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ORIGINAL ARTICLE

Reconstructive

Vascularized Fibula TMJ Reconstruction: A Report of Five Cases featuring Computerized Patient-specific Surgical Planning

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Background: Mandibular defects involving the condyle represent a complex reconstructive challenge for restoring proper function of the temporomandibular joint because it requires precise bone graft alignment, or alloplastic materials, for complete restoration of joint function. The use of computerized patient-specific surgical planning (CPSSP) technology can aid in the anatomic reconstruction of mandibular condyle defects with a vascularized free fibula flap without the need for additional adjuncts. The purpose of this study was to analyze clinical and functional outcomes after reconstruction of mandibular condyle defects using only a free fibula graft with the assistance of virtual surgery techniques.

Methods: A retrospective review was performed to identify all patients who underwent mandibular reconstruction utilizing CPSSP with only a free fibula flap without any temporomandibular joint adjuncts after a hemimandibulectomy with total condylectomy.

Results: From 2018 to 2021, five patients underwent reconstruction of mandibular defects involving the condyle with CPSSP technology and preservation of the native temporomandibular articulating disk. The average age was 62 years (range, 44–73 years). The average follow-up period was 29.2 months (range, 9–46 months). Flap survival was 100% (N = 5). The maximal interincisal opening range for all patients was 22–45 mm with no lateral deviation or subjective joint pain. No patients experienced progressive joint hypomobility or condylar migration.

Conclusion: The use of CPSSP technology can aid in the anatomic reconstruction of mandibular condyle defects with a vascularized free fibula flap through precise planning and intraoperative manipulation with optimal functional outcomes. *(Plast Reconstr Surg Glob Open 2022;10:e4465; doi: 10.1097/GOX.0000000000004465; Published online 18 August 2022.)*

INTRODUCTION

Mandibular condyle reconstruction in the adult population may be required to treat facial trauma, oncologic resection, or chronic infection, particularly in managing chronic osteoradionecrosis (ORN). In a retrospective analysis of 929 trauma-associated facial fractures, 200 fractures involved the mandible. Of these, nearly 50% involved the mandibular condyle.[1] However, sizable defects of the posterior mandible, including the condyle, most likely result from pathologic resection. Therefore, reconstructive efforts may include the utilization of soft tissue flaps or the vascularized osteocutaneous fibula flap.[2,3] ORN as a sequela of managing head and neck cancers by radiation therapy may occur months to years after treatment. If conservative management fails, various vascularized osteocutaneous flaps may be utilized for mandibular reconstruction; these commonly comprise those from the fibula or scapula axis, with flap selection based on patient needs and overall health status.[4–6] Biologic reconstructive techniques for mandibular condylar reconstruction have historically centered around the use of autogenous ribs.[7] Although obtainable in a sufficient volume and number

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Received for publication February 18, 2022; accepted June 3, 2022.

DOI: 10.1097/GOX.0000000000004465

Disclosure: *The authors have no financial interest to declare in relation to the content of this article.*

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with minimal postoperative morbidity for the patient, the limitations of this treatment modality are well known.

These include the development of either soft or hard tissue ankylosis with resulting trismus or resorption of the reconstructed neo-condyle, iatrogenic resorption of the contralateral nonoperated condyle due to abnormal occlusal forces, and occlusal discrepancies due to changes in the overall ramus-condyle height and subsequent migration of the dentition.[7] The anticipated lifespan of the prosthesis complicates alloplastic techniques of temporomandibular joint (TMJ) reconstruction, generally accepted as 15–20 years, and the need for surgical replacement during the patient's lifetime.[8] Alloplastic TMJ reconstruction classically consists of an articulating fossa and a separate condylar/ramus construct. Complications with TMJ reconstruction center around the specific components of the materials used in fabrication—not only with potential contact sensitivities to the compositional makeup of the implants but also as a consequence of function. Fully metallic replacements present the potential for the development of metallosis. At the same time, the component prostheses that consist of a high-molecular-weight polymer (HMWP) fossa articulating against a cobalt-chromium-molybdenum (Co-Cr-Mb) alloy condylar head have foreign body reactions due to the resorption of the HMWP. Component prostheses also can have catastrophic separation of the HMWP from the underlying cast framework.[9]

Based on these potential difficulties and expressed desires of certain patients to maintain autogenous reconstructive options, the vascularized fibula has been used in certain circumstances for TMJ reconstruction. In addition, with the increase in both the access and accuracy of computer-designed, patient-specific reconstructive surgical platforms, the investigation into the feasibility of incorporating autologous reconstructive options into craniomaxillofacial surgery has proliferated in multiple institutions.[10–15] The authors present their most recent approach utilizing computerized patient-specific surgical planning (CPSSP) and execution in mandibular condylar head reconstruction using the autologous vascularized fibula, preserving the native temporomandibular joint disks, thereby negating the need for alloplastic materials. The surgical technique is described in detail, and the long-term outcomes of five patients are presented.

