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Systematic Review

Methods for functional and aesthetic rehabilitation of maxillectomy defect: a systematic review

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ABSTRACT

Maxillectomy, a surgical procedure often required for the treatment of maxillofacial tumors, results in significant anatomical and functional defects. Reconstruction of these defects poses a substantial challenge due to the complex anatomy and the need to restore both form and function. Various techniques, including obturators, free flaps, virtual surgical planning (VSP), zygomatic implant and PSI have been developed to address these challenges. Objective; This systematic review aims to evaluate the effectiveness, outcomes, and complications associated with different reconstructive techniques for maxillectomy defects. A systematic literature through electronic and manual search was conducted. A total of 8 studies met the inclusion criteria, encompassing 390 patients undergoing maxillectomy reconstruction. Free flap reconstructions also showed favorable outcomes but required longer operative times and were associated with a higher incidence of donor site morbidity. While obturators are effective for small palatal defects, larger defects benefit more from autologous free tissue transfer, achieving superior functional and aesthetic outcomes. The incorporation of VSP and computer-aided design/computer-aided manufacturing (CAD/CAM) technologies significantly enhances the precision of osseous reconstructions, leading to improved patient outcomes.

Keywords: Maxillectomy, Midface, Rehabilitation, Oncologic defect, Obturators, Surgical flaps, Microvascular flaps

INTRODUCTION

The maxilla is the functional and aesthetic keystone of the midface, separating the oral, antral, and orbital cavities, and providing support to the globes, lower eyelids, cheeks, lips, and nose. In addition, the maxilla plays a critical role in speech, swallowing, and mastication. The reconstruction and rehabilitation of patients after ablative surgery of the maxilla and midface remains one of the greatest challenges currently faced by head and neck surgeons. Ablative surgery affects physical function, particularly speech, chewing, and swallowing.[1,2] Maxilla and midface defects caused by ablative surgery involve a high level of psychological and physical trauma in patients.[3]Segmental resection of the maxilla often results in complex maxillofacial defects, involving soft tissue, bone and dentition. These defects can be debilitating since they impair oral functions and disturb aesthetic contours, and may lead to social isolation and poor quality of life (QoL).

Maxillary reconstruction is a challenging endeavour in functional and aesthetic restoration. Given its central location in the midface and its contributions to the midface, maxillary defects are inherently complex because they generally involve more than one midfacial component.

Traditionally, rehabilitation with a palatal obturator has been the most common approach for treating maxillectomy defects. The advantages of this technique include a shorter operative time, shorter postoperative hospital stay, and complete visualization of the maxillectomy cavity, which simplifies oncologic surveillance.[4] Unfortunately, there are also numerous

disadvantages associated with obturators, including the potential for hyper-nasal speech, regurgitation of foods and liquids into the nasal cavity, difficulty in maintaining hygiene of the maxillectomy cavity, and the need for repeated prosthesis adjustments due to progressive changes in the size and shape of the palatal defect, especially in patients who receive radiation therapy.[5] However, over the past 20 years, vascularized free flaps have become increasingly integral to the overall reconstructive approach.[6] In several studies, it has been shown that surgical reconstruction may have advantages in terms of function and aesthetic outcomes.[1] A variety of local and regional flaps have been used to reconstruct maxillary defects with variable success.[7,8] Maxillary reconstruction changed radically with the advent of microvascular free tissue transfer, which provides abundant tissue for reconstruction, the freedom to orient, shape, and inset the flap as required for the specific defect, and the ability for reconstruction to be performed as a single-stage procedure.[9] Additionally, transfer of vascularized bone provides option of dental restoration via implantation of osseointegrated implants. Microsurgical techniques introduced are still being updated and researched greatly there still remains its complex nature and complications accompanied with it.[10]

Because of the wide range of treatments available, the objectives of this study will identify studies that are relevant to the treatment of patients after maxillectomy, to establish which treatments give the best functional and aesthetic results.

METHODS

PICO criteria

Participants/population: Patients with maxillectomy defect were included in study.

Intervention(s) and exposure(s): Reconstruction of maxillectomy defect included.

Comparator(s)/control: Different treatments for rehabilitation.

