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REVIEW ARTICLE

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Contemporary Concepts in Treatment Planning, Reconstruction and Rehabilitation of the Maxillofacial Region: An Overview of Methods used in Practice

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ABSTRACT

Treatment planning, reconstruction and rehabilitation of maxillofacial and dental defects have always been a challenge for a maxillofacial surgeon. Reconstruction of the oral cavity is often a difficult task as it involves the restoration of both the esthetic or cosmetic form as well as the preoperative function. Understanding the oral cavity anatomy as well the functional capacities of its various subunits is required to achieve good results.

The recent advances in treatment planning, diagnostic imaging and reconstructive techniques, especially in the field of osseointegration, tissue expanders, perforator flaps, microvascular free tissue transfer and bone engineering, have yielded excellent functional and esthetic outcomes. This article provides a brief overview on various advanced reconstructive and rehabilitation techniques available in contemporary clinical practice.

Keywords: Maxillofacial, Treatment planning, Reconstruction, Rehabilitation.

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INTRODUCTION

Defects of the maxillofacial and dental tissues often have detrimental effects both on the patient's health and appearance; and thus, it requires a holistic approach to restore the lost dentition along with bone and soft tissue. The stage of the disease and extent of resection are the most significant parameters that must be kept in mind before planning the reconstruction.

In maxillofacial surgery, reconstruction refers to the wide range of procedures designed to rebuild or enhance soft or hard tissue structures of the maxillofacial region. The reconstruction of defects of the jaw and mouth region represents a challenge to the maxillofacial surgeon.[1-5] Although this type of reconstruction procedures are most commonly indicated in patients with carcinoma's, such as oral squamous cell carcinoma, they are also employed in cases of benign tumors, trauma, osteoradionecrosis, infection, chronic non-union of bone, clefts and congenital deformities.[5,6]

A new era of success has dawned in maxillofacial reconstruction with advances in the development of antibiotics, improved diagnostic imaging and anesthesia.[2-4,6] Other developments like the development of bone technology,[8-12] osseointegration,[13-17] microsurgery[7,18,19] and improved dental prosthetics in the past two decades have further revolutionized such reconstruction. The postsurgical goals of reconstructive surgery include early wound closure, restoration of the form, cosmetics and function.[6]

This article seeks to present an overview of the contemporary methods employed in the treatment planning, diagnostic imaging, reconstruction and rehabilitation of the form and function of the jaws and mouth.

Treatment Planning and Diagnostic Imaging

For many years, physicians relied on two-dimensional (2D) radiographs of the facial skeleton to evaluate facial injuries. However, such radiographs were relatively difficult to interpret because of the superimposition of bony landmarks and defects. Alternative modalities include advanced imaging procedures, such as computerized tomography

(CT), stereolithography, three-dimensional (3D) model reconstruction and reconstructive surgery simulation.

Computerized Tomography

Technological advances in CT have reduced data acquisition and reconstruction time so that 3D CT images of maxillofacial injuries may be economically and quickly generated. Although 3D CT is unable to demonstrate soft-tissue injuries well, the surgeon's improved appreciation of the disrupted bony architecture may facilitate preoperative planning.

Numerous studies have underscored the utility of CT over conventional plain radiographs with respect to diagnostic accuracy and preoperative planning. CT's accurate representation of facial fractures and their spatial relationships facilitates surgical exploration, fracture reduction and the selection and contouring of rigid reconstruction plates. CT can thus, decreases complications resulting from delays in diagnosis and treatment including malunion, nonunion and other functional and/or esthetic deficits that may require revision surgery later. Recent advances in computer software algorithms have also permitted 3D reconstructions of the facial skeleton from 2D CT images.

Stereolithography

This has become a well-known technique in the rapid prototyping sector for preoperative model planning and surgery simulation in the field of craniofacial surgery, tumor surgery, reconstructive and orthognathic surgery.

Color Stereolithography

The recently developed technique of color stereolithography allows the selective coloring of structures in a 3D solid model. The 3D information of a solid model combined with the extra information from the selective coloring of certain anatomical structures both combine as an ultimate diagnostic and preoperative planning tool. Preoperative model planning by color stereolithography is useful in ablative surgery of the maxilla and the ethmoid bone. The coloring of the tumor clarifies its relation to surrounding structures, such as the paranasal sinuses, the orbit, the infratemporal fossa the cranial base and illustrates eventual extension in the adjacent tissue. The main advantages of this technique are visualization of the problem, planning of the surgical approach and determination of extent of the resection in areas of complex anatomy.

