Free-Flap Reconstruction of the Mandible

Roderick Y. Kim, DDS, MD[1] Mofiyinfolu Sokoya, MD[2] Yadranko Ducic, MD, FRCS(C), FACS[2]
Fayette Williams, DDS, MD, FACS[1]

[1] Division of Maxillofacial Oncologic and Reconstructive Surgery, Department of Oral and Maxillofacial Surgery, John Peter Smith Health Network, Fort Worth, Texas
[2] Department of Facial Plastic and Reconstructive Surgery, Otolaryngology and Facial Plastic Surgery Associates, Fort Worth, Texas

Address for correspondence Fayette Williams, DDS, MD, FACS, Division of Maxillofacial Oncologic and Reconstructive Surgery, Department of Oral and Maxillofacial Surgery, John Peter Smith Health Network, 1500 S. Main Street, Fort Worth, TX 76100 (e-mail: fayettewilliams@hotmail.com).

Semin Plast Surg 2019;33:46–53.

Abstract

Mandible reconstruction has evolved over the years with advances in surgical options and three-dimensional technology. Although nonvascularized bone grafting is still used, vascularized flaps show advantages with immediate reconstruction, the possibility of immediate dental implants, and the ability to reconstruct composite defects of both soft tissue and bone. This article discusses current vascularized techniques for mandible reconstruction. While each reconstructive method has advantages and disadvantages, a defect-based reconstruction focused on full rehabilitation allows surgeons to plan and counsel the patient for the best available reconstruction.

Keywords
- mandible reconstruction
- free flaps
- complications

Mandible reconstruction remains a challenging area of head and neck reconstructive surgery. The complexity of mandible reconstruction is due to the multiple purposes of the mandible, including facial form, airway support, speech and swallowing through attachments to the tongue, and chewing. Considerations for reconstruction include vascularized versus non-vascularized grafts, immediate versus delayed grafting, and immediate versus delayed restoration of the dentition. There is a trend toward using vascularized bone as defects become larger and more anatomically complex, for composite defects of bone and soft tissue, and when radiation therapy is anticipated.

Historically, the goal of mandible reconstruction has been limited to establishing bone continuity and facial form, although a complete reconstruction with a functional dentition has not always been possible. The authors will review vascularized bone graft options for mandible reconstruction, including options for total jaw reconstruction including immediate dental implants and immediate teeth.

Defect Types and Subunits of Mandible

There have been multiple attempts to classify mandibular defects, yet the optimal classification has been elusive. Many surgeons follow a classification, described in 1991 by Urken et al, separating the mandible based on functional, esthetic, and anatomical considerations.[1] This classification divides the mandible into the condyle, ramus, body, and symphysis. From their description, symphysis is described as the portion of mandible between the canine teeth, the body is canine to the ramus, the ramus defect is angle to the subcondylar region, and a condylar defect encompasses the condylar neck and the temporomandibular joint. More recently, Brown et al performed a comprehensive literature review and described a new classification for oncological defects of the mandible.[2] This classification divides the defect into I to IV based on the canine and angle of the mandible, giving subclassification "c" for condylar involvement. Higher classification is based on the increase in size and complexity of the anatomy of the mandible requiring reconstruction. These classifications allow the surgeon to optimally plan for the reconstruction. We will discuss considerations for mandibular reconstruction, using both of the common classifications described previously.

In a classic lateral defect (►**Fig. 1**, posterior body of the mandible and ramus or class I), the defect is typically straight without curvature. These defects encompass minimal muscle attachment that can lead to disturbances in function such as speech and swallowing. A straight bony reconstruction would be sufficient and typically does not require osteotomy of the free flap. It is important to note, when considering implant reconstruction in the future, that the bone is in the

Issue Theme Free Tissue Transfer Reconstruction; Guest Editor: Yadranko Ducic, MD, FRCS(C), FACS

DOI https://doi.org/10.1055/s-0039-1677791.
ISSN 1535-2188.

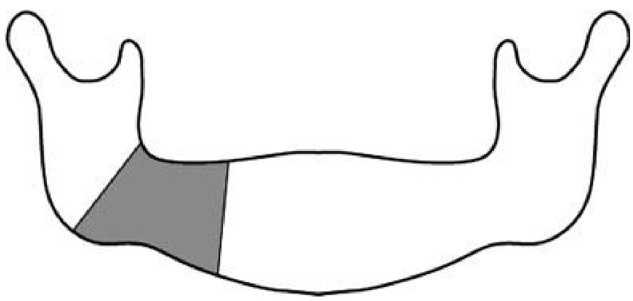

Fig. 1 Posterior body and ramus (lateral) defect.

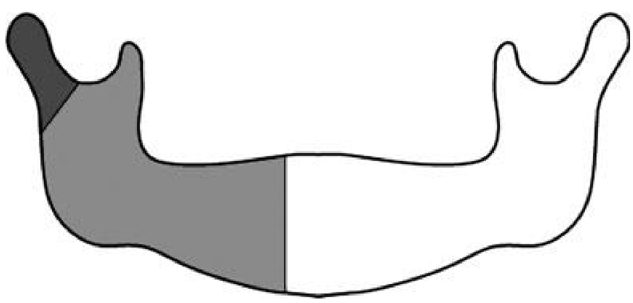

Fig. 2 Ramus/condyle defect.

harmonious occlusion of maxillary teeth. This allows dental rehabilitation-based reconstruction, which should be a part of the surgeon's overall reconstructive plan.

