and service requirements needed because this surgical laser has a solid-state system and has no moving parts. The laser energy delivery system uses a flexible fiber whose diameters range from 400 to 1,000 um [20, 31] and give easy access to confined areas and is also compatible with endoscopic instrumentation for surgical applications (Fig. 24.3).

Surgical Procedure

General or local anesthesia can be used for ECLDCR. Any laser with a rigid laser fiber optic can be utilized, but in the past decade, the diode laser has been the preferred laser of choice due to the advantages reported earlier. The diode laser setting used is at an average of 10 W with continuous laser delivery using the contact mode. A 600 um semirigid laser fiber optic is used. Nasal packing is done with a ¼ inch gauze soaked with 0.5 % oxymetazoline hydrochloride. This is left in place for 10 min and removed just before the laser treatment.

The punctum is dilated using a punctum dilator and a bowman 0 probe slid through the canaliculus to also dilate it before the insertion of the fiber optic. Once a hard stop is felt, the Bowman probe is removed. The 600-um laser fiber optic is inserted in the lower punctum into the canaliculus up to the level of the lacrimal sac in a 45° fashion (Figs. 24.4 and 24.5). The nasal pack is removed and a 0° nasal video endoscope attached to a TV monitor (Fig. 24.6) is inserted through the nostril to visualize the transilluminated laser light from the lacrimal sac. We call this the "laser glow." If the laser glow cannot be visualized, an assistant can minimize the light source from the nasal endoscope. This will reveal the location of the laser glow corresponding to the thinnest portion of the lacrimal bone. This area is anterior and inferior to the insertion of the middle turbinate [16] (Fig. 24.7). A periosteal elevator can be used to medialize the middle turbinate for good exposure during the laser procedure while protecting it from the heat of the laser probe (Fig. 24.8). Laser osteotomy is done by first puncturing the laser fiber optic through the lacrimal bone and nasal mucosa via contact energy mode with continuous setting. This is called "laser puncture" (Fig. 24.9). Once the laser penetration is done, an area of coagulation and necrosis will be seen on the nasal mucosa surrounding the laser fiber optic. From this position, the fiber optic can be moved sideways, upward, and downward in a

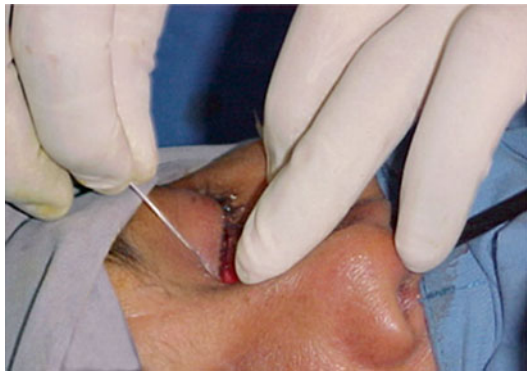

Fig. 24.4 Insertion of laser fiber optic at 45° (Note the glow of the laser from the medial canthal area)

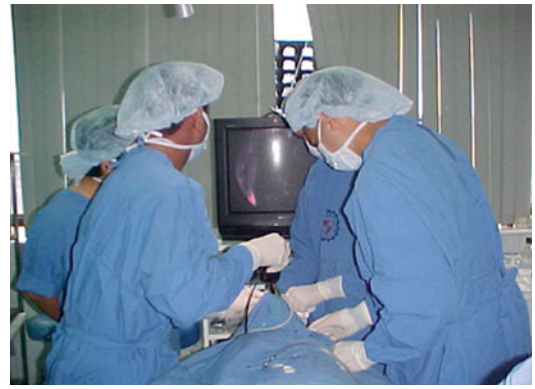

Fig. 24.6 Visualization of the surgery using a endoscopic viewing system

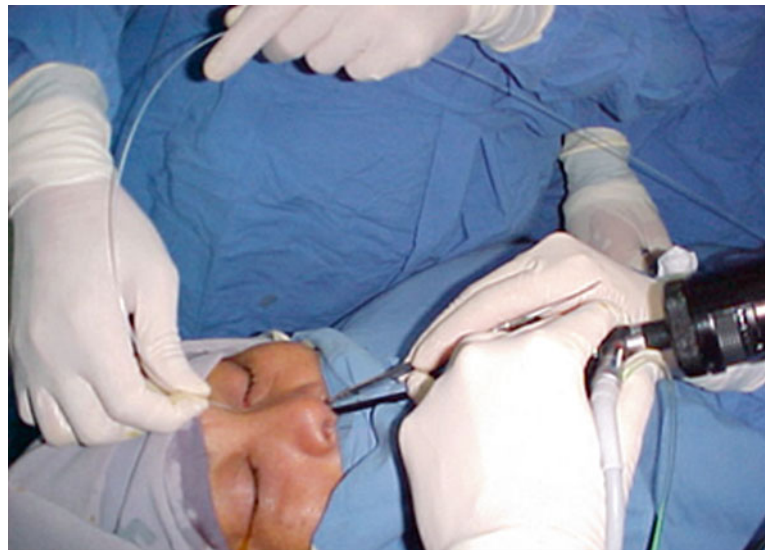

Fig. 24.5 Overview of laser fiber-optic insertion toward lacrimal bone

circular fashion, thereby enlarging the osteotomy (Fig. 24.10). The direction of the laser fiber optic is emphasized mostly on the inferior area. Enlarging this area using a downward direction of the laser fiber optic may prevent the lacrimal sump syndrome. A 10-mm cotton ball is soaked with 0.1 ml of a 0.2 mg/ml of Mitomycin-C (MMC). This is placed on the osteotomy site for 5 min with no irrigation after the application (Fig. 24.11). Nonirrigation of MMC will increase its maximum pharmacologic effect on the osteotomy site [20]. The silicone stents are guided through the inferior and superior canaliculi and retrieved with hooks or mosquito forceps under endoscopic visualization (Fig. 24.12). They are tied in a square knot and encircled using 6–0 silk sutures.

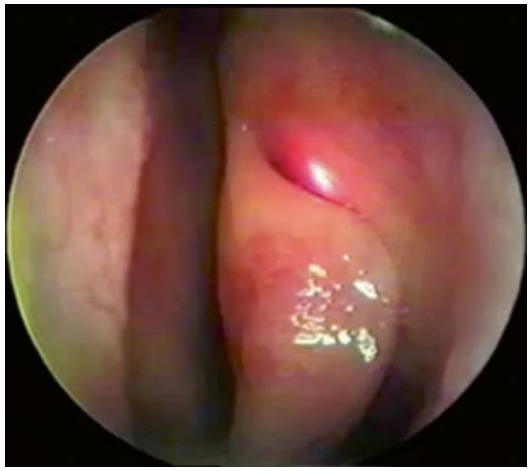

Fig. 24.7 Nasal endoscopic view of the "laser glow." This corresponds to the thinnest portion of the lacrimal bone

Postoperative Care and Mitomycin-C Application

Postoperative medications for ECLDCR include tobramycin–dexamethasone eye drops used four times a day in the ipsilateral conjunctival sac and mometasone furoate steroid nasal spray, one dose to the operated nostril three times per day are prescribed. The medications are tapered gradually over a 12-week period. Postoperative examinations are done at 1 week, 2 weeks, 3 weeks, 1 month (Fig. 24.13), 3 months, 6 months (Fig. 24.14), and 12 months (Fig. 24.15).

In each postoperative visit, nasal endoscopic guided cleaning of the ostium from blood clots, dried mucus, and debris is done using a suction machine. This is of paramount importance in ECLDCR because it can reduce the inflammatory stimuli that these may create after the surgery [19, 24, 31]. Lacrimal irrigation is also done to further clear the debris inside the lacrimal passageway. Postoperative nasal endoscopy may also be needed to assess problematic cases [31].

The use and advantages of MMC in lacrimal surgeries is well known [32–44]. MMC, the

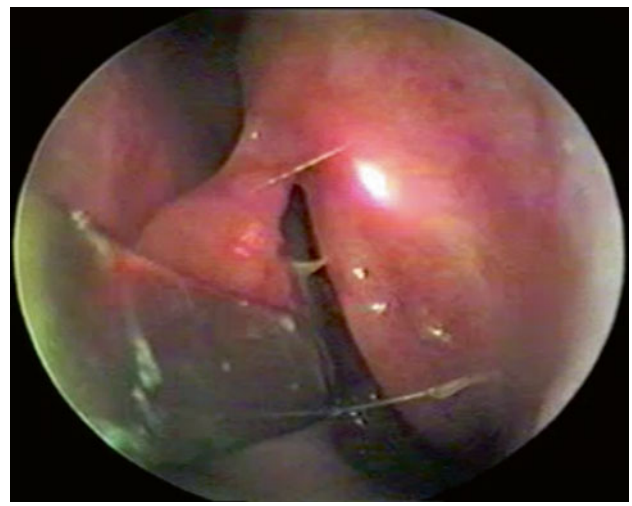

Fig. 24.8 Periosteal elevator medializing and protecting the middle turbinate before the laser application

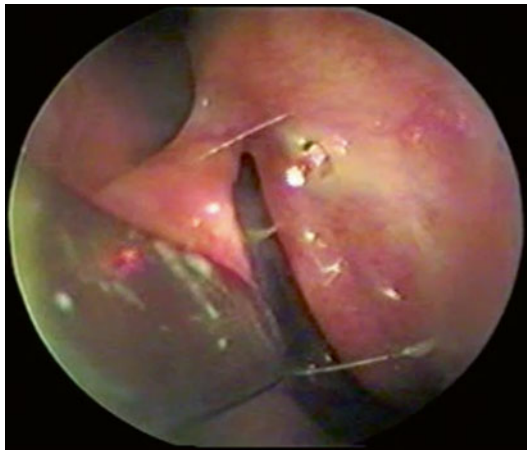

Fig. 24.9 Creating the first osteotomy using the laser fiber optic. This is also called "laser puncture." (Note no bleeding during the puncture with whitening and coagulation of the mucosa around the tip)

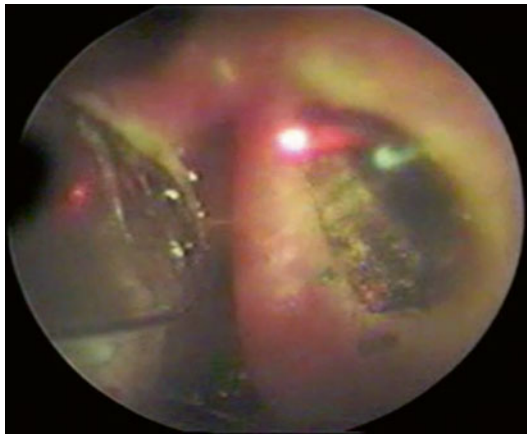

Fig. 24.10 Enlarging the osteotomy (Note the periosteal elevator protecting the middle turbinate and absence of bleeding during the laser process)

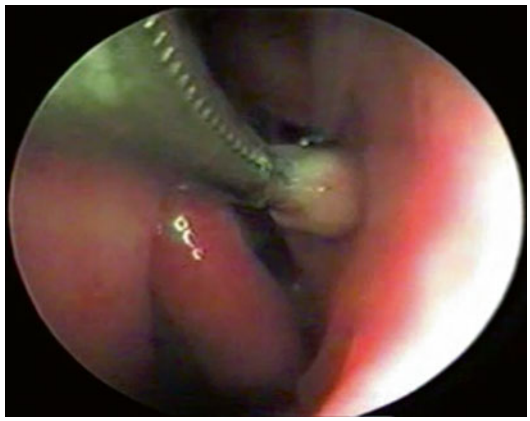

Fig. 24.11 Intraoperative Mitomycin-C application

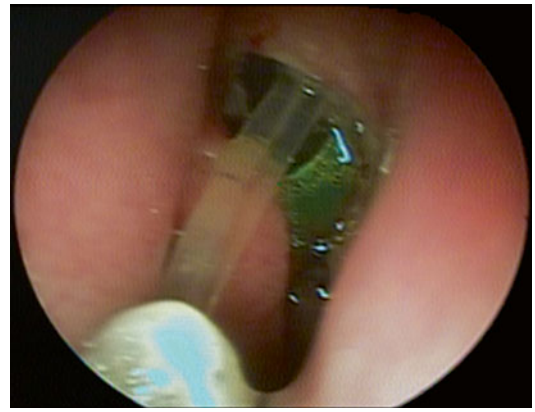

Fig. 24.12 Postoperative osteotomy with silicone tubes

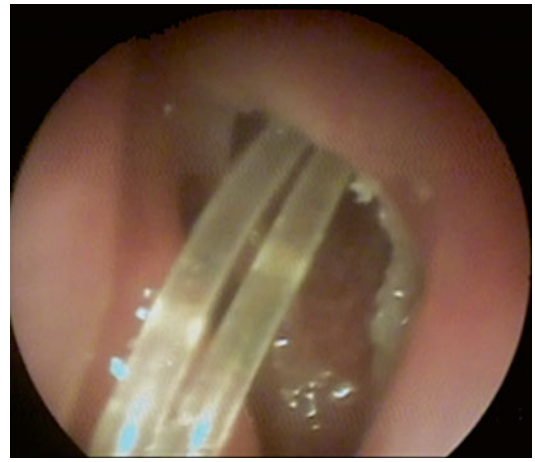

Fig. 24.13 Postoperative image of the osteotomy with the tubes intact at 1 month

preferred adjuvant during ECLDCR, can be applied not only during surgery but also in the postoperative phase of osteotomy healing [25]. After cleaning the osteotomy during each postoperative visit, a 10-mm cotton ball soaked with 0.1 ml of MMC (0.2 mg/ml) is applied at the ostium site for 2 min without irrigation. This will inhibit fibroblast formation around the edges of the ostium, thereby reducing the chance of phimosis or closure. Topical MMC application can be done on a weekly basis for a maximum of 3 weeks after the surgical procedure. Residual fibroblasts that may remain on each follow-up visit, can be further inhibited until the ostium edges are healed resulting in its continued patency [25].

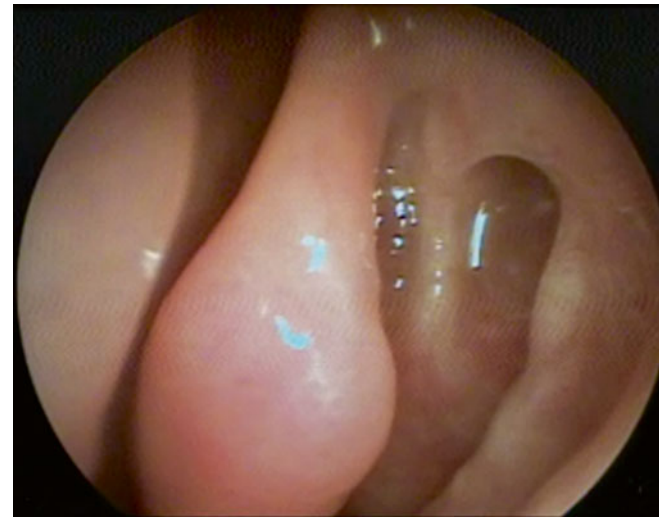

Fig. 24.14 Postoperative image of osteotomy at 6 months

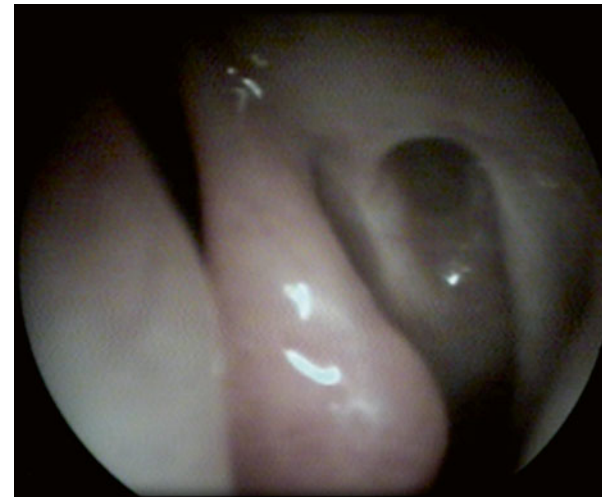

Fig. 24.15 Postoperative image of osteotomy at 1 year

Once the edges of the ostium are fully healed, the silicone tubes are removed approximately 8 weeks after the surgery. The combination of naso-endoscopic cleaning, nasal steroid application, lacrimal irrigation, and adjuvant application can increase the chance of nonclosure of the ostium during the postoperative period.

Adjuvant Endoscopic Procedures

In recent years, combined nasal surgery and ECLDR have been done to maximize the exposure of the surgical area to ensure the patency of the ostium. This is true for patients with enlarged middle turbinates that need to be partially removed [24, 30, 34]. The laterally retracted middle turbinates can also be medialized or infractured to expose the surgical area [20, 34]. Good exposure will lead to a bigger osteotomy and can prevent turbino-ostial synechial adhesions. One recent study utilized endonasal mucosal flaps with ECLDCR. Their success rate is 89 % but only seven eyes were done [30]. This mucosal flap–ECLDCR technique appears to be promising; however, larger sample size with long follow-up is needed to prove its efficacy.

Advantages and Disadvantages of Ecldcr

ECLDCR is one of the alternatives to an external or endoscopic DCR for the management of PANDO. There are numerous advantages of ECLDCR [5–30] and these are listed in Table 24.4. However, the additional expense of the laser and the endoscope, steep learning curve initially, and poor outcomes if improperly done are the hindrances most doctors face, although its similarity to lacrimal probing makes the procedure easier to adapt for the Ophthalmologist [6, 9, 16, 18, 20].

Complications

Despite ECLDCR being a novel alternative to ExDCR, it has its share of complications [5–30, 45, 46]. Table 24.5 enumerates the possible complications of ECLDCR.

Table 24.4 Advantages of ECLDCR

1. Absence of a skin incision
2. Preservation of the medical canthal structures
3. Preservation of the lacrimal pump mechanism
4. Less operative time
5. Local anesthesia and outpatient surgery
6. Laser directed away from the orbit
7. Minimal intraoperative and postoperative bleeding
8. Decrease or no periorbital swelling postoperatively
9. Low morbidity
10. Shorter functional recovery

Table 24.5 Complications of ECLDCR

1. Occasional bleeding
2. Eyelid hematoma
3. Preseptal cellulitis
4. False passage
5. Canalicular stenosis and obstructions
6. Lacrimal sump syndrome
7. Tissue necrosis
8. Nasocutaneous fistula
9. Orbital infarction syndrome

Outcomes

Success after lacrimal bypass is defined as patency to irrigation and resolution of epiphora. Through the years, the success rates of ECLDCR surgeons have been varied ranging from 47 to 97 % [6–30] (Table 24.6). Reports on short-term success rates of less than a year of follow-up range from 47 to 94 % [7, 8, 11, 13, 16, 18, 23, 26, 28]. Medium-term success rates of more than 1 year range from 64 to 97 % [9, 10, 12, 14, 19–21, 24, 25, 27, 29]. Long-term success rates of more than 3 years' follow-up were reported by Nuhoglu and Maeso at 88 and 95.2 %, respectively [22, 27]. These success rates have been widely variable owing to the use of different lasers and technical modifications [21]. However, the use of the diode laser has started a new era in ECLDCR. Most studies using this type of laser have more successful outcomes than their YAG laser counterparts (Table 24.4).

Since there is no flap anastomosis in ECLDCR; the patency of the ostium is the most important concern. The ostium can be reduced in size during the postoperative phase; therefore, the bigger the ostium intraoperatively, the better it is for the patient, although this is not substantiated with strong evidence. The ostium should be endoscopically monitored in the postoperative period just like monitoring a bleb after glaucoma surgery [25]. Intranasal application of MMC intraoperatively has shown to reduce scar formation and prevent closure of the ostium in DCR [13, 19, 20, 22, 25, 29, 32–44]. Hu and Ugurbas have proven that a longer contact time with MMC will lead to apoptosis of nasal mucosal cells with in vitro studies [47, 48]. Ali et al. [49] have shown the ideal in vitro concentrations and durations of MMC using numerous molecular biology techniques on the nasal mucosa fibroblasts; however, these need to be verified with in vivo studies. Kamal et al. [50] have described a new technique of circumostial Mitomycin-C or COS-MMC, where 0.02 % of MMC was injected intraoperatively into the circumostial mucosa with good results. All these studies along with variable results of intraoperative MMC with

Table 24.6 Published literature on primary ECLDCR

Author	*N* (eyes)	Laser	Adjunct	Success rate (%)	Follow-up (months)
Christenbury (1992)	12	Argon	None	50	N/A
Piaton et al. (1994)	41	Nd:YAG	None	75	6
Dalez et al. (1996)	26	Ho:YAG	None	47	7
Pearlman et al. (1997)	49	Nd:YAG	None	85	24
Rosen et al. (1997)	14	Nd:YAG	None	64	20
Eloy et al. (2000)	26	Diode	None	65	N/A
Muellner et al. (2001)	48	KTP	None	83	6
Caversaccio et al. (2001)	12	Er:YAG	None	75	19
Piaton et al. (2001)	317	Nd:YAG/Ho:YAG	MMC/5FU	63.2	6
Hofmann et al. (2003)	78	KTP	None	83	12
Alanon et al. (2004)	34	Diode	None	94.1	11
Hong et al. (2005)	102	Nd:YAG	None	73.6	9.5
Alanon et al. (2006)	150	Diode	Intraop MMC	92	15
	50	Diode	None	78.2	15
Henson et al. (2007)	40	Diode	Intraop MMC	87.5	12
Plaza et al. (2007)	25	Diode	None	88	36
Maeso and Sellarès (2007)	75	Diode	None	92	16
	75	Diode	Intraop MMC	97	16
Cintra and Anselmo-Lima (2008)	32	Diode	None	88	6
Basmak et al. (2011)	37	Diode	None	65.7	14
Henson et al. (2012)	125	Diode	Intraop and Postop MMC	92.8	12
Drnovsek-Olup and Beltram (2010)	126	Diode	None	83.3	6
Nuhoglu et al. (2012)	42	Diode	None	95.2	42
Derya et al. (2013)	25	Diode	None	68	7
Dogan et al. (2013)	30	Diode	Intraop MMC	84.3	24
	27	Diode	None	80	24
Robert et al. (2013)	7	Diode	Mucosal flaps	89	10

ECLDCR suggests that possibly intraoperative and postoperative application of MMC may be the next logical step for maintaining the patency of the ostium.

Conclusion

The advantage of ECLDCR lies in its minimally invasive nature [30]. It is a simple procedure that is more familiar to an Ophthalmologist and Oculoplastic surgeons. It is also an effective procedure that can be performed faster than the other methods of DCR [32]. Improvements in laser technology, surgical technique, use of adjuvants, proper training, appropriate instrumentation, and good patient selection have improved the success of ECLDCR and can be a good alternative to an external or endoscopic DCR.

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5- and 9-mm Balloon-Assisted Dacryocystorhinostomy

25

David I. Silbert and Noelle S. Matta

Introduction

Incisional Daryocystorhinostomy (DCR) was first introduced by Toti in Italy in 1904 [1]. Modifications were introduced over the years resulting in successful procedures by the 1920s. Advances over the past few decades have included the introduction of silicone tubes, antibiotics, and steroids both oral and topical to minimize scarring and infection. Various modifications have been introduced to decrease the size of the external incision or to relocate the incision into the eyelid to decrease the risk of scarring and webbing [2]. Despite this, external DCR remains an invasive procedure with significant morbidity.

In 1988, Becker showed a success rate in external DCR of 92 % without creating flaps [3]. Becker later developed balloon catheters to perform both dacryoplasty and DCR procedures endoscopically.

Advantages of external DCR reported include high success rates of 90–95 % [4]. It is also widely stated that external DCR is more effective in identifying tumors than endoscopic procedures. Disadvantages of incisional DCR include prolonged recovery, significant risk of blood loss, and risk of hypertrophic scarring [4]. Bleeding can result from injury to the angular vessels, as well as bleeding from the nasal mucosa, which is entered in a relatively blind fashion, and cannot be visualized well from the external incision. Postoperative nasal packing is typically needed in external DCR, which is uncomfortable for patients and increases risk of infection. Finally, hypertrophic scarring can lead to difficulty wearing glasses with the nose pad pressing on the incision site.

Endoscopic balloon-assisted DCR offers the experienced lacrimal surgeon a simpler, shorter, and less invasive procedure. Although there is a steep learning curve, once mastered, the procedure has a very low complication rate. The procedure can be performed under monitored anesthesia care, though Laryngeal mask anesthesia is often preferred as it provides greater comfort for the surgeon and the patient while minimizing the depth of the anesthesia and the risk of valsalva associated with an endotracheal tube, which can lead to postoperative bleeding. Other advantages of the balloon-assisted endoscopic approach include the absence of a skin incision, minimal bleeding, absence of edema, less discomfort, shorter recovery time, and a high success rate.

Endoscopic balloon-assisted DCR is indicated for most cases of nasolacrimal duct obstruction. Since the procedure is less invasive, even cases of relative nasolacrimal obstruction which are nonresponsive to other treatment can be considered. Although it is often stated that endoscopic DCR is contraindicated in cases of dacryocystitis or

D.I. Silbert, MD, FAAP (✉)
N.S. Matta, CO, CRC, COT
Department of Pediatric Ophthalmology,
Family Eye Group, Lancaster, PA, USA
e-mail: DSilbert@familyeyegroup.com

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cellulitis, this is not accurate [5]. In fact, the endoscopic approach, which drains the infected sac directly to the nose minimizes the risk of infecting skin structures and the development of cellulitis [5]. Nasal septal deviation is a relative contraindication, though with experience, this becomes less of an issue.

Preoperative Workup

Preoperative workup should include history of tearing, discharge, and infection. It should include dye disappearance test, irrigation of the nasolacrimal system, and probing of the upper and lower canaliculi to verify patency. Endoscopic nasal examination can be performed preoperatively in the office and is useful to assess location of the turbinates and the space in the nose. In cases where patients have significant inflammation in the nose, preoperative inhaled steroids, or a visit to ENT to decrease the inflammation can improve outcomes of the endoscopic procedure.

The preoperative regimen for endoscopic balloon-assisted DCR should serve to suppress infection and treat inflammation in the nose. If the patient has significant dacryocystitis or cellulitis, this should be suppressed preoperatively with oral antibiotics prior to surgery. Amoxicillin with clavulinic acid or clindamycin in penicillin-allergic patients are typically good choices. If there is no response or if *methicillin-resistant Staphylococcus aureus (MRSA)* is suspected, cultures of purulent discharge should be performed that can help in choosing antibiotics. Antiplatelet medications, such as Coumadin, aspirin, Clopidogrel bisulfate, as well as the newer anticoagulants should be discontinued prior to surgery. They should not be restarted until 48 h following surgery or until any postoperative bleeding has ceased.

Immediately, preoperatively all patients should be treated with intravenous antibiotics. Generally, Cefazolin, 1–2 gm IV is given in adults and 25 mg/kg in children. Clindamycin may be used in penicillin-allergic individuals. Intraoperatively, Dexamethasone 8 mg is given, though in diabetics and children the dose is often reduced.

Anesthesia

Anesthesia for endoscopic balloon-assisted DCR typically includes a local block, packing of the nose, and general anesthesia with laryngeal mask anesthesia (LMA) or endotracheal tube, though monitored anesthesia care (MAC) or strict local anesthesia is possible. Typically, lidocaine 2 % with epinephrine mixed 10:1 with bicarbonate is injected intranasally using a 25 gauge spinal needle to the nasal mucosa beneath and anterior to the middle turbinate (Fig. 25.1). The middle turbinate can also be injected, especially if the procedure is being done under strictly local anesthesia (Fig. 25.2). The nose is then packed with

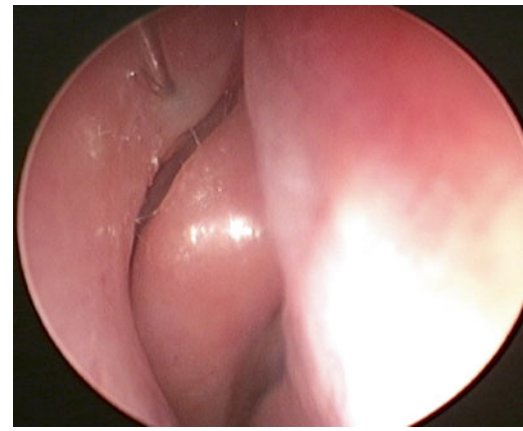

Fig. 25.1 Injection 2 % Lidocaine with Bicarbonate using 25 gauge spinal needle into area of lacrimal fossa and middle turbinate

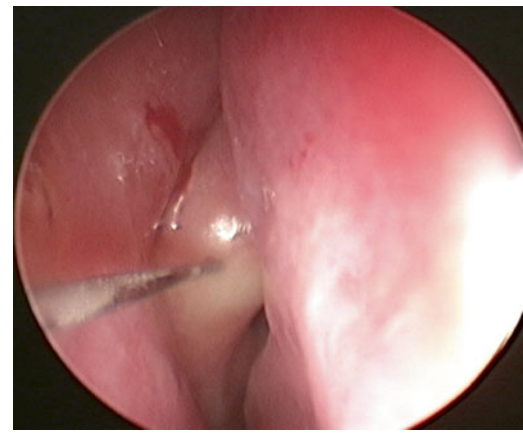

Fig. 25.2 Local anesthetic injection into the middle turbinate

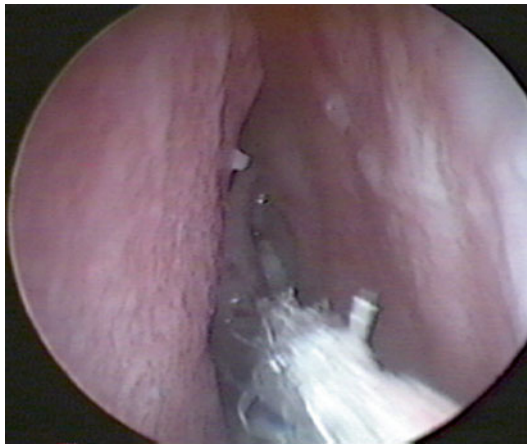

Fig. 25.3 Nose packed with cottonoids soaked in oxymetozoline and cocaine

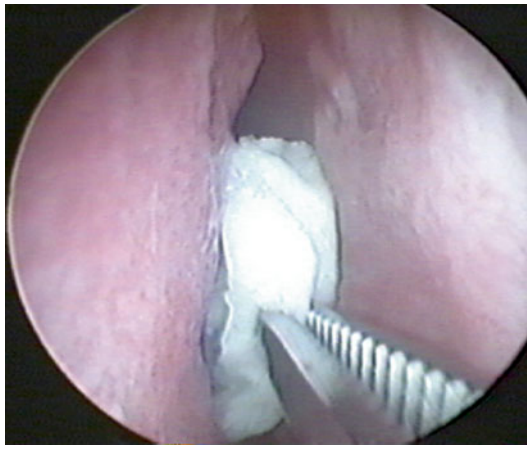

Fig. 25.4 Nose packing completed with cottonoids soaked in oxymetozoline and cocaine

cottonoids soaked in 4 % cocaine mixed 1:1 with oxymetazoline beneath and around the middle turbinate (Figs. 25.3 and 25.4). Local block is injected transcutaneously into the lacrimal sac. Infratrochlear and medial canthal blocks are recommended if the procedure is being performed under strict local or MAC anesthesia.

Balloon DCP Equipment

Equipment for balloon-assisted endoscopic DCR includes the following:

- 25 gauge spinal needle
- Punctal dilators
- Reinforced stainless steel 3–4 Bowman probe (Quest Medical)
- Dandy nerve hook
- Blakesly/true-cut forceps
- Backbiting forceps
- Freer elevator
- Turbinate scissors
- Nasal speculum
- Headlight
- Sinuscope, 4.0/2.7 mm, 0°, occasionally 30°
- 5 or 9 mm Lacricath balloon (Quest Medical)
- Inflation device
- Frazier suction
- Neurosurgical cottonoids
- 4 % Cocaine/Afrin
- Lidocaine
- Irrigating canula

9-mm Endoscopic Balloon DCR: Surgical Technique

The packing is first removed from the nose to visualize the decongested nose (Fig. 25.5). The punctum is dilated well to allow passage of a reinforced stainless steel #3–4 Bowman probe. This can be viewed endoscopically if an assistant is available who can hold the endoscope in place, but most often is done by feel, and after the probe is passed the endoscope is then introduced into the nares. Optionally, a retinal light pipe can be passed while viewing the nose with the endoscope (Figs. 25.6 and 25.7). This nicely demonstrates

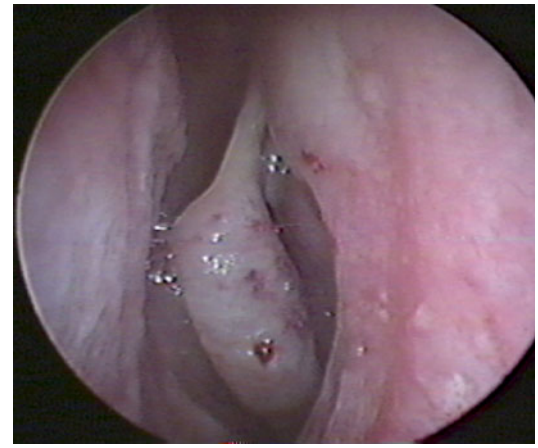

Fig. 25.5 Decongested turbinate after packing removed

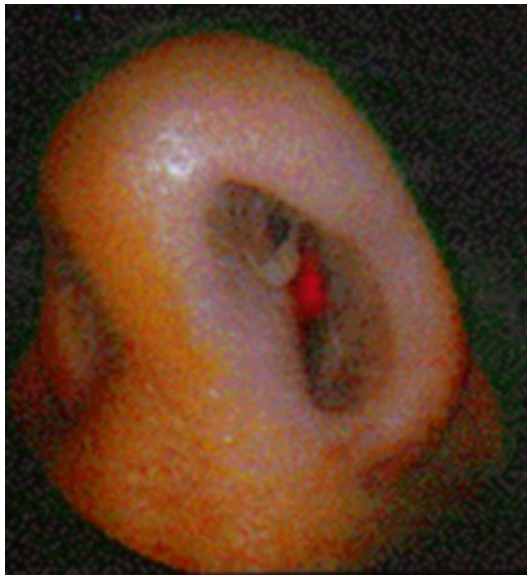

Fig. 25.6 Passing of transcanalicular light pipe (Note the light visualized even externally)

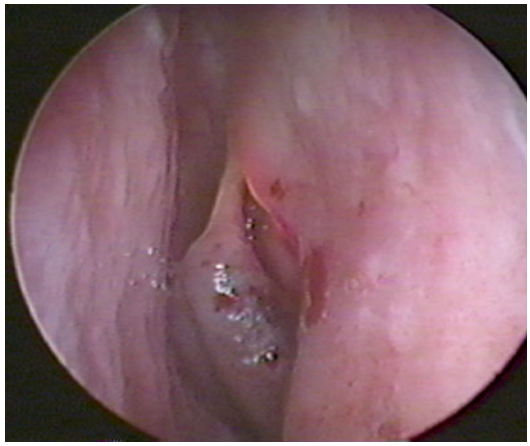

Fig. 25.7 Endotransillumination of lacrimal sac following passing of transcanalicular light pipe

the location of the nasolacrimal sac in relation to the middle turbinate and can help the beginning surgeon to appreciate the appropriate orientation for the passage of the probe (Figs. 25.8 and 25.9). After the surgeon is familiar with the procedure, this step can often be omitted.

The reinforced Bowman probe is passed into the nose (Fig. 25.10). The probe should be oriented somewhat inferiorly and posteriorly and is then passed through the soft posterior por-

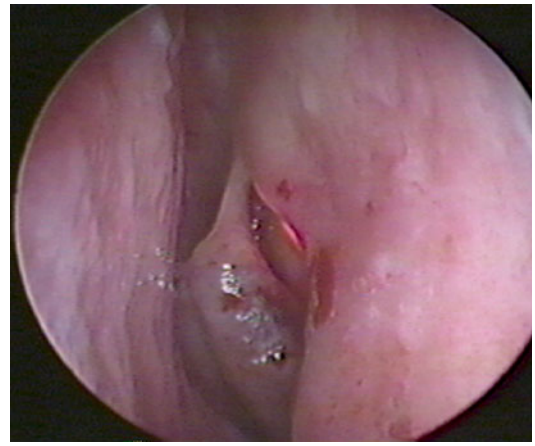

Fig. 25.8 Endotransillumination of NLD following passing of transcanalicular light pipe

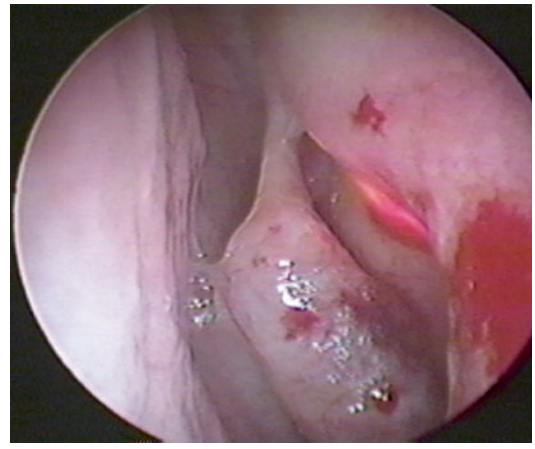

Fig. 25.9 Light pipe demonstrating ideal location for initial entrance into nose

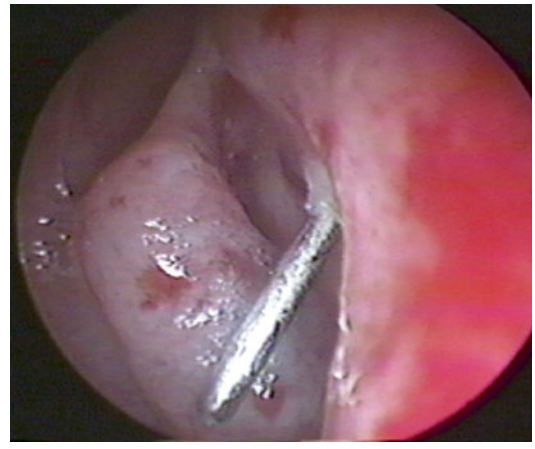

Fig. 25.10 Passage of reinforced probe into nose

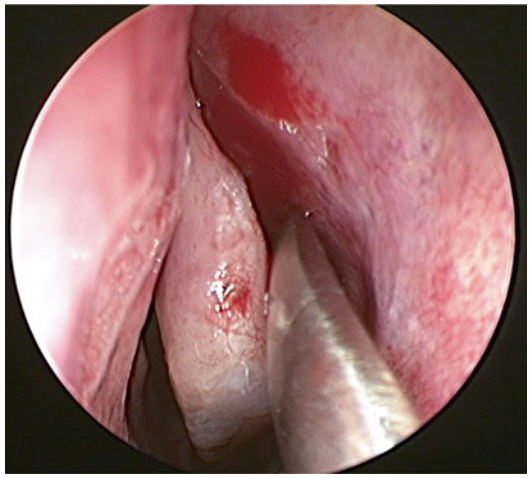

Fig. 25.11 Probe entry assistance to avoid injury to middle turbinate

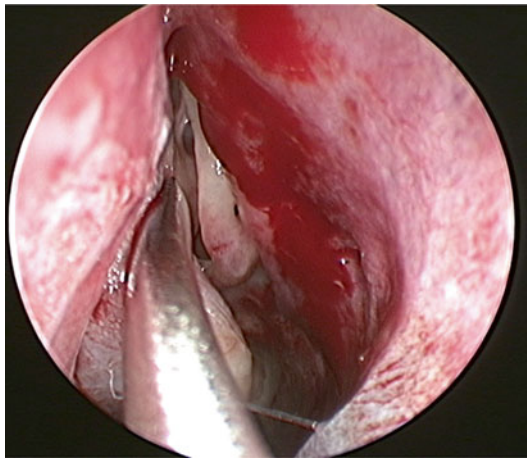

Fig. 25.12 Gentle medialization of middle turbinate

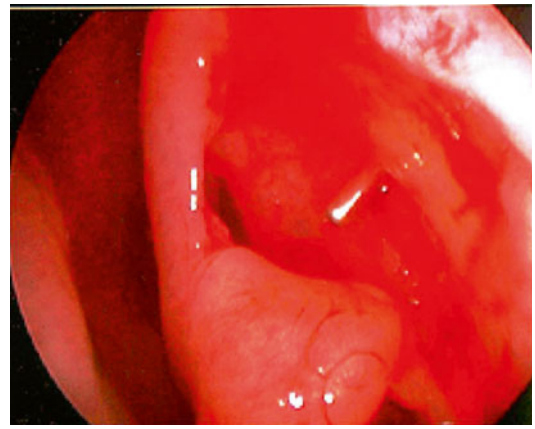

Fig. 25.13 Partial middle turbinectomy where needed

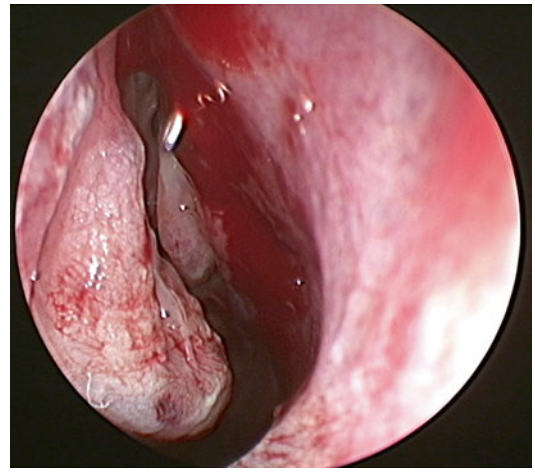

Fig. 25.14 Final probe entry by the reinforced probe

tion of the lacrimal fossa. The probe should be viewed with the sinuscope. It should be found just inferior and beneath the attachment of the middle turbinate, or just slightly inferior and anterior to the middle turbinate. If the probe is inadvertently passed through the turbinate, it should be pulled back slightly. If the probe is in the wrong location or cannot be located, it should be removed and repassed. If the turbinate interferes, it can be gently pushed nasally with a freer elevator (Figs. 25.11 and 25.12). Resection of the turbinate can be performed in cases where it is severely encroaching on the area of the osteotomy (Fig. 25.13). Turbinate resection, however, is rarely necessary and can lead to additional scarring.

The nasal mucosa and thin posterior lacrimal fossa bone is filleted open with the stainless-steel-reinforced Bowman probe, by directing the probe posteriorly and superiorly around its pivot point (Figs. 25.14 and 25.15). In cases where this is difficult, a freer elevator can be used to guide the probe in the nose to perform this filleting process. A medium up-biting Blakesly forceps is then inserted closed into the osteotomy and spread, gently enlarging the osteotomy (Figs. 25.16, 25.17, and 25.18).

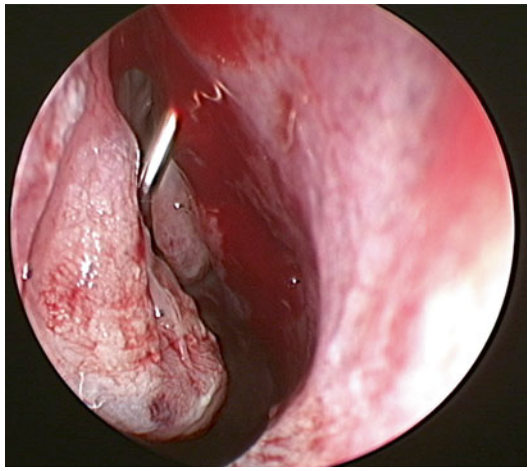

Fig. 25.15 Fillet open mucosa with reinforced probe

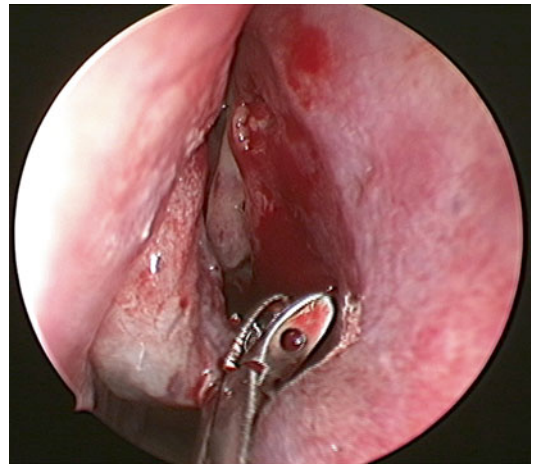

Fig. 25.18 The ostium after the Blakesly spread

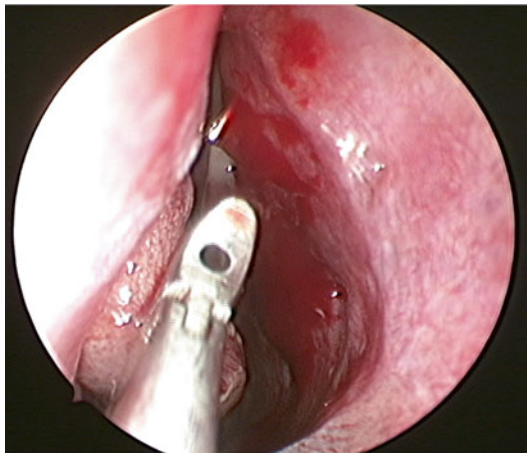

Fig. 25.16 Insert, spread, and remove Blakesly forceps with Bowman probe as guide

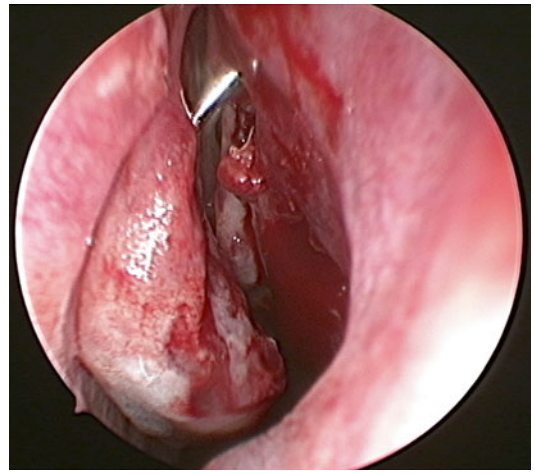

Fig. 25.19 Closer view of the ostium after the Blakesly spread

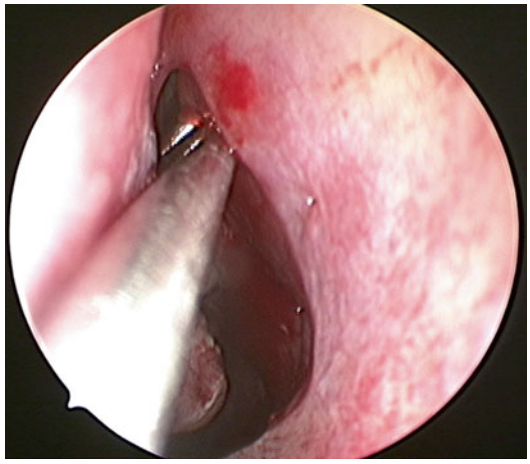

Fig. 25.17 The inserted Blakesly forceps

At this point, the osteotomy is ready for insertion of the deflated 9 mm endonasal balloon (Fig. 25.19). The placement is viewed endoscopically. The balloon is placed approximately 60 % into the osteotomy (Figs. 25.20 and 25.21). It is held in place as viewed with the endoscope as the assistant inflates the balloon to 8 atm of pressure. The balloon gradually enlarges the osteotomy, further fracturing the thin bone of the lacrimal fossa (Fig. 25.22). At this point, the balloon is pulled in a nasal direction into the nose while fully inflated (Figs. 25.23 and 25.24). This serves to pull the fractured lacrimal fossa bone and nasal mucosa toward the surgeon where they can be removed with endonasal instrumentation. This

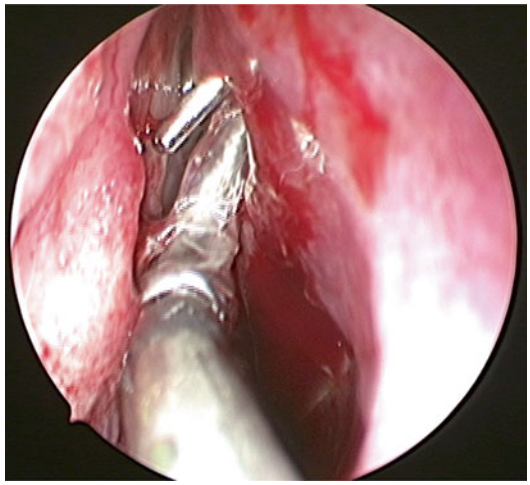

Fig. 25.20 Insertion of the deflated 9-mm balloon into the ostium

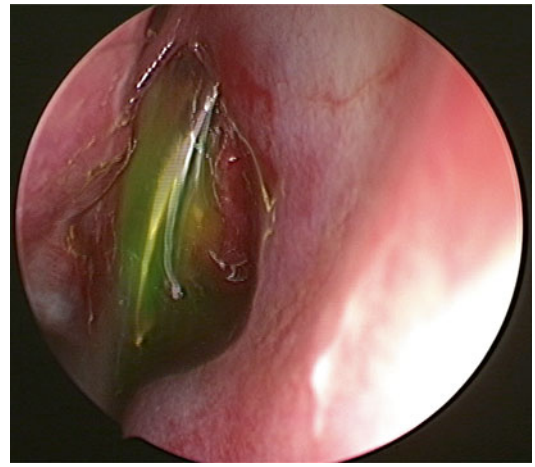

Fig. 25.23 Removal of the balloon in an inflated stage

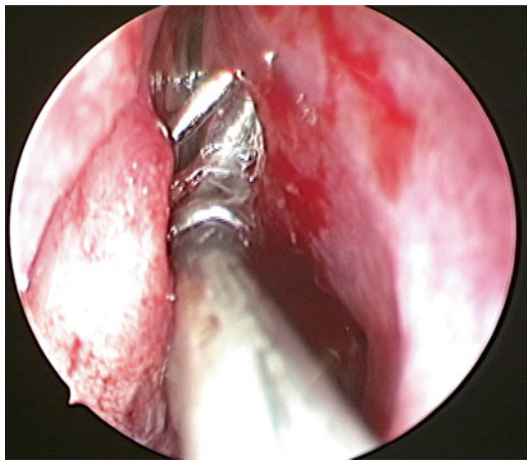

Fig. 25.21 Up-directed balloon to involve the entire ostium

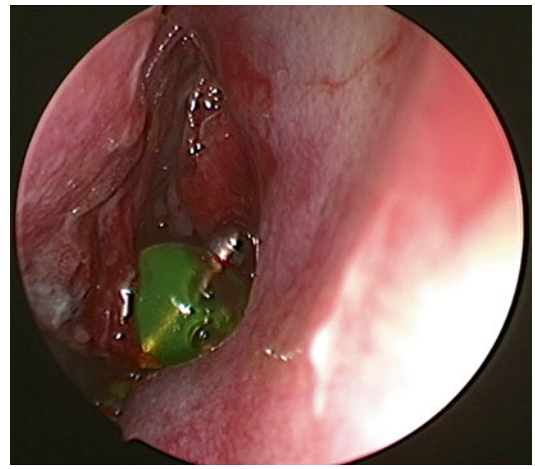

Fig. 25.24 The dilated balloon away from the ostium

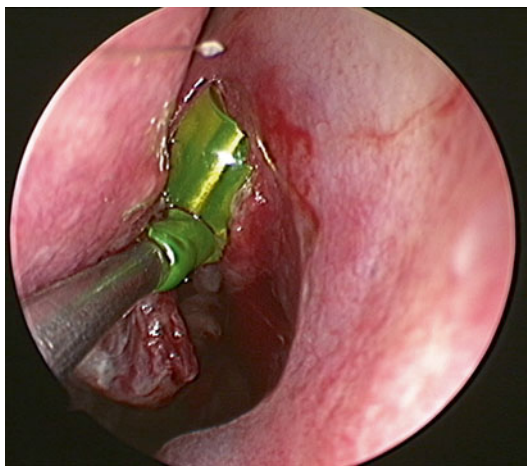

Fig. 25.22 The inflated balloon

can be performed with a medium up-biting Blakesly forceps, or an up-biting cutter such as a Greenawalt forceps (Figs. 25.25 and 25.26). The osteotomy can be enlarged anteriorly with the use of up-biting or backbiting cutters (Fig. 25.27). A motorized suction cutter can also be used but is rarely necessary. We reported a success rate of 92 % utilizing this procedure in a series of 97 cases [6].