3D Model Reconstruction

3D model reconstruction is performed in several patients suffering from acute maxillofacial trauma. In late primary repair, when open reduction and internal fixation had to wait for a decrease in facial swelling or cerebral edema, computer-aided surgery has proven to be useful in terms of facilitating anatomical reduction, minimizing surgical approaches, and saving operating time. Due to surgery simulation it was possible to adjust prefabricated mini-or microplates in the patient as in the preoperative planning. The configuration and bending of the plates also acted as a device for the anatomical reduction of the fragments. However, in cases of comminution with very small fragments, surgery simulation with complete reduction on the 3D model is not advisable. In such cases the 3D model is only useful for planning the reduction of the buttresses. Exact reduction of small fragments is only possible in the patient itself by maintenance of the occlusion, but not in the 3D model.

Reconstructive Surgery Simulation

Trauma, cranial bone tumors and external decompression are the major reasons for cranial defects indicated in reconstructive procedures for the protection of intracranial structures and cosmetic reasons. Surgery simulation is helpful in primary reconstruction of maxillofacial defects caused by ablative surgery to determine the donor area, such as the scapular bone, the fibula or the iliac crest. Positioning of the graft can be studied, thus reconstructing different bony structures such as the mandible, the orbital floor, the zygoma or the hard palate. The large cranial defects can be covered with precision fitting carbonic implants prefabricated on the 3D model to facilitate surgery; thus, saving operating time.

MAXILLOFACIAL RECONSTRUCTION

Orofacial defects caused by disorders, such as neoplastic disease are a challenge for a reconstructive surgeon. We have reviewed the modern techniques for reconstruction and overviews of the flaps used in reconstruction are discussed below.

Vascularized Free Tissue Transfer

Vascularized free tissue transfer (VFTT), also known as free flap transfer, is now considered the gold standard for maxillofacial reconstruction.[4,6] It involves the harvesting and detachment of tissue with its blood and nerve supply and transferring it to repair a defect, where its blood and nerve supply are re-established by reanastomosis to suitable recipient site vessels.[6] Success rates for this procedure are estimated at between 90 and 94%.[20-22]

VFTT is advantageous over nonvascularized transfer, as postoperative radiation affects the vascularized flap less severely compared to the nonvascularized flap. A number of different donor sites are used for VFTT, the selection of which depends on the recipient site location and the type of tissue being replaced.[5,6]

Fibula Free Flap

This is considered as the mainstay in mandibular reconstruction[19,20] as the long vascularized cortical bone provided from the fibula can restore angle to angle mandibular defects and also allows placement of osseointegrated dental implants[19] (Figs 1 and 2). The chief disadvantages for such flaps include donor site morbidity and numbness of the foot and toe.

Radial Forearm Flap

This is a versatile technique that is widely adopted for microvascular reconstruction of the oral, oropharyngeal, hypopharyngeal lining and is used mainly to restore lateral edentulous defect. Nowadays, the technique for harvesting is standardized, while reconstruction of the forearm donor site defect is somewhat controversial. The drawbacks of this flap are inadequacy of available bone and donor site morbidity, such as limited motion, grip strength and supination.[4] Since the limited bone stock reduces the quality of osseointegration[19] and the risk of radial fracture is estimated to be 17%[23] this flap is now considered as less suitable for mandibular reconstruction; however, it is useful when restoring the soft tissues (Fig. 3).

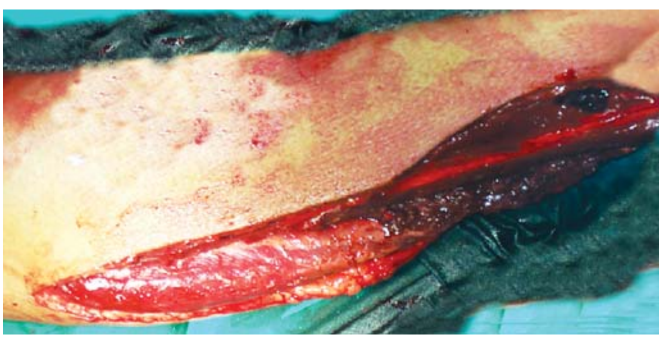

Fig. 1: Harvested site of the fibula

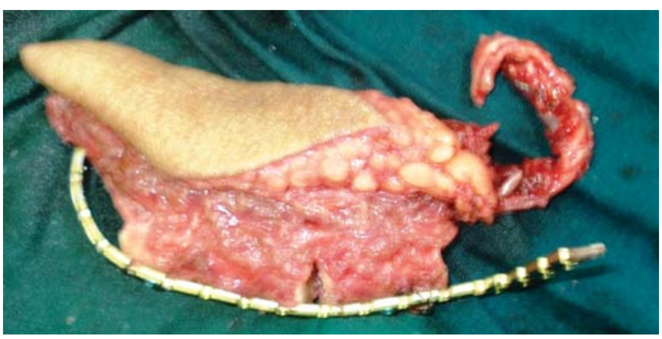

Fig. 2: Free flap prepared for transfer to mandible with reconstruction plate

Iliac Crest Free Flap

The natural contours of the bone are regarded suitable for reconstructing lateral and hemimandibulectomy defects. It also offers the best bone stock for dental implants while the success rate in a recent review averaged 96%.[1,9]