In a defect that approaches the condyle (►**Fig. 2**, ramus/condyle, class II or IIc) after oncological resection, the consideration should be based on whether if the condyle could be plated or not. If the condyle cannot be plated without violating the joint space, consider removing the condyle completely. If the joint space is violated and the condylar fossa is exposed, it is important to make sure that the hardware does not approach the condylar region, as it may lead to erosion of the base of skull and perforation into the middle cranial fossa.[3] The optimal reconstruction of the fossa/condylar complex and the interpositional graft is beyond the scope of this chapter and under debate.

For anterior mandible defects (►**Fig. 3**, symphysis, class III), the symphysis can be reconstructed with one or two osteotomized bone segments. Since smaller and multiple bone segments are at a greater risk of losing vascularity, a single segment is often preferred in reconstructing symphysis defects. Furthermore, the symphysis is the location of important muscle attachments such as the genioglossus and suprahyoid muscles. These muscles stabilize the floor of mouth, the tongue, and the pharynx, with implications in swallowing and airway protection. It is also important in terms of esthetics and lip support to consider using presurgical computer-aided planning. A free flap that has enough bone height, soft tissue bulk, and support for chin projection improves the outcome of this defect. Ultimately, dental rehabilitation is required to allow adequate lip support for optimal speech and chewing.

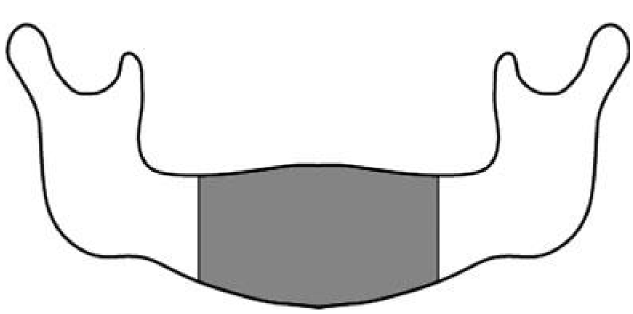

Fig. 3 Anterior mandible defect.

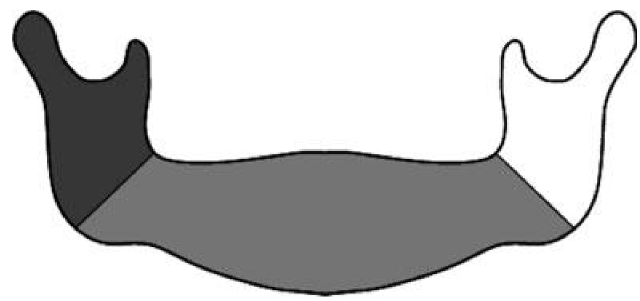

Fig. 4 Long-span defect.

For long-span defects from angle to angle (►**Fig. 4**, symphysis and body, class IV), the free-flap reconstructive options are more limited. The typical span of this area is around 15 to 28 cm.[2] Although it is not crucial to replicate this length exactly, it is important to consider the reconstructive options that could achieve this length. The fibula can span 25 cm,[4,5] with decent pedicle length, and scapula could give long bone up to 14 cm[6] but likely require vessel grafting to achieve ideal length and is sometimes too thin to allow endosseous implant placement. Positioning the chin in a slightly retrognathic position can decrease the length of the required bone with minimal cosmetic consequence.

Types of Free Flaps and Relationship with the Defect Type

Fibula

The fibula free flap was originally described in 1975 by Taylor et al for reconstruction of an open fracture of the leg.[7] It is a versatile free flap that can be used as an osseous, osteocutaneous, or osteoseptocutaneous free flap. There is a lengthy segment of bone available for reconstruction (20–26 cm).[5] It is based on the peroneal artery and two venae commitantes. Advantages of this flap include large vessel caliber, long bony length,[4,5] good bone quality amenable to implants, and ability to use osteotomies to contour the bone. Nerve graft harvest of the sural nerve can also be performed through the same wound if needed.[8] Distal location of the donor site also permits simultaneous ablative procedures in the head and neck. Donor-site morbidity includes a long scar and frequent need for skin grafting if an osteocutaneous flap is used. Inability to flex the flexor hallucis longus and valgus deformity have been described as possible complications.[9] Perforators to the skin island are centered over the posterior crural septum and can be found between the middle and distal thirds of the fibula. Expedited harvest of the fibula free flap can be performed using the tunneling technique as described by Ducic et al (►**Figs. 5**, **6**)[10]