Fayet et al. [7] have suggested that anterior resection of the uncinate process is important in better exposing the medial aspect of the lacrimal fossa during endonasal DCR to improve outcomes. Rather than enlarging the osteotomy

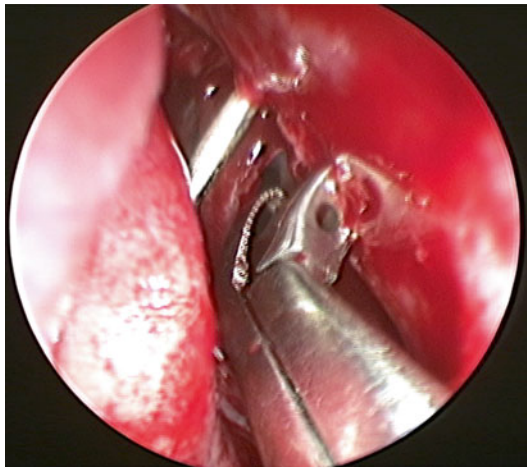

Fig. 25.25 Mucosa removal with Blakesly or true-cut forceps

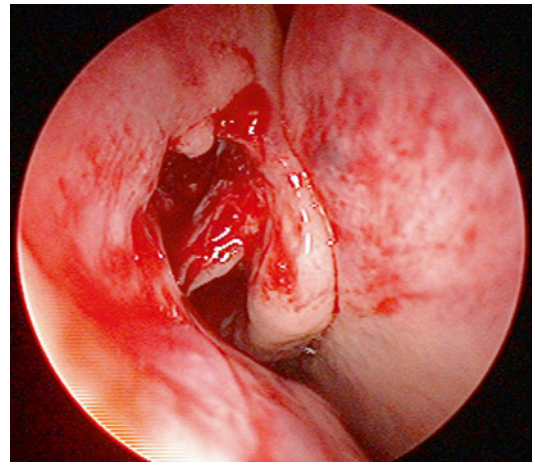

Fig. 25.27 The regular final ostium

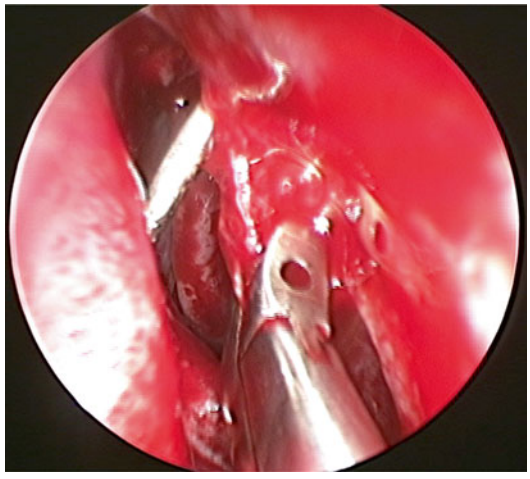

Fig. 25.26 Bone chips removal with Blakesly or true-cut forceps

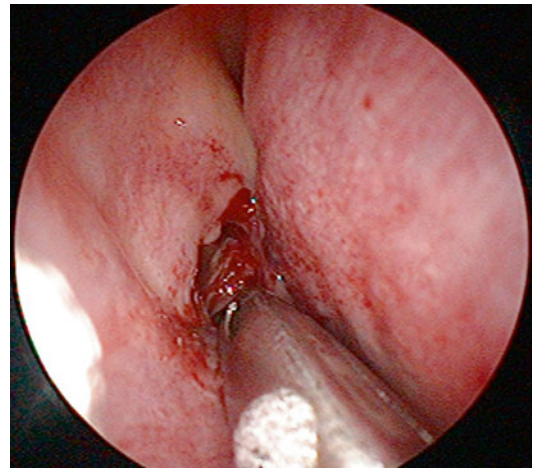

Fig. 25.28 Osteotomy can be enlarged with Blakesly forceps

anteriorly, we have begun enlarging the osteotomy posteriorly by performing an unciformectomy (Fig. 25.28). The procedure is performed similarly to its description previously, but following the removal of the balloon rather than removing mucosal tissue and bone anterior to the osteotomy, attention is focused toward the posterior lip of the osteotomy. The posterior lip is grasped firmly with a straight or up-biting medium Blakesly, not a cutter, and the tissue is pulled firmly toward the surgeon removing the uncinate process, markedly enlarging the osteotomy posteriorly. When done correctly, this is much less likely to induce bleeding than anterior removal of tissue. With unciformectomy creating such a large ostium (Fig. 25.29), we have found that it is unnecessary in most cases to remove bone in the area of the anterior lacrimal crest. In 83 eyes of 59 patients, our success rate utilizing the endoscopic balloon technique combined with unciformectomy was 94 % with one procedure, and 96 % following two procedures [8].

At this point, the soft sheath of an angiocath is used to irrigate an antibiotic steroid solution through the nasolacrimal system (Fig. 25.30). This serves to present redundant soft tissue and

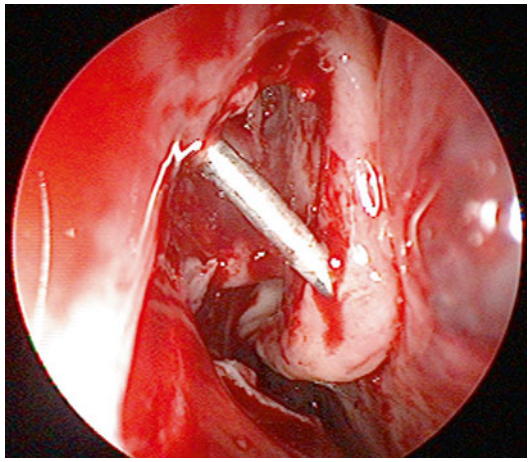

Fig. 25.29 Ostium following unciformectomy

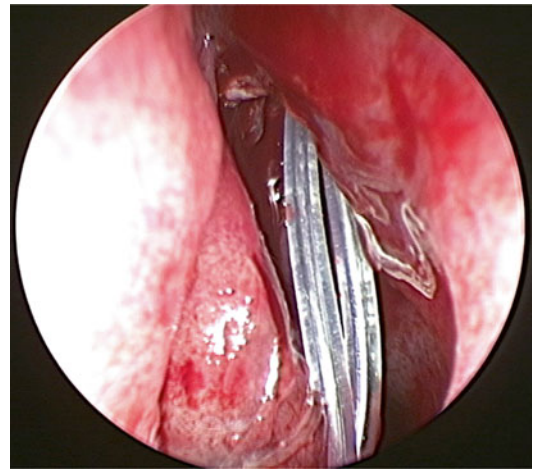

Fig. 25.31 Stent tube insertion

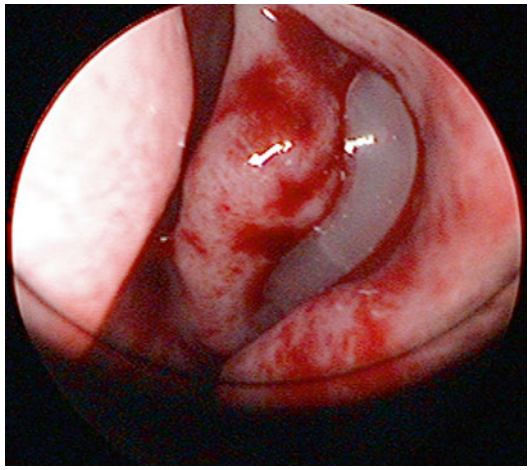

Fig. 25.30 Irrigation of antibiotic and steroid solution

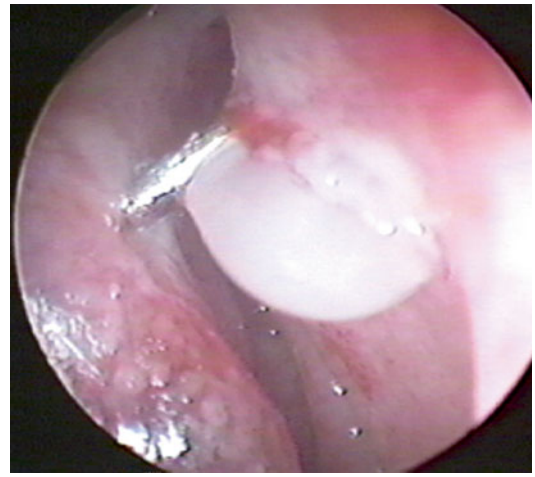

Fig. 25.32 Draining infected sac into nose

bone fragments into the operative area where they can be removed with Blakesly forceps under endoscopic control. At this point, the stent tubes are placed (Fig. 25.31). The stent tubes are preferable to typical Crawford tubes as they enlarge in diameter as they pass from the canaliculi into the osteotomy [9]. It is important to make sure that the smaller caliber endocanalicular portion of the tube is located properly in the canaliculi. This is done by gently pulling the tube from the canaliculi with a Crawford hook to verify that the superior and inferior portion of small caliber tube are equal in size. Once the tube is placed properly it is secured to itself with a single 4–0 silk tie. Alternatively, the tube may be left in place without securing the tube. Due to the increase in caliber as the tube passes through the osteotomy, it tends to be self-retaining [8, 9]. The author typically leaves the tube untied in children as it allows for removal of the tube from the punctum since endonasal removal without anesthesia is difficult in children. In adults, however, the tube is typically secured with a silk tie to itself. Although it is often stated that endoscopic DCR or placement of tubes is contraindicated in cases of dacryocystitis or cellulitis, this is not accurate [5]. In fact, the endoscopic approach, which drains the infected sac directly to the nose minimizes the risk of infecting skin structures and the development of cellulitis [5] (Figs. 25.32 and 25.33)

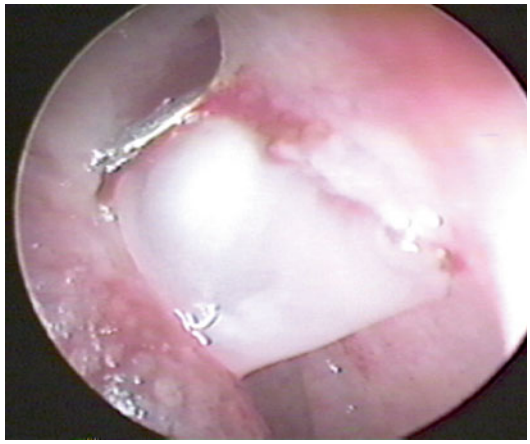

Fig. 25.33 Progressive draining of the infected material into the nose

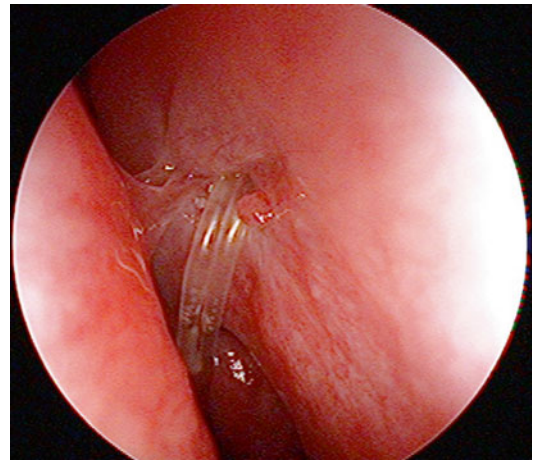

Fig. 25.34 Failed external DCR with osteotomy site anterior and superior to anterior lacrimal crest

Postoperative Care

For the experienced surgeon, there is rarely significant blood loss with the procedure. It is preferable to perform the procedure with laryngeal mask anesthesia as there is less risk of bucking and increased valsalva coming out of anesthesia. This significantly decreases risk of postoperative bleeding. It is rarely necessary to pack the nose postoperatively; however, if there is significant bleeding during the procedure, the nose can be packed with Vaseline gauze and left in place for up to 3 days. It is important to discontinue anticoagulants prior to surgery.

Postoperatively, patients are treated with a quick steroid taper (methylprednisolone pack) over 6 days, as well as oral antibiotics, topical antibiotic and steroid drops for 10 days, as well as intranasal steroids and saline spray irrigation of the nares for 1 month. Patients are generally seen 2–4 weeks postoperatively for endoscopy and saline irrigation of the nasolacrimal system. Any crusting or scar tissue can be removed from the ostium at the first postoperative visit. Often patients will continue to have tearing due to the presence of the sten tube, which due to its large caliber can impede fluid passage in the short term. The sten tubes are removed endoscopically at 3 months by cutting the tubes at the punctum and then grasping them in the nose and removing under endoscopic control with pediatric up-biting Blakesly forceps. At this visit, additional scar tissue and crusting is removed. Typically, the patient is restarted on a topical antibiotic steroid drop for 1–2 weeks, then reexamined and reirrigated in 1 month.

9-mm Revision DCR

The 9-mm endonasal approach can be utilized in some but not all reoperations following external DCR (Fig. 25.34). Frequently, endonasal inspection with an endoscope following a failed external DCR can reveal a bony osteotomy that is too small, located too anteriorly or superiorly (Fig. 25.35). In these cases, an endonasal DCR utilizing the 9-mm endonasal balloon can be appropriate. The procedure is completed as previously described, placing the new osteotomy site lower and more posteriorly (Figs. 25.36, 25.37, and 25.38).

5-mm Endoscopic Balloon-Assisted DCR

Some surgeons prefer utilizing a 5-mm endocanalicular balloon rather than the 9-mm balloon [10]. The 5-mm balloon is useful in situations

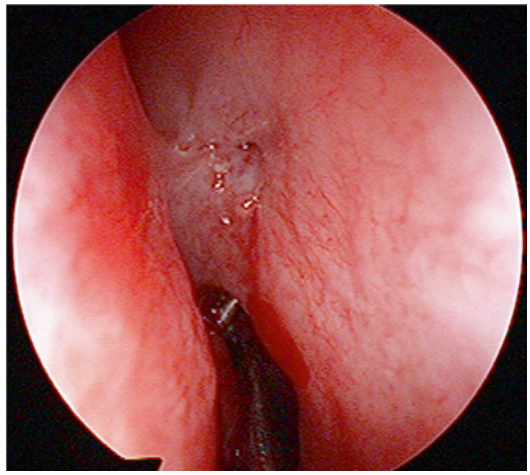

Fig. 25.35 Same patient as in Fig. 25.34. Note probe in new posterior location of osteotomy site posterior to anterior lacrimal crest

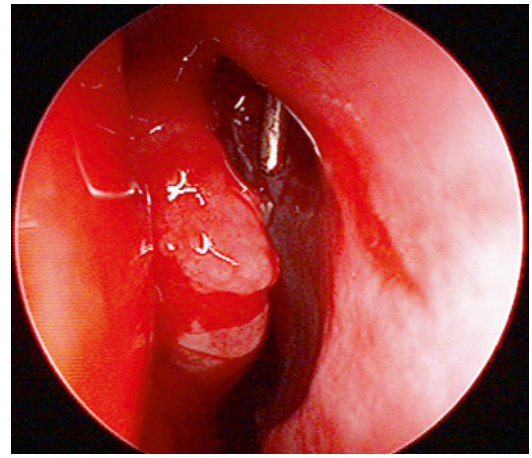

Fig. 25.37 A new large osteotomy following 9-mm balloon-assisted revision DCR

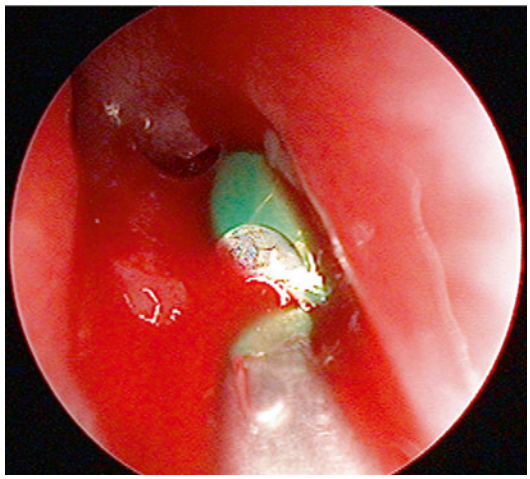

Fig. 25.36 Balloon placement in new osteotomy of the failed DCR case

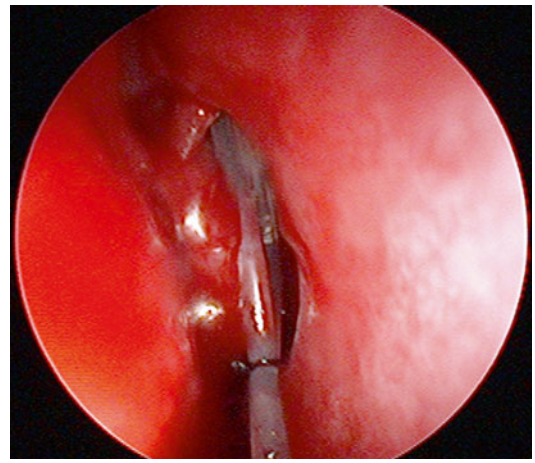

Fig. 25.38 Stent tube secured in the revision case subsequently

where the nose is quite tight, such as in children. Since the 5-mm balloon is passed via the canaliculus, it requires less space in the nose. The 5-mm balloon is also quite useful in endoscopic reoperations following failed external or endoscopic DCR especially when the failure is primarily due to soft tissue scarring and obstruction.

The procedure is similar to the 9-mm balloon procedure previously described but differs in a few important ways. The punctum is dilated. Optionally, a light pipe is passed into the nose to delineate the area where the probe will pass through. Nasal packing is removed and the turbinate is typically gently medialized. The probe is then passed into the nose similar to as described in the 9-mm procedure (Fig. 25.39). The probe is repositioned and 4–5 punctures are created through the lacrimal fossa (Fig. 25.40). These are then coalesced with a Dandy nerve hook (Fig. 25.41). Mucosa and bone fragments are then removed with a Blakesly forceps (Fig. 25.42). The osteotomy can be expanded anteriorly with up-biting cutters and backbiting cutters if desired. It is more difficult to perform

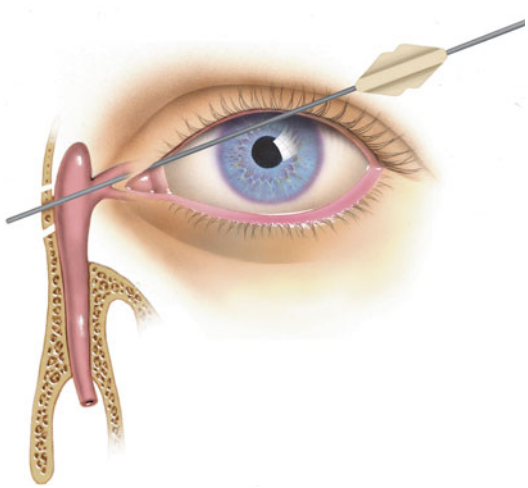

Fig. 25.39 Passing Bowman probe to create multiple punctures

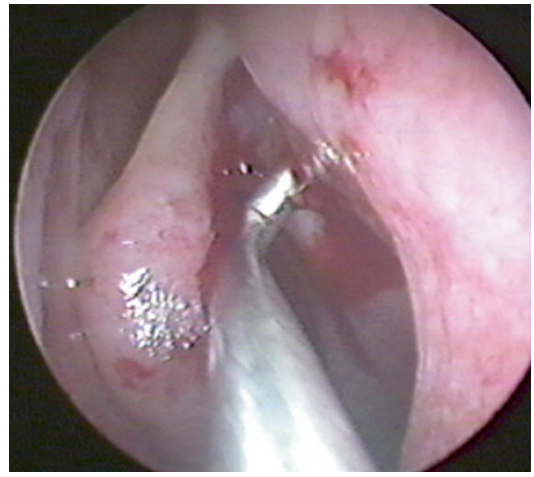

Fig. 25.41 Coalesce of the punctures with Dandy nerve hook

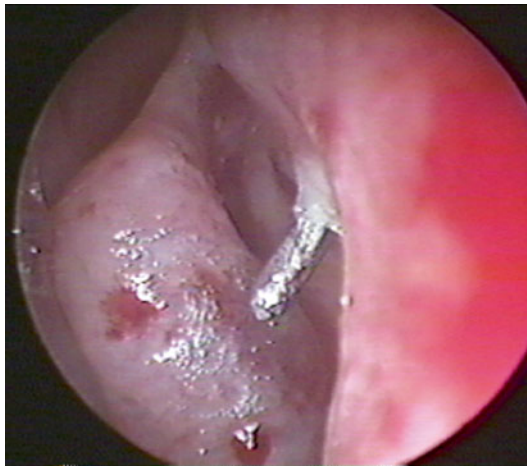

Fig. 25.40 Endoscopic view of the passing of reinforced Bowman probe and creating multiple punctures

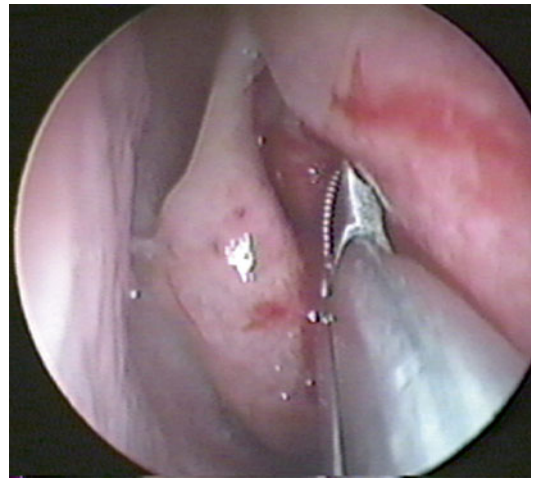

Fig. 25.42 Remove bone chips with Blakesly or cutter

an unciformectomy, however, without use of the 9-mm balloon first.

At this point the balloon is passed via the canaliculus (Fig. 25.43). The balloon is first coated with ointment as this will ease the passage through the canalicular system. Since the balloon is larger in caliber than the 3- and 2-mm balloon that most surgeons are typically familiar with, it is crucial that the punctum and canaliculi are maximally dilated to prevent punctal or canalicular trauma and tearing. The balloon is then passed into the nose via the canaliculus, it is visualized in the nose, inflated to 8 atm for 60 s (Fig. 25.44), deflated, pulled back and forth toward the canalicular system, reinflated for an additional 60 s, and then the tube is deflated by pulling back on the inflator and

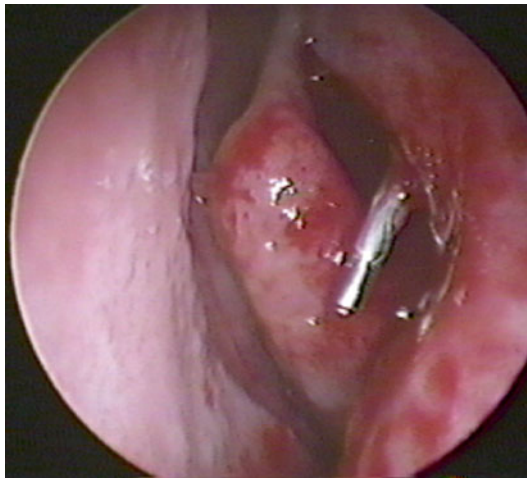

Fig. 25.43 Passing of the 5-mm balloon through transcanalicular route

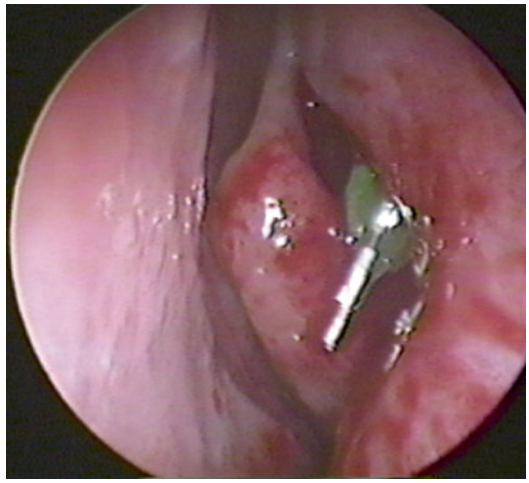

Fig. 25.44 Inflated 5-mm balloon within the ostium

locking it with negative pressure to insure that the balloon has the smallest profile. It is then removed from the canalicular system with gentle traction to prevent canalicular trauma. The ostium is checked with the endoscope, and any additional redundant tissue is removed with Blakesly forceps or cutters. sten tubes are then place as previously described (Fig. 25.45) and secured (Fig. 25.46).

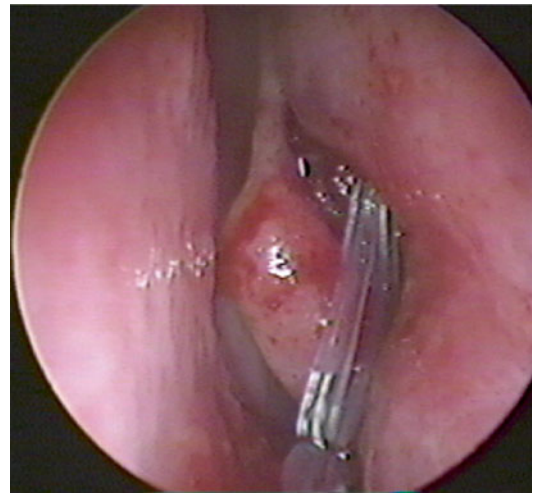

Fig. 25.45 Stent tubes placement following the ostium creation

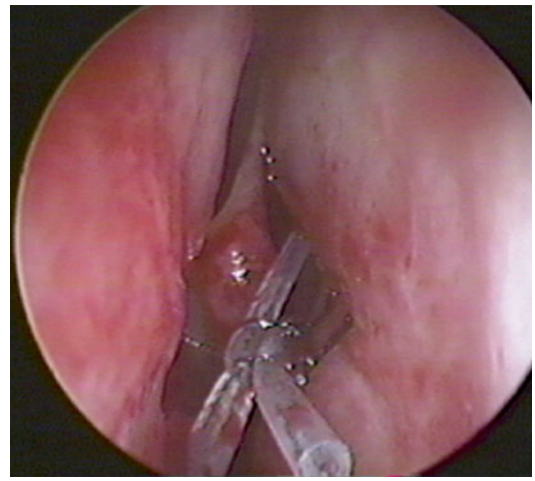

Fig. 25.46 Securing the stents

Conclusion

The endoscopic balloon DCR procedures described herein have a number of advantages as compared to other endoscopic procedures. The two endoscopic balloon DCR procedures are relatively easy to master, as they require minimal mechanical instrumentation. By eliminating the use of blades, burrs, and drills,

bleeding can be minimized. The procedure can be mastered easily as a team approach between an ophthalmologist and an ENT surgeon with gradual transition to the ophthalmologist performing the procedure unaided. The experienced surgeon will find improvement in patient acceptance of this procedure as compared to the external approach. Since there is so little morbidity postoperatively, the procedure can also be utilized for partial obstruction when other interventions have been unsuccessful. The procedure is relatively quick, typically requiring 15 min. Blood loss is minimal, and recovery is rapid with little postoperative morbidity or swelling. Results in the hands of an experienced surgeon show success rates in excess of 90 %, comparable to success rates reported for external DCR. Initial data show that the addition of unciformectomy further improves outcomes.

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Revising a Failed Dacryocystorhinostomy

26

Emmy Lee, Hunter Yuen, and Mohammad Javed Ali

Introduction

The aim of dacryocystorhinostomy (DCR) is to establish a patent fistula between the lacrimal sac and the nasal cavity with removal of intervening bone. The main indications for DCR are clinically significant epiphora and/or infection in the presence of nasolacrimal duct obstruction (NLDO). While most NLDOs are primary and acquired, other causes of NLDO include lacrimal sac tumor and nasal and facial fractures involving the nasolacrimal canal. Associated common canalicular obstructions may also be managed along with the DCR be it external or endoscopic, with trephination and intubation.

The success rate of DCR varies with the surgical approach adopted. Although external DCR has been the gold standard with success rates ranging from 85 to 95 %, the endonasal endoscopic approach has gained much popularity in recent years, with success rates between 59 and 100 % [1]. For endoscopic DCR, the success rates were higher for the mechanical approach when compared to the laser-assisted ones and were similar when ultrasonic bone aspirator was used to create the osteotomy [2]. The experience of the surgeon also counts. Fayers et al. reported an overall lower rate of success for trainees in terms of both functional (64 %) and anatomic (68 %) improvement as compared to 81 % functional and 87 % anatomic success rate for the consultant surgeon [3]. However, direct comparison of success rates is difficult given the significant variation in surgical techniques, definition of success, and follow-up duration across studies.

Considering the cause of NLDO, congenital NLDO and traumatic NLDO probably carry a higher risk of failure [4, 5]. Pediatric patients with craniofacial abnormalities are also at greater risk of persistence of symptoms after surgery [6]. Conventionally, it was proposed that endoscopic DCR in the setting of acute dacryocystitis has a higher risk of failure, but recent studies showed that using the mechanical approach, success rates were over 90 % and comparable with surgery in the absence of active infection [7, 8].

Etiopathogenesis

The best way to prevent a failed DCR is to perform a proper preoperative evaluation and a meticulous primary surgery. Preoperative evaluation should focus on ruling out other causes of epiphora like dry eyes. Careful examination should be done to assess if there are any canalicular or common canalicular obstructions. The common causes of

E. Lee, FRCS • H. Yuen, MRCS (✉)
Department of Ophthalmology, Chinese University of Hong Kong, Shatin, New Territories, Hong Kong
e-mail: hunterklyuen@gmail.com

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 500034, India

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DOI 10.1007/978-81-322-2020-6_26, © Springer India 2015

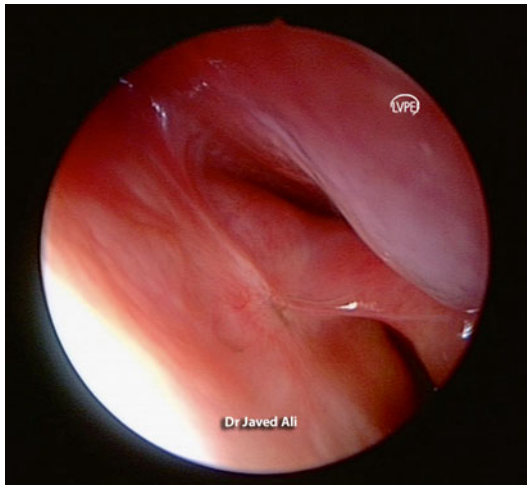

Fig. 26.1 Endoscopic view of a cicatricial closure of the ostium

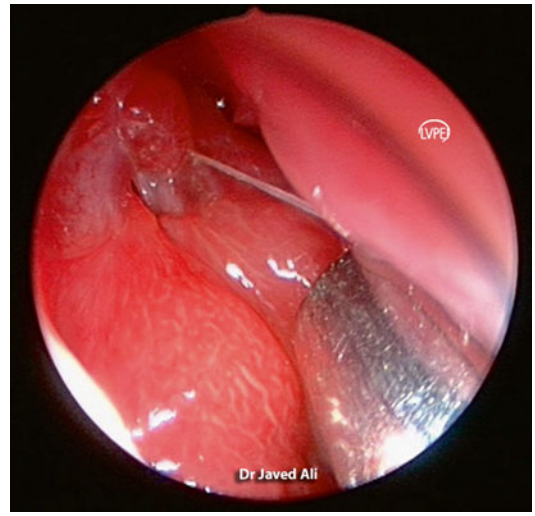

Fig. 26.3 Nasal endoscopic view showing an internal ostium stenosis along with periostial active granuloma

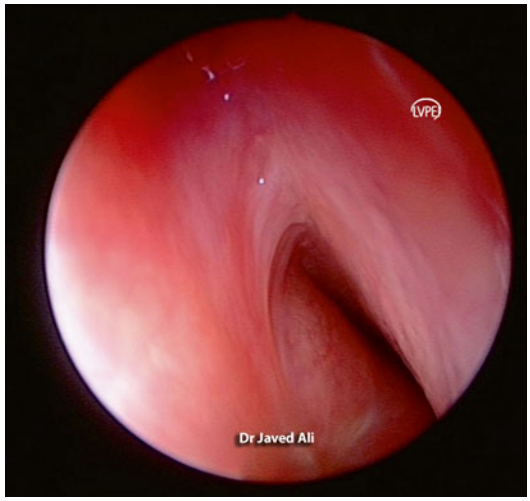

Fig. 26.2 An extensive turbinoseptal synechiae involving the ostium

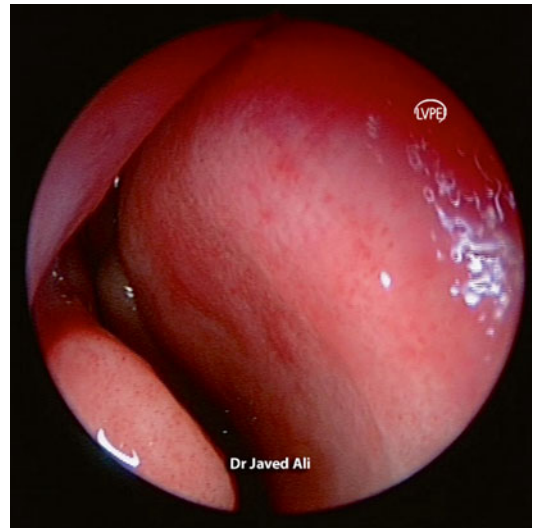

Fig. 26.4 Nasal endoscopic view of a gross deviated nasal septum

a DCR failure are cicatricial closure of the ostium (Fig. 26.1), inadequately sized osteotomy, inadequate sac opening, common canalicular obstruction, intervening ethmoids, inappropriately placed osteotomy with respect to the lacrimal sac leading to sump syndrome [9], turbinoseptal synechiae in and around the ostium (Fig. 26.2), inappropriate granulation tissue (Fig. 26.3), and internal ostium stenosis (Fig. 26.3) [10]. Not uncommonly, multiple causes for failure may be noted [9, 10]. Other less common causes of failure include a deviated nasal septum (Fig. 26.4) and inadequately excised middle turbinate where needed. Rare causes may be occult carcinoma, bony obstruction caused by Paget disease, ethmoidal sinus osteoma, and soft tissue obstruction caused by inflammatory diseases like sarcoidosis and Wegener granulomatosis (Fig. 26.5) [11–13].

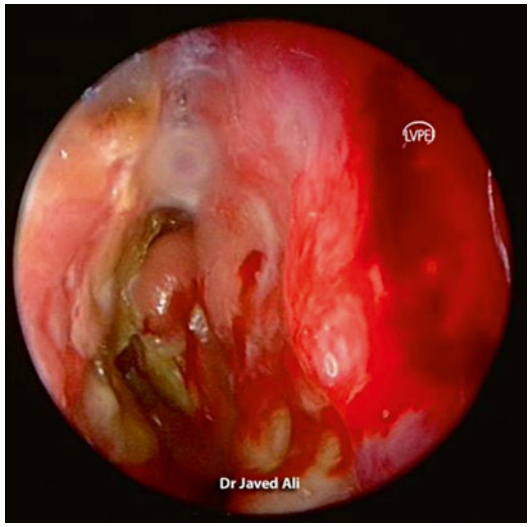

Fig. 26.5 Nasal endoscopic view showing intense inflammation in a case of Wegener's granulomatosis

Factors that have been reported to be associated with higher risk of failure include small lacrimal sac opening, prolong surgery, active inflammation, inadequate or inappropriate flaps, and intraoperative prolapse of orbital fat [9–14]. It was also proposed that thermal damage might increase the risk of failure [15].

DCR failures usually occur in early postoperative period. The average time to failure reported is 4.9 months after surgery. Failure can occur as early as 1 week postoperative. Early obstruction was frequently found proximal to the common internal punctum [16]. Late failure, defined as recurrence of symptoms at least 12 months after surgery, is uncommon (<1 %), and most of the obstruction occurred at the common canaliculus [17].

Clinical Features and Diagnostic Evaluation

The success of DCR can be gauged by functional success and anatomical success. Functional success refers to lack of tearing 3 months after surgery, a good indicator of successful surgery as suggested by the Royal College of Ophthalmologists guidelines. Anatomical success can be confirmed by patency on lacrimal irrigation, visualization of ostium on nasal endoscopy, positive functional endoscopic dye test, and scintillography or contrast dacryocystography.

In most cases, the causes of failed DCR can be determined by lacrimal probing and nasal endoscopy. Syringing will be nonpatent in cases of failed DCR and probing should be performed to identify the site of obstruction. For a scarred internal ostium, a negative endoscopic dye test will be observed. The use of imaging studies like scintillography or dacryocystography (DCG) with plain films may provide further information in delineation of the lacrimal drainage tract and determination of the exact site and nature of obstruction, helping to formulate a surgical strategy for revision. DCG can also be performed with computed tomography (CT) or magnetic resonance imaging (MRI). However, cost and availability may be an issue. Typically, a patent fistulous tract confirmed by lacrimal probing and irrigation gives a characteristic "Y-on-its-side" configuration of the soft tissue on CT. Occlusion of osteotomy by soft tissue corresponds to a mucocele-like soft tissue density with a central lucency and soft tissue obstruction. Occlusion of osteotomy by inadequately excised bone is evident by bone in the region of osteotomy [11]. Using the spiral technique, CT-dacryocystography (CT-DCG) of high resolution allows measurement of the diameter of the osteotomy window, evaluation of osteotomy position relative to the lacrimal sac and reveals abnormal finding around the osteotomy-like extension of ethmoidal air cells medial to the lacrimal sac, concha bullosa, nasal polyp, and any medial canthal mass that might contribute to the failure of DCR (Fig. 26.6) [18]. In the study by Choi et al. [19], preoperative evaluation of obstruction level using DCG was helpful in predicting surgical outcome of endoscopic DCR. Among all, treatment of sac–duct junction obstruction with DCR had the highest success rate, followed by NLDO, common canalicular obstruction. Saccal obstructions carried the worst prognosis [19]. Finally, dacryoendoscopy, if available, may be used to delineate the intraluminal pathology within the lacrimal system.

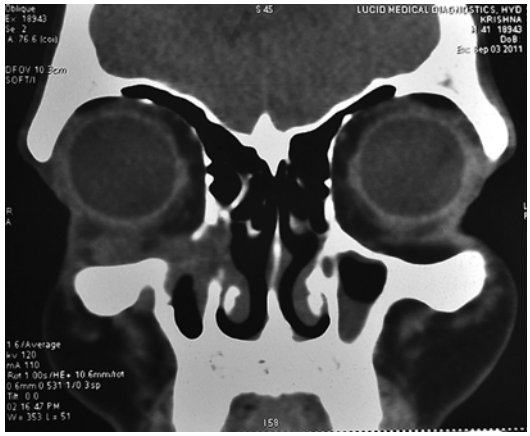

Fig. 26.6 CT scan, coronal view, showing the right DCR ostium with extensive scar tissue in and around the ostium

Differential Diagnosis

Before deciding on revision surgery, patient with a failed primary DCR must be reexamined to determine the etiology of symptoms, especially to rule out other causes of tearing, such as blepharitis, trichiasis, lid malpositions like lower-lid laxity, entropion, ectropion, punctal abnormalities, and canalicular obstructions. Systemic inflammatory disease should also be excluded. Standard preoperative evaluation includes dye-disappearance testing, lacrimal irrigation and probing, and endoscopic evaluation of the internal ostium and nasal cavity are essential. If the ostium is found to be patent on irrigation and with a nasal endoscopy, the diagnosis of functional NLDO should be considered. Functional NLDO is defined as delayed tear clearance on scintillography or dacryocystography in the absence of anatomic obstruction. It is thought to be caused by a narrowing of the nasolacrimal duct or failure of the pump mechanism [20, 21]. Functional NLDO has a greater incidence of surgical failure, and patients may experience persistence of symptoms despite adequate surgery. Revision surgery in this subset of patients has been shown to be of little value [22].

Management

In managing a failed DCR, the options are mainly surgical, though some patients may opt for observation. A failed primary external DCR can be revised externally or endoscopically; likewise, a failed primary endoscopic DCR can be amended endoscopically or externally. Various adjunctive measures including intraoperative application of Mitomycin-C (MMC) and intubation with silicone stents have been proposed to enhance the success rate of revision surgery. Recently, balloon dacryoplasty has been suggested as a less traumatic alternative to salvage a failed primary surgery. In cases of common canalicular obstruction, the revision can be as well performed by external or endoscopic approaches [9].

In the setting of revision DCR, the keys to success include:

1. A thorough understanding of intranasal endoscopic anatomy, especially the location and extent of the lacrimal sac
2. Complete excision of the cicatrix if present
3. An efficient bone removal to achieve complete exposure of the lacrimal sac
4. A complete incision and marsupialization of the lacrimal sac mucosa

Surgical Technique for Revision Endoscopic DCR

The nasal mucosal flap is incised slightly more anteriorly over the frontal process of maxilla than for primary cases (Fig. 26.7). This allows the mucosal incision to be made onto bone and when this flap is elevated off the bone, it allows the correct surgical plane to be established for dissection of the mucosal flap off the underlying scar tissue. The osteotomy is then enlarged with ronguer until the lacrimal sac is completely exposed. If the sac is relatively normal in size, standard mucosal flaps are fashioned. In cases when the sac is scarred and contracted and it is difficult to fashion mucosal flaps, the mucosal apposition between the nasal and lacrimal mucosa can be

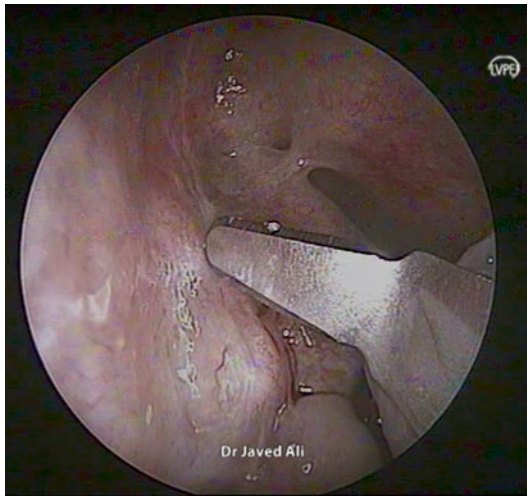

Fig. 26.7 Elevating the nasal mucosal flap at a higher level to expose the underlying bone superiorly

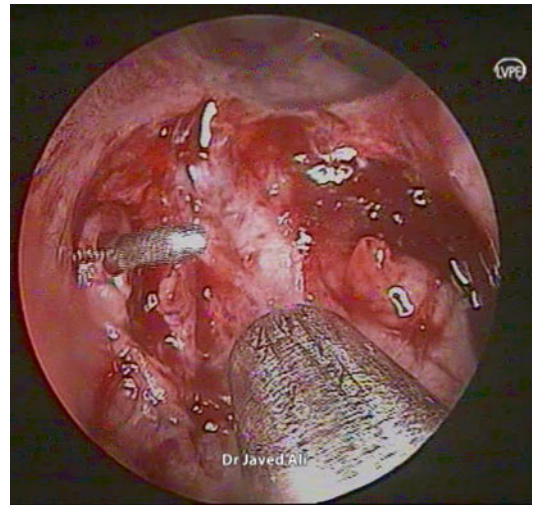

Fig. 26.9 Area of the common canaliculus completely cleared

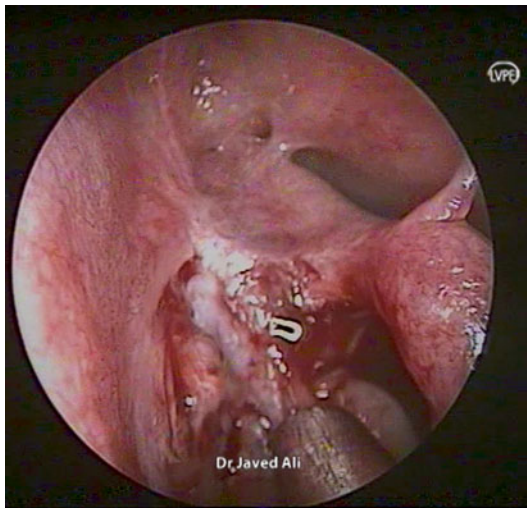

Fig. 26.8 Flaps being raised of the underlying scarred lacrimal sac

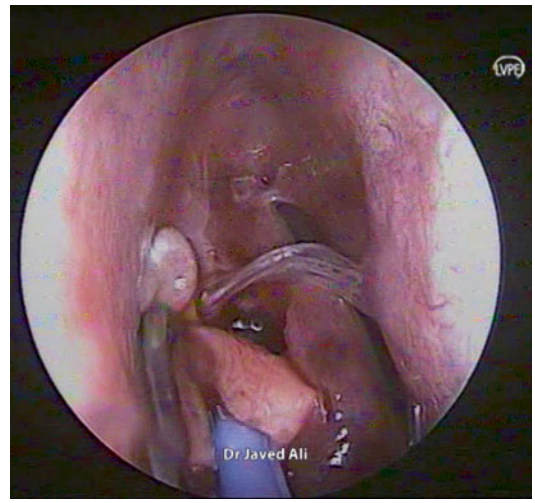

Fig. 26.10 Mitomycin-C application to the newly created ostium

obtained by trimming correspondingly less of the nasal mucosal flap (Fig. 26.8). One may also consider using the agger nasi mucosa as a free graft to create functional mucosa surrounding the common canaliculus–sac junction [23]. It is very important to clear the area around common canaliculus and expose it well (Fig. 26.9). Correction of nasal pathologies such as deviated nasal septum or turbinoseptal synechiae around the ostium might be required to allow adequate surgical exposure [24]. The rest of the procedure is similar to primary cases. Intraoperative MMC (Fig. 26.10) and silicone intubation (Fig. 26.11) should ideally be used. Additional use of Sisler's canalicular trephines for distal canalicular obstructions and balloon dacryoplasty to dilate

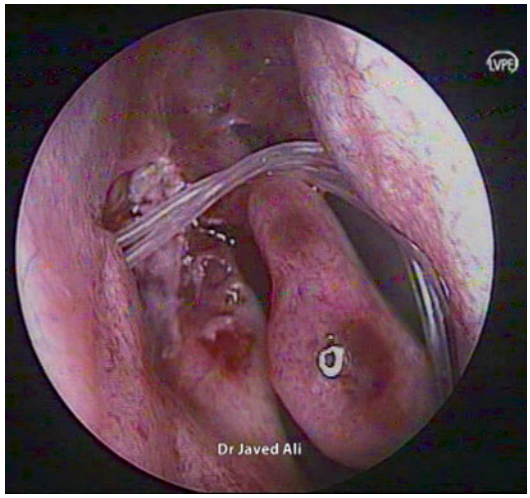

Fig. 26.11 Newly created ostium with intubation

the ostial stenosis can be combined with revision endoscopic DCR as a multimodal management for selected cases.

Apart from the established advantages for endoscopic primary DCR, namely the avoidance of cutaneous scar and preservation of pump action of the orbicularis muscle, some authors suggested that the endonasal approach is well-catered for revision surgery given its direct access to the residual lacrimal sac through the previously created bony ostium, improved visualization of osteotomy position relative to the lacrimal sac, easier hemostasis, and the ability to address concurrent intranasal pathologies [25]. However, like the primary procedure, the potential drawbacks are steep learning curve and high equipment cost.

Surgical Technique for Revision External DCR

A skin incision is made through the original scar (Fig. 26.12). Orbicularis is separated at the junction of orbital and palpebral portions (Fig. 26.13). Bowman lacrimal probes are used to check the patency of both inferior and superior canaliculi. The medial palpebral tendon, if present, is divided. A combination of sharp and blunt dissection is used to separate the scar above and below the probes. Great care is taken not to enter

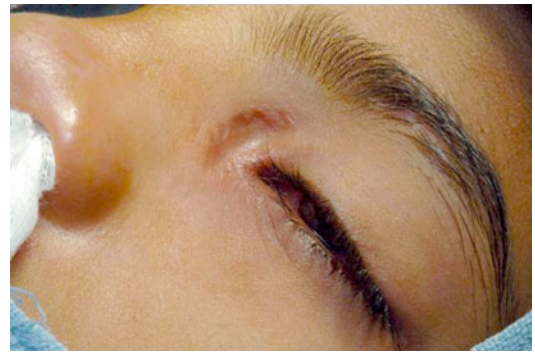

Fig. 26.12 External scar in a failed DCR

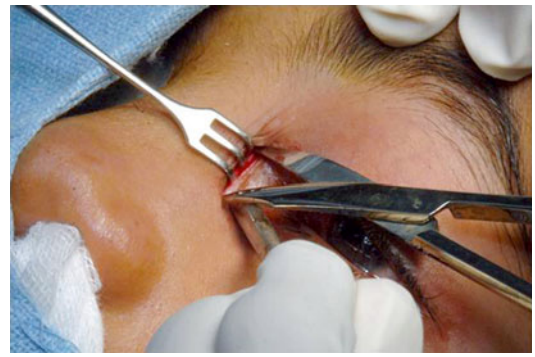

Fig. 26.13 A gentle separation of the orbicularis and underlying scar tissues

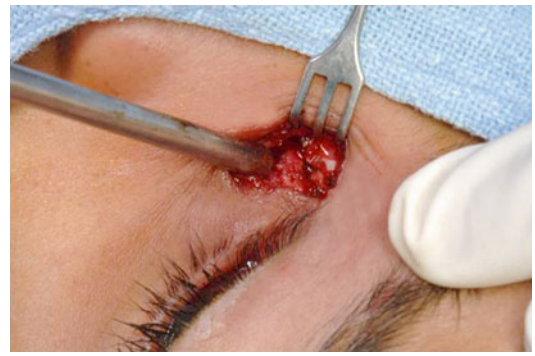

Fig. 26.14 Exposing the virgin bone (Note the ostium with scarring)

the lumen of the common canaliculus. The anterior edge of the original rhinostomy is identified and periosteum is freed from bone for approximately 4 mm anterior to the bony edge of the original rhinostomy to expose the uncut bone all around (Fig. 26.14). The bony ostium is enlarged (Fig. 26.15) to allow adequate exposure of the sac

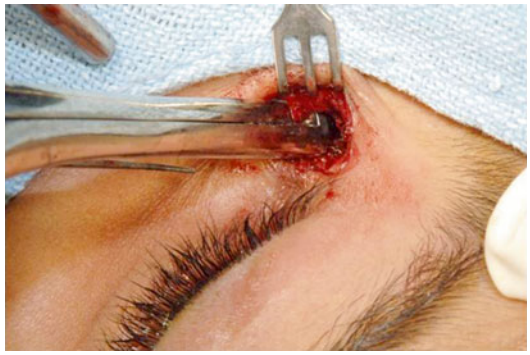

Fig. 26.15 Enlarging the osteotomy with Kerrison bone punch

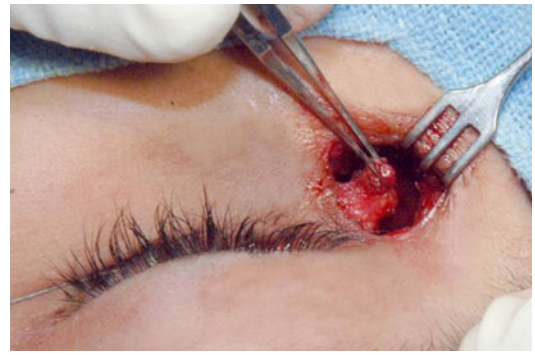

Fig. 26.17 Elevation of anterior sac flap

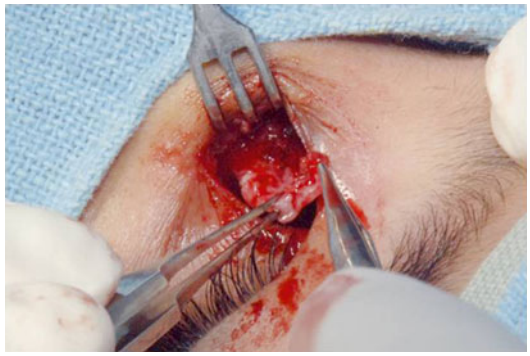

Fig. 26.16 Salvaging the virgin nasal mucosa

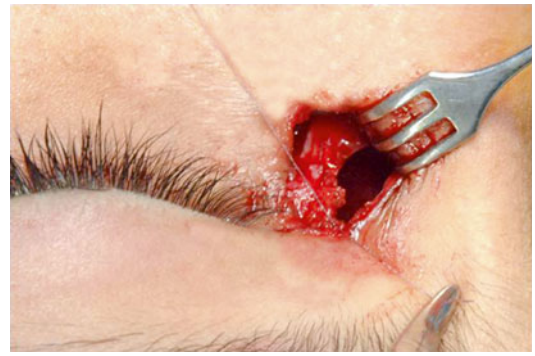

Fig. 26.18 Anastomosis of salvaged anterior nasal and lacrimal sac flaps

and to expose virgin nasal mucosa (Fig. 26.16). A trapdoor incision based in the newly exposed virgin nasal mucosa is cut so that the lateral free edge is close to the previously identified common canaliculus and the upper and lower edges are next to the edges of the newly enlarged rhinostomy. The nasal mucosal flap is reflected anteriorly with traction sutures. The interior of the rhinostomy is then examined for any intervening bone, ethmoid air cell, synechiae, dacryoliths, or simple cicatrix and appropriately removed. The virgin lacrimal sac flaps if any are fashioned as usual but in cases of intense fibrosis, careful elevation is mandatory (Fig. 26.17). Anterior alone or both anterior and posterior mucosal flaps are sutured with fine absorbable suture like Dexon or Vicryl (Fig. 26.18). If common canalicular obstruction is present, the area can be trephined to remove the cicatrix or an endocanaliculotomy can be done. It is important that the flaps be sutured under slight tension so that they do not adhere

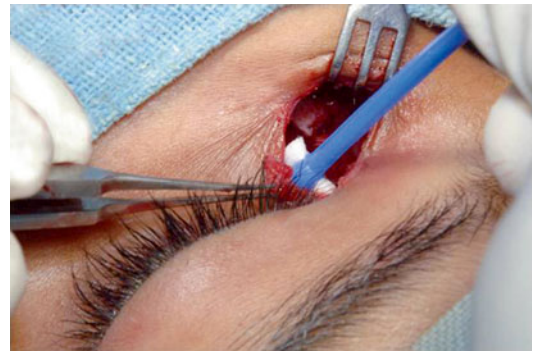

Fig. 26.19 Mitomycin-C application

internally and form obstruction. Mitomycin-C (Fig. 26.19) and silicone stents (Fig. 26.20) have been found to be beneficial in revision DCRs specially if there is canalicular pathology or if the sac is small, scarred, or inflamed. Lastly, orbicularis and tendon are repositioned with an absorbable suture and the skin is closed with an interrupted nylon suture [9].

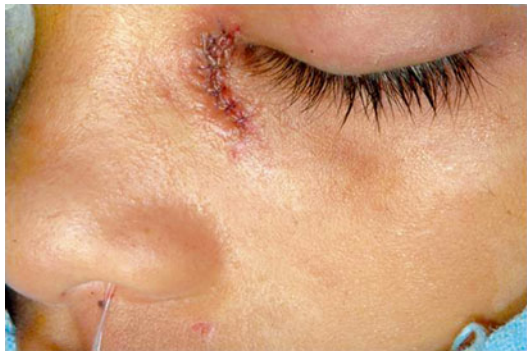

Fig. 26.20 Wound resutured after silicone intubation

The success rates for revision endoscopic DCR are in the range of 76–100 % [23, 26–29], comparable to that reported for external revision DCR, which varied from 80 to 90 % [9, 30]. Tsirbas A et al. [23] showed a direct comparison of the endoscopic and external techniques and showed that revision endoscopic DCR surgery was successful in 77 % of cases and external revision was successful in 85 %, yet this difference was not statistically significant. In another study by Paik et al. [31], which included 82 endoscopic revisions, a success rate of 84 % was achieved for those with failed primary external DCR and 81 % for those who failed a primary endoscopic DCR. In preoperative nasal endoscopy, more of those who underwent primary external DCR exhibited a hypertrophic middle turbinate or severe septal deviation, whereas more of those who underwent primary endoscopic DCR exhibited a small ostium.

