Chapter

Mandibular Resection: Disabilities, Challenges, Reconstruction Techniques, Advances, and Quality of Life

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Abstract

Congenital anomalies, trauma caused by road traffic accidents, sports, and violence, cyst removal, and benign and malignant tumor eradication may require mandibular resection. A procedure that has many adverse effects, such as facial disfigurement, esthetic impairment, compromised masticatory efficiency, speech problems, bargained social interaction, and physiological circumstances that adversely affect the patient's quality of life. The rehabilitation of patients with mandibular resection still presents a challenge for both maxillofacial surgeons and prosthodontists and emphasizes the role of a multidisciplinary team approach for optimum treatment outcomes. This chapter aims to elucidate the different disabilities associated with mandibular resections, challenges encountered, the different surgical and prosthetic reconstructive techniques that can be used for rehabilitation, and their impacts on patient quality of life.

Keywords: mandibular resection, marginal mandibulectomy, prosthetic reconstruction, segmental mandibulectomy, surgical reconstruction

1. Introduction

Congenital anomalies; trauma from road traffic accidents, sports, and violence; and cyst removal and benign and malignant tumor resection may result in maxillofacial defects that have several adverse effects, including facial disfigurement, esthetic impairment, compromised masticatory efficiency, speech problems, limited social interaction, and physiological circumstances that hamper the patient's quality of life [1–8].

2. Oral cancer and mandibular defect

Head and neck cancers (HNC) pose a significant global issue, ranking as the seventh most common neoplasm worldwide, with over 900,000 new cases annually [9, 10]. Of these, 40% are oral cancers, accounting for 377,713 new diagnoses per year [9–12] .

Surgical irradiation of the tumor, alone or in combination with radiotherapy (RT) and/or chemotherapy (CT), is the most common treatment modality for oral cancers [9, 13].

Considering the mandibular oral cancer cases, two different surgical resection techniques can be performed according to the tumor extension: marginal mandibulectomy and segmental mandibulectomy [5, 8]. Marginal mandibulectomy is defined as the surgical removal of a segment of the mandible, without resulting in a continuity defect while segmental mandibulectomy is a type of mandibulectomy that involves the surgical removal of a portion of the mandible. Both techniques result in several disabilities that necessitate expeditious rehabilitation (**Figure 1**) [14].

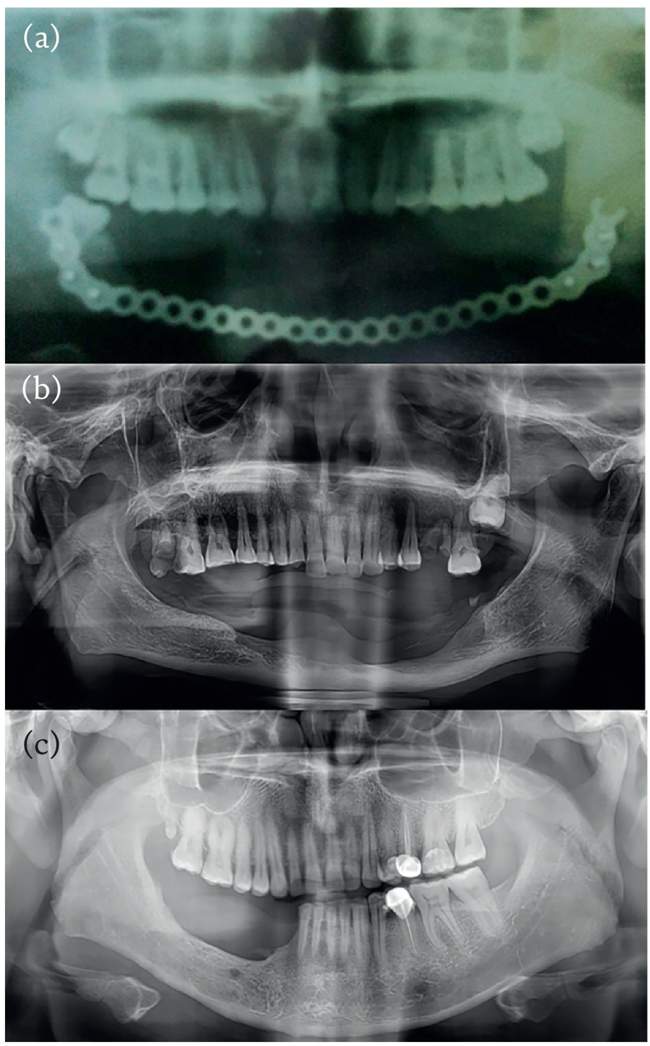

Figure 1.
Panoramic radiograph of a patient with (a) segmental mandibulectomy, (b) completely edentulous patient with marginal mandibulectomy, and (c) posterior marginal mandibulectomy showing inadequate vertical height above the mandibular canal.

3. Disabilities associated with mandibular resection

The geometrical U shape of the mandible defines the esthetic of the lower third of the face, supporting the tongue and the muscles of the mouth and facilitating the patient's mastication, deglutition, articulation, normal breathing, and salivary control [15]. Following mandibulectomy, the patient may encounter several disabilities, including cosmetic deformity, impaired speech and articulation, compromised control of salivary secretion, deviation of the mandible during opening, closing, and functional movement, difficulty in swallowing, chewing problems, diminished social activity, and reduced patient quality of life [1–8].

The main goals of mandibular reconstruction are to re-establish the form of the lower third of the face, ascertain the required alveolar bone height, establish the arch form and width, improve the patient's esthetics, mastication, swallowing, deglutition, and phonation; maintain the airway passage; control the saliva dropping; and improve the patient's psychology and quality of life (**Figure 2**) [1–8, 15, 16].

The selection between the different reconstructive modalities is significantly determined by many factors [1, 2, 5, 17, 18], such as the position and extension of the defects [1, 2, 5, 17], the depth of the vestibular sulci [6, 7, 15, 16, 19], the remaining soft and hard tissues [4, 5, 15–17], the degree of tongue impairment [5–7], the need for radio- and/or chemotherapy as adjunctive therapy and the associated circumstances [5–9], the cost [4, 15], the expertise of the maxillofacial surgeon, the presence of a specialized centre, and the patient's preference [1–7, 15, 20–22].

Figure 2.
Extra-oral frontal view of anterior marginal mandibular resection patient. (a) Before reconstruction. (b) After reconstruction.

