Reconstruction

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9.1 Introduction

Head and neck vascular malformations are complex. Surgical resection and reconstruction are extremely challenging in these areas. The management depends upon the type of the lesion, flow in the lesion, and size of the lesion. Anatomically, the presence of major vessels, nerves, laryngeal and tracheal airway, oral cavity and esophagus makes the head and neck region a complex one for resection and reconstruction of vascular malformations. However, resection often proceeded by embolization of the lesion and its feeding vessels remain a mainstay of the treatment of these malformations.

Reconstruction of the defect after excision is essential to restore the form and function to provide cover for the major nerves and vessels, to restore the functions of the maxilla and mandible and, to avoid cosmetic disfigurement. Apart from these reasons, placement of normal healthy tissues in the diseased area has a role in the prevention of recurrences by changing the local hemodynamics.

Magnetic Resonance Imaging with MR angiogram is the best investigation to assess the extent of the lesion, the underlying neurovascular structures involvement and, to delineate the feeding vessels. High-resolution CT will be beneficial for the assessment of bony involvement. Digital subtraction Angiography (DSA) is particularly useful for preoperative embolization of the lesion, and it also shows the vascular tree, which is helpful in selecting the vessels for anastomosis away from the diseased if free tissue transfer is considered. All these investigations will be helpful in identifying the patients who need reconstruction and counsel them preoperatively.

9.2 Indications for Reconstruction and Tissue Requirements

Small vascular malformations, especially of the neck, cheek or scalp will not need reconstruction. But when the lesion is large or affecting multiple regions of the head and neck in different planes reconstruction becomes mandatory after their excision. The surgical morbidity associated with the resection in the head and neck area varies from anatomical disintegration to vital functional disturbances like speech, mastication,

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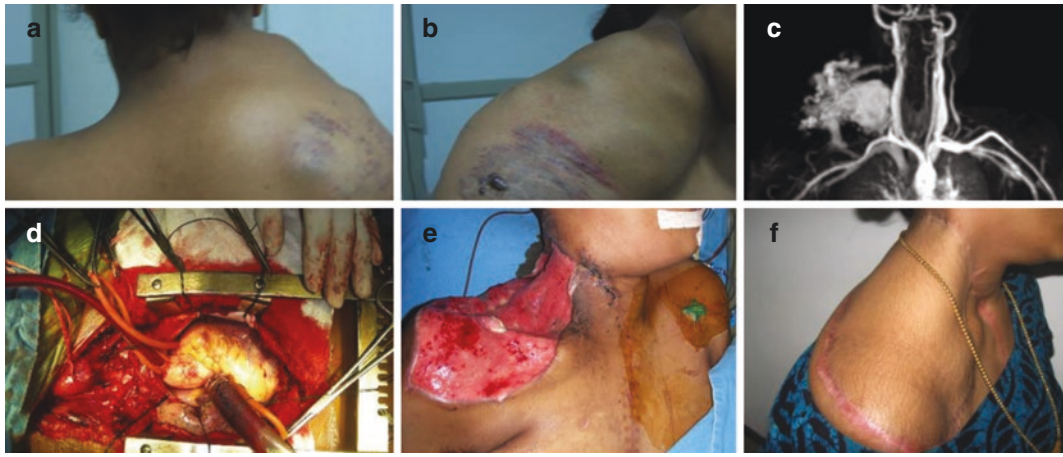


Fig. 9.1 (**a**, **b**) Large vascular malformation involving neck and shoulder (**c**) MRI angiogram showing the feeders and extensive lesion (**d**) Cardiopulmonary bypass (CPB) assisted resection (**e**) Defect at 7 days post-excision and wound packing (**f**) Free anterolateral thigh flap for soft tissue cover at 6 months follow-up

swallowing, speech, and facial expression. Provision of skin cover and providing the integrity of mucosal lining becomes the priority goals.

When mandible or maxilla is involved, they will need radical resections. Reconstruction of these structures becomes mandatory to provide skeletal support as well as the best possible dental and functional rehabilitation. Reanimating the facial units for the defects caused by accidental or purposeful damage to the facial nerve will have to be included in the goals of reconstruction in some lesions involving the parotid. Achieving aesthetically pleasing reconstruction by using the appropriate method and tissue is important, especially when a large amount of the skin and soft tissue is lost or the defects involve structures like nose or pinna.