Takeaways

Question: Does computerized patient-specific surgical planning (CPSSP) assist with autologous reconstruction of the temporomandibular joint?

Findings: Five patients underwent reconstruction of mandibular defects involving the condyle with CPSSP technology and preservation of the native temporomandibular articulating disk. The average age was 62 years (range, 44–73 years). The average follow-up period was 29.2 months (range, 9–46 months). Flap survival was 100% (N = 5). The maximal interincisal opening range for all patients was 22–45 mm with no lateral deviation or subjective joint pain. No patients experienced progressive joint hypomobility or condylar migration.

Meaning: CPSSP technology can aid in accurate reconstruction of mandibular condyle defects with a vascularized free fibula flap without the need for additional adjuncts.

PATIENT EVALUATION AND SURGICAL PLANNING

The patient's oral and overall head and neck evaluation mainly includes the oral mucosa for possible deficiency or clinically apparent defect and plans to utilize the (osteo-septo-cutaneous) fibula flap skin island to restore the intraoral lining. If the oral mucosa is intact, the skin island may be utilized for external skin replacement with tension-free closure. The bilateral neck vessels are clinically evaluated using conventional acoustic Doppler ultrasound. A computed tomography (CT) angiogram of the neck is obtained if in question. Similarly, the bilateral lower extremities are evaluated for skin quality and perfusion (anterior and posterior tibial artery pulse by palpation) and the aforementioned acoustic Doppler, supplemented by a CT angiogram of the bilateral lower extremities if required. CT with a minimum of 0.6-mm cuts is necessary to initiate current commercially available CPSSP. A key component of the CPSSP is to design the fibula vascular pedicle to be inferiorly positioned and to have the vascular anastomosis to occur anteriorly. This allows for occlusion of the vascular pedicle just inferior of the neo-condylar head, and to prevent potential iatrogenic injury to the pedicle with function and mastication. The height of the proposed neo-condyle should exactly recreate the height of the contralateral condylar head, with the design for the shape of the neo-condyle to rest naturally within the articulating fossa. The surgeon must decide the materials to be used for the custom cutting guides, either titanium or polyamide, as well as the specifics of the reconstruction plate. After approval of the CPSSP via email or phone conference, the osteotomy cutting guides and the plating system are provided by industry partners. The patient is preferably scheduled to undergo surgery in an operating room (OR) with intraoperative computed tomography assessment available. After surgery, a postoperative stay in the intensive care unit may be recommended based on the degree of mandibular resection and potential soft tissue collapse of the airway should the anterior aspect of the mandible be involved due to the disarticulation of the genioglossus and geniohyoid muscles and resulting collapse of the tongue posteriorly. If necessary, the patient undergoes a tracheostomy and percutaneous gastric tube placement on the day of surgery, primarily if the resection incorporates the anterior aspect of the mandible resulting in the loss of attachment of the geniohyoid muscles and collapse of the posterior airway.

OPERATIVE TECHNIQUE AND EXECUTION

Recipient Site Preparation

The dissection for the hemimandibulectomy is ideally performed intraorally to preserve the marginal mandibular branch of the facial nerve and mitigate the soft tissue scarring associated with a classic external approach to the mandible. Should the patient be dentate, the initial incision is accomplished in the lateral-posterior aspect of the mandible near the ascending ramus, transitioning to intrasulcular incisions around the dentition. If the patient is edentulous, the approach is similar, except the continuation of the incision is along the crest of the alveolar bone to the projected area of the resection. Lateral and inferior reflection of the soft tissue is accomplished facially and lingually with a Molt or Freer elevator, taking care to remain completely subperiosteal along the lingual border of the mandible to protect the lingual nerve. Care is taken during the dissection to maintain as much of the soft tissue envelope as possible to facilitate closure of the reconstructed neo-condyle without the need for a soft tissue pedicle harvest in conjunction with the fibula resection. Utilizing standard orthognathic surgery instruments, dissection occurs in a superior vector identifying the coronoid process of the mandible, if present, and continues posteriorly and superiorly along the ascending condylar process of the mandible. Along the anterior aspect of the mandible, the fovea is identified, representing the attachment of the inferior belly of the lateral pterygoid muscle. The inferior belly of the lateral pterygoid is separated with electrocautery, and a Freer elevator is used to dissect above the condylar head of the mandible, freeing the mandibular body from the articulating disc of the temporomandibular joint, which should remain intact due to the attachment of the superior belly of the lateral pterygoid muscle. This dissection is often simplified with the use of intraoperative navigation. Previously fabricated cutting templates are placed on the mandibular body in the region of the expected resection and are secured with the application of monocortical surgical screws. The cutting templates are designed with predictive holes for the final reconstruction plate, and these sites are prepared before the resection. After securing the cutting template, the hemimandibulectomy is conducted in the standard fashion with a sagittal saw, and the resected mandible is removed and submitted for definitive histopathologic analysis.