4. Classification of mandibular defects

The literature documented several classifications for mandibular defects. The mandibular defects are generally classified according to their positions into anterior, lateral, and ramus/condyle defects [8].

Jewer et al. [23] provide another classification based on the complexity of the restoration, with central defects extending between canine to canine, forming a C“-shaped defect, and lateral segments excluding the condyle in the form of “L.“ When the condyle is resected together with the lateral mandible, the defect is in the form of an “H,” or hemi-mandibular defect [23, 24].

Boyd et al. [25] considered the mucosal and/or soft tissue component of the defect by adding characters o, m, and s as osseous only, mucosa, and/or external skin, respectively.

Another classification provided by Urken et al. [26] is based on functional considerations caused by the detachment of different muscle groups and difficulties with cosmetic restoration. C—condyle, R—ramus, B—body, S—total symphysis, and SH—hemisymphysis.

Petrovic et al. [21] classified the marginal mandibular resection patients from a prosthetic aspect into three subgroups, including completely edentulous patients, partially edentulous patients, and dentate patients with non-tooth-bearing area marginal mandibulectomy, that is, the ascending ramus of the mandible.

5. Timing of mandibular reconstruction (immediate/delayed)

Following mandibular resection, the defect can be immediately reconstructed, or after a while, using a delayed/staged approach, which provides an observational period of tumor recurrence. However, in benign cases, nowadays, the immediate reconstruction approach is widely acceptable with a high success rate and significant improvement in the patient’s quality of life [23, 27–32].

5.1 The role of the maxillofacial team in the management of mandibular resection patients

Management of mandibular resection cases necessitates the interaction between the different oral and maxillofacial team members for successful rehabilitation [2, 21]. The primary objective of the maxillofacial team is to restore the patient to their previous state of health. The target of the treatment plan should be restoring the continuity of the mandibular bone, if possible, and replacing the soft and hard tissue loss with a stable, well-functioning prosthesis [2, 5, 21, 33, 34].

Seok H [35] emphasized the role of the multidisciplinary approach for the management of patients with oral cancer; the team can include the following specialists: oral and maxillofacial surgeons, plastic surgeons, otolaryngologists, radiation oncologists, hematology oncologists, prosthodontists, general dentists, and speech-language pathologists, depending on the case, extension, and tumor grading.

Wang et al. [36] reported a relatively lower risk mortality rate in patients treated with a multidisciplinary team. In the same line, de Boer et al. [37], Kutuk emphysized et al. [38], Ahmad et al. [39], Shah [40], and Suliman and Awadalkreem [41] underscore the role of interprofessional collaboration in optimizing the oral health management for head and neck cancer patients with and without radiation therapy.

6. Rehabilitation of mandibular resection defects

The rehabilitation of mandibular resection defects may follow two stages/approaches:

1. Surgical reconstruction of the mandibular defects.

2. Prosthetic reconstruction of the mandibular defects.

6.1 Surgical reconstruction of the mandibular defects

Through the past decades, several surgical techniques [2, 3, 8, 18, 21, 42–126] have been described in the literature for the reconstruction of mandibular defects, including primary closure of the defect (healing by primary intension), skin graft, the use of alloplastic metallic mesh and plate, regional flaps, non-vascularized flaps, free vascularized bone graft, distraction osteogenesis, bone substitutes, and advance technology (**Figure 3**).

6.1.1 Primary closure

Primary closure of the oral tissues is the simplest method as it does not involve replacing the defected bone and instead allows the mucosa to heal with secondary intention. Small defects less than 2 cm can be closed primarily by expanding the surrounding buccal or floor-of-mouth mucosa over the bony defect (**Figure 3**) [1, 3, 5, 8, 18, 55].

6.1.2 Skin graft

Reverdin first described the skin graft in 1869; later in 1972, Ollier highlighted its usage, which had been reviewed by Stele in 1870 and documented by Pai et al. [55]. The use of split skin grafts is a simple technique that allows close oncologic monitoring while ensuring excellent speech and swallowing function. Both spilt-thickness and full-thickness skin grafts can be used for small-defect mandibular reconstruction with the advantages of rapid healing, extended flaps with limited morbidity of the

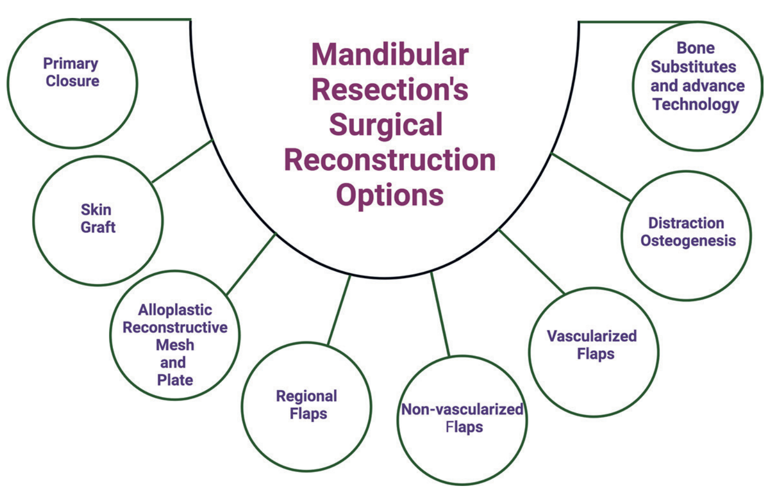

Figure 3.
Surgical mandibular reconstructive techniques.

donor site, and avoidance of the flap's bulk. The immobilization of the flap during the healing process plays a significant role in its success and can be facilitated by the construction of a surgical stent. However, in some cases, the intra-oral bulk of the skin graft may limit the use of a removable reconstructive prosthesis. Additionally, the preoperative radiation therapy may compromise the healing of the graft [127].

6.1.3 Alloplastic mandibular reconstructive mesh and plate

Reconstructive mesh and plate are the most commonly used alloplastic devices for mandibular reconstruction due to their low costs, reliability, and short intraoperative time, which require less surgical expertise than other surgical techniques [2, 15, 55–59]. Before completing the resection, surgeons commonly shape and place the plates to ensure correct segment alignment. Furthermore, it is crucial to exercise meticulous care in maintaining proper occlusion to ensure satisfactory joint function (**Figure 4**).

