Mandibular Reconstruction

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3.1 Introduction

The cartoon character Andy Gump demonstrates very accurately the physical deformity that results from loss of the anterior mandible (Fig. 3.1). The Andy Gump character was inspired by a real patient, Andy Wheat, who was born in 1890. He lost the anterior part of his mandible secondary to osteomyelitis [1]. The original surgery was performed at the Johns Hopkins Hospital, on August 28, 1915 [2].

Patients with the "Andy Gump" deformity could not eat or speak properly, drooled constantly, and rapidly became abhorrent to themselves and their families [2]. Prior to reconstructive techniques made available, this deformity was not uncommonly seen by head and neck surgeons after ablative techniques for anterior oromandibular tumors. Now, due to the advances in mandibular reconstructive techniques, this deformity is rarely seen. This chapter will discuss a step-by-step approach to contemporary mandibular reconstruction.

3.2 Historic Perspective

The loss of mandibular tissue has always challenged patients and their surgeons. Over the last century, novel procedures to reconstruct mandibular defects to achieve the best form and function continued to evolve.

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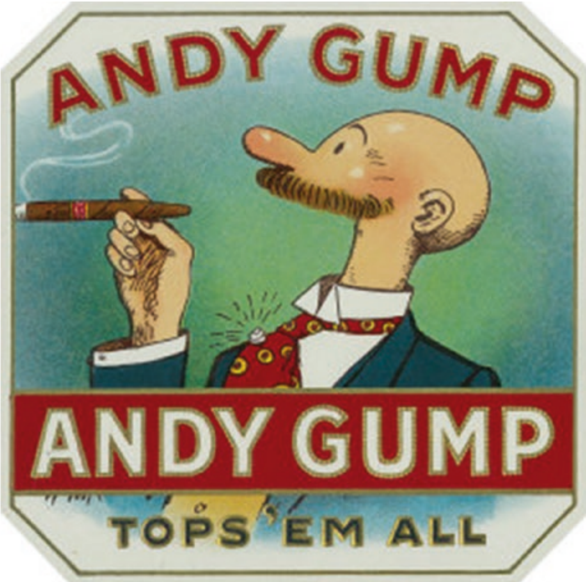

Fig. 3.1 Cartoon of Andy Gump showing the physical deformity resulting from loss of the anterior mandible

In 1833, Sir William Whymper described a case of a 22-year-old gunner in the French artillery, Monsieur Alphonse Louis, who received shrapnel injuries from an exploding shell at the Siege of Antwerp [3]. M. Louis' maxillofacial injuries included loss of the entire mandible. As a consequence, the patient had a grotesque appearance and was unable to eat or talk properly. At that time the surgeons had no knowledge or expertise on how to reconstruct the massive lower jaw defect. Where specialist knowledge or facilities were absent, improvisation was called for. A silversmith was duly approached and asked to construct a mask to act as a replacement for the deficient lower face (Fig. 3.2) [3, 4].

Almost a century later, pioneering works by Sir Harold Gillies and his team of dental surgeons and anesthetists are considered to be the first attempts at anatomical mandibular reconstruction. His patients were soldiers injured in the battles during World War I. In nearly all of the cases described by Gillies, the first of the plastic and reconstructive surgical procedures was undertaken up to 3 or more months after the initial injuries were sustained. While this period of time clearly allowed the surrounding tissue to fully heal, the facial features of these individuals were often seriously, and in many cases hideously disfigured (Fig. 3.3) [4, 6]. This led to the surgical principles such as delayed reconstruction until sepsis was absent and the use of prolonged external fixation. Tibial bone grafts and pedicled mandibular bone grafts were the standard of care at that time [7].

The experience with the wounded soldiers from World War I led to marked improvements in the anesthetic agents and techniques and the establishment of intensive care units. These advances allowed long operative procedures to be performed with relative safety. This was in sharp contrast to the multiple and short procedures with prolonged hospital stay which was previously the norm [4].

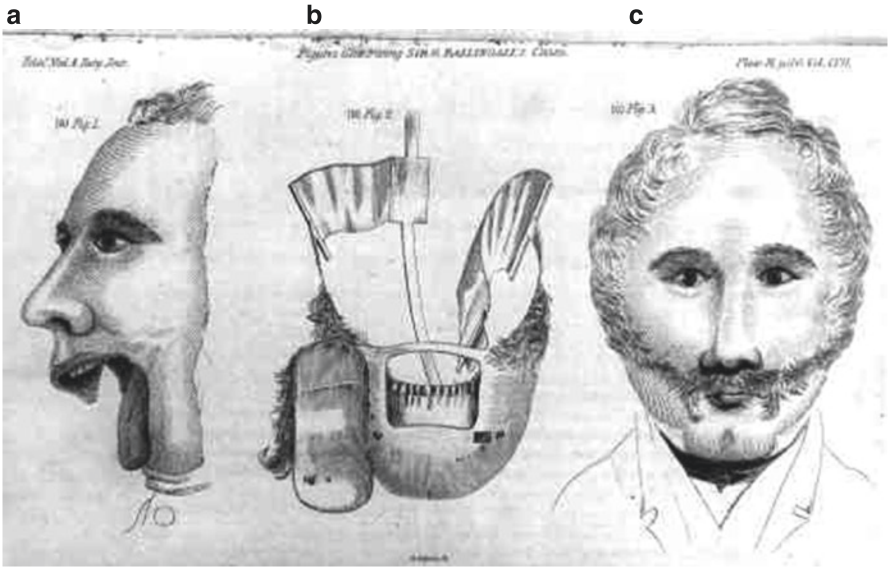

Fig. 3.2 (**a**) Drawing of the disfigured face of M. Louis. (**b**) Drawing of the mask made to cover his deformity. (**c**) Drawing of M. Louis wearing his silver mask [4, 5]

Another major advances in the surgical care for the injured patients were seen during World War II with the use of antibiotics and internal fixation of bone grafts [8]. Since World War II, a wide range of techniques for reconstruction were developed. Principles learned from post-traumatic injuries were applied to oncologic reconstructions. Nonvascularized autogenous bone grafts, pedicled osteomyocutaneous flaps, and metallic plates were used to reconstruct the mandible [9–11].

Free autogenous bone grafts were the gold standard of reconstructing traumatic and oncologic defects of the mandible in the 1950s and 1960s. These techniques relied on the use of bone harvested from the iliac crest, ribs, and tibia [12, 13]. However, problems with free bone grafts were seen in composite radical resections of malignant disease and postoperative radiation therapy. The high failure rate was due to graft resorption and infection [14–17].

Pedicled grafts, such as pectoralis major muscle with an associated rib, sternocleidomastoid muscle with a clavicle, trapezius muscle with a portion of the scapula, and temporalis muscle with a parietal bone (outer table), were used for mandibular reconstruction to avoid the problems seen with nonvascularized bone grafts. These “flaps” had less resorption compared to the nonvascularized bone grafts; however, their functional results were generally poor due to the less than optimal quality of the transferred bone, the insufficient amount of bone, and the difficulty in insetting the flap [17, 18].

In 1976, Spiessl et al. first reported the use of a three-dimensional (3-D) bendable plate for mandibular reconstruction after tumor resection. Since then, many surgeons have used similar techniques to bridge mandibular defects [19–22]. However, the use of plate, with or without bone graft, had a high rate of complications such as fracture,