Outcome(s): Functional and aesthetic rehabilitation.

Protocol and registration

This study is registered with prospero (ID-CRD42023385312). The review can be accessed through the following link{https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42023385312}.

Inclusion criteria

Randomized controlled trial, non-randomized controlled trial, interventional studies or cohort studies**.** Patients with unilateral or bilateral maxillectomy defects, independent of the amount of resection were included.

Exclusion criteria

Congenital defect, cosmetic/plastic surgeries, animal studies, studies evaluating surgical approach rather than reconstruction technique, soft tissue defects without a bony component and in languages other than English were excluded.

Information sources and search

Published articles in English or those which have a detailed summary in English were included. Sources searched will be : PubMed-Medline; Google Scholar; clinical trials registry India; Cochrane oral health group's trials register; the Cochrane central register of controlled trials (central); searched will also be done encompassing all online issues of head and neck; international journal of oral and maxillofacial surgery; journal of oral and maxillofacial surgery; journal of cranio-maxillo-facial surgery; journal of prosthodontic research; and the British journal of oral and maxillofacial surgery.

Study selection

The PRISMA flow diagram of the screening and selection process is presented in Figure 1. 1152 records were identified after the initial search through the database searching, 786 were excluded after duplicate record. 366 were screened through abstracts and 321 searches were excluded according to inclusion and exclusion criteria. The remaining 45 were assessed for eligibility as the complete articles were screened for eligibility criteria. The total number of studies which matched the eligibility criteria, included in the systematic review were 8 (n=08) and were subsequently analysed.

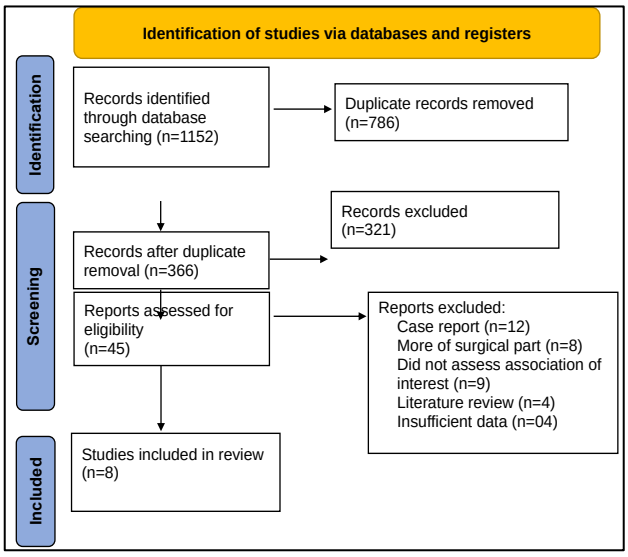

Figure 1: Flow chart of systematic search and review process.

Data collection process

An initial literature search (Titles and abstracts) was done by the two reviewers separately using the afore mentioned key terms. Titles were assessed and the articles addressing the research question were separated for abstract analysis. Abstracts were further assessed and articles specifically addressing the review question were selected for full-text analysis. The data were tabulated on a spreadsheet that contained the details of the patients, postoperative results and complications, functional results, aesthetics, and QoL (Table 1).

Risk of bias assessment

A system modified from the US agency for healthcare research and quality methods guide for comparative effectiveness reviews was used to assess the sources of possible bias. Of the eight articles selected, one was a randomized control trial (RCT), one was cross-sectional, four articles were retrospective and two were prospective. Criteria were judged with high, medium, low/ unknown risk of bias: case selection bias and confounders, attrition bias, detection bias, and reporting bias, and a summary of the risk. Six studies were rated as having low risk of bias, and one study was rated as having moderate and high risk of bias each as shown in Table 3.

RESULTS

A total of 8 studies were selected for the study. A flow diagram of the study selection is presented in Figure 1. Four studies were retrospective, one prospective study, one cross sectional, one prospective RCT and one was a pilot study, selected studies is shown in Table 1 and Table 2.[3,11-17]

Of the 390 patients, 186 had surgical reconstruction and 204 were treated with an obturator prosthesis and obturator prostheses associated with osseointegratable implant. The mean ages ranged from 49 to 64years, and patients had a maxillectomy for malignant or benign tumours. Data was collected from the selected articles in customized forms and tabulated (Table 1 and 2) and the risk of bias assessment presented in Table 3.