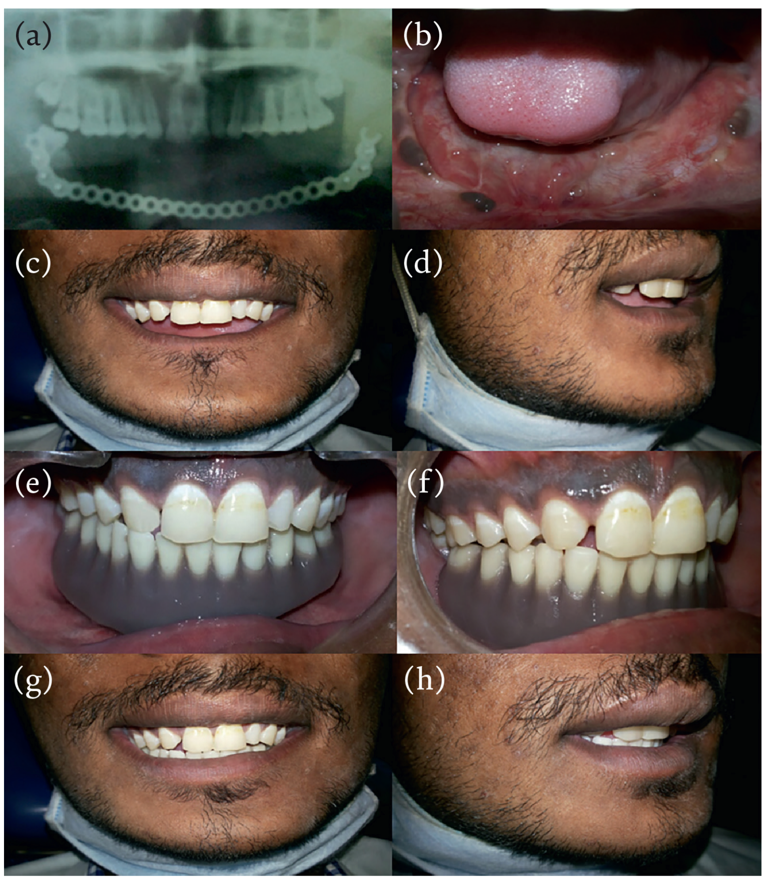

Figure 4.
Mandibular reconstruction with alloplastic reconstructive plate. (a) Postoperative patient's orthopantomography showing segmental mandibular resection reconstructed with alloplastic reconstructive plate. (b) Intra-oral view of the patient at the time of the presentation. (c) Extra-oral frontal view photograph of the patient showing compromised lower lip support. (d) extroral lateral view photograph of the patient. (e) Intra-oral frontal view of the patient showing reconstruction with tissue borne acrylic tissue-supported prosthesis. (f) Intra-oral lateral view of the reconstructive prosthesis (g) Extra-oral frontal view photograph of the patient after reconstruction showing improved lower lip support. (h) Extra-oral lateral view photograph of the patient after reconstruction showing improved lower lip support and patient's esthetic.

However, the compromised esthetic outcome, the limited support for the soft tissues, limited masticatory function, and the possibility of infection that may or may not result in plate exposure and painful sensation, especially in patients with radiotherapy, are the main drawbacks of this reconstructive modality [2, 15].

To improve the esthetic result of reconstructive plate combination with a soft tissue pedicle flap had been considered. Furthermore, this technique has the potential to alleviate tension and minimize the risk of plate exposure, particularly in patients who are radiated [2].

The most commonly used metals for reconstructive plates are stainless steel, vitallium, and titanium. Nowadays, a titanium hollow osseointegrated reconstruction plate (THORP) which is a specialized system has been used widely. It allows bone ingrowth, improving the stability of the bony interface and preventing the necrosis of the bone underneath, without reported adverse effects with radiation per se (**Figure 4**) [15, 56, 57].

6.1.4 Regional flap

The goals of the regional flap are to restore the form and function and minimize donor site morbidity. The buccal fat pad flap, the facial artery musculomucosal flap, the platysma, the pectoralis major, the temporalis muscle flap, and the trapezius flaps are some of the regional pedicle flaps that can be used for reconstruction inside the mouth [55].

The choices between the different regional flaps depend mainly on the size and anatomic position of the defect. Small to medium defects can be reconstructed using local mucosal or cutaneous flaps [55].

Moreover, the amount of the flap tissue needed and the arc of rotation are the main determinants for a regional flap's success. Therefore, it can be used with predictable success for smaller defects or as a salvage of partially failed reconstructions [55].

6.1.4.1 Autogenous bone reconstructed flap

6.1.4.1.1 Historical background

According to the literature [60, 61], the first reported successful bone transfer was performed by an unknown Russian surgeon and documented by van Meekeren in 1668. The graft was a xenograft correcting a cranial defect of a soldier. Von Walther documented the first autograft in 1821, while Bardenheuer in 1892 described the use of a pedicle graft of the mandible itself to restore continuity. However, this flap did not restore the bone tissue loss [60, 61]. Additionally, researchers have used several free, nonvascularized bone grafts from the tibia, iliac crest, or ribs, supported by metallic reconstruction plates [60, 62]. In 1950, Converse reported the use of 12 bone grafts and 14 bone and cartilage grafts for the reconstruction of maxillary and mandibular defects. Vascular surgery led to the use of pedicle osteomyocutaneous flaps [15], ribs with the pectoralis major (15), clavicles with the sternocleidomastoid [15, 50], and the scapula with the trapezius [15, 51], all of which had limited esthetic results.

Later, with the advancement in microsurgical flaps, Taylor et al. [62] and Sanders and Mayou [63] dissipated the use of a deep circumflex iliac artery and vein-free flap, while Swartz et al. [64] documented the use of a scapular osteocutaneous-free flap in 1986.

According the literature, bone grafting techniques have been categorized into the following:

1. The non-vascularized bone graft

2. The vascularized free bone flaps.

The choice between the two techniques is based on [15].

1. The soft tissue quality at the reconstruction site, along with the history of radiation and infection linked to or unrelated to prior graft failure, is crucial.

2. The quantity of soft tissue.

3. The contour and size of the defect.

4. Surgeon expertise and specialized centre availability.

5. Patient preferences.

6.1.5 The non-vascularised bone graft

Commonly utilized for small- to medium-sized defects with limited or no soft tissue loss (less than 5 cm long), it is usually used in cases of benign tumors rather than malignant ones, as well as in orthogenic cases [20].