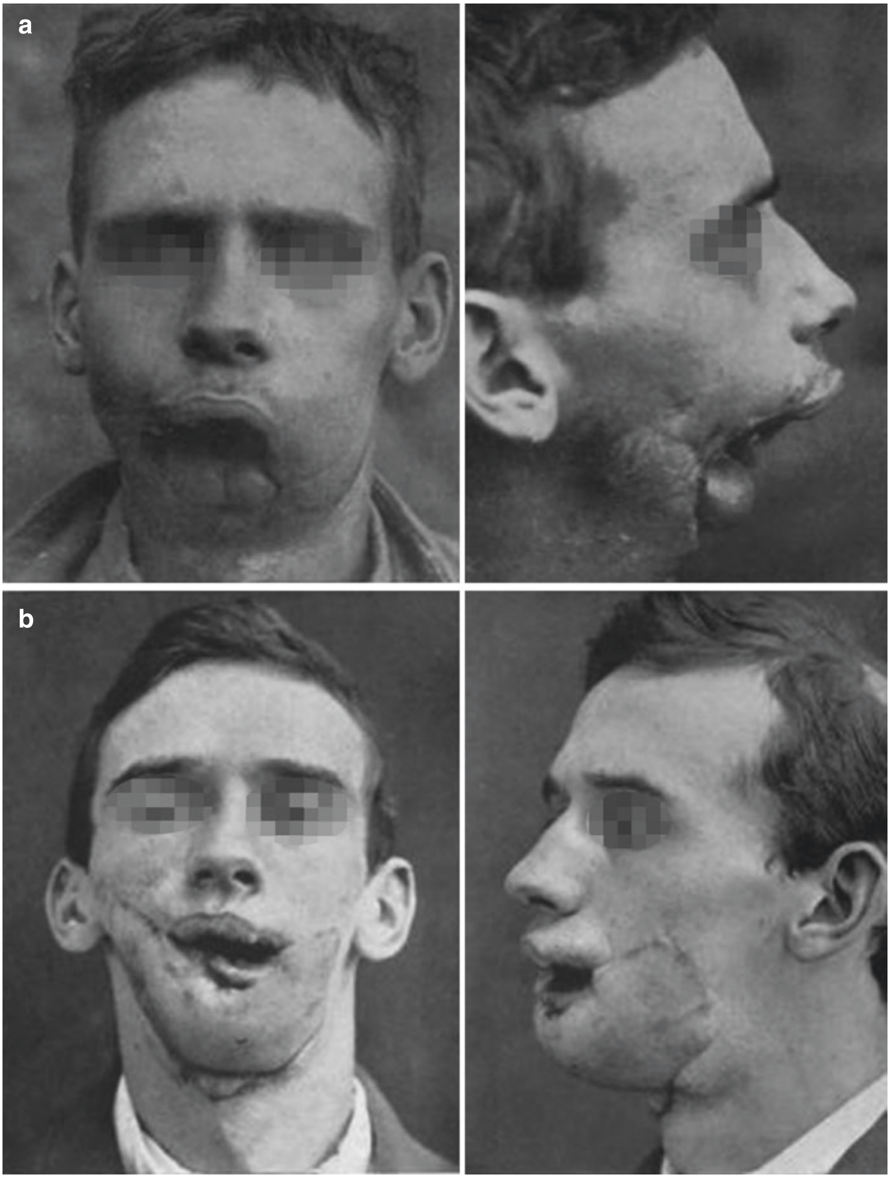

Fig. 3.3 A patient with extensive maxillofacial injuries from the series published by Sir Harold Gillies in 1920. (**a**) Frontal and lateral views of the face showing the extent of injuries before reconstruction. (**b**) Frontal and lateral views of the patient after large double-pedicle scalp flaps and with prosthetic chin in position [6]

exposure, and infection. The incidence of plate failure was even higher for defects located anteriorly and in patients receiving radiation therapy (Fig. 3.4) [17, 23–26].

Surgeons recognized the detrimental effects of salivary contamination and radiation therapy on the survival of the grafted mandible, and the general approach was

Fig. 3.4 Plate exposure in a patient who was previously reconstructed with plate only for an anterior mandibular defect

to perform delayed reconstruction after intraoral soft tissue healing was achieved and radiation therapy was completed. Unfortunately, that led to patients being subjected to multiple operations. After soft tissue healing was achieved, the efforts to secondarily reconstruct the mandible using nonvascularized or pedicled bone grafts were complicated with poor wound healing, bone resorption, fibrosis, trismus, malunion, and the inability to perform dental rehabilitation [27–29].

In the early 1980s, mandibular reconstruction was revolutionized by the introduction of free tissue transfer. In 1975, Taylor et al. introduced the fibula flap for limb reconstruction [30]. In 1979 Taylor et al. and Sanders and Mayou described the first iliac crest bone transfer based on the deep circumflex iliac artery and vein as the vascular pedicle [31, 32] Finally, in 1986, Swartz et al. introduced the scapular osteocutaneous free flap for use in head and neck reconstruction [33]. These three bone containing flaps will later become the main sites for free tissue transfer for mandibular reconstruction. In 1989, Hidalgo popularized the use of the fibula osteocutaneous flap for mandibular reconstruction in his report of a 12-case series [34]. Since then, multiple modifications and applications of the fibula flap have been proposed [35].

The high success rate and significantly improved functional outcome seen with free tissue transfer led to a paradigm shift in mandibular reconstruction [36–38]. Today, composite bone containing free tissue transfer with titanium plate fixation is the gold standard for mandibular reconstruction [35, 37, 38] (Fig. 3.5).

3.3 Anatomy and Physiology of the Mandible

The mandible forms the esthetic and functional foundation of the lower third of the face. It defines the shape of the lower face and forms the border between the neck and face. It has two major components: a horizontal U-shaped arch (body and symphysis) that supports the dentition, provides attachment of the musculature of the tongue and floor of the mouth, and indirectly suspend the larynx via the suprahyoid muscular attachments, and two vertical segments (angle, ramus, coronoid, and

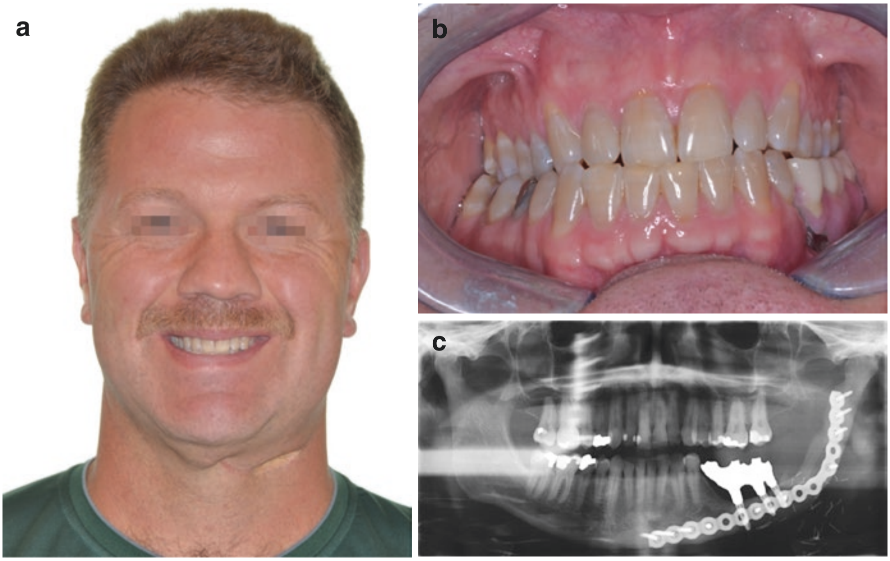

Fig. 3.5 (**a**) Frontal photo showing good mandibular contour and symmetry after mandibular reconstruction with fibula free flap. (**b**) Intraoral photo after prosthetic rehabilitation. (**c**) Postoperative panorex showing bony continuity and successful implant restoration

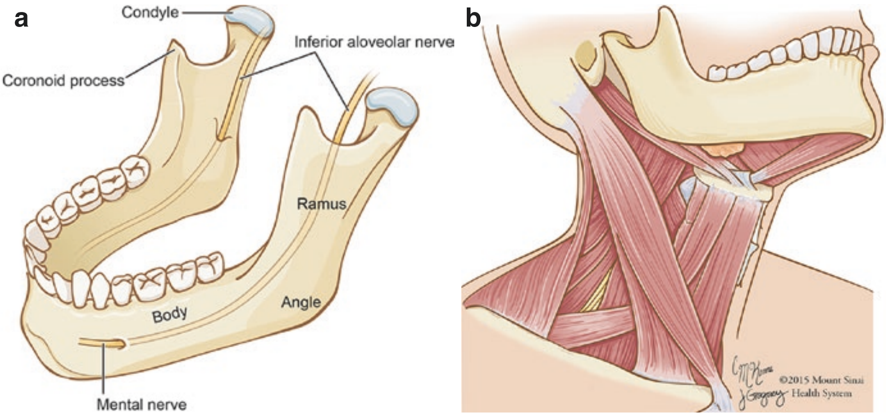

Fig. 3.6 (**a**) Bony anatomy of the mandible. (**b**) The mandible provides the functional and esthetic foundation of the lower face

condyle) that articulate with the base of the skull. The muscles attached to the mandible carry important functions such as mastication, speech, and deglutition (Fig. 3.6).

The bony anatomy of the mandible is unique. It is composed of two types of bone: basal and alveolar. The alveolar bone houses the roots of the teeth. The anterior alveolar bone and the teeth provide lower lip support and assist oral competence. The basal bone supports the alveolar bone and houses the inferior alveolar neurovascular bundle that provides blood flow to the mandible and sensation of the lower lip, dentition, and mucosa.

The blood supply to the mandible is rich. It is partially provided by the inferior alveolar artery (centripital) and partially by the periosteal envelope (centrifugal) which is supplied by the surrounding muscles and mucosa.

The temporomandibular joint (TMJ) is a “ginglymoarthrodial” joint that has rotational and translational movements. It serves as the articulation between the mandible and the skull base and allows mandibular motion that contributes to the masticatory function.

3.4 Pathology of the Mandible

Because of the mandibular unique anatomy, it is exposed to wide range of pathologic conditions. The mandible is surrounded by mucosa which is exposed to many insults and toxins and can acquire malignant transformation. The mandible also houses odontogenic tissues which can cause a variety of odontogenic tumors, cysts, and infections. The mandibular projection puts it at risk for traumatic injuries.

These unique anatomic features expose the mandible to different congenital, infectious, traumatic, iatrogenic (e.g., osteoradionecrosis, medication-related osteonecrosis), and neoplastic conditions.

The techniques and goals of ablative surgery have not changed significantly over the past 50 years, with a goal to achieve complete extirpation of the tumor [39, 40]. On the other hand, the reconstructive techniques have changed and advanced significantly to restore the form and function of the missing tissue.

3.5 Goal of Treatment

Patients with mandibular defects often suffer from significant functional problems (e.g., salivary drooling, difficulty swallowing, and difficulty in chewing) and disfigurement that has significant emotional and psychological effects. Reestablishing form and function is the main goal of reconstructive mandibular surgery (Table 3.1).

There is no “best reconstructive method.” The best method is the one that meets the objectives for a given patient. Ideally, every patient should be restored to predisease form and function. The bony and soft tissue defect size, the patient’s wellbeing and associated comorbidities, the patient’s prognosis, the need for adjuvant therapy, the donor site availability and morbidity, and the need to restore swallowing, speech, or mastication are all important considerations when planning the reconstruction.