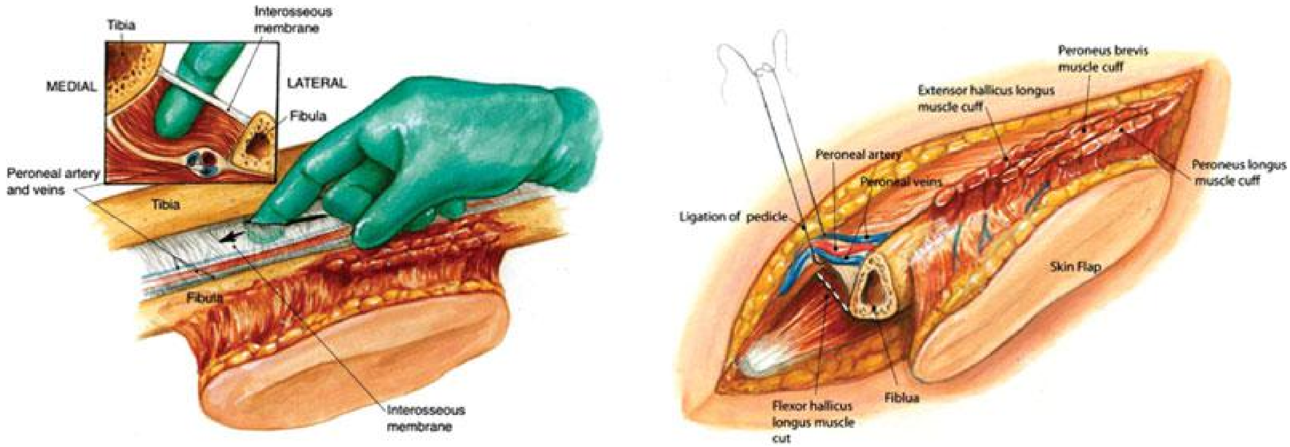

Fig. 5 Tunneling technique. (Reproduced with permission of Ducic et al.[10])

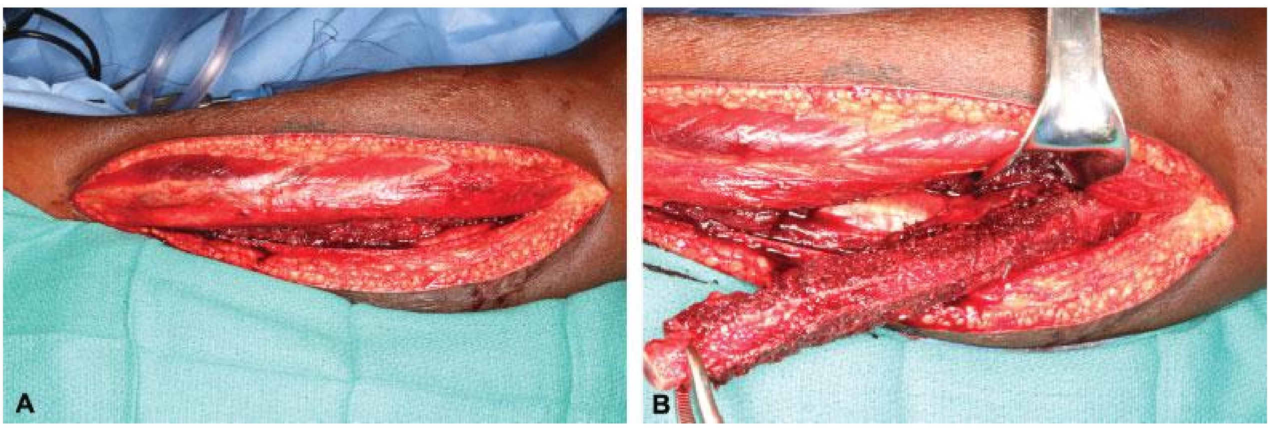

Fig. 6 (**A**) Fibula harvest with the peroneus longus exposed. (**B**) Fibula lateralized after completion of osteotomy.

Iliac Crest

Although the versatility of the fibula free flap has led to replacement of the iliac crest free flap in most situations, there are still a few indications where this flap can be used. It is particularly suited for mandible reconstruction due to the natural contour of the bone, and its stock makes it available for endosseous implants. The flap is based on the deep circumflex iliac artery and vein from the external iliac system. Pedicle length is usually 4 to 7 cm (►**Fig. 7**) The main disadvantages of this flap include its short vascular pedicle and the difficulty in performing osteotomies due to lack of segmental perforators. Convenience of harvest is also influenced by body habitus. Donor-site morbidities include hematoma, numbness in the hip region, bulging, and hernia formation.

Radial Forearm Osteocutaneous

A partial segment of the radius can be safely harvested with a vascular pedicle for mandible reconstruction. However, over the last couple of decades, its use has declined. This is likely due to a high rate of donor-site morbidity, most commonly radial fracture. The use of keel-shaped osteotomies and prophylactic internal fixation has reduced the incidence of these fractures.[11] The flap is based on the radial artery and its perforators, as well as the subcutaneous venous system of the cephalic vein (►**Fig. 8**).

Scapula

The scapula free flap is based on the subscapular system, notably the circumflex scapula artery and vein. The scapula can provide up to 14 cm of bone (►**Fig. 9**).[6] However, the bone stock obtained is poorer than the fibular and the iliac crest. A main advantage of the scapula free flap is the ability to harvest a large area of soft tissue and bone base on a single pedicle. The skin island can also be harvested in an axial or transverse orientation based on the size and geometry of the defect. The latissimus dorsi and serratus anterior can also be harvested based on the same vascular pedicle.[12] The patient has to be in the decubitus position during the harvest of this flap. This makes simultaneous ablation and flap harvest difficult. An advantage is the avoidance of postoperative mobility issues associated with the fibula, iliac crest, and radial forearm osteocutaneous flaps.