The most common sites of non-vascularised bone grafting are the rib (whole rib graft/split rib graft) and the iliac crest, with an advantage of faster revascularisation with split rib graft. Despite the fact that the rib graft provides a favorable shape that matches the geometrical shape of the mandible, resulting in a high esthetic outcome, the limited quality and quantity (length and width) of the rib may compromise the use of osseointegrated implants (**Figure 5**) [2, 20].

On the other hand, iliac graft can be used in medium-sized defect sites as it is associated with an abundant amount of both cancellous and cortical bone with increased demand on sculpture and good planning to ensure the correct geometrical shape needed [15, 50].

The literature reported several drawbacks and contraindications for the use of autologous bone, including the increased cost compared to alloplastic plates, increased intraoperative and recovery time, the need for hospitalization, and physiologic resorption of the bone graft with a range from 15–20% [15, 65–69] that may hamper the successful use of osseointegrated dental implants, which require a minimum of 7 mm of bone height for stable anchorage [15, 69–74]. Some investigators reported an increased amount of this resorption, such as Johansson et al. [74], who documented an average of 49.5, and Pai et al. [55], who reported a physiological resorption up to 60%.

6.1.6 Vascularised free flaps

Microvascular free tissue transfer presents the greatest milestones in reconstructive surgery. This surgical approach ensures the transfer of the flap, including the blood anastomosis structures, and its harvesting with a cutaneous or muscular component, thereby increasing the possibility of soft tissue reconstruction. It facilitates the healing of the flap independent of a compromised recipient bed in antagonism to the non-vascularising flap. Moreover, it has advantages of early bone union (within 6 weeks), reduced bony

Figure 5.
Mandibular reconstruction with rib bone graft. (a) Preoperative patient's photograph. (b) Preoperative patient's orthopantomography. (c) Intraoperative photograph illustrating the demarcation of the proposed resected area. (d) Intraoperative photograph immediately before resection. (e) Intraoperative photograph of the resected mandibular portion. (f) Intraoperative photograph of the supporting reconstructive plate. (g) Intraoperative photograph of the rib bone graft. (h) Intraoperative photograph illustrating the attachment of the supporting reconstructive plate. (i) Intraoperative photograph of the rib graft and supporting reconstructive plate.

resorption rate, and better toleration for radiation therapy subject to complications such as resorption, fracture, necrosis, and extrusion [20, 75]. Hence, it is commonly used in cases associated with extensive segmental loss and/or compromising precipitant bed.

Several vascularizing free flaps have been documented based on the donor sites including free fibular flap, scapula free flap, anteriolateral thigh flap, the pectoralis major myocutaneous flap, the metatarsus osteocutaneous flap, iliac crest free flap, clavipectoral osteomyocutaneous free flap [20].

6.1.6.1 The fibula free flap

The free fibula osteocutaneous flap is the most frequently used free flap for mandibular reconstruction. It was first described by Hidalgo in 1989 [20, 76]. This flap can provide up to 22–25 cm of bony segment [20].

The use of a free fibula flap has the superiority of an abundant blood supply from the peroneal artery via both endosteal and periosteal branches, as well as a bicortical bone anchorage and a low donor site morbidity rate [20, 77, 78].

The limitation of the skin paddle is the primary disadvantage of the free fibula flap; hence, in larger soft tissue defects, a need may arise for a second soft tissue flap [15, 86].

Moreover, studies have highlighted the potential for donor-site morbidities, wound healing issues, compromised graft survival, and incomplete reconstruction goals such as persistent disfigurement, bone resorption, delayed or unsuccessful bone union, stress plate fracture, recurrent infection, and traumatic ulcer (**Figure 6**) [15, 20, 77, 78, 86].

6.1.6.2 The iliac crest free flap

This flap provides an abundant amount of cortical and cancellous bone for mandibular reconstruction with generous blood supply. It is characterized by natural curvature that facilitates its use for the replacement of lateral mandibular defects; however, for anterior defects, it requires more osteotomy for reshaping [15, 20, 81].

Donor site complications include the challenge of restoring the abdominal wall, the susceptibility of hernia formation, and the poor pliability of the overlying skin, which may limit its regular usage [15, 20, 82].

6.1.6.3 The radial forearm free flap

The radial forearm fasciocutaneous flap can provide 10–12 cm of bone with a thin, abundant amount of skin. This limited amount of bone may prevent the use of osseointegrated implants, thus restricting their use to cases of limited mandibular defects, after which a tissue bone reconstructive prosthesis can be constructed [15, 20, 96].

Additionally, the lack of curvature necessitates a lot of reshaping; the possibility of a pathological fracture of the remaining donor site and susceptible postoperative hand weakness or pain may limit its routine use [15].

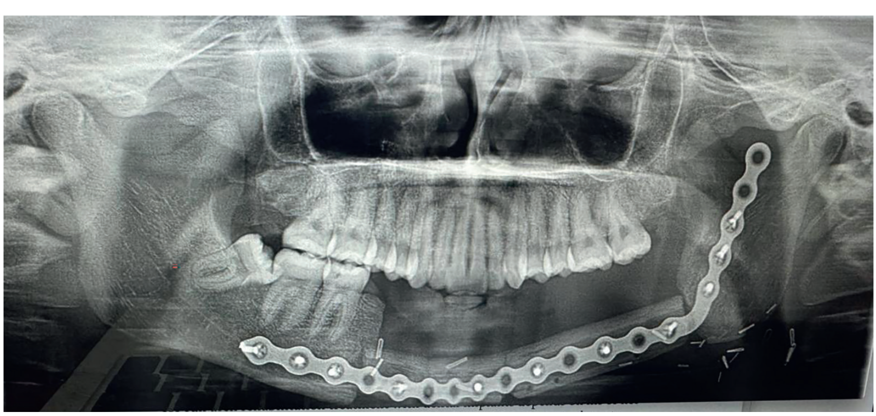

Figure 6.
Panoramic radiograph of a patient presented with segmental mandibulectomy reconstructed with free fibula bone graft supported with reconstructive plate.

6.1.6.4 The scapula free flap

In 1982, Gilbert and Teot [84] described the first use of a free scapular flap. Later, Teot et al. highlighted the use of an osteocutaneous scapular flap for mandibular reconstruction in one patient [85].