Regardless of the prospects for a cure, optimizing the quality of life is a worthwhile and attainable goal in all head and neck reconstruction patients [41].

Table 3.1 Goals of mandibular reconstruction

Goals of treatment
Restoration of facial contour, projection, and symmetry
Restoration of the soft tissue defect to allow functional recovery of the tongue mobility and bulk, restore speech and swallowing, and restore lip competency
Allow complete and immediate wound closure to minimize risk of wound contracture, salivary leak, infections, and fistula formation
Withstand the effects of adjuvant therapy and protect the surrounding tissues
Allow dental rehabilitation and restoration of the dental occlusion
Restore the range of motion and minimize the risk of trismus when the TMJ is involved

3.6 Defect Evaluation and Classification

When the resection of the mandibular segment is partial thickness and maintains its continuity, it is referred to as a marginal resection. When the resection is full thickness and causes loss of the bony continuity, it is referred to as a segmental resection (Fig. 3.7). Segmental resection can be (1) simple (bone), (2) compound (bone and oral lining or skin), (3) composite (bone, oral lining, and skin), and (4) en bloc (bone, oral lining, skin, and soft tissue) [42].

Topography of the bony defect is paramount to the ultimate reconstructive outcome. Similar-sized mandibular defects in different segments of the arch have different cosmetic or functional outcomes [43]. For example, an anterior arch defect that results in the well-known “Andy Gump” deformity leads to devastating esthetic and functional outcome [2]. In contrast, a lateral defect in a dentate or edentulous mandible is more tolerated [17]. In general, the loss of mandibular continuity has significant effects on the mechanics of mastication especially in the dentate mandible. In addition, the disturbance in facial appearance can have a significant impact on the patient’s feeling of self-confidence and desire to return to pre-disease employment and social interactions [35, 44]. Posterior defects involving the ramus and TMJ are usually camouflaged well by overlying soft tissue. Similar to the lateral defects, problems with occlusion and mastication plus deviation of the mandible will still result if these defects are left unreconstructed [17].

When dealing with a marginal mandibulectomy, the reconstructive efforts are geared toward achieving soft tissue coverage using local, regional, or free tissue transfer. A minimal of 1 cm of basal bone should remain to avoid iatrogenic fractures [45]. When dealing with a segmental resection, the reconstructive techniques become more challenging, and more analysis of the defect is required to achieve the best result [38]. As discussed earlier, nonvascularized bone grafts and pedicled bone flaps are associated with a high failure rate and have limited indications [14–17]. Free tissue transfer has become the preferred method to reconstruct segmental defects. Multiple classifications have been introduced to facilitate the planning of the reconstruction [42, 43, 46, 47]. Simple bony segmental resections can be restored with a bony flap. Compound, composite, or en bloc resections require a more

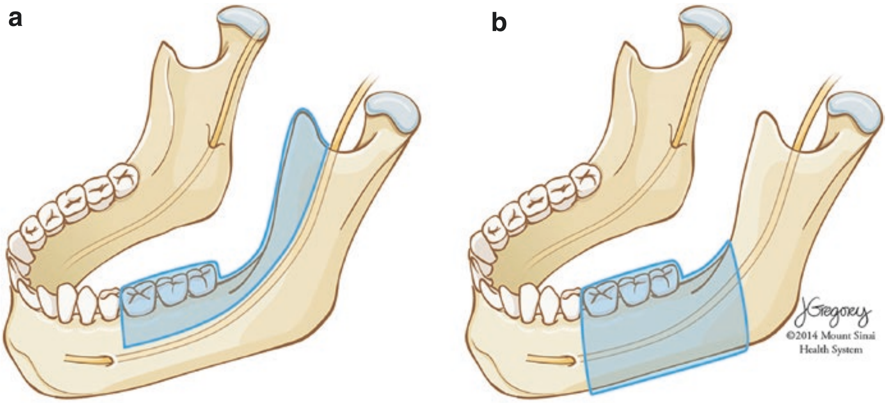

Fig. 3.7 (**a**) Marginal resection. (**b**) Segmental resection

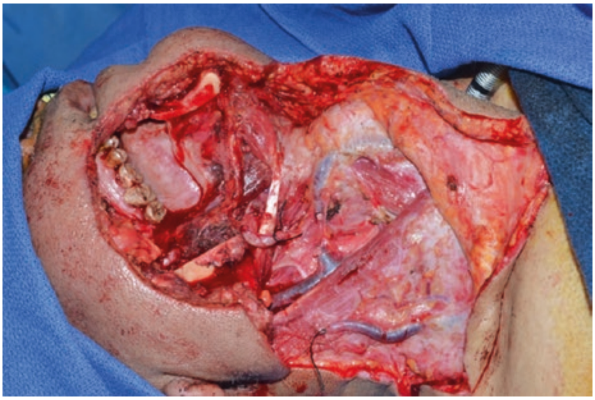

Fig. 3.8 Large en bloc resection of the mandible. The soft tissue defect component will determine the flap selection

complex reconstruction. The soft tissue defect component is the most important factor on the functional result of the mandibular reconstruction and will determine the flap choice (Fig. 3.8) [17, 47, 48].

The ideal flap should provide anatomic, functional, and esthetic restoration. Anatomically, the soft tissue coverage should restore cutaneous and mucosal lining; minimize infections, salivary leak, and fistula formation; augment the wound bed; protect vital structures (e.g., carotid vessels); and tolerate adjuvant therapy. The bony reconstruction should restore the bony height, length, and inter-arch relationship, allow the placement of dental implants and prosthesis, and, when indicated, reconstruct the TMJ articulation. Functionally, the reconstruction should restore oral competency, speech, mastication, swallowing, and occlusion. Esthetically, it should restore facial symmetry, profile, and facial width and height.

Anterior mandibular defects should be reconstructed with vascularized bone when possible. Lateral defects are also best reconstructed with vascularized bone. However, if the patient's general medical condition or prognosis makes him/her a poor candidate for a free tissue transfer, plate reconstruction with or without pedicled soft tissue flap might be the best option [23, 49, 50].

3.7 Flap Selection

Microvascular free tissue transfer has afforded the surgeon an opportunity to more critically address the esthetic and functional outcome of mandibular reconstruction due to the wide array of tissue that can be used. Primary mandibular reconstruction has been refined to the point that it can be offered to virtually all patients who are faced with the devastating prospect of ablative surgery [47]. We will briefly review the most common bony flaps used for mandibular reconstruction (iliac crest, scapula, and fibula), followed by detailed discussion on using the fibula (Fig. 3.9). The radial osteocutaneous flap does not provide sufficient amount of bone stock and therefore has a limited role in mandibular reconstruction [35].

3.7.1 Iliac Crest Osteocutaneous Flap

The iliac crest osteocutaneous free flap, described separately by Taylor et al. [31] and Sanders and Mayou [32] in 1979 and popularized by Urken for mandibular reconstruction, is based on the deep circumflex iliac artery (DCIA) and deep circumflex iliac vein (DCIV) [51–53]. These vessels arise from the external iliac vessels (Fig. 3.10). It can be harvested with skin and muscle making it ideal for large composite defects. It provides a large cancellous bone stock that has ideal height and width for the placement of dental implants.

When the iliac crest osteocutaneous free flap is used to reconstruct lateral mandibular defects, the ipsilateral ilium is harvested using the anterior superior iliac crest as the mandibular angle. For anterior mandibular defects, opening osteotomies are necessary to contour the bone. The thin pliable internal oblique muscle can be harvested with the flap to reconstruct the lining of the oral cavity and recreate the buccal and lingual sulci. The ascending branches of the DCIA should be preserved to harvest the internal oblique muscle (Fig. 3.10) [35].

Although the iliac crest osteocutaneous free flap provides ideal bone stock for mandibular reconstruction (Fig. 3.11), the donor site morbidity is of primary