The success rates of revision surgery would be lower if there is scarring and cicatrization of the lacrimal sac. It is because even with adequate bony ostium and full sac exposure, only a small amount of lacrimal mucosa can be marsupialized. This leads to a higher risk of repeated scarring and stenosis. This may partly explain why those who failed the first revision surgery are likely to fail additional revision [5]. In the study by Tsirbas A et al. [23], all the failed revisions, both external and endoscopic, have undergone more than one previous DCR. In the presence of proximal canalicular obstruction or multiple failed revisions, a conjunctivodacryocystorhinostomy with the insertion of a Lester Jones or Gladstone–Putterman's tube can achieve the target of resolution of epiphora.

Transcanalicular laser-assisted revision DCR has been proposed as a simple office-based procedure to reestablish a patent drainage tract when soft scar tissue was the cause of failed DCR. In this procedure, the laser probe is carefully inserted through the upper canaliculus into the nasal cavity. The laser energy is applied until the tip of the laser probe was recognized by nasal endoscopy. Both the use of diode laser and continuous wave neodymium-doped yttrium–aluminium–garnet (Nd:YAG) laser demonstrated a success rate of approximately 80 % after the first attempt [26, 32, 33]. Theoretically, the targeted application of laser energy allows effective tissue dissection with accurate removal of the cicatrix away from the internal common opening. It is believed to cause minimal collateral damage and retrograde damage of the lacrimal drainage system. Other advantages include short operative time, avoidance of skin incision, good hemostasis, less surgical trauma, and quick postoperative recovery. However, lack of robust studies and doubtful long-term efficacy of this approach were probably responsible for it not finding much favor worldwide for a revision DCR.

Adjunctive Use of Mitomycin-C (MMC)

The adjunctive use of intraoperative MMC is a popular choice to enhance the success rate of DCR. Being an antibiotic isolated from *Streptomyces caespitosus*, MMC impedes the synthesis of DNA, cellular RNA, and protein by inhibiting collagen synthesis by fibroblasts. It has been used widely in other ophthalmic procedures like glaucoma filtration surgery and pterygium excision to enhance surgical success. Based on a histological study, Ugurbas et al. [34] proposed that MMC could enhance success rate of DCR by decreasing the density and cellularity of nasal mucosa. Many studies have attempted to define the role of MMC in DCR. It was in general recognized to be a safe adjunct, but might not necessarily increase the success rate in primary DCR [1, 35–40].

The role of MMC seems to be more definite in revision surgery. Success rates ranging from 89 to 93 % were noted for revision endoscopic DCR with intraoperative application of MMC, much higher compared to success rates of 56–60 % when MMC was not used and the difference observed was statistically significant [41, 42]. In the meta-analysis performed by Cheng and his group, which evaluated 11 relevant studies including 574 DCRs, success rates were significantly higher in the MMC groups in comparison with the control groups, both in primary and revision endoscopic DCR. The size of osteotomy was also significantly bigger in the MMC group at 3 months and 6 months after surgery. Similar beneficial effects were also reported in another meta-analysis by Feng Y et al., which assessed nine randomized controlled trials comprising 562 external DCRs [43]. Based on the existing literature, we believe in the use of MMC for all revision DCRs.

Adjunctive Silicone Intubation

The role of silicone lacrimal in enhancing surgical success of primary or revision DCR is still controversial. Theoretically, the intubation prevents obliteration of the fistulous tract during early postoperative period, yet some have reported that it may cause granulation tissue formation, infection, canalicular laceration, or discomfort to the patient [44, 45]. In a randomized controlled trial by Chong et al., the success rate of primary endoscopic DCR was almost the same (96 % vs. 95 %) with and without intubation. The difference was not statistically significant [46]. There is no study in the existing literature to specifically define the efficacy of silicone intubation in revision DCR. In the subgroup analysis of Smirnov's study, revision surgery was successful in 100 % with silicone tubing and 85 % without silicone tubing. However, the sample size was small and the difference was not statistically significant [47]. Silicone tube placement seems to be more important in setting of common canalicular obstruction. The duration of silicone tube placement is controversial. In general, we prefer to keep the silicone tubes for up to 3 months postoperatively in revision surgeries.

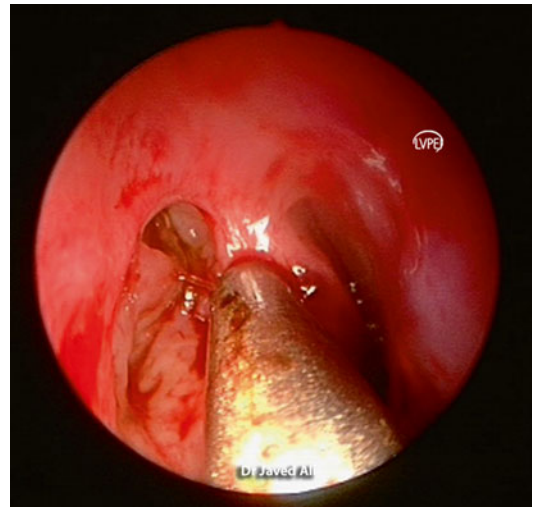

Fig. 26.21 Nasal endoscopic view showing positive FEDT after endocanaliculotomy

Probing, Endocanaliculotomy, and Silicone Intubation

Late failure after primary DCR is rare and can be considered as a distinct clinical entity. Studies have shown that in majority of patients, the level of obstruction was at the common canaliculus. McMurray et al. showed that in all patients with secondary common canalicular obstruction, they performed a probing with either common canalicular membranotomy (Fig. 26.21) or membranectomy followed by silicone intubation for an average of 8 weeks. The outcomes were favorable and this can yet be considered as a less invasive surgical alternative to a repeated DCR in selected cases [17].

Balloon Dacryoplasty for Internal Ostium Stenosis

Balloon dacryoplasty has been introduced for over two decades. Using specially designed balloon catheters of various diameter and length

(LacriCATH, Quest Medical Products, Inc, Allen, TX, USA), targeted dilatation at different sites of the lacrimal outflow tract can be performed. The use of endoscopically assisted balloon dacryoplasty was initially proposed for congenital NLDO in children [48] and incomplete NLDO in adults [49]. In the largest series for adults, Couch et al. reported that 90 % of patients who received balloon dacryoplasty reported symptomatic improvement and 56 % experienced complete resolution of symptoms [49]. The use of balloon dacryoplasty for failed DCR was first described by Lee et al. [50] in a cohort of sarcodosis patients. Of the three failures in the study, two early failures were successfully treated by balloons, while the one late failure case (47 months) was not amendable by balloon catheter dilatation. From our experience, this therapy has a role in a highly selected group of patients with internal ostium stenosis. Internal ostium stenosis was defined by our group as minimal dye passage via a tiny internal ostium on irrigation as visualized on nasal endoscopy, resistance on syringing, together with partially relieved tearing symptoms. In our series, balloon dacryoplasty could achieve an anatomical success of 84 % and functional success of 74 % [51]. This provides a less traumatic and minimally invasive alternative to a revision DCR with additional advantages of short operative time, quick recovery, and can be performed under local anesthesia.

Conclusion

Common causes of failed DCR include inadequately sized osteotomy or sac opening, inappropriately placed osteotomy and scarring causing contracture, granulation tissue, or synechiae formation at the ostium. Meticulous primary surgery, intraoperative adjuncts where needed, and good postoperative care can prevent the occurrence of some of these factors. Most failed primary procedures can be revised via endoscopic or external approaches with relatively good success rates. MMC is likely to have a role in revision DCRs. Silicone tube placement can be considered in the presence of common canalicular obstruction. Balloon dacryoplasty, in carefully selected patients, may achieve comparable results. However, a subset of patients with functional epiphora may not improve with revision surgery.

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Conjunctivodacryocystorhinostomy: Indications, Techniques, and Complications

27

Mohammad Javed Ali

Introduction

Complete proximal bicanalicular obstructions remain one of the most intriguing lacrimal disorders posing a dilemma on both diagnostic and management fronts. Conjunctivodacryocystorhinostomy or CDCR was initially described by Von Hoffman in 1904 [1] and, later, with Jones tubes by Lester Jones in 1962 [2, 3]. In this procedure, a new passage is created for drainage of tears from the conjunctival cul-de-sac directly into the nasal cavity. The procedure can be performed via an external approach (external CDCR), an endoscopic approach (endoscopic CDCR), a minimally invasive approach (MICDCR), or an endoscopic conjunctivorhinostomy (CR) without a DCR. Though the procedure is useful with a success rate hovering around 90 %, large series have shown two major complications, namely extrusion of the tube ranging from 28 % to as high as 51 % and tube malpositions ranging from 22 to 28 % [4–7]. In order to avoid these complications numerous modifications of the bypass tube have been published including additional flanges, wide medial ends, angulated tubes, and porous polyethylene-coated tubes [8–11]. The complications though reduced still continue to be a matter of concern. Minimally invasive placement of Jones tubes without a DCR with and without the use of endoscopic guidance is gaining popularity in recent times [12–14]. Although most of the contraindications to CDCR are relative, careful patient selection is of utmost importance. The chapter will discuss indications, contraindications, techniques, complications, and outcomes of various approaches for CDCR.

Indications

1. Punctal agenesis
2. Canalicular agenesis
3. Proximal canalicular obstructions
4. Post-dacryocystectomy rehabilitation
5. Multiple times failed DCR with canalicular obstructions
6. Lacrimal pump failures
7. Unresolved epiphora following a patent DCR

Contraindications

1. Scarred medial canthus
2. Gross eyelid anomalies
3. Gross nasal deformities
4. Early childhood
5. Mentally unstable patients

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute,
Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

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6. Unrealistic expectations or patients not keen on tube maintenance
7. Poor systemic health
8. Patient who cannot come for follow-ups (relative)

Instruments and Setup

The standard Ophthalmic plastic instrument sets and operating room are adequate to perform a CDCR. To perform the endoscopy-assisted technique of CDCR, a nasal endoscope with viewing system should be available.

The ideal bypass tube is nonhydrophobic, nonreactive with the tissues, and rigid enough not to collapse. The original Jones tubes are a set of pyrex glass tubes of varying sizes; the usual lengths vary from 9 to 28 mm (Fig. 27.1) The ocular end has a flange with a diameter of 3, 3.5, or 4 mm. The nasal end has a gentle flange. The outer diameter of the tube is 2.5 mm, and the inner diameter is 1.5–1.7 mm. Straight tubes are more commonly used but curved tubes are also available. Flanges with holes have also been designed to secure the tube by passing suture through the holes. Gold-plated dilators (Fig. 27.2) and tube measuring slabs (Fig. 27.3) are available with the complete set (Fig. 27.4).

Several modifications have been attempted to prevent the migration of the tube. The Gladstone–Putterman modification (Fig. 27.5) of the Jones tube has a flange section in the middle, and is said to have less chance of dislocation [9]. Frosted glass Jones tubes and porous polyethylene-coated tubes have also been used to reduce the incidence of dislocated tubes [10, 11].

Fig. 27.1 Lester Jones tubes of various sizes

Fig. 27.2 The three gold dilators

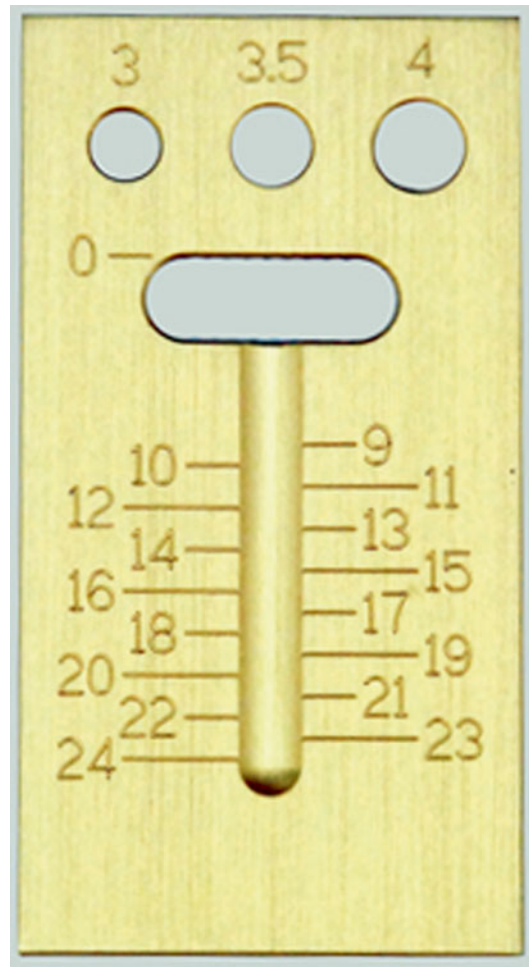

Fig. 27.3 Tube measuring scale

Fig. 27.4 A CDCR set

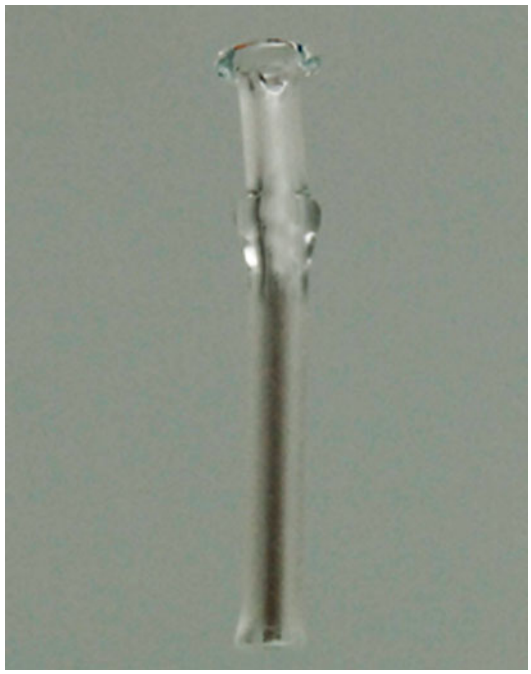

Fig. 27.5 Gladstone–Putterman's tube

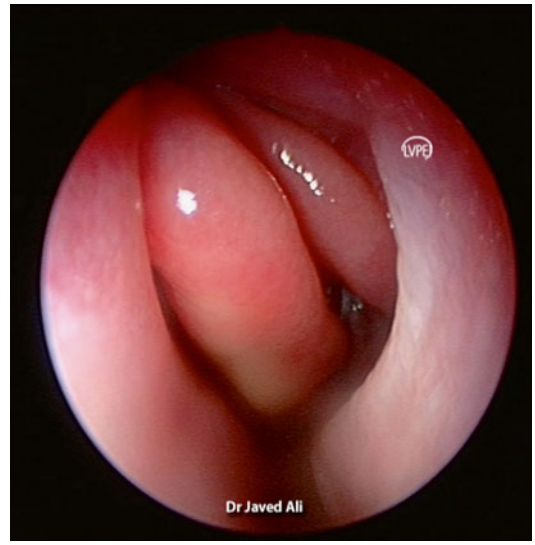

Fig. 27.6 Preoperative endoscopic examination of middle meatus

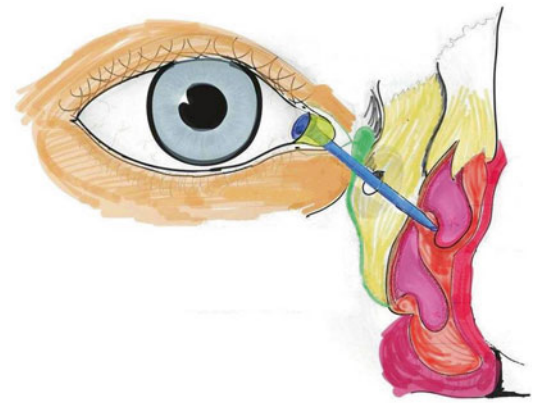

Fig. 27.7 Schematic diagram showing minimally invasive bypass tube placement without DCR. Note the head of middle turbinate obstructing the path of the tube (Photo courtesy: Himika Gupta)

Techniques

The nasal cavity of every patient must be inspected in the preoperative evaluation (Fig. 27.6). If a septoplasty for deviated nasal septum or a middle turbinectomy is required, they can be completed along with the CDCR procedure (Figs. 27.7 and 27.8).

The caruncle, medial canthal soft tissues may be anesthetized by deep infiltration with equal parts of 2 % lignocaine and adrenaline 1:200,000, and 0.5 % bupivacaine (Fig. 27.9). The nasal cavity is anesthetized by packing with a mixture of 4 % lignocaine and adrenaline, and submucosal injection of 2 % lignocaine with adrenaline (Fig. 27.10). Adrenaline is to be avoided in hypertensive patients.

Once the preparation is complete, the technique may vary. For external or endoscopic CDCR, regular DCR osteotomy is performed respectively, followed by creation of the lacrimal sac flaps. A portion of the caruncle is then excised followed by enlargement of the track from the conjunctival cul-de-sac to the middle meatus of the nose with the help of Wheeler of Von-Graefe's knife [4–6]. A Bowman's probe is introduced

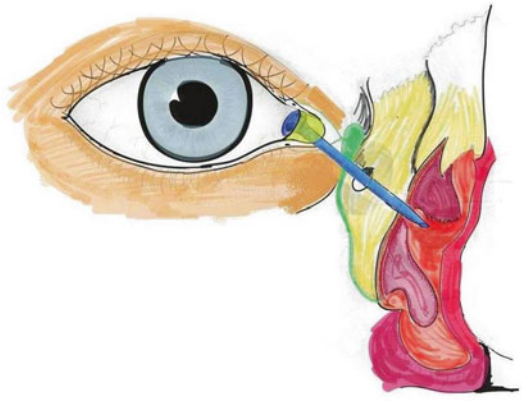

Fig. 27.8 Schematic diagram showing a partial middle turbinectomy (Photo courtesy: Himika Gupta)

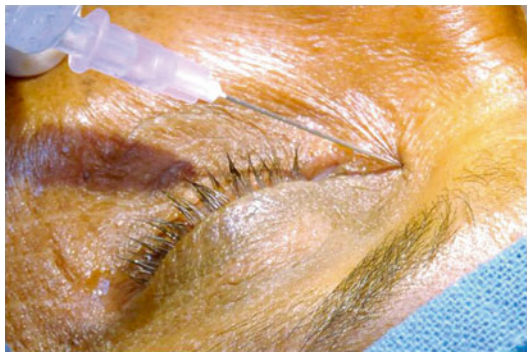

Fig. 27.9 Local anesthetic infiltration

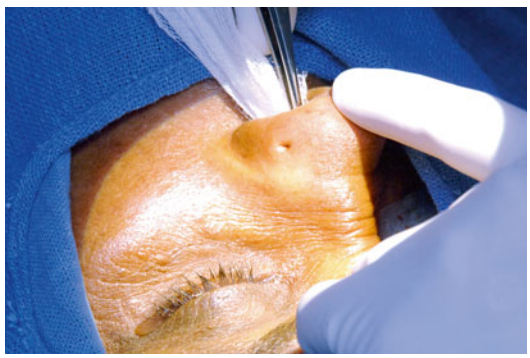

Fig. 27.10 Nasal decongestion with medicated packing

into the track and it is further enlarged with blunt dissection. The Bowman's probe is allowed to touch the septum and the length from the medial canthus to the tip is measured. Subtracting 2 mm

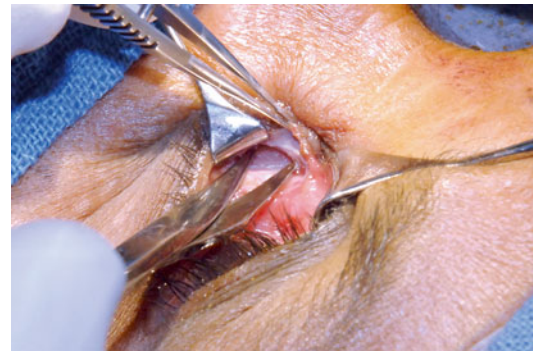

Fig. 27.11 Conjunctival incision and dissection

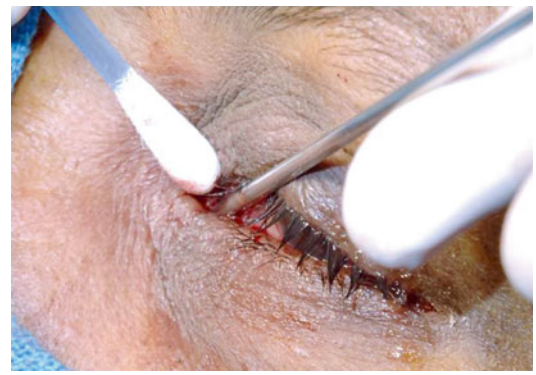

Fig. 27.12 The 14 gauge needle to create track for bypass tubes

from this measurement would give the length of Jones tube to be placed [5]. Jones tubes or bypass tubes of the surgeon's preference are then placed in the track under visualization to avoid touching the septum and secured at the medial canthus with 6-0 prolene. Tubes with a flange hole are preferred for ease of suturing.

For the minimally invasive placement of bypass tubes without a DCR (the author's preferred technique) [14], a 4-mm incision is given just below the caruncle and the tissues gently separated with a Wescott scissors (Fig. 27.11). A 14 gauge needle is then used through this track and directed inferomedially through the thin lacrimal bone into the middle meatus under endoscopic guidance (Fig. 27.12). A partial anterior middle turbinectomy is done where needed (Fig. 27.8). The ideal position of the needle in the nasal cavity is midway between the nasal septum and the lateral wall of

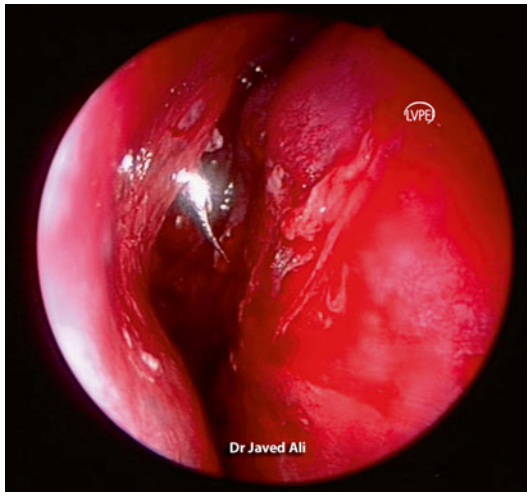

Fig. 27.13 Endoscopic view of the desired tube position being measured with the needle

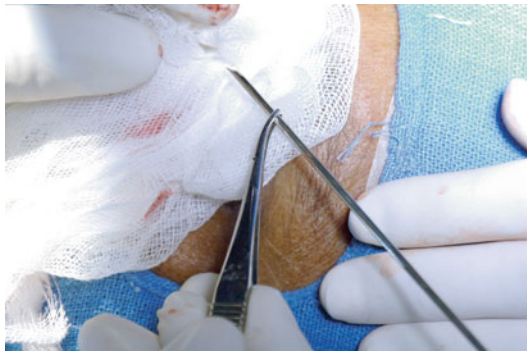

Fig. 27.14 Needle measurement for the Jones tube length

the nose (Fig. 27.13). Once this position is achieved, the caruncular end of the needle is grasped and the length of the needle measured (Fig. 27.14), which is correlated with the length of the Jones or Gladstone–Putterman tube (Gunther–Weiss company, Portland, Oregon) to be used. The track is dilated with gold dilators (Gunther–Weiss Company, Portland, Oregon) and the tube mounted on lacrimal probe steadily placed into the nasal cavity through the newly created track (Fig. 27.15). The nasal end of the ostium is not enlarged and this leads to a snugly fitted tube (Fig. 27.16). The tube is then secured with a 4-0 prolene at the caruncular end (Fig. 27.17).

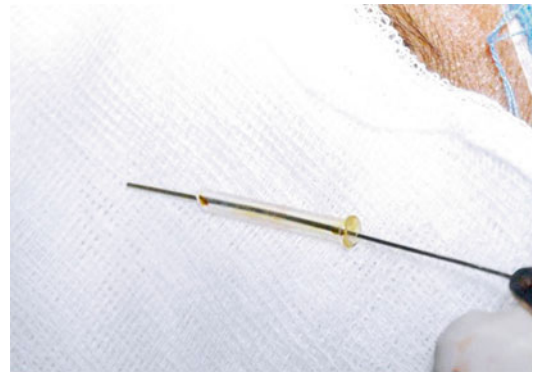

Fig. 27.15 Tube being mounted onto a Bowman's probe

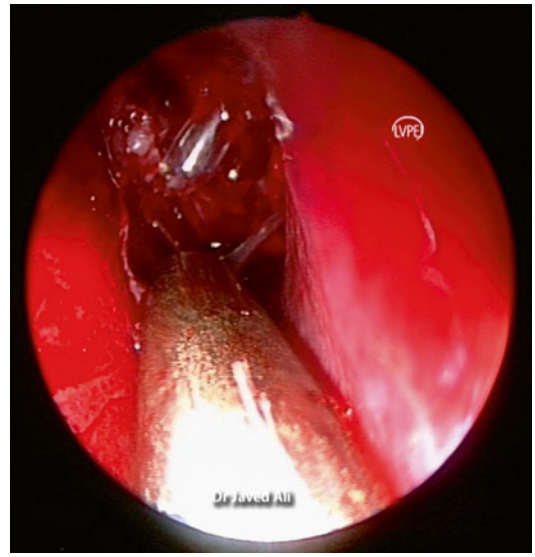

Fig. 27.16 Ideal tube placement. Note middle turbinectomy has already been performed

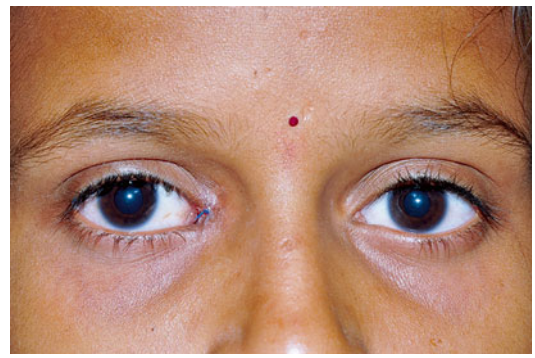

Fig. 27.17 Postoperative view of a patient with right bypass tube placement

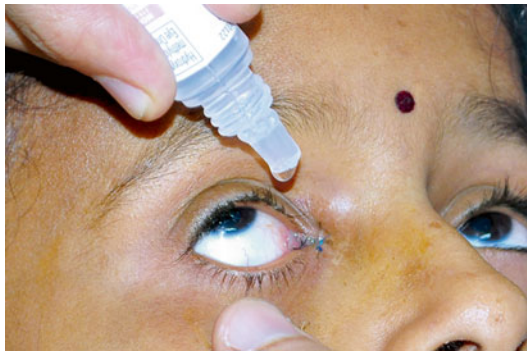

Fig. 27.18 Tube cleaning procedure: Introduction of few drops of nonviscous fluid or normal saline

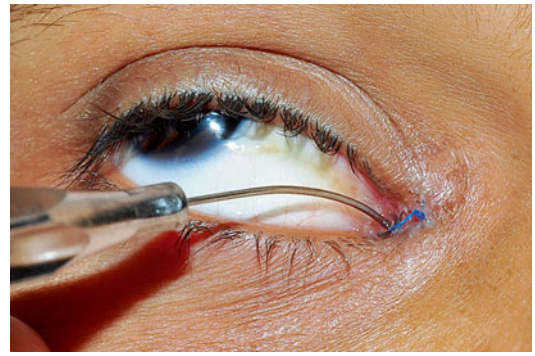

Fig. 27.20 Tube being irrigated to clear off the mucous plugs or debris

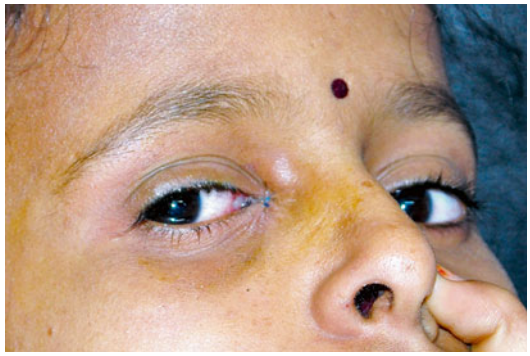

Fig. 27.19 Tube cleaning procedure: Drainage into the tube by negative pressure

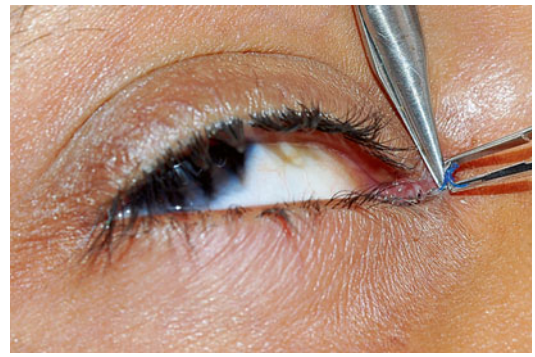

Fig. 27.21 Tube suture removal

The postoperative regimen includes topical antibiotics and steroids, nasal decongestants and steroids for a period of 3 weeks. The patients are trained to clean the tubes using negative pressure. Nonviscous lubricating drops or normal saline are placed in operated eye (Fig. 27.18). With the contralateral nostril closed, the patient gently sniffs, which creates a negative pressure in the nasal cavity and drains the cul-de-sac fluid into the nose (Fig. 27.19). The patients are postoperatively followed up on day 1, 1 week, 6 weeks, 3 months, quarterly for 1 year, and 6 monthly thereafter (Fig. 27.2c). At every visit, the class of lacrimal drainage is determined, followed by irrigation through the tube to clear the mucus or debris (Fig. 27.20). Suture removal is done at 6 weeks follow-up (Fig. 27.21).

Objective Assessment of Tube Functions: Drainage Classes

There are four categories to assess drainage [15]. A few drops of sterile water of nonviscous lubricant is placed in the conjunctival cul-de sac with the head tipped backward, and the drainage of the fluid toward the nasal cavity is assessed:

Class I drainage: Spontaneous fluid drainage.

Class II drainage: There is no spontaneous drainage but the fluid disappears on exaggerated nasal respiration.

Class III drainage: Fluid does not drain with respiration but the tube can be irrigated.

Class IV drainage: The tube cannot be irrigated.

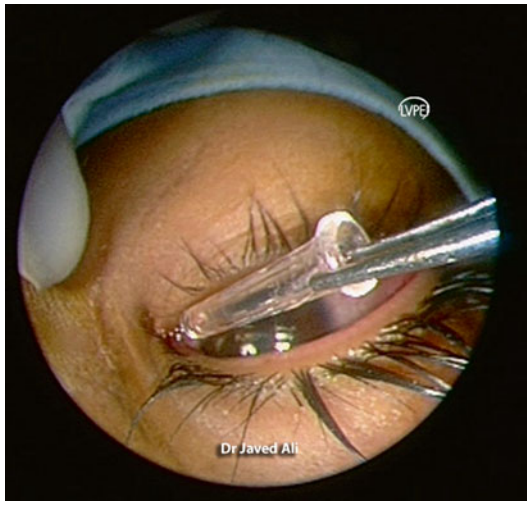

Fig. 27.22 Extrusion of inadequately sized and positioned tube

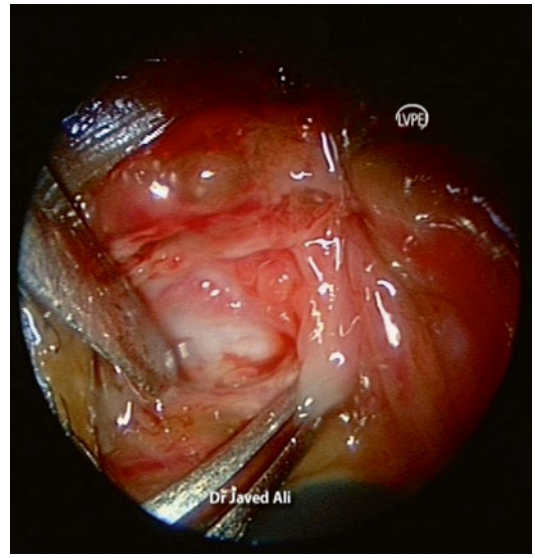

Fig. 27.24 Peritubal soft tissue infection

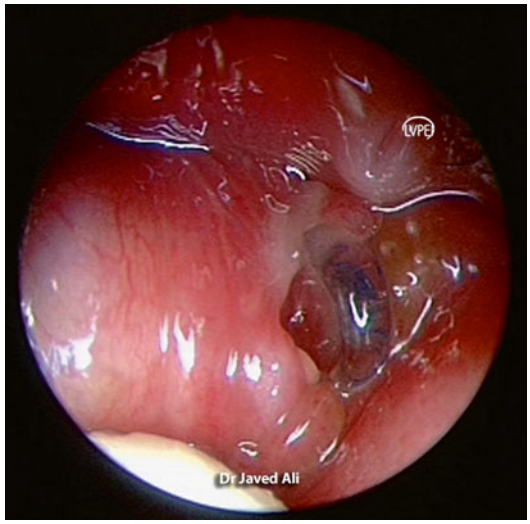

Fig. 27.23 Peritubal conjunctival granuloma

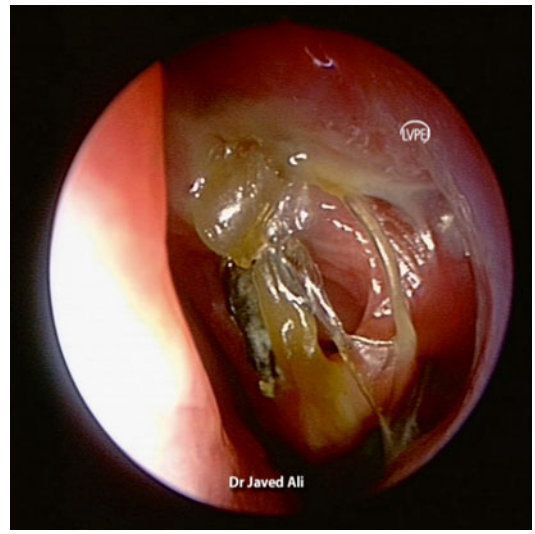

Fig. 27.25 Tube blocked by mucous plugs and discharge

Complications

1. Tube extrusion (Fig. 27.22)
2. Tube migration
3. Conjunctival granuloma (Fig. 27.23)
4. Peritubal soft tissue infections (Fig. 27.24)
5. Septum irritation
6. Tube blockage (Fig. 27.25)
7. Tube breakage (trauma)
8. Conjunctival pressure necrosis (Fig. 27.26)

Tube extrusion, malposition, or migration is the most common complication after surgery. These patients often need repositioning of the tube under endoscopic guidance, or even tube

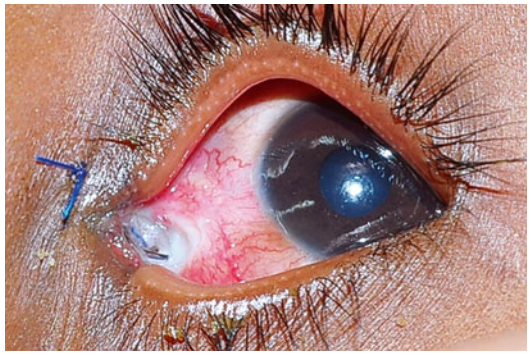

Fig. 27.26 Conjunctival pressure necrosis

replacement, some needing replacement more than once [16]. If a new tube is not inserted within days, the passage created may close. Occasionally in patients, complications, maintenance, and secondary procedures required may cause dissatisfaction even with a successful, functioning CDCR [17].

Outcomes

The overall outcomes of a CDCR are good but subsequent issues related to the tube are one of the main concerns for the surgeon. Stiensapir et al. [4] studied 79 eyes with CDCR and reported a success rate of 96 %; however, the extrusion rate was 51 %, tube malposition in 22 %, and tube obstructions in 23 %. Sekhar GC et al. [5] studied 69 eyes and reported 98.5 % of patients to be free of symptomatic epiphora; however, extrusion, malposition, and obstruction rates were 30, 28, and 28 %, respectively. In the largest study in the literature by Rose G et al. [6], 326 eyes were studied and an extrusion of 41 % was reported and the patient satisfactory outcomes were achieved in 91 %. Lee et al. [18] studied 124 eyes and reported a successful outcome in 97 % of patients and also found lower rates of extrusion (10 %); however, conjunctival overgrowth was noted in 12 % of their patients.

Choi and Yang [12] described an endoscopic guided transcaruncular Jones tube intubation without a DCR with a success rate of 91.4 %. They defined success as relief of epiphora along with patency of the tube to irrigation. Idiopathic canalicular obstruction was the commonest indication in their series (77 %) and the length of Jones tube varied from 16 to 30 mm. The significant point to note is dramatic reduction in tube extrusions (2.9 %). Although 22.9 % had inferior migration, majority of them were corrected in the clinic itself with good results. However, the time of suture removal was not specified and neither was the lacrimal drainage assessed objectively. Devoto MH et al. [13] published a similar technique which they termed "Minimally Invasive Conjunctivodacryocystorhinostomy" (MICDCR), using the Jones tubes with an average length of 16 mm. Notable feature of this series was that no case had any extrusion of the tube, although inferior migration was seen in 12.7 % of the patients, which were easily repositioned satisfactorily in all patients. Success in the Devoto series was based on demonstrating the aspiration of 2 % topical fluorescein into the nose with endoscopy. Ali MJ et al. studied 15 patients with endoscopically guided minimally invasive bypass tube placement without a DCR and found encouraging results with regard to extrusions. However, they reported other complications like peritubal soft tissue infection and conjunctival pressure necrosis [14].

In conclusion we state that endoscopic guided minimally invasive placement of a bypass tube without DCR is an easy and effective alternative to the traditional conjunctivodacryocystorhinostomy and is likely to help in avoiding major complications of tube extrusion and malpositions seen with the latter procedure. Objective evaluation of lacrimal drainage helps in typifying and uniformly assessing the outcomes in future.

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Adjunctive Endonasal Procedures with Dacryocystorhinostomy

28

Joseph Brunworth, Alkis James Psaltis, and Peter-John Wormald

Introduction

Considering the wide breadth of nasal disorders commonly encountered in the general population, it is not surprising to find overlap with patients presenting with lacrimal ailments. In fact, within the subset of patients in whom surgical intervention is deemed prudent, it is occasionally necessary to perform simultaneous endonasal procedures at the time of dacryocystorhinostomy. In addition to septal deviation requiring septoplasty for access to the lacrimal system, one must also assess for various other nasal diseases including turbinate hypertrophy, nasal polyposis, rhinosinusitis, and multiple other neighboring disease processes. Emphasis must be placed on proper preoperative evaluation of concurrent disease to ensure the surgical candidate is properly consented prior to the day of surgery.

In addition to the common disease processes found in the nasal passages, it is important to first rule out some of the more threatening disorders that could necessitate further evaluation or treatment. Office endoscopy may show signs of a nasal mass, which may warrant a biopsy prior to surgical planning. Reports can be found citing lymphoma, carcinoma, or other malignant or benign tumors contributing to nasolacrimal duct obstruction [1]. In males, especially adolescents, it is important to also consider juvenile nasopharyngeal angiofibromas, as these are not to be biopsied in the office setting due to risk of hemorrhage. Once the more aggressive diseases have been ruled out, the more common nasal disorders should be considered.

Of the inflammatory sinonasal disease processes that commonly affect patients, the most common include anatomical nasal airway obstruction, some form of rhinitis or rhinosinusitis, or a combination. These entities are further broken down into various categories each with their own etiopathogenesis. Chronic rhinitis is further categorized as allergic and nonallergic, although the initial treatment of both is comparable. Acute rhinitis is frequently infectious (i.e., viral) in nature and is generally self-limiting.

Rhinosinusitis also can be categorized into its various forms, including acute or chronic, with or without polyposis, fungal, bacterial, viral, or a combination of the aforementioned (Table 28.1).

As a clinician, it is important to elicit the symptoms that accompany the disease process as this will help determine the diagnosis as well as the subsequent course of action.

For rhinitis, symptoms generally include nasal airway congestion, postnasal drip, and allergy-like symptoms including sneezing, clear nasal discharge/nose blowing, and pruritus.

J. Brunworth, MD
Department of Otolaryngology,
University of Adelaide, Adelaide, SA, Australia

A.J. Psaltis, FRACS • P.-J. Wormald, FRACS (✉)
Department of Otolaryngology, Head Neck Surgery,
University of Adelaide, Adelaide, SA, Australia
e-mail: pjwormald@professorwormald.com.au

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Table 28.1 Classification of rhinosinusitis

Acute rhinosinusitis (<4 weeks duration)
Bacterial
Viral
Invasive fungal (immunocompromised patients)
Recurrent acute rhinosinusitis (each episode <4 weeks)
Subacute rhinosinusitis (4–12 weeks duration)
Chronic rhinosinusitis (can be a combination of the following)
Bacterial
With polyposis or without
Allergic fungal
Eosinophilic mucin
Fungal ball/mycetoma/aspergilloma
Chronic fungal/saprophytic
Aspirin sensitivity and/or asthma
Mucocele formation

Table 28.2 Major and minor criteria for the diagnosis of rhinosinusitis[a]

Major symptoms	Minor symptoms
Purulent anterior nasal discharge	Headache
Purulent or discolored posterior nasal discharge	Ear pain, pressure, or fullness
Nasal congestion or obstruction	Halitosis
Facial congestion or fullness	Dental pain
Facial pain or pressure	Cough
Hyposmia or anosmia	Fever (for subacute or chronic sinusitis)
Fever (for acute sinusitis only)	Fatigue

Source: Meltzer et al. [25]
[a]Diagnosis based on presence of at least two major symptoms, or one major plus two or more minor symptoms

Symptoms of sinusitis include those listed earlier for rhinitis, in addition to the following: mucopurulent/purulent nasal or postnasal drainage, facial pressure/pain, hyposmia, fevers, headaches, halitosis, dental pain, cough, ear pain, and malaise/fatigue. Multiple sets of criteria have been proposed to help distinguish true sinusitis from various clinical imitators such as migraines, dental pains, headache syndromes, allergies, etc. A basic understanding of the algorithms used to define sinusitis and the ability to differentiate it from other diagnoses can help physicians other than otolaryngologists who may encounter these symptoms while working up a patient for a DCR or other combined procedure (Table 28.2).

Patients will often have a preconceived notion that they suffer from "sinus headaches." The most common misdiagnosis of sinusitis is migraine headaches. An alarm should go off in the clinician's mind when intermittent unilateral facial pain exists with no other accompanying symptoms in addition to a negative physical exam or negative CT scan. Multiple studies emphasize the risks of misdiagnosing migraines as sinusitis and many have even recommended a trial of antimigraine medication prior to a trial of antibiotics in such cases [2–4].

Once a thorough history has been obtained, physical exam can help narrow the differential diagnosis. Upon anterior rhinoscopy with an otoscope, the clinician can assess the anterior nasal airway for septal deviation and turbinate hypertrophy (Fig. 28.1). Significant purulence as well as polyposis or other nasal masses may also be picked up with this initial evaluation (Fig. 28.2). The next step is to assess deeper within the nasal passage, using nasal endoscopy. In-office nasal decongestant spray and topical anesthetic allows for a rigid endoscope to gently be passed into the anterior nasal cavity, the middle meatus under the axilla of the middle turbinate, and medial to the middle turbinate to assess the posterior nasal cavity. During this inspection, the various diseases of the nose can be more readily seen, such as polypoid changes, purulence, mucosal edema, nasal masses, or other conditions.

Over the past few decades, the use of CT scans for diagnostic purposes and surgical planning has become increasingly utilized. If findings such as a nasal mass or polyposis are found during the initial

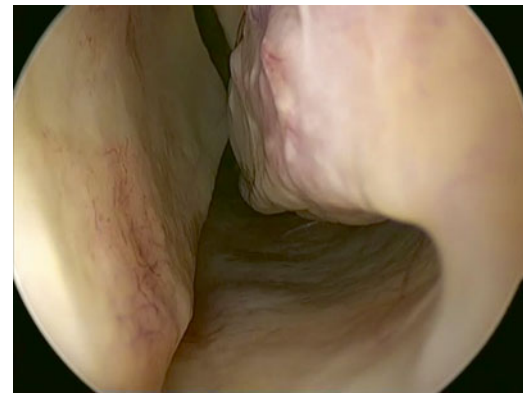

Fig 28.1 Left nasal endoscopy showing significant septal deviation as well as mild turbinate hypertrophy narrowing the nasal airway

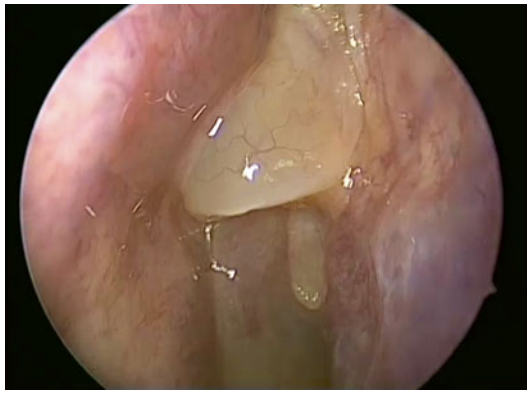

Fig 28.2 Classic view of severe but benign appearing nasal polyps

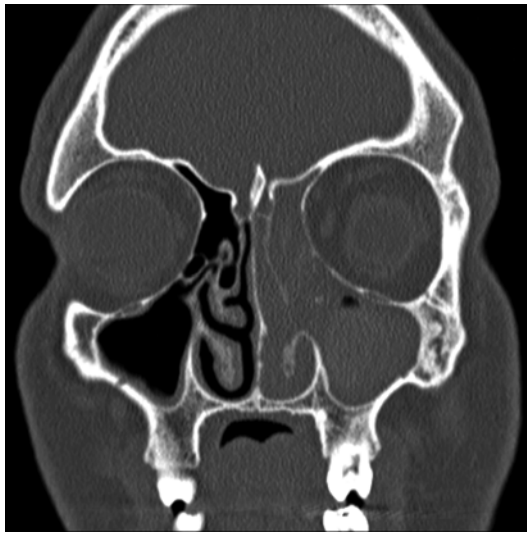

Fig 28.3 Patient with mild mucosal thickening of the right maxillary sinus but otherwise normal appearing sinuses on that side. Contrast this to the patient's left side, where pan-sinusitis is seen as opacification of the sinuses and will require surgical intervention to correct

physical exam, imaging is generally accepted as part of the primary workup. However, most other nasal diseases warrant a trial of medical therapy prior to obtaining further diagnostics.

If septal deviation or turbinate hypertrophy is encountered during endoscopy and they account for the patient's symptoms, then radiologic confirmation is unlikely to be necessary. However, if criteria of rhinosinusitis are met and symptoms persist despite medical therapy, then a CT scan of the sinuses is generally obtained prior to further intervention (Fig. 28.3).

Surgical Techniques of Adjunctive Procedures

If the decision is made to proceed with an endonasal procedure in addition to a dacryocystorhinostomy, the order of the surgeries becomes relevant. In general, surgeries done for access and anatomical obstruction such as a septoplasty are performed first to allow the surgeon proper visualization of the nasolacrimal system. If bilateral DCRs are to be performed, the DCR on the nonobstructed side can be performed prior to a septoplasty. In the rare case that a septal deviation requiring surgical intervention protrudes to the opposite side of the nasolacrimal duct obstruction, the DCR can be performed first followed by the septoplasty. Inferior turbinate reduction can be performed after a DCR as this procedure generally does not influence the work done on the nasolacrimal system. Middle turbinate work is usually performed before the DCR to allow improved access and can include anterior partial turbinectomy or concha bullosa excision. If an axillary mucosal flap is going to be utilized for the DCR as described by Wormald [5], and a middle turbinate procedure is required, the mucosal flap must be raised prior to the middle turbinate procedure to prevent its loss during the preceding interventions. If functional endoscopic sinus surgery (FESS) is going to be performed with the DCR, then the DCR is performed first. This is done because during DCR one removes the anterior wall of the agger and exposes it; this makes the first step in FESS easy as the agger is exposed and ready to be taken down. Again, if the axillary flap is to be utilized, this is to be performed as the first part of the DCR and can be later trimmed as needed for a mucosal graft to promote healing.

Septoplasty

One of the keys to a successful endoscopic DCR is adequate surgical access during the surgery and ample space surrounding the surgical bed in the postoperative period. Therefore, it is recommended to have a low threshold in performing an adjunctive septoplasty. By straightening such a

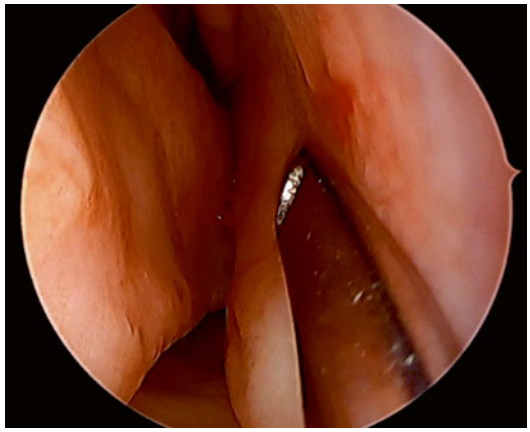

Fig 28.4 Endoscopic view of right deviated nasal septum narrowing the nasal cavity

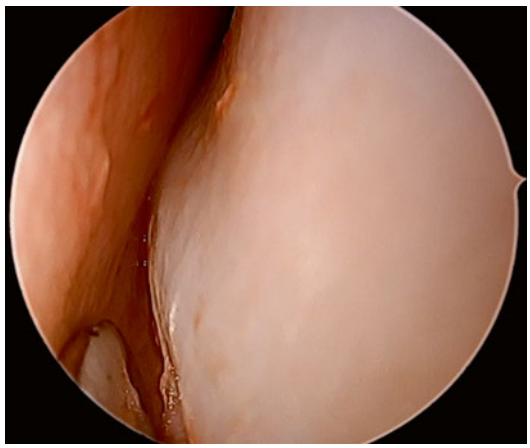

Fig 28.5 Endoscopic submucoperichondrial view showing the septal deviation

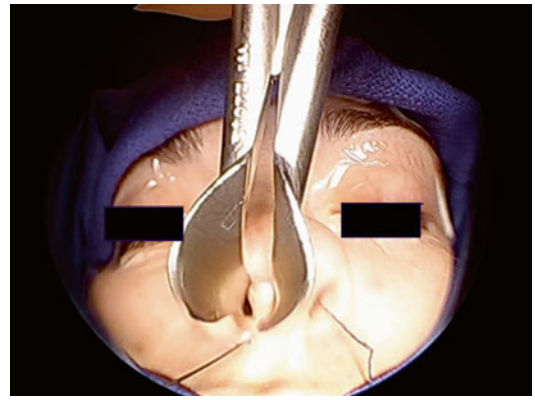

Fig 28.6 External view of right caudal deviation

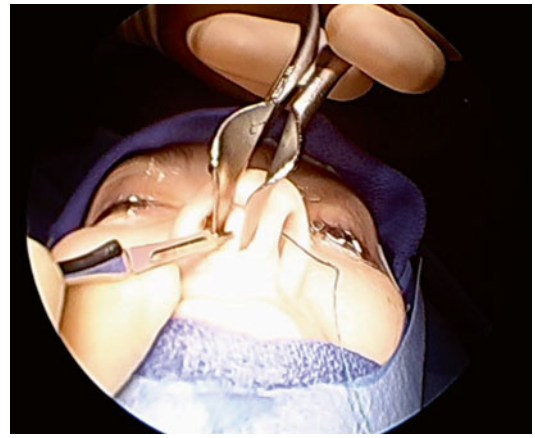

Fig 28.7 Right hemitransfixation incision

deflection (Figs. 28.4, 28.5, and 28.6), the surgeon gains improved access to the axilla of the middle turbinate and the area surrounding the proposed neo-ostium of the DCR. Considering the surgeon has all required instrumentation already set up including endoscopes, suction, lighting, etc., our recommendation is to perform an endoscopic septoplasty rather than an open version.

To be able to perform an endoscopic septoplasty, certain instruments are necessary. A suction Freer elevator helps keep a clear surgical field while allowing the surgeon to continue to elevate the flaps. The endoscopic lens cleaner can remove blood without reinsertion of the endoscope repeatedly throughout the procedure and facilitates surgical progress.

The initial incision is made either in the location of a Killian incision or, if there is caudal dislocation of the cartilaginous septum, in the more anterior location of a hemitransfixion incision (Fig. 28.7). The subperichondrial plane is exposed using a scalpel, iris scissors, or other sharp instrumentation, and then further elevated using the suction Freer (Fig. 28.8).