Defects were reconstructed with rectus abdominis, latissimus dorsi myocutaneous flaps, temporalis flaps, iliac crest and fibular osteo muscular flaps, fibular osteomyocutaneous flaps, radial forearm osteocutaneous free flap, radial forearm fasciocutaneous free flaps (RFFF); and antero lateral thigh, lateral arm, serratus composite, free rectus, iliac, and fibular free flaps.

Result of individual study

In the study by de Groot et al 24 patients were examined, with 11 undergoing reconstruction and 13 in the non-reconstructed group.[17] The results indicated that the reconstructed patients had superior mixing ability, bite force, and overall mean health-related QoL (HR-QoL). Interestingly, the non-reconstructed group did not show significant differences from the reconstructed group in terms of maximum mouth opening, bite force on the operated side, and most HR-QoL domains, suggesting specific areas where reconstruction had the most impact.

Aladashi et al conducted a study involving 60 patients, divided equally into two groups: one receiving submental island flap reconstruction and the other using a surgical obturator. The study found significant improvements in QoL for the submental group in areas such as chewing, swallowing, speech, taste, mood, and anxiety. Specifically, the submental group showed improvements with $p=0.034$ for chewing, less than 0.001 for swallowing, 0.009 for speech, 0.04 for taste, 0.01 for mood, and 0.003 for anxiety. On the other hand, the obturator group showed greater improvements in appearance ($p<0.001$) and masticatory function scores post-rehabilitation ($p<0.001$).[16]

The study by Buurman et al included 20 patients, with 11 undergoing surgical reconstruction and 9 using implant-supported obturators.[15] Both groups displayed similar mixing ability indices (18.20±2.38 for the reconstructed group versus 18.66±1.37 for obturator group, $p=0.614$) and masticatory ability. However, the implant-supported obturator group faced issues such as loss of 5 implants, 2 damaged implants, and 2 non-functional implants, highlighting potential complications with this method.

Wang et al examined 38 patients, divided into two groups: 18 patients with obturator prostheses and 20 patients with vascularized free flap reconstructions.[3] The study found no significant differences between the groups in terms of the oral health impact profile (OFS), the European organisation for research and treatment of cancer (EORTC) head and neck assessment, and the mental health inventory (MHI) global scale. However, the obturator group had higher median subscale scores, with a significant difference observed ($p=0.024$).

Breeze included 39 patients, with 18 undergoing surgical reconstruction and 21 using obturators.[14] The study reported a significant decrease in health-related QoL after treatment ($p<0.001$). Despite this overall decline, there was no significant difference in post-treatment QoL between the surgical and obturator groups, indicating that both methods had similar impacts on patients' QoL.

In the study by Rieger et al there were no significant differences found between the surgical reconstruction group and the prosthodontic intervention group regarding facial attractiveness and speech outcomes.[11] The study highlighted that patients with involvement of the orbital rim or the orbital rim and zygoma were rated as significantly less attractive than those without such involvement. Speech outcomes for both groups were within normal limits, suggesting that both methods were equally effective in this regard.

Table 1: Details of selected articles.