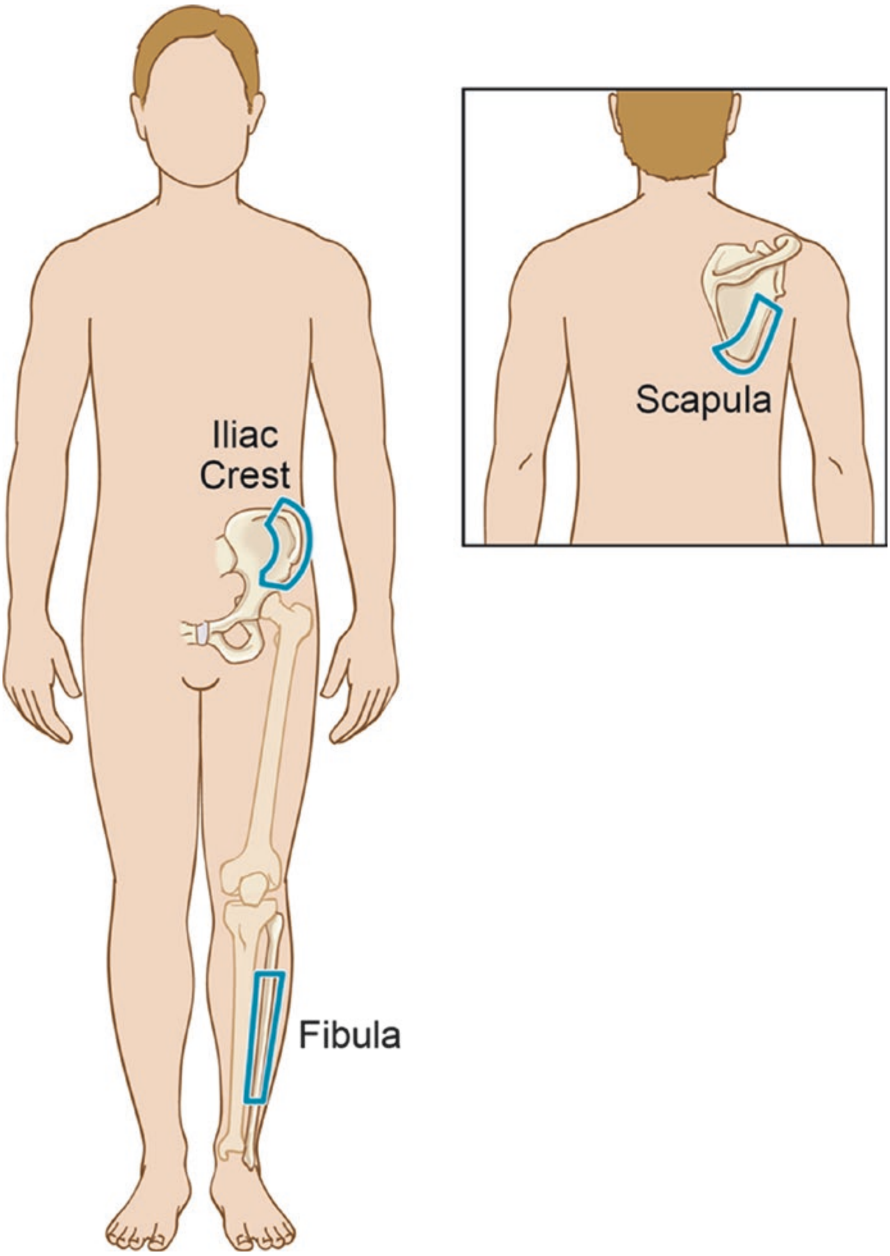

Fig. 3.9 Common donor sites for flaps used to reconstruct oromandibular defects (*JKG* ©2015 Mount Sinai Health System)

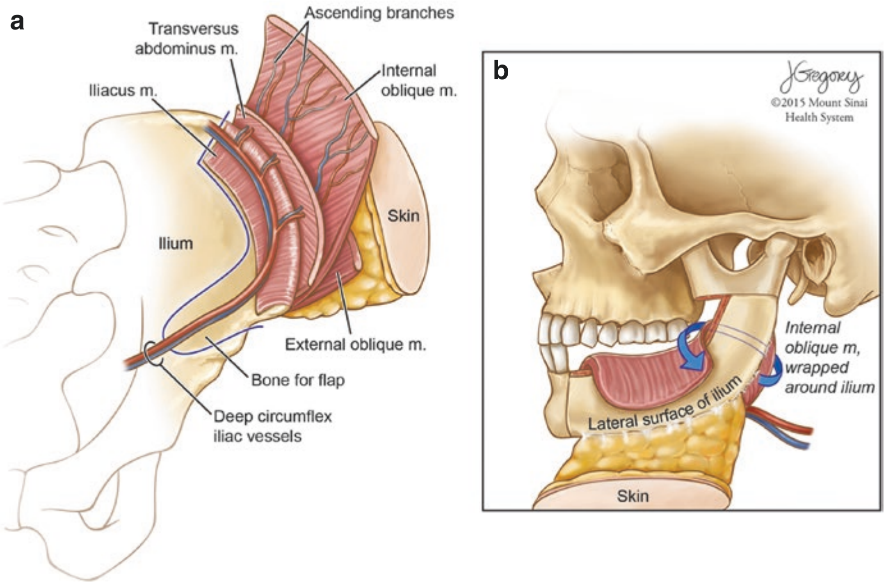

Fig. 3.10 (**a**) Anatomy of the iliac crest osteocutaneous free flap. (**b**) Inset of the iliac crest osteocutaneous free flap

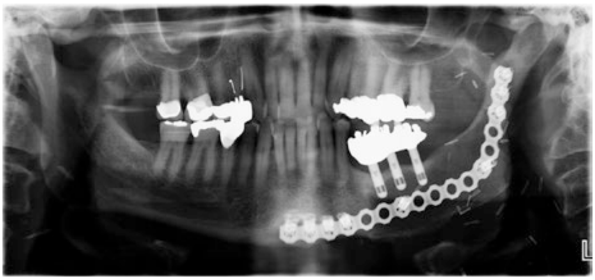

Fig. 3.11 Postoperative panorex showing the large bony stock of the iliac crest osteocutaneous free flap

concern making the fibula free flap a preferable donor site. Ventral hernia and gait disturbance are the feared complications. Reinforced closure can prevent hernia formation. Gait disturbance can be a problem in the immediate postoperative period [35]. The short vascular pedicle and the bulky skin paddle can also make the reconstruction challenging.

3.7.2 Scapula Free Flap

The scapula free flap was popularized by Swartz for mandibular reconstruction in 1986 [33]. It is based on the subscapular artery and vein, which most commonly arise from the third part of the axillary artery and vein. The two major branches of the subscapular artery are the circumflex scapular artery and the thoracodorsal artery. The circumflex scapular artery runs through the muscular triangular space and branches into both transverse and descending cutaneous branches, which form the basis of the scapular and parascapular fasciocutaneous flaps, respectively. When the thoracodorsal vessel arises from the subscapular system, a latissimus dorsi flap can be harvested with the scapular flap (Fig. 3.12) [54].

This versatile flap has many advantages. In addition to the scapular bone, this flap can provide a large, separate and flexible skin paddle, allowing the reconstruction of large composite and through-and-through defects. The latissimus dorsi muscle can also be incorporated which has an important utility to cover vital neck structures especially in the irradiated patient. The ability to use the thoracodorsal artery in a reverse flow design adds significant length to the pedicle and facilitates reconstruction in the vessel depleted patient [35, 54].

The donor site morbidity is well tolerated and does not affect ambulation. This makes the flap ideal in older patients whom immobility can add significant morbidity or in patients with peripheral vascular disease [35, 54].

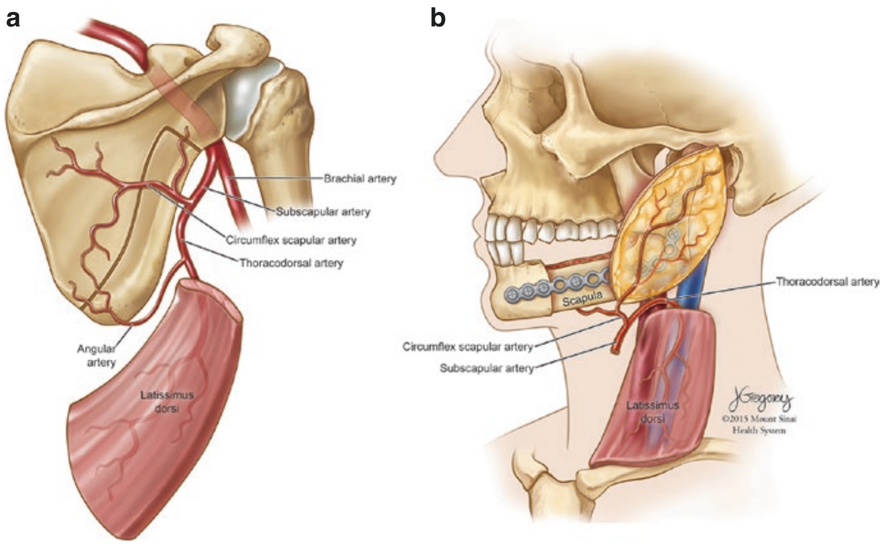

Fig. 3.12 (**a**) Anatomy of the scapula and the latissimus dorsi free flap. (**b**) Inset of the scapula free flap and the latissimus dorsi free flap

Fig. 3.13 Postoperative panorex after scapula bone flap

The decreased shoulder range of motion, the need to turn the patient during the procedure, and the difficult two-team approach are some of the disadvantages of this flap. The harvested bone provides a large bony stock; however, it can be too thin to place dental implants particularly in the female patient (Fig. 3.13) [35, 54].

3.7.3 Fibula Free Flap

Taylor et al. first introduced the fibula flap in 1975 for extremity reconstruction [30]. It was not until 12 years later when Hidalgo popularized its use for mandibular reconstruction [34]. Since then, multiple modifications and applications of the fibula flap have been proposed [55–59]. In 1994, Wei et al. popularized the incorporation of a skin paddle to the fibula and proofed its reliability [56]. The fibula free flap has since become the workhorse donor site for mandibular reconstruction [35].

The vascular supply to the fibula is through the peroneal artery and two venae comitantes. The peroneal artery originates from the posterior tibial artery. Throughout its course lateral and posterior to fibula, it maintains a uniform caliber (2–3 mm) that matches many vessels in the head and neck for anastomosis [60]. It provides both endosteal and periosteal circulation to the fibula bone making multiple osteotomies possible [56]. The peroneal artery sends multiple septocutaneous and/or musculocutaneous perforators to the skin of the lateral leg. One or two perforators can be found in the posterior crural septum at the junction of the middle and lower third of the fibula which can provide adequate circulation to a skin paddle approximately 22–25 cm in length and 10–14 cm in width [61]. When the quality or caliber of the skin perforators are doubtful, incorporation of a cuff of the underlying soleus and flexor hallucis longus muscle can be advantageous [62]. The lateral sural cutaneous nerve innervates the lateral skin of the leg, and this nerve can be preserved and reinnervated to restore sensation to the skin paddle [57].