Special points of consideration in the reconstruction of defects following excision of vascular malformations include preparing the area for reconstruction as follows:

- Achieving secure hemostasis is mandatory to a successful reconstruction. Use of tools like harmonic scalpel, liberal use of ties, clips, and electrocautery may help in getting a bloodless bed for reconstruction. The author's group has resorted to Cardio Pulmonary Bypass (CPB) to have bleeding control and to achieve bloodless field for complete excision of complex malformations where resection could not be possible without its assistance (Fig. 9.1). Wound packing is one of the effective ways of controlling bleeding. Wound packing for at least 24–48 h after the excision may be the best option for securing a bloodless field for reconstruction.

9.3 Methods of Reconstruction

The options for reconstruction range from direct closure, skin grafting, locoregional flaps, free tissue transfers and use of tissue expanders. The selection of these options varies depending upon the type of the defects, patient factors and surgeon factors.

9.3.1 Type of Lesion

Vascular malformations vary according to the type of vascular components capillary, arterial, venous, lymphatic or variable different combinations of the above components. The presence of large arterial component or arteriovenous connetion makes the physiology of the lesion high-flow, which makes the resection and reconstruction

difficult. The pathological nature and fast-flow in these malformations may lead to a high chance of flap failure, and the recurrence rate makes the management complicated. In hemangioma, the role of surgery is mostly limited to removal of the residual deformed skin and subcutaneous tissue, and the objective is mostly aesthetic enhancement.

9.3.2 Type of the Defects

The defect components could be skin, mucosal lining, intervening soft tissue, as well as the bone.

9.3.2.1 Bony Defects

The goals of reconstruction are to maintain the continuity of bony defect, arch form, and alveolar height to achieve anatomical integrity and functional restoration. The optimal reconstruction of the mandible and alveolar part of the maxilla requires vascularized bone grafts and osseointegrated implants. Apart from these, the management of the orbital floor is a concern in the maxillary defect. The options for orbital floor reconstruction are placement of titanium mesh, non-vascularized bone graft, pedicled bone grafts like coronoid bone with temporalis and calvarial bone, and a free vascularized bone graft. In bony reconstruction, vascularized bone flaps are ideal as most of these patients are young helping to achieve good long-term results. Free fibula flaps are considered the gold standard in these reconstructions. Pre-plating of the mandible may not be possible in all cases as these lesions can present as expansile growth in the mandible. In such cases, virtual planning using CT images will guide us to get better outcomes in terms of osteotomy and plating.

9.3.2.2 Soft Tissue Defects

In major vascular malformations, the skin and entire subcutaneous tissue are involved. In the oral cavity, the lesion affects mucosa as well. Hence the soft tissue defect encountered usually will be large and may be through and through. Although preservation of facial muscles and facial nerves is important for functional significance, it may need resection and plan of reconstruction of the facial nerve should be considered (Fig. 9.2).

9.3.3 Timing of Reconstruction

The reconstruction can be carried out primary (immediately), delayed primary (within 7 days) or secondary (after 7 days). The key to successful reconstruction is perfect hemostasis. Any bleeding beneath the reconstructed tissue is a risk for failure of the flaps. Up to 20% flap failure has been reported in patients undergoing immediate free tissue reconstruction following resection of head and neck arteriovenous malformations. The risk of bleeding is more with fast-flow malformations like arteriovenous malformations. It may be prudent to do wound packing immediately after resection to control hemostasis. This is followed

Fig. 9.2 (**a**) Vascular malformation involving right parotid region (**b**) Intraoperative image showing the malformation (**c**) Intraoperative image showing preserved facial nerve post-excision

Fig. 9.3 (**a**) Preoperative image of vascular malformation with partial involvement of lower lip (**b**) Immediate postoperative image after excision and primary closure (**c**) At 1 year follow-up

by reconstruction as a delayed primary or secondary manner, being ideal in reconstructing these malformations. The primary reconstruction may be carried out only if complete hemostasis is possible.