Authors	Study design	N	Mean age (in years)	Type of maxillectomy	Treatment provided	Follow-up period (months)	Outcomes
De Groot et al[17]	Pilot study	24 M: 10 F: 14	58.9	Brown class I-II: 20 III-IV: 4	Fibular: 11 Obturator: 4	30± 22	Mixing ability, maximum bite force, maximum mouth opening, and HR-QoL
Aladashi et al[16]	Prospective RCT	60 M: 27 F: 33	55.9	Brown class II_A: 3 II_B: 57	Surgical Obturator: 30 Submental flap: 30	6	University of Washington Quality of Life Questionnaire (UW-QOL)
Buurman et al[15]	Cross sectional study	20 M: 15 F: 5	53.4	Brown class I: 1 II: 15 III: 4	Fibular: 11 Obturator: 9	NR	Masticatory performance. Oral health related quality of life (OHRQoL)
Wang et al[3]	Retrospective analysis	38 M: 23 F: 18	50.9	Okay class I_B: 15 II: 15 III: 8	Fibular: 15 Ilium: 5 Obturator: 18	NR	QOL assessed by OFS, EORTC Head and Neck 35, MHI
Breeze et al[14]	Prospective study	39 M: 22 F: 17	64	Brown class I: 8 II: 19 III: 7 IV: 5	Obturator: 21 Temporalis: 10 RFFF: 4 ALT: 2 Scapula: 2	14±4	QOL assessed by UW-QOL
Rieger et al[11]	Retrospective study	39 M: NR F: NR	52	Okay class I_b: 9 II: 27 III: 3	Fibular: 16 Obturator: 23	NR	Aesthetic nasalance Speech intelligibility
Moreno et al[12]	Retro-spective analysis	113 M: 63 F: 50	54	Brown class II: 59 III: 32 IV: 22	Obturator: 73 ALT: 11 Fibular: 11 Fibula + ALT: 3 RAFF: 10 LA: 1 Free rectus + composite: 1 Serratus composite: 1	6	Diet outcomes Speech outcomes
Bernhart et al[13]	Retro-spective analysis	57 M: 42 F: 15	49	Classification by authors: total maxillectomy, premaxilla resection, palatectomy, total bilateral maxillectomy, and total maxillectomy including contralateral premaxilla	Obturator: 26 RAFF: 16 RFOFF: 6 RFFF: 2 LDFF: 2 SFF: 2 Fibular: 2 Temporalis: 1	37.5	Aesthetic masticatory function speech intelligibility

NR: not reported; RFFF: radial forearm free flap; ALT: Antero lateral thigh; RAFF: rectus abdominus free flap; LA: lateral arm; RFOFF: radial forearm osteocutaneous free flap; LDFF: latissimus dorsi free flap; SFF: scapular free flap.

Table 2: Selected studies parameters.

Authors	Treatment provided	Measurements					Complication	Follow up period (months)
		Speech	Swallowing	Mastication/diet	Aesthetic	QoL		
De Groot et al[17]	Reconstruction with fibula (n=11), obturator prosthesis (n=13)	12.1±12.6 12.8±13.5	3.0±4.2 16.7±22.8	8.3±11.2 20.5±24.0	NR	Better QoL as compared to obturator group	NR	30±22
Aladashi et al[16]	Reconstruction with submental flap (n=30) obturator prosthesis (n=30)	88.8 60	93.3 70	82 61	74.5 94.1	Better QoL as compared to obturator group	NR	6
Buurman et al[15]	Reconstruction with ART protocol and Rohner's Technique (n=11) Implant supported obturator (n=9)	NR	NR	No significant difference	NR	NR	5 implant lost, 2 damaged, 2 non-functional	NR
Wang et al[3]	Reconstruction (Fibula, ilium) n=20, obturator prosthesis + dental implants (n=18)	No significant difference between groups, but slightly better for obturator group	No significant difference between groups, but slightly better for obturator group	No significant difference between groups, but slightly better for obturator group	No significant difference between groups	No significant difference between groups	3 implants failed	NR
Breeze et al[14]	Reconstruction (TF, RFFF, ALT, scapula) n=18, obturator prosthesis (n=21)	68 77	78 68	88 77	76 81	No significant difference between groups	NR	14±4
Rieger et al[11]	Reconstruction (Fibula) n=16 obturator prosthesis (n=21)	97.6±3.4 97.1±3.4	NR	NR	6.75 (1-10) 5.9 (1-10)	NR	NR	NR
Moreno et al[12]	Reconstruction (ALT, fibula, RAFF, LA) n=28, obturator prosthesis (n=73)	Excellent-19 Good-16 Average-3 Poor-2 Excellent-34 Good-25 Average-12 Poor-2	NR	Unrestricted-22 Soft-14 Liquid -2 NPO-2 Unrestricted -40 Soft-23 Liquid-8 NPO-2	NR	NR	Total flap loss (n=2) and partial flap loss (2), fat necrosis (1), 6 patient developed nasocutaneous fistulas who had radiotherapy	6
Bernhart et al[13]	Reconstruction (RAFF, RFOFF, RFFF, LDFF, SFF, Fibular, temporalis) n=31 reconstruction + obturator prosthesis (n=26)	Normal- 8 Poor-1 Not reported- 22 Normal-25 Hypernasal-1 Hyponasal-0	NR	Full diet-12 Soft diet-9 Pureed diet-3 Not reported- 7 Full diet-21 Soft diet-4 Pureed diet- 1	Normal-5 Poor-2 Not reported- 24 Normal- 21 Limited-1 Poor-4		Partial loss of free flap. Obturator caused difficulty chewing solids and lacked retention and also resulted in hyper nasal speech, but most patients had satisfactory results. Final outcome: prosthetic rehabilitation is better when it follows reconstruction	37.5