The fibula bone is triangular in cross section with high-density cortical bone, which allows reliable osseointegration of dental implants due to primary stability,

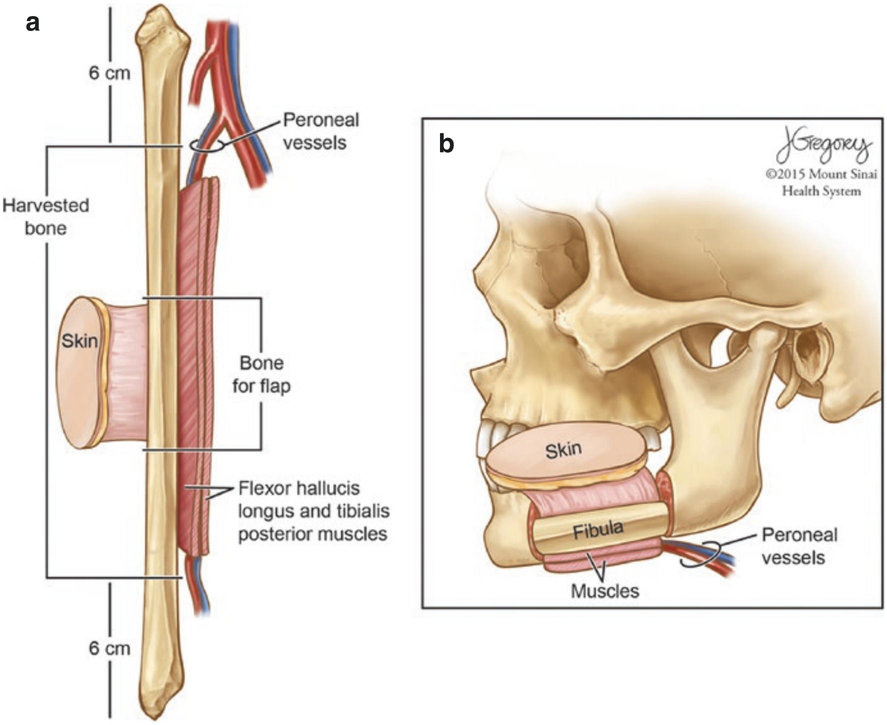

Fig. 3.14 (**a**) Anatomy of the fibula free flap. (**b**) Inset of fibula free flap

withstanding the forces of mastication [63]. 20–26 cm of bone can be harvested that allows reconstruction of large osseous defects and near total mandibulectomy defects [64]. When harvesting a skin paddle with the bone, the posterior crural septum that contains the perforators allows easy manipulation of the skin during the flap inset. The skin is pliable and thin which is ideal to restore intraoral lining. Preserving 6 cm of the fibula bone proximally and distally will maintain ankle and knee stability and will avoid injury to the common peroneal nerve which wraps around the fibular neck (Fig. 3.14).

The height of the fibula (12–15 mm) is insufficient to reconstruct both the basal and alveolar bone [65, 66]. Implant placement becomes more challenging, and prosthetics replacement of the alveolar bone will be required to provide lower lip support. Several techniques have been developed to restore alveolar bone height. The fibula can be inset 1 cm above the inferior border of the mandible to facilitate implant restoration, while a soft tissue cuff is used to fill the inferior border irregularities [67]. Double barrel design can also be used in some cases especially in symphyseal reconstruction to replace both basal and alveolar bones (Fig. 3.15) [68]. Lastly, vertical distraction has been used to increase the height of the fibula [69, 70].

Fig. 3.15 Postoperative panorex of a double barrel fibula free flap and implant reconstruction

Table 3.2

Advantages
Long bone
Thick cortex
Long vascular pedicle with good caliper
Dual blood supply to the bone
Allows two-team approach
Can be harvested with fascia, muscle, and/or skin

Table 3.3

Disadvantages
Insufficient bone height
Long scar
Need to graft large soft tissue defect
Weakness in toe dorsiflexion
Ankle discomfort and gait disturbance

The flap is not without donor site morbidities. However, they are minimal and tolerable in most patients. The long visible scar can be problematic to young patients who prefer to wear short clothing. If the skin defect is wider than 4 cm, skin graft is required which can result in a poor cosmetic result. The function of the lower extremity can also be affected. Extensive dissection of the flexor hallucis longus muscle and/or its motor nerve can cause weakness in toe dorsiflexion. Excessive distal osteotomy can cause ankle discomfort and decreased range of motion [17, 71, 72].

Careful planning and good technique can minimize these complications. Suturing the flexor hallucis longus to the tibialis posterior muscle and the intermuscular septum can minimize its contraction. Preserving the flexor hallucis longus muscle motor nerve and minimal dissection to maintain its vascular supply can minimize muscle weakness [71, 73].

A summary of fibula free flap advantages and disadvantages is presented in Tables 3.2 and 3.3.

3.8 Fibula Orientation

The fibula is triangular in cross section and has three surfaces: a plating surface, a surface that has the vascular pedicle, and a surface that carries the skin perforates (Fig. 3.16).

When planning the reconstruction for a segmental defect, the surgeon should be aware of the orientation of the fibula bone. The plating surface should be buccal and the surface that carries the peroneal vessel should be lingual. The vascular pedicle exit point should be posterior. However, in TMJ reconstruction or in a previously operated neck with vessel paucity resulting in the need to go to the contralateral neck for a recipient vessel, the vascular pedicle should exit the fibula anteriorly to avoid acute turns at the level of the joint and having to double back down to the neck resulting in a shortened pedicle (Fig. 3.17).

By following these principles, the posterior crural septum carrying the perforators can either be superior or inferior depending on whether the ipsilateral or contralateral fibula is used. If the posterior crural septum is positioned inferiorly, the skin paddle can easily cover external skin defects or a mucosal ridge defect if the mesentery is stretched over the plating surface. If the posterior crural septum is facing superiorly, intraoral mucosal defects can be easily closed with minimal stretch of the perforators (Fig. 3.18).

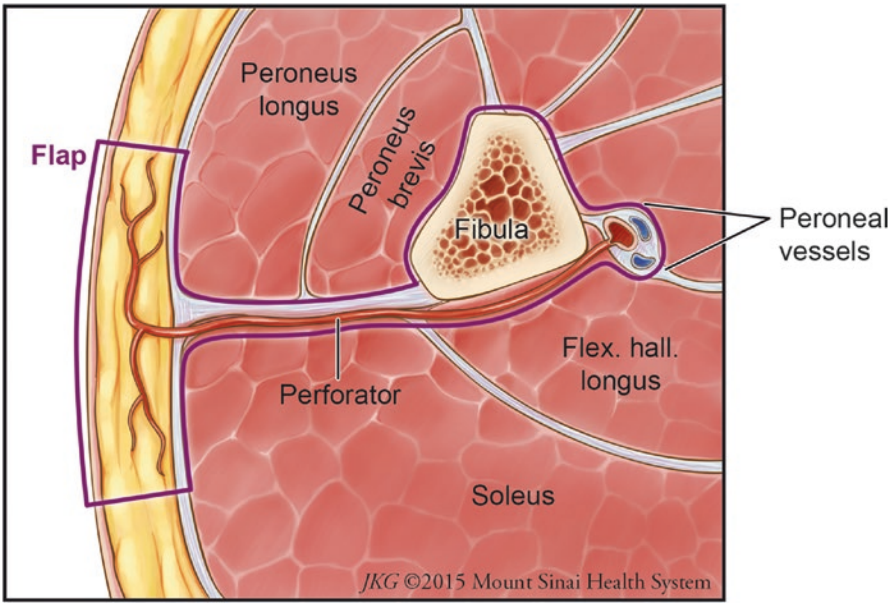

Fig. 3.16 Cross section of fibula free flap showing the perforator to the skin paddle

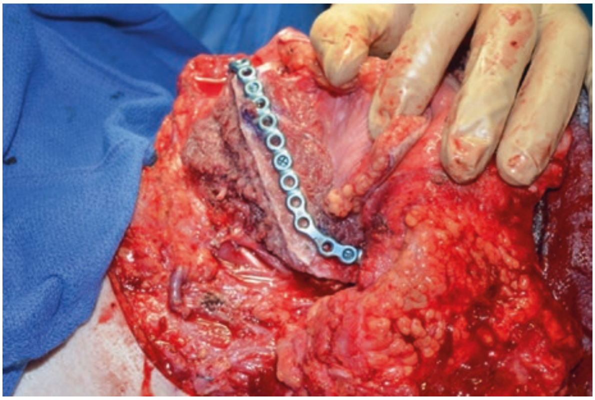

Fig. 3.17 Inset of the fibula free flap with a vascular pedicle exit anteriorly (*yellow arrow*)