Perioperative Care of the Mandibular Reconstruction Patient

It is imperative to monitor the viability of the free flap in the acute postoperative setting. The purpose of monitoring is early identification and intervention to correct perfusion problems that might lead to flap loss. In osteocutaneous flaps, the perforator to the skin paddle can typically be used

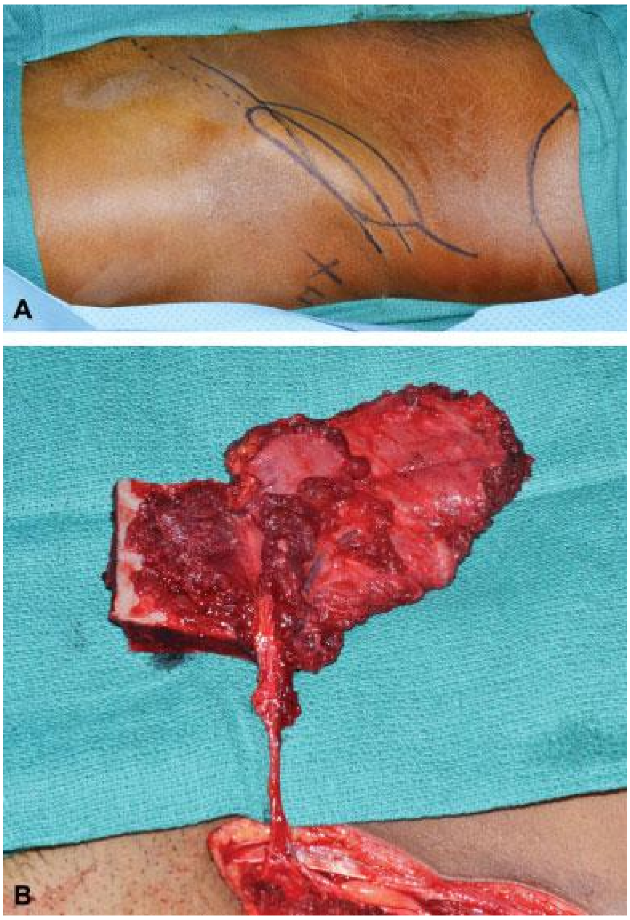

Fig. 7 (**A**) Iliac crest free-flap markings. (**B**) Completed harvest of the iliac crest, with the pedicle length shown.

as an indicator of the performance of the entire flap. The handheld Doppler can be used to evaluate the arterial and venous blood flow. Pinprick using an 18- to 25-gauge needle can also be used to evaluate venous drainage and arterial supply of the skin paddle. In the case of osseous flaps without a skin paddle, monitoring becomes problematic due to the lack of a visible external surface. Implantable Dopplers can also be placed on the arterial or venous pedicle. These are sometimes unreliable, and audibility of the Doppler pulse can be positional. However, a recent systematic review and meta-analysis showed that the implantable Doppler probe is significantly more efficacious than clinical monitoring.[13] The use of a small external skin paddle, also known as a buoy, solely for monitoring purposes has been described.[14] Blood flow through the donor pedicle can also be monitored with an external Doppler if accessible. Other methods of noninvasive monitoring of free flaps include near-infrared spectroscopy and indocyanine green angiography.[15,16]

Postoperative nutrition using nasogastric, nasojejunal, or gastrostomy tubes is commonly needed in patients undergoing mandibular reconstruction. Adequate nutrition with amino acids and carbohydrates is necessary for recovery and healing. It is also associated with improved surgical outcomes and disease survival.[17] Other important considerations in the immediate postoperative period include prophylaxis against thromboembolism, antibiotic prophylaxis, nausea and vomiting prevention, and intravenous fluid management.

Decision and timing of oral diet should be weighed on an individual basis. The level of confidence of the surgeon in patient protoplasm and speed of healing will typically affect the timing of oral diet. The combination of floor-of-mouth, tongue, and oropharyngeal defects in the reconstruction will also affect when the patient will tolerate oral feeds. Typically, postoperative feeding should occur after 5 days, and mastication should follow similar outline as other bony discontinuity defects, beginning with no-chew diet at 2 weeks and regular diet at 6 weeks postoperatively to prevent malunion or nonunion.

State-of-the-Art Reconstruction

Virtual Surgical Planning

Virtual surgical planning (VSP) has gained significant popularity and widespread usage due to improved surgical precision and decreased operating time.[18–21] VSP is a term to describe a section of computer-assisted surgery (CAS), which is frequently used to describe the surgery; where the planning, rapid prototyping of surgical guide and models, and recently preidentification of drill holes, nerves, and tumor margins can be obtained.[21,22] Recent advances particularly focuses on the preoperative planning for the rehabilitation, beyond the bony reconstruction, such as Jaw In A Day.