9.3.4 Options of Reconstruction

Similar to any oncologic reconstructions, the options vary from locoregional flaps to free tissue transfer. The methods chosen will depend on the size, site as well as age of the patient. Local tissue is preferable to achieve the best cosmesis in some parts of the face. Methods of using local tissue include direct closure and the use of local flaps. Regional flaps like deltopectoral, forehead, pectoralis major flaps may be used in larger defects. But their usefulness is quite limited in the reconstruction of these defects because the aesthetic and functional issues involved with these flaps are unacceptable in a benign condition like this. In certain scenarios like nasal defects where forehead flap gives better outcomes, similarly lip defects the better cosmesis will be by replacing like with like using the adjacent lip or opposite lip. Free tissue transfers may be needed in many head and neck vascular malformations as majority of these patients belong to young age group and only free tissue transfers often satisfy the tissue requirements. The choice of free flaps also helps to mitigate the donor site-related problems. The workhorse flaps were anterolateral thigh flaps and radial forearm flaps in soft tissue defects.

Direct closure is useful and possible in many situations where tissue laxity is not a concern. Lip defects upto one-third of the original lip size can be closed directly (Fig. 9.3). In tongue lesions, the expanded tongue can be excised in such a way, that allow us to directly close the defect, retaining the mobility and shape of the tongue.

9.4 Use of Tissue Expanders

The tissue expansion plays a vital role in the reconstruction of scalp, nasal defects and soft tissue defects of the face. The problem with tissue expansion is the necessity of multiple stages. It may not be feasible to use the expander at the time of primary resection and may need to be expanded and reconstructed at a later stage. In these cases, the defect is allowed to be repaired suboptimally by direct closure or with skin graft initially. When the wound is well settled the reconstruction starts. In case of nasal defects, a medially based forehead flap is the best using the supratrochlear/supraorbital vessels in the pedicle. In large nasal defects, the tissue expander is placed under the proposed flap area in order to achieve the primary closure of the donor defect. Usually, for the forehead, a rectangular tissue expander is better suited for expansion. The incision for placement of the expander is chosen in such a way that it will be included in the incision for flap rising later on. The injection port is placed at an adjacent area, preferably on a bony surface aiding its detection and easy injection of saline later on. Expansion is usually started 2 weeks later and continued till desired expansion of the flap area has been achieved. This may necessitate weekly or twice weekly injections for

Fig. 9.4 (**a**) Vascular malformation involving the nose and upper lip (**b**) Preoperative planning for excision (**c**) Postoperative image after stage 1 excision and closure of upper lip, partial excision of nasal malformation and placement of tissue expander (**d, e**) Stage 2 excision of nasal malformation and planning of expanded oblique forehead flap for nasal defect (**f**) post-operative image at 10 months

4–6 weeks. After this, the expander is removed and the flap transferred to the nose to resurface it. The donor area is primarily closed. Allowing another 3–4 weeks for the transferred flap to settle down and the third step of surgery, i.e. The division of the pedicle and inset, is completed (Fig. 9.4).

9.5 Free Tissue Transfer in Reconstruction of These Defects

In larger defects with the requirement of composite tissues, free flaps are the choice for reconstruction (Figs. 9.5 and 9.6). The advantages of these flaps include the transfer of suitable tissue in large volumes in a single stage. The selection of the flap will depend on the tissue requirement and the safety of its transfer. Usual choices are radial forearm or anterolateral thigh flaps for soft tissue alone defects and fibula free flap for bony reconstruction. Radial forearm flap is a suitable choice for total lip reconstruction or facial resurfacing. In total lip reconstruction, the flap can be combined with reconstruction of the oral sphincter using fascia. Advantage of the radial forearm flap is the long pedicle which allows us to use the opposite side as the source vessel. Anterolateral thigh flaps are useful wherever a larger defect of soft tissue resurfacing is needed.

