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Research Article

ANATOMIC CHALLENGES IN SURGICAL RECONSTRUCTION AND FUNCTIONAL REHABILITATION OF MAXILLOFACIAL SKELETON

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ABSTRACT

Maxillofacial skeleton is unique with regard to its constitution and function. It comprises of 14 bones; 6 of which are paired and 2 unpaired. This bony architecture supports numerous functions such as vision, hearing, breathing, mastication, speech apart from its esthetic value. Restoration and reconstruction of defects of facial skeleton is therefore a complex procedure requiring not just anatomic continuity but also the ability to support critical functions inherent to this region. This review focuses on the complexity of facial skeleton and the challenges it poses for surgeons in reconstruction and rehabilitation. It also discusses the conventional reconstruction modalities, their disadvantages and the need for better techniques.

INTRODUCTION

Anatomy of Maxillofacial region

The structure of any part of the body corresponds to its function and so is it with the face. This part of the body supports numerous functions such as vision, hearing, breathing, mastication, speech apart from its esthetic value. Out of the five sense organs that humans have, four are exclusively located in the maxillofacial region.

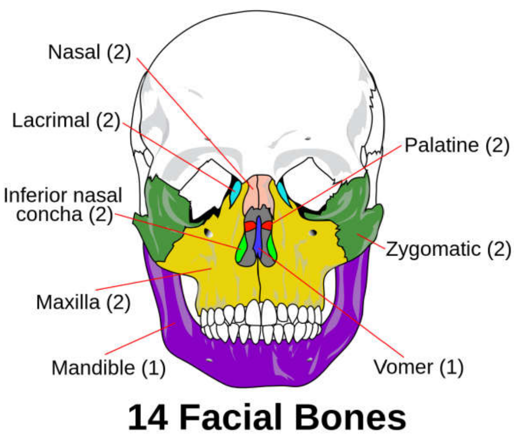

Fig 1 - Bones of the face

The maxillofacial skeleton is therefore a unique combination of bony architecture. It comprises of 14 bones; 6 of which are paired and 2 unpaired (Grays, 2006). The facial skeleton is universally divided into three parts; the upper face comprising mainly of the forehead, the mid face comprising of 13 bones and the lower face comprising of mandible (Fig 1). This review is restricted to midface and mandible.

Mandible is the largest and the strongest bone of the face and is the only movable bone in the maxillofacial region (Fig 2).

Fig 2 Mandible

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It is connected to the rest of the skull by two temporomandibular joints which are unique, as these are the only joints in the body which function exclusively simultaneously. Structurally mandible is in the shape of a parabola, the vertex of which houses the chin which is a unique esthetic feature of humans. Like other bones in the body, mandible has a medullary core with a cortical rim but unlike any other bone in the body, maxilla and mandible have multiple sockets in their alveolar processes for teeth. Maxilla is a paired bone and constitutes majority of the midface (Fig 3).

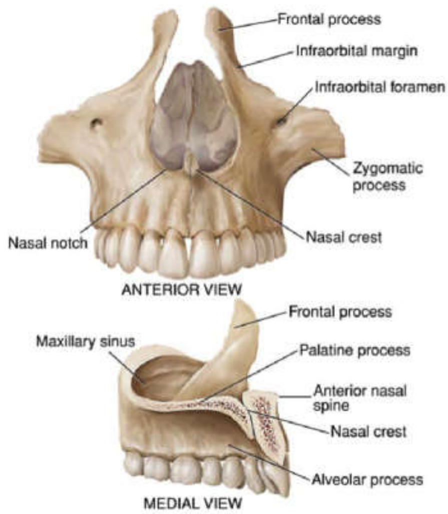

Fig 3 Maxilla

Apart from supporting the teeth, which occlude with those in the mandible, maxilla forms part of palate, lower part of the nose and supports the eye. It houses the maxillary sinus which is an air filled cavity within bone, and humidifies breathed in air, lightens the skull, adds resonance to voice, and produces protective mucus.

The zygomatic buttress of maxilla is a thick extension of dense bone from maxilla towards zygomatic bone, the main function of which is to transmit occlusal forces to the cranium.