Although the scapula osteocutaneous free flap can provide a range of 11 to 14 cm tissue pedicle with acceptable soft tissue bulk and donor morbidity and deformity, its selection as a reconstructive flap for mandibular cases may be limited by the difficulty in positioning the patient to allow for simultaneous resection and microvascular anastomosis, extended intraoperative time, and post-operative shoulder stiffness [15, 20, 87].

The literature describes a number of other mucosal/cutaneous flaps, including the pectoralis major myocutaneous flap for reconstruction of the mandible, floor of mouth, upper neck, and lower one-third of the face when the defect is primarily mucosal or cutaneous [15, 20, 87].

The association between the use of various surgical reconstructive flaps and the different types of mandibular defect reconstruction is well established as follows:

6.1.6.5 Anterior mandibular defects

Reconstruction of anterior defects is commonly done using vascularizing bone grafts, with the free fibula flap reported superiority. Moreover, the use of supportive reconstructive plates guides the shaping of the mandible [20]. Nowadays, computer-generated cutting techniques guide precise treatment planning using computer-aided design software, leading to more acceptable esthetic and functional results.

6.1.6.6 Lateral mandibular defects

For lateral mandibular defect reconstruction, both vascularizing and non-vascularizing flaps can be considered, with a preference for vascularizing in large defect cases and non-vascularized bone grafts in small defects with healthy wound beds [20].

6.1.6.7 Posterior mandibular defects

Cases of posterior mandible reconstruction associated with limited condyle and subcondylar ramus present controversy with reported acceptable appearance, speech, and swallowing function with the use of soft tissue flaps [128, 129]. Other advantages of this flap may include potentially reduced operative time compared to bony flap harvest and shaping, faster recovery, and a low complication rate.

6.1.6.8 Condylar defects

Reconstruction of the condyle with titanium prostheses has been documented with some reported complications, including infection, plate fracture, and erosion into the middle cranial fossa [20].

Takushima et al. [87] emphasized that the selection of a suitable flap for mandibular reconstruction depends mainly on the type of soft and hard tissue defect. They categorized the mandibular defects into two categories: bony defects, which can be either lateral or anterior, and soft tissue defects, which are further subdivided into three categories: none, skin or mucosal, and through-and-through defects. Moreover, they recommended considering the bony defect for perfect flap selection, followed by the soft tissue defect. In addition, they highlighted the use of free fibula flaps for lateral defects with minor "skin or mucosal defects," the scapula flap for lateral defects with extensive skin, mucosal, or through-and-through soft tissue defects, and the fibula flap in conjunction with other soft tissue flaps for optimal outcomes in anterior defects with extensive skin, mucosal, or through-and-through soft tissue defects [87].

6.1.7 The use of distraction osteogenesis

Transport disc distraction osteogenesis is a well-known procedure where a segment of bone is cut contiguous to the defect and moved gradually across the defect by a mechanical device; hence, new bone will fill the space in between the two separated bone segments [2, 88, 89].

Despite the fact that distraction osteogenesis can be used successfully for marginal mandibular resection cases, the patient's advanced age, metabolic diseases, radiation therapy, extensive scar tissue, and tissue necrosis can prohibit the bone-promoting potential at the recipient site. Furthermore, a second surgery is required to remove the distraction device [2, 88, 89].

6.1.8 The use of bone graft substitutes and advance technology

Despite the reported success rates of the traditional surgical approaches, that is, autogenous bone grafting, vascularized free flaps, and alloplastic materials, these techniques may be associated with various limitations, including donor site morbidity, limited availability of graft material, and potential for infection or rejection, highlighting the need for a more conservative approach [5, 94].

Bone morphogenetic proteins (BMPs) are a group of growth factors characterized by their ability to induce bone formation. Their osteoinductive properties can stimulate new bone growth. Researchers have explored BMPs as alternatives to traditional bone grafts and associated donor site morbidity in mandibular reconstruction [94, 95].

Moghadam et al. [94] reported the first human application of BMPs in mandibular reconstruction in 2001, successfully using a BMP bioimplant to reconstruct a 6-cm mandibular defect following ameloblastoma resection. Radiographic evidence at 3 and 9 months postoperatively showed new bone formation, with histological confirmation at 9 months. Later, several studies reported the successful use of bone morphogenetic protein-2 (rhBMP-2) [95, 97–100], bioimplants containing BMP-7 [94, 96], and recombinant human bone morphogenetic protein-2 (rhBMP-2) [98, 99] for reconstruction of mandibular bone defects in humans; however, challenges still exist and limit its regular use, such as the determination of the optimal dosing, delivery methods, and cost.

In the same line, the successful use of a cancellous bone and marrow (PBCM) graft, researchers have documented the successful use of cancellous bone and marrow (PBCM) in conjunction with custom-made titanium mesh (TiMesh) [46, 77, 102–106]. Nevertheless, a skilled operator/technique is mandatory to achieve high esthetic and functional results; a limitation has been overcome with the use of computer-assisted virtual surgical simulation and a three-dimensional (3D) printed model [107–111].

Recent advances in tissue engineering documented the possibility of using patient autologous cells to regenerate functional tissues [15, 82, 100, 101].

Today, studies have highlighted the use of stem cells as a successful method for reconstructing and regenerating crucial-sized maxillofacial defects [112, 113]. Stem cells are characterized by their ability to self-renew and differentiate into various cell types. In the context of mandibular reconstruction, mesenchymal stem cells

(MSCs) are of particular interest due to their capacity to differentiate into osteoblasts, the bone-forming cells [112, 113, 115–126, 130]. MSCs can be sourced from various tissues, including dental pulp tissue [116, 120], bone marrow [121], umbilical-cord blood [122], and adipose tissue [123]. Isolating these cells, expanding them in vitro, and seeding them onto suitable scaffolds implanted into the defect site allows them to differentiate into osteoblasts, mimicking the biological process of natural bone development and bone regeneration, which can be a promising alternative to bone grafting procedures and associated risk factors [112–126, 130, 131].

Recent Advance Technology and mandibular reconstruction include 3D planning and 3D printing:

The historical background of 3D planning and 3D printing had been documented in 1986, when 3D printing technology, or rapid prototyping (RP) or additive manufacturing (AM), was introduced and used for the fabrication of objects with complex geometries and architecture. This technology is considered a major innovation in the medicine, dentistry, engineering, and education fields. Based on the literature, the most established 3D printing technologies are stereolithography (SLA), selective laser sintering (SLS), fused deposition modeling (FDM), and direct metal laser sintering (DMLS) [132].