In order to preserve the septal flap during elevation of the flap off the maxillary crest, it is best to raise the flap as far posterior as possible prior and then to dissect toward the floor in the posterior region and bring this plane progressively anteriorly releasing the flap from the crest (Fig. 28.8). This helps prevent perforation of the

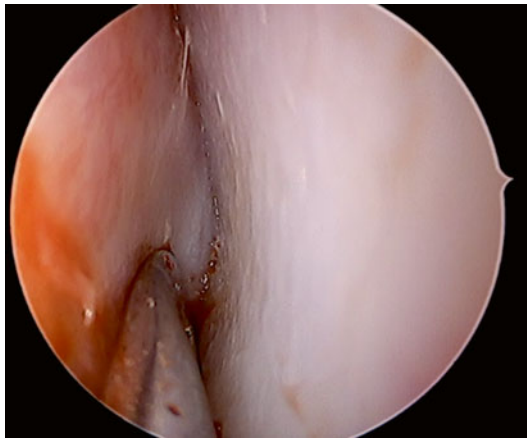

Fig 28.8 Submucoperichondrial elevation of the flap

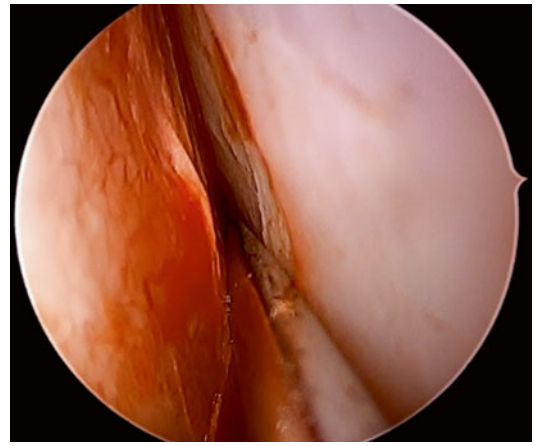

Fig 28.9 The bony–cartilagenous junction (Note the smooth cartilage and the rough bony area behind)

mucosa as it thins out over the junction of the cartilage and nasal crest. This is best done by starting on the side of the septum without a spur or significant deviation to ensure at least one septal flap is preserved. In most cases, if there is a significant spur or deviation it can be very difficult to maintain the integrity of the flap, so preserving the nondeviated side flap becomes critically important in avoiding a septal perforation.

Often, if the cartilaginous septum is elongated and dislocated off the crest, and an inferior strip of cartilage needs to be removed just above the maxillary crest, rather than attempting to elevate all the way to the floor in this circumstance, the flap can be raised down to the presenting edge of the spur. The flap is not raised over the entire deflection, as it is likely to tear. Rather, using the sharp end of a regular Freer elevator, a horizontal incision is made above the spur through the cartilage onto the crest. This allows for removal of the cartilaginous insertion into the crest from anterior to posterior. If the bony crest is found to contribute significantly, this can be removed using an osteotomy chisel. In general, patients should be counseled preoperatively that numbness of the central incisors can be common, but most often dissipates after several weeks. Ideally, only half of the crest that is protruding into the nasal cavity is removed because damage to the nerves is more common when the whole maxillary crest is removed.

As the septoplasty proceeds, occasional glances with the endoscope into the bilateral nasal cavities

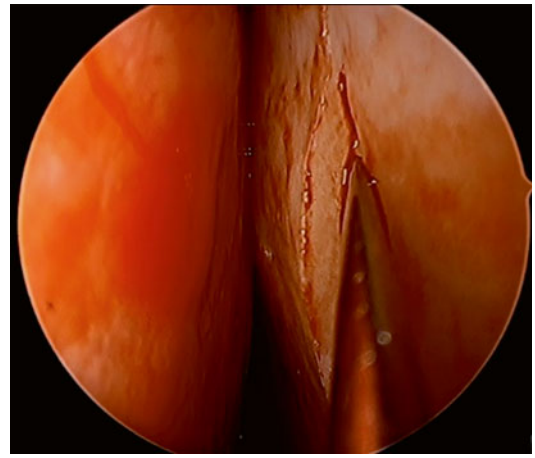

Fig 28.10 Cartilage incision with a sharp Freer elevator (Note the spared cartilage anterior and above the incision)

will allow the surgeon to correct the areas of greatest concern. The posterior bony deflections can be addressed by disarticulating the bony and cartilaginous junction (Fig. 28.9) followed by bilateral subperiosteal planes. A sharp Freer elevator is used to incise the cartilage leaving a good strut anterior and above (Fig. 28.10) and disarticulate the portion to be removed (Fig. 28.11). The bony spur is then exposed (Fig. 28.12) and can be removed superiorly using a through-biting instrument such as an open Jansen–Middleton to prevent torqueing on the roof and thus preventing a skull base damage and CSF leak (Fig. 28.13). A good space is thus created within the nasal cavity (Fig. 28.14).

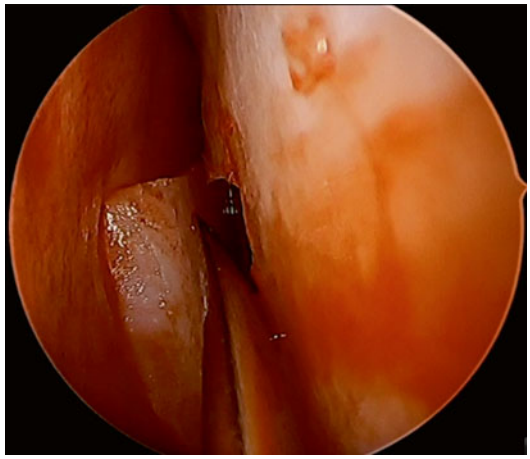

Fig 28.11 Disarticulating the incised cartilage

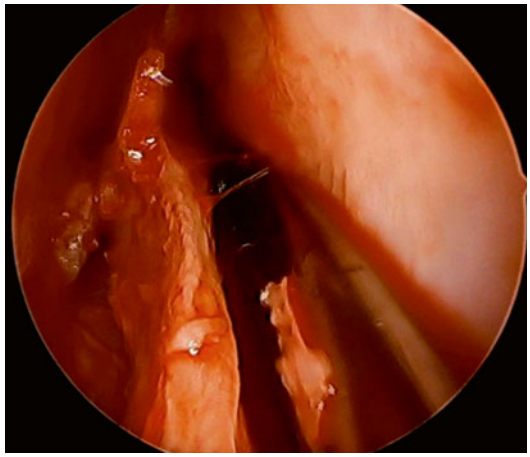

Fig 28.12 Isolation of bony spur

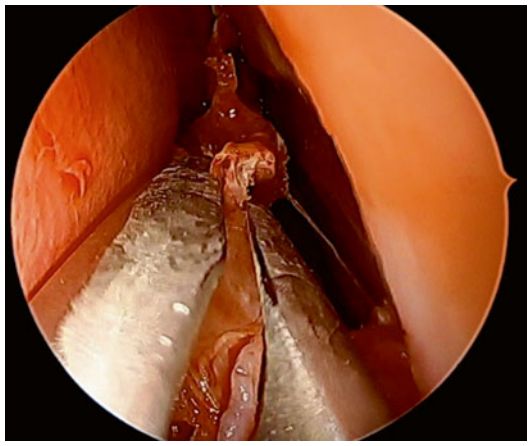

Fig 28.13 Bony spur removal using the Jansen–Middleton forceps

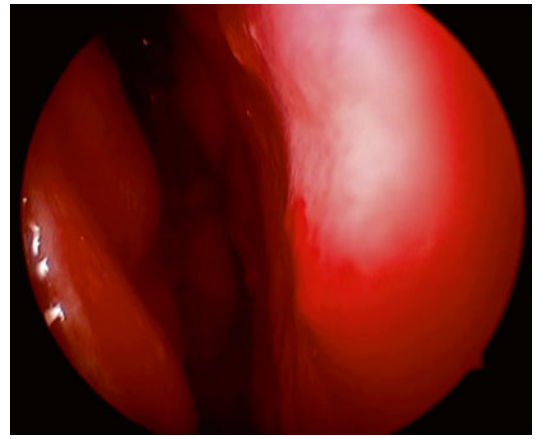

Fig 28.14 Increased space within the nasal cavity following surgery

Anteriorly, the quadrangular cartilage is removed only in areas that are obstructing the nasal airway, taking precautions to leave an L-strut of at least 1 cm to prevent saddle nose deformity.

If no prior tears have been created in either mucosal flap, the scalpel is used to make a 2–3 cm horizontal incision posteriorly on the floor of one flap to prevent a septal hematoma. A quilting suture is placed through the septum to hold the flaps together as well, also preventing fluid collection between the mucosal flaps. A review of the literature shows that in patients undergoing DCRs, septoplasty was necessary in up to 47 % of patients [5–10].

Turbinate Reduction

Like most procedures, the surgical interventions used for hypertrophy of the nasal turbinates have evolved over time. Proper patient assessment and a trial of medical therapy should be performed before the decision is made to reduce the turbinates. In those patients that fail medical therapy and in whom other contributing factors have been eliminated (allergies, sinus disease, etc.), turbinate reduction is a valid option with improvement of the patient's nasal airway and frequently in their quality of life [11–19].

Inferior turbinoplasty is the procedure of choice as it maintains the functional medial surface of the

turbinate while effectively reducing the size of the turbinate avoiding such complications as atrophic rhinitis and empty nose syndrome.

This preservation of the medial wall of the inferior turbinate maintains the airflow receptors in this wall and avoids the "empty nose syndrome" in which the patient cannot perceive airflow despite a widely patent nasal airway. In this technique, local anesthetic agent is infiltrated into head of the inferior turbinate (IT) (Fig. 28.15) and an incision is taken on the head (Fig. 28.16). The head is trimmed onto bone allowing space for the endoscope and a powered microdebrider to be placed. The microdebrider is used to remove the soft tissue over the inferior and medial portions of the turbinate. Next, a dissector is used to dissect in the subperiosteal plane (Fig. 28.17) the medial mucosa and remaining lateral mucosa from the vertical portion of the inferior turbinate bone, isolating the bone (Fig. 28.18). The bone is removed and any residual bone fragments are cleared with a ball probe, back-biter, or other endoscopic instruments (Fig. 28.19). Once this bone is removed, the two vessels supplying the inferior turbinate can be visualized in the posterior region of the turbinate. These vessels are cauterized with bipolar forceps. The residual turbinate is then outfractured and rolled laterally so that the medial mucosa covers any exposed tissue, minimizing postoperative crusting (Fig. 28.20). The rolled turbinate is held in place with a strip of oxidized cellulose or surgicel. No other packing is used in the nose. The powered inferior turbinoplasty

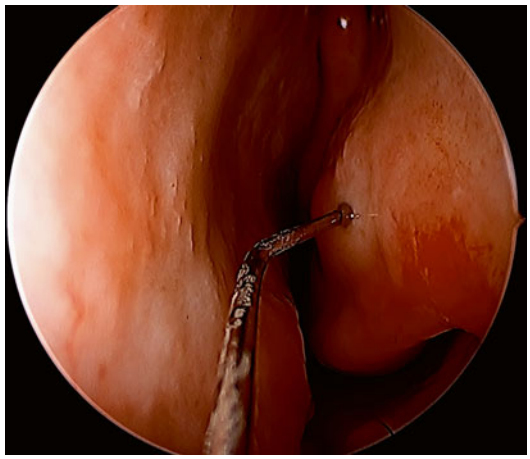

Fig 28.15 Injecting into the head of inferior turbinate for decongestion

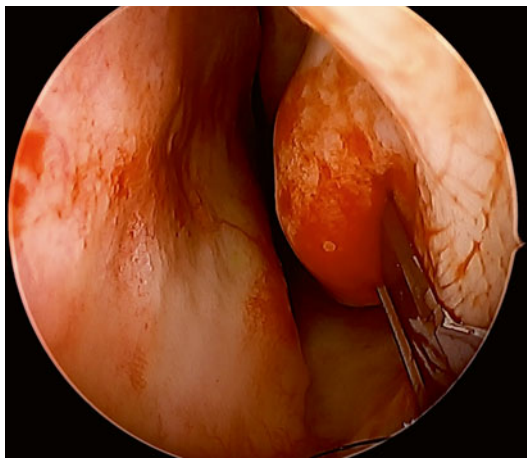

Fig 28.16 Inferior turbinate incision

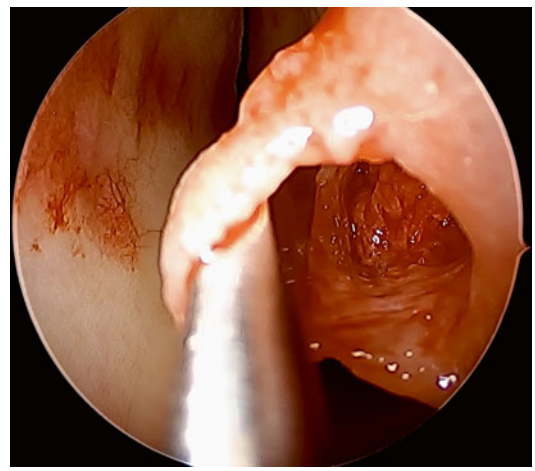

Fig 28.17 Raising the submucosal plane

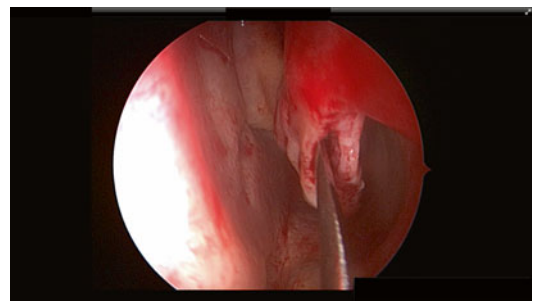

Fig 28.18 Isolation of the inferior turbinate bone

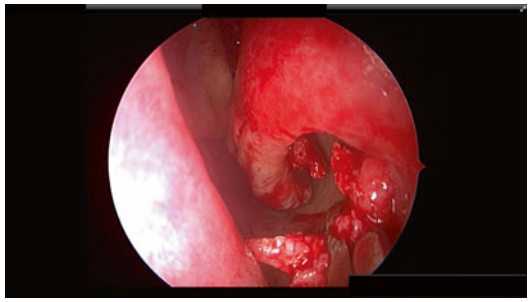

Fig 28.19 Removal of the inferior turbinate bone

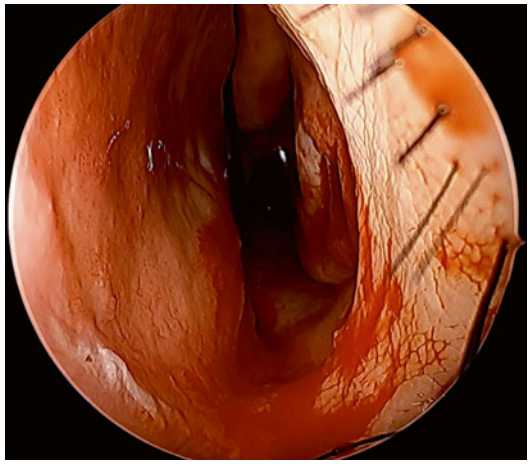

Fig 28.20 Intraoperative photo following turbinoplasty

preserves the medial aspect of the mucosal covering of the inferior turbinate and therefore reduces the risk associated with standard turbinectomy procedures while still giving long-lasting results [20] (Fig. 28.21).

Middle turbinate procedures can also be performed in conjunction with an endoscopic DCR. If the middle turbinate is pneumatized as per the CT scan, this is considered an anatomical variation known as a concha bullosa. This cell can obstruct access for the DCR or become infected, block the natural osteomeatal complex, cause a contralateral septal deviation, or block the neo-ostium after a DCR has been performed. To excise the concha bullosa, an incision is made into the anterior face of the turbinate using a scalpel or sickle knife. Once the concha bullosa has been entered, endoscopic scissors are placed through the aperture in the closed position, and then opened inside in order to pry the cell open

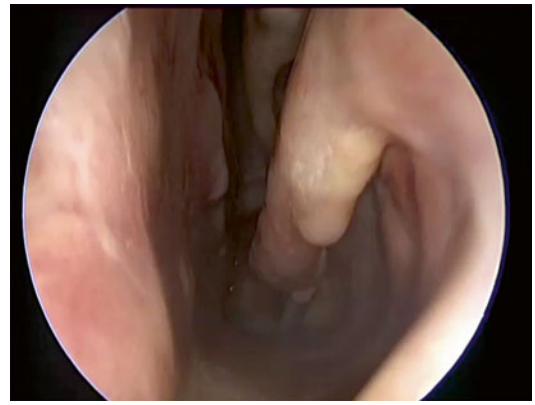

Fig 28.21 Several months after septoplasty and inferior turbinoplasty, the well-healed mucosa and patent airway demonstrate the drastic improvement from the preoperative view seen in Fig. 28.1

further. The lateral portion of the concha bullosa can then be removed using the endoscopic scissors or straight through-cutting instruments until the posterior aspect is released.

Even if the middle turbinate is not pneumatized, occasionally middle turbinate work (including partial or complete turbinectomy) is still required to ensure adequate space at the neo-ostium after DCR. This space surrounding the os is crucial to prevent synechiae and stenosis of the new nasolacrimal aperture [5, 21–23].

Functional Endoscopic Sinus Surgery

In the same review of DCR literature mentioned earlier, 15 % of patients underwent ancillary endoscopic sinus surgery for ongoing nonresponsive chronic sinusitis or nasal polyposis [5–10].

The various nuances of functional endoscopic sinus surgery (FESS) are too numerous to cover in this chapter, although certain points are worth mentioning. Due to the small but devastating chances of catastrophic complications such as carotid artery injury, skull base violation, and blindness, sinus surgery is generally performed only by a fully trained otolaryngologist. Regardless of the technique used, the DCR is most often performed prior to the sinus surgery. During the initial steps

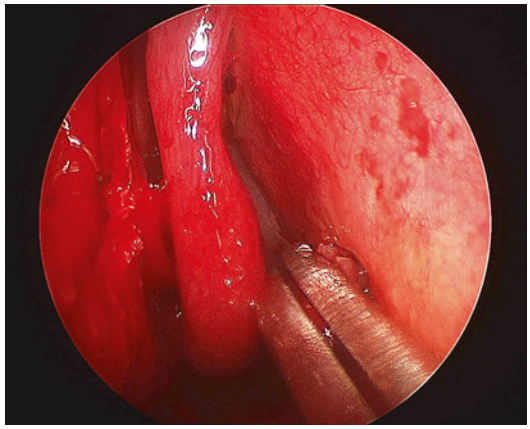

Fig 28.22 Uncinectomy (*horizontal*) by backbiting forceps

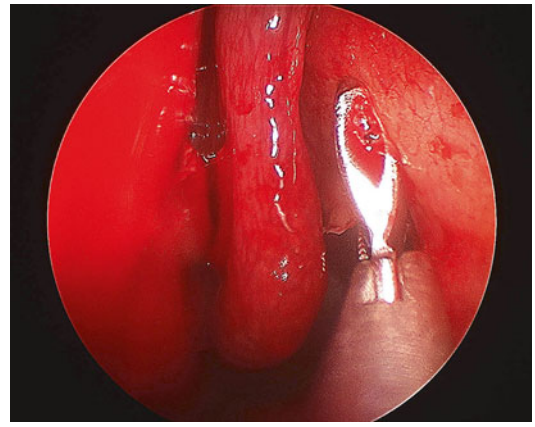

Fig 28.23 Vertical portion removed with 45° up-biting Blakesly forceps

of the DCR, the axillary flap can be raised and the agger nasi cell opened, thus preparing for further exenteration of the ethmoid and frontal cells during the FESS. Occasionally, severe polyposis requires that the FESS be initiated prior to the DCR as the disease may block the middle meatus and the area of lacrimal dissection. The goal of the FESS is to open the sinuses in a natural pathway to allow proper drainage of mucus while preserving the maximal amount of mucosa. In addition, proper aeration and improved access for saline irrigation is thought to decrease the inflamed or polypoid nature of the mucosa found in diseased sinuses. At the time of the FESS, each diseased sinus is addressed individually in order to remove entrapped mucus, mucopurulent discharge, polyps, or fungal growth that may have accumulated. Figures 28.22, 28.23, 28.24, 28.25, 28.26, 28.27, 28.28, 28.29, 28.30, 28.31, 28.32, 28.33, 28.34, 28.35, and 28.36 give a brief pictorial overview of a standard FESS surgery. Once the sinus surgery has been performed, the surgery can be completed as planned with standard postoperative care. Sinus rinses with saline are a mainstay in most sinus surgeons' postoperative care regimen and are utilized in the DCR/FESS patients as well. Nasal saline spray and douche can be started within 24 h of surgery. This helps to remove blood clots from the nose and creates a clear nasal passage. If stenting is to be performed, it also prevents mucous from accumulating around the O'Donoghue tubes, which can create a medium or become a nidus for secondary infection.

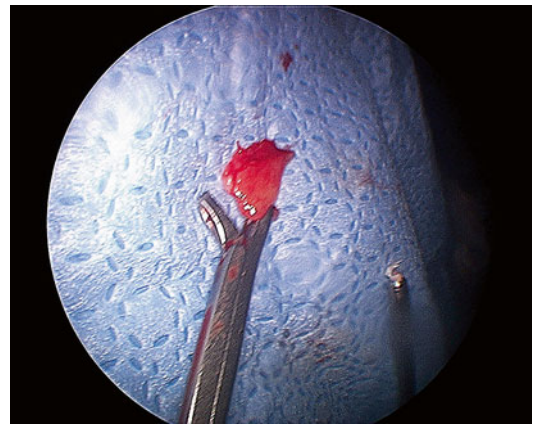

Fig 28.24 Uncinate removed en-block

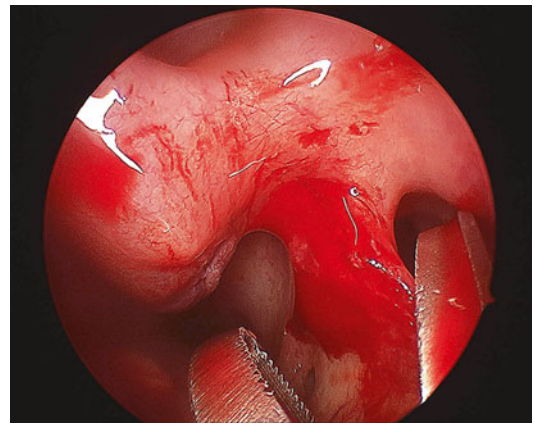

Fig 28.25 Middle meatal antrostomy

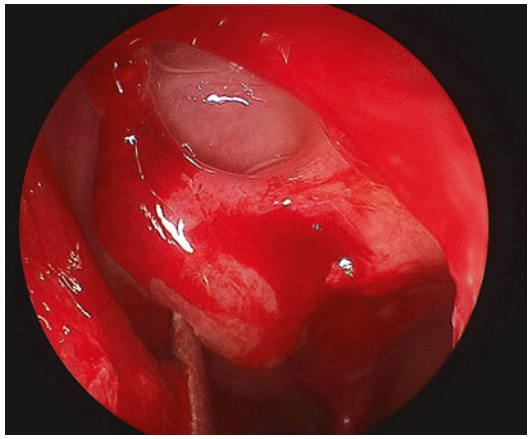

Fig 28.26 Beginning of anterior ethmoidectomy

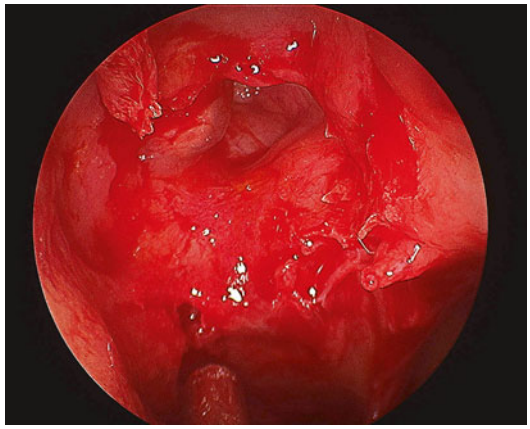

Fig 28.27 Completed anterior ethmoidectomy

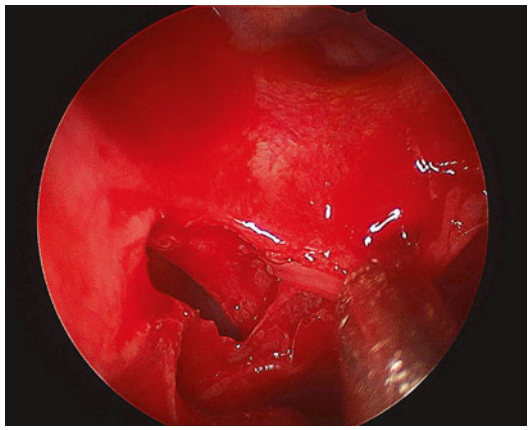

Fig 28.28 Commencing posterior ethmoidectomy

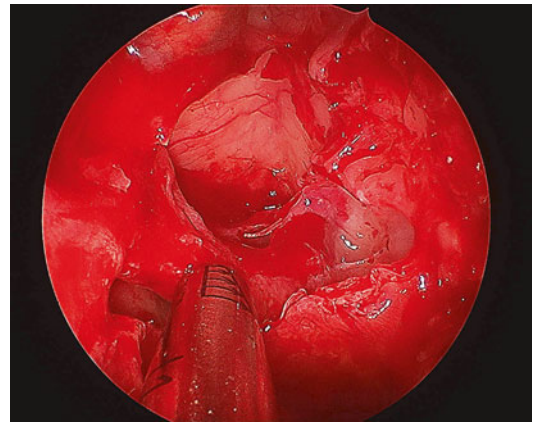

Fig 28.29 Completed posterior ethmoidectomy

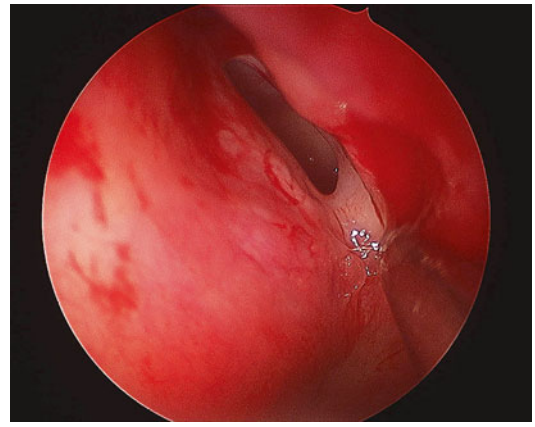

Fig 28.30 Sphenoid ostia visualized

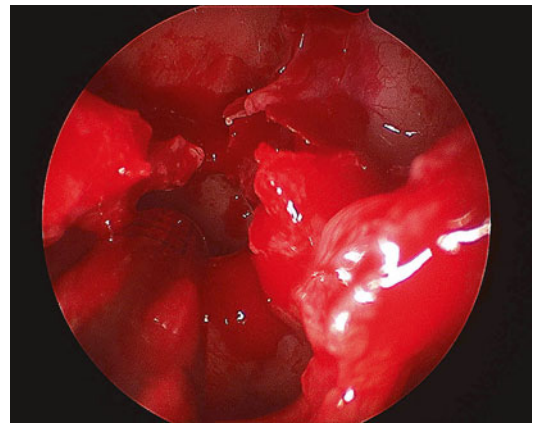

Fig 28.31 Sphenoidotomy

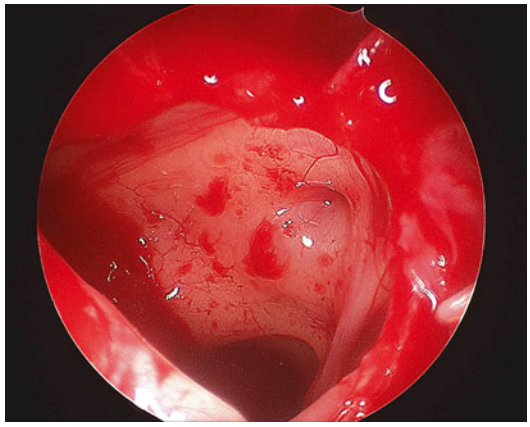

Fig 28.32 Completed sphenoidotomy (Note the opticocarotid recess in sphenoid cavity)

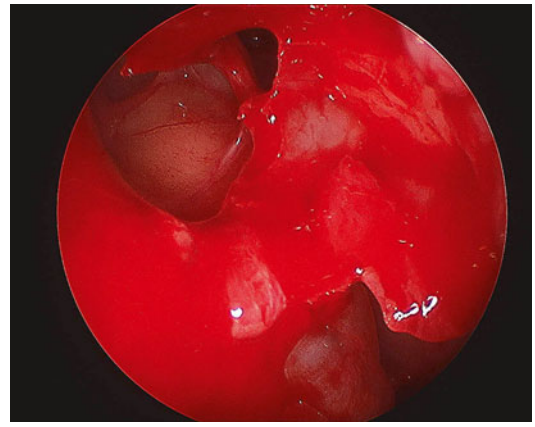

Fig 28.35 Enlarged opening of the frontal sinus

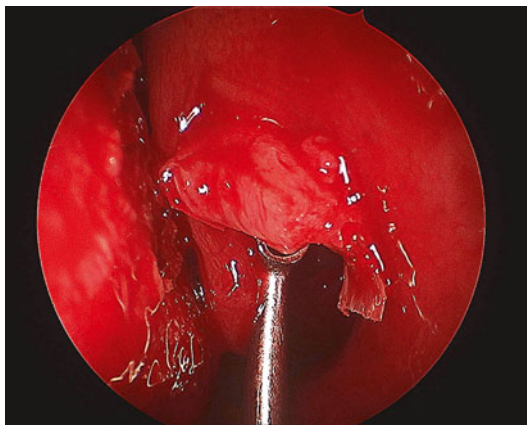

Fig 28.33 Axillary flap access to agger nasi and frontal recess

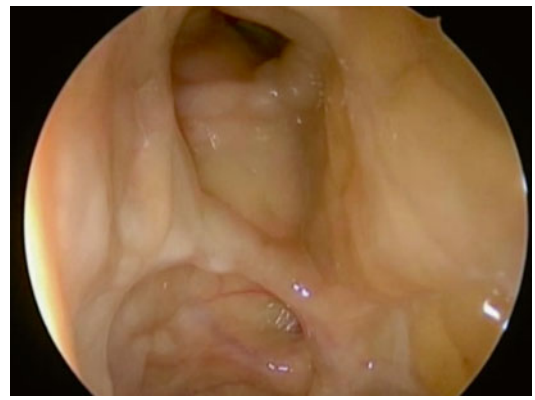

Fig 28.36 Wide opened and well-draining sinuses following FESS

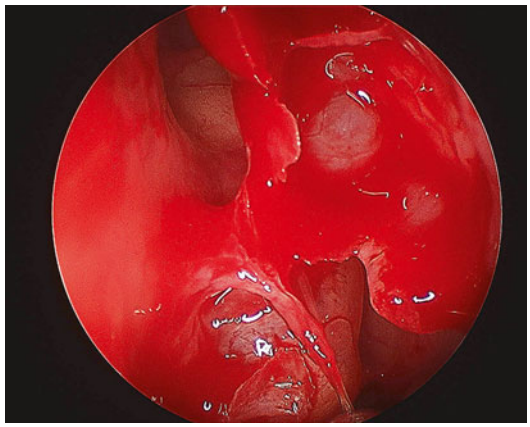

Fig 28.34 Frontal recess

Conclusion

It is beneficial for both Ophthalmologists and otolaryngologists to develop a close liaison with each other when starting an endoscopic DCR practice [24]. Both have expertise in different areas and can improve the overall patient care, the preoperative evaluation, the surgical outcomes, and even the postoperative management. The main advantage of a two-team approach is allowing the Ophthalmologist to assess for additional eye disease while the sinus surgeon is able to endoscopically assess the nasal cavity, septum, and perform ancillary endonasal procedures that may be

necessary while avoiding multiple trips to the operating room. Both surgeons should learn to be comfortable with all aspects of assessment and surgery and should be able to assist each other with ease in order to provide optimal patient care.

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Evaluation of a DCR Ostium and DOS Scoring

29

Mohammad Javed Ali, Alkis James Psaltis, and Peter-John Wormald

Introduction

Dacryocystorhinostomy (DCR) is common surgery employed for the management of nasolacrimal duct obstruction and chronic dacryocystitis with a high success rate [1–8]. However, the failure rates can occur from 4 to 13 % [1, 9–11]. Many causes of failures can be attributed to ostium, the most common being scarring and cicatricial closure of the osteotomy site [9–12]. The other causes related to ostium include inadequate size, inappropriate location, intervening ethmoids, DCR to air cell, membranes over the internal common opening, granulomas, and sump syndrome [10, 12, 13]. Numerous studies in the past have focused on the size and measurement techniques of the ostium and patency tests [14–22]. It is amply evident that many finer physical and functional details of the ostium need to be evaluated postoperatively in an orderly manner to appreciate pathological behaviors early on and institute corrective measures toward prevention or treatment. This chapter presents a DCR ostium protocol for a detailed evaluation and also the DCR ostium or the DOS to standardize the evaluation.

M. Javed Ali, MS, FRCS, FRCGP (✉)
Dacryology Service, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

A.J. Psaltis, FRACS • P.-J. Wormald, FRACS
Department of Otolaryngology, Head Neck Surgery, University of Adelaide, Adelaide, SA, Australia

Evaluation of an Ostium

Defining an Ostium

The different parts of an ostium need to be defined before we start evaluating it. The ostium can be arbitrarily defined to have a base with four edges surrounding it, namely anterior, posterior, superior, and inferior (Fig. 29.1).

Location of Ostium

The location of an ostium should be described in relation to the middle turbinate, which is the

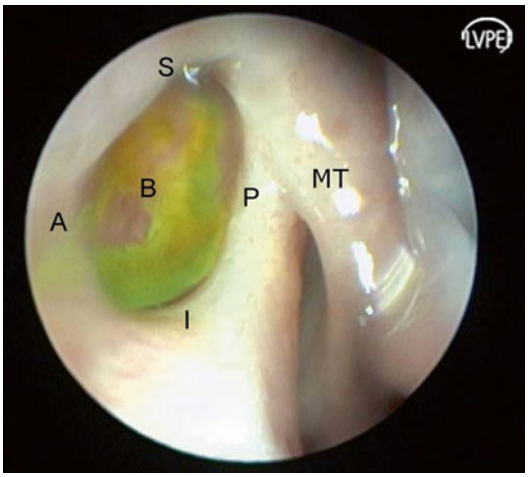

Fig. 29.1 Endoscopic view of an ostium with its named edges and base. *A* anterior edge; *P* posterior edge; *I* inferior edge; *S* superior edge; *MT* middle turbinate

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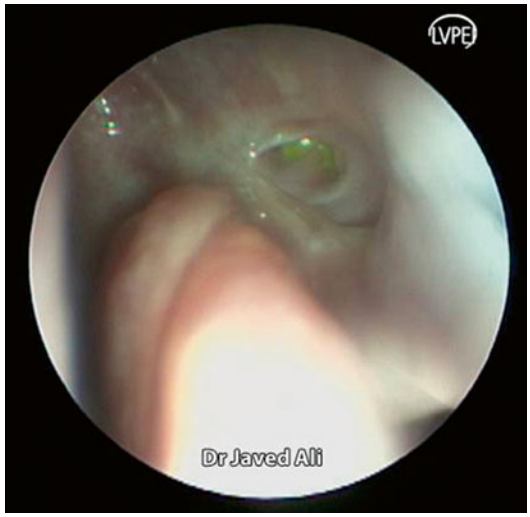

Fig. 29.2 Abnormal location: Ostium above the axilla of middle turbinate

most prominent landmark in the vicinity. The most common location of the lacrimal sac is in front of the axilla of middle turbinate (MT) with two-thirds of the sac length above the insertion [23, 24]. Hence, most of the healed ostia should ideally be in front of axilla of MT with some portion above it (Fig. 29.1). Occasionally it may be found behind the axilla of MT or completely above the axilla of MT owing to lacrimal sac's location (Fig. 29.2).

Shape of the Ostium

With a good primary intention healing, majority of the ostia are circular to oval (Figs. 29.1 and 29.3). The more important part of a shape is the depression of the base. The base is depressed but shallow in cases of good mucosa to mucosa approximation all across after a sufficient osteotomy to completely expose the sac (Fig. 29.4). Deep bases are also noted with good mucosal approximation but when the osteotomy is beyond what is sufficient (Fig. 29.3). Although ostia with deep bases are not a problem, the one with shallow bases should be strived for to be as natural as possible. Other shapes like crescentric or vertically narrow are seen in cases of irregular healing and inadequate, patchy cicatrization (Fig. 29.5).

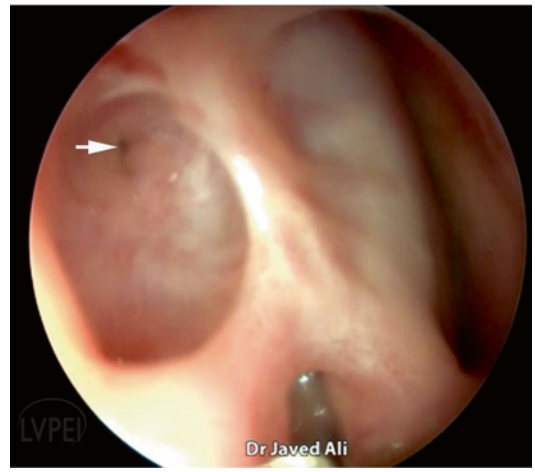

Fig. 29.3 Ostium with a deep base

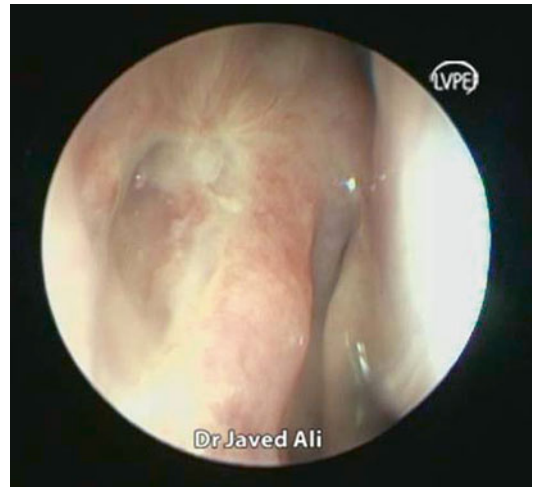

Fig. 29.4 Ostium with a shallow base

Size of Ostium

Numerous studies have demonstrated multiple techniques of measuring an ostium (Fig. 29.6) [14–22]. The percentage of reduction from original size subsequently are variable and the reasons are probably multifactorial. However, if mucosa-to-mucosa approximation is achieved all across and the healing completes with primary intention, the reduction in surface area is around 20 % only [23]. Based on the literature and one of the authors' (PJW) publication and detailed study of ostium, at 4 weeks evaluation, we propose to

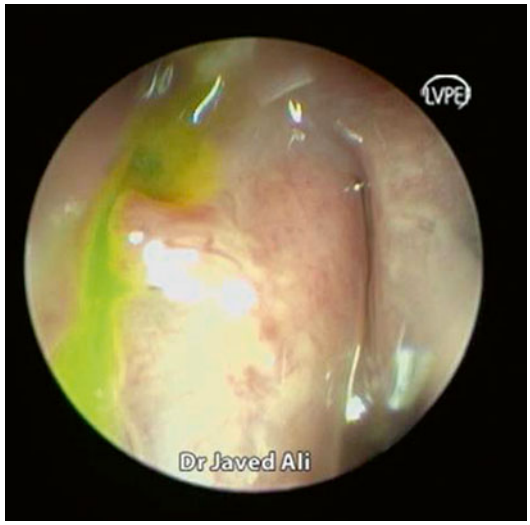

Fig. 29.5 Vertically narrow ostium

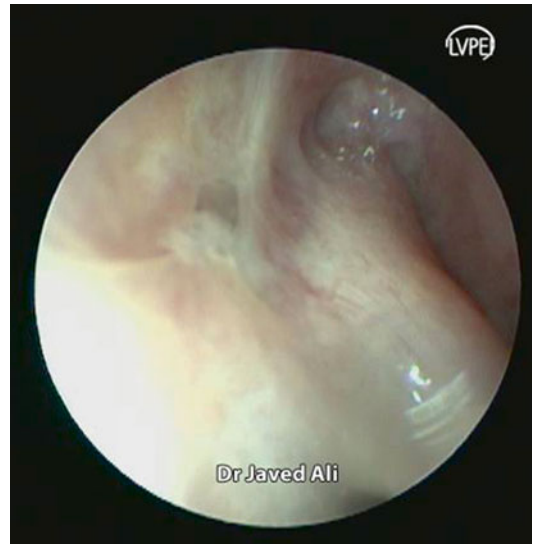

Fig. 29.7 A mini-ostium

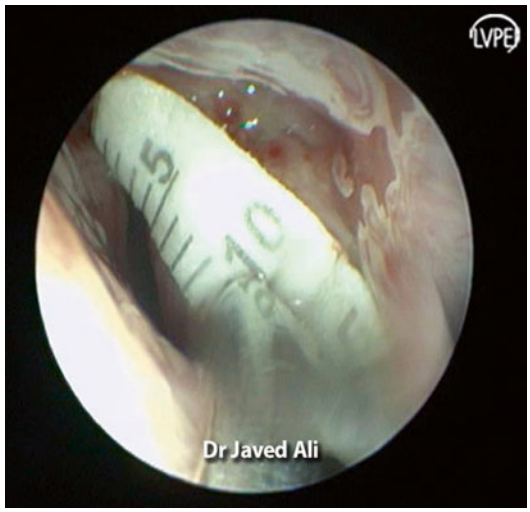

Fig. 29.6 Measuring an ostium

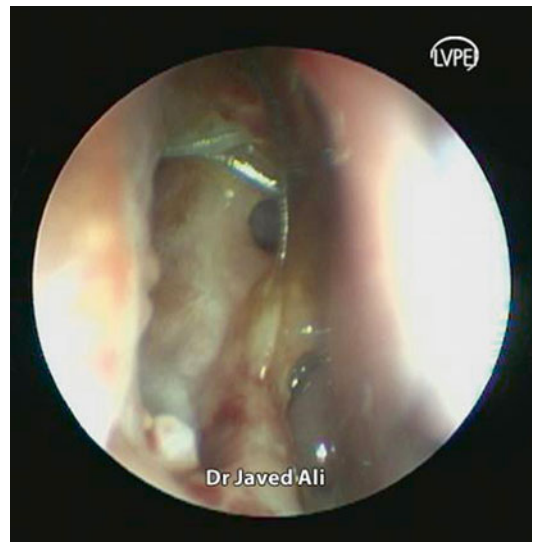

Fig. 29.8 Ostium at 1 week

consider any ostium better than 8×5 mm as good (Figs. 29.1 and 29.3) and <4×3 mm as a mini-ostium (Fig. 29.7).

Evolution of an Ostium

Evolution of an ostium in the postoperative period is an important parameter to monitor (Figs. 29.8, 29.9, 29.10, 29.11, and 29.12). It helps in sequentially assessing the healing process and any deviant behaviors that demands intervention. Most of the ostium shrinkage happens in the first 4 weeks and very little if at all beyond that [19, 20]. Regular monitoring helps the surgeon also understand the response to the operative technique and if there is any need to modify step(s) of the surgery. Studying evolution of an ostium would perhaps be partly helpful in determining the benefits or harm of adjunctive procedures in DCR.

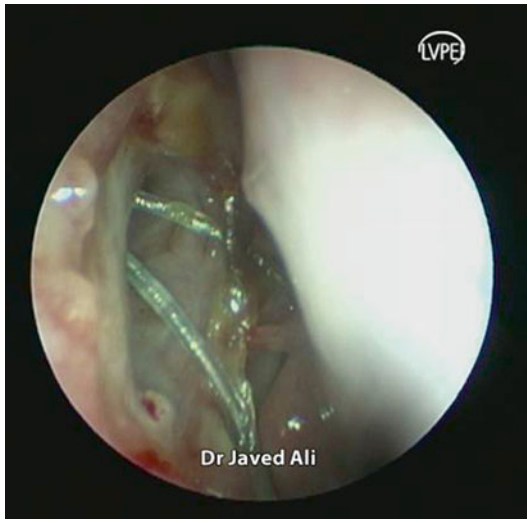

Fig. 29.9 Ostium at 2 weeks

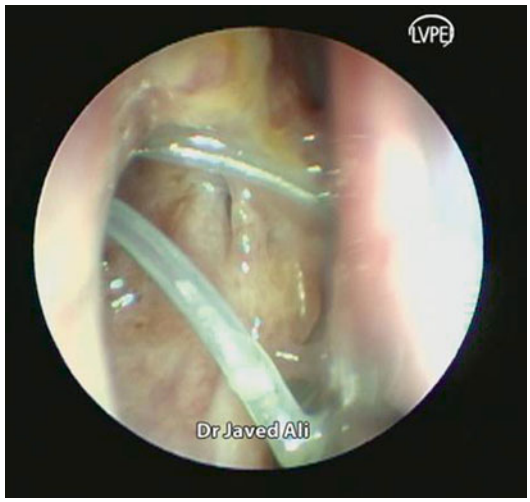

Fig. 29.10 Ostium at 3 weeks

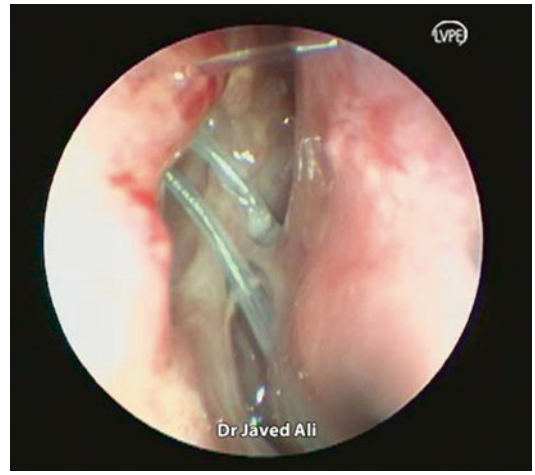

Fig. 29.11 Ostium at 4 weeks

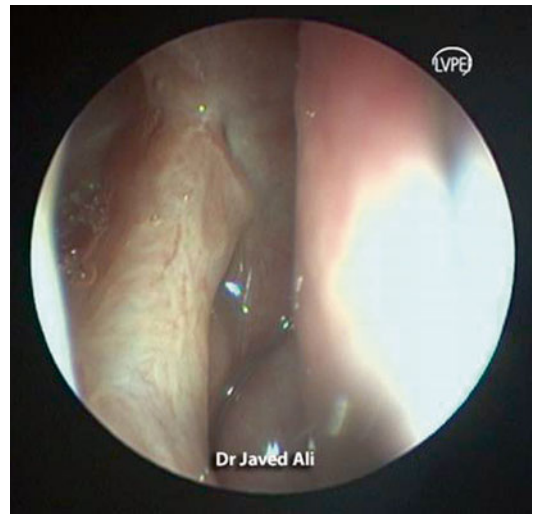

Fig. 29.12 Ostium at 6 weeks

Ostium Cicatrix

Cicatrization is healing of the ostium with a scar tissue. The authors here describe a term, "ostium pseudocicatix," where the ostium and its parameters are good but much medially toward the septum, there is a vertical thin layer of scar tissue like a curtain (Fig. 29.13). It is important to differentiate this from true cicatrization.

The patient is asymptomatic and functional endoscopic dye test (FEDT) and irrigation are patent. On endoscopy with a 2.7-mm telescope, there is usually a dehiscence, and on visualizing from the edge or through it would make one visualize the normal ostium or FEDT flow (Fig. 29.13). Irregular healing can lead to incomplete cicatrization (Fig. 29.14) or a complete cicatricial closure (Fig. 29.15).

Ostial or Periostial Synechiae

It is important to evaluate any synechiae involving the ostium in the early phases and if found to be directly threatening the tear flow pathway, synechiolysis may be required. Early detection and management prevents consolidation of syn-

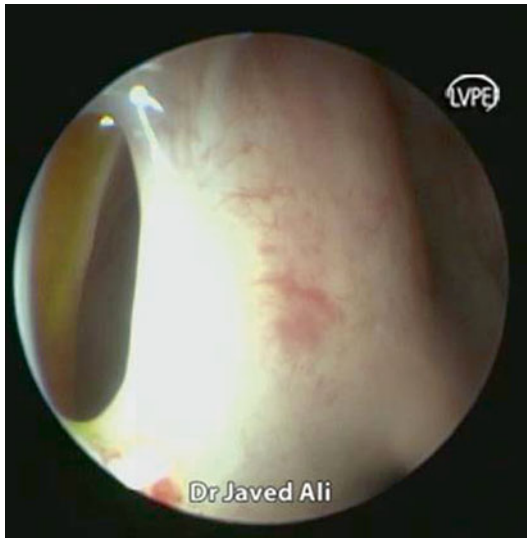

Fig. 29.13 Pseudocicatricial ostium

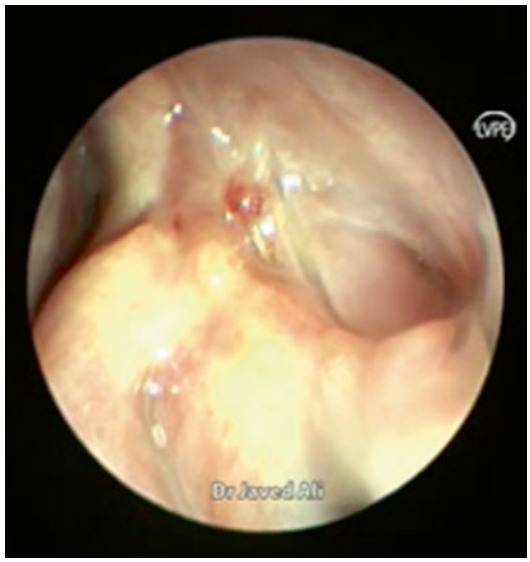

Fig. 29.14 Incomplete cicatrization

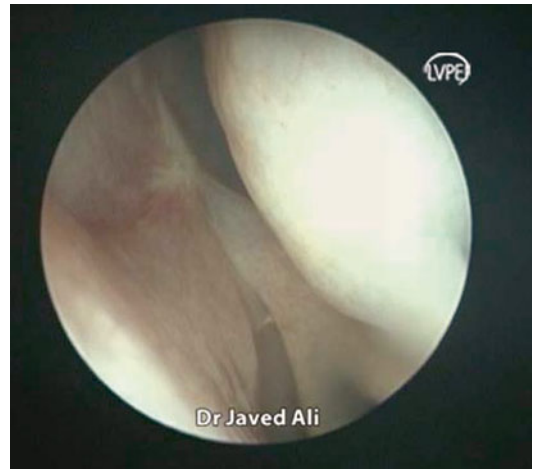

Fig. 29.15 Complete cicatricial closure

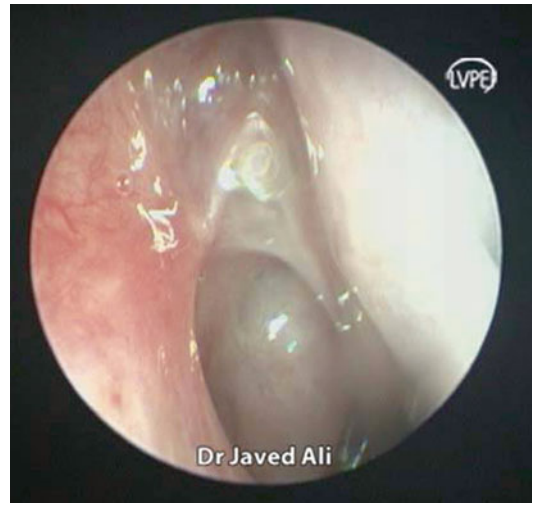

Fig. 29.16 Interfering ostioseptal synechiae

echiae. Based on the anatomical location and threat, synechiae can be broadly divided into noninterfering and those interfering or likely to interfere with ostium functions (Fig. 29.16).

Internal Common Opening (ICO)

The ICO is the junction between the canaliculi and lacrimal sac and represents the distal end of the common canaliculus. The position of the ICO and its dynamicity should be evaluated. The most common location in an ideal ostium is at the base (Fig. 29.3). Occasionally, it is in close relation to one of the four edges (Fig. 29.17) and uncommonly may be hidden by an overhanging edge (Fig. 29.18). ICO can be traced by simple visualization of an opening (Fig. 29.3), its movements, or using a dye test (Fig. 29.17). Beginners can also trace it with the help of silicone tube. While viewing the ICO, the patient is asked to blink and the dynamic movements of ICO are studied with opening and closing of the eyelids. Presence of any obstructive tissues like

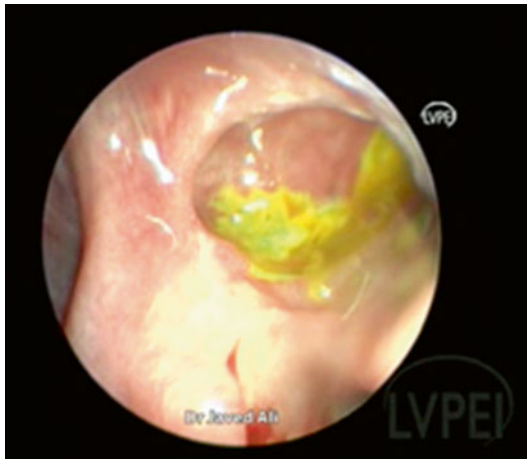

Fig. 29.17 Anterior edge ICO

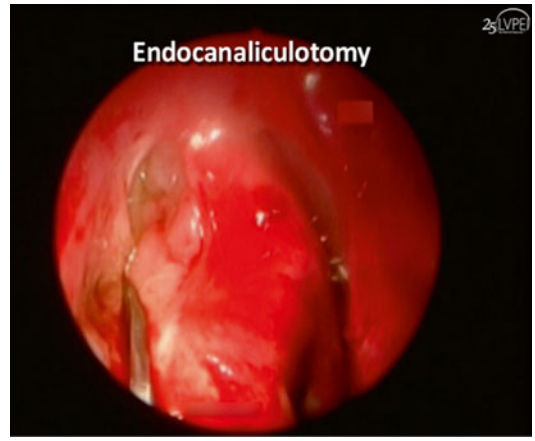

Fig. 29.19 Endocanaliculotomy

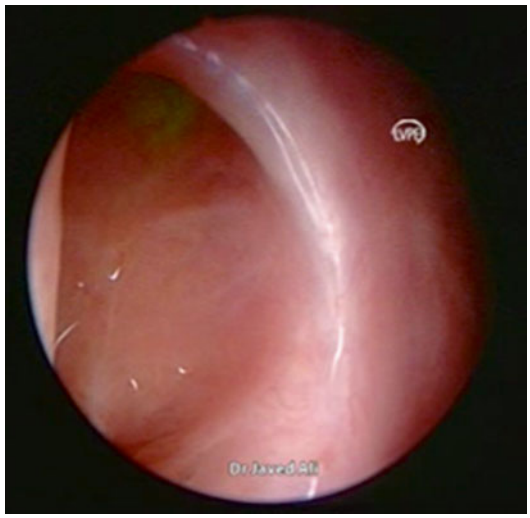

Fig. 29.18 ICO covered by an overhanging edge

membranes or rarely granulomas covering the ICO should be noted and appropriate measures like endocanaliculotomy initiated if warranted (Fig. 29.19).