Tissue Expansion

Tissue expansion has become a major reconstructive modality over the past 30 years with widespread application particularly in the fields of breast reconstruction, burn surgery and pediatric plastic surgery. In many cases, tissue expansion can be said to have revolutionized plastic surgery.[24]

The lack of available soft tissues is a common challenge facing the reconstructive surgeon. The phenomenon of tissue expansion of the skin and underlying soft tissues has been observed commonly in pregnancy, slow-growing tumors and fluid collections, where the local tissue expands and enlarges in response to the tension generated by the increased volume of the mass. This response has been found to be a metabolically active process with increased mitotic activity and vascularity of the expanded skin and has been applied clinically as an important skill in the armamentarium of the reconstructive surgeon.

Tissue expansion procedures have numerous advantages. While it provides skin with a near-perfect match in color and texture, minimal donor site morbidity and scarring occur. In addition, expanded flaps are more resistant to bacterial invasion than random cutaneous flaps. This technique has been extended to other types of tissue,

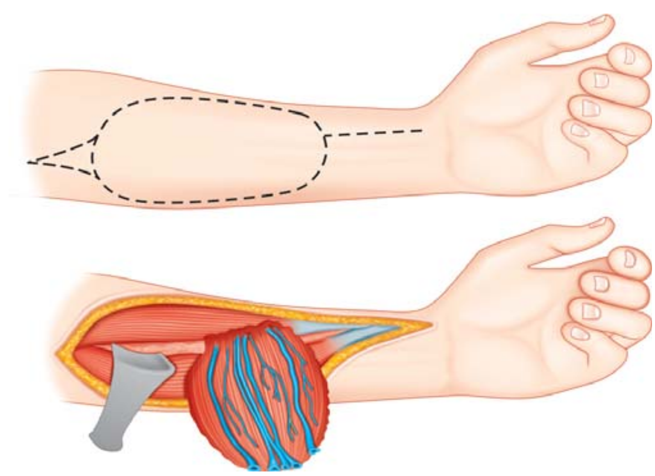

Fig. 3: Radial forearm free flap

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including bladder reconstruction, vascular elongation and nerve lengthening too.

Disadvantages include temporary cosmetic deformity during the expansion phase, prolonged period of expansion, the need for multiple procedures and complications associated with implant placement.

Physiology of tissue expansion: Tissue expansion induces changes in the vascularity and cellular activity in involved skin. Alterations in microcirculation have been shown to create hardier flaps in expanded *vs* nonexpanded skin. These flaps had significantly increased survival length when compared with acutely raised random-pattern flaps. The capsule that forms around the prosthesis is involved in the increased vascularity and has been shown to have a circulation exceeding that of the subdermal plexus. Removal of this capsule compromises the integrity of the expanded tissue, so it is often unnecessary and sometimes risky. Studies of the skin surrounding an expander indicate that the epidermis initially thickens slightly while the dermis demonstrates rapid thinning during the first 3 weeks. Skeletal muscle atrophies under expansion but retains its activity. However, adipose tissue undergoes permanent atrophy of 30 to 50% with loss of fat cells.

Use of tissue expansion in face, head and neck regions: Tissue expansion has been particularly useful in the reconstruction of face, head and neck areas. In addition to treatment of male pattern baldness, expansion has been used to eliminate large scalp defects and large burn scars. Unilateral forehead flaps can be designed using expansion to reconstruct contralateral defects of the forehead and nose. Neck contractures have been managed with flaps developed with an implant in the supraplatysmal plane. Correction of congenital microtia has been described, where tissue expanders were used to provide local skin coverage over the cartilaginous graft framework.

Rehabilitation: This is an important step in the management of patients with orofacial defects, as it restores the function of the region. Several important modern methods are discussed below.

Maxillofacial Prosthodontics

This branch of prosthodontics is concerned with the restoration and/or replacement of the stomatognathic (jaws) and craniofacial (facial) structures with prostheses that may or may not be removed on a regular or elective basis. Craniofacial implant-retained facial prostheses; obturators, cleft palate speech aid prostheses, implant prostheses, and a wide array of unique and challenging rehabilitation efforts comprise this area of endeavor.