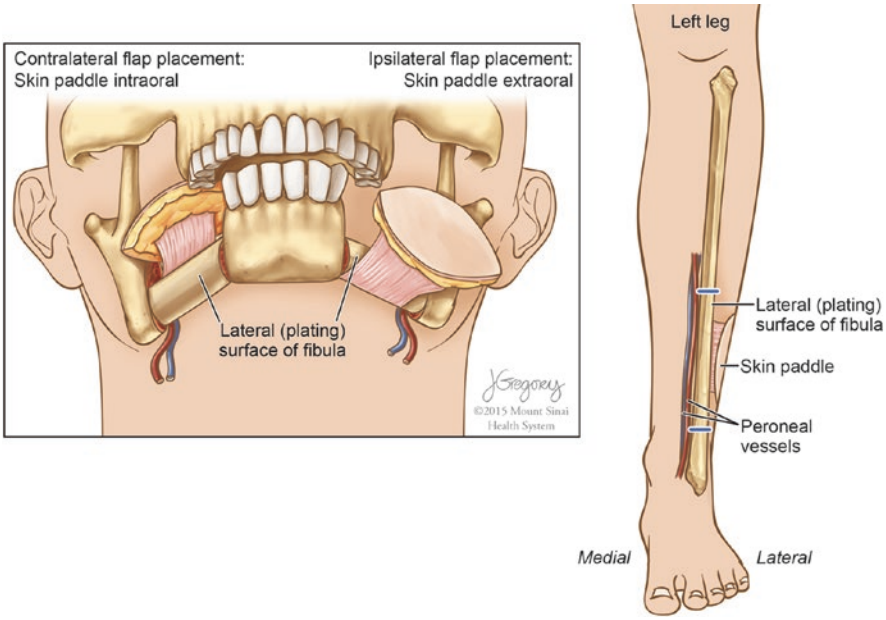

Fig. 3.18 Donor site selection: fibula free flap inset and orientation. If the ipsilateral fibula is used to reconstruct the mandibular defect and the vascular pedicle exits posteriorly (at the angle), the skin paddle will be extraoral. If the contralateral fibula is used and the vascular pedicle exits at the angle, the skin paddle will be intraoral

With preoperative lower extremity imaging, the surgeon can evaluate the vascular supply to the fibula and plan the reconstruction. In some circumstances (trauma to lower extremity or atherosclerosis), the surgeon has one available extremity for harvest. Therefore, understanding of the fibula flap orientation and geometry will allow proper planning and inset.

3.9 Plating and Fixation

The choice of fixation (rigid vs nonrigid) in mandibular reconstruction does not seem to influence the healing of the graft and the need for intervention for complications [74, 75]. However, the use of rigid fixation, using reconstruction plates, has many distinct advantages. In the case where the mandible is not distorted, the plate is contoured to the native mandible and fixed to the bone using bicortical screws proximal and distal to the area of the proposed resection. The plate is then removed and the screws are tagged. Following the mandibulectomy, the plate is replaced and secured to the remaining segment using the previously labeled screws, ensuring the exact anatomical alignment of the segments (Fig. 3.19). This is not possible when using nonrigid techniques. Furthermore, it is easier to shape the bone flap and fix it into a specific gap rather than to have to estimate its position and shape when the fragments are free floating [74]. Other advantages of rigid fixation are early resumption of oral function, avoidance of intermaxillary fixation, maintenance of the condylar position, and restoration of lower facial form [38, 76].

In cases when the tumor distorts the buccal cortex of the mandible or if the tumor margin might be violated in attempts to expose the outer cortex, the plate cannot be precontoured to the native mandible. In this situation, different techniques can be used: (1) use of temporary long miniplate, spanning the defect while resection occurs; (2) fixation of proximal mandibular segments to maxillary tuberosities with temporary supramucosal miniplates while resection occurs; (3) use of intermaxillary fixation in dentate patients with anterior segment resection; (4) use of external fixation systems [75, 77]; and (5) use of virtual surgical planning. In virtual surgical planning, a mirror image of the unaffected side can be created and superimposed on the affected side and a stereolithographic model can be generated. This “hybrid” model can be used to precontour the plate intraoperatively (Fig. 3.20) or have a

Fig. 3.19 Plate was contoured on the native mandible prior to the resection and now fixed to predrilled holes prior to flap inset

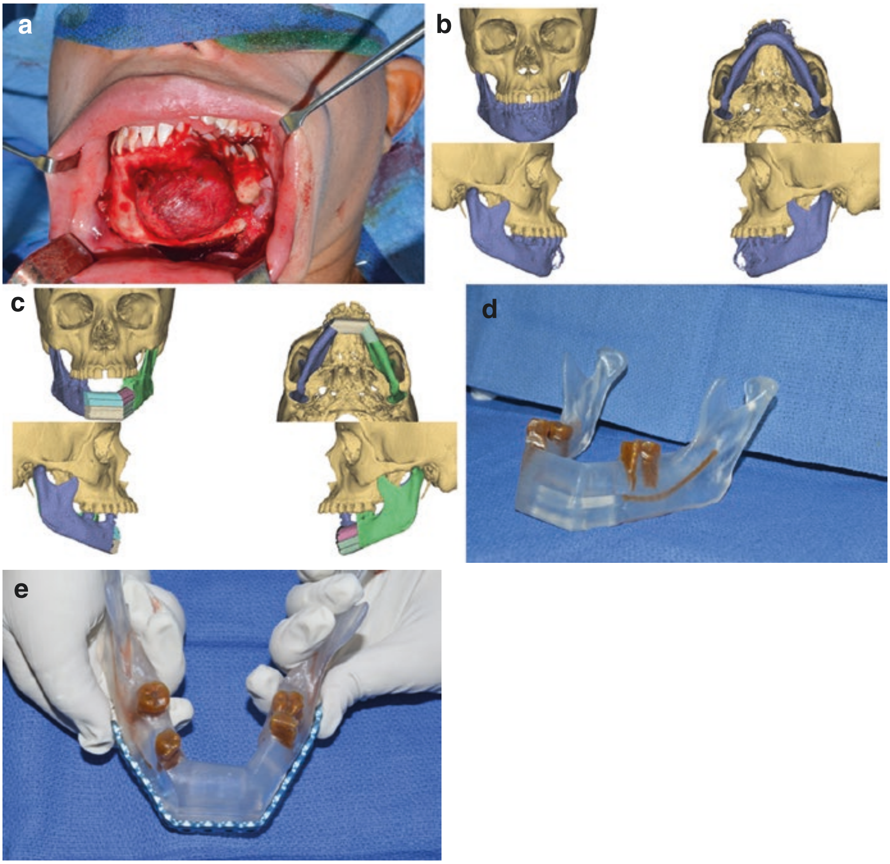

Fig. 3.20 (**a**) Tumor distorting the outer cortex of the mandible. The plate could not be contoured on the native mandible. (**b**) 3-D CT reconstruction showing the extent of the tumor with expansion of the outer cortex. (**c**) Virtual planning of a double barrel free fibula design. (**d**) Stereolithographic hybrid model was made from the virtual computer planning. (**e**) The hybrid model was used to prebend the plate

custom patient-specific plate designed and milled by the plating company [78] (Fig. 3.21).

The plate is fixed to the mandible on either side of the defect using at least 3–4 bicortical screws. With the use of the locking screws, less accurate adaptation of the plate can be accepted. However, to minimize plate extrusion, the plate should abut the underling bone and minimize the dead space. Reconstruction plates are stress shielding and will insure stability of the reconstruction during the healing period and allow early function. However, this stress-shielding effect may cause demineralization and decrease in bone strength [79].

The fibula segments should be fixed to the plate using monocortical screws to avoid injury to the vascular pedicle on the medial side. Only few screws are needed to fix the

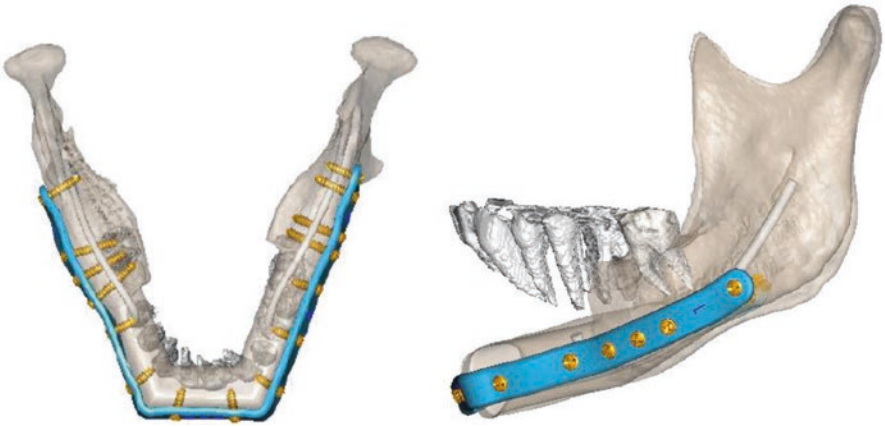

Fig. 3.21 Patient specific plate milled from a block of titanium

flap to the plate. Adherence to good technique during screw placement, including the use of a drill guide and copious chilled saline irrigation is essential to avoid thermal injury to the bone and subsequent screw loosening and hardware failure.

3.10 Flap Tailoring and Osteotomies

Depending on the size and location of the defect, a single segment, two segments, or multiple segments are used to shape the fibula to the mandibular contour (Fig. 3.22). Because of the fibula's dual blood supply, osteotomies can be done, leaving only periosteal blood supply to the osteotomized segments. The healing of the osteotomized fibula is not different between endosteal circulation only, periosteal circulation only, and circulation from both systems [56, 61]. In order to preserve an adequate blood supply, the osteotomized fibula segments should not be smaller than 3 cm [17].