Conditions affecting maxillofacial region

Various conditions affect the maxillofacial skeleton ranging from infections to malignancies. A list of the most common conditions affecting maxilla and mandible is given in Table 1. Barring a few such as arthritis, Garre's osteomyelitis, osteoporosis, almost all of these conditions require one or the other form of surgery. Treatment of these conditions requires surgeries like fracture fixation, cyst enucleation, tumor resection, ankylosis release, contouring etc.The extent of surgery depends on the extent and severity of the condition. Because of the nature of the disease, malignant lesions and certain locally aggressive lesions such as ameloblastoma and odontogenic keratocyst require resection of a rim of normal bone along with the lesional tissue. The residual deformity due to such resections, if not treated, can cause serious esthetic and functional problems. Reconstruction of the defects caused by jaw lesions and related surgeries may be done immediately or as a second stage procedure but has to be definitely addressed if one wishes to provide an acceptable quality of life to the patient.

Maxillofacial skeletal reconstruction

Most of the walled defects of the jaws such as bony cavities secondary to cyst enucleation heal physiologically. Larger defects of this kind may need particulate or granular bone grafts. Alloplastic grafts are osteoconductive which means that these grafts act as a scaffold for new bone formation. Osteoinduction is a process where osteogenesis is induced by recruitment and stimulation of immature cells. Addition of growth factors into alloplastic materials makes them osteoinductive. These two properties are considered adequate for new bone formation in bony cavities.

Table 1 List of some common conditions affecting maxillofacial skeleton

Infections	**Cysts**	**Benign tumours**	**Bone lesions**
Osteomyelitis Suppurative Non-suppurative Garre's Infantile Arthritis	Odontogenic Cysts Radicular OKC Periodontal Dentigerous Calcifying odontogenic ABC	Odontogenic tumours Ameloblastoma CEOT AOT Non-Odontogenic Hemangioma Osteoma Chondroma Fibroma	Fibro-osseous lesions Pagets disease Cherubism Fibrous dysplasia Ossifying fibroma Giant cell lesions CGCG Cemento-ossifying lesions
Malignanttumours	**Congenital**	**Others**	**Conditions specific to maxillofacial region**
SCC Malignant odontogenic tumor Osteosarcoma Ewings sarcoma	Aplasia Atresia Syndromic hypoplasia Cleft alveolus Hemifacialmicrosomia Osteogenesis imperfecta	Fracture AV malformations TMJ ankylosis Osteoradionecrosis Osteoporosis	Garre's osteomyelitis Cherubism Ameloblastoma Dental cysts Cemento-ossifying lesions Cleft deformities

OKC – Odontogenic keratocyst, ABC- Aneurysmal bone cyst, CEOT –Calcifying epithelial odontogenic tumour, AOT – Adenomatoid odontogenic tumour, CGCG – Central giant cell granulaoma, SCC- squamous cell carcinoma, AV- Arteriovenous, TMJ – temporomandibular joint

Table 2 Grafts currently used for small defects of the jaws

Autogenous corticocancellous grafts	**Commercially available allografts**	**Growth factors**
Iliac	Hydroxyapatite	Bone Morphogenetic Protein
Symphysis	Tricalcium phosphate	Platelet Rich Plasma
Tibial head	Bioactive glass	Platelet Rich Fibrin
Calvarium	Calcium sulphate	Interferon alpha

Therefore alloplastic grafts alone or in combination with growth factors, are sufficient for large bony cavities where physiologic healing is expected. Table 2 gives a list of grafts currently used in treatment of small defects of the jaws.

Reconstruction of defects secondary to resection is not as simple. Grafts used in such reconstruction must have osteogenic potential which is the ability of a graft to form new bone by the action of vital osteoblasts. For long, the only grafts which had osteogenic potential were autografts. A number of autografts have been used to reconstruct maxilla and mandible along with associated soft tissue (Table 3).

However, in vascularized grafts, remodeling takes place across the whole graft at a time and therefore grafts as large as 15-20 cm have high level of viability for the majority of bone forming cells inside the graft survive through the established blood supply. The primary perfusion of the grafted bone also sustains resistance against infection allowing survival of the graft independently from the donor site complications (Booth, 2007). Because of these considerations free vascularized bone grafts are currently the most suitable for reconstructing large segmental defects of the jaws.