Silicone Stent

Silicone stents and ostium's response to their presence should be carefully assessed. After clearing the discharge, the stent should be traceable from its distal cut end right up to the internal common opening (Figs. 29.8, 29.9, 29.10, and 29.11). The dynamicity of the ICO is transmitted to the stents and it is common to observe the tubes moving with each blink. Hence, the stent movements are an indirect indicator of ICO dynamicity. It is important to assess any developing contact granulomas or stent entrapment within healing tissues. Entrapment may rarely occur if the tube is cut very short combined with an aggressive cicatrization.

Functional Endoscopic Dye Test (FEDT)

Functional endoscopic dye test is performed by placing 2 % fluorescein drops in conjunctival cul-de-sac and assess its natural flow into the ostium with normal blinking. In the presence of normal functioning lacrimal pump and patent passages, the dye is visualized in the ostium within few seconds (Figs. 29.1) and at maximum within a minute (Figs. 29.1, 29.5, and 29.17). The authors do not irrigate unless patient is symptomatic and FEDT is delayed or negative (no dye in ostium). If no spontaneous flow of dye is noted into the ostium, irrigation can occasionally show a fluoroscein dye into the ostium, reflecting lacrimal pump failure. No dye in the ostium on irrigation and reflux indicates a physical obstruction at ICO or proximal to it.

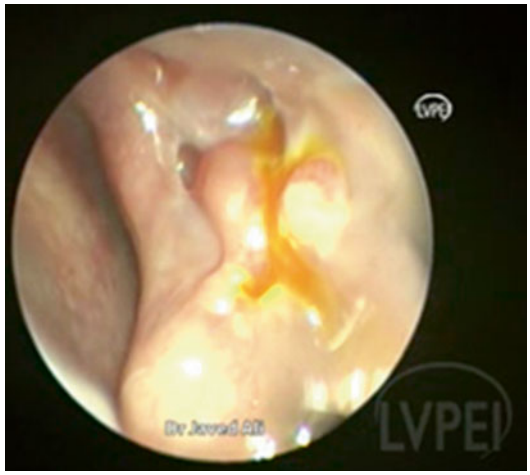

Fig. 29.20 A basal granuloma

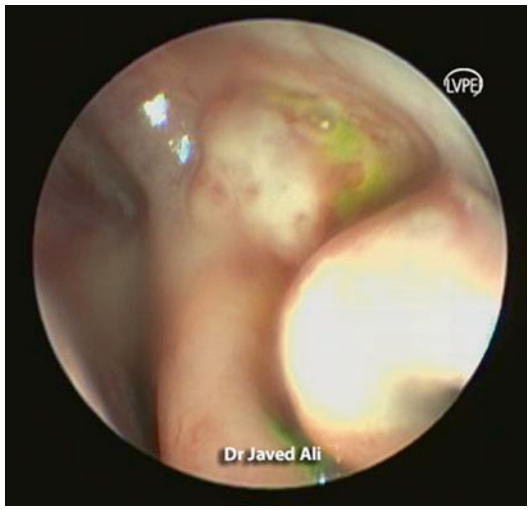

Fig. 29.21 ICO threatening granuloma

Ostial and Periostial Granulomas

Ostial granulomas are occasionally encountered since a good endoscopic DCR with mucosa-to mucosa approximation and primary intention healing prevent their occurrence. However, aggressive healing or contact granulomas secondary to stents may be noted (Fig. 29.20). Most of the granulomas resolve with topical ocular and nasal steroids. Granulomas threatening the ICO (Figs. 29.21 and 29.22) or entrapping a stent within them may require a careful surgical removal.

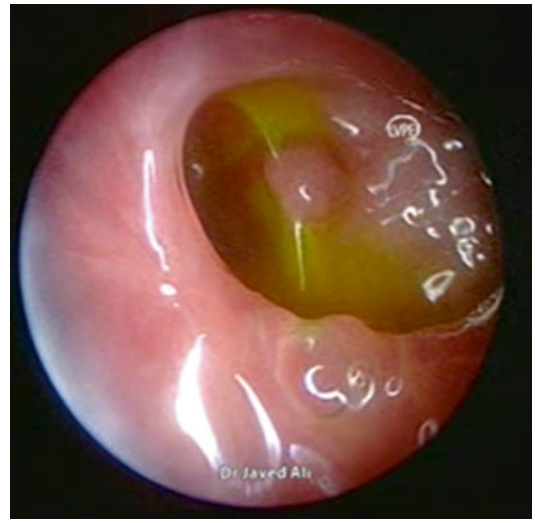

Fig. 29.22 Bang on ICO granuloma

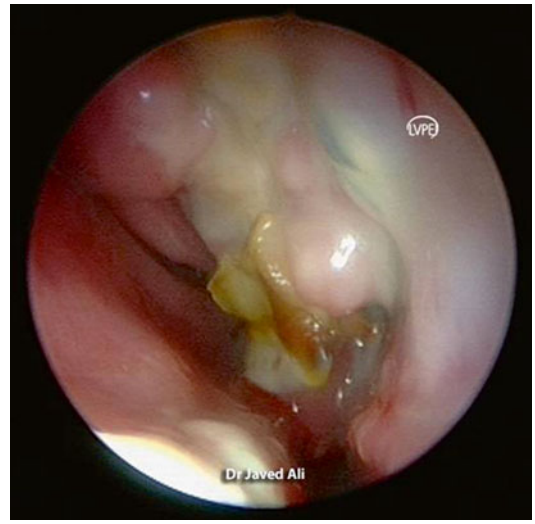

Fig. 29.23 Infected soft tissues of ostium

Other Ostium Pathologies

There are numerous ostium pathologies or deviations from normal behaviors that need to be identified, monitored, and treated if indicated. Arbitrarily they can be classed into major and minor. Major pathologies are rare and include soft tissue infection (Fig. 29.23) of the ostium, orbital breach and fat prolapsed toward ostium, and organizing or obstructive tissues threatening the ICO. Minor pathologies can be diffuse

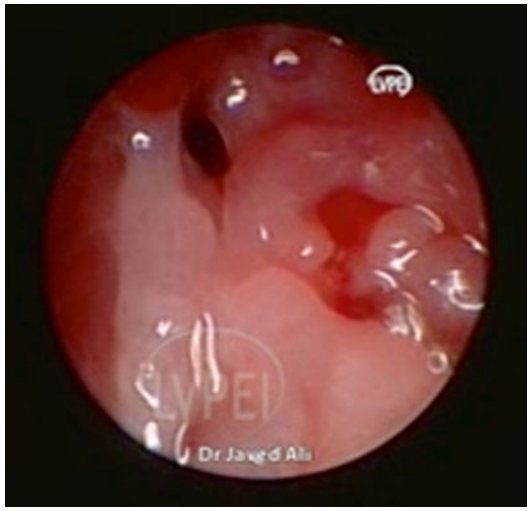

Fig. 29.24 Diffuse ostium edema

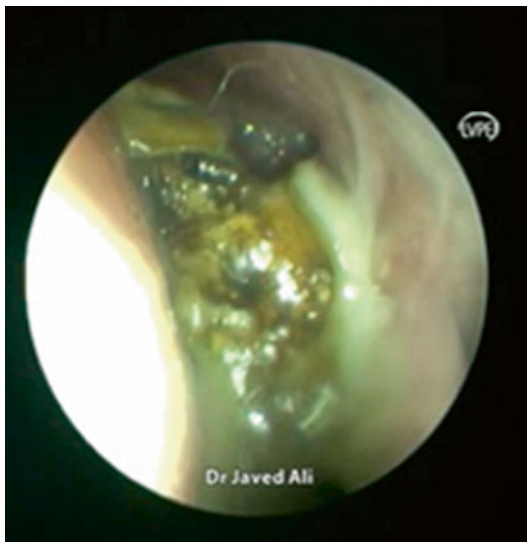

Fig. 29.25 Organizing discharge

ostium edema (Fig. 29.24), organizing discharge (Fig. 29.25), and ethmoid entry secondary to posterior location of sac (Fig. 29.26). There may be many more examples of each category and should be classed based on the physical and functional threats to the ostium and outcome parameters.

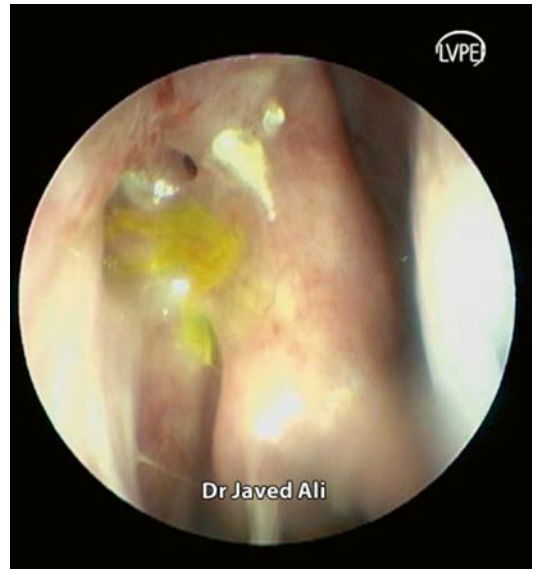

Fig. 29.26 Opened up ethmoids

DOS Scoring

The DCR ostium scoring or simply the DOS scoring system has been devised by the authors taking into consideration all the important parameters described in evaluation of an ostium. While giving different scores to each subparameter, current evidence-based understanding [14–22], authors' past publications [6, 19, 23, 25–31], as well as clinical experience of ostium evaluation were taken into account. In spite of many details to note in each of the parameters, only the most significant have been included in the scoring to make it simple and easy to use.

The DOS scoring evaluates ten major parameters. Each major parameter is subdivided into four subparameters with a specific score for each in a descending order. Normal subparameter gets the highest score of 4 points and the worst subparameter gets the lowest score of 1. The maximum points that can be achieved for an ostium evaluation are 40 and the minimum is 10. Based on the significance of each subparameters, overall ostia are graded as excellent (score of 36–40), good (31–35), fair (21–29), and poor (10–20). Table 29.1 depicts the DOS scoring.

Table 29.1 The DCR ostium (DOS) scoring

PARAMETER	SUBPARAMETER WITH SCORES
1.Location of Ostium:	In front and above axilla of MT – 4
	Behind axilla of MT -- 3
	Any other location -- 2
	Not recognizable -- 1
2.Shape of the Ostium:	Circular / Oval with shallow base – 4
	Circular / Oval with deep base -- 3
	Crescentric / Vertical slit /others – 2
	Not recognizable -- 1
3. Size of the Ostium: (Length x breadth)	> 8 x 5 mm -- 4
	5 - 9 x 3 – 5 mm -- 3
	1 – 4 x 1 – 3 mm -- 2
	Obliterated -- 1
4. Ostium Cicatrization:	None -- 4
	Pseudocicatrix -- 3
	Incomplete cicatricial closure -- 2
	Complete cicatricial closure -- 1
5. Synechiae:	None -- 4
	Non-ostial / Non-interfering -- 3
	Interfering Ostial -- 2
	Complete synechial closure -- 1

PARAMETER	SUBPARAMETER WITH SCORES
6. Internal Common Opening (ICO):	Uncovered by edge, Dynamic -- 4
	Overhanging edge, Dynamic -- 3
	Partially obstructed / membrane -- 2
	Not traceable with FEDT / irrigation - 1
7. Silicone Stents:	Course traced, moves with blink/Unintubated- 4
	Intubated but lost /removed before 4 weeks -- 3
	Associated contact granuloma -- 2
	Entrapped into ostial tissues -- 1
8. FEDT:	Spontaneous and in < 1 minute -- 4
	Spontaneous and in > 1 minute -- 3
	Not spontaneous but positive with irrigation- 2
	Negative with irrigation -- 1
9. Ostium Granulomas:	None -- 4
	On one or more edges -- 3
	Peri ICO / threatening ICO -- 2
	Covering / obstructing ICO -- 1
10. Other Ostium Pathologies :	None -- 4
	1 minor -- 3
	> 1 minor -- 2
	Major -- 1

Maximum possible Score :	40
Minimum possible Score :	10
Ostium Grading Score :	36 – 40 = Excellent
	30 – 35 = Good
	21 – 29 = Fair
	10 – 20 = Poor

Overall Ostium Score :

OSTIUM GRADE : EXCELLENT
GOOD
FAIR
POOR

Conclusion

Evaluation of the DCR ostium at regular intervals is crucial in achieving very high success rates. A better understanding of pathophysiology of healing and tissue response to operative techniques and adjunctive procedures can be additional advantages. Routine ostium evaluation helps the surgeon in early detection of pathologies and guides with indications for an appropriate intervention. The DOS scoring is an elaborate yet simple scoring system that can be easily applied in routine clinical evaluation. However, this still needs validation (ongoing) and modifications to make it more simpler.

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Intubation in Lacrimal Surgery: Devices and Techniques

30

Tarjani Vivek Dave and Mohammad Javed Ali

Introduction

Lacrimal drainage obstructions causing epiphora is a common lacrimal disorder. Depending on the age of the patient and the pathophysiology of the condition, the disorder can either be relieved by simple probing or by a dacryocystorhinostomy (DCR). In certain conditions, the success rates of the treatment can be improved by intubating the lacrimal system. Canalicular intubation is also indicated in the management of lacerated canaliculus. Intubation is achieved commonly by placing a silicone stent in the lacrimal passages. The silicone stent maintains the passages where it is present and is also believed to allow tissue healing around itself, thus maintaining lacrimal patency.

Historical Aspects

The first usage of a canalicular stent was by Graue who used a silver wire and passed it through the lower punctum into the nose [1]. The first description of polyethylene tubing for treatment of canalicular strictures was published in 1950 by Henderson [2]. Huggert was the first to describe bicanalicular intubation in 1959 using polyethylene tubing, with tubes being secured in the nose and bridging the gap between upper and lower puncta [3]. The first reported use of silicone tube stent was in 1968 by Keith [4]. Various probes for silicone intubation were subsequently popularized by Quickert and Dryden [5]. In 1977, Crawford introduced the Crawford lacrimal intubation set for bicanalicular intubation [6]. He subsequently made a series of technique modifications [7–11] in the 1980s. To facilitate the retrieval of the Crawford probe, other workers proposed a modification, known as the groove director, in 1983 and 2001 [12, 13]. In 1989, Fayet and associates [14] introduced the monocanalicular intubation system known as Monoka and Mini-Monoka. It was further modified by Ruban and associates in 1995 [15]. In 1998, another bicanalicular intubation system—the Ritleng lacrimal intubation set—was introduced [16].

Indications

There are numerous indications for intubation and these vary among surgeons. Its use in pediatric age group is for cases of failed probing, demonstrable nasolacrimal duct (NLD) narrowing, complex CNLDO, or as adjuncts following balloon dacryoplasty. Lacrimal intubation is preferred in pediatric DCRs. In the pediatric

T.V. Dave, DNB, FLVPEI (✉)
Ophthalmic Plastics Surgery,
L.V. Prasad Eye Institute, Hyderabad, India
e-mail: tvdeye@gmail.com

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute,
Banjara Hills, Hyderabad 500034, India

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population, aggressive healing response of the tissues often causes failure of patency of the created passage [10]. In such cases, intubation provides a stent around which healing can occur, thus helping maintain patency. It is useful adjunct when there are partial or complete canalicular obstructions. DCRs with poor flaps, membrane at common internal opening, and revision DCRs may probably benefit from intubation. Traumatic canalicular tears, posttraumatic canalicular strictures and congenital/acquired canalicular/punctal stenosis may also merit intubation during surgery. Intubation may not be preferred in acute dacryocystitis where it may spread the infection across planes and in cases of suspected false passages to minimize further trauma.

The Ideal Stent

An ideal stent should have a few desirable properties. It should be soft and pliable so as to minimize tissue trauma during passage. It should be inert and not incite inflammatory response by the host tissue. The stent tube should be retained safely in tissues for a long time.

Stent Materials

The various stent materials used over the years can be classified as organic, metal composites, and synthetic. The initial stents used were organic material like hair and catgut [17]. But as these materials were organic they incited inflammation and led to post-procedure strictures. The metal stents used were initially composed of silver [18]. Later, the Veirs' rod, which was a malleable metal rod 1 cm in length with 4-0 braided silk attached to one end was introduced [19]. The various synthetic materials used over the years for intubation have been nylon, polyethylene, supramid, silicone, and Teflon. In view of its relative flexibility, durability, inertness, and tolerability, silicone has so far been proven to be close to the ideal intubation material [20].

Types of Intubation Devices

Generically, the lacrimal intubation tubes are classified as monocanalicular and bicanalicular. A monocanalicular stent passes the site of pathology (tear or stricture) in a particular canaliculus but does not traverse the fellow canaliculus. On the other hand, a bicanalicular stent occupies both canaliculi and thus is a "closed loop" system. Monocanalicular intubation is either monocanalicular simple or monocanalicular annular [21]. Bicanalicular intubation could be either annular or nasal in configuration [21] (Table. 30.1). The common monocanalicular stents used are Monoka stents, Mini-Monoka stents, Monoka-Crawford stents, and Masterka stents. The common bicanalicular stents used are Crawford stents, Ritleng tubes, ring intubation system, and self-retaining tubes.

Monocanalicular Intubation

Simple Monocanalicular Intubation

Here the medial portion of the stent extends variably into the lacrimal sac and the nasolacrimal

Table 30.1 Classification of canalicular intubation systems

Lacrimal intubation			
Monocanalicular intubation		Bicanalicular intubation	
Traverses only the involved canaliculus		Traverses both the canaliculi	
Monocanalicular–annular intubation	Monocanalicular simple intubation	Bicanalicular–annular intubation	Bicanalicular nasal intubation
Stent brought out to skin through a Dacryocystostomy	Lateral stent fixation to lid margin, skin, conjunctiva, or within punctum	Greaves' technique or pigtail probe method	Modified Quickert-Dryden method of nasolacrimal intubation

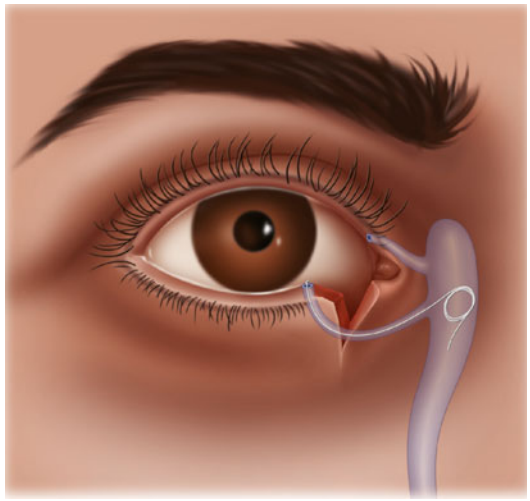

Fig. 30.1 Schematic diagram representing a simple monocanalicular intubation

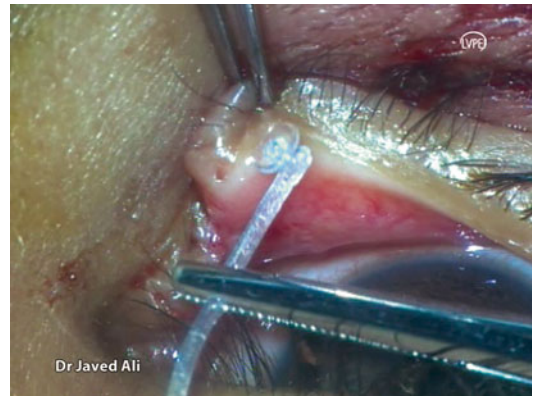

Fig. 30.2 The Mini-Monoka stent

duct. The lateral portion lies at the punctum or within the canaliculus or deeper eyelid tissue (Fig. 30.1). It may also lie on the conjunctiva, skin, or eyelid margin. The stability of a monocanalicular stent depends on a snug fit into the punctum or fixation to the eyelid margin by sutures. Traditionally, an angiocath silicone glide was used for intubation of a lacerated canaliculus. Improvement was achieved by a manufactured coupling of a punctal plug (as popularized by Freeman) and a silicone rod used for lacrimal intubation (Long & Fayet), available as the Monoka and Mini-Monoka devices (FCI Ophthalmics, MA, USA) [22].

The Mini-Monaka Device

The mini-Monoka is a silicone stent that can be securely anchored at the punctum with no need for sutures. It is threaded through the punctum into the lacrimal system. As the Mini-Monoka does not feed all the way through the nasolacrimal system, it eliminates possible injury to the normal canaliculus and nasolacrimal duct.

This device consists of three components: (1) a silicone rod, which is a hollow tube 0.64 mm in external diameter and 27 cm long; (2) a superior fixation device (SFD), which allows for a secure seating of the punctal plug part of the device in the ampulla; and (3) a seating instrument, which can either be a metallic or a plastic probe point to push the plug securely into the punctum.

The superior fixation device has a collaret, which is wider than the lacrimal meatus to prevent burying or migration of the Monoka into the canaliculus. It is the only part of the device which is visible once the Monoka has been properly placed in the lacrimal duct. It permits postoperative evaluation and simple removal when appropriate. Three sizes of collarets are available. These are fused to a bulb, which forms the inferior part of the SFD. When the Monoka is in place, the bulb is securely fixed in the ampulla. Its bulbous shape prevents the spontaneous extrusion of the SFD. Yet its size is not so wide that it would prevent simple removal when desired. The silicone tubing is fused together with the bulb, forming a right angle (Fig. 30.2). The Mini-Monoka device does not require a probe to be inserted into the nasolacrimal duct as it has a solid silicone rod. Placement of this device requires gentle punctal dilation. The proximal part of the punctum and canaliculus is intubated with the free silicone rod part of the device, which is brought out via the wound. Then a smooth pulling of the free silicone part of the Mini-Monoka allows the SFD to set into the punctum. The punctal plug seating delivery device may sometimes be needed. The end of the rod is then shortened sufficiently to pass into the distal canalicular wound and the lacrimal sac. Since these are commonly used for canalicular

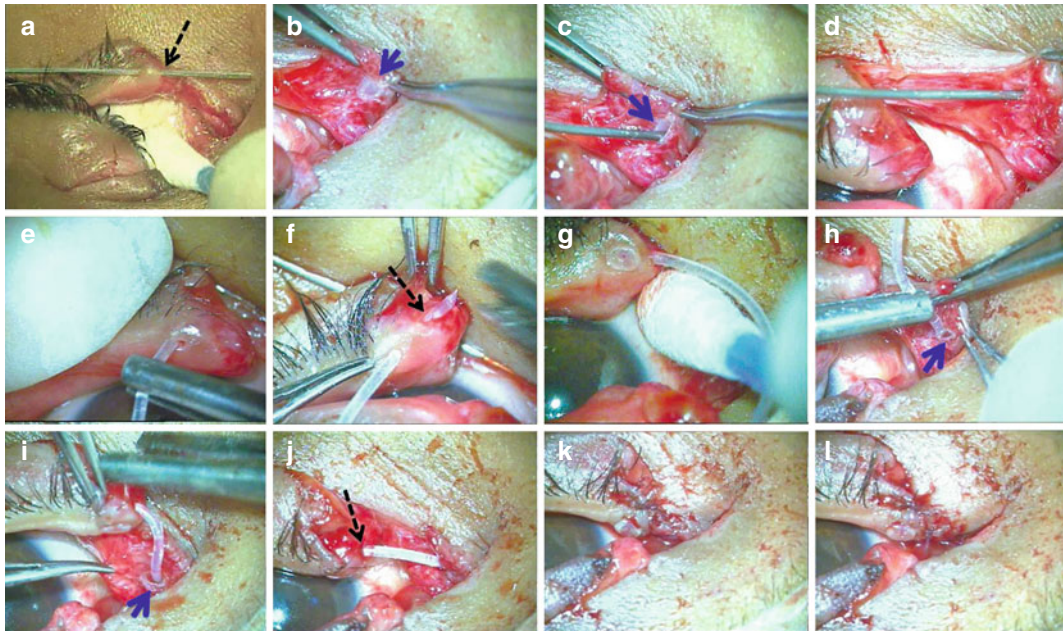

Fig. 30.3 Technique of insertion of a Mini-Monoka stent for lower canalicular laceration. Identification of the lateral cut end of the canaliculus (**a**). Identification of the medial cut end (**b**). Probe through the medial cut end (**c**). Confirming hard stop with the probe (**d**). Mini-Monoka pass through the punctum (**e**). Retrieval through the lateral cut end (**f**). Securing the SFD at the punctum (**g**). The pass of Mini-Monoka through the medial cut end (**h**). Approximating the two cut ends of the eyelid (**i**, **j**). Securing with a suture (**k**). The completed lid repair with a snugly fitting Monoka (**l**)

lacerations, sutures are carefully placed to close the canalicular wound and to reconstruct the canthal tendon by standard techniques (Fig. 30.3a–l). The average duration of intubation following trauma is 3 months [23]. Removal of the stent is simple and is accomplished by pulling out the collaret with a forceps.

Self-Threading Monoka Over a Ritleng Probe

The self-threading Monoka (Ritleng style) tube (Fig. 30.4) is attached to a thin thread-guide, which is fed through a Ritleng probe and gently out the nose. The probe is then removed, and the thread-guide is pulled along with the silicone tubing into proper position in the nasolacrimal duct. The tube is securely anchored at the punctum by the SFD. Intubation can be a complicated process in infants and small children, as the nasal passages are compact with narrow anatomical confines. The removal of a thin suture or thread-guide from the nose is easier and less traumatic than traditional metallic probes, facilitating canalicular procedures in young children.

Monoka-Crawford

The Monoka-Crawford (Fig. 30.5) can be used for monocanalicular repairs, DCR with agenesis or proximal obstruction of one canaliculus, pre-saccal stenosis, or partial nasolacrimal duct obstructions. This stent feeds all the way down into the nasolacrimal duct, and unlike the Mini-Monoka, it is anchored at the punctum by the SFD and then retrieved using a Crawford Hook.

The Masterka Device

Designed by Oculoplastic surgeon Bruno Fayet, the Masterka offers a safer and faster intubation of tear ducts as it does not require the frequently

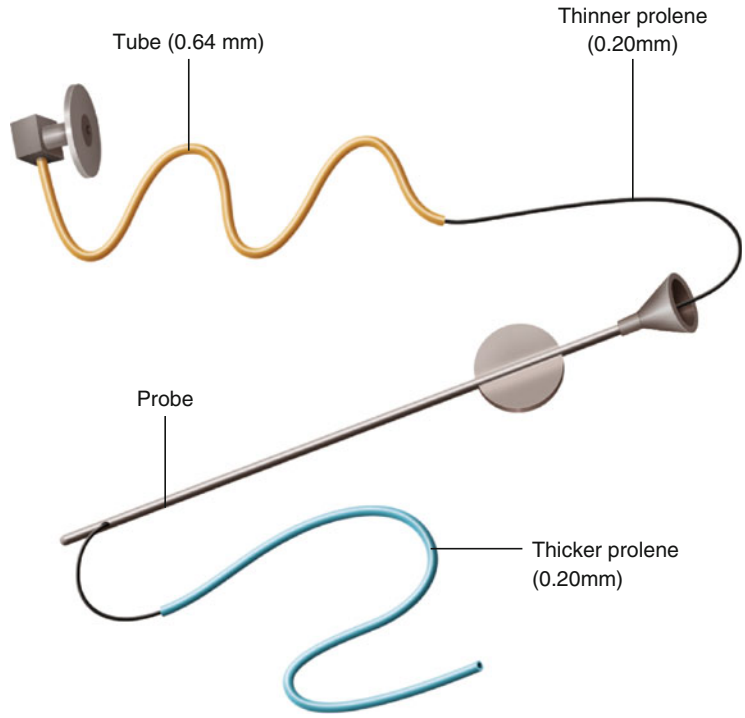

Fig. 30.4 Monoka over a Ritleng probe

difficult step of recovery inside the nasal cavity [24]. Unlike the traditional "pulled" technique in which the stent is advanced through the nasolacrimal system and retrieved through the nose by pulling on the guide probe or thread, the Masterka has no metallic probe or suture attached to it and, therefore, it is not pulled out of the nose. Instead, the Masterka is pushed into the nasolacrimal duct and anchored in place at the punctum by a plug-like fixation head similar to Monoka stents. A pushed intubation is more similar to a simple probing than a pulled intubation and significantly reduces time for the intubation procedure. The Masterka device consists of a silicone tube moulded to a fixation head and premounted on an introducer to facilitate insertion (Fig. 30.6). The introducer is easily and completely removed once the intubation of the lacrimal passages has been completed. The Masterka comes in three different lengths of 30, 35, and 40 mm.

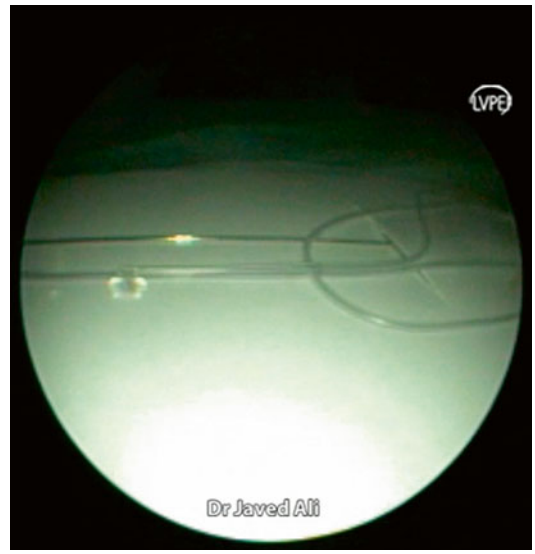

Fig. 30.5 Monoka-Crawford intubation set

Fig. 30.6 Masterka Device mounted on the inserter

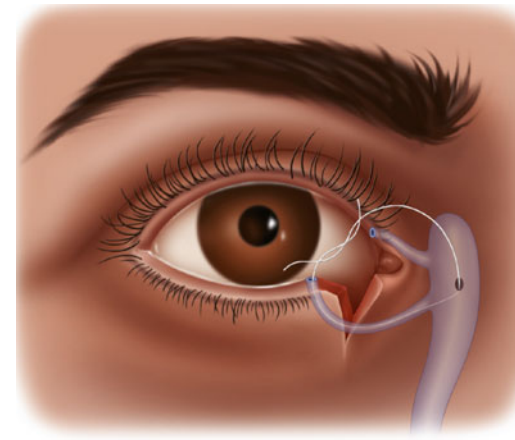

Fig. 30.7 Monocanalicular–annular intubation

Monocanalicular–Annular Intubation

In a monocanalicular–annular stent placement, the lacrimal stent is passed through the length of the involved canaliculus only and into the lacrimal sac. The stent is then exteriorized to the skin through the wall of the sac and the medial end of the stent may be tied to the laterally protruding end in the form of a "sling." [21] (Fig. 30.7) In addition to silk, various materials used for these monocanalicular–annular stents included chromic gut, nylon suture, and polyethylene tubing. However, with the advent of the Mini-Monaka, the annular technique of monocanalicular stenting has taken a backseat.

Bicanalicular Intubation

In this "closed loop" system, it is possible to expose only a short segment of the stent between the superior and inferior puncta or canaliculostomy, and is therefore to a certain extent protected from extrusions [21].

Bicanalicular–Annular Stent

In bicanalicular–annular stent, both the canaliculi are occupied as a part of a continuous loop. The lateral portion of the loop lies between the lacrimal puncta and the medial portion is united to itself in the common canaliculus or the lacrimal sac (Figs. 30.8 and 30.9). Stallard cited Greaves' technique of bicanalicular–annular stenting using a nylon suture over a lacrimal cannula [25]. Pigtail probes have also been used for annular stent placement [26]. The ends of the stent can be secured

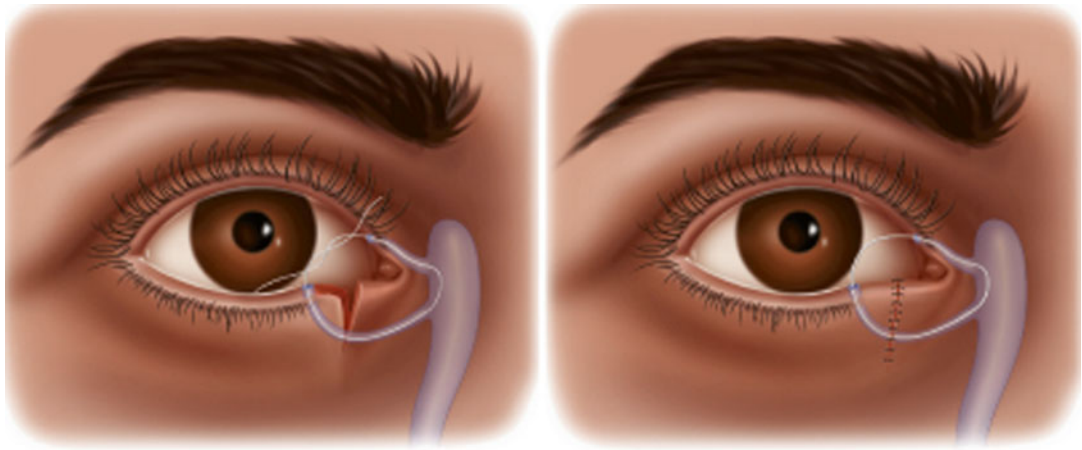

Fig. 30.8 Bicanalicular–annular intubation

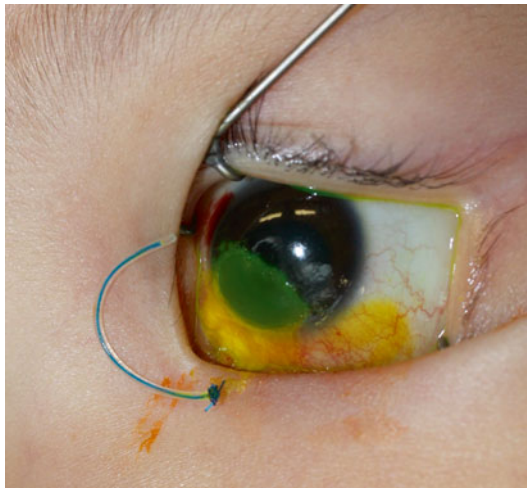

Fig. 30.9 A patient with bicanalicular–annular intubation (Photo courtesy: Dr Gangadhar Sundar, Singapore)

with a suture or a sleeve. The flexibility of silicone allows it to be tied to itself in a knot between the punctae [26]. Alternatively, the ends of the tubing may be tied and fixated away from the eye to the skin of the canthus [27, 28]. Marube recommended placing a nylon thread within the lumen of the silicone tube along its entire length and then tying the nylon [17]. The united ends of the tube can then be rotated into the canaliculus (Figs. 30.8 and 30.9). Self-retaining stents are an example of bicanalicular–annular intubation.

Self-Retaining Stent

Self-retaining stents made of silicone are a recent development (Fig. 30.10). They consist of a silicone tube in three different lengths (25, 30, and 35 mm) to cover for patients anatomical variations and two flexible anchoring ends designed to stabilize the stent into the common canaliculus. The outer diameter of the silicone tube is 0.64 mm. It has a central reference marking that offers control over proper positioning. Each end has two flexible flaps that fold inward during insertion through the punctum. Flaps open at the lacrimal sac for secure fixation. The flaps fold backward upon removal of the stent.

Bicanalicular Nasal Stent

In a bicanalicular nasal stent, both canaliculi are occupied as a part of a continuous loop. The lateral portion of the loop lies between the lacrimal puncta and the medial portions of the stent together pass down the nasolacrimal duct to be fixated within the naris (Fig. 30.11). Passing one arm of the stent from the superior canaliculus to the nose and the other arm from the inferior canaliculus to the nose does this.

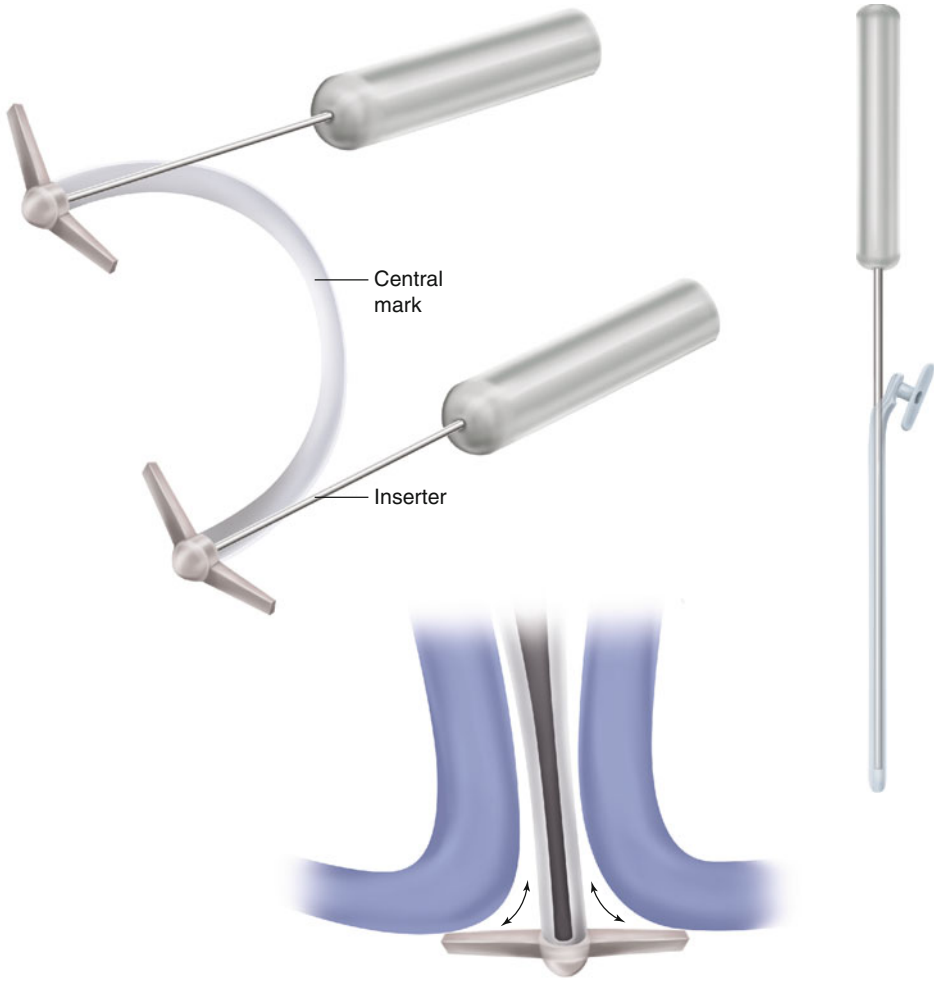

Fig. 30.10 Self-retaining stents

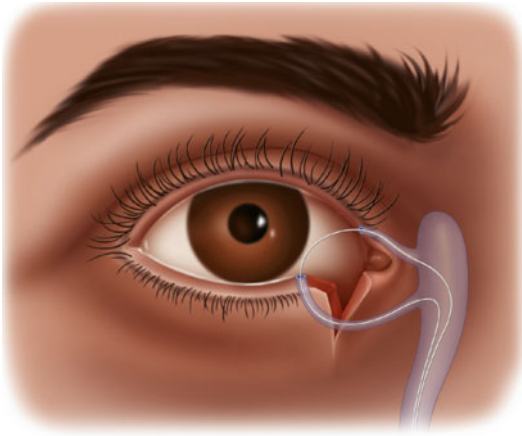

Fig. 30.11 Schematic diagram of bicanalicular nasal intubation

The Crawford Bicanalicular Nasal Intubation System

The Crawford Bicanalicular Intubation attaches to a metallic glide with an olive tip that is fed through the system and retrieved below the inferior turbinate using a Crawford Hook (Fig. 30.12). This is a simple procedure designed by the Crawford, which speeds up the process of inserting a lacrimal stent with less trauma and tearing of the nasal floor. The Crawford Intubation set comprises of two flexible stainless steel wires 0.40 mm in diameter and a hollow silicone tube with an outside diameter of 0.64 and a 0.30 mm lumen. The stainless steel wires have olive-shaped tips for grasping with a special retrieval hook and permit ease of extraction from the inferior meatus of the nose (Fig. 30.12).

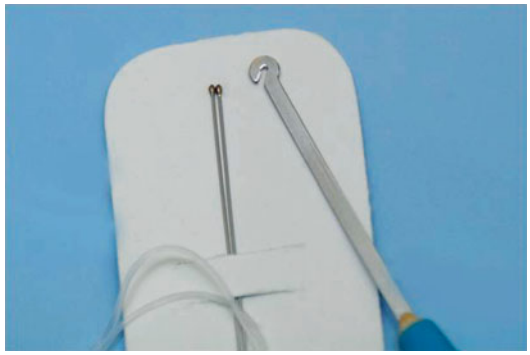

Fig. 30.12 The Crawford bicanalicular nasal stent with the retrieval device

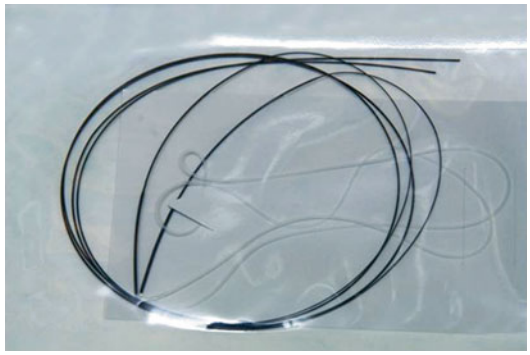

Fig. 30.13 The Ritleng threads with attached silicone tubes

The Ritleng Bicanalicular Nasal Intubation System

The Ritleng device provides a technique for bicanalicular nasal intubation without the need for retrieval of the metal probes from the inferior meatus. This system consists of (1) a Ritleng tubular probe that is hollow and (2) two prolene or other monofilament guide threads that have a silicone tube securely fastened between their ends (Fig. 30.13). In this technique, the nasolacrimal system is probed with the Ritleng probes as a part of the routine surgical procedure. The probe opens into the inferior meatus of the nose. With the probe in place, the prolene monofilament guide thread is introduced through the slit in the probe. In the inferior meatus of the nose the prolene is easier to locate than the metal probes because the prolene material spreads out widely as it exits the Ritleng probe and also because prolene is blue in color. As the prolene is pulled out of the nose, the silicone tube comes into the nasolacrimal duct and can then be secured to the nose by standard techniques.

A tabulated comparison of Crawford and Ritleng tubes is as described in Tables 30.2, 30.3, and 30.4.

Table 30.2 Specifications of the Crawford and Ritleng bicanalicular nasal intubation devices

Crawford Bicanalicular nasal intubation device	Ritleng Bicanalicular nasal intubation device
Crawford probe	Ritleng probe
Stainless steel	Stainless steel
Olive tip 1 mm in diameter	Funnel-shaped end with a disc for orientation
Probe diameter 0.4 mm	Inferior blunt end with a lateral outlet opening 5 mm above tip
Silicone tube	Narrow slit, 0.3-mm wide, that runs the length of the probe from the funnel-shaped entrance to the outlet opening dimensions:
0.64 mm in external diameter and a lumen of 0.30 mm attached to two flexible Crawford probes also known as "BODKINS"	Probe Diameter: 1 mm
The Crawford II intubation system is available with wider diameter of silicone tube – 0.93 mm	Probe length: Length 105 mm
Retrieval device – hook	Prolene monofilament: thicker dark blue initial portion, 0.4 mm in diameter followed by a thinner light blue portion, 0.2 mm in diameter
	Silicone tube:
	Attached to Prolene monofilament guide at each end
	Outer diameter 0.64
	Length 300 mm

Table 30.3 Techniques of canalicular intubation with Crawford and Ritleng devices

Technique of bicanalicular nasal intubation with Crawford device	Technique of bicanalicular nasal intubation with Ritleng device
GA vs. LA	GA vs. LA
Punctum dilatation	Punctum dilatation and probing
Probe – Canaliculus, NLD	Ritleng introducer with stillette
Upper – lower punctum	Retrieve through nose
Deliver below inferior turbinate	Remove stillette
Crawford hook device with endoscope	Feed polypropylene
Traction over silicone tubes with hemostat forceps	Repeat through other punctum
Square knot	Position silicone tube
Allow knot to retract	Traction over silicone tubes with hemostat forceps
	Tight square knot
	Allow knot to retract

Table 30.4 Advantages and disadvantages of the Crawford and Ritleng bicanalicular nasal intubation systems

Intubation device	Advantages	Disadvantages
Crawford bicanalicular nasal intubation device	Olive tip	Availability
	Reduced false passage	Cost
	Decreased trauma	Potential damage to narrow canaliculi
	Easy retrieval	Difficult to introduce through punctum and common canaliculus due to olive tip
	Flexible	Tight obstructions difficult to overcome
	"Tactile" feedback	Risk to both canaliculi in case of single canalicular pathology
	Nonendoscopic	
	Easy to use	
Ritleng bicanalicular nasal intubation device	Technique same as probing	Stiff probe
	Reusable hardware	False passage
	Spontaneous prolene prolapse	May need endoscope
		Risk to both canaliculi in case of single canalicular pathology

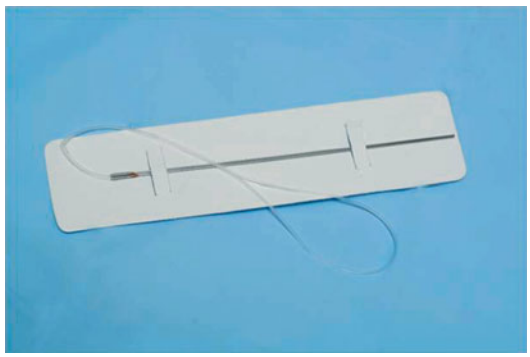

Fig. 30.14 The Bika bicanalicular nasal intubation device

The Bika Bicanalicular Nasal Intubation System

The Bika is similar to the Crawford intubation system except that the metal bodkins have straight tip as against the olive tip (Fig. 30.14).

Intubation Dynamics in FNLDO

Epiphora in the presence of a patent lacrimal pathway and absence of alternative etiology could be the simplest description of a functional nasolacrimal duct obstruction or FNLDO. There is an increasing evidence of the benefits of silicone intubation (SI) in FNLDO patients [29–31]. Moscato et al. [29] studied 44 eyes of 30 patients diagnosed as FNLDO, who underwent SI for a mean duration of 4 (±4.1) months. They were followed for a mean of 2.6 (±2.0) years from the time of intubation. The overall success for resolution of symptoms was seen in 77 %. Extrapolating the data showed success at 50 % between 5 and 6 years. They concluded that SI has good long-term success in cases of FNLDO.

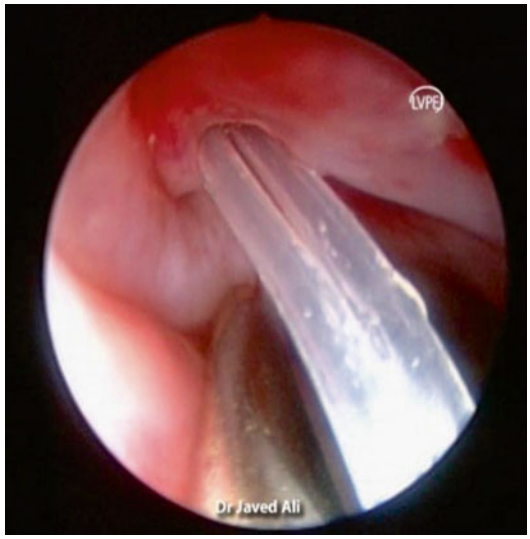

Fig. 30.15 Endoscopic view of the two arms of intubation tube coming through the NLD opening in inferior meatus

Multiple mechanisms have been postulated to explain the benefits seen with SI in FNLDO [29–33]. Stent placement increases the volume and hence reduces resistance to outflow. Poiseuille's law states that resistance to flow is inversely proportional to fourth power of the radius. Hence, the stents by increasing the diameter of the lumen reduces resistance to flow (Fig. 30.15). In addition, Moscato et al. [29] proposed the riverbed phenomenon where an increased outflow following reduced resistance helps to maintain the enlarged passage. In addition, the stents may straighten up acute curves impeding outflow as well as help tear outflow by capillary action.

Complications

- Intraoperative:
  - False passage
  - Tube separation
  - Inability to complete procedure (anatomy vs. technique)
- Postoperative:
  - Tube or stent prolapse (Fig. 30.16)

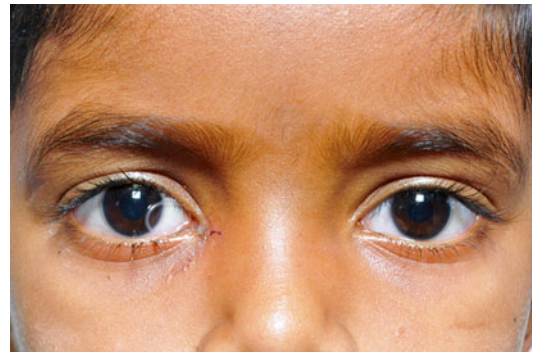

Fig. 30.16 Stent prolapsed

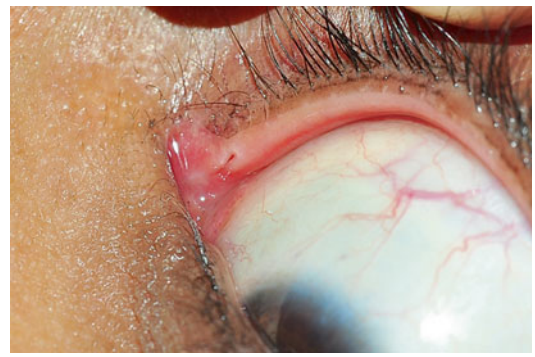

Fig. 30.17 Punctal and canalicular cheese wiring

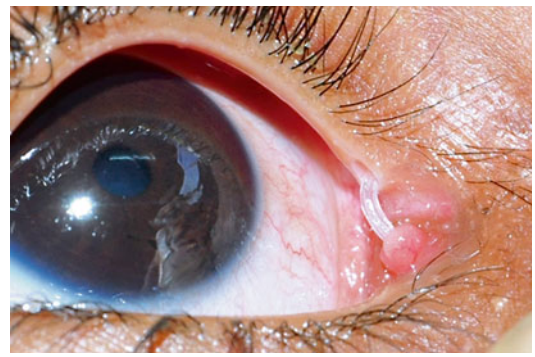

Fig. 30.18 Peritubal granuloma

  - Erosion/cheese wiring (Fig. 30.17): material, too tight
  - Pyogenic granuloma (Fig. 30.18): punctal, nasal
  - Lost tubes: external versus internal
  - Tube incarceration in the cicatrix

Management of Complications

- Tube prolapse: Minimal prolapsed can be observed; however, others need repositioning either through the canalicular push technique or the nasal pull technique. Tube prolapsed can be minimized by the use of clips, suture to the lateral wall just within the vestibule (Fig. 30.19), or endoscopic self-linking of stents (Fig. 30.20) [34].

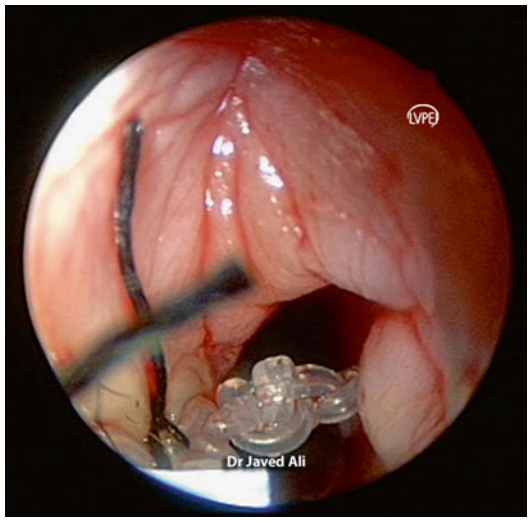

Fig. 30.19 Securing the stents by a suture at just within the vestibule

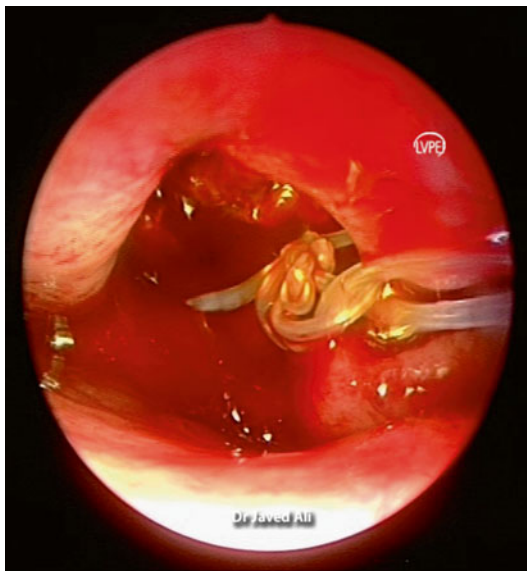

Fig. 30.20 Endoscopic self-linked stent

- Erosion/granuloma: surgical excision of granuloma.
- Lost tubes: Can reintubate if early on in post-operative period. The medical versus legal implications of a lost tube should be kept in mind.