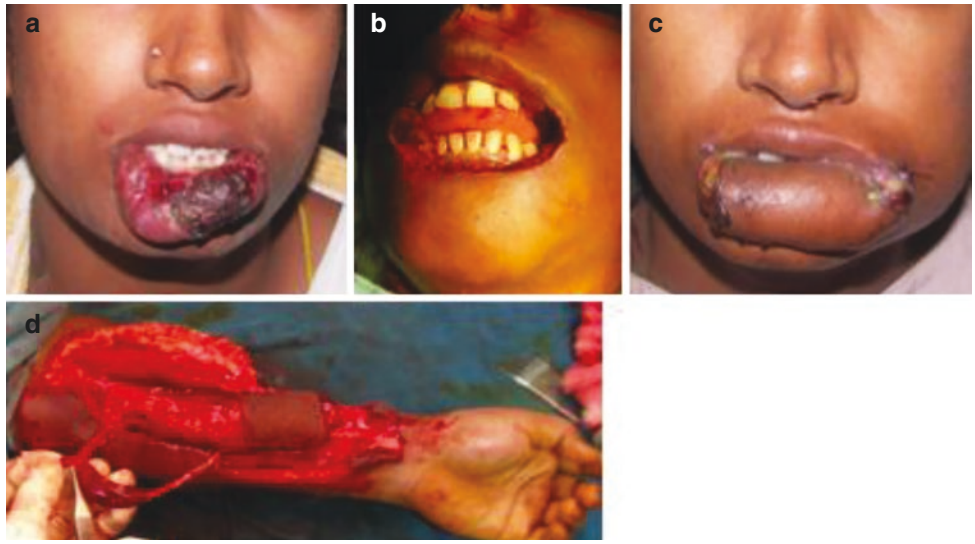


Fig. 9.5 (**a**) Preoperative image of vascular malformation involving the lower lip (**b**) Immediate postoperative image after near-total excision (**c**) 2 weeks postoperative image after reconstruction with radial forearm free flap (**d**) Harvested radial forearm free flap

Fig. 9.6 (**a**) Recurrent vascular malformation involving cheek, upper lip (**b**) CT angiogram showing the Abnormal vasculature (**c**) Intraoperative control of facial artery prior to excision (**d**) Defect post-excision (**e**) wound packing post-excision (**f**) Delayed primary free radial forearm flap cover

Bony reconstruction can and should be attempted when the defect involves the mandible or the maxilla. Fibula becomes an obvious choice due to its excellent bone stock as well as pedicle length.

9.5.1 Pedicle Selection in Free Tissue Transfer

The selection of normal vessels for anastomosis is crucial for the success of the free faps in these cases. The vessels on the same side may be unsuitable as the arteries are hypertrophied and the veins huge. The chance of anastomotic complications was high in the diseased vessels. Hence they have to be chosen outside the area of the pathology, which may necessitate to go close to the origin of the vessel on the same side or even to use the opposite side vessels.

9.5.2 Prevention of Flap Failures

As discussed previously selection of a safe flap as well as the normal vessels as the recipients is most important in prevention of failure of free flaps in these defects. The chance of flap failure is still high mostly due to bleeding issues related to these malformations. Delaying the reconstruction by days or weeks after the excision prevents this.

9.5.3 Advantages of Free Tissue Transfer apart from its Reconstructive Benefits

Frequently post-excision, the microscopic lesions exist, which results in recurrence. There has been a report on the suppression of these malformations by placing a new vascularized tissue on the wound bed of the resected malformation. This concept of "regulatory flap" by use of free tissue changing the local hemodynamics and suppressing the collaterals or microfistula formation which results in decrease in recurrences. The free tissue transfer also reduces the postoperative complications like seroma, pain, deformity, and functional problems.

9.6 Computersied Planning, Surgical Guides and Patient-Specific Implants

Technological advances have provided the clinician with opportunities to meticulously plan the surgical resection and reconstruction in advance with the help of dedicated computer software. Intraoperative navigation and imaging provide an additional layer of control to determine if the preplanned objectives have been achieved during the operation. Though these methods can be utilised for many surgical interventions, they are most useful for operations involving bony resections and complex three-dimensional reconstruction (Fig. 9.7a, b).

A dedicated CT scan with a minimum slice thickness of 1 mm and "zero" degree gantry tilt is obtained of the area of interest. The scans are uploaded to the local laboratory or commercial organisation, which has access to the relevant software. These same scans can also be used for intraoperative navigation, if so desired.

The clinician is able to plan the surgical resection on the computer with the knowledge of the clinical and imaging parameters (Fig. 9.7c). Once the clinician is happy with the resection, the planned segment is "removed" on the computer, and the ensuing defect "reconstructed by mirroring" from the opposite (uninvolved) side (Fig. 9.7d). Modifications to the "mirrored" reconstruction can be incorporated to account for any residual lesion or other eventualities (e.g. muscle atrophy, enophthalmos, exophthalmos,

etc.). A stereolithographic model can be manufactured from the final plan and utilised to construct a local or outsourced patient-specific implant using titanium mesh or sheet (Fig. 9.7e). Accurate restoration of premorbid anatomy and excellent aesthetic outcomes can be obtained by utilising patient-specific implants (Fig. 9.7f–h).