Table 3 Currently used maxillofacial reconstructive methods

Graft	History	Disadvantages
Local soft tissue flaps		Insufficient for large defects
1. Tongue flap	Guerrero-Santos[10] 1966	Not applicable for composite defects
2. Masseter flap	Tiwari[18] 1987	Donor site morbidity
3. Buccal fat pad	Egyedi[6] 1977	
Regional soft tissue flaps		Limited size of graft
1. Nasolabial flap	Cohen and Edgerton[3] 1971	Not applicable for composite defects
2. Temporalis flap	Lentz 1895	Donor site morbidity
3. Forehead flap	McGregor[13] 1963	Compromised esthetics
4. Deltopectoral flap	Mc Gregor14 1970	
Regional composite flaps		Limited size of graft
1. Sternocleidomastoid	Jianu 1908	Donor site morbidity
2. Trapezius flap	Conley[4] 1972	Compromised esthetics
3. Pectoralis major flap	Ariyan[1] 1979	Difficult to adapt to recipient site
4. Platysma flap	Futrell et al[8] 1978	
5. Lattismusdorsi flap	Quillen et al[19] 1978	
6. Submental flaps	Martin et al[11] 1993	
7. Infrhyoid flaps	Wang et al[21] 1986	
Free nonvascularized bone grafts		Limited size of graft
1. Iliac crest		Necrosis of graft
2. Rib	Taylor[17] 1982	Donor site morbidity
3. Calvarium		
Free vascularized grafts		Donor site morbidity
1. Fibular grafts	Ueba& Fujikawa[20] 1973	Increased intraoperative time
	O'Brien & Morrison[15] 1973	Need for microvascular surgical skills
2. Radial forearm grafts	Soutar et al[16] 1983	
3. Iliac crest grafts	Taylor[17] 1982	
4. Scapular grafts	dos Santos[5] 1980	
5. Dorsalis pedis grafts	McCraw& Furlow[12] 1975	
Allograft and Xenograft		Infections
1. Freeze dried bone graft		Disease transmission
2. Decellularized FDBG		Immunogenecity
Implants		Inadequate reconstruction
1. Stainless steel		No functional rehabilitation
2. Titanium		Implant rejection
3. Vitallium		Implant breakage or exposure
4. Silicon		Impedes growth in children
5. Acrylic resins		Allergy

The gold standard of skeletal reconstruction in maxillofacial region is still autogenous bone: vascularized or nonvascularized. Segmental defects of 4-5 cm in size can be reconstructed with nonvascularized free bone grafts whereas defects larger than 5 cm require vascularized free flaps. This is because bone remodeling within a graft prerequisites adequate vascular supply especially to the core of the graft. Bone cells within a graft survive on diffusion from the margins during the first 5 days. The central parts of large nonvascularized bone grafts become necrotic and are revascularized within weeks to months depending on the vascularity of the donor site and the structure of the grafted bone. The sources of newly formed bone are perivascular osteoprogenitor cells and undifferentiated mesenchymal cells which enter the graft accompanying the proliferating vessels (Booth, 2007).

The most commonly used vascularized graft for mandibular segmental defects are the fibula and iliac crest. The fibular graft has the advantage of adequate length, good stability and adaptability to recipient site. The disadvantages are patient immobility postoperatively, reduced height of graft for dental rehabilitation and donor site morbidity. The iliac crest is a curved piece of mainly cancellous bone that allows three dimensional carving into the shape of hemimandible but has the disadvantage of great deal of postoperative pain, gait disturbances, nerve injuries, hernia and paresthesia (Forrest, 1992). Both the grafts need prolonged intraoperative time to harvest and reshape the bone to adapt to the recipient siteand for donor site management. Moreover, such a reconstructive procedure does not completely restore jaw function. Functional dental rehabilitation requires restoration of mandible to near normal which is clinically difficult. Figure 4 shows the inadequacy of a vascularized fibula graft for a hemimandibulectomy defect in restoring the height and width of mandible.