Mandibular reconstruction has significantly advanced with the integration of 3D planning and 3D printing technologies. These innovations enhance surgical precision, reduce operative time, and improve patient outcomes [77, 110, 133]. The application of 3D printing in mandibular reconstruction has evolved to include the creation of patient-specific implants and surgical guides. Virtual surgical planning (VSP) allows the surgeons to meticulously plan mandibular reconstructions preoperatively and facilitate patient education. By creating detailed digital models from patient imaging data, surgeons can simulate osteotomies, design optimal bone grafts, and foresee potential challenges. This preoperative planning enhances surgical accuracy and efficiency while the 3D printing translates virtual plans into tangible tools and implants.

Nowadays, the applications of VSP in head and neck reconstruction continue to broaden and include anterior mandible, delayed mandible, maxillary, skull base surgery, trauma, and immediate dental implantation [133–136].

Despite improvements, achieving precise anatomical replication can be challenging. Virtual plans and actual surgical outcomes diverge [77]. The current 3D printing materials may not fully replicate the mechanical properties of natural bone. The lack of standardized protocols and regulatory guidelines, technical expertise, and high cost may present challenges. This underscores the necessity for additional research to improve the effectiveness and dependability of 3D-printed solutions in mandibular reconstruction [132, 137].

Recent studies have explored the combination of mixed reality, 3D printing, and robotic-assisted navigation technologies to enhance the accuracy of mandibular reconstructions. This multidisciplinary approach aims to further refine surgical outcomes and reduce operative times [37, 138–141].

Although the previously discussed surgical techniques can restore the hard and soft tissue deficiencies owing to mandibular resection, the restoration of the patient's ability to eat, chew, and speak requires the replacement of the patient's dentation with prosthetic restoration [90, 91].

6.2 Prosthetic rehabilitation in mandibular reconstruction

From a prosthetic reconstructive perspective, both marginal and segmental mandibulectomy patients can be further subdivided into three categories: complete edentulous patients, partial edentulous patients, and patients with non-tooth-bearing defects [1].

6.2.1 Prosthetic rehabilitation in marginal mandibular reconstruction cases

6.2.1.1 Completely edentulous cases

Completely edentulous cases with mandibular resection present a complex and challenging situation owing to the compromised ridge support, vital structure approximation (inferior dental and mental nerves), the large inter-ridge space, and the compromised tongue movement [5, 21]. Moreover, the obliterated vestibular sulci may aggravate the situation and necessitate the use of vestibuloplasty with or without stent incorporation [5, 19, 21].

Researchers have documented the use of implant-supported prostheses when sufficient bone height and width are available to ensure high primary stability [5, 6, 21]. Nevertheless, a bone graft is necessary in cases with compromised ridge support to provide the necessary bony foundation for implant anchorage.

6.2.1.2 Partial edentulous cases

For partial edentulism patients, both fixed or removable reconstructive prostheses supported by teeth or implants can be used. The selection is based mainly on the extent and location of the defect, the number and health status of the remaining teeth, the inter-occlusal distance, the tongue impartment, the specialist's expertise, and the patient's preference [5, 21].

In cases with anterior defects, the height and width of the remaining bone, as well as the health of the remaining teeth, play a critical role in treatment selection [5, 18, 21]. In cases where the bone height is satisfactory, both implant- and tooth-supported prostheses can be considered, leading to predictable results and significant satisfaction [5, 6, 17, 21, 126, 142].

Moreover, a clasp-retained partial reconstructive prosthesis can provide notable stability, retention and function in cases with compromised bone support and an adequate number of healthy teeth [5–7, 21].

On the other hand, telescopic partial reconstructive appliances may be the preferred treatment approach when the limited number of remaining teeth compromise the prosthesis' retention and support (**Figure 7**). Alternatively, implant-supported reconstructive prostheses can be considered with bone grafting [5, 21].

Cases with posterior defects and limited bone height and width are not suitable for endosseous implant-supported prostheses unless they proceed with bone grafting, a treatment modality that may be associated with many complications [5, 21, 142, 143]. Hence, the use of removable reconstructive appliances may be a feasible solution with limited or no complications [5, 9, 144].

6.2.2 Prosthetic rehabilitation in segmental mandibular reconstruction cases

Cases of segmental mandibulectomy may be associated with mandibular deviation toward the resected side, exhibiting rotation and angular path of jaw closure, which is challenging the prosthetic rehabilitation of the patient, especially in edentulous patients, and highlights the importance of using intermaxillary fixation at the time of surgery or mandibular/maxillary guidance appliances afterward (**Figure 8**) [145–162].

Additionally, the use of monoplane teeth in a neutrocentric concept is recommended to avoid restricted/deflective occlusal contacts. In cases where the

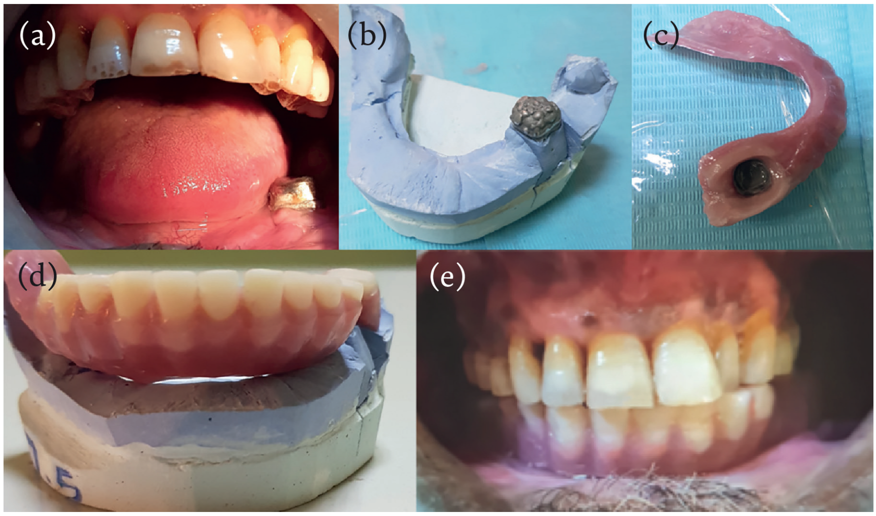

Figure 7.
Mandibular reconstruction with telescopic reconstructive prosthesis. (a) Postoperative patient's intra-oral view showing marginal mandibular resection and inner metal copping cemented over the left mandibular first molar tooth. (b) A photograph presenting the outer metal copping on the cast. (c) A photograph illustrating the fitting surface of the acrylic reconstructive prosthesis. (d) A photograph illustrating the polishing surface of the acrylic reconstructive prosthesis. (e) An intra-oral frontal view of the patient showing the acrylic reconstructive prosthesis after insertion.

mandibular deviation cannot be corrected, a twin occlusion (palatal row for occlusion and buccal row for check support) should be considered [153, 163–168].