The same process can also be utilised for the creation of a "surgical guide", once the surgical resection has been finalised (Fig. 9.8a). This guide can be used once the lesion is exposed and allows quick and accurate resection of the lesion with predetermined margins (Fig. 9.8b). The guide also allows the clinician to avoid critical structures determined in the planning process and can minimise the exposure required.

Various alloplastic materials are available through commercial organisations and can be utilised for the reconstruction of complex three-dimensional defects. Each material has its merits and shortcomings, and the clinician will have to choose the most appropriate one based on the individual patient characteristics, need for cross-sectional imaging surveillance, radiotherapy, cost, etc. The illustrated case was reconstructed with PEEK (poly ether ketone) patient-specific implant (Fig. 9.8c).

The use of patient-specific alloplastic implants allows accurate and predictable reconstruction of complex three-dimensional defects, especially in the upper facial skeleton/peri-orbital region, which cannot be easily achieved with the use of autologous reconstruction. Mirroring allows the achievement of excellent symmetry, and the lack of an additional donor site helps reduce patient discomfort and surgical time. There is, however, a financial cost associated with the planning, creation of the surgical guide and patient-specific implant, which will principally be determined by the type and size of the implant and the complexity of the planning process. Care should be exercised with its use in patients with compromised soft tissue cover, potential risk of infection, especially when exposed to the sino-nasal or oral environment and those who have had or likely to have radiotherapy.