Conclusion

It is imperative to understand the anatomy and anatomical variations of the lacrimal system well. In a lacerated canaliculus, monocanalicular intubation significantly improves the surgical outcome. In patients undergoing dacryocystorhinostomy with a compromised common canaliculus or lacrimal sac or nasal mucosal flaps, bicanalicular nasal intubation is perhaps a useful adjunct. However, it is to be borne in mind that intubation in a DCR should not be viewed as a rescue device for a poorly performed surgery. The type of device to be used depends on the indication for repair and surgeons comfort. Appropriate use of technology helps in improving the surgical outcome and patient satisfaction.

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Pediatric and Adult Balloon Dacryoplasty

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David I. Silbert and Noelle S. Matta

Introduction

Over the past 15 years balloon dacryoplasty has become a widely accepted treatment for nasolacrimal duct obstruction, for both primary treatment and as a secondary procedure following failed probing. In 1996 Becker et al. [1] reported on the efficacy of balloon catheter dilation in the treatment of congenital nasolacrimal duct obstruction (CNLDO) in children over 12 months of age, and those children failing probing or silicone intubation. The commercial lacricath balloon was introduced shortly thereafter.

Classical treatment of CNLDO in children has included medical management consisting of massage of the nasolacrimal sac and topical antibiotics to control infection. Though this may increase the rate of spontaneous resolution, there are no good data to prove this as the majority resolve spontaneously by 6–12 months of age. For those cases that do not resolve, typically nasolacrimal probing is performed either under general anesthesia or under topical anesthesia by 1 year of age. Classically, failure of probing has been treated with repeat probing with or without infracture of the turbinate; however, Pediatric Eye Disease Investigator Group (PEDIG) has shown that the success rate of a repeat probing following initial probing failure was poor [2]. Following failure of probing, silicone intubation of the nasolacrimal system was the classical treatment followed by DCR for those patients failing intubation.

Surgical Technique

For children under 30 months, typically, a 2-mm balloon is recommended, while a 3-mm balloon is recommended for older children and adults. A larger balloon however, can be used in younger children at the surgeon's discretion. Preoperatively, intravenous dexamethasone should be given. Cefazolin can also be given if there are signs of infection. The nares should be packed with cottonoids soaked in oxymetazoline beneath the inferior turbinates. A sterile prep of the face is not required for the procedure as the nose is inherently dirty. At this point the puncta are widely dilated (Fig. 31.1), and Bowman probes can be used to probe first (Figs. 31.2 and 31.3), though newer balloon probes can be passed without first passing Bowman probes with the help of hash marks (Fig. 31.4). At this point cottonoids are removed and proper placement of the probe is confirmed beneath the inferior turbinate. Placement of the balloon is verified in the nose by direct inspection, use of an endoscope, or with direct metal-on-metal contact. Inspection with an endoscope, however, provides the most certainty of proper placement.

D.I. Silbert, MD, FAAP (✉)
N.S. Matta, CO, CRC, COT
Department of Pediatric Ophthalmology, Family Eye Group, Lancaster, PA, USA
e-mail: DSilbert@familyeyegroup.com

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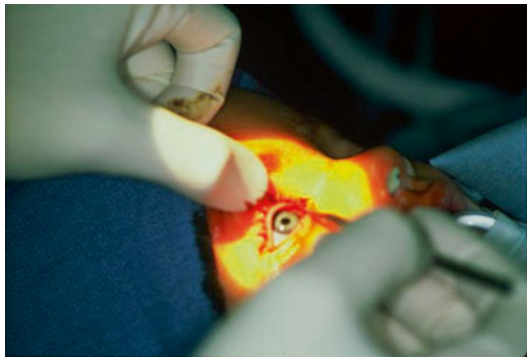

Fig. 31.1 Wide dilation of punctum

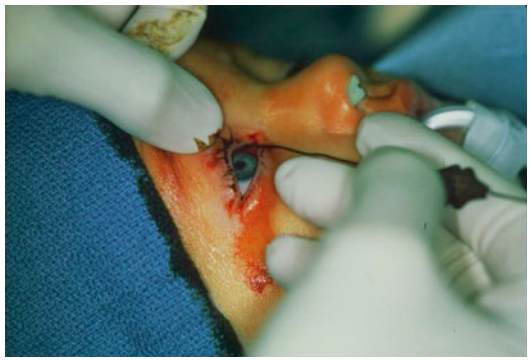

Fig. 31.2 Primary passage of Bowman probe or balloon probe into canaliculus

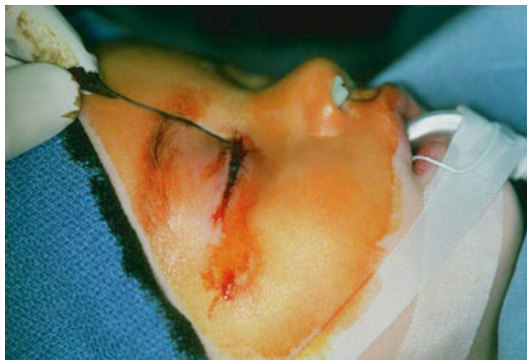

Fig. 31.3 Proper orientation to pass probe into duct

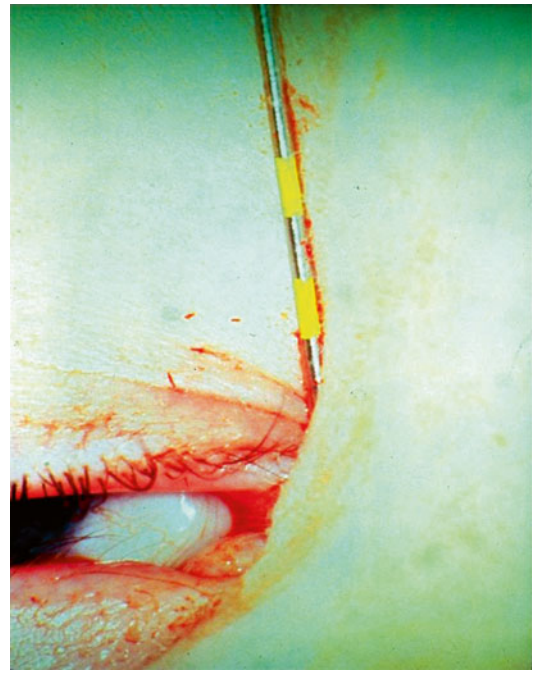

Fig. 31.4 Balloon probe in place showing hash marks

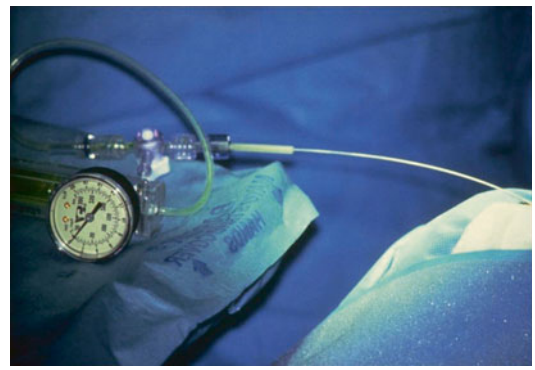

Fig. 31.5 Balloon probe attached to inflation device. Note flexibility of probe

Once the balloon catheter is assembled with the manometer as per standard protocols (Fig. 31.5), the balloon is inserted into the nasolacrimal duct just like a probe under endoscopic guidance up to the opening in the inferior meatus (Fig. 31.6) and inflated with an inflation device using saline. Fluorescein can be used to color the saline, making the balloon more visible during inflation in the nose (Fig. 31.7). The balloon is then inflated to 8 atm of pressure for 1 min (Fig. 31.7), deflated (Fig. 31.8), and repositioned higher in the duct, and the inflation is repeated an additional one to two times. Hash marks on the tube can help guide placement of the tube, but due to the variation in anatomy between younger and older patients direct visualization is best to ensure that the balloon is across the valve of Hasner for the first dilation (Fig. 31.4). After that the balloon can be pulled back so the first hash mark is visible at the

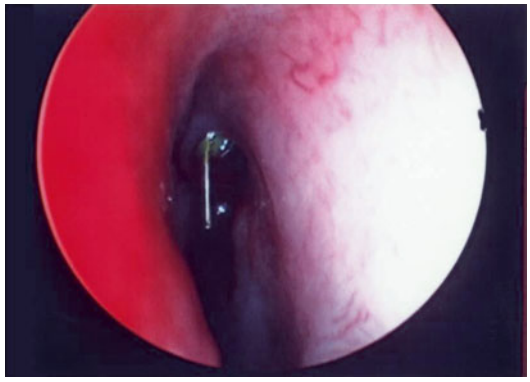

Fig. 31.6 Endoscopic view of deflated balloon ensuring proper placement through valve of Hasner

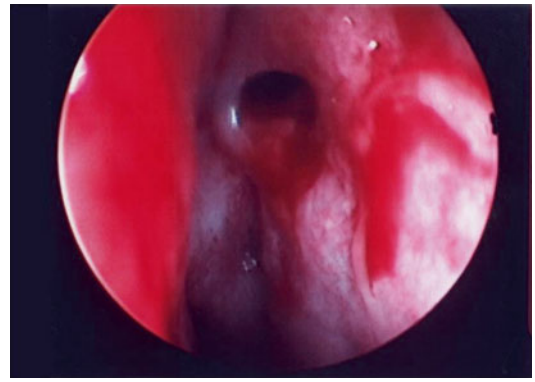

Fig. 31.9 Dilated valve of Hasner following balloon removal

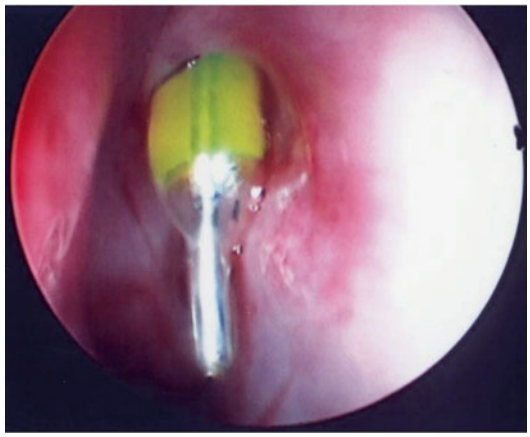

Fig. 31.7 Inflated balloon with fluorescein-tinged saline across valve of Hasner

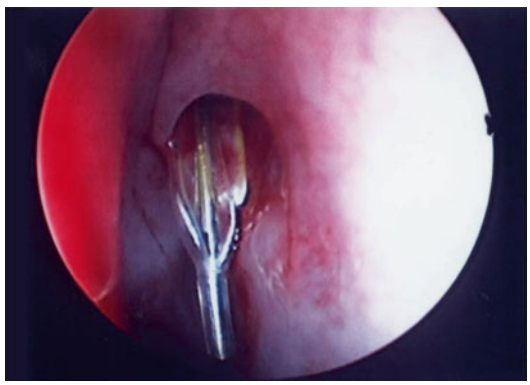

Fig. 31.8 Deflated balloon

punctum, then reinflated for a minute, deflated, and pulled back to the second hash mark for a final inflation. The second hash mark typically corresponds to balloon placement in the nasolacrimal sac and proximal duct. A stopcock can be used in bilateral procedure to inflate both balloons simultaneously saving surgical time. At the end of the procedure, a dilated nasolacrimal duct opening is usually noted (Fig. 31.9).

Advantages of the balloon include the lack of an implant in the nasolacrimal system, and the ability to dilate the system much larger than with typical lacrimal probes without traumatizing the canalicular system. Disadvantages to the balloon include their relative cost. However, balloon dacryoplasty is effective following failed probing as well as a primary procedure per physician preference. Some surgeons prefer a balloon in older children; however, the PEDIG NLD1 study showed good results with primary probing even in older children [3, 4].

Postoperative care following balloon dacryoplasty is intended to prevent infection, scarring and restenosis of the nasolacrimal system and should include topical, oral, and intranasal steroids and antibiotics as appropriate. For children it is advisable to use a steroid antibiotic drop such as tobramycin–loteprednol or tobramycin–dexamethasone four times daily for a week. An oral antibiotic such as cephalexin should be given for 7 days. Finally, oral prednisolone 5 mg/5 ml can be used in children at a dose of up to 2 mg/kg per day split in three doses for 3 days, then half the dose for an additional 3 days while a prednisolone taper pack can be used in adults. Intranasal steroids can be added in older children and adults once daily for a few weeks.

Balloon Dacryoplasty and Complex CNLDO

Balloon dacryoplasty is particularly useful in cases of partial obstruction. These children typically present to the Ophthalmologist at an older age with waxing and waning symptoms. They will have periods of relative normalcy followed by periods of apparent obstruction. Often the parents are frustrated with their primary care physician for not diagnosing the problem, but this is likely due to the intermittency of the problem. The symptoms are most likely related to a stenosed but patent nasolacrimal system, which intermittently becomes obstructed during periods of rhinitis, allergy, or upper respiratory infection. History taking is more important in diagnosing intermittent obstruction as symptoms during exam will vary widely and may not even be present. Balloon dacryoplasty is the preferred treatment for partial obstruction as it can enlarge the stenotic duct preventing intermittent obstruction.

Failure in balloon dacryoplasty as in probing and silicone intubation is typically due complicated factors like creation of a false passage, bony anomalies, or infection and scarring following the procedure. Utilization of an endoscope can help verify proper placement and guide passage of the probe in more difficult cases. The surgeon can be deceived by apparent metal-on-metal since a probe can be passed into the nares through a false passage. Becker's higher success rate compared to other studies may relate to the use of an endoscope or direct visualization of the probe in most cases.

When utilizing an endoscope, a 2.7-mm pediatric endoscope should be used in children while a 4-mm endoscope may be used in adults. The use of a 0° or a 30° endoscope is as per surgeon preference, though depending on the anatomy, a 30° may be more useful as it can be placed lower in the nose to look superiorly. The Ophthalmologist who wishes to learn this skill can begin utilizing endoscopes on all nasolacrimal procedures to begin to understand the appearance of the normal nasal anatomy.

In patients with obvious bony anomalies during initial probings, it is wise to document this in the operative note and inform the parents. Many of these children can benefit from an endoscopically guided balloon dacryoplasty; however, if the passage cannot be negotiated with the balloon probe, conversion to an endosopic DCR can be a good option. Especially in secondary procedures it is prudent to treat infection with oral antibiotics preoperatively and treat with systemic antibiotics and steroids postoperatively to prevent rescarring of the NLD.

Results of Pediatric Balloon Dacryoplasty

Becker's prospective study was performed on 61 lacrimal systems in 51 patients from age 13 to 73 months (average 26 months); 44 % had no previous surgery, while 34 % had one or more failed probing, and 21 % had failed silicone intubation. Procedures were performed with the aid of a nasal endoscope to visualize the probe beneath the inferior turbinate before dilatation. In order to optimize results, infection was suppressed preoperatively with oral and topical antibiotics, which were continued for 10 days after surgery. Oral and topical steroids were added postoperatively for 5 and 10 days, respectively, to suppress inflammation and prevent rescarring of the nasolacrimal duct (NLD). Success was measured at 6 weeks postoperatively and was defined as absence of tearing or discharge, a normal tear meniscus, and a normal dye disappearance test (DDT). In this tightly controlled study, success rate was 96 % in those patients treated with the balloon as a primary procedure. In patients treated following failed probing or silicone intubation, 94 % were successful at 6 weeks [1].

In Becker's original study, children were placed under general anesthesia [1]. The nares were packed with cottonoids soaked in cocaine 4 or 0.25 % phenylephrine and patients were given intravenous antibiotic and steroid. The punctum

were then dilated, and the nasolacrimal system was probed. The probe was directly visualized in the nose beneath the inferior turbinate either with headlight and nasal speculum, or endoscope in many cases, and in the other cases was touched with a Bowman probe or mosquito hemostat, which is more typical of how most Ophthalmologists currently perform the procedure. A balloon probe was then inserted, and placement was similarly confirmed. A 2-mm balloon was used for children 30 months of age or younger, while a 3-mm balloon was used for older children. The balloon was inflated to 8 atm for 90 s, deflated, reinflated for 60 s, then deflated, moved more proximally to just beyond the common canaliculus, and then inflated two additional times for 90 and 60 s, was then deflated and withdrawn from the system. In addition to postoperative oral and topical steroids and antibiotics postoperatively, children were also treated with oxymetazoline or phenylephrine intranasal drops for 5 days postoperatively. Of the three failures in Becker's study, two were anatomic failures, as the probe could not be visualized beneath the inferior turbinate. The third failure was a partial failure such that the child was symptomatic when allergic rhinitis was present but was asymptomatic with a patent nasolacrimal system at other times.

Becker postulated that chronic infection and fibrosis might account for failure of probing in certain children. He felt that nasolacrimal systems with fibrosis and constriction proximal to the valve of Hasner would not respond well to probing since a typical number 0 Bowman probe measures only 0.71 mm, but would respond to the balloon since the inflated balloon profile measures 2 or 3 mm. Elimination of infection prior to surgery and elimination of inflammation postoperatively was felt to be critical for success of the procedure.

Subsequent reports on balloon dacryoplasty in children have shown good results. Maheshwari [5] showed an 87.5 % (7 of 8) success rate in secondary balloon dacryoplasty following initial probing failures in children aged 2–6 years with complex obstructions [5]. Casady et al. [6] reported on a stepwise treatment of nasolacrimal duct obstruction in 127 patients ranging in age from 1 to 81 months [6]. Balloon dacryoplasty was performed after failure of initial probing. Of 39 probing failures, 32 were cured with balloon catheterization with a success rate of 82.1 % [6]. Chen and Hsiao reported a success rate of 79 % (57 of 72 children) for balloon dacryoplasty as primary treatment in a group of older children aged 18–112 months [7]. Tien and Young reported an 82 % (32/39) success rate for secondary balloon dacryoplasty following failed probing in children aged 10–84 months and concluded that although the success rate might be lower than some published reports of silicone intubation, the simple and atraumatic nature of the balloon procedure makes it an attractive alternative to silicone intubation [8].

In the most definitive study, the NLD2 study, the PEDIG prospectively enrolled patients into one of two groups following failed probing. The study included children 6 to <48 months of age following a failed probing. The patients were not randomized but were treated with silicone intubation, balloon dacryoplasty, or repeat probing as per choice of the investigator. Treatment success was defined as no epiphora, mucous discharge, or increased tear film at a follow-up visit 6 months following the procedure. In the balloon group, success was found to be 77 %, while in the intubation group it was found to be 84 %. Repeat probing was successful only 56 % of the time. Although the study was prospective, it is limited by the lack of randomization. The PEDIG group concluded that both procedures were successful in a similar proportion of patients [2].

Adult Balloon Dacryoplasty

Balloon dacryoplasty can also be used for adults with partial obstruction; however, results typically are not as good as for children. Couch and White [9] reported on results of endoscopically assisted balloon dacryoplasty for treatment of partial NLDO in 100 adult patients. While 90 %

of patients had improvement in their symptoms postoperatively, only 56 % of patients experienced complete relief of their epiphora [9]. This is similar to the author's experience and that of a few others [10]. While the procedure is most often successfully completed in adults, symptoms are often not completely eradicated to the patient's satisfaction.

Perry et al. reported on the combined use of balloon dacryoplasty and silicone intubation in 13 adults with partial NLDO [11]. The patency to irrigation at 6 months (tubes were removed at 2 months) was noted to be 73 %, while 60 % had a subjective reduction in epiphora. In the case of adults, the endoscope is invaluable as it can let the surgeon know whether the probe is passed properly or the presence of false passage. Also in the adult, the endoscope is far easier to use as compared to children, as the nares are larger. In the case of adults when a balloon dacryoplasty under general anesthesia is under consideration, consent can also be obtained for an endoscopic balloon-assisted DCR. After initial probing, if the system is felt to be too tight or if it is difficult to navigate the system with the probe, the procedure can be converted to an endoscopic DCR. Patients appreciate this approach as it has a higher chance of success. Although complete NLDO in adults can be treated with balloon dacryoplasty under fluoroscopy, and it was possible to pass a balloon successfully through the nasolacrimal system, only 25 % of patients were ultimately successfully treated [12].

Conclusion

Balloon dacryoplasty has become a popular procedure over the past 15 years. It has shown itself to be successful in children as a secondary procedure following failed probing, and as a primary procedure in select patients especially children with partial nasolacrimal obstruction or older children. Advantages of the balloon include the lack of a retained implant as in the case of stents and the relative ease of the procedure. Use of an endoscope may improve outcomes. Suppressing pre- and postoperative inflammation and infection likely improves outcomes. Although the results in adults with partial NLD obstructions are encouraging, long-term results are awaited to conclusively ascertain its role as an alternative to a dacryocystorhinostomy.

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32 Dacryoendoscopic Guided Canalicular and Nasolacrimal Duct Recanalization

Mohammad Javed Ali

Introduction

Dacryoendoscopy is a procedure utilizing microendoscopic techniques to visualize the entire lacrimal system from the puncta to the inferior meatus [1–10]. It is gaining firm ground and increasing in popularity for expanding indications in lacrimal disorders, thus having many diagnostic and potential therapeutic implications [1–10]. Till the late 1990s, the microendoscopic systems were not well-developed; however, with the advancement in other specialties like endoscopic retrograde cholangiopancreatography (ERCP), numerous microendoscopes with a good image quality were designed. Dacryoendoscopes used in the past include the Junemann probe and the vitroptic. Additional channels were added, for example, for laser delivery of KTP-YAG or Erbium-YAG laser for laser dacryoplasty and micropunches for sample collection [8]. The author performs it using a 0.6-mm microendoscope (Karl Storz, Tuttlingen, Germany), which was adapted and partly modified from the original sialoendoscope (Figs. 32.1 and 32.2). The current chapter will discuss the instruments, indications, and techniques of lacrimal passage recanalizations.

Canalicular obstructions and NLDO are therapeutic challenges. Most of the lacrimal obstructions are known to follow the common final pathway of inflammation and fibrosis, even if there is a wide range of etiological factors. Canalicular obstructions can occur following

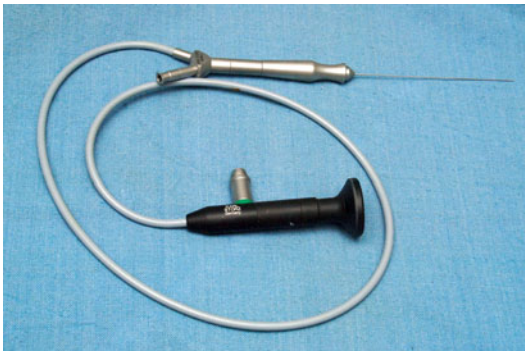

Fig. 32.1 Dacryoendoscope with rigid telescope and black eye piece

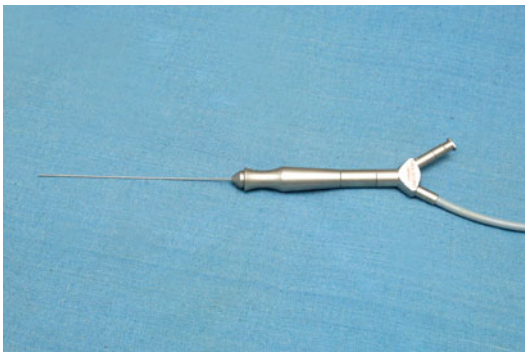

Fig. 32.2 A closer view of side port

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute,
Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

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infections, inflammations like Stevens-Johnson's and lichen planus, posttraumatic and post-topical ocular medications and systemic chemotherapy [11–13]. Numerous modalities with variable success rates have been described for canalicular obstructions and include retrograde intubation dacryocystorhinostomy, membranectomy, endocanalicular laser surgery, canalicular trephination, and balloon canaliculoplasty [14–18]. For nasolacrimal duct obstructions (mostly partial), alternative options to a DCR described include therapeutic trephination and intubation, silicone intubation alone and anterograde balloon dacryoplasty, electrocauterization or diathermy-assisted recanalization of NLDO (RC-NLDO), radiofrequency recanalization, and microsurgical NLD rhinostomy with eversion technique [19–26].

Instruments and Techniques

1. Dacryoendoscope
2. 1-ml syringe with saline
3. Camera head
4. Endoscopic viewing system
5. Antifog solutions (ex-diluted chlorhexidine)
6. Sisler's trephines
7. Huco trephines
8. Additional instruments based on the technique like Microdrill or laser or balloon dacryoplasty

The dacryoendoscope has a thin, rigid fiber endoscope and a side port on the hand piece (Figs. 32.1 and 32.2). The rigid fiber endoscope is attached to the eyepiece through a fiber-optic cable (Fig. 32.1). The eyepiece of the dacryoendoscope is connected to the camera head and secured. The camera head is then connected to the endoscopic viewing system (Fig. 32.3), and the tip of the scope is gently cleaned with antifog solution and image quality is assessed.

The dacryoendoscopy can be performed in an anterograde or a retrograde manner. For the recanalizations procedures, the anterograde approach is used. It is important to know that illumination may need to vary in different parts of the lacrimal system, especially when there are obstructions.

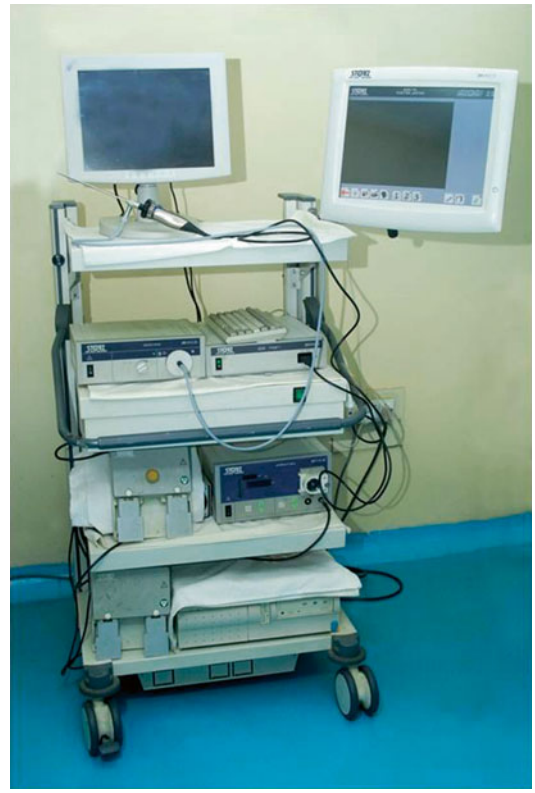

Fig. 32.3 Endoscopic viewing system

Indications

The indications for the recanalizations procedures are as follows:

1. Complete canalicular obstructions
2. Complete nasolacrimal duct (NLD) obstructions
3. Symptomatic partial obstructions.
4. Patchy or multifocal canalicular or NLD strictures
5. Obstructive dacryolithiasis
6. Obstructive foreign bodies, for example, migrated punctal plugs
7. Membranous canalicular obstructions following a DCR

Contraindications

1. Acute canaliculitis
2. Acute dacryocystitis
3. Posttraumatic obstructions following gross fractures

4. Misaligned canaliculi
5. Acute infective rhinitis (for nasolacrimal recanalizations)

Techniques

1. Dacryoendoscopic guided canalicular and NLD trephination
2. Laser dacryoplasty
3. Microdrill canaliculoplasty
4. Balloon canaliculoplasty
5. Diathermy-based recanalizations

Canalicular Recanalization Techniques

Canalicular trephination can be carried out using laser, microdrills, or balloons under dacryoendoscopic visualization or, alternatively, using trephines under similar guidance. Sisler's trephines were described in the year 1990 as specialized microtrephines designed for the canaliculi [14]. The trephine is 16 mm in length and 0.81 mm wide with a plastic hub behind for a syringe or simply to hold during the boring movements. It is accompanied by an intraluminal stylet or guide (Fig. 32.4). Dacyroendoscope is used to assess the type of obstruction (partial or complete), its distance, and its appearance. It is important to differentiate stenosis from various degrees of obstructions (Figs. 32.5, 32.6, 32.7, and 32.8). Lubricated trephine is inserted to the point of obstruction with its accompanying stylet in place to minimize trauma to the proximal, patent canaliculus. The syringe is then affixed to the trephine's luer-lock hub and trephination is carried

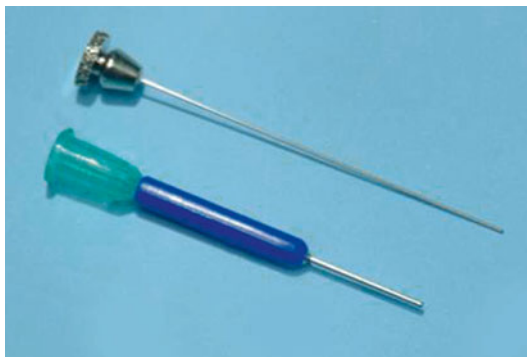

Fig. 32.4 Sisler's canalicular trephine with intraluminal stylet

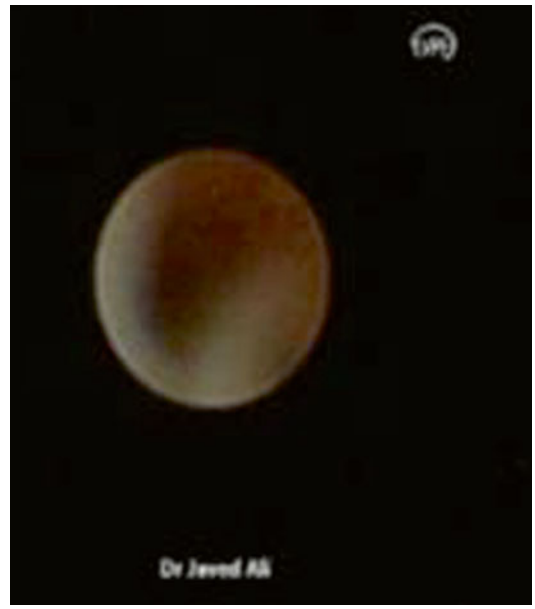

Fig. 32.5 Canalicular stenosis

Fig. 32.6 Partial canalicular obstruction

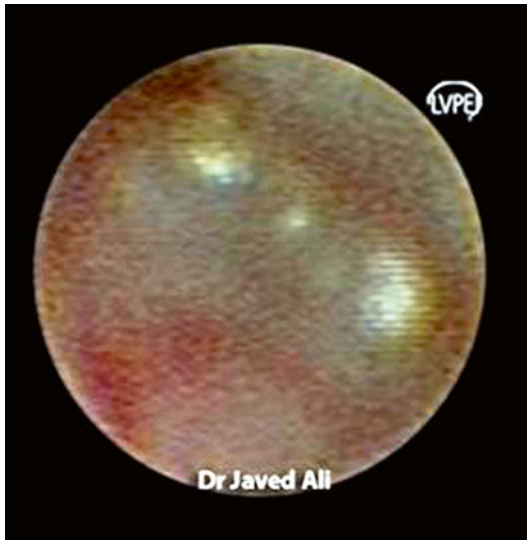

Fig. 32.7 Complete canalicular obstruction

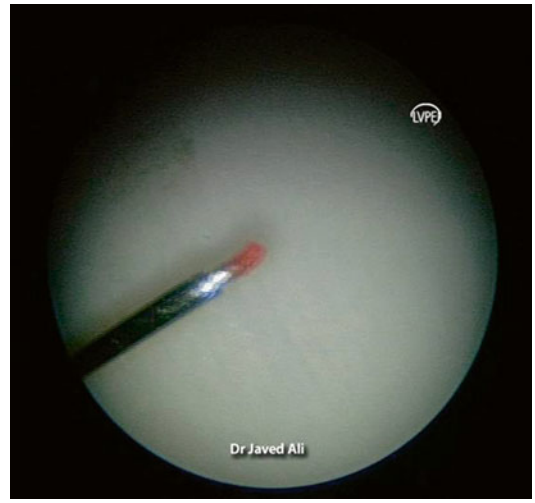

Fig. 32.9 Obstructed sculpted segment in trephine barrel

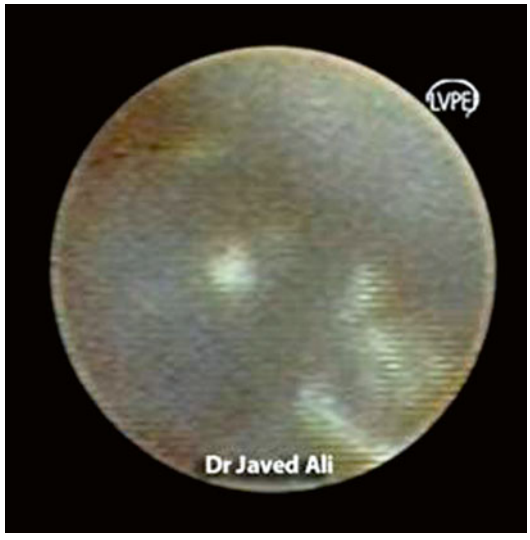

Fig. 32.8 Complete canalicular obstruction

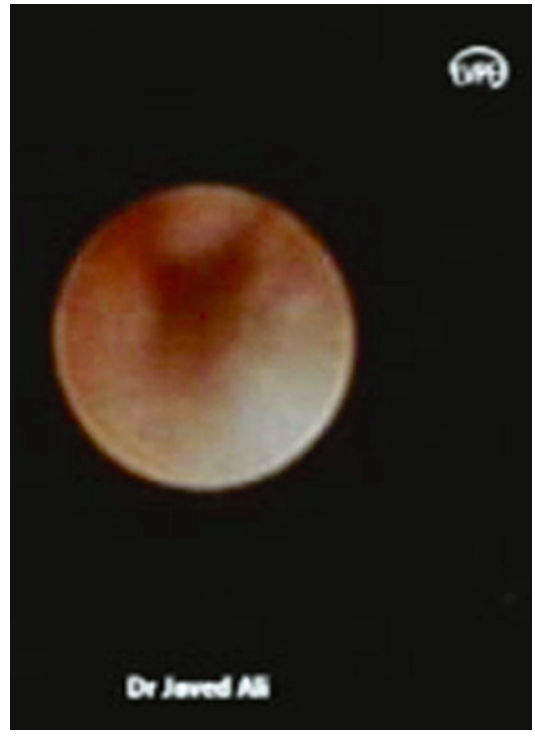

Fig. 32.10 Complete canalicular recanalization

out by gentle rotation of the assembly. After each millimeter boring, dacryoendoscope is used to assess the extent of clearance, assess further passage, and obstruction. Bleeding is usual since the obstruction is a fibrovascular tissue and it should be simultaneously cleared by irrigating the canaliculus with saline from the side port. The trephination is continued and when the sac is entered, the syringe will pop indicating achievement of the desired passage and a plug of scar tissue is seen either within the lumen of trephine or barrel of the syringe (Fig. 32.9). Dacryoendoscope is inserted to ascertain completer recanalization (Fig. 32.10). This is followed by stenting of the new passage with mono- or bicanalicular stents. Postoperatively, a combination of topical antibiotic and steroid is

continued in a tapering fashion for 4 weeks. The author retains the tubes for 3 months in recanalizations cases.

Laser dacryoplasty is performed using Erbium:YAG laser or KTP:YAG laser [8, 17]. For this purpose the dacryoendoscope needs to have an additional channel for the passage of laser fiber. Laser delivery using a sapphire fiber of 375 μm, and energy of 50 mJ with 1–3 Hz frequencies have been described. The procedure is the same as described earlier but instead of a mechanical trephine, laser is used to lyse the fibrous tissues, followed by irrigation and intubation [8, 17].

Microdrill dacryoplasty was introduced by Busse [6]. The additional channel on dacryoendoscope is designed to carry a battery-operated 0.3-mm stainless steel microdrill shaft. The frequency to begin was 50 Hz but now powerful drills up to 3,000 Hz are available. The microdrill is best suited for partial obstructions, where the drill starts from the edge of the patent lumen to recanalize it further. It is very important to have a continuous irrigation and suction with a clear visualization and utmost control on the instruments, since the possibility of canalicular lacerations can be high if the shaft is not accurately positioned [6].

Balloon canaliculoplasty is sparsely reported in the literature [16]. It uses a 2-mm balloon for recanalizations following probing just like in balloon dacryoplasty. The inflation–deflation cycles at 8 atm of pressure is followed by intubation. It was found to be more effective in common canalicular obstruction as compared to isolated canalicular obstructions.

Nasolacrimal Duct Recanalizations Techniques

Nasolacrimal duct obstructions are an enigma. Recanalization approaches used include dacryoendoscopic guided Huco trephination and intubation, anterograde balloon dacryoplasty, electricity-assisted recanalization of NLDO (RC-NLDO), and Javate's mechanical recanalizations under simultaneous guidance [19–25]. Trephination is usually done using the Huco trephine (Fig. 32.11). Lubricated trephine is inserted to the point of obstruction with its accompanying stylet in place to minimize trauma to the proximal, structures. The trephination is carried out by gentle rotation of the assembly. After each millimeter boring, dacryoendoscope is used to assess the extent of clearance, assess further passage and obstruction, modify the course, and confirm complete recanalizations (Figs. 32.12, 32.13, 32.14, and 32.15). Bleeding is usual since the obstruction is a fibrovascular tissue and this needs to be cleared simultaneously with saline irrigation of the NLD from the irrigation port (Fig. 32.2). Crawford silicone intubation was performed and retrieved through the NLD and secured in the inferior meatus (Fig. 32.16), following the recanalization procedure.

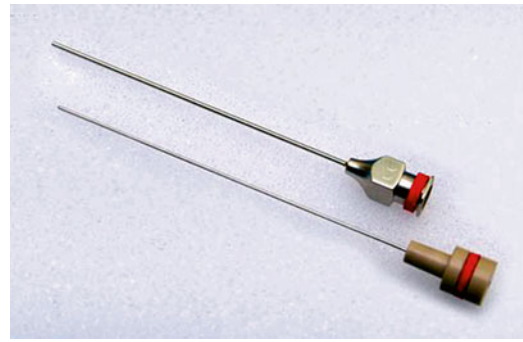

Fig. 32.11 Huco trephine

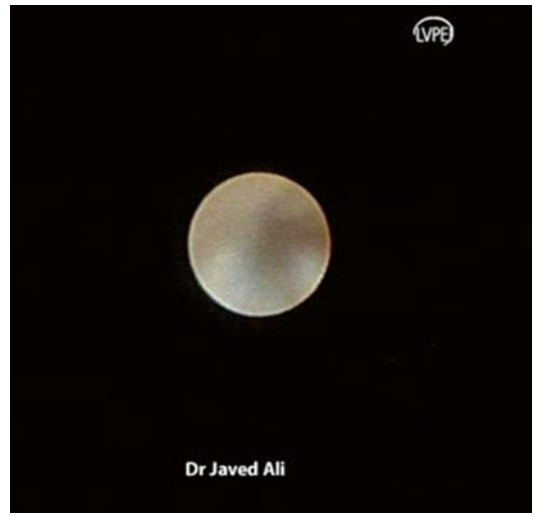

Fig. 32.12 Obstructed nasolacrimal duct

Fig. 32.13 Following early trephination

Fig. 32.14 Residual tissue in lumen following recanalization

Fig. 32.15 Complete recanalization

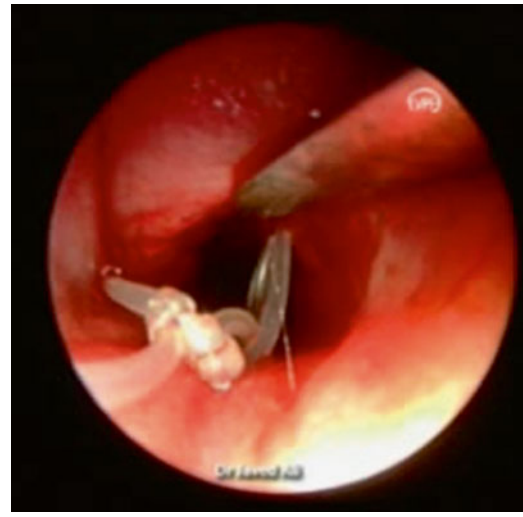

Fig. 32.16 Crawford intubation secured in inferior meatus

Anterograde balloon dacryoplasty is usually used for recanalizing partially obstructed nasolacrimal ducts [19]. The ducts are initially probed and the probe confirmed with an endoscope in the inferior meatus. A 3-mm lubricated balloon is then passed into the distal portions of the nasolacrimal ducts and inflated to 8 atm for 90 s, deflated, and reinflated to 8 atm for 60 s. The same procedure is repeated for the proximal portion of the nasolacrimal duct. This is followed by stenting of ducts with Crawford bicanalicular tubes [19].

Electrocautery or diathermy-based NLD recanalizations have also been described and claimed to be effective. The electrocautery-based recanalizations with bicanalicular intubation (RC-BCI) have shown efficacy for overcoming both the canalicular obstructions and NLDO [18, 21]. The instrument consists of a lacrimal canalizer (Tonxing Co, Changyi, China), whose console can discharge current between 50 and 150 W at a frequency of 500 KHz. The hand piece is a high-frequency lacrimal probe made of copper–silver alloy with 2-mm blunt, smooth but naked tip for electrocauterization. Another variant of this in a more practical setting has been described by Agarwal et al. [24], where a 20 gague, 7-W, endodiathermy probe connected to phaco machine has been used and recommended this as an alternative to DCR.

Complications

1. Bleeding
2. Proximal healthy structure trauma
3. Punctal trauma
4. Canalicular or NLD lacerations (rare)
5. False passage (rare)
6. Aggressive reocclusion
7. Tube-related complications

Prevention of Complications

1. Prior proximal dilatation
2. Lubrication of trephines
3. Good knowledge of anatomical course and variations
4. Avoid forceful entries
5. Periodic blood and debris clearance
6. Always perform under visualization

Advantages of Recanalization Procedures

1. Minimally invasive procedure
2. Major surgical interventions can be avoided
3. Sculptured passage creation
4. Smooth edges and less reclosures
5. Minimal trauma
6. Quick recovery
7. Early rehabilitation

Outcomes

Canalicular Recanalization

Nathoo et al. [15] studied canalicular trephination and intubation in 45 eyes of 43 patients and at 1 year follow-up showed a success rate of 64 %. Khoubian et al. [27] studied the effects of trephination and intubation based on the level of canalicular obstructions in 41 eyes and found that 80 % of eyes had complete resolution from epiphora in lower distal canalicular obstructions, 66 % in distal bicanalicular obstructions, and 59 % in common canalicular obstruction. No cases of complete resolution were noted in the proximal group.

In the pilot study conducted by the author [28] on ten patients treated with dacryoendoscopic guided recanalizations, 40 % were mid and 60 % were distal obstructions; 40 % of these were partial, equally divided between the mid and distal groups. At 1 year follow-up, 70 % of these were patent. The author found that dacryoendoscopy helped in avoiding false passages, accurate assessment of the obstructions, as well as its complete clearance following trephination.

Laser dacryoplasty has been shown to be effective in 80 % of the patients with regard to relief from epiphora at a mean follow-up of 20.4 months [8, 17]. The success rate in canalicular stenosis was 67 %, whereas in isolated com-

mon canalicular stenosis it was as high as 86 %. Microdrill dacryoplasty showed a success of 78 % in reducing epiphora at 12 months follow-up [6]. Balloon dacryoplasty showed that an immediate success rate of 82 % was achieved but long-term follow-up success is only 57 % and not encouraging [16]. The outcomes of RC-BCI in canalicular obstructions in 32 eyes showed a complete resolution from epiphora in 81 % at a mean follow-up of 21.5 months [18].

Nasolacrimal Duct Recanalization

Ali et al. [19] performed anterograde balloon dacryoplasty in 21 partially obstructed NLD, followed by silicone intubation for 3 months. At a minimum follow-up of 6 months after tube removal, anatomical success was noticed in 71 % of the lacrimal passages. The use of silicone intubation along with a balloon dacryoplasty is not clear. Kashkouli et al. [20] retrospectively compared balloon dilatation with intubation versus intubation alone and reported no statistical difference between the groups (61 % vs. 54 %) in the outcomes at a mean follow-up of 14.60 months. However, it is important to note that this was not a randomized study. Bleyen et al. [23] conducted a similar study but it was a randomized control trial. They also did not find a significant difference between the groups (52 % vs. 57 %).

In a pilot study conducted by the author [28] on ten partially obstructed NLD with dacryoendoscopic guided recanalizations showed very good immediate success in all patients; however, the long-term outcomes were discouraging. There was a success rate of only 50 %, even though only partial obstructions were chosen for the procedures. An 80 % (4/5) of the failed NLD recanalization worsened symptomatically because of complete obstructions and needed dacryocystorhinostomy.

The outcome of diathermy recanalization has been reported to be 92.7 % at a 2 year follow-up. The surgical time taken was 21.3 ± 6.2 min with complications noted in 1.3 % and include punctal cheese wiring [24]. Javate et al. [25] performed a comparative trial between endocanalicular lacrimal duct recanalization (ELDR) and a standard external DCR and found that the anatomical and functional success rates were 93 and 85 %, respectively, as against 94 and 90 % in external DCR, and concluded that both are equal in efficacy without the major complications of external DCR.

Conclusion

In conclusion, for canalicular obstructions, the outcomes of various procedures are more convincing especially trephination and canaliculoplasty. Dacryoendoscopic guided recanalization in the author's experience is a useful and effective technique with a success rate of 70 %. However, the same was not found true for NLD recanalizations, which had a success rate of only 50 %, even though only partial NLDO were chosen for in their study. The fundamental block needed to make recanalizations a real alternative modality is accurate understanding of the etiopathogenesis, which is still elusive. Apart from this, modifications in instrumentation techniques with a larger sample size and longer follow-up are required and till then skepticism on NLD recanalizations is justified.

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Tumors of the Lacrimal Drainage System

33

Gangadhara Sundar

Introduction

> The tears of the angels form a river where you can wash your pain, and even in the middle of the thunder, don't forget the love inside the rain-David Bailey

The lacrimal drainage apparatus are paired structures that commence from the medial end of the upper and lower eyelid margins as the lacrimal puncta at the mucocutaneous junction, course through the medial end of the eyelid and the anterior limbs of the medical canthal tendon as the upper and lower canaliculi, which in most individuals merge into a common lacrimal canaliculus. The common canaliculus enters the lacrimal sac at its lateral wall with the fundus above and the body below, which then courses along the medial wall of the maxilla to open into the inferior nasal meatus under the inferior turbinate at the valve of Hasner. In general, tumors arising from the upper lacrimal drainage system are uncommon and when occur are usually benign especially at the punctal orifices. Tumors of the lacrimal sac and the nasolacrimal duct are extremely rare and when suspected, all efforts should be ensured to rule out malignancy [1–3].

G. Sundar, DO, FRCSEd, FAMS
Orbit and Oculofacial Surgery,
National University of Singapore,
Singapore, Singapore
e-mail: gsundar1@yahoo.com

Lacrimal sac tumors are only rarely encountered by the Ophthalmologists and constitute only a minority of head and neck tumors [1–5]. The most common clinical presentation is fullness, presenting as a mass, usually above the medial canthal tendon (Fig. 33.1), associated either with epiphora (Fig. 33.2) or not infrequently a chronic dacryocystitis [1–5]. Almost always unilateral, the presence of bloody tears and partial patency of the lacrimal drainage system on irrigation are highly suggestive of an underlying tumor. Telangiectasia or ulceration of the overlying skin, globe displacement (superolaterally)

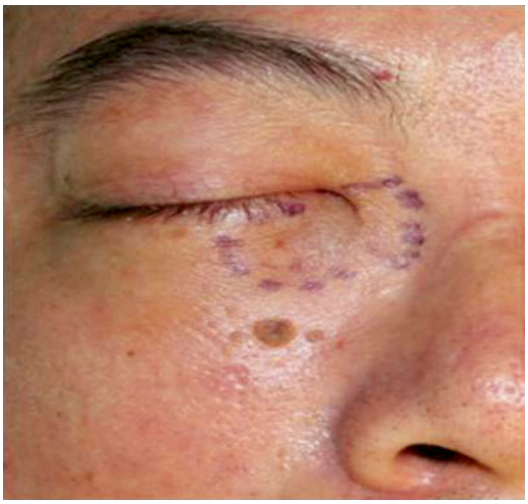

Fig. 33.1 Clinical photograph of a patient presenting with a palpable mass above the medial canthal tendon with epiphora

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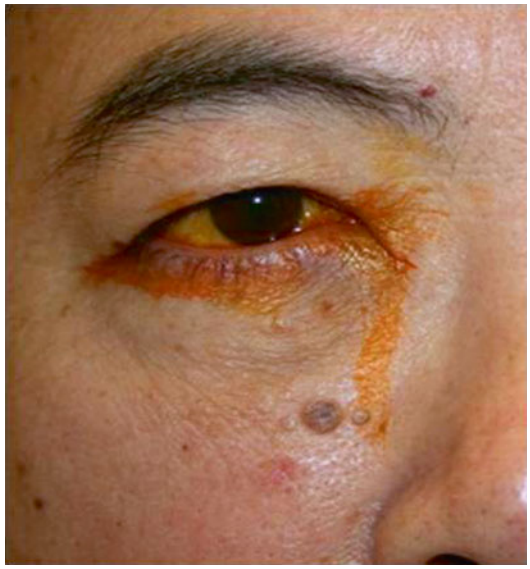

Fig. 33.2 A positive fluorescein dye disappearance test (FDDT) in the same patient

especially with regional lymphadenopathy are late presentations [1–5]. An early diagnosis can only be made because of a high degree of suspicion and low threshold to perform a biopsy especially when lesions are recurrent. It is therefore imperative that such a suspicion should be made in all cases of adult dacryocystitis especially when any of the clinical features described earlier are present. An astute Ophthalmologist will be able to diagnose based on high clinical suspicion, appropriate imaging, followed by either a needle or incisional biopsy. Most cases, however, are diagnosed only upon open examination of the lacrimal sac and atypical findings of mass lesions or atypical mucosa during a dacryocystorhinostomy. Therefore, when the suspicion of lacrimal sac tumor is present in a patient with dacryocystitis, it is advisable to open the lacrimal sac prior to performing an osteotomy of the lacrimal sac fossa and sending representative lacrimal mucosa and sac wall specimen for histopathologic examination.

Majority of the lacrimal drainage system tumors arise in the lacrimal sac and these can be classified based on histopathology. Table 33.1 provides an overview of the lacrimal sac tumors' classification. In general, 30–40 % of tumors of the lacrimal sac are benign and 60–70 % are malignant [1–5]. A 70 % of the tumors is of epithelial origin. Most benign lesions are squamous papillomas [6, 7]. A true papilloma demonstrates epithelial papillomatosis and acanthosis, while an inflammatory papilloma demonstrates granulomas. While most neoplasms are sporadic and of random origin, the Human Papilloma Virus (HPV) has been implicated in the pathogenesis of benign neoplasms (HPV 11) and malignant neoplasms (HPV 18). Rarely, a squamous papilloma may undergo oncocytic metaplasia and develop into an oncocytoma [6, 7].

A not so uncommon type, the inverted papilloma, also known as the Schneiderian papilloma, although histologically benign, has a high recurrence rate with malignant potential to a squamous cell carcinoma (10–15 %) and thus should be treated as an aggressive neoplasm. Comprising 0.5–4 % of primary nasal tumors, affecting men more than women, and commonly unilateral, these may either arise de novo or more commonly from involvement from the adjacent nasal cavity of maxillary sinus. While aggressive surgical treatment is indicated, radiation is contraindicated as it may increase the malignant transformation from a benign papilloma to a malignant carcinoma [1–3].

Malignant epithelial tumors commonly include squamous cell carcinoma and transitional cell carcinomas [1–3]. The squamous cell carcinomas have a wide range of differentiation from a well-differentiated to an undifferentiated tumor with corresponding prognoses. Transitional cell carcinomas behave similar to others present in the urinary bladder. Since these tumors have a tendency for intraepithelial spread down to the nasolacrimal duct and nasal cavity, its obligatory to carefully evaluate the nasal cavity and plan management accordingly [1–3]. Amongst carcinomas, mucoepidermoid carcinomas carry a very poor prognosis with almost 0 % 5-year survival rate [8].

Lymphomas are the second-most common primary malignant tumors [2, 9, 10]. They are mostly of the B-cell type and although quite rare, are more common than idiopathic inflammatory pseudotumors. Its occurrence in females has been reported to have a less favorable prognosis. Primary non-Hodgkin's lymphoma of the lacrimal sac has also been reported in children. Most,

Table 33.1 Tumors of the lacrimal sac

Pseudotumors	Lacrimal sac mucocele, dacryocele
	Dacryoliths
	Granulomas
	Nonspecific inflammatory disorder
	Granulomatous disorders like sarcoidosis, Wegener's granulomatosis, and tuberculosis
	Infective lesions, e.g., rhinosporidiosis
	Infiltrative lesions, e.g., amyloidosis
True tumors	*Epithelial tumors*
	Lacrimal sac lining elements
	Papillomas:
	Inflammatory papilloma
	True papilloma:
	Benign:
	Squamous papilloma
	Inverted (transitional cell/Schneiderian) papilloma
	Adenomatous papilloma
	Malignant:
	Transitional cell carcinoma (arising from inverted papilloma, Schneiderian papilloma)
	Squamous cell carcinoma
	Epidermoid carcinoma
	Mucoepidermoid carcinoma
	Lacrimal sac glandular elements
	Benign tumors:
	Eosinophilic cystadenoma (oncocytoma)
	Pleomorphic adenoma (benign mixed tumors)
	Adenoacanthoma
	Malignant:
	Oncocytic adenocarcinoma
	Adenoid cystic carcinoma
	Adenocarcinoma
	Lymphoproliferative tumors
	Non-Hodgkin's B-cell lymphoma
	Lymphosarcoma
	Hodgkin's lymphoma
	Mesenchymal tumors
	Capillary hemangioma
	Cavernous hemangioma
	Hemangiopericytoma
	Neurilemmoma
	Plexiform neurofibroma
	Fibroma
	Kaposi's sarcoma
	Osteoma
	Melanotic tumors: Malignant melanoma
	Secondary tumors
	Nasal mucosa/maxillary sinus: Inverted papilloma, squamous cell carcinoma, nasopharyngeal carcinoma, mucoepidermoid carcinoma
	Orbital tumors: Orbital lymphangioma, squamous cell carcinoma of the conjunctiva, melanoma of the eyelid/conjunctiva
	Skin: Basal cell carcinoma, squamous cell carcinoma, sebaceous gland adenocarcinoma
	Metastasis: Head and neck tumors

however, are diagnosed incidentally during a dacryocystorhinostomy from an altered mucosal appearance or a mass lesion [2, 9, 10].