Definitive dental rehabilitation of segmental mandibular resection cases without bone reconstruction is difficult and present a challenge for prosthodontists.

Figure 8.
(a) Extra-oral frontal view of the patient with lateral segmental mandibular resection. (b) Extra-oral frontal view of the patient illustrating mandibular deviation following mandibular resection. (c) Extra-oral frontal view of the patient showing the patient's esthetic improvement following reconstruction using mandibular reconstructed and guidance appliances at 1 month follow-up visit.

However, cases associated with corrected mandibular deviation, optimum soft tissue bulk, sufficient supporting natural dentition, and adequate space for replacement of teeth can be rehabilitated using removable and fixed prostheses (**Figure 9**).

Cases where the mandibular continuity is maintained using a reconstructive plate alone, a tissue-bone-removable reconstructive prosthesis can be used to improve the patient's esthetics, function, satisfaction, and quality of life (**Figure 10**).

On the other hand, when sufficient bone is available after reconstruction with bone grafting procedure, both conventional removable prostheses and implant supported prostheses including basal implants can be used with predictable success.

A non-tooth-bearing defect highlighted the use of free vascularizing flaps with the superiority of the fibula and iliac crest flap [5, 6, 9, 23].

Figure 9.
(a) Extra-oral frontal view of the patient with anterior segmental mandibular resection. (b) Intra-oral frontal view of the patient illustrating the anterior segmental mandibular resection. (c) Extra-oral frontal view of the patient showing the patient after reconstruction with removable reconstructive prosthesis.

Figure 10.
(a) Intra-oral frontal view of the patient showing lateral mandibular resection. (b) Intra-oral lateral view of the patient illustrating the lateral mandibular resection. (c) Intra-oral frontal view of the patient after reconstruction with acrylic mandibular reconstructive prosthesis.

6.2.2.1 Mandibulectomy and basal implant-supported prosthesis

Today, with advancements in implant treatment, basal implants have become widely used due to their high reported survival and success rates, predictable biomechanical, prosthetic, esthetic, and phonetic outcomes, and improvements in patient satisfaction [3, 5, 18, 22, 86]. A treatment modality that has been described as an alternative option in cases of extensive ridge loss and maxillofacial defect rehabilitation with many advantages, including the following: implants utilize the strongest basal bone to gain satisfactory cortical engagement because of their high primary stability without the need for bone grafting and its vulnerable complications (**Figure 11**).

Moreover, implant splinting with a framework enhances the biomechanical force distribution, reduces the force per unit implant, and strengthens the possibility of immediate loading. Furthermore, there is the possibility of using acrylic veneer

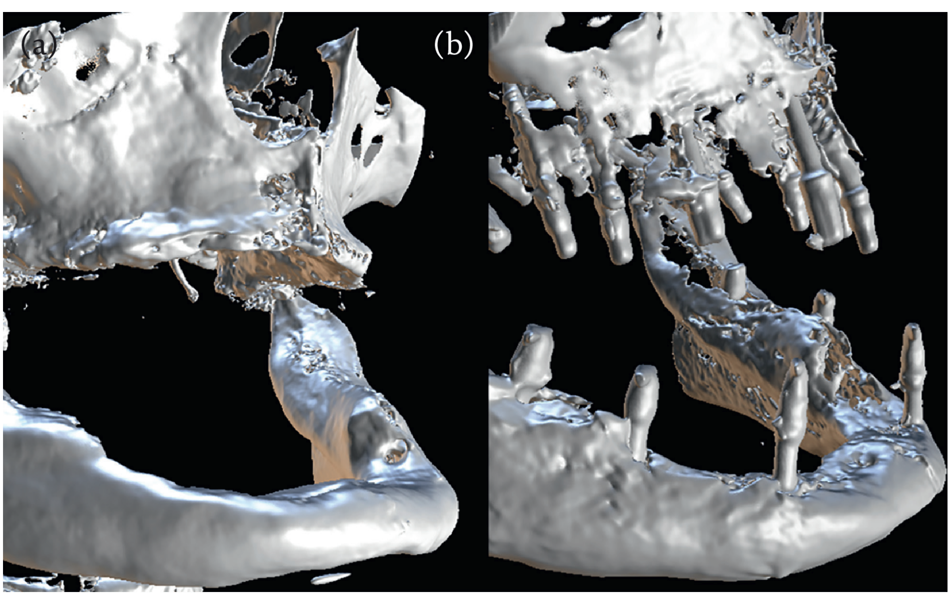

Figure 11.
(a) A cone beam 3D photograph of the patients showing a mandibular complete edentulous jaw with anterior marginal resection. (b) A cone beam 3D photograph of the patients showing a mandibular complete edentulous jaw with anterior marginal resection and basal implant insertion (Corticobasal® implant, BCS® implant design, Dr. Ihde Dental AG, Switzerland).

material to compensate for the tissue loss and restore the patient's esthetic (**Figures 12** and **13**) [3, 5, 18, 22, 86].

Awadalkreem et al. [5] investigated the use of basal implant-supported prostheses (BCS® implant design, Dr. Ihde Dental AG, Switzerland) in patients with marginal mandibulectomy for 5 years. The examined patients showed a 100% implant survival rate with optimum peri-implant soft tissue health, increased per-implant bone level, and high reported patient satisfaction concerning comfort, esthetics, mastication, and phonation. Only one patient reported an increase in the amount of teeth shown owing to midline lip splinting incision.

Recently, Akifuddin S and Awadalkreem F [86] described the successful use of a Corticobasal® implant reconstructive prosthesis following a free fibula flap after 5 years of function with a 100% implant survival rate with no implant loss or fracture, excellent peri-implant soft tissue health, complete union of the bone graft, and a very stable prosthesis.