Prosthodontic treatments depend on the degree of edentulousness or the type of defect present. Fixed prostheses avoid pressure on the mucosa, which may be tender, dry and friable in irradiated patients.[25] Reports have shown that bone loss in the edentulous maxilla is greater when fixed prostheses are used in place of overdentures.[26] A recent consensus report stated that the implant-supported overdenture is the gold standard in restoring the edentulous mandible.

Dental Implants

The basis of dental implants is osseointegration, which has revolutionized the restoration of the oral cavity. Osseointegration was first described by Brånemark et al.[27] The technique involves the direct attachment of osseous tissue to an inert, alloplastic material without intervening connective tissue. It has allowed increased denture retention and fixed placement of restorations in otherwise edentulous spaces. Implants placed in reconstructed bone perform identically to those placed in native bone, and the quality of bone was found to be the greatest determinant of fixture loss.[28]

Limitations of implants in irradiated bone and methods to overcome.

The use of implants in irradiated bone has been controversial, as there is a risk of developing osteoradionecrosis of the mandible when carrying out surgical procedures. In patients about to receive radiation postoperatively, implants should not be loaded for 6 months. The overall success rate for endosteal dental implants was 92%. The implant success rate was 86% when the bone in which the fixtures were placed was irradiated postoperatively. In the 14 fixtures that were placed into previously irradiated bone, the success rate was 64%.[7] The greater success of native bone and vascularized bone flap osseointegration compared to free bone grafts has been noted.[29] Several factors need to be considered in placing implants in patients treated with radiation therapy for oral malignancies.

Hyperbaric oxygen therapy (HBO): The use of HBO has been shown to prevent osteoradionecrosis in patients undergoing postradiation mandibular surgical procedures.[30] The vascular vessels in the field of irradiation are narrowed, causing a decreased blood flow to the region. Irradiated host bone had been regarded as a contraindication to implant placement.[31] HBO is used by some as a precaution before implant placement in irradiated bone to reduce the likelihood of osteoradionecrosis.[32] However, studies have shown acceptable results in irradiated bone without HBO.[33]

Role of radiation dose in implant survival: This is considered to be critical with an acceptable upper limit of 55Gy30, only when used with HBO. However, disagreement still remains as to when implants should be placed in irradiated bone.[29]

Zygomatic implants: This is a long implant introduced by Branemark in 1998 for use in restoration of the atrophic posterior maxilla in maxillectomy patients and has a success rate of between 82 and 97% in oncology patients.[8,34] Zygomatic implants are a useful treatment modality in conditions where insufficient bone exists for maxillary implant placement and may be an alternative procedure to bone augmentation and sinus lift's;[8] however, failure is more problematic than with dental implants.

Future Advances in Rehabilitation Procedures

Among the several advances that are currently under investigation the most promising ones that may in time have significant applications include use of materials like scaffolding materials, growth factors, alloplastic materials and procedures, such as distraction osteogenesis and rigid fixation.[35]

Scaffold materials: A bioscaffold can be broadly termed as a structure used to substitute an organ either permanently or temporarily to restore functionality. The material that can be used varies with the application intended. Tissue engineering is one such application demanding certain requirements to be met before it is applied.

In maxillofacial rehabilitation procedures, scaffold materials, such as proceramics and polymers are gradually being used more commonly used to help rebuild bone. Ceramics, such as hydroxyapatite and ß-tricalcium phosphate, are strong enough to provide mechanical strength when replacing load-bearing skeletal structures.[12] Polymers, such as polyglycolic and polylactic acid, are also used but lack mechanical strength and may cause uncontrolled shrinkage of bone.[11]

Growth factors: Bone morphogenic proteins (BMPs) are growth factors and cytokines known for their ability to induce the formation of bone and cartilage.[36] Basic fibroblast growth factor is considered to enhance angiogenesis and support bone formation in the presence of vital bone cells.[10] However, as there is no reliable evidence supporting the efficacy of agents, such as platelet-rich plasma (PRP) in conjunction with dental implant therapy[2] and the lack of availability of a suitable carrier agents for the BMP, the use of growth factors in reconstructive maxillofacial procedures has been limited.

Alloplastic materials: These include rigid locking plates with osteosynthetic capacity, such as titanium hollow screw osseointegrating reconstruction plates (THORP) that have been used successfully in the treatment of defects in conjunction with VFTT reconstruction.[35,36] The latest innovation's are locking miniplates and double-threaded screws, which allow locking to both bone and plates to increase stability.