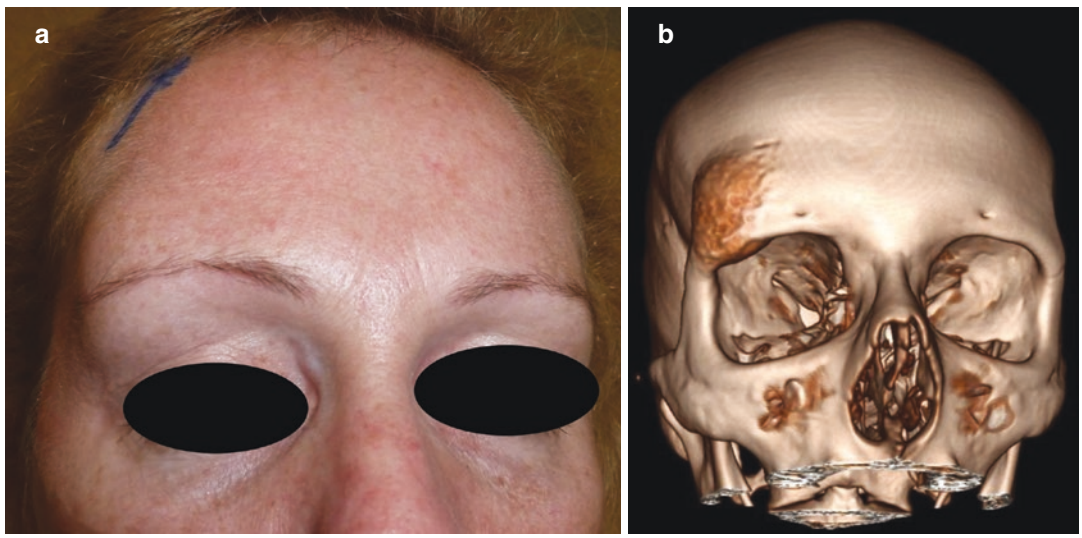
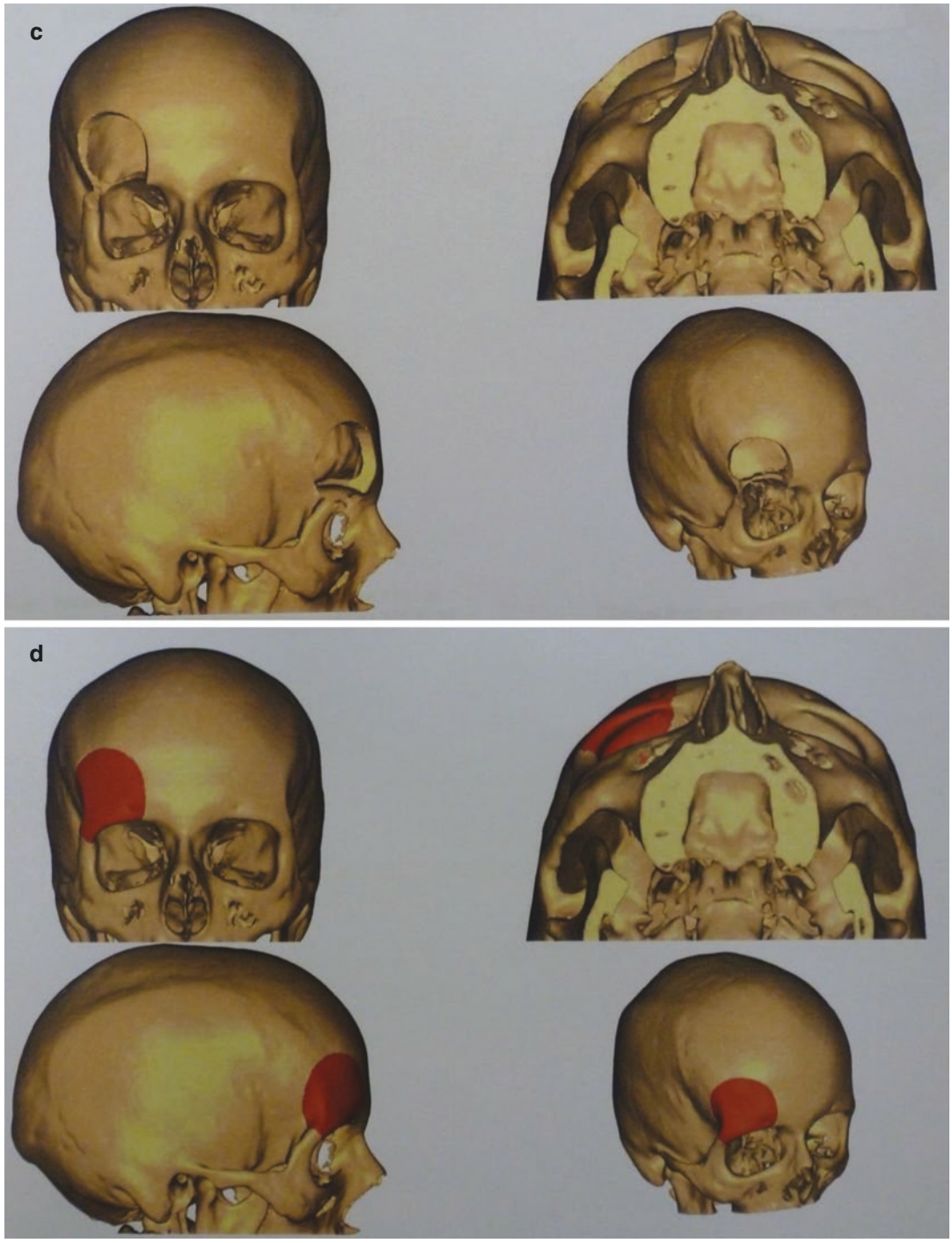


Fig. 9.7 (**a**) Right Supraorbital intra-osseous VM of the frontal bone. (**b**) 3-D reformatted CT scan demonstrating location and extent of the lesion. (**c**) Virtual surgical planning with the 3D modeling of the "excision" of the lesion. (**d**) Virtual surgical 'mirror modeling' of the contralateral side for planning following "mirroring reconstruction" of defect. (**e**) Stereolithographic model with adapted titanium mesh patient-specific implant. (**f**) Patient-specific implant in situ following resection