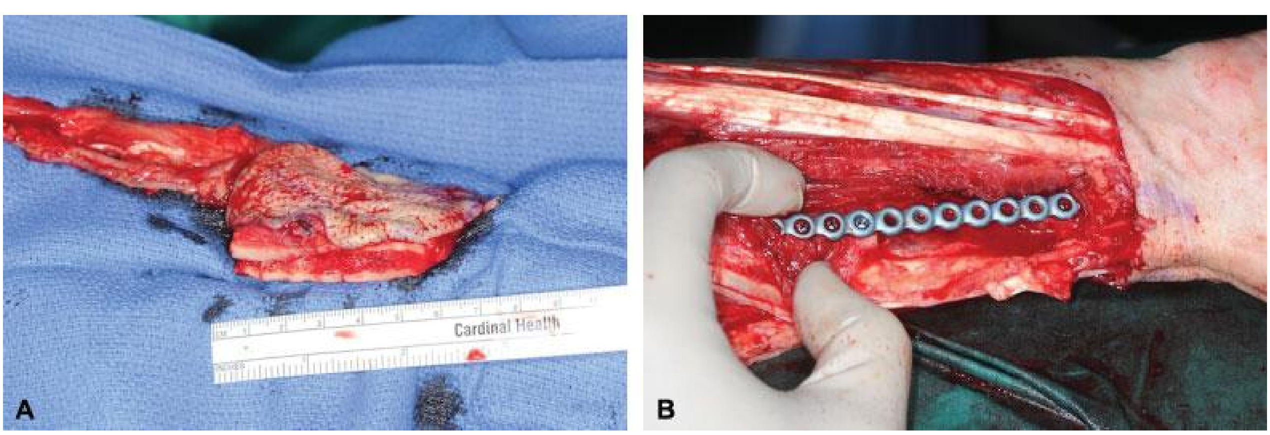

Fig. 8 (**A**) Radial forearm osteocutaneous flap harvested. (**B**) Prophylactic internal fixation of the radius.

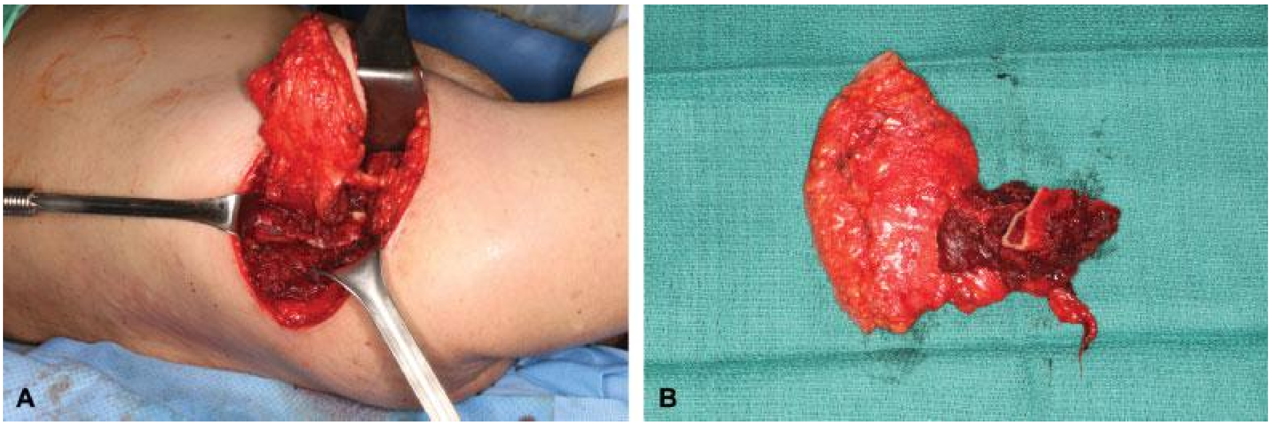

Fig. 9 (A) Scapula osteocutaneous flap harvest position. (B) Scapula osteocutaneous flap harvested.

In general, the flow of CAS includes data acquisition, data export to the treatment planning platform, data manipulation and VSP, and generation of surgical plan and aids. The surgical plan and aids include surgical blueprint, tactile models, cutting guides, patient-specific implants (PSIs), and more.[21] Most current maxillofacial computed tomography (CT) and cone-beam CTs acquire enough data to perform this task, although 1-mm cuts of the maxillofacial CT are ideal.

The utility of VSP/CAS continues to expand. First, it allows the surgeons to perform their surgery preoperatively and plan ahead in their mind, allowing to visualize possible difficulties and complications. Second, with a "wrap" of the tumor, you can plan the resection margins in the three-dimensional (3D) vantage point and thus categorize reconstruction based on the defect expected after the surgical margin is applied. Third, using mirroring features, you can create perfected tactile models where plates could be prebent or PSI could be created with 3D printing. The 3D printing options include titanium, PEEK (polyetheretherketone), or PEKK (polyetherketoneketone). Lastly, recent advances with predictive screw holes, endosseous implants, and immediate nerve grafts allow faster reconstruction with optimal dental and neural rehabilitation. However, cost is still a factor that prevents widespread usage, although some clinicians note that the amount of time saved intraoperatively alleviates the increase in cost.

Jaw In A Day

Dental rehabilitation after mandibular reconstruction typically requires 6 to 12 months before completion. However, the Jaw In A Day procedure offers concurrent reconstruction and dental rehabilitation in one surgical procedure (►**Figs. 10–15**).