NR: not reported; ART:Alberta Reconstructive technique; QoL; quality of life; RFFF: radial forearm free flap; ALT: Antero lateral thigh; RAFF: rectus abdominus free flap; LA: lateral arm; RFOFF: radial forearm osteocutaneous free flap; LDFF: latissimus.

Table 3: Risk of bias assessment.

Authors	Year	Study type	Selection bias and confounding	Performance bias	Attrition bias	Detection bias	Reporting bias	Summary assessment
Aladashi et al[16]	2021	RCT	Low	Low	Low	High	Low	Low
Bernhart et al[13]	2023	Retrospective	Low	Medium	Low	Low	Low	Low
Breeze et al[14]	2016	Prospective	Low	High	High	High	Low	High
Buurman et al[15]	2020	Cross-sectional	Low	Low	Low	High	Low	Low
De Groot et al[17]	2020	Prospective	Low	Medium	Low	High	Low	Medium
Moreno et al[12]	2010	Retrospective	Low	Low	Low	High	Low	Low
Reiger et al[11]	2011	Retrospective	Low	Low	Low	Low	Low	Low
Wang et al[3]	2017	Retrospective	High	Low	Low	Low	Low	Low

Table 4: Maxillectomy classification.

Class	Brown[9]	Okay[18]
I	Maxillectomy with no oroantral fistula. Removal of alveolar bone does not result in an oronasal or oroantral fistula. Resections of defects in the ethmoidal and frontal sinus cavity, or removal of the lateral nasal wall would fit into this category. It includes the removal of palatal bone only, which inevitably results in an oronasal fistula, but leaves the tooth-bearing part of the maxilla intact	Defects that involve the hard palate but not the tooth-bearing alveolus categorised as class Ia Defects that involve any portion of the maxillary alveolus and dentition posterior to the canines, or which involved the premaxilla are categorised as class Ib. They involve a small portion of the dental arch; the anterior sextant and a unilateral posterior quadrant of teeth remain intact
II	Low maxillectomy. Includes alveolus and antral walls but not the orbital floor or rim	Defects that involve any portion of the tooth-bearing maxillary alveolus, but include only one canine, are categorised as class II. The anterior margin of these defects is within the premaxilla. This class also includes anterior transverse palatectomy defects that involve less than one half of the palatal surface
III	High maxillectomy includes the orbital floor with or without periorbita and with or without resection of the base of the skull	Defects that involve any portion of the tooth-bearing maxillary alveolus and include both canines, total palatectomy defects, and anterior transverse palatectomy that involve more than half of the palatal surface
IV	Radical maxillectomy plus orbital exenteration with or without resection of the anterior base of the skull	-
Subclass A	Resection of unilateral alveolar maxilla and hard palate. Less than or equal to resection of half the alveolus and hard palate, and does not cross the midline or involve the nasal septum.	-
Subclass B	Resection of bilateral alveolar maxilla and hard palate. Includes smaller resection that crosses the midline of the alveolar bone, including the nasal septum	-
Subclass C	Removal of entire alveolar maxilla and hard palate	-
Subclass F	-	Defects that involve the inferior orbital rim
Subclass Z	_____	Defects that involve the body of the zygoma

DISCUSSION

Ablative surgery dramatically affects the patient's life and physical function. Thus, reconstruction of the maxilla is considered after maxillectomy in order to minimize any facial deformity, restore oral function, and maintain psychological receptive.[1,2] Brown and Shaw proposed a classification scheme for maxillectomy that is commonly used today. In their scheme, defects are described based on their vertical extent, horizontal extent, and whether they involve the orbit or nasal passageway.[10] Another classification for maxillectomy was given by Okay et al.[18] The comparison of Brown's and Okay classification is shown in Table 4.