Closing wedge osteotomies are used to create the 3-D contour of the mandible. The osteotomies can be done "freehand" or using computer-aided design and computer-aided manufacturing (CAD-CAM) cutting guides (Fig. 3.23). This can be done on the back table or while the fibula pedicle is still uninterrupted. The wedge design should allow adequate contouring and maximize the bone-to-bone contact between the osteotomized segments. This requires a clear appreciation of angles in more than one plane, which is easier with the flap mobile in hand rather than attached by its intact pedicle [67]. Subperiosteal dissection circumferential to the planned osteotomy should be made. A thin malleable should be placed subperiosteally on the medial surface to protect the pedicle during the osteotomy. Each osteotomized fibula segment should intimately abut the adjacent segments or native mandible without interfering soft tissue impingement to ensure bone-to-bone contact and to promote bony union. Once the contouring is done, miniplates or wires can be used to hold the segments prior to rigid fixation.

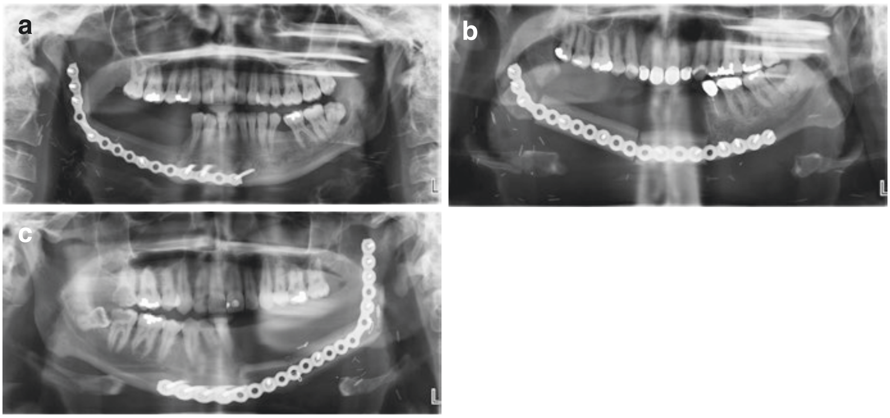

Fig. 3.22 Contouring of the fibula segments to the shape of the mandible. (**a**) One segment. (**b**) Two segments. (**c**) Multiple segments

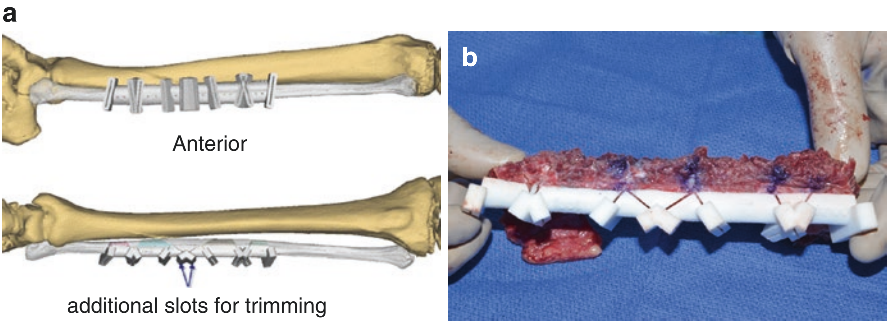

Fig. 3.23 (**a**) Virtual design of the osteotomy guide. (**b**) CAD-CAM generated osteotomy guides is used to guide the wedge osteotomies in a complex double barrel fibula free flap design

3.11 Donor Vessel Selection

There is plethora of vessels in the head and neck region that can be used for the microvascular anastomosis. However, patients with history of prior neck dissection, radiation therapy, regional metastasis or atherosclerosis may have limited options.

Recipient vessel exploration should be done prior to the flap harvest. This will allow the surgeon to plan the type of free flap, the orientation of the flap during inset, and the need for interpositional vein grafts. Ischemia time is also reduced when the vessels are ready for the microvascular anastomosis.

At least one artery and one vein should be explored, isolated, and prepared for the anastomosis prior to the flap harvest. When selecting the donor vessels, the length, location in relation to the planned flap pedicle, and caliber should be considered.

Branches of the external carotid artery and the thyrocervical trunk are most commonly used for the arterial anastomosis. The external jugular, common facial, transverse cervical, and internal jugular veins are most commonly used for the venous anastomosis.

The transverse cervical artery, a branch of the thyrocervical truck, is very useful in patients with neck vessel paucity after previous radiation and/or neck dissection. It is usually not affected by the external beam radiation therapy or neck dissection. In the more complex cases, the contralateral neck vessels should be reached to complete the anastomosis. However, this usually requires a vein graft. The internal mammary artery and vein are also available to harvest in the neck-depleted neck [80].

After the donor vessels are selected and prepared, the vessels are irrigated with a vasodilator, such as papaverine or lidocaine, and covered to prevent desiccation.

3.12 Flap Contouring and Insetting

The bony defect size is first measured. Then the pedicle length required for the donor vessel to reach the recipient vessel should be measured. Once this determination is made, the fibula flap can be tailored, and more proximal pedicle length can be gained by performing subperiosteal dissection, leaving the periosteum and muscle cuff and discarding the excess proximal bone. After ensuring adequate reach and size match of the pedicle to the donor vessels, the bony component of the flap is osteotomized and inset to the defect underneath the plate. The contoured graft is then fixed to the reconstruction plate with consideration of the geometry of the soft tissue component and the vascular pedicle. Monocortical screw fixation to the plate is recommended over bicortical screws to minimize risk of bone devascularization [67]. The bony graft should be oriented to place the vascular pedicle on the lingual side and the exit point at the angle when possible to maximize pedicle length [34].

The next step is insetting the soft tissue component of the flap. The soft tissue component of the flap is inset with care not to create torsion or tension on the small septo- or musculocutaneous perforators. Horizontal mattress sutures are used to insure watertight closure to minimize the risk of salivary leak and fistula formation. When the soft tissue paddle is used to close inaccessible defects, the skin can be partially inset prior to the bony inset.

Finishing the majority of the flap inset prior to the anastomosis has many advantages: (1) the insetting of the flap into defects of the pharynx and oral cavity must be accomplished with maximum exposure, which may be limited when the surgeon is concerned about disruption of the completed anastomosis; (2) the insetting is also facilitated by working with an ischemic flap, which frees the surgeon from the troublesome bleeding and engorgement that occur after revascularization; and (3) the position of the donor vessels becomes fixed after insetting, which eliminates the guesswork of setting the tension on the vascular pedicle [81].

3.13 Microvascular Anastomosis

After completing the flap inset and preparing the recipient and the donor vessels, the anastomosis is done using the operating microscope.

The anastomosis is started with the arterial system. The donor artery should match the caliber of the recipient artery. It should demonstrate a brisk pulsatile bleeding when the clasp is released. The anastomosis is done circumferentially using 9–0 or 10–0 interrupted nylon sutures. The venous anastomosis is then performed using circumferential sutures or a coupling device when possible.

The pedicle should lie in the neck without any tension or kinking. The head position should be accounted for. If the pedicle is redundant, the pedicle should be tagged to the underlying tissue to give it a gentle curve. The remaining inset can be completed at that time.

Careful attention to proper drainage of the neck is important to avoid hematoma formation or infections. Drainage should ensure evacuation of accumulated blood, exudate, or chyle which may lead to secondary infection. Open drainage system (Penrose) can be placed near the anastomosis, and closed drainage system (Jackson Pratt) can be placed in the dependent areas of the neck away from the anastomosis to prevent venous collapse and flap congestion.

3.14 Special Considerations

3.14.1 TMJ Reconstruction

The TMJ is a unique joint. It is a ginglymoarthrodial joint that produces both rotational and translational movements. Functional reconstruction of the TMJ is challenging. When oncologically sound, the TMJ and subcondylar stump should be preserved [82, 83]. If the resection involves the condyle, vascularized reconstruction is preferred with a goal to avoid complications such as malocclusion, difficulty in mastication, trismus, ankylosis, and loss of posterior mandibular height [35].

In resections that involve the condylar head, the proximal end of the fibula is rounded to simulate the shape of a condyle and inserted into the glenoid fossa (Fig. 3.24) [83]. Interposition of soft tissue into the joint space is important to prevent ankylosis [35]. A cuff of muscle is used to cover the neocondyle and act as an interposition graft. Other materials such as lyophilized dermis can be used as an interpositional graft [84]. To prevent "sag" of the neocondyle, suspension should be placed using Mitek sutures to the glenoid fossa or nonresorbable sutures to the zygomatic arch or temporal fossa. A pseudarthrosis develops that seems to be well tolerated and functional, although no translation of the neocondyle is possible [83]. Alloplastic materials such as prosthetic titanium implants, proplast, and silastic are mostly abandoned in oncological resections because of the high risk of complications such as erosion of the glenoid fossa [85], foreign body reaction, infection, and joint ankylosis [86]. Nonvascularized autogenous bone grafts such as costochondral bone and cartilage can undergo resorption, fracture, and hardware failure [35, 85, 87].

Fig. 3.24 Postoperative panorex after fibula free flap to reconstruct the TMJ/ramus complex. Temporary maxillomandibular fixation allows condylar positioning

3.14.2 Irradiated Patients

Patients with osteoradionecrosis and heavily irradiated wounds are at higher risk of wound healing complications. The feared complication in these patients is fistula formation and salivary contamination of the anastomosis and the carotid artery resulting in flap failure or carotid blowout, respectively. In high-risk patients, coverage of these vital vascular structures with a well-vascularized muscle is indicated. This may involve the incorporation of a segment of the latissimus dorsi muscle when using a scapular free flap (Fig. 3.12), or the use of the pectoralis major muscle separately for coverage in the neck.