Primary lacrimal sac melanoma is an extremely rare clinical entity with fewer than 25 cases reported in the literature [1–4]. The incidence of melanomas among lacrimal sac tumors varies between 4 and 13 % in various series [2, 4]. The development of lacrimal sac melanoma has been related to multiple risk factors including: older age, presence of dysplastic moles or nevi, delayed presentation, past history of surgery or interventions like incision biopsy, family history of melanoma, and other sites with cutaneous melanoma [2, 4]. Unfortunately, due to the lack of experience with lacrimal sac melanomas, there are no standard treatment guidelines. Wide surgical excision with tumor-free margins is the preferred treatment. Radiotherapy, chemotherapy, or immunomodulatory agents like alpha-interferon have all been described as an adjuvant modality of management, but with questionable efficacy [1–4].

Secondary neoplasms of the lacrimal system are not uncommon and usually arise from direct contiguity from the ocular surface and eyelid malignancies, underlying nasal cavity and par nasal sinuses, or rarely the overlying skin. Rarely tumors from adjacent structures including frontoethmoidal osteomas and esthesioneuroblastomas from the skull base may also affect the lacrimal system. Likewise, metastasis to the lacrimal sac is a rare phenomenon [11].

Investigations

When a clinical suspicion of lacrimal sac is made, a preoperative imaging is warranted [1–6]. Initial investigation may include either a Computed Tomography or Magnetic Resonance Imaging with contrast of the lacrimal sac fossa, adjacent orbit, and paranasal sinuses. A dacryocystography can also be performed to identify space-occupying lesion of the lacrimal sac/nasolacrimal duct with a finding of filling defect. However, it may not be able to differentiate between a dacryolith and primary tumor.

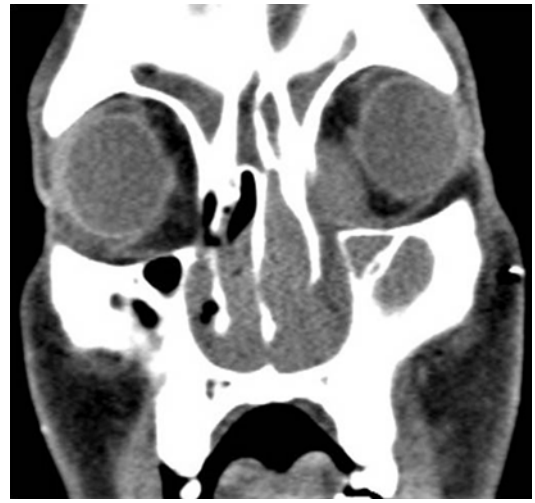

Fig. 33.3 Coronal CT showing lacrimal sac tumor (T cell lymphoma) with orbital and nasal/paranasal sinus extension crossing midline

Computed Tomography

CT scan of the orbits and paranasal sinuses including the lacrimal fossa is the principal modality of investigations for all suspected cases of lacrimal drainage tumors [1–6]. Performed with and without contrast, with fine cuts soft tissue and bone windows, a clear outline of the bony nasolacrimal sac fossa and nasolacrimal duct with soft tissue enhancement usually identifies the tumor with high precision (Figs. 33.3 and 33.4).

Magnetic Resonance Imaging (MRI)

An MRI of the lacrimal sac fossa, orbits, and paranasal sinuses provides a clear delineation of the soft tissue involvement of the nasolacrimal duct and, more importantly, is able to differentiate soft tissue mass lesions from normal adjacent sinus mucosa and sinusitis (Figs. 33.5, 33.6, 33.7, and 33.8). Early infiltration of the surrounding structures is also seen well with MRI as compared to CT scans. Thus, a combination of CT scan and MRI may be complementary as well.

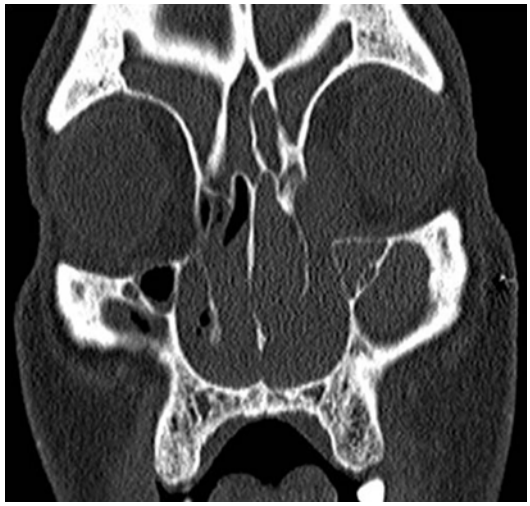

Fig. 33.4 Coronal CT (bone window) of the same patient clearly showing the bony destruction by the lacrimal sac tumor

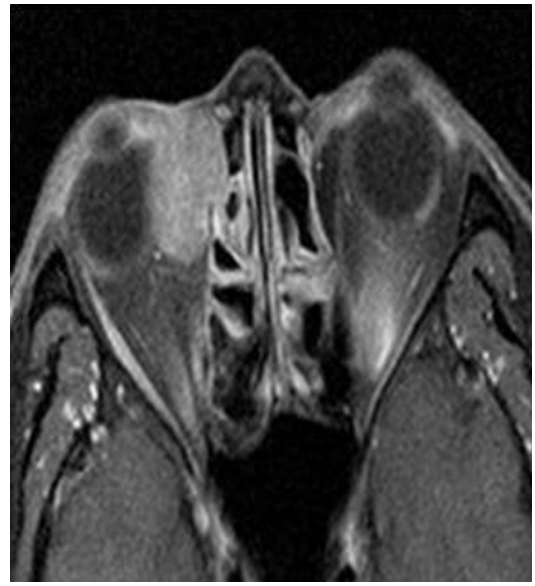

Fig. 33.6 MRI, T1-weighted, axial cut of the same patient in Fig. 33.5 shows enhancement with contrast. The mass was later proved histopathologically to be an undifferentiated carcinoma of the lacrimal sac

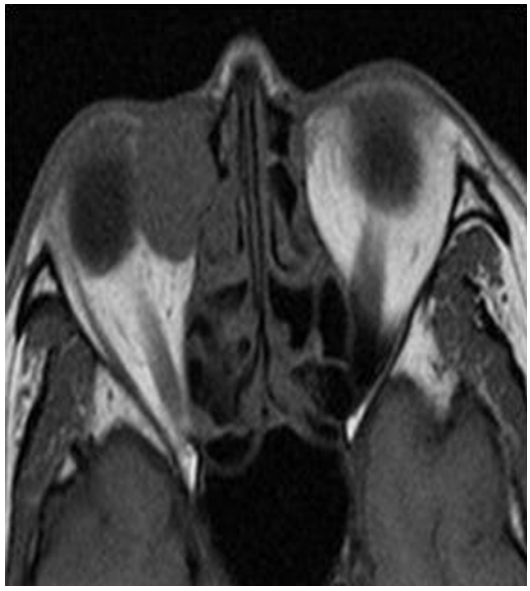

Fig. 33.5 MRI, T1-weighted, axial cut showing a lacrimal sac mass lesion abutting and displacing the globe. Note the lesion is hypointense on T1

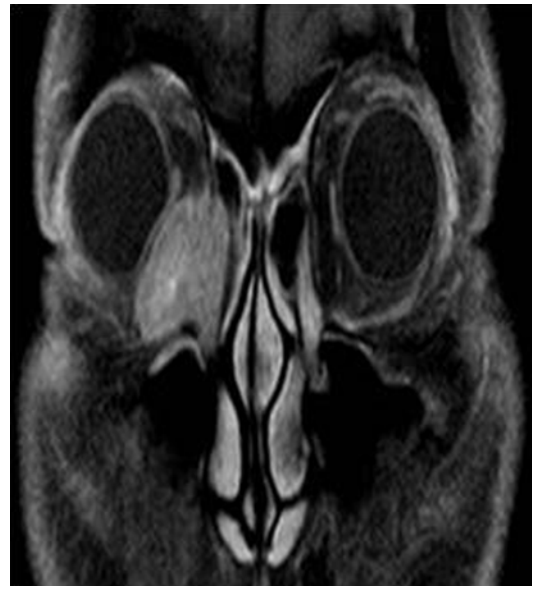

Fig. 33.7 MRI, T1-weighted, coronal cut showing a lacrimal sac mass indenting the globe and displacing it superolaterally. Note the lesion is hypointense on T1

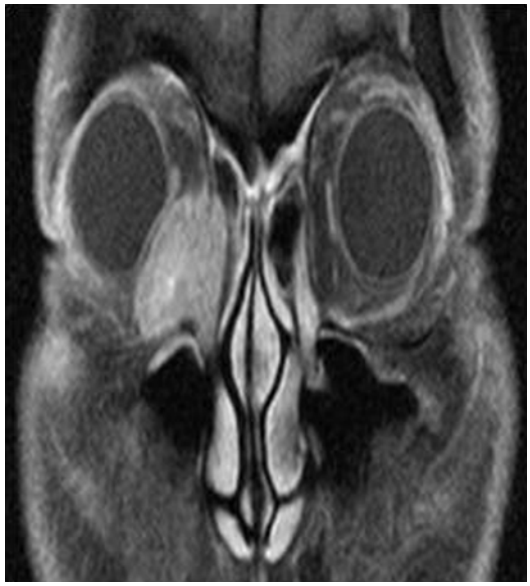

Fig. 33.8 MRI, T1-weighted, coronal cut of the same patient as in Fig. 33.7 showing uniform enhancement with contrast

Making a Diagnosis

Almost all preoperative diagnoses are made based on a high degree of suspicion based on symptoms and signs described earlier, confirmed by imaging studies [1–11]. When suspected, either a closed or open biopsy may be performed. Not infrequently a diagnosis is made on the presence of abnormal lacrimal mucosal features during a dacryocystorhinostomy. Caution should be exerted on inadvertent extensive tissue manipulation while performing either an endonasal or external DCR before opening the lacrimal sac.

Closed Biopsy

This may be performed under topical anesthesia in the outpatient setting. A blunt needle or canula may be passed through the upper or lower punctum, past the common canaliculus into the lacrimal sac with multiple passes made (Fig. 33.9). Either a cytology or cell block may be prepared or an immediate diagnosis can be made.

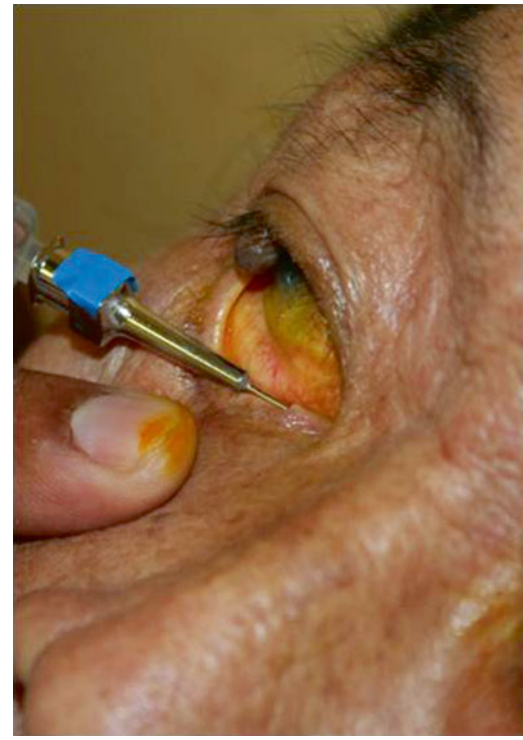

Fig. 33.9 Transcanalicular core needle biopsy

Open Biopsy

This may be performed either as an intentional biopsy or as an inadvertent finding during lacrimal drainage surgery. When electively performed, it is performed under local anesthesia through a skin crease, medial canthal incision with care taken to prevent tumor seeding of the wound. As mentioned earlier, when a tumor is suspected in a patient with dacryocystitis, it is advisable to expose and inspect the lacrimal sac mucosa with histopathological examination prior to performing an osteotomy. Routine biopsy of the lacrimal sac, although not commonly performed, has been reported to detect otherwise undetectable lacrimal sac tumors. The author is aware of lacrimal sac tumors inadvertently being diagnosed after exposure of the lacrimal sac during an endoscopic DCR, warranting additional and extensive surgery. Elective transnasal biopsy is indicated when there is a visible infiltrative lesion of the nasal/sinus mucosa along the lateral wall, inferior meatus, or maxillary sinus ostium encroaching on the lacrimal drainage system.

Management

Management of lacrimal sac neoplasms is dependent upon the histopathological diagnosis complemented by immunohistochemistry and the clinical stage of the disease.

Most benign lesions may be managed by either limited excision or dacryocystectomy with care being taken to ensure complete resolution of tumor [1–4]. However, in cases of papillomas, specifically inverted papilloma, as the recurrence rate is quite high with potential malignant transformation, a more aggressive surgical treatment may be warranted [12].

Primary malignant epithelial or stromal neoplasm localized to the lacrimal sac and nasolacrimal duct should be managed appropriately. In most cases, a globe-sparing tumor resection followed either by radiotherapy alone or chemo-radiotherapy results in good outcomes. A complete excision of the entire nasolacrimal duct from the lacrimal sac fossa down the bony nasolacrimal duct and when appropriate including a medial maxillectomy through an endoscopic or lateral rhinotomy approach, performed in concurrence with rhinologists, under frozen section control without breach of the underlying lateral nasal wall is advised (Figs. 33.10, 33.11, and 33.12). Recent advances in imaging techniques and precision image guided navigational surgery to plan treatment ensure accuracy and completeness of resection and have contributed to a greater surgical success rates. Any residual tumor may be controlled with external beam radiotherapy (60–70 Gy) tailored to cover adjacent areas. More extensive lesions involving the orbit, paranasal sinuses, midline or skull base may require an orbital exenteration with craniofacial resection followed by flap reconstruction, and

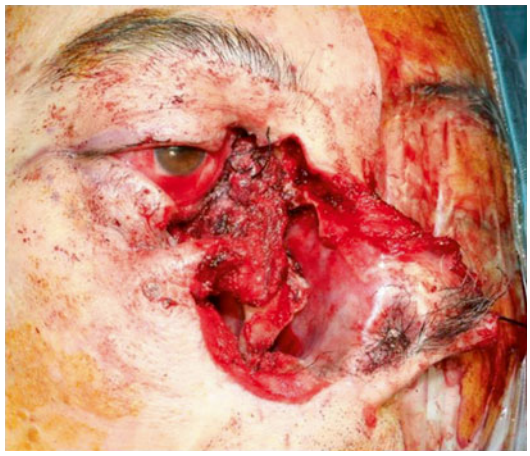

Fig. 33.10 Medial maxillectomy through lateral rhinotomy approach showing the tumor exposure with good margins

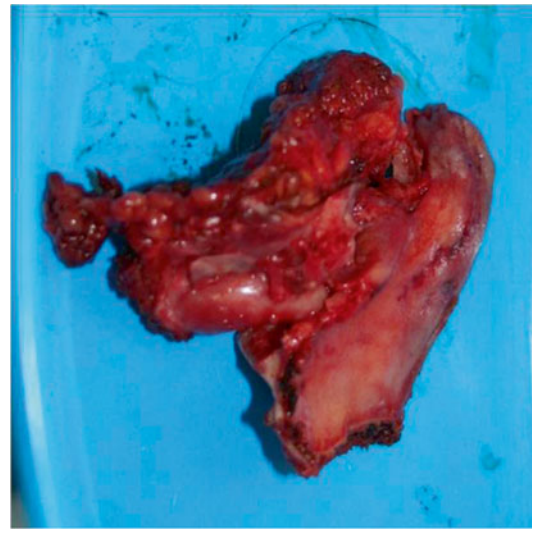

Fig. 33.11 The tumor specimen

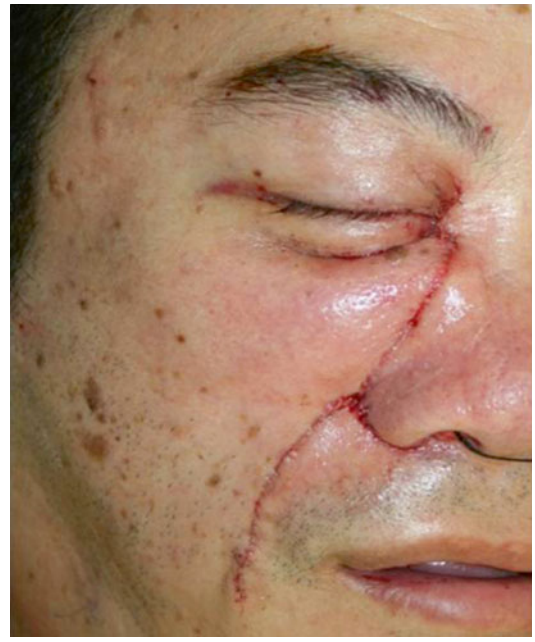

Fig. 33.12 Medial maxillectomy through lateral rhinotomy approach showing immediate post-reconstruction image

postoperative radiotherapy with or without concurrent chemotherapy. Even when aggressively treated, the recurrence rate for invasive squamous cell carcinoma and transitional cell carcinoma is approximately 50 with 50 % of those being fatal [1, 3, 5].

Lymphoproliferative infiltrative disorders warrant a systemic workup, and if documented to be localized disease, may be treated with irradiation. Systemic disease may warrant systemic chemotherapy and additional treatment as indicated [9, 10].

Primary lacrimal duct malignant neoplasms may be either localized or may have invaded the adjacent nasal cavity, paranasal sinuses, or the orbit. Erosion of the skull base, extensive regional lymphadenopathy, and systemic metastasis are quite rare and generally considered late-stage disease with a poor prognosis. Likewise, metastatic disease to the lacrimal system is quite rare and may be treated appropriate to the patient status and the nature of primary, but most amenable to external beam radiotherapy [11, 12].

Management of lacrimal drainage obstruction after tumor removal: When a malignant tumor has been diagnosed and managed appropriately, a lacrimal drainage procedure, DCR, or conjunctivo-DCR with Jones tube placement may be considered if there is no regional recurrence in 5 years. Long-term follow-up of these surgical procedures is not very well-known, given the rare incidence of the lacrimal drainage system tumors.

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Dacryocystectomy: Indications and Techniques

34

Mohammad Javed Ali

Introduction

Dacryocystectomy or DCT refers to a complete surgical extirpation of the lacrimal sac. It was first described by Thomas Woolhouse in 1724 and was the standard of care in its crude form, before the advent of dacryocystorhinostomy for management of dacryocystitis and lacrimal fistulae [1]. Rudolph Berlin later popularized it in the nineteenth century [1]. Dacryocystectomy in its journey since then has unfortunately seen many ups and downs and suffered major humiliation in the 1920s wherein it was described by few authors as "an act of surgical despair"; "a useless and barbaric mutilation"; and "a malpractice." [1] We have come far from those days and DCT is now considered an important part of the lacrimal surgeon's armamentarium. The usual approach in most of the cases is through a transcutaneous incision, except in certain exceptional circumstances where endoscopic approach may be needed [2].

Goals

There are two clear goals of the dacryocystectomy procedure. The first is to have a clear plane of sac excision and avoid injury to periorbita and surrounding bones. The second is to have a complete excision of the sac along with the nasolacrimal duct without leaving any remnants behind. Since both these purposes are well-served by an external route, it is the preferred approach.

Indications

(a) Dacryocystectomy is one of the recognized surgical modalities for the management of malignant lacrimal sac tumors [3–5]. This may have implications on live salvage, increased survival, or improving quality of life in such patients. Indications apart from this can be considered as relative indications and can be a subject of debate.
(b) Recurrent dacryocystitis in patients with severe dry eyes [6, 7].
(c) Dacryocystitis in patients with coexisting bleeding diathesis [6, 7].
(d) Dacryocystitis in patients with predisposing conditions that cause nasal scarring like cicatricial pemphigoid, systemic lupus erythematosus, and Crohn's disease [6–8].
(e) Rare cases of extensive Wegener's granulomatosis which requires nasal bones for future reconstructions [8].
(f) Frail elderly patients with chronic dacryocystitis with cardiac or neurological comorbidities [6, 7, 9, 10].
(g) Elderly patients with dacryocystitis with ocular comorbid conditions that require

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

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urgent attention like microbial keratitis, advanced cataract, or lens-induced glaucoma, where epiphora is not a serious complaint [11]. The implication here is facilitation of visual rehabilitation.

(h) Recurrent dacryocystitis in elderly patient on beta-blockers where epiphora is not a serious complaint [10]. Serious systemic toxicity of beta-blockers is aggravated after DCR since there is direct absorption of drug from the nasal mucosa into systemic circulation, bypassing the hepatic metabolism.

(i) Multiple times failed DCR in patients with dry eyes or recurrent dacryocystitis [6, 12]

(j) Recurrent inflammation from the remnant of sac in a previously incomplete dacryocystectomy, especially if associated with comorbidities.

(k) Recurrent chronic dacryocystitis with fibrotic sacs following severe trauma [13].

(l) Severe atrophic rhinitis [13].

(m) Lacrimal sac mucopyoceles with nasal malformations [13], congenital partial arrhinia, or nasal hypoplasia.

Advantages

Where indicated, dacryocystectomy has advantages in terms of aiding complete extirpation of tumors, technically easier, less learning curve, quickly performed under local anesthesia, less invasive and does not violate nasal mucosa, minimal bleeding, no hospitalization, early recovery, and overall lesser morbidity [3–11].

Preoperative Requisites

(a) Confirmation of the diagnosis of dacryocystitis with nasolacrimal duct obstruction

(b) Imaging modalities like CT-scan and MRI in cases where lacrimal sac tumors are suspected

(c) Schirmer's test and others for establishing severe dry eyes if any

(d) Good counseling about the objectives of surgery and persistence of epiphora postoperatively

(e) Stable medical status

(f) Bleeding and clotting times (PT/aPTT) and INR if on anticoagulants

(g) Fitness for anesthesia (LA/MAC vs. GA)

Surgical Technique

Anesthesia

The surgery can be done under general anesthesia or local anesthesia. The latter is the most commonly employed modality. Local anesthesia is given by both infiltration as well as topical application. For infiltration, 2 % lignocaine with 0.5 % Bupivacaine with adrenaline (1:200,000) is used, unless there is a medical contraindication for use of adrenaline. Infratrochlear nerve that supplies the lacrimal apparatus is blocked first. The nondominant hand marks the supraorbital notch and the needle is inserted into the lateral edge of the medial third of the eyebrow and advanced to just medial-to-medial canthus and 2 cc of the drug is injected (Fig. 34.1). The tissue along the anterior lacrimal crest is infiltrated subcutaneously and the needle enters deeper at about 3-mm medial-to-medial canthus, and without withdrawing the needle the drug is injected into deeper tissues up

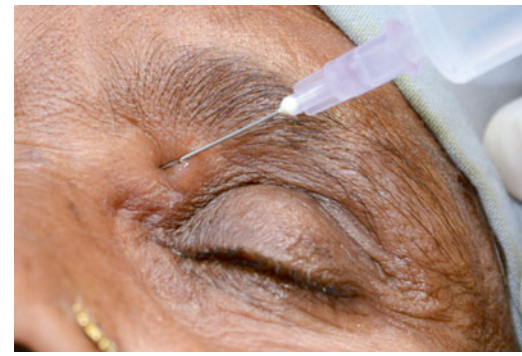

Fig. 34.1 Local infiltration anesthesia

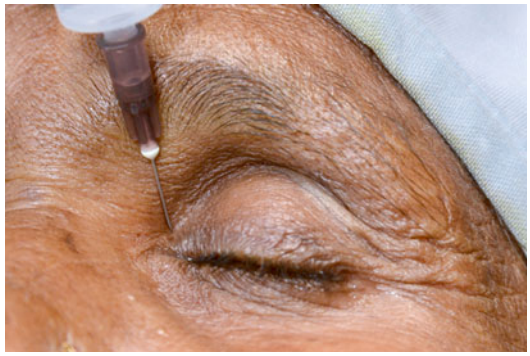

Fig. 34.2 Anterior ethmoidal nerve block

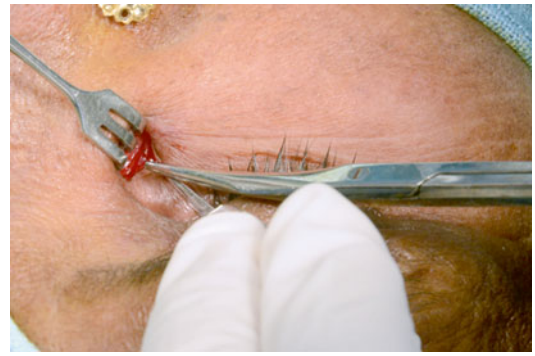

Fig. 34.4 Dissection to reach the periosteum

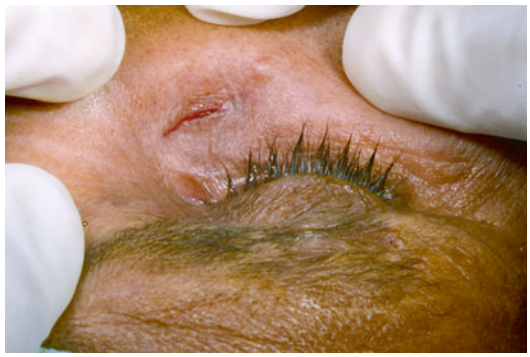

Fig. 34.3 Curvilinear incision

to periosteum both superiorly and inferiorly to block the nasociliary and anterior ethmoidal nerves (Fig. 34.2). Occasionally, an infraorbital nerve block may be required in cases of wide excision (malignancies). A drop of topical proparacaine is placed in conjunctival cul-de-sac for intraoperative comfort.

Incision

Though various incisions have been described, the author prefers the commonly used curvilinear incision of about 10–12 mm in length, 3–4 mm from the medial canthus along the anterior lacrimal crest and along relaxed skin tension lines (Fig. 34.3). However, extension of this skin incision above the medial canthus can lead to scars and epicanthic folds. An alternate can be the use of a straight incision at the lateral surface of the nose, 8–10 mm from the medial canthus. In cases of malignant lacrimal sac tumors, the incisions may be much longer and at variable locations based on the size and adjacent spread of the lesion. For example, the Weber–Ferguson incision if lateral rhinotomy is additionally planned. The Ophthalmologist should follow a multidisciplinary approach as appropriate when managing lacrimal sac malignancies.

Sac Exposure

Blunt dissection is carried on to separate the subcutaneous tissues and orbicularis muscle and reach the periosteum (Fig. 34.4). A Freer's elevator is used to separate the periosteum from the bone and reflect it laterally (Fig. 34.5). As the periosteum is being reflected laterally, the anterior limb of medial canthal tendon is noted attached to it just anterior to the anterior wall of the lacrimal sac (Fig. 34.6). The lacrimal fascia, which is contiguous with the periosteum is adherent near the medial canthal tendon and hence reflection of tendon aids in lacrimal sac dissection (Fig. 34.6). The tendon is cut at the suture of Notha and the medial wall of the sac is bluntly separated from the bones of the lacrimal fossa.

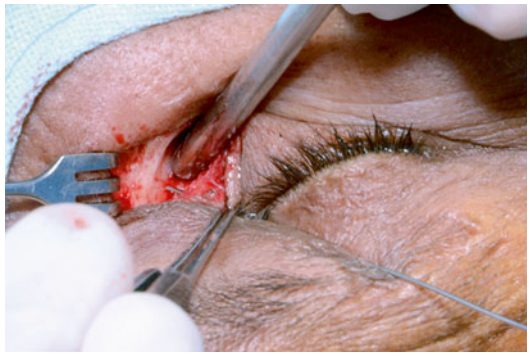

Fig. 34.5 Lateral reflection of sac from lacrimal fossa

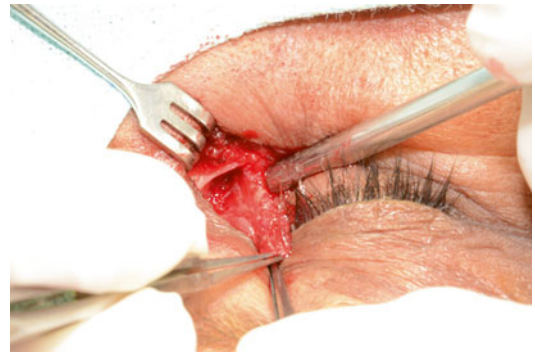

Fig. 34.7 Complete dissection of sac up to nasolacrimal duct

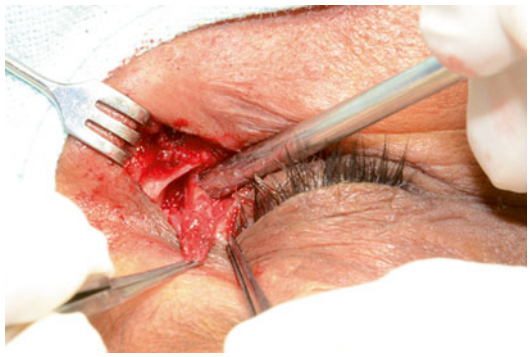

Fig. 34.6 Exposing the medial canthal attachments

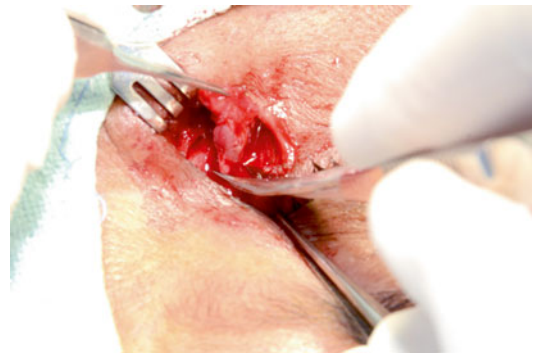

Fig. 34.8 Lacrimal sac amputation

Sac Dissection

The lateral wall is separated with the help of Westcott scissors by separating it from the orbicularis oculi. The closed blades of the scissor are then directed downward between the lateral wall of the sac on one side and orbicularis and periorbita on the other. The common canaliculus needs to be severed from the sac during this step. To avoid perforation of sac as well as to detect inadvertent perforation intraoperatively, one can use fluorescein-stained viscoelastics or methylene blue [6, 8]. The sac needs to be filled with either of this material before the beginning of dissection. The superior wall and the posterior wall can be separated from the fascia with a Westcott scissor right up to the nasolacrimal duct (Fig. 34.7).

Sac Amputation

Once the sac is dissected all around and separated from its soft tissue attachments, the sac is amputated at its junction with the nasolacrimal duct (Fig. 34.8). In cases of lacrimal sac tumors, the amputation is carried at a point as far as possible toward the distal nasolacrimal duct. Occasionally, bony nasolacrimal duct along with a lateral rhinotomy or medial orbital wall excision is combined with dacryocystectomy depending on the extent of malignancy.

Cautery

After the sac removal, the common internal canaliculus, nasolacrimal duct stump, and any remnant

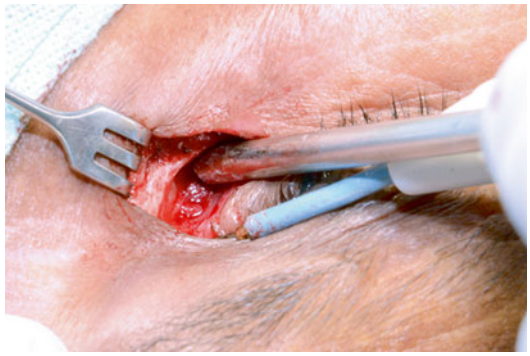

Fig. 34.9 Cautery to secure hemostasis

sac lining should be cauterized to prevent recurrences (Fig. 34.9). The canaliculi are cauterized separately using Ellman Surgitron needle (Ellman Int Inc, New York, USA) in a coagulation mode or with the help of a probe within the canaliculus. The punctum and the canaliculi show an immediate whitish discoloration following a successful cautery.

Wound Closure

Once hemostasis is achieved, the orbicularis is sutured back with 6-0 vicryl followed by skin closure with 6-0 prolene or vicryl or silk based on surgeon's preference.

Extended Dacryocystectomy

Extended dacryocystectomy refers to complete extirpation of lacrimal sac along with any of the surrounding structures like nasolacrimal duct, overlying lacrimal fossa bone, frontal process of maxilla, ethmoids, lateral nasal wall, anterior part of medial orbital wall, and surrounding soft tissues (Figs. 34.10, 34.11, 34.12, 34.13, and 34.14). Extended dacryocystectomy is indicated in lacrimal sac tumors and the extent of tumor infiltration into surrounding structures determines the extent of the surgery [3–5].

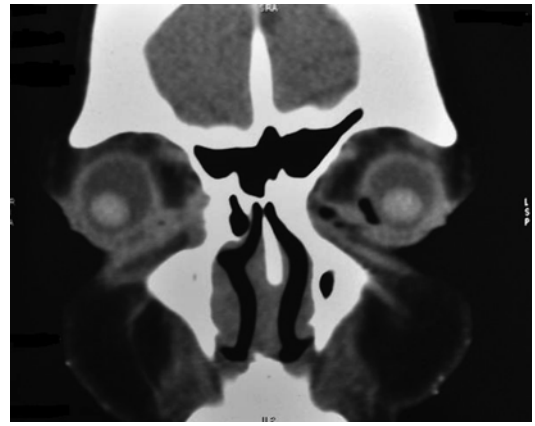

Fig. 34.10 Coronal CT of a lacrimal sac malignancy with lacrimal crest involvement

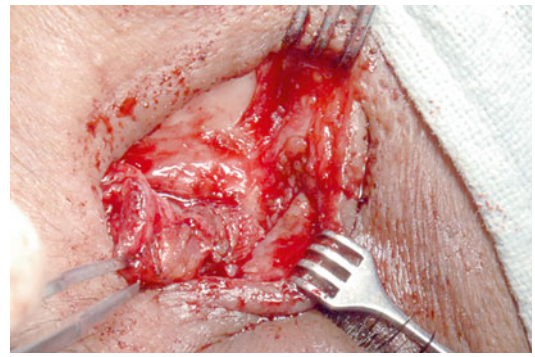

Fig. 34.11 Extended dacryocystectomy showing wide soft tissue margins

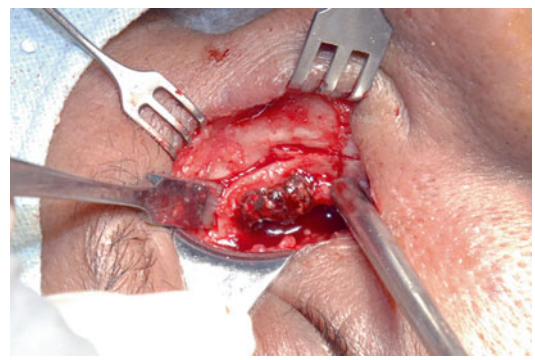

Fig. 34.12 Margins for the bony osteotomy around the tumor infiltration

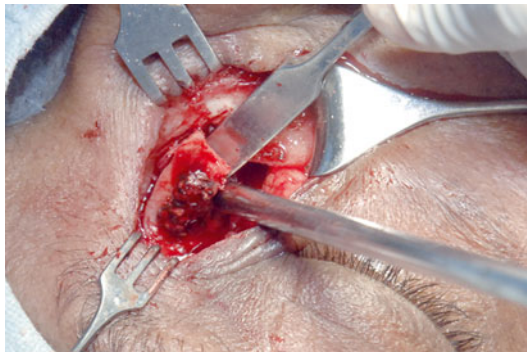

Fig. 34.13 Osteotomy completed

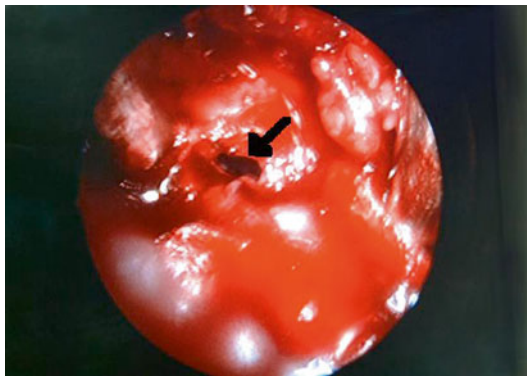

Fig. 34.14 Endoscopic view of the removed nasolacrimal duct till the opening in inferior meatus (*black arrow*)

Endoscopic Dacryocystectomy

Shams and Selva [2] described a bilateral endoscopic dacryocystectomy as an alternative in an elderly patient suffering from chronic dacryocystitis without symptomatic epiphora, where an external incision was undesirable in view of past history of wound infections secondary to picking. This indication can be extended in any case where the mental state of the patient may be a restrictive factor in maintenance of a healthy external wound. The technique is initially just like a routine endoscopic DCR, where after raising the mucosal flaps the osteotomy is performed to expose the lacrimal sac completely. The sac can then be removed completely in one go or piecemeal by incising the sac and removing anterior and posterior walls separately. The common canalicular opening and the remnant nasolacrimal ducts can be cauterized just like in an external dacyrocystectomy. Although endoscopic approach entails bone removal, we believe that a few exceptional circumstances may warrant its need.

Tips for Hemostasis

Although profuse bleeding is rarely expected in a dacryocystectomy, the profile of the patient (bleeding diathesis, anticoagulant therapy) and etiology (tumors) can sometimes influence the need for a preoperative assessment and intraoperative management of hemorrhage. The following can be useful tips in such patients:

(a) Good preoperative assessment to rule out bleeding diathesis or anticoagulant use
(b) Preoperative blood pressure assessment
(c) Raising the head end of the table when needed
(d) Avoid known blood vessels
(e) Good illumination and a well-powered suction
(f) Judicious use of cautery
(g) Keep materials like gel foam or bone wax in the armamentarium

Postoperative Measures and Follow-Up

Once wound is closed, reassure the patient that the surgery went fine. The wound can be patched. The patient is started on topical antibiotics and oral analgesics.

On the first day after surgery, the patch, if any, is gently removed and wounds are dressed with povidone iodine 5 % or other similar drugs based on surgeon's preference along with topical antibiotics and oral analgesics. Extended dacryocystectomy may warrant prophylactic oral antibiotics. Patients who underwent endoscopic dacryocystectomy may need additional nasal decongestants based on surgeon's preference. One week postoperatively, the sutures are removed and medications discontinued. Further follow-ups are tailored according to the indication for which a dacryocystectomy was performed.

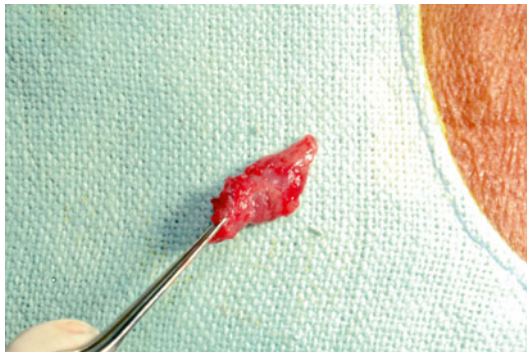

Fig. 34.15 Lacrimal sac for histopathological examination

Histopathology

All samples of lacrimal sac should be examined grossly (Fig. 34.15) to look for any unusual features like any mass, unusual discoloration, diverticulas, and partly missing walls, before sending for a histopathological analysis. In case of lacrimal sac tumors, the margins of the extended dacryocystectomy are studied separately to comment on tumor infiltration and this has significant bearing on further treatment. Lacrimal sacs removed for nontumor indications are also important since a lot of information on chronic inflammatory changes and specific granulomatous disorders that may have been undetected preoperatively can be studied and the information utilized for further management [4, 6]. Recently, there has also been a lot of interest to look into lacrimal drainage-associated lymphoid tissues and its derangements in chronic dacryocystitis [14].

Complications

Complications following a dacyrocystectomy are rare. Inadvertent injury to the angular vein may cause profuse bleeding. This can easily be avoided if incisions are not on the site or in close vicinity of angular vein. Other complications include wound dehiscence, wound infection, increased tear meniscus and epiphora, recurrent dacyrocystitis secondary to remnant sac, and a prominent facial scar.

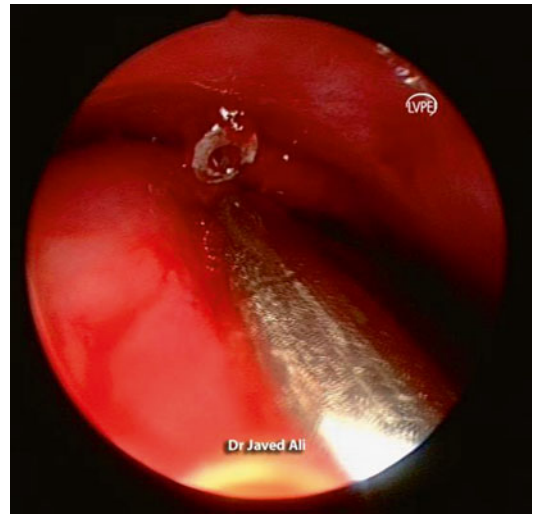

Fig. 34.16 Endoscopic CDCR

Although very rare, two cases of retrobulbar hematomas causing visual loss and one case of orbital cellulitis following a dacryocystectomy have been reported [1, 11]. The possible cause could be violation of periorbita and orbital septum during the surgery, which may result in orbital hemorrhage and hematoma and consequent optic nerve compression and visual loss. In the eventuality of a vision-threatening hematoma, standard protocols for managing a retrobulbar hemorrhage should be followed.

Lacrimal Rehabilitation

Numerous options have been described in the literature for managing epiphora following a dacryocystectomy. The most commonly practiced option is a conjunctivo-dacryocystorhinostomy (CDCR) using either the Jones tubes or Gladstone–Putterman tubes (Fig. 34.16) [15]. A canaliculo-dacryocystohinostomy has been described in cases where the entire canaliculi are normal with absence of sac following a dacryocystectomy [16]. Occasional cases where a remnant sac is suspected, a regular dacryocystorhinostomy has been described [16]. Botulinum toxin injection into the lacrimal gland to manage epiphora following a dacryocystectomy is still not a well-established or widely practiced procedure.

Conclusion

In conclusion, although dacryocystectomy is a sparingly used lacrimal surgery, it has its own specific and relative indications. Extended dacryocystectomy is a very useful and life-saving surgery in lacrimal sac tumors. It also appears to make sense to perform a dacyrocystectomy in recurrent dacryocystitis in patients with dry eye or certain systemic comorbidities. The surgery is technically easier with a quick learning curve and should be taught to ophthalmology residents and Oculoplastics fellows.

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Debates in Dacryology: The Ostium Dilemma

35

Andrea Zarkovic, Edwin C. Figueira, Simon N. Madge, Marcus M. Marcet, and Dinesh Selva

Intraoperative and Postoperative Ostium: Does Size Matter?

One of the commonest causes of dacryocystorhinostomy (DCR) failure is the closure of the ostium due to healing of the mucosal edges, formation of synechiae, or presence of granulation tissue [1]. Another postulated cause of failure is the sump syndrome where a remnant of the inferior lacrimal sac acts as a nondraining reservoir [2]. These complications can be minimized by creating an adequately sized and appropriately placed ostium.

The ideal dimensions for the bony ostium in DCR remain unclear. Many authors believe the ostium should be long enough to allow opening of the entire lacrimal sac from the fundus to the junction with the nasolacrimal duct. It should be wide enough to allow creation of lacrimal sac flaps that lie apposed to the nasal mucosal flaps to promote primary intention healing. Similarly, complete marsupialization of the sac into the lateral nasal cavity is thought to achieve the lowest rate of ostial closure [3–5]. Others accept a smaller opening of the sac with a correspondingly smaller bony ostium.

Argin et al. attempted to define the exact dimensions for a bony ostium in the belief that creation of a large ostium will prevent closure [6]. Ben Simon et al. found a positive correlation between intraoperative osteotomy size and postoperative ostium measurements [7]. In contrast, other studies reported that the initial ostium size does not necessarily correlate with the final size [8–10]. Many authors also found that the intraoperative and final ostium size were not predictive of success [7, 8]. However, Ezra et al. observed a correlation between ostial size at 2 weeks and a successful outcome [9].

In a prospective study of 161 endoscopic DCRs where the entire sac was marsupialized, Chan and Selva found the majority of ostial shrinkage occurred within the first 4 weeks. The average ostial measurement 12 months postoperatively was 64.7 % of the initial bony osteotomy [8]. In another prospective study of 49 endoscopic DCR procedures, Mann and Wormald showed very similar results with the ostium measuring 77 % of the intraoperative size after 4 weeks and very little change after that [11]. Similar results have been observed for external DCR [7, 9, 10].

A. Zarkovic, FRANZCO
S.N. Madge, FRCOphth
Department of Ophthalmology,
Wye Valley Trust, NHS, Hereford, UK

E.C. Figueira, FRANZCO
Ophthalmic Plastics Surgery,
Royal Adelaide Hospital, Adelaide, SA, Australia

M.M. Marcet, MD
Department of Ophthalmology,
University of Hong Kong, Cyberport, Hong Kong

D. Selva, FRANZCO (✉)
Ophthalmology and Visual Sciences,
University of Adelaide, Adelaide, SA, Australia
e-mail: saioph@gmail.com

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Ostium and Anatomical Variations

Some patients have features that make the endoscopic DCR surgery easier, such as a large lacrimal sac, thin lacrimal bone, small middle turbinate, posterior uncinate process, or an internal common opening that is situated more inferiorly in the lacrimal sac. Others have more challenging anatomy, for example, small lacrimal sac, thick frontal process of the maxilla, ethmoidal air cells significantly overlying the lacrimal sac, or a high internal common opening, which may predispose them to a higher failure rate [12]. Konuk identified large middle turbinates and severe septal deviation as causative factors in 14 % of failed cases [13].

Planning the best location and size of the bony osteotomy in endonasal DCR is dependent on awareness of the variations in anatomical landmarks of the lateral nasal wall. The most commonly used landmarks are the maxillary line and the axilla of the middle turbinate [14]. Based on cadaveric dissections, Orhan found that the maxillary line overlapped the lacrimal sac in 18/20 cadaveric specimens and that the lacrimal sac was located posterior to the maxillary line in the other two specimens [15]. However, Ali et al. [16] in their cadaveric study found that the spatial relationship of maxillary line and head of middle turbinate is not constant and hence should not be solely relied upon during surgery. There is also considerable variability in the location of another important landmark, the lacrimo-maxillary suture (LMS). Shams et al. found that the LMS was centrally located in the fossa in 25 % of Caucasian orbits, while in 32 % of orbits it was located closer to the posterior lacrimal crest indicating predominance of the thicker maxillary bone [17]. In contrast, a study of Indian orbits noted a centrally located LMS in 79 % of specimens and a maxillary dominant fossa in only 8.3 % [18]. A study based on CT findings in Asian orbits found that the lacrimal fossa was formed predominantly by the frontal process of maxilla in 79 % of patients [19].

Factors Affecting Wound Healing and Soft Tissue Ostial Size

Factors other than the size of the bony osteotomy may also affect the ultimate size of the ostium. Studies have shown that in cases of failed surgery due to osteotomy closure, healing occurs predominantly by fibrosis with very little new bone formation [20]. Especially in adults, bone growth would not be expected across a mucosal anastomosis or in the absence of periosteum, which is removed during surgery.

Once an ostium is created, the mucosal and bony edges will trigger an inflammatory response. The extent of the inflammation depends on the size of the defects between the raw edges and the individual's innate healing response. While it seems intuitive that approximation of mucosal edges would lead to less granulation and scarring, several authors have described comparable success rates regardless of the number of created flaps [21–23]. Khalifa et al. conducted a prospective randomized controlled trial comparing endoscopic DCR with double posteriorly based nasal and lacrimal flaps to a technique in which the nasal and lacrimal mucosa are removed without creation of flaps. Although there was a better healing profile with fewer debridement sessions in the double flap group, this did not lead to a statistically significant increase in success rate (92 % vs. 87 %) [21]. However, several authors reported anatomical patency rates of more than 95 % in endoscopic DCR with the double flap technique, which allows complete marsupialization of the lacrimal sac into the lateral nasal wall [8, 24]. For external DCR, comparable success rates were achieved between groups where both anterior and posterior flaps were sutured and groups where only the anterior flaps were sutured and the posterior flaps were left either unsutured [25] or were excised [26]. Baldeschi et al. compared different patterns of mucosal dissection resulting in different number and extent of unsutured mucosal margins in external DCR. They found that the length of the margins did not adversely affect the success rate [27].

Anatomical variations in the lacrimal fossa and location of ethmoidal air cells mean that the apposition of mucosal edges may be achieved with different flap designs in different individuals. One may postulate that mucosal apposition rather than a standardized flap design may influence healing and hence the success rate. Despite the lack of evidence regarding the need for mucosal apposition, it is the authors' preference to achieve apposition where possible to minimize secondary intention healing and the associated fibrosis.

Modulation of Wound Healing and Influence on Ostium Size

Numerous studies have evaluated the antifibrotic properties of adjunctive Mitomycin-C (MMC) in an attempt to modulate the healing process during the initial stage of soft tissue granulation and thereby reduce the rate of anatomical failure.

Studies comparing the postoperative osteotomy size have found significantly larger ostia in patients treated with intraoperative MMC compared to control group both for external [28] and endoscopic DCR [29, 30]. A recent meta-analysis suggested that intraoperative MMC application may reduce the closure rate of osteotomies and enhance the success rate in external DCR [31] and both primary and revision endo-DCR [32]. However, several studies have failed to show any beneficial effect [33–36] No adverse effects from MMC were found in any of the DCR studies.

MMC dosage has ranged between 0.2 and 0.5 mg/ml and the exposure time from 2 to 30 min [32, 37]. Ali et al. [38] in their in vitro study attempted to address this issue and found that a concentration of 0.02 % for 3 min was the right dose. The MMC is generally applied topically but circumostial injection can also be used [39]. In their randomized controlled study, You and Feng found no significant difference in patency rate and ostium size between the groups receiving topical MMC in concentrations of 0.2 or 0.5 mg/ml and both groups had better outcomes compared to the control group [36]. In contrast, intraoperative or postoperative use of 5-Fluorouracil does not appear to influence the ostial size or the success rates [40, 41]. Wu et al. reported significant improvement of ostial patency for endoscopic DCR with use of Merogel, a hyaluronic acid derivative thought to promote epithelial healing and reduce scarring but there have been no other studies with this agent [42].

Surgeons have also utilized steroids both topically and in the form of injections into the tissue adjacent to the ostium but again there remains no evidence base on the effect this might have on patency rates.

Conclusion

There is currently no consensus on optimum bony ostium size. We advocate a bony ostium that enables full exposure of the sac and complete marsupialization with flap apposition to promote primary intention healing. At present, no strong evidence exists that the use of wound modulators improves success rates. However, such agents can be considered in the context of a possible higher risk of ostial closure such as in revision DCR [43].

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Debates in Dacryology: The Mitomycin-C Dilemma

36

Yi-fan Feng

Introduction

The most common reason for the failure of dacryocystorhinostomy (DCR) surgery is the formation of scar or granulation tissue over the osteotomy site. From the literature, it is clear that fibrous tissue growth, scarring, and granulation tissue formation during the healing process will decrease or compromise the created surface area of the osteotomy site, leading to surgical failure [1, 2]. Also, the healing process has the potential to promote adhesion of the osteotomy to the middle turbinate and septum, or induce obstruction of the common canaliculus [3]. Thus, if we can inhibit fibrous tissue growth and scarring by applying anti-proliferative agents over the anastomosed flaps and osteotomy site, the failure rate may be minimized [4].

Mitomycin-C (MMC) is an antibiotic isolated from *Streptomyces caespitosus*. It has a molecular weight of 334 Daltons and is soluble in water and organic solvents [5]. MMC contains quinone, carbamate, and aziridine groups, all of which may contribute to its activity. The drug is a bioreductive alkylating agent that undergoes metabolic reductive activation, and has various oxygen-tension-dependent cytotoxic effects on the cells, including the cross-linking of DNA [6]. Although DNA alkylation can occur at any stage in the cell cycle, the biological consequences are most severe during DNA synthesis. In addition, inhibition of RNA and protein synthesis is a nonspecific mechanism of cell toxicity. Furthermore, under aerobic conditions, as occurs predominantly in ophthalmic use, intermediates react with molecular oxygen to generate free radicals, causing cytotoxicity via lipid peroxidation, and, subsequently, DNA and protein damage [5].

MMC is primitively used systemically for the treatment of malignancies and has gained popularity as a topical adjunctive therapy in ocular and adnexal surgery over the past two decades. Now, MMC is used as anti-scarring agent in a wide range of ocular surgeries and laser-assisted procedures, including glaucoma filtering surgery [7, 8], pterygium surgery [9, 10], corneal refractive surgery [11], and lacrimal surgery [12, 13]. In this chapter, we will focus on the application of MMC in Dacryocystorhinostomy.

Experimental Evidence

Normal wound healing is a complex cascade of events involving multiple cell types and their products, including growth factors and chemokines. The fibroblast is the key player in the scarring response; among its crucial functions are proliferation, extracellular matrix (ECM) production, and contraction and migration. Many of

Y.-f. Feng, MD, PhD
Department of Ophthalmology, Zhongshan Hospital and Fudan University, Shanghai, China
e-mail: wzafengyifan@163.com

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these functions are under the control of growth factors and the specific receptors through which they elicit their effects. For example, exposure to MMC resulted in an increased production of transforming growth factor β (TGF-β) and basic fibroblast growth factor (bFGF), decreased number of receptors for TGF- β, bFGF and epidermal growth factor (EGF), as well as type I collagen and fibronectin production, and cellular migration were reduced, thereby influencing wound healing [14].