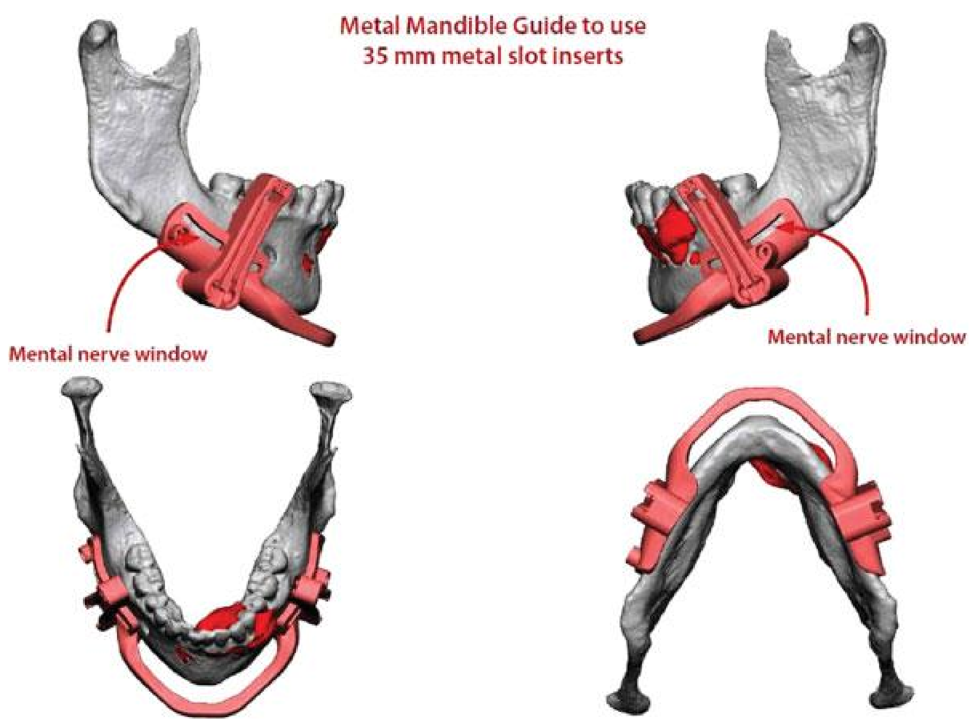

Fig. 10 Virtual surgical planning cutting guides.

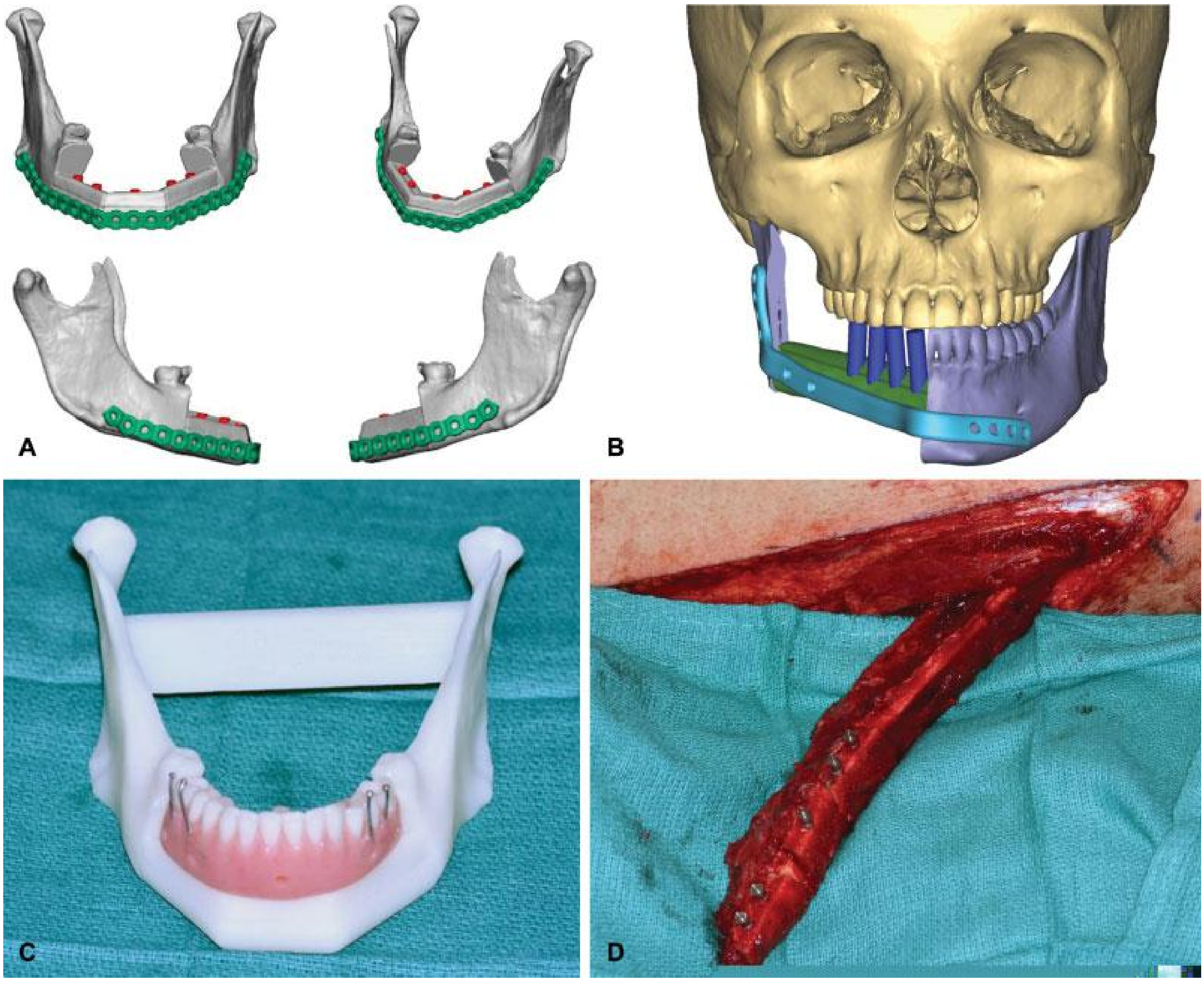

Fig. 11 (A) Patient-specific prebent mandible reconstruction plate. (B) Patient-specific milled reconstruction plate with implant positions. (C) Immediate prosthesis fitting precisely on a three-dimensional printed patient model. (D) Endosseous dental implants placed in the attached fibula.