3.15 Prosthodontic Rehabilitation

The final phase of mandibular reconstruction is restoring the dentition. The use of vascularized bone grafts provides a good platform for the placement of dental implants. Long-term success of dental implantation in fibula-based mandibular reconstruction has been well documented [88, 89]. It is important to realize that the goals to reconstruct the outline form of the lower third of the face and limited bone volume of the fibula can result in a significant height discrepancy with the native jaw. These factors for prosthetic rehabilitation are ameliorated with computer-assisted planning and implant framework design (Fig. 3.25).

Titanium implants can be placed immediately at the time of flap reconstruction or can be delayed after the reconstruction. Traditionally, implants were delayed 4–6 months after the initial reconstruction to allow healing of the wound, completion of radiation therapy and planning the prosthetic phase. Unless carefully planned, implants placed in the primary setting can lead to poor implant position and angulation making prosthetic restoration difficult if not impossible [88]. The decision for immediate placement and taking advantage of the blood supply prior to radiation therapy needs to be weighed against these considerations. Additionally, immediate implant placement cannot always be performed (e.g., the perforator surface is facing superiorly). Delayed implant placement has to be performed in such cases.

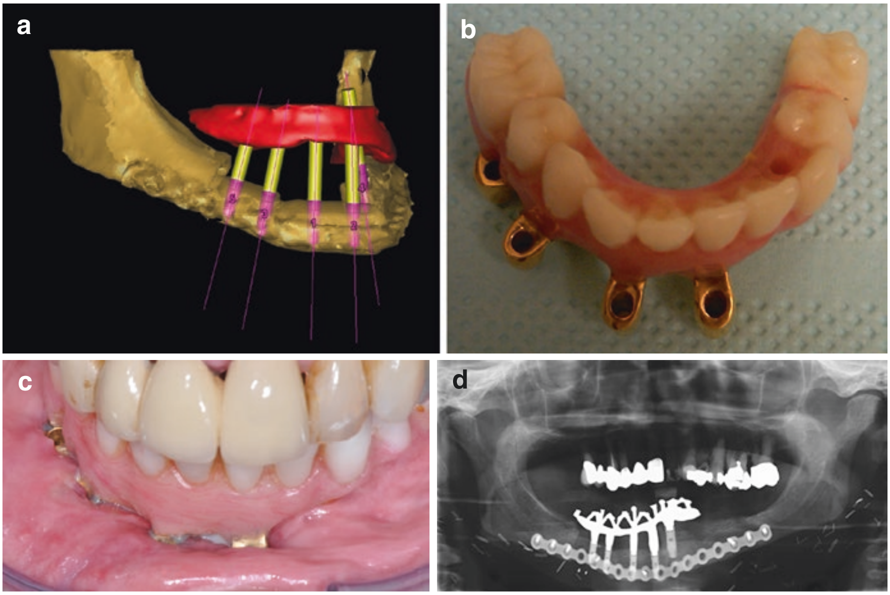

Fig. 3.25 (**a**) Three-dimensional reformation of mandible reconstruction with a fibula free flap. Scanning appliance (*in red*) identifies the position of the occlusal and facial surfaces of the teeth for virtual implant surgery and the fabrication of a CAD-CAM surgical template. (**b**) Definitive prosthesis with cantilevered framework to be fixed with screw retention. (**c**) Favorable mucosal reaction 1 week after insertion. The patient is restored to normal overbite and cross-bite relationship. (**d**) Panoramic view of fibula free flap reconstruction with four implants and one into native mandible supporting the framework of the definitive prosthesis. Note the location of the implants to plating screws determined on computer planning software (Courtesy of Dr. Devin Okay)

When planning the reconstruction of the complete dental arch with an implant-borne fixed prosthesis, a minimum of five or six implants with the greatest anterior-posterior spread is recommended to minimize the cantilever forces of the posterior extension of the prosthesis. Three to four implants are recommended for unilateral hemi-arch mandibular defects. As the defect crosses the midline, more implants are necessary to support the prosthesis [90]. No more than two implants are placed on any small fibula segment so as not to compromise perfusion of the bony segment or fracture of the segment [91].

In recent years, the use of computer-assisted planning has allowed prosthetic-guided treatment planning and implant placement. Computer-assisted planning provides a platform for prosthodontic treatment planning by using a radiographic scanning device worn by the patient during cone beam computerized tomography (CBCT). Virtual implant surgery and an opportunity to translate the planning to stage I surgery with CAD-CAM stereolithographic drilling templates achieve accurate, reproducible position and angulation of the implants in the immediate or delayed reconstructive setting (Fig. 3.26) [90, 92].

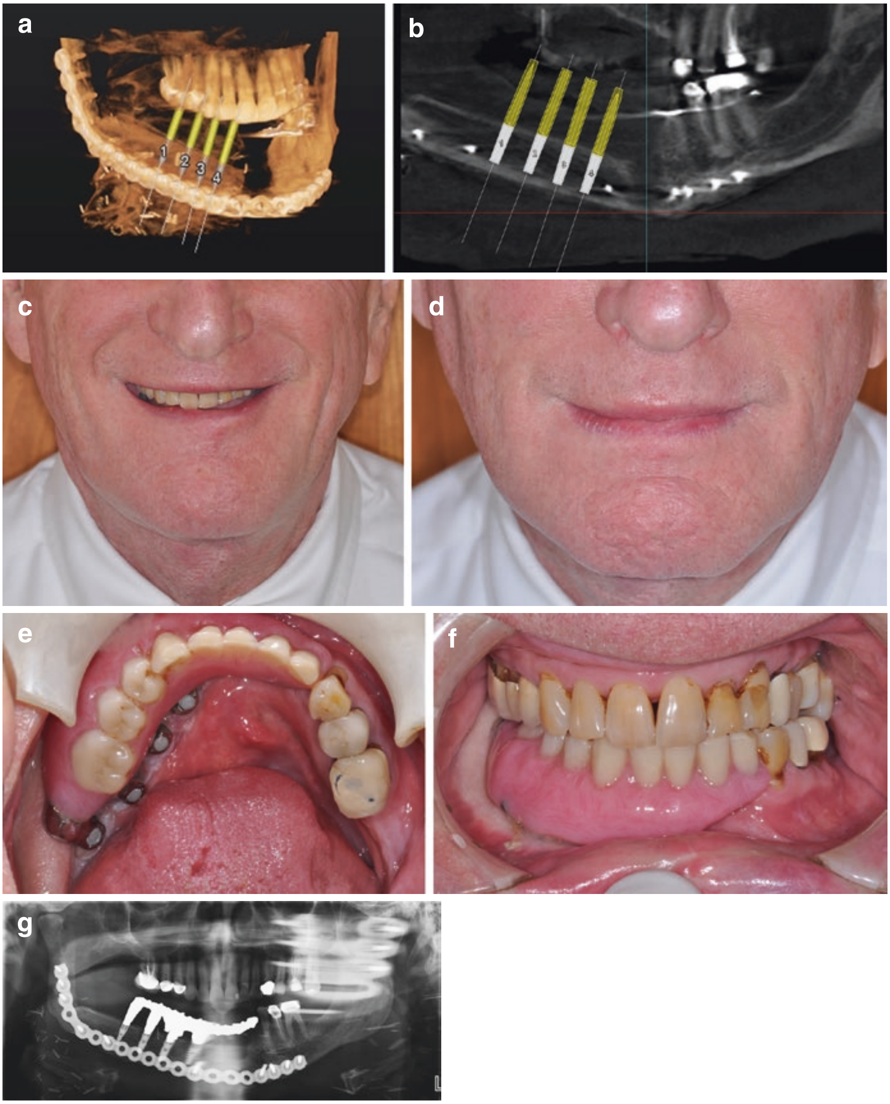

Fig. 3.26 (**a**) Computer-assisted planning for a 70-year-old gentleman after fibula reconstruction of the right mandible from angle to symphysis. (**b**) In anticipation for implant rehabilitation, reconstruction plate screws are placed away from implantable bone. (**c**, **d**) The marginal branch of the facial nerve was involved resulting in lip asymmetry. Support to the lower lip with an implant prosthesis can camouflage lip asymmetry. (**e**) The implant fixed dental prosthesis is screw retained for retrievability. (**f**) The occlusion is restored to bilateral contact. (**g**) Panoramic radiograph of completed reconstruction (Courtesy of Dr. Devin Okay)

3.16 Postoperative Care

Patients who undergo vascularized free flap oromandibular reconstruction routinely have a temporary tracheostomy to prevent airway compromise during the immediate postoperative period. The majority of patients can be decannulated within the first 5–7 days.

Many of the patients are nutritionally compromised preoperatively. Postoperative nutrition is important and essential to their general health, wound healing, and fast recovery. The severe edema and limited mouth opening prohibit the patient from oral feeding in the immediate postoperative period. Also oral feeding can have detrimental effects on the flap and wound breakdown when an intraoral skin paddle is used. Therefore, to ensure healing, minimize wound breakdown and salivary leak while maintaining the patient's nutritional needs, a feeding tube should be considered.

The use of perioperative antibiotics to cover the oral and cutaneous flora should also be considered. Deep venous thrombosis (DVT) chemoprophylaxis using low-dose heparin is essential to prevent postoperative DVT [93]. Antiplatelet therapy (asprin) is used to minimize pedicle thrombosis. These interventions do not seem to increase the incidence of postoperative hematoma when compared with the other anticoagulation agents [94, 95]. However, other data has demonstrated an increase in complications with the use of anticoagulation [96]. The flap is monitored according to the surgeon's preference. Doppler and pinprick at frequent intervals are used to check for the flap viability.

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