After resection of the maxilla, the primary goals are to reconstruct the maxillary defects and restore oronasal functions and facial contours. One common approach to achieving these objectives is the use of an obturator. Obturators offer several advantages: they are a less expensive reconstructive option compared to extensive surgical reconstruction while providing satisfactory functional results. This makes them particularly beneficial for patients who are poor candidates for surgery. Additionally, obturators can be removed, allowing for direct observation of surgical margins and making clinical surveillance for cancer recurrence easier.

However, while obturators provide good functional results for small to medium-sized maxillectomy defects, they have inherent limitations that can affect patient quality of life. These limitations include difficulties in maintaining the cleanliness of the maxillectomy cavity and residue buildup on the obturator despite vigilant cleaning. Reports have highlighted poor masticatory function and difficulties with drinking, particularly in cases of large initial maxillectomy defects.[19] Issues with improper nasalance, including both hyponasality and hypernasality, are also prevalent among patients using obturators post-maxillectomy.[20] Furthermore, poorer swallowing ability is commonly reported, especially in patients with extensive horizontal defects such as large palatal. These factors must be carefully considered when opting for obturator use in maxillary defect reconstruction.

The concept of remote bone anchorage using zygomatic implants was introduced in 1998 by Brånemark P-I to rehabilitate cases with severe maxillary atrophy, which could be congenital or acquired as a result of resective surgery or trauma. A major advantage of using zygomatic implants is the elimination of the need for extensive grafting procedures. The development of zygomatic implants, along with the use of magnets and bar-attachments, significantly changed the treatment modality. These innovations provided enhanced retention force, support, and improved the stability of the obturator prosthesis. A treatment approach involving three or four zygomatic implants offered a source of vertical resistance and retention, effectively addressing the issues associated with limited residual bone. The use of zygomatic implants has been extensively supported by studies conducted by Schmidt and Hackett et al highlighting their effectiveness for maxillary reconstruction following extensive ablative resection.[21,22]

Fibula grafts, based on the peroneal artery, are frequently chosen when a bone graft component is required for midfacial reconstruction. The use of an osteocutaneous fibular graft is particularly beneficial due to its freely movable soft tissue component, a feature not present in other composite grafts. This type of graft has been reported to successfully provide a platform for the future insertion of dental implants and prosthesis placement, despite not following normal anatomical structures.[23] The fibular flap offers excellent bony stock but often requires multiple osteotomies to fit the contour of the maxilla. VSP has proven particularly valuable when immediate endosseous implantation is planned at the time of fibula transfer. Avraham et al found that patients receiving CAD-CAM based reconstructions had increased rates of dental rehabilitation and experienced minimized operative time.[24] VSP offers several advantages for immediate implant placement: it allows for the determination of the fibula bone shape and the specific segments to be used for reconstruction during the virtual planning session. This eliminates guesswork in selecting the height and size of implants to be used intraoperatively. Additionally, the use of a fibula jig for implant placement ensures that the implants are loaded into the bone with the appropriate trajectory and inclination, further enhancing the precision and effectiveness of the reconstruction process.

The RFFF is a workhorse of many head and neck reconstructions; it can be relatively easily harvested, has a reliable and long pedicle, can be harvested synchronously with head and neck ablation, and often provides good skin color match for head and neck reconstruction.[25] High success rates in terms of graft incorporation; function restoration (speech and oronasal separation) and esthetic outcomes (patient accepting social interaction) have been reported.[26] It carries donor site morbidity, however, with the risk of tendon exposure, and the harvest site requires a split-thickness skin graft for closure. The radial forearm osteocutaneous flap is useful for smaller reconstructions, but the bony component of the flap is not sufficient for total maxillectomy defects, and occasionally it is not sufficient to allow later dental implantation.