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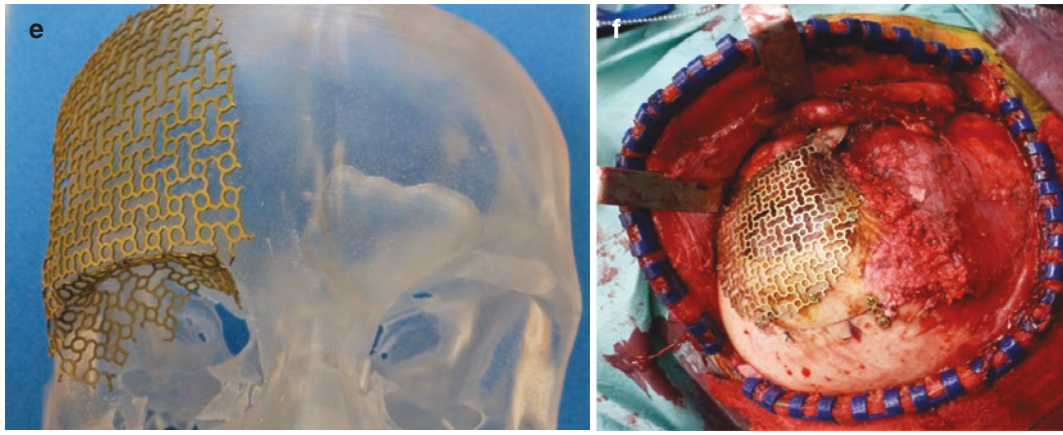

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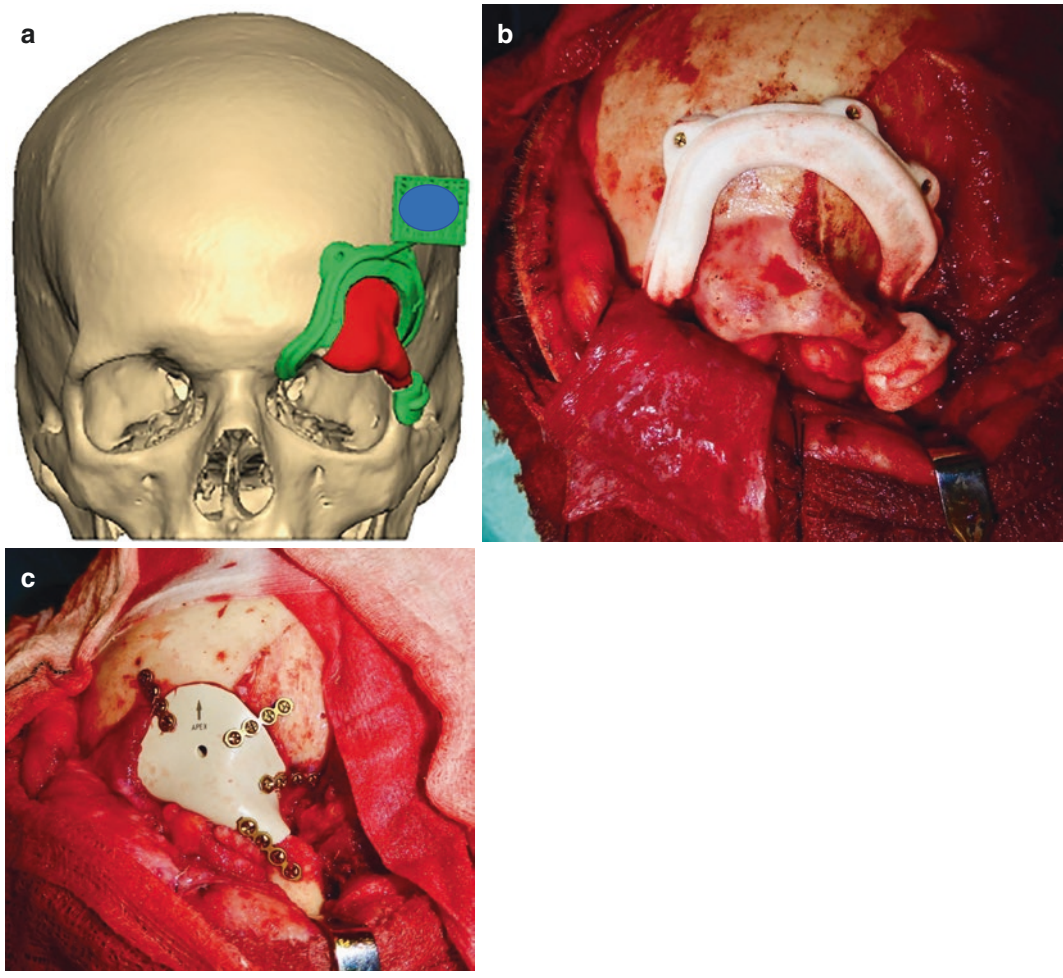
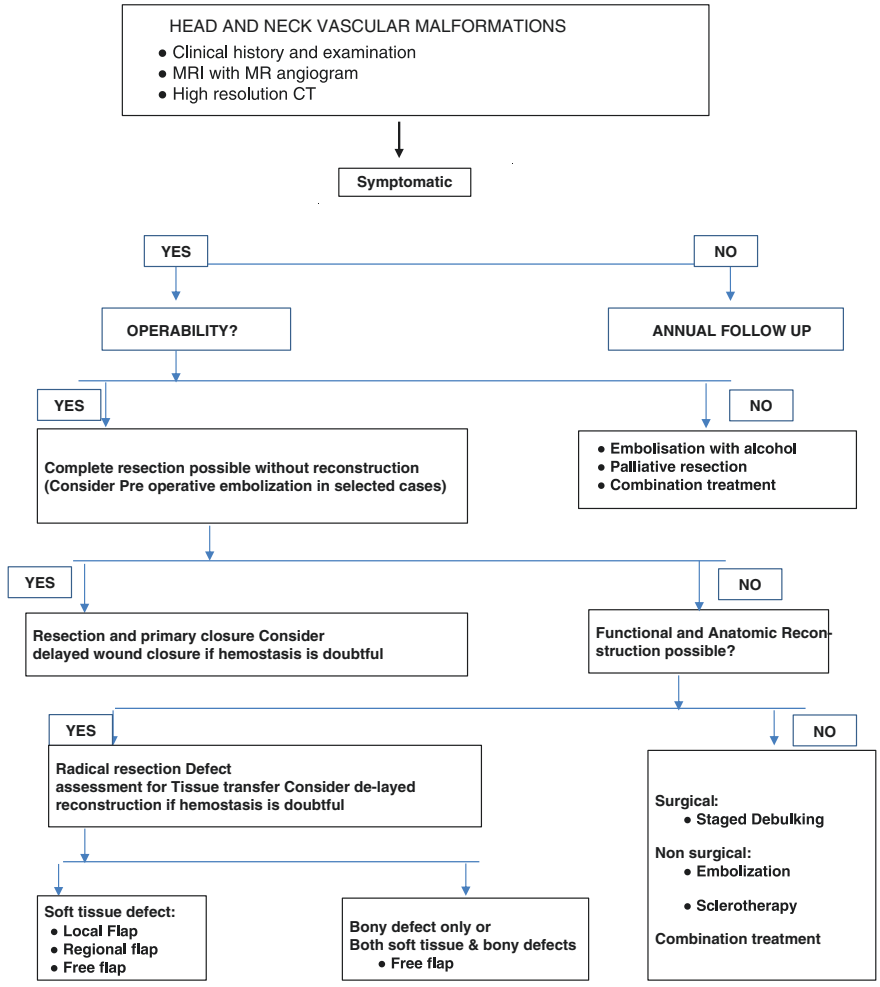