Figure 12.
(a) Extra-oral frontal view of a patient presenting with a complete mandibular edentulous arch with marginal mandibular resection. (b) Extra-oral lateral view of the patient. (c) Intra-oral view of the patient showing reduced ridge height after marginal mandibulectomy and obliterated mandibular sulci anteriorly. (d) Intra-oral view of the patient showing the Corticobasal® implant distribution using the flapless technique. (e) Intra-oral view of the patient illustrating metal framework connecting the implants. (f) Intra-oral view of the patient showing mandibular implant reconstructive prosthesis insertion. (g) Extra-oral frontal view of the patient. (h) Extra-oral lateral view of the patient (note the improvement of the patient's esthetic).

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Figure 13.
(a) Extra-oral frontal view of a patient presenting with anterior marginal mandibular resection. (b) Intra-oral view of the patient showing reduced ridge height after marginal mandibulectomy and obliterated mandibular sulci anteriorly. (c) Dental panoramic view showing anterior marginal resection. (d) Vestibuloplasty acrylic stent o cast. (e) Clinical intra-oral view of the patient showing the Corticobasal® implant distribution and stent insertion using the flap technique (Corticobasal® implant, BCS® implant design, Dr. Ihde Dental AG, Switzerland). (f) Extra-oral view of the patient showing mandibular implant reconstructive prosthesis insertion. (g) Intra-oral view of the patient at 2 weeks follow-up visit.

7. Timing of dental implantation

Historically, dental implants were placed using a delayed setting in mandibulectomy cases but have more recently been placed immediately into a bony flap freehand without any form of guidance or referencing. This approach yielded satisfactory, functional outcomes [169–172].

With the introduction of Computer-Aided Design/Manufacturing (CAD/CAM), surgeons now have the capability to virtually plan cases with personalized models and guides that minimize operative time and maximize precision outcomes [142, 169, 170].

8. Mandibular resection and patient quality of life

Mandibular resection had adversely affected the patient's esthetic, function, and quality of life (QOL). Several factors can govern this effect, including the patients' age, tumor stage, tumor location, and radiotherapy [171, 172]. Female patients with advanced stage and treated with radiotherapy or chemotherapy showed lower rates of quality of life [172, 173].

In a study by Karayazgan et al. [144] comparing segmental and marginal mandibulectomy patients, the marginal mandibulectomy group documented acceptable levels of function, phonation, and esthetics, as well as improvement in the health quality of life.

Aimaijang et al. [174] reported no difference in patients' quality of life after rehabilitation among patients with marginal mandibulectomy, segmental mandibulectomy, and glossectomy; however, the glossectomy group showed lower food mixing ability.

Resections involving the mandibular angle and parasymphysis have the most adverse effects on appearance and overall QOL. In a study conducted by Warshavsky et al. [95, 175, 176], patients who underwent a segmental mandibulectomy that included the symphysis had worse outcomes in chewing, recreation, health-related, and social QOL domains compared to those whose mandibulectomy did not involve the symphysis. Increased time intervals from the initial resection and the stage of reconstruction were associated with better QOL [11].

Landstrom et al. [176] documented a significant decrease in all the functional outcomes after 1 year of tumor treatment with reported problems associated with taste and smell, talking, mouth opening, and dry mouth with better-reported overall function following reconstruction [177].

Terrell et al. [177] described 13 factors in relation to the deterioration of the head and neck cancer patient's quality of life, including the presence of a feeding tube, comorbid medical conditions, tracheotomy, chemotherapy, and neck dissection. Moreover, a history of radiation exposure exacerbates the condition. Furthermore, male patients reported a higher quality of life (QOL) compared to female patients, likely due to their higher esthetic concerns.

Mandibular reconstruction with reconstruction plates tended to have a lower QOL and is subject to plate fracture eventually [177]. Davudov et al. [173] compared the health-related quality of life in patients who received free fibula flaps versus reconstruction plates following the segmental resection of the lateral mandible, despite the fact that a non-significant difference was reported among the three groups. Patients receiving free fibula flaps reported better function and fewer complications, while those with no reconstruction showed the worse state.

On the other hand, the history of radiation is a delineating factor affecting QOL [178, 179]. Men have better QOL compared to women, as females are more concerned with esthetics [180, 181]. Patients with an implant-supported prosthodontic reconstruction achieved a higher overall QOL [182].

Garrett et al. [183] studied the effectiveness of conventional and implant-supported prostheses following surgical reconstruction; they recommended the use of implant prostheses after 1 year of resection to avoid recurrence risk and to reduce the patient complication turnover in comparison to conventional prostheses.

Moreover, Karayazgan et al. [144] compare the patient satisfaction and oral health quality of life in patients with marginal mandibulectomy rehabilitated with implant-retained overdentures and fixed metal acrylic resin prostheses; the overdenture prosthesis revealed a higher improvement.

A recent review conducted by Shankar et al. [184] found that restoration of the function, psychological comfort, and improvement in esthetics were significantly improved in patients who underwent prosthetic rehabilitation. Similar QoL was reported between conventional and implant prostheses. Despite the fact that the number of implants does not affect the quality and denture satisfaction, it improves their chewing ability. Additionally, the quality and quantity of the remaining hard and soft tissue structures have a major influence on patient comfort, emphasizing the influence of the extent of surgical excision.

9. Conclusion

Management of mandibular resection cases necessitates the interaction between the different oral and maxillofacial team members for successful treatment outcomes.

Rehabilitation of a patient with mandibular resection can be performed using several surgical reconstruction techniques based on the extension of the resection; however, to retain the patient's normal functions, a prosthetic rehabilitation is mandatory.

In a complete edentulous marginal mandibulectomy patients with favorable bony support, removable reconstructive appliance can be used with high success rate.

For partial edentulous patients, implant-supported prostheses are advantageous in cases with favorable bony support, while tooth-supported removable and telescopic removable prostheses can be used in posterior and anterior defects with sufficient remaining teeth.

Basal implant reconstructive prostheses can be considered a treatment modality offering the advantage of eliminating the need for bone grafting and ensuring a predictable success rate.

For segmental mandibulectomy patients, both removable and fixed implant reconstructive prostheses can be considered after providing the hard and soft tissue-supported foundation through surgical reconstruction, with priority given to the free fibula flap in large defects.

In cases of deviated mandible, the use of a guidance appliance is mandatory to improve the final treatment outcome.

Surgical and prosthetic rehabilitations following mandibular resection significantly improve the patient's esthetic, function, satisfaction, and hence quality of life.

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Conflict of interest

There are no conflicts of interest to declare.

Ethical approval

Institutional approval was not required.

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