The scapular free flap is a viable option for reconstructing type II or III hemimaxillectomy defects, providing sufficient bone volume to support dental implants. Proper graft orientation and fixation in the optimal three-dimensional position are crucial for successful outcomes. Compared to other microvascular bone grafts, the scapular graft offers several advantages: it has relatively low donor-site morbidity, a high-quality and appropriately sized pedicle, and a shape well-suited

for maxillary reconstructions.[27] One of the key advantages of the scapular graft is its versatility in maxillary reconstruction. The bone can be divided into different components, allowing for independent positioning of each component, which is particularly beneficial for class III defects. Additionally, a skin paddle can be harvested, if necessary, which can be used to address intraoral defects and midfacial or paranasal soft-tissue defects. The scapular tip transplants also feature a long pedicle and a triangular or round shape, allowing for the reconstruction of a wide variety of defects.[28] However, there are also disadvantages associated with the scapular free flap. Harvesting procedure is time-consuming, and simultaneous flap raising is not possible. The dissection of the vascular pedicle is also challenging. Furthermore, correct graft orientation is essential due to the limited bone volume of the scapula compared to other microvascular flaps.

The iliac crest free flap, also known as the deep circumflex iliac artery (DCIA) flap, was popularized by Urken et al in 1989 for oromandibular reconstruction and applied to maxillary reconstruction by Brown in 1996.[29] This flap offers several unique advantages. It allows for the simultaneous harvesting of a large amount of bone and soft tissue when the internal oblique muscle is included in the flap. The DCIA flap is particularly advantageous for reconstructing midfacial bone defects due to its substantial bone height and flexible skin for external soft tissue coverage, along with muscle that rapidly epithelializes to attached mucosa for internal coverage. Surgeons can customize the height and length of the flap to achieve optimal restoration of the facial bone buttress and orbital rim, which is crucial in cases with extensive defects. Additionally, the muscular component used for resurfacing the oral and nasal lining typically undergoes re-epithelialization within a few weeks, and the iliac bone is ideal for dental implant placement.[30] The main drawbacks are the short pedicle and possible donor site morbidity, particularly in obese patients, when the flap is too bulky and the dissection more difficult. Despite these challenges, the iliac crest free flap remains a valuable option for complex maxillary reconstructions, providing substantial bone and soft tissue for effective rehabilitation.

The submental flap, dependent on the submental vessel, is a viable option for maxillary defect repair. It is an axial pattern skin flap based on the submental artery, a consistent branch of the facial artery. This flap can be used as a pedicled flap, free tissue transfer, or perforator flap, depending on its composition.

The submental flap offers several advantages, including an excellent skin color match and a wide arc of rotation, which can extend to cover the entire lateral face and oral cavity, except for part of the forehead.[31] The submental pedicled flap can be oriented inferiorly, depending on the integrity of the facial artery, or superiorly, based on the anastomosis between the external and internal carotid arteries via the angular artery. Advantages of the submental flap approach are primarily related to the donor site. These include the ability to perform a very thin section, its flexibility, and the adaptability of the design. These features make the submental flap a valuable option for reconstructing maxillary defects, offering both functional and aesthetic benefits. However, in defect requiring osseous reconstruction, this flap is not indicated.

The temporalis myofascial flap (TMF) serves as a useful option for maxillofacial reconstruction. TMF consist of temporalis muscle with the overlying temporalis fascia and it has rotational radius 8 cm3 to gain access to midface defect. Temporalis muscle is strong enough to bear the rotation of 180 degrees for reconstruction of intraoral defect. Muscle length of 12-16 cm is reported in the literature with more length seen in males.[32] TMF serves as an axial flap with anterior, posterior deep temporal arteries which are branches of internal maxillary artery and middle temporal artery which is a branch of superficial temporal artery as a pedicle. The TMF can reach the contralateral palate as well, allowing complete coverage of hemi-palatal defects. The hemi-coronal scar provides satisfactory cosmetic results since it starts in the pretragal region and extends superiorly often within the hairline. Many authors have used TMF for the reconstruction of maxillary defects after oncological procedures, with good results in speech, swallowing and appearance. Another important aspect favouring the use of this flap after oncological procedures is the excellent viability of the flap that permits very early post-operative radiotherapy; this complementary treatment can be administered much earlier than with any other type of reconstruction and may be critical when dealing with cancer patients.[33] The disadvantage of this flap include the aesthetic results are often poor because of donor site depression and the lack of cheek soft tissue support. In addition, the bulking of the flap does not provide a good cheek contour and is insufficient to fill the residual cavity.