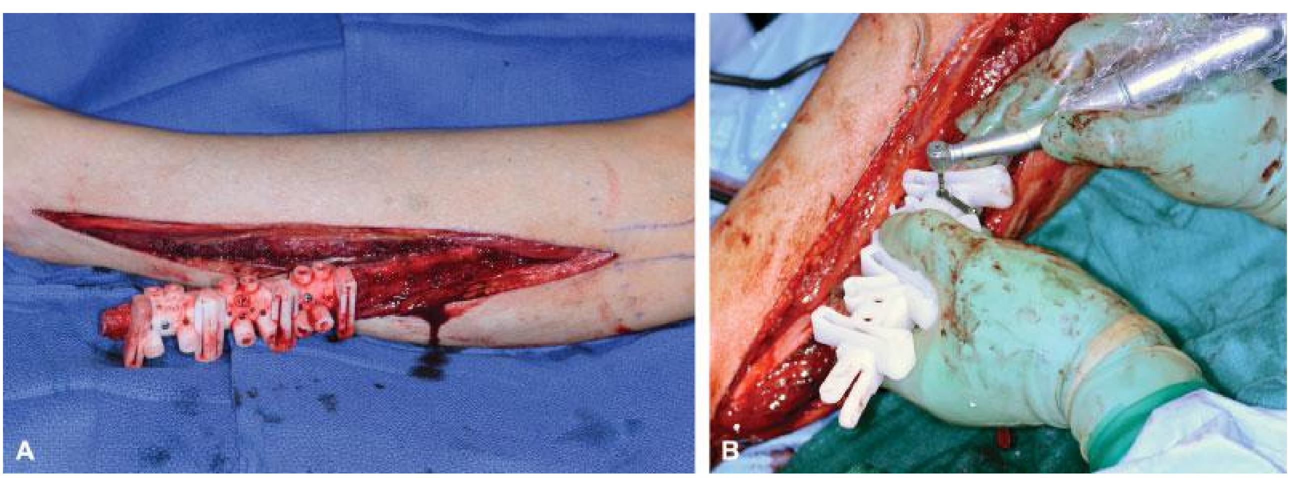

Fig. 12 (A) Implant placement guides from virtual surgical planning. (B) Placement of endosseous implants with three-dimensional printed guide.

Fig. 13 Correct angulation of implants.

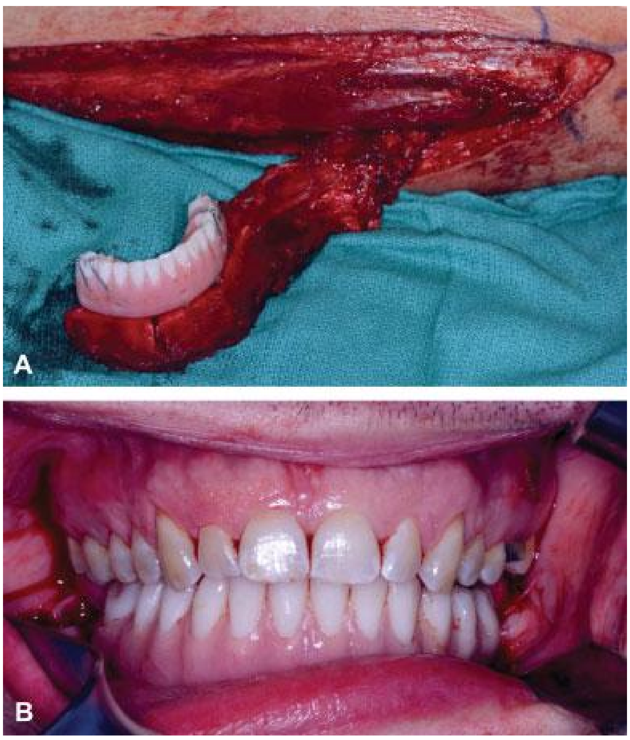

Fig. 14 (A) Immediate prosthesis in harmonious form with the osteotomized fibula. (B) Immediate prosthesis and fibula inset in the oral cavity.

Fig. 15 Postoperative panoramic radiograph.

David Hirsch's group from the New York University initially reported a series of four patients in whom immediate dental implants and implant retained dental prosthesis was placed during mandible free tissue transfer.[23] The advantages of the Jaw In A Day procedure lie in the avoidance of the psychological impact experienced by a patient who faces imminent loss of a considerable portion of the jaw. The early restoration of form is important to the psyche and quality of life of the patient. However, it is recommended that the patient adheres to a strict pureed diet for a few months after reconstruction to allow for adequate healing and union of bony segments. The long-term implant success rates are unknown due to the relatively small sample sizes in the current literature.