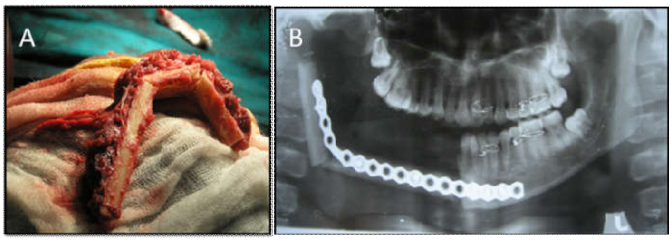

Fig 4 A. Harvested vascularized fibula graft. B.Radiograph of mandible with vascularized graft in situ.

The inability to replicate complex facial contours is another major drawback. For instance, reconstruction of segmental defects in the anterior mandible is challenging due to the geometry of bone in this region. Restoring its horseshoe shape to achieve proper contour and adequate function with the limitations of autogenous bone grafts is difficult. Figure 5 shows a case of segmental resection in the anterior mandible and the problems associated with its reconstruction.

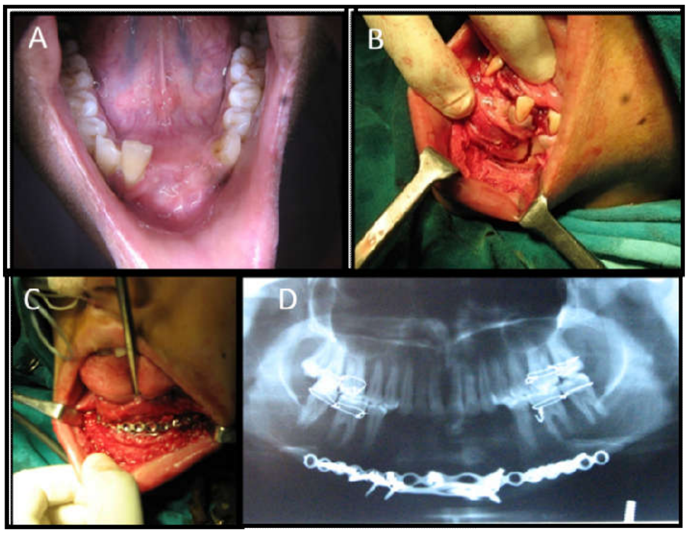

Fig 5 Management of segmental defect in anterior mandible.A. clinical photograph of ameloblastoma in anterior mandible. B. Intraoperative photograph of resection of ameloblastoma. C. and D photograph and radiograph of mandible after implant reconstruction.

The midface poses a greater challenge because of its intricate anatomy and multiple interlacing and communicating spaces. Before the development of more sophisticated reconstructive techniques, prosthetic appliances were the only modality available to address the functional and esthetic requirements of such a complex defect. Free tissue transfers have made autologous maxillary reconstruction possible but functional and esthetic results are far from optimal. Another alternative, distraction osteogenesis, a technique increasingly being used as endogenous bone tissue engineering in cases such as mandible lengthening, also renders severe complications in more than 35% cases including pin-tract infections, scarring of the defect site, device failure, and failure to form a bony union. In pretext of the above treatment options and their associated drawbacks, there is we believe, an urgent need to explore finding improved methods for maxillofacial reconstruction in clinical setup.

Requirements of an ideal reconstructive option

The main aim of any maxillofacial skeletal reconstruction is to provide esthetic and functional rehabilitation as near normal as possible. Mandibular continuity is indispensable for oral functions mainly because its support to intraoral soft tissues plays a central role in chewing, deglutition, speech and patency of airway. Graft selection for reconstruction of mandibular body must take into consideration not only establishing continuity but also providing adequate thickness and height to accommodate and support implants for dental rehabilitation. An ideal graft would need to perfectly fit the size and shape of the defect without having to be reshaped intraoperatively. Additionally it should have the ability to either regenerate new bone or support physiologic bone remodeling without complications of necrosis, infection or graft rejection. This would be possible only when the graft can support neoangiogenesis along its entire length and breadth. An ideal graft should also have mechanical properties to withstand masticatory forces on immediate loading without physical distortion or fracture.

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