Distraction osteogenesis (DO): This technique has been used in correcting craniofacial deformities of the mandible, allowing gradual deposition of bone where two segments of bone are moved apart from one another. In a study on the reconstructed mandible, an average gain of 11 mm of bone length was achieved using DO.[37] The procedure works well in oncology patients who experience poor functional outcomes after surgery due to scar formation or inadequate bone length, but comes with a higher risk of failure and complications.

Rigid fixation: The recent developments in osteosynthesis plate technology have allowed the use of biocompatible materials in the internal fixation of fractures. In addition, biodegradable, self-reinforcing polylactide and polyglycolic plates/screws have also been recently used for internal fixation of mandibular fractures with high success rate.[1] Although, this technique allows accurate correction of fractures, the invasive nature of this system still presents a drawback in its application.

DISCUSSION

Reconstructive maxillofacial surgery can now draw upon many techniques in the reconstruction and rehabilitation of the orofacial region and reliable osseous reconstruction. Many institutions boast successful bony union rates of 95%.[4,38] In reconstruction, the choice of flap depends on the tissue type being replaced and the choice of donor site. It seems that nonvascularized tissue transfer is no longer the accepted first-line treatment in orofacial defects, and it is now superseded by vascularized tissue transfer.

In the past, nondistant pedicles were used to restore maxillofacial defects, giving way in recent years to free flaps. Initial research has reported high levels of success with free flaps, but data from randomized or comparative trials are needed to support this research.[5] Because of these advances, the quality of life in patients has improved significantly in post-SCC reconstruction.

Stereolithographic skull models have proven to be very useful for preoperative model planning and surgery simulation. The compact structure allows cutting with a saw, drilling with burrs and the fixation of screws. A further advantage is the reproduction of closed cavities, and the transparent structure makes the course of intraosseous canals visible, as well as intraosseous tumor expansion.

However, stereolithographic skull models are expensive and thus are not indicated or necessary in every patient. Thus, it can be summarized that the indicators for preoperative model planning and computer aided surgery are as follows:

1. Late primary repair of complex craniomaxillofacial fractures.
2. Complex ablative surgery of the maxilla, the paranasal sinuses and the cranial base.
3. Maxillary reconstruction.
4. Primary mandibular reconstruction when tumor expansion has led to extensive osteodestruction.
5. Secondary mandibular reconstruction in case of displaced resection stumps.
6. Cranioplasties.

From the review of the literature it seems that osseo-integrated implants offer the best functional and esthetic outcomes, achieving success rates up to 94%. However, some papers expressed caution about their use in irradiated patients,[32,33] they are employed not only to restore the dentition, but also to restore other structures such as the eye. Advances in grafting and biomaterials have led to much success, not only in maxillofacial surgery but also in periodontics and restorative dentistry. Sinus augmentation procedures allow implants to be placed in areas of bony atrophy. Bone substitutes may prove to be as effective as autogenous grafts for augmenting extremely atrophic maxillary sinuses. Upon healing, sites treated with xenografts and barrier membranes show a higher position of the gingival margin compared to sites treated with barrier membrane alone.

Distraction osteogenesis and the use of growth factors, such as BMPs have shown promise, but further research needs to be undertaken before these modalities can be recommended for routine implementation. A lot of research is being carried out in the field of muscular and neural tissue regeneration and this may play a role in orofacial reconstruction in the future.

The term 'perforator flap', used for the first time by Koshima in 1989,[39] was specifically provided by Wei (2001) and has achieved popularity only in recent years and its application in the intraoral region is even more recent. Vascularization of perforator flaps is based on small caliber cutaneous blood vessels, which, originating from a deep main pedicle, reach and cross the superficial fascia after passing through the muscles or the fibrous septa which separate them. The progressive increase in indications to use free flaps has provided an excellent boost to the development of this reconstructive technique over the last 25 years. Further innovative impetus has appeared over the last few years following the increase in popularity of the free flaps, known as perforator flaps.

An outline of the common characteristics of each perforator flap can be summarized as follows: Thinness of the cutaneous segment of the flap compared to myocutaneous flaps, short pedicle length, modest vessel caliber, minimum donor site morbidity.

CONCLUSION

Orofacial defects can have detrimental functional and psychological effects on the patient. However, in the modern maxillofacial world, the surgeon has a wealth of techniques to draw upon to manage such defects. The management involves sophisticated diagnostic imaging techniques, surgical reconstruction, prosthetic reconstruction or a combination of both. Microsurgery, osseointegration and bone technology have become the keystones in orofacial reconstruction, and major advances in recent years have resulted in more treatment modalities and increased success. The future is bright, as a wide range of techniques is being developed to improve upon the advances of the past few decades.

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