Conclusion

Although there is no one ideal reconstructive option for mandibular defects, free tissue transfer addresses the most common challenges. Although each reconstructive method has advantages and disadvantages, with defect-based reconstruction with full rehabilitation of the patient in mind, surgeons can plan and counsel the patient for the best available reconstruction.

Funding
None.

Conflicts of Interest
None declared.

Acknowledgments
Special thanks to Megan Kim RA for the illustrations.

References

1 Urken ML, Weinberg H, Vickery C, Buchbinder D, Lawson W, Biller HF. Oromandibular reconstruction using microvascular composite free flaps. Report of 71 cases and a new classification scheme for bony, soft-tissue, and neurologic defects. Arch Otolaryngol Head Neck Surg 1991;117(07):733–744
2 Brown JS, Barry C, Ho M, Shaw R. A new classification for mandibular defects after oncological resection. Lancet Oncol 2016;17(01):e23–e30
3 Marx RE, Cillo JE Jr, Broumand V, Ulloa JJ. Outcome analysis of mandibular condylar replacements in tumor and trauma reconstruction: a prospective analysis of 131 cases with long-term follow-up. J Oral Maxillofac Surg 2008;66(12):2515–2523
4 Fernandes RP, Yetzer JG. Reconstruction of acquired oromandibular defects. Oral Maxillofac Surg Clin North Am 2013;25(02):241–249
5 Schrag C, Chang YM, Tsai CY, Wei FC. Complete rehabilitation of the mandible following segmental resection. J Surg Oncol 2006; 94(06):538–545
6 Urken ML, Buchbinder D, Costantino PD, et al. Oromandibular reconstruction using microvascular composite flaps: report of 210 cases. Arch Otolaryngol Head Neck Surg 1998;124(01):46–55
7 Taylor GI, Miller GD, Ham FJ. The free vascularized bone graft. A clinical extension of microvascular techniques. Plast Reconstr Surg 1975;55(05):533–544
8 Halim AS, Yusof I. Composite vascularised osteocutaneous fibula and sural nerve graft for severe open tibial fracture–functional outcome at one year: a case report. J Orthop Surg (Hong Kong) 2004;12(01):110–113
9 Hsu LC, O'Brien JP, Yau AC, Hodgson AR. Valgus deformity of the ankle in children with fibular pseudarthrosis. Results of treatment by bone-grafting of the fibula. J Bone Joint Surg Am 1974;56 (03):503–510

10 Ducic Y, Defatta R, Wolfswinkel EM, Weathers WM, Hollier LH Jr. Tunneling technique for expedited fibula free tissue harvest. Craniomaxillofac Trauma Reconstr 2013;6(04):233–236
11 Silverman DA, Przylecki WH, Arganbright JM, et al. Evaluation of bone length and number of osteotomies utilizing the osteocutaneous radial forearm free flap for mandible reconstruction: an 8-year review of complications and flap survival. Head Neck 2016; 38(03):434–438
12 Disa JJ, Cordeiro PG. Mandible reconstruction with microvascular surgery. Semin Surg Oncol 2000;19(03):226–234
13 Chang TY, Lee YC, Lin YC, et al. Implantable Doppler probes for postoperatively monitoring free flaps: efficacy. A systematic review and meta-analysis. Plast Reconstr Surg Glob Open 2016; 4(11):e1099
14 Pellini R, Pichi B, Marchesi P, Cristalli G, Deganello A, Spriano G. External monitor for buried free flaps in head and neck reconstructions. Acta Otorhinolaryngol Ital 2006;26(01):1–6
15 Takasu H, Hashikawa K, Nomura T, Sakakibara S, Osaki T, Terashi H. A novel method of noninvasive monitoring of free flaps with near-infrared spectroscopy. Eplasty 2017;17:e37
16 Hitier M, Cracowski JL, Hamou C, Righini C, Bettega G. Indocyanine green fluorescence angiography for free flap monitoring: a pilot study. J Craniomaxillofac Surg 2016;44(11):1833–1841
17 Müller-Richter U, Betz C, Hartmann S, Brands RC. Nutrition management for head and neck cancer patients improves clinical outcome and survival. Nutr Res 2017;48:1–8
18 Han HH, Kim HY, Lee JY. The pros and cons of computer-aided surgery for segmental mandibular reconstruction after oncological surgery. Arch Craniofac Surg 2017;18(03):149–154
19 Rodby KA, Turin S, Jacobs RJ, et al. Advances in oncologic head and neck reconstruction: systematic review and future considerations of virtual surgical planning and computer aided design/ computer aided modeling. J Plast Reconstr Aesthet Surg 2014;67 (09):1171–1185
20 Modabber A, Legros C, Rana M, Gerressen M, Riediger D, Ghassemi A. Evaluation of computer-assisted jaw reconstruction with free vascularized fibular flap compared to conventional surgery: a clinical pilot study. Int J Med Robot 2012;8(02):215–220
21 Edwards SP. Computer-assisted craniomaxillofacial surgery. Oral Maxillofac Surg Clin North Am 2010;22(01):117–134
22 Markiewicz MR, Miloro M. The evolution of microvascular and microneurosurgical maxillofacial reconstruction. J Oral Maxillofac Surg 2018;76(04):687–699
23 Levine JP, Bae JS, Soares M, et al. Jaw In A Day: total maxillofacial reconstruction using digital technology. Plast Reconstr Surg 2013; 131(06):1386–1391