Fig. 9.8 (**a**) Computer planned surgical guide left supraorbital lesion. (**b**) Surgical guide in situ with predetermined resection margins. (**c**) Reconstruction with patient-specific PEEK implant in situ



Flow chart for reconstruction of defects after resection of vascular malformations

9.7 Points to remember while undertaking reconstruction of defects after resection of major vascular malformations

- Assess the patient clinically, radiologically by MRI with MR angiogram.
- High-resolution CT will be helpful in suspected bony lesions
- Pre operative embolization should be considered in selected cases like High-flow vascular malformations where temporary surgical occlusion of the feeding vessel is not possible during surgery
- Temporary clamping of the source vessel prior to the resection in will help in controlling the blood loss and also a clear surgical field for preservation of vitals structures like facial nerve
- Complete excision in the form of radical resection in all possible cases will drastically reduce the recurrence rate
- Compression wound packing and delayed wound closure or reconstruction to be considered in cases of incomplete hemostasis
- Delayed primary reconstruction would be an ideal time for tissue transfers
- Primary closure can be done ideally after 48 h of wound packing

- Locoregional flaps gives better results in specific defects of small to moderate size (rotation flap for scalp defects, lip switching/estlander flap for lip defects, forehead flap for nasal defects)
- Free tissue transfers are ideal for moderate to large size defects and in bony defects

Palliative resection can be considered in patients at risk for impending life threatening bleeding