The anterolateral thigh (ALT) flap based on the musculocutaneous and septocutaneous perforators of the descending branch of the lateral circumflex femoral artery has enjoyed increasing popularity since first being described by Song et al in 1984.[34] This flap has a long vascular pedicle with large-diameter vessels, is reliable and versatile, and provides a large amount of soft tissue that may also include the fascia Lata, for flap suspension to the residual structures, preventing ptosis of the flap in the oral cavity. It can be harvested as a musculocutaneous or perforator flap, depending on the size and type of defect. It provides significant tissue bulk and a long pedicle (10-15 cm), allows for primary closure of the donor site, and can be sensate. When a wide residual cavity is present, muscle harvesting permits filling of all the space, thereby preventing air communication and providing cheek soft tissue support. Furthermore, the anterolateral thigh flap may be harvested with two skin

paddles, when reconstruction of the external coverage of the cheek is needed. The harvesting may be performed simultaneously with the tumor resection surgery, reducing intraoperative time. Chen et al described an alternative technique in which bilateral skin paddles with a palatal bridge were designed, as opposed to dividing the ALT flap into two separate flaps as previously described. This technique allows bilateral skin paddles for buccal reconstruction and a palatal skin bridge overlaid on the palate after denuding the mucosa, and permits a single vascular anastomosis.[35]

Over the past decade, significant advances have been made in preoperative planning and, specifically, the use of 3D modelling. For complex maxillary reconstructions, preoperative 3D planning can allow for more precise intraoperative bone cuts and improved orientation of the pedicle. Together, these can improve overall intraoperative efficiency, shorten operative times, and, potentially, further minimize risks to patients.[23] Maxillary access is difficult due to limited exposure constraining the reliable and accurate positioning of the final reconstruction. The advent of additive manufacturing (AM), 3-dimensional (3D) printing, and the recent advances in those technologies has positively influenced the biomedical field, leading to the utilization of patient-specific implants (PSIs) in the surgical repair of maxillofacial defects. Materials that are used for PSIs are made from titanium, poly (methyl methacrylate) (PMMA), hydroxyapatite, polyether ether ketone (PEEK), and other bioinert materials became an alternative tool for facial reconstruction.[36] In a retrospective study by Lim et al evaluated patients with maxillofacial defects reconstructed using patient-specific titanium implants over an average follow-up of 36.7 months.[37] The study reported high rates of bone fusion, low complication rates, and high patient satisfaction. Clinical studies have reported high success rates and patient satisfaction with the use of PSIs.[38-40] These implants not only restore functionality, allowing patients to regain essential abilities such as chewing and speaking, but also contribute to significant aesthetic improvements, thereby boosting the patients' self-esteem and social interactions. As technology continues to advance, the future holds even greater promise for the refinement and effectiveness of these implant-based rehabilitation techniques.

CONCLUSION

The best treatment of patients with defects of the maxilla and midface is with a multidisciplinary team, including the surgeon, prosthodontist, and speech pathologist, from the start of patient care to help educate patients about all reconstructive options and likely outcomes. Obturators are sufficient for small, palatal defects, but larger maxillectomy defects are better reconstructed with autologous free tissue transfer. Many patients can achieve successful reconstruction with a return of intelligible speech, a regular diet, and acceptable aesthetic. VSP and CAD/CAM are an important tool for osseous reconstruction of the midface, this technological advancement provides improved precision and accuracy. With the advancement in AM technology and 3D printing, it can revolutionize the concept of reconstruction. As experience with this technology grows, continued refinements will lead to greater accuracy, efficiency, and potentially improved patient outcomes.

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