A series of basic studies have been performed to investigate the effect of MMC exposure to Tenon's capsule fibroblasts and confirmed suppression of Tenon's capsule fibroblasts by MMC [15–17]. However, studies on human tenon's fibroblast cannot entirely be extrapolated since the application of MMC in DCR is to the nasal mucosa. To date, only two published studies were performed to observe the effect of MMC on cultured human nasal mucosa fibroblasts [18, 19]. Hu et al. [18] reported that higher doses and longer exposures resulted in higher rates of growth suppression with a maximal effect of 31.3 % suppression following 5 min exposure with 0.4 mg/ml of MMC. Of note, normal regrowth occurred within 2–3 days and complete confluence was observed after 5–7 days. More recently, the results in another fundamental study by Ali et al. [19] indicated that 0.4 mg/ml MMC beyond 5 min and 0.5 mg/ml concentration at all time points were lethal and caused extensive cell death. They suggested that the probable optimal MMC treatment for preventing cell proliferation of human nasal mucosal fibroblasts in vitro by inducing cell cycle arrest, without causing extensive cell death, is 0.2 mg/ml when used for 3 min [19].

A few studies have investigated the effects of MMC on sinonasal tissue in a rabbit model of maxillary sinus antrostomies and attempted to provide further evidences for the MMC applications. Ingrams et al. [20] investigated the effects of 5 min applications of varying doses of MMC to surgically created maxillary antrostomies in a rabbit model. Their results demonstrated improved rates of ostial patency with increasing doses when compared with the control side. Additionally, return to normally ciliary function was demonstrated in all MMC-treated sides including those that received doses considered cytocidal (1.0 mg/ml) to fibroblasts. Their results were supported by a similar study by Rahal et al. [21] that demonstrated a significantly higher rate of ostial patency in the MMC-treated side with normal re-epithelialization at the time of animal sacrifice. Kavuzlu et al. [22] investigated the effect of the topical use of MMC intraoperatively in single dose versus two doses (intra- and postoperatively) on the narrowing of antrostomy in maxillary rabbit sinus antrostomies created experimentally. Animal sacrifice at 8 weeks revealed that the antrostomy areas were significantly larger in the two-doses group than the single-dose group. Unfortunately, there was no study directly to investigate the effects of MMC in the animal model of DCR surgery.

The collective evidence as detailed in the preceding supports the dose-dependent, suppressive effects of MMC on fibroblast activity. Given the critical role of fibroblasts in scar formation, these studies highlight the potential for MMC to modulate postoperative wound healing in DCR surgery.

Clinical Evidence

The cumulative basic science foundations and clinical experience in other disciplines have prompted clinical trials investigating the efficacy of MMC to decrease scar formation following DCR in humans and numerous clinical studies have been published in this regard [12, 13, 23–47]. In DCR surgery, the most familiar way is to soak MMC over the osteotomy site and the anastomosed flaps. This modification should theoretically reduce the fibrous adhesion between the osteotomy site and the nasal septum as well as inhibit scarring around the opening of the common canaliculus, which prevents further shrinkage of the final surface area of the osteotomy and obstruction of the common canaliculus opening.

Multiple issues require resolution prior to determining the role of MMC in DCR, including safety and efficacy. To date, there have been no complications directly associated with the use of MMC following DCR surgeries. Both systemic and local complications, however, have been described in other fields. This is because of its

prolonged cytological toxicity. Myelosuppression following the use of MMC results from systemic absorption and would be unlikely when used in topical form. Local complications have been described in ophthalmologic applications including ulceration and epithelial toxicity. Some complications such as corneal ulcer, corneal perforations, scleral thinning, secondary cataract, endophthalmitis, hypotony, and maculopathy have been reported from the use of MMC in pterygium and glaucoma surgery [23, 24]. Differentiation of normal postoperative healing from local complications due to MMC can only be determined with endoscopic surveillance of the ostium.

More and more prospective, randomized studies have attempted to determine the efficacy of MMC following DCR in humans (Table 36.1). In the first randomized controlled study, Kao et al. [25] reported the use of MMC in a series of 14 patients who underwent DCR with and without MMC. At 6-month follow-up, osteotomy size was significantly larger in patients in whom MMC was used compared with controls. These findings were supported in subsequent studies which showed an increase in both ostium size and patency with the use of MMC during external DCR [26] and endoscopic DCR [27]. These studies revealed that MMC can minimize postoperative fibrosis and granulations, thereby maintaining a bigger postoperative ostium throughout the postoperative observation period [28]. With the popularity of evidence-based medicine, separate meta-analyses on the efficacy of MMC both in external and endoscopic DCR have been performed more recently and demonstrated it to be not only a safe adjuvant but was also useful in decreasing the osteotomy closure rates [12, 13, 29, 30]. Meta-analyses also found MMC to enhance the success rates of both primary and revision endoscopic DCR [12, 13, 29, 30].

Dilemmas and Challenges

As described earlier, the preliminary basic science evidence, in addition to the ophthalmology experience, provides theoretic support for the use of MMC in DCR. Although the anti-proliferative effect of MMC was proven both in cell cultures and animal studies, it could not be demonstrated in clinical studies that the use of MMC following DCR influenced healing significantly. A discussion of the possible reasons behind these results is critical for improved protocol designs for future studies.

Firstly, while MMC has been used extensively in DCR surgery, the appropriate concentrations and treatment durations have not been standardized. However, wound healing in the postoperative ostium is a complex series of events mediated by several cell types and occurs over a period of 6–8 weeks [31]. Modulation of this process by MMC would require a prolonged effect that may not be possible with a single intraoperative application. Therefore, it may be worth noting that new treatment schemes should be developed, such as the use of MMC intra- and postoperatively in two separate applications as shown by Henson et al. [32]. Similarly, given the dose-dependent activity of MMC on fibroblasts demonstrated in basic science studies, clinical application would require an adequate dose for an adequate period of time. It is possible that higher doses of MMC and/or longer exposure times of MMC may be required following DCR surgery than in other applications because it may be diluted with the bleeding and irrigation that occurs postoperatively [31]. For exactly this reason, Ali et al. [33] have proposed a new technique of injecting MMC circumostially and their 1-year data in DCR are encouraging.

Secondly, the question remained unanswered whether MMC application can reduce scarring and enhance the success rate in presence of confounding effects of silicone intubation. To prevent obliteration of the intranasal lacrimal sac ostium, many surgeons prefer to insert either bi- or monocanalicular silicone tubes to stent the internal ostium. However, it has been postulated that silicone tubing itself may cause tissue granulation, predisposing the site to postoperative infection and adhesions, and canalicular lacerations, resulting in surgical failure [34]. Thus, some surgeons suggested the use of MMC to suppress fibrous proliferation and scar formation during DCR surgery along with silicone intubation. Further studies are needed to discuss

Table 36.1 Comparison of randomized controlled studies on dacryocystorhinostomy with intraoperative Mitomycin C (MMC)

First author/year	Surgical technique	Type of DCR	MMC concentration (mg/ml)	MMC exposure time (min)	No. eyes (MMC/ control)	Follow-up (months)	Silicone tube use	Success rate (MMC vs. control)
Kao et al. (1997) [25]	EX-DCR	Primary	0.2	30	15 (7/8)	6	Yes	100 % vs. 87.5 %
Yildirim et al. (2007) [37]	EX-DCR	Primary	0.2	30	40 (20/20)	12	Yes	95 % vs. 85 %
Liao et al. (2000) [4]	EX-DCR	Primary	0.2	30	88 (44/44)	10	Yes	95.5 % vs. 88.6 %
Roozitalab et al. (2004) [38]	EX-DCR	Primary	0.2	30	130 (65/65)	6	No	90.5 % vs. 92.4 %
Yalaz et al. (1999) [39]	EX-DCR	Primary	0.5/1.0	5	40 (20/20)	12–18	No	95 % vs. 90 %
Eshraghy et al. (2011) [40]	EX-DCR	Primary	0.2	5	88 (42/46)	6–15	Yes	73.8 % vs. 69.6 %
Gonzalvo et al. (2000) [26]	EX-DCR	Primary	0.2	2	17 (9/8)	6-18	No	100 % vs. 75 %
Qadir et al. (2014) [41]	EX-DCR	Primary	0.2	5	50 (25/25)	6	No	96 % vs. 80 %
Ghosh et al. (2006) [42]	EN-DCR	Primary	0.2	2	30 (15/15)	12	No	80 % vs. 86.7 %
Prasannaraj et al. (2012) [43]	EN-DCR	Primary	0.2	10	38 (17/21)	6	No	82.3 % vs. 85.7 %
Tirakunwichcha et al. (2011) [27]	EN-DCR	Primary	0.5	3	50 (26/24)	12	Yes	84.6 % vs. 79.2 %
Farahani et al. (2008) [44]	EN-DCR	Primary	0.2	3/15	92 (46/46)	12.17/12.80	Yes	91.3 % vs. 87 %
Penttilä et al. (2011) [45]	EN-DCR	Revison	0.4	5	30 (15/15)	6	No	93 % vs. 60 %
Özkiriş et al. (2012) [46]	EN-DCR	Revison	0.5	5	36 (18/18)	11.5/12.7	Yes	88.9 % vs. 55.5 %
Ragab et al. (2012) [47]	EN-DCR	Revison	0.5	10	76 (38/38)	12	Yes	82.9 % vs. 80.6 %

whether adjunctive MMC application during silicone intubation has additional benefit over silicone intubation alone.

Lastly, despite apparently higher rates of success with no significant complications using MMC in adult lacrimal surgery, similar studies are scarce in pediatric DCR surgery. In a prospective, large case series study, Dolmetsch et al. [35] showed nonlaser endonasal DCR with MMC was a safe and successful procedure for the treatment of congenital nasolacrimal duct obstruction in children. Young patients (especially children) may present with a failure of lacrimal drainage procedures on account of an overwhelming healing response [36]. Given that the management and indications for MMC in DCR surgery are different in young patients and adults, more data are needed to draw definitive conclusions.

Conclusion

The successful use of MMC in ophthalmology and increasing use in otolaryngology have spurred interest in its use following lacrimal surgery. Although animal and clinical studies support its use in DCR surgery, overall evidence is actually lacking. The major criticism for using MMC in the nose, particularly with DCR, is the short-term effect noted. There are still many issues that remain to be addressed, including perhaps the most important one: efficacy versus safety. In the future, large randomized studies are required prior to definitive conclusions regarding the use of MMC in DCR surgery.

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Debates in Dacryology: The Intubation Dilemma

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Edwin C. Figueira, Andrea Zarkovic, Simon N. Madge, Marcus M. Marcet, and Dinesh Selva

Introduction

The use of stenting in dacryocystorhinostomy (DCR) for primary acquired nasolacrimal duct obstruction (PANDO) in the absence of canalicular disease is controversial. There is no definitive evidence to support the routine use of intubation in DCR for PANDO [1–3]. Advocates for stenting report an increased patency rate, due to presumed maintenance of canalicular and ostial patency [4, 5]. However, recent meta-analyses have not found a significant benefit from routine intubation. In addition, there are reports of a higher failure rate in DCR patients who had routine intubation for PANDO [6]. It has been suggested the higher failure rates are possibly a result of intubation-related granulomatous inflammation. Stenting of the nasolacrimal system is also associated with complications including punctal erosion and "cheese-wiring" of the canaliculi [7].

Rationale for Intubation

Maintaining Canalicular Patency

The primary rationale used by many surgeons who perform routine intubation during DCR for primary acquired nasolacrimal duct obstruction is that it maintains patency of the common canalicular opening into the sac, preventing closure from inflammation or intraoperative trauma [2, 8–10]. It may also play a role in treating any undetected canalicular stenosis [8].

Prevention of Ostial Closure

An alternate reason for intubation that can be gathered from papers studying the DCR ostium is that the tubes maintain the ostium from the sac to the nose, probably acting as a guard against fibrosis [11–13]. Some surgeons also selectively intubate in scenarios where they believe there may be a higher risk of anatomical failure, such as small sacs, dacryocystitis, and poor flaps in the belief that the stent will assist in maintaining patency.

E.C. Figueira, FRANZCO
Ophthalmic Plastics Surgery,
Royal Adelaide Hospital, Adelaide, SA, Australia

A. Zarkovic, FRANZCO
S.N. Madge, FRCOphth
Department of Ophthalmology,
Wye Valley Trust, NHS, Hereford, UK

M.M. Marcet, MD
Department of Ophthalmology,
University of Hong Kong, Cyberport, Hong Kong

D. Selva, FRANZCO (✉)
Ophthalmology and Visual Sciences,
University of Adelaide, Adelaide, SA, Australia
e-mail: saioph@gmail.com

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Rationale for No Tubes

Advocates against routine intubation believe there is no evidence in the literature to suggest improved anatomical patency in DCR for anatomical obstructions at either the canalicular or the ostial level. Furthermore, intubation-related morbidity such as punctal or canalicular cheesewiring, granuloma formation, nasal irritation, corneal erosions, nasal bleeds, and displacements have been reported [14]. Intubation in DCR surgery also increases the cost and the duration of DCR surgery in addition to requiring removal at a later date.

Evidence Base for Use of Intubation in DCR Surgery

The studies on behavior of the postoperative ostium has shed important light on its evolution [11, 15, 16]. Advocates supporting intubation report an increased patency rate, due to maintenance of the ostium of the lacrimal sac into the middle meatus and correction of presaccal stenosis. Older reported a success rate of 94 % with the routine use of silicone tubes in a series of 70 patients [17]. Seven years later, Rosen et al. presented a series of 253 cases with routine intubation. Although they acknowledged that their success rate was not significantly higher than that reported with other techniques, they listed some advantages of silicone intubation. They found that the surgery was easier to complete in the presence of excessive bleeding or inadvertent mucosal tears and that the suturing of anterior flaps was easier with the tubes in place. They also commented that the stent can act as a support structure for torn anterior flaps [14].

In a retrospective review of 338 DCR cases that excluded patients with common canalicular pathology, Panday and colleagues found that intubation time of longer than 6 months was associated with better outcome compared with shorter intubation times [18].

Many lacrimal surgeons have advocated "selective" silicone intubation in PANDO cases, where there is an intraoperative appearance of a tight common canaliculus [19, 20]. Other putative indications used by some surgeons include previous history of dacryocystitis, revision procedures, small sacs, narrow nasal cavities, excessive intraoperative hemorrhage, and poor mucosal flap formation [3, 21, 22].

Evidence Base Against the Use of Intubation in Routine DCR

Many recent studies comparing the surgical success of endoscopic DCR with and without silicone intubation have reported that a functionally patent DCR can be achieved without the need for routine nasolacrimal stenting [23–29].

Gu et al. [28] in their meta-analysis of endoscopic DCR and simultaneous intubation retrieved 4 trials and could appraise only 2 trials involving 84 patients that met their inclusion criteria for analysis. There was no statistically significant heterogeneity between the studies. Their analysis revealed using the fixed-effects models, that the pooled risk ratio for DCR failure in the nonintubated group was 0.85 (95 % confidence interval: 0.71–1.02). Feng et al. [30], in a meta-analysis that included five randomized controlled trials and four cohort studies, reported that there was no benefit from silicone tube intubation in primary DCR cases. However, this meta-analysis had many potential limitations, which included analysis from follow-ups of different duration (4–96 months), and inclusion of many clinical trials that were not randomized. Chong et al. [12] in a prospective randomized trial with a 12-month follow-up of bicanalicular silicone intubation in endonasal endoscopic mechanical dacryocystorhinostomy (EEM-DCR) for PANDO reported no statistical difference in the success rates between patients with (96.3 %) and without (95.3 %) intubation. The odds ratio of failure without silicone intubation was analyzed to be 1.28 (95 % confidence interval: 0.21–7.95). There was no difference in the incidence or the time taken to develop granulation tissue between the two groups of intubation and nonintubation [12].

In a single comparative study, Unlu et al. [29] described 91.7 % anatomical success in intubated cases compared to 92.3 % in their nonintubated subgroup. Smirnov et al. [27] in a 46-patient, randomized controlled, intubation versus nonintubation primary endo DCR study (absence of canalicular pathology confirmed in these cases) performed by three rhinologists reported a 100 % anatomical and functional success in the nonintubated group, in comparison to 78 % in the intubated subgroup, a difference that was statistically significant. In an another study by Unlu et al. [26] with postoperative endoscopic examination revealed that the rhinostomy opening could be visible in 89.5 % of the intubated cases and 94.7 % without intubation. Cannon et al. [31] report a single-surgeon prospective study of 163 endoscopic DCR with nonintubation cases and a zero incidence of canalicular closure at 12-months follow-up and found an anatomic patency rate of 98.5 % and a combined anatomical and functional success rate of 90.7 %.

Conclusion

There is currently no evidence basis for routine intubation in DCR for PANDO. Hence, it is the authors' belief that intubation should be limited to the setting of preoperatively or intraoperatively proven canalicular disease. However, it is acknowledged that routine intubation for DCR in the context of PANDO remains widely practiced.

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The Great Debate: External Versus Endonasal Dacryocystorhinostomy

38

Andre Litwin and Raman Malhotra

Introduction

The principles of standard surgery for blockage of the lacrimal outflow tract probably dates back 1,000 years now when the twelfth-century Andalusian Oculist Mohammad Ibn Aslam Al Ghafiqi described a small spear-shaped instrument perforating the lacrimal bone in a nasal direction "*until blood flows through the nose and mouth with care given not to direct the instrument downward as this would be the incorrect direction*." The probe was then wrapped in cotton that was either *dry or soaked in ox fat*. This would then be exchanged every day in order to maintain the patency of the created fistula [1]. This principle remains the same to date as that for contemporary conjunctivodacryocystorhinostomy. Modern dacryocystorhinostomy (DCR), however, dates back to the dawn of the twentieth century [1–4]. In terms of anatomic goals, the aims of surgery are simple: the lacrimal sac is connected directly to the nose by removal of the separating bone and mucosa. A fistula is hence formed that allows tears to pass directly into the nasal vault through the lateral nasal wall. This must occur at a level above the mechanical obstruction in order to bypass it [5]. The traditional popular method has been through an external approach as described by Toti [3] and modified by Dupuy-Dutemps [4]. Although the endonasal approach was described perhaps prior to this [2] it is only in recent decades with the introduction and development of the endoscope, that attention has turned to endoscopic DCR for both primary procedures and to revise failures [6]. DCR is indicated for patients with lacrimal sac or nasolacrimal duct obstruction (NLDO) causing either epiphora or dacryocystitis (infection).

Surgery may be performed through a cutaneous incision (*external DCR*) and although alternative ophthalmic approaches to avoiding skin scarring have been described [7, 8], the only effective alternative remains an endonasal approach. While maintaining the same principles as an external approach, endonasal DCR simply describes an approach through the nose rather than a specific technique. Many endonasal techniques exist by either direct visualization [6], or, more commonly, when viewed through an endoscope (*endoscopic DCR*). Endoscopic DCR has itself evolved over time. Endoscopic laser DCR progressed to mechanical endoscopic DCR [9] and powered endoscopic DCR. This shift toward "powered" instruments was because laser could not remove the thick bone of the frontal process of the maxilla and root of the middle turbinate, resulting in higher failure rates [10, 11]. The principles of the evolved "powered endoscopic

A. Litwin, FRCS
Oculoplastic Surgery,
Queen Victoria NHS Trust, London, UK

R. Malhotra, FRCS (✉)
Oculoplastic Surgery, Cadogan Clinic and Queen Victoria NHS Trust, London, UK
e-mail: raman@ramanmalhotra.com

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DCR" have shifted forward ("back") to mechanical DCR, aiming to achieve full sac exposure whilst still creating mucosal flaps [12, 13].

Through dissection and manipulation of tissue, there is no reason why a skilled surgeon with the right tools cannot remove the same amount of bone from either approach [14]. Until the twenty-first century, external DCR was historically regarded as the "gold-standard." However, the reported success rate of both procedures in the modern literature is now similar when compared with endoscopic procedures that remove adequate bone for full lacrimal sac exposure, marsupialization, and mucosal flap apposition [11, 15–19].

Overview of the Procedures

DCR surgery can be performed under either local or general anesthesia. If local anesthesia is to be used, infratrochlear and infraorbital nerve blocks using bupivacaine 0.5 % or lidocaine 2 % with epinephrine are administered. Anesthetic may also be infiltrated along the lateral wall of the nose at the proposed osteotomy site, and nasal packs soaked in cocaine 4 %, adrenaline 1:1,000, or a mixture (e.g., Moffett's solution) may be applied, via packing, buds, or patties.

External DCR

To perform an external DCR, a 15-mm skin incision is made medial to the medial canthus. A skin-muscle flap is formed to reveal the anterior limb of the medial canthal tendon. This is divided and the periosteum opened. The periorbita is elevated to displace the lacrimal sac and duct laterally. A 3-mm up-biting right-angled Kerrison rongeur is used to break through the thin bone of the lacrimal fossa and a bony osteotomy is formed, initially proceeding anteriorly, inferiorly, and then posteriorly. An osteotomy of at least 15 mm in diameter is created. The lacrimal sac is then probed and opened longitudinally. Any grossly suspicious mucosa should be biopsied and submitted for pathologic review. The nasal mucosa is incised in a similar longitudinal fashion, with relieving incisions at either ends forming an "H" shape. A silicone stent is inserted and tied loosely to prevent cheese-wiring of the canaliculi. The posterior lacrimal sac flap is sutured to the posterior nasal flap, typically with a single continuous 6/0 Vicryl suture. Three sutures are then used to appose the anterior nasal mucosal and anterior lacimal sac flaps. Where possible, these are suspended by attachment to the overlying orbicularis. The anterior limb of the medial canthal tendon is reapproximated and the skin is typically closed with a 6-0 polypropylene suture.

Endonasal Non-endoscopic DCR

When carrying out endonasal, non-endoscopic DCR, surgeons often utilize a 20-gauge disposable vitrectomy light pipe threaded through the upper canaliculus to guide placement of the osteotomy [6]. After decongestion, an elliptical nasal mucosa incision down to bone, centered over the transilluminated light target is made. Mucosa is stripped from underlying bone and peeled away. An osteotomy is fashioned with an attempt to rongeur sufficient bone superiorly and anteriorly to easily visualize the entire width and most of the length of the lacrimal sac and duct. Care is taken to remove sufficient bone superiorly to ensure that the target light pipe when held horizontally across the common canaliculus can be visualized tenting the lacrimal sac within the nose. A posteriorly hinged U-shaped oval flap is made and reflected posteriorly and the lacrimal system is usually intubated.

Early Mechanical Endoscopic DCR

Standard functional endoscopic sinus surgery (FESS) scopes were commonly used, in addition to keratomes, standard blades, Freers elevators, Blakesley forceps, and up-biting Kerrison rongeurs. Lacrimal probes or a light pipe passed into the lacrimal sac were often used to guide placement of the osteotomy. The nasal mucosa was incised and excised overlying the planned

osteotomy site before carrying out the osteotomy with up-biting Kerrison ronguers. The inferior two-thirds (or less) of lacrimal sac was often all that was exposed. The sac was incised and its mucosa either reflected anteriorly and posteriorly, or trimmed. Silicone tubes were passed and the nose was often temporarily packed [15, 20, 21].

Powered Endoscopic DCR

After decongestion, the nasal mucosa is usually infiltrated with 2 ml of lignocaine 2 % with 1:80,000 epinepherine using a dental syringe above and anterior to the middle turbinate. A mucosal incision with a small-angled crescent blade is made on the lateral nasal wall, 2–3 mm posterior to the maxillary line, starting 8 mm above the insertion of the middle turbinate and extending vertically down to a level just below the body of the middle turbinate. Using a number 15 scalpel blade, two horizontal incisions are made, 8 mm above the insertion of the middle turbinate and just below the body of the middle turbinate, respectively. This creates the posterior nasal mucosal flap, which is reflected using a Freer elevator, exposing the junction of the hard frontal process of the maxilla and the thin lacrimal bone. The lacrimal bone is removed off the inferior half of the sac using a Freer elevator or a forward-biting up-cutting 40° Kerrison rongeur. The frontal process of the maxilla, overlying the anterior and inferior portions of the lacrimal sac is removed and the osteotomy continued superiorly until it is no longer possible using the standard Kerrison. A burr or drill is utilized at this stage, exposing the fundus of the sac. The agger nasi air cell (the anterior most ethmoid cell) is often exposed as the fundus extends above the axilla of the middle turbinate [22].

The medial wall of the sac is then tented with a probe to ensure that all bone at least 5–10 mm above the common canalicular opening has been removed. The medial wall of the sac is incised vertically with a crescent blade to create large anterior and smaller posterior flaps. Small additional relieving incisions allow the flaps to be reflected onto the lateral nasal wall and sit "flat." Good mobility and marsupialization of the lacrimal mucosal flaps has been associated with better outcomes [23]. A silicone stent can be passed and tied loosely to protect the internal ostium.

Modern Nonpowered Endoscopic DCR with Flaps

A posterior [12] or inferiorly hinged [13] nasal mucosal flap is formed along the frontal process of the maxilla. The mucosal flap (which will form the anteriornasal mucosal flap) is elevated using a Freer elevator, maintaining the tip of the elevator on the bone, reflecting it out of the surgical field. The technique proceeds the same as powered endoscopic DCR until the osteotomy can no longer be continued superiorly using a standard Kerrison rongeur. A modified bone nibbler may be used at this time to aid bone clearance at the fundus of the sac [13].

Considerations for Both Approaches

The goal of DCR surgery is to create a functioning fistula, by means of adequate bone removal to allow the lacrimal sac to be fully marsupialized into the lateral nasal wall. Primary intention wound healing of all mucosa should be the aim. Trauma to adjacent tissues should be avoided to minimize the scarring response and reduce the risk of closure of the *soft-tissue ostium* (the entire marsupialized lacrimal sac when viewed endonasally) or the internal ostium of the *common canaliculus*.

Anatomic Factors

In order to achieve an absolute cure, a large fistula between the lacrimal sac and the nose is required leaving the canaliculi as the only zone of residual tear resistance [24]. It is generally agreed that exposure of the inferior and superior parts of the lacrimal sac should be accomplished, usually requiring an osteotomy of at least 15 mm, even

approaching 20 mm [22, 24, 25]. Whether the new *soft-tissue ostium* of the entire marsupialized lacrimal sac remains stable in size beyond the first few postoperative weeks is unclear. It appears to reduce a small amount, with one endoscopic study measuring an average *soft-tissue ostium* size 12 months after surgery of 10.1 by 6.6 mm [26]. This is most in keeping with our own experience. Some have suggested that the *soft-tissue ostium* may shrink by 50 % at 6 months or even smaller [27, 28]. Others have found no significant relationship between *bony ostium* size and outcomes of surgery [23].

Biological (Healing) Factors

The main cause of failure in DCR surgery is fibrosis of the intranasal soft-tissue ostium, both in external DCR and endonasal DCR [11]. For the surgery to be successful, the mucosa of the lacrimal sac must anastamose to the nasal mucosa with the fistula remaining patent. The natural response from a surgical insult means granulation tissue can grow over the surgical ostium, rendering the procedure a failure. In successful surgery, once the lacrimal and nasal epithelium have healed together, the signal for secondary intention healing is turned off [14]. In a recent article looking at 20 failed DCRs, all had rhinostomy sites that were closed with fibrous tissue. None had canalicular or common internal ostium obstructions before undergoing revision surgery [29]. Presuming we should aim for anatomic surgery, we can maximize the success of DCR surgery by any means that helps tip the balance toward primary intention healing of the mucosa and away from secondary intention granulation [14]. The benefits of anatomic surgery may be difficult to prove, with many studies comparing different techniques or simple flap removal, but the concept should be sensible to any contemplative surgeon. Many authors have found that creation of mucosal flaps does not seem to increase the success rate of endoscopic DCR and can be technically challenging or time-consuming [5]. Others have described successful results with simple flap removal [30, 31]. It is only when endonasal DCR began to emulate the approach of external DCR that success rates improved [22].

Intubation

The evidence base either in favor of or against the practice of routine intubation remains lacking [32]. Certainly, in experienced hands it does not appear to be necessary to intubate every patient, but until very recently, the majority of surgeons still routinely did [18, 32–35]. Silicone tubes are inserted with the aim of reducing the risk of fibrosis of the internal ostium of the *common canaliculus* while epithelial migration and repair takes place. In the absence of definitive canalicular disease, there is no clear evidence that intubation in routine DCR is superior to nonintubation. In the setting of canalicular disease, nonintubation may not be appropriate [36]. Other situations prompting intubation, but for which evidence is also currently lacking, include previous acute dacryocystitis, poor flap creation, revision surgery, excessive bleeding, inflammatory disease, and small lacrimal sacs [32].

Mitomycin-C (MMC)

A retrospective study has attempted to compare surgical outcomes in a group of 48 endonasal laser DCR procedures without MMC to outcomes in a group of 123 consecutive procedures in which MMC (0.5 mg/ml) was applied to the intranasal ostium for 5 min. The success rate in the MMC-treated group was statistically significantly greater than that of the controls (99 % vs. 90 %) [37]. Assessment of outcomes with or without MMC further blurs true differences. MMC cannot always deliver success from a poor procedure and should not be regarded as the solution for poor primary surgery. “The MMC Dilemma” chapter in this volume has analyzed in depth the usefulness of MMC in DCR surgery.

Time Taken to Perform Surgery

It may be fair to say that in experienced hands, there is no significant difference in the time taken to perform a successful DCR. Any technique that inadequately removes bone and incompletely excises mucosa would be faster, hence endoscopic laser DCR is arguably the quickest surgery [21].

Efficacy

Success rates for external DCR have historically been quoted as over 90 % [38], and often over 95 % [11, 16]. These high success rates are similar for both anatomical patency and resolution of patient symptoms. Early mechanical endoscopic DCR could not match these figures: in an early series of 123 patients, 83 % success was reported [39]. Subsequent smaller series claimed to have improved upon this (86–100 %) [40, 41].

Due to the perceived inferiority and technical complexities of endoscopic DCR, it remained unpopular with Ophthalmologists when compared to external DCR [42]. The development of surgical lasers was thought to hold the key, as a less invasive form of lacrimal surgery that would improve success. Despite early promise (100 % success in ten patients) [43], it became accepted that success was still lower than conventional surgery (77–83 %) [42, 44]. The high failure rate of endoscopic laser DCR was attributed to scarring (nasal and medial lacrimal sac mucosa was excised or obliterated) and the small size of the bony osteotomy. It is not possible to remove the thick bone of the frontal process of the maxilla with most lasers, leading to a small and inadequate osteotomy [45]. This led others to focus on mechanical means of creating a larger osteotomy, with slightly greater success (86 %) [46, 47].

Modern endoscopic DCR respects anatomic surgical principles key to all successful DCR surgery. A large osteotomy is created with preservation of mucosa so that flaps can be fashioned to achieve a mucosal anastomosis with the lacrimal sac, minimizing secondary intention healing and scarring response [22]. Endoscopic anatomical success could finally be achieved and replicated at other centers in 95 % (or more) of cases [10, 13].

Long-term analyses have reported 91 % success with external DCR (437 cases, average follow-up 71 months) [48]. Long-term studies of endoscopic DCR describe 82–94 % success (108 and 165 cases, average follow-up 49 and 92 months) [49, 50]. Grouping endoscopic DCR as a single entity, one can see is unhelpful. It does not distinguish between types of endoscopic techniques, nonstandard osteotomy, or flap formation. There are many individual variations. Published success rates, therefore, do not allow direct comparison of techniques. Success itself is a loosely applied term. Subjective dependence on symptoms is unreliable and some early papers based their outcomes on this [36]. It is rare for symptoms to completely resolve in elderly patients, yet these papers report a high level of symptom "resolution."

Attempts to be more objective by incorporating syringing into the assessment, does not necessarily provide a straightforward "black or white" success or failure. Syringing is not physiological and papers that report "obstructed" or "completely patent" may either have excluded those with a small (10–20 %) degree of regurgitation on syringing or are ignoring subtleties before or after surgery. Other objective tests such as fluorescein dye retention testing or functional endoscopic dye test have been inconsistently utilized. Patient selection is not standard. It is easy to offer and predict a good outcome for patients with complete obstruction, but less so for those with partial obstruction, canalicular disease, or that *overused* and *loosely defined* term, the group with "functional epiphora." [51] The lack of agreed or standardized outcome measures or even duration of follow-up, highlights how difficult comparisons actually are.

Resolution of mucocele or dacryocystitis is the probably the only true outcome measure that is absolute and not relative. The symptoms and findings of stenosis lie more along a spectrum. The most practical measure of success is the control of symptoms, although this can be at odds with anatomic outcome [24]. Should we therefore be purists and ignore symptoms as a marker of success? Is this defying the initial indication and aim of surgery?

Comparative studies have tried to tackle some of these inconsistencies but often failed to demonstrate a significant difference between techniques [19]. This is not surprising, considering to adequately power a study seeking a 5 % difference (e.g. 90 % vs. 95 % success), a sample size of approximately 900 patients would be required [52]. Of the published studies, anatomic success of endoscopic DCR has therefore been found to be similar to that of external DCR (97 %) [11], although occasional comparative series have suggested higher success rates for endonasal DCR [5].

This means we are left with other ways of deciding where the role of external and endoscopic DCR lies.

Advantages of External DCR

External DCR is an ideal option for elderly patients not suitable for general anesthesia. Although many centers perform endoscopic DCR under local anesthetic with sedation, there is valid concern that sedation reduces or dampens the gag reflex and raises the risk of aspiration during the procedure.

External DCR avoids potential need for a septoplasty in patients with narrow nasal passages. An external approach allows lacrimal sac masses to be biopsied prior to osteotomy and may also be preferred if there is previous fracture with abnormal bone anatomy [53].

In patients with proximal or mid-canalicular disease, external DCR has an obvious advantage, allowing for retrograde intubation. This will alleviate or reduce epiphora in the majority of patients and could also spare a proportion of patients from requiring Jones canalicular bypass tubes [54].

Disadvantages of External DCR

Risks common to all forms of DCR surgery include bleeding, wound infection, and damage to the lacrimal punctae by silicone stents. Cerebrospinal fluid leaks occur exceedingly rarely in DCR, with only a few case reports in the literature [55].

Noticeable scar is a potential complication unique to external DCR. In a survey of 263 patients who underwent external DCR, visible scars were reported by 19 %, with 10 % describing their scars as cosmetically significant [56].

Damage to the facial nerve during external DCR is also a proven risk [57]. This complication is likely to be caused by an insult to peripheral fibers of the zygomatic and buccal branches of the facial nerve as they course in the medial canthal area and provide innervation to the upper eyelid orbicularis muscle in a subset of individuals. Amongst a cohort of 215 patients, 7 % demonstrated abnormalities of eyelid closure (lagophthalmos or hypometric blink), 20 % of which were permanent [57]. This risk should be included when counseling patients as to which approach is suitable.

Advantages of Endoscopic DCR

Advantages of endoscopic DCR include the absence of any skin incision and lack of significant trauma to orbicularis. This results in a faster soft-tissue recovery, with preservation of the lacrimal pump mechanism. It also allows nasal or paranasal sinus abnormalities to be addressed at the same time (e.g., septoplasty may be of help where patients have problems breathing through one side of the nose) [50].

In the setting of dacryocystitis, endoscopic DCR offers rapid resolution of symptoms, converting an anaerobic abscess cavity into an aerobic cavity through noninfected tissue planes with associated drainage and long-term control of epiphora [45, 58, 59].

Given a common cause for failed DCR is formation of membranous scarring at the internal ostium (at the common canalicular opening), it appears to make logical sense that the most direct means of addressing this problem would be endoscopically. Good success rates have been safely demonstrated through both endoscopic and external approaches [29, 60, 61].

Disadvantages of Endoscopic DCR

Risks of endoscopic DCR surgery include damage to the nasal mucosa with adhesion formation, orbital fat prolapse, and rarely a potential damage to the medial rectus muscle. The latter complications would only occur where a surgeon mistakenly loses orientation of the location of the sac and operates posterior to it. This is a risk for any procedure that removes bone behind the sac and inadvertently breaches the periorbita.

A historic disadvantage of endoscopic DCR is the suggestion that biopsy of the lacrimal sac is not achievable. Although the rate of unsuspected sac tumors is low [62, 63], it is possible to take a sac biopsy (or nasal mucosal biopsy) when performing an endoscopic DCR [11]. Blakesley or

fine nasal biopsy forceps can be used to submit nasal or lacrimal mucosa to pathology, and dacryoliths or pus can also be sent for culture [6].

Conclusion

Despite recent acceptance of equivalent success between external and endoscopic DCR, more surgeons still prefer and perform greater numbers of external procedures, whilst reporting higher success rates [64]. Is the tide turning amongst Ophthalmologists? Approaches to DCR surgery may no longer represent such a great debate, but a division of experience and training between generations of surgeons!

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39 Quality of Life in Lacrimal Disorders and Patient Satisfaction Following Management

Mohammad Javed Ali

Introduction

Lacrimal disorders need not necessarily always have only a physical or a functional dimension, there may be emotional, social, and economic or a combination of these aspects to them. Understanding the different facets of patient and the caregiver's perspectives of the disease before and after medical or surgical interventions contributes significantly to overall patient satisfaction. Rather than objective anatomical outcomes of a surgery alone, patient satisfaction is what all surgeons should ideally aim for. It is in this context that the validated quality of life (QOL) questionnaires help the health-care providers. They are also a very useful tool for clinical research and standardization of outcomes.

CNLDO: Patient and Parental Quality of Life

Congenital nasolacrimal duct obstruction or CNLDO is the commonest pediatric lacrimal disorder that affects up to 20 % of newborns with spontaneous resolution in a vast majority [1]. The symptomatology or the success rates have been largely assessed using isolated elementary questionnaires that included both parental perception and examinations [2, 3]. Holmes et al. [4] published a novel and comprehensive parental questionnaire addressing symptoms and health-related QOL in CNLDO. The questionnaire included 17 questions with the first 3 questions having 4 subtypes each. All the questions were evaluated on 5 parameters (always, often, sometimes, rarely, and never) with scoring for each parameter. The questionnaire is briefly listed in Table 39.1. Holmes et al. [4] enrolled 87 children, 56 with

Table 39.1 Brief Holmes questionnaire for CNLDO

1. Tears "well up" in my child's eye(s) (Has 4 subtypes and 5 parameters to score).
2. Tears run down my child's cheek.
3. My child has gunk in the corner of the eye(s).
4. My child's eye(s) looks glassy.
5. The skin around my child's eye(s) is red.
6. My child's eyeball is red.
7. My child rubs his or her eye(s).
8. The appearance of one or both of my child's eyeballs bothers me.
9. The appearance of one or both of my child's eyelids bothers me.
10. Child is bothered by his or her eye(s)
11. Child's eye condition interferes with his or her daily activities.
12. Child's eye condition interferes with my daily activities.
13. I feel fine about my child's eye(s).
14. I worry about my child's eye(s).
15. Other people comment about my child's eye(s).
16. I feel fine about the way my child's eye(s) appears in photos.
17. Other children tease my child about his/her eye(s).

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

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and 31 without NLDO. The Cronbach's values were impressive for not only the overall questionnaire (0.95) but also for its two subscales, namely, symptoms scale (0.95) and health-related quality of life (HRQL) scale (0.85). The CNLDO patients had worse scores for both the scales as compared to normal children and the affected eye had worse score as compared to the normal fellow eye. Both these scales showed improvement in scores following intervention in the form of probing. The study found that the questionnaire is very useful in quantifying parental perception of symptoms and HRQL in CNLDO.

The author's (Ali MJ) group has compared the parental quality of life (QOL) in CNLDO children who were successful following intervention versus complex CNLDO with poor outcomes. However, we did not include the last two (16, 17) questions. The early analysis has shown the Holmes questionnaire to be very useful for comparisons within the CNLDO group as well.

Quality of Life After DCR Surgery

The QOL after a DCR surgery has been usually assessed using the Glasgow-Benefit Inventory or GBI Questionnaire which was developed by Robinson et al. [5] for evaluating otorhinolaryngology procedures. This questionnaire is well known and validated in many studies across subspecialties of otology and rhinology [6, 7]. It consists of 18 questions, each assessed on a 5-point Likert scale; 12 questions are related to general perception of well-being and 3 each for physical health and social parameters. A positive GBI score represents a beneficial effect. The range of scoring extends from −100 (maximal negative benefit) to 0 (no change) to +100 (maximum positive benefit). Table 39.2 lists briefly the 18 questions that constitute the GBI.

Bakri et al. [8] assessed the benefits of external DCR versus endoscopic laser-assisted DCR and found no statistical difference in GBI scoring between the two groups. Mansour et al. [9] studied the long-term patient satisfaction following an external DCR and concluded that long postoperative times negatively affects the exact subjective symptom scoring after surgery. Yeniad et al. [10] compared the patient satisfaction between external and transcanalicular laser DCR and found that the mean symptoms scoring reduced from 24.2±4.6 at baseline to 3.5±1.8 in the external group and 22.8±3.4 to 3.37±1.2 in the transcanalicular group ($p=0.67$). The GBI scoring was similar and did not reach statistical significance in either group. However, there were concerns regarding follow-ups [11].

Ho et al. [12] studied the impact of endonasal DCR on QOL and found GBI scores of +34 in successful cases as compared to −19 in failed cases. The mean total GBI for endoscopic DCR in another study was +15.04 (95 % CI: 9.74–20.35). Hii et al. [13] compared patient satisfaction

Table 39.2 Brief Glasgow Benefit Inventory Questionnaire

1. Has the result of operation/intervention affected the things you do?
2. Has the result of the operation made your overall life better or worse?
3. Since your operation, have you felt more or less optimistic about the future?
4. Since your operation, do you feel more or less embarrassed when with people?
5. Since your operation, do you have more or less self-confidence?
6. Since your operation, do you find easier or harder to deal with company?
7. Since your operation, do you have more or less support from your friends?
8. Have you been to your family doctor, more or less since operation?
9. Since your operation, do you feel more or less confident about job opportunities?
10. Since your operation, do you feel more or less self-conscious?
11. Since your operation, are there more or fewer people who really care about you?
12. Since you had the operation, do you catch colds or infections much or less often?
13. Have you taken more or less medicine for any reason, since your operation?
14. Since your operation, do you feel better or worse for any reason?
15. Since your operation, do you have more or less support from your family?
16. Since your operation, are you more or less inconvenienced by health problem?
17. Since your operation, have you participated in more or fewer social activities?
18. Since your operation, are you more or less inclined to withdraw from social situations?

between external versus endonasal DCR and found no difference. When patients who underwent external DCR on one side and endonasal on the other side, retrospectively reported preference of endonasal DCR [14, 15]. In cases of bilateral NLDO, simultaneous bilateral DCR was shown to confer significant improvement of QOL with a statistically significant GBI score difference between 1 month and 3 months postoperatively [10].

Quality of Life in FNLDO and Minimally Invasive NLDO Treatments

Functional nasolacrimal duct obstruction is an underdiagnosed entity [16]. Epiphora in the presence of a patent lacrimal pathway and absence of alternative etiology could be the simplest description. Cheung et al. [17] conducted a detailed study on 33 FNLDO patients and studied their symptoms in relation to the vision, reading, driving, moods, work, and embarrassment. All these parameters were affected, specifically vision, reading, and embarrassment, resulting in lower quality of life. Overall symptom scores significantly reduced after dacryocystorhinostomy (DCR) from a mean preoperative score of 3.50 (SD = 2.07) to 2.0 (SD = 1.65) in the postoperative period ($p < 0.05$).

Kabata et al. [18] studied the effects of silicone intubation using Nanchaku-style tube on vision-related QOL in patients with lacrimal passage obstructions. They used the 25-item National Eye Institute Visual Function Questionnaire (NEI-VFQ). Silicone intubation showed a significant improvement in NEI-VFQ composite score ($p = 0.0001$), ocular pain score ($p < 0.0001$), and mental health score ($p = 0.0003$).

Specific Lacrimal QOL Questionnaires – The Way Forward

Most of the questionnaires used so far in lacrimal surgery are general in nature and most are administered postoperatively. The morbidity with lacrimal obstructions should ideally not be assessed using questionnaires that were designed for more general conditions where systemic morbidity may change a lot of parameters. This need for lacrimal-specific questionnaires has resulted in two new models, one for NLDO and another for DCR. Smirnov et al. [19] conceptualized the NLDO-symptom score survey (NLDO-SS), which has six parameters that need to be scored on a scale of 0 (no symptoms) to 10 (severe symptoms). The timing of administration can be individualized based on the follow-up protocols of each surgeon but is usually carried out at 1 week, 1 month, and 3 months. Five of these parameters are symptoms related to NLDO. Hence, this is not only more specific but also simpler to use once validated. Table 39.3 lists the parameters in the NLDO-SS questionnaire.

Mistry et al. [20] reviewed 100 consecutive patients of lacrimal duct obstruction and studied their symptomatology and subsequently developed the Lac-Q questionnaire. The questions were specific to lacrimal disorders (four questions with multiple subparameters) including their social impact (five questions). They showed that not only is Lac-Q useful in pre- and postoperative comparisons but also correlates well with objective methods of assessment. Table 39.4 lists the parameters of the Lac-Q questionnaire:

Table 39.3 The NLDO-Symptom Score (NLDO-SS) parameters

1. Tearing (0–10 scale scoring for each)
2. Irritation
3. Pain
4. Discharge
5. Swelling
6. Visual acuity

Table 39.4 The brief 'Lac-Q' questionnaire parameters

Lacrimal parameters	Social parameters
1. Watery eye	1. Watery eye comment by family or friends
2. Soreness of eyelids	2. Watery eye causing embarrassment
3. Sticky eye	3. Watery eye interfering with daily activities
4. Swelling at medial canthus	4. Watery eye causing blurred vision
	5. Medical consultation for watery eye

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Future Directions in Lacrimal Disorders and Their Management

40

Mohammad Javed Ali

Introduction

> If we wish to make a new world we have the material ready. The first one, too, was made out of chaos.

This quote by Robert Quillen perhaps is applicable to lacrimal surgery at this point of time. The enormous explosion in the knowledge we had in the last decade and newer developments in terms of instrumentations, diagnostics, surgical techniques, and molecular biology techniques augurs well for the future of Dacryology. This chapter discusses some of the current trends and the possible future direction related to those trends. The ideas as to future directions are innumerous and the author has highlighted those that strike him. This list is by no means comprehensive or exhaustive and many more can be added.

Etiopathogenesis of PANDO

Exact etiopathogenesis of PANDO has remained a big question for quite some time now. Inflammation, disturbances in helical structure of NLD, and cavernous bodies have been implicated; however, the accurate understanding is still elusive [1]. Future directions in this regard include careful studies of the vascular plexus surrounding the NLD, the possible protective role of tear-duct-associated lymphoid tissue, cytokine expression in obstructed ducts, developing diagnostic modalities to recognize early inflammation, and possible specific pharmacological blockers.

Lacrimal Passage Recanalization

Recanalization of obstructed lacrimal passage under guidance is one of the current hot topics [2–6]. It is now recognized as a major therapeutic challenge. Although good success rates are occasionally reported, the long-term results are unclear and skepticism is well-justified at this stage. The major hurdle is our understanding of the etiopathogenesis. The future directions include characterizing the cytokine expressions during a scar formation, understanding the complete tissue response to recanalization and possibly developing pharmacological blockers of undesirable molecular communications.

Mitomycin-C (MMC)

Mitomycin-C is commonly used to reduce the cicatrix in DCR, especially the high-risk ones and thus may prevent failures. The MMC meta-analysis has shed good light on the role of MMC in DCR surgery [7]. Possible optimal

M. Javed Ali, MS, FRCS, FRCGP
Dacryology Service, L.V. Prasad Eye Institute,
Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

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concentration and duration have recently been identified in vitro [8]. The future direction is to standardize the appropriate concentration and duration by further basic studies like collagen contractility assays and clinical validation of these results. Standardized treatments of MMC will to a large extent make the clinical results comparable and objectively assessable and this would further help in knowing the clinical benefits of MMC in DCR.

Lacrimal Intubation

The major question on lacrimal intubation is: "Does it really help?" It has been a controversial topic although a recent meta-analysis has helped straighten a few curves [9]. Major questions to explore with the use of intubation include the appropriate retention duration, significance of biofilms on stents, and the feasibility of anti-proliferative drug-coated stents.

Lacrimal Drainage-Associated Lymphoid Tissue (LDALT)

LDALT is a term used to describe the specific lymphoid tissue of the lacrimal drainage system. It is known to possibly influence the local immunity as well as ocular surface immune integrity [10]. Numerous derangements of LDALT have been noted in dacryocystitis [11]. The future directions would be to study LDALT in well-established ovine models of lymphocyte homing and recirculation. Changes in conjunctival-associated lymphoid tissues (CALT) following dacryocystectomy could be studied to decipher CALT and LDALT interactions and how the ocular surface influences lacrimal system and vice versa. LDALT of the nasolacrimal duct should be further investigated to assess whether it confers any protective effect against symptomatic dacryostenosis.

Diagnostic and Therapeutic Dacryoendoscopy

Dacryoendoscopy is gaining firm ground and increasing popularity for expanding indications in lacrimal disorders, thus having many diagnostic and potential therapeutic implications [12–14]. Today, we can study every part of the lacrimal system in detail and it has helped us in some cases to avoid more cumbersome diagnostic techniques like DCG and CT or MR-DCG. The future directions possibly include improved instrumentation for better clarity of images, better intraluminal mobility, less traumatic adjunctive instruments, and newer minimally invasive intraluminal surgical techniques.

Lacrimal Embryology

A thorough insight of lacrimal embryology is essential for advancing lacrimal science in terms of fundamental reasoning and developing minimally invasive interventions. Newer terminologies and description of embryonic conditions have been noted recently [15, 16]. The future direction is to study the cellular mechanism of mesenchymal condensation around the lacrimal primordium during Carnegie stage of embryonic development and create models to assess the effects of its dysregulation.

Lacrimal Microbiology

The microbes involved in acute and chronic lacrimal passage inflammation are well-known [17, 18]. However, their exact roles are unknown. The concept of microbiome is picking up, which essentially studies the microbial diversity and its abundance in a specified environment using molecular biology techniques [19]. The future is to establish the microbiome of the lacrimal system in detail, study the secretomes of the suspects and its mucosal barrier effects, biofilms on stents and their significance, and the role of appropriate antibiotics if any.

Electron Microscopy

Transmission electron microscopy (TEM) is being increasingly used to study the subcellular effects in lacrimal disorders and pharmacological response of tissues to medications [20, 21]. However, the normative data are inadequate.

The future direction would be to map the entire lacrimal system with both the TEM and scanning microscopes, establish a large normative data, and subsequently study the ultrastructural changes in common lacrimal disorders.

Revisiting the Dead!

Current trends and studies in cadavers had a paradigm shift effect in our understanding of lacrimal anatomy with regard to topography, Horner's muscle, medial canthal structures, and canalicular–lacrimal sac mucosal folds (CLS-MF) [22–24]. The crucial studies should be replicated across various races to validate their significance. The future directions perhaps should direct toward studying the embryos and stillborn cadavers up to cellular level to unravel the pathogenesis of congenital anomalies. It would also be interesting to take the CLS-MF concept further and study its characteristics and implications on dacryocystitis and DCR surgery.

Stem Cells

Stem cells is a buzz word across the specialties. The possibilities of managing lacrimal disorders through stem cells should definitely be a long-term goal. Stem cells have been isolated and characterized within the lacrimal gland earlier [25]. The future direction could be to explore the stemness within the lacrimal system, followed by its characterization, the cell–cell interactions, and the distant goal of regrowing the entire lacrimal system in vitro!

Quality of Life in Lacrimal Diseases

Most of the questionnaires used so far in lacrimal surgery are general in nature and most are administered postoperatively [26]. The morbidity with lacrimal obstructions should ideally not be assessed using questionnaires that were designed for more general conditions where systemic morbidity may change a lot of parameters. This need for lacrimal-specific questionnaires has resulted in two new models, the NLDO symptom score or the NLDO-SS questionnaire and "Lac-Q" questionnaire for DCR [27, 28]. The future direction would be to validate these in more clinical studies and add lacrimal-disorder-specific morbidities and specific psychosocial impacts.

Translational Research and Collaborations

As enumerated earlier on in the text on numerous occasions, the future research would increasingly focus on its translational values. The lacrimal surgeons today are increasingly focused on addressing questions that can have immediate or early translational value. Good forethought, planning, and meaningful collaborations contribute enormously toward this goal. The future lacrimal surgeons should intensely collaborate with appropriate people and systems, work on questions of immediate concern, both in the clinics and lab, and always keep an eye on the larger picture of the impact of their research and how it is going to benefit mankind at large.

Cross-Specialization

Lacrimal drainage system traverses a good distance in the lateral wall of the nose. It is imperative to know both the nasal anatomy as well as surgical interventions through the nasal cavities. A resurgence of the EENT (Eye, Ear, Nose, and Throat) doctors, as was in the past, may not be practical owing to the vast nature of each specialty; however, the benefits of limited cross-specialization are numerous. The future lacrimal surgeons should cross-specialize into rhinology and be as efficient as any ENT surgeon while managing lacrimal disorders.

The Clinician–Scientist

This breed of doctors is on the edge. The future largely belongs to the basic science approach to understand and manage diseases. The best people to take the clinical problems to the lab are clinicians themselves. Their participation with basic science research should be equal on the field. The

future lacrimal surgeons should acquire knowledge of the basic sciences and related techniques and dedicate a specific time in labs on a routine basis. The results in the labs should be carefully analyzed by the clinician and if suitable brought back to the clinic for validation.

Conclusion

The 15 points elucidated in this chapter are just a few among many more ideas. As discussed in the epilogue, the lacrimal surgeons had a glorious past, an exciting present era and all looks set for a bright future. Constant discussions, meaningful collaborations, and working as a community to make the life of patient with lacrimal disorders comfortable could well be a legacy we want to hand over to subsequent generations.

> Take the opportunity by beard as it is bald behind – Bulgarian proverb

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