Fibula Harvest

The fibula harvest is completed in the standard fashion taking care to protect the vascular pedicle. After complete flap harvest but with the composite graft remaining attached at its proximal vascular pedicle, the proximal fibula bone is dissected from the periosteal sleeve and proximally cut using an oscillating saw. The fibula cutting guide is secured away from the posterior vascular pedicle using monocortical screws (Fig. 1). Next, osteotomies are performed as preplanned by protecting the pedicle with narrow malleable retractors. Finally, the prefabricated plate is secured to the fibula segments in situ and with the flap remaining perfused to reduce ischemia time (Fig. 1). Therefore, the preplanned construct is prepared for the oral inset and final microsurgical anastomosis.

Preparation of Neo-condyle

The previously fabricated neo-condyle cutting templates are placed on the proximal aspect of the fibula graft in the

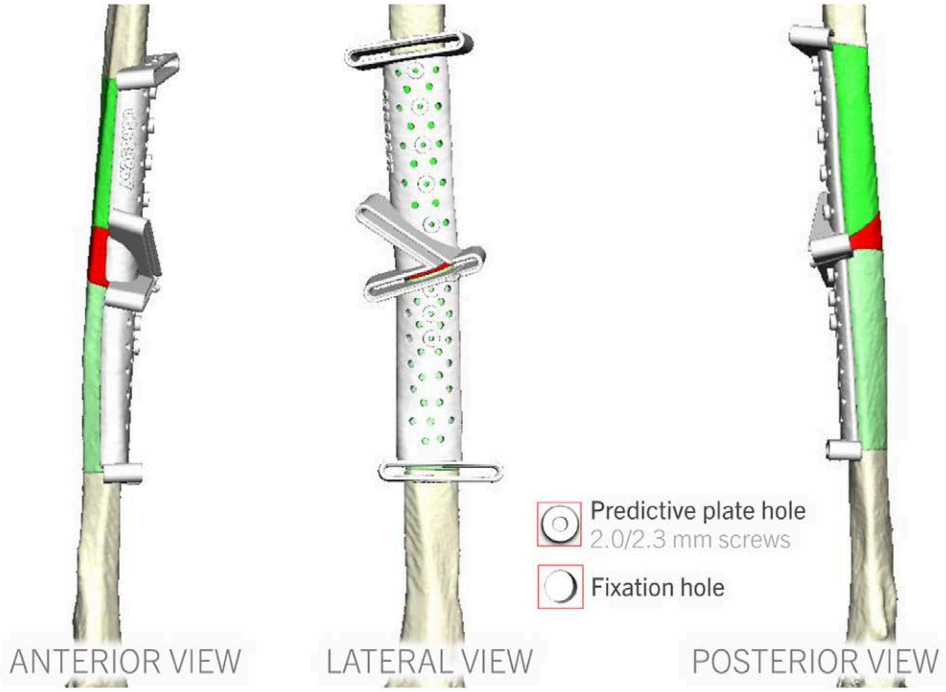

Fig. 1. CPSSP fibula cutting-guide template with planned osteotomies for reconstruction of the TMJ.

region of the expected contouring. They are secured with the application of monocortical surgical screws. The cutting templates adapt intimately with the reconstruction plate ensuring proper orientation to create a new condylar head (Fig. 2). The neo-condyle is shaped utilizing a flame-shaped carbide bur in a rotary handpiece to protect the vascular pedicle. Before insetting the neo-condyle construct into the patient, the terminal ends of the recontoured fibula graft are covered with redundant soft tissue/muscle from the fibula harvest site to serve as an additional biologic barrier to the remaining native temporomandibular disk to prevent heterotopic bone formation and ankylosis (Fig. 3).

CASE PRESENTATIONS

1. *Case 1*—The patient was a 62-year-old man with a medical history significant for chronic myelogenous leukemia and right T1N0 squamous cell carcinoma (SCCa) of the right tonsil status-post radiotherapy and T4N1 SCCa of the right retromolar trigone status-post chemoradiation. He presented with significant ORN of the right mandible with chronic infection. The approach to the mandibular resection was via a classic Risdon submandibular percutaneous incision (Figs. 4, 5).
2. *Case 2*—The patient is a 44-year-old man with a new-onset biopsy-proven odontogenic myxoma of the left mandible, which extended to the condylar head, necessitating resection of the hemimandible for definitive treatment. The approach for the mandibular resection was via an intraoral mandibular labial vestibule access only (Figs. 6, 7).
3. *Case 3*—The patient is a 72-year-old man presenting with a medical history of resection of a "benign tumor" from his mandible. The patient was a poor historian and claimed resection of a lesion of the right mandible "in the early 1990s," which was immediately reconstructed with a posterior iliac crest bone harvest. He could not remember the location of the hospital, the surgeon's name, or the actual histopathology results. He presented with a slowly enlarging expansile mass of the right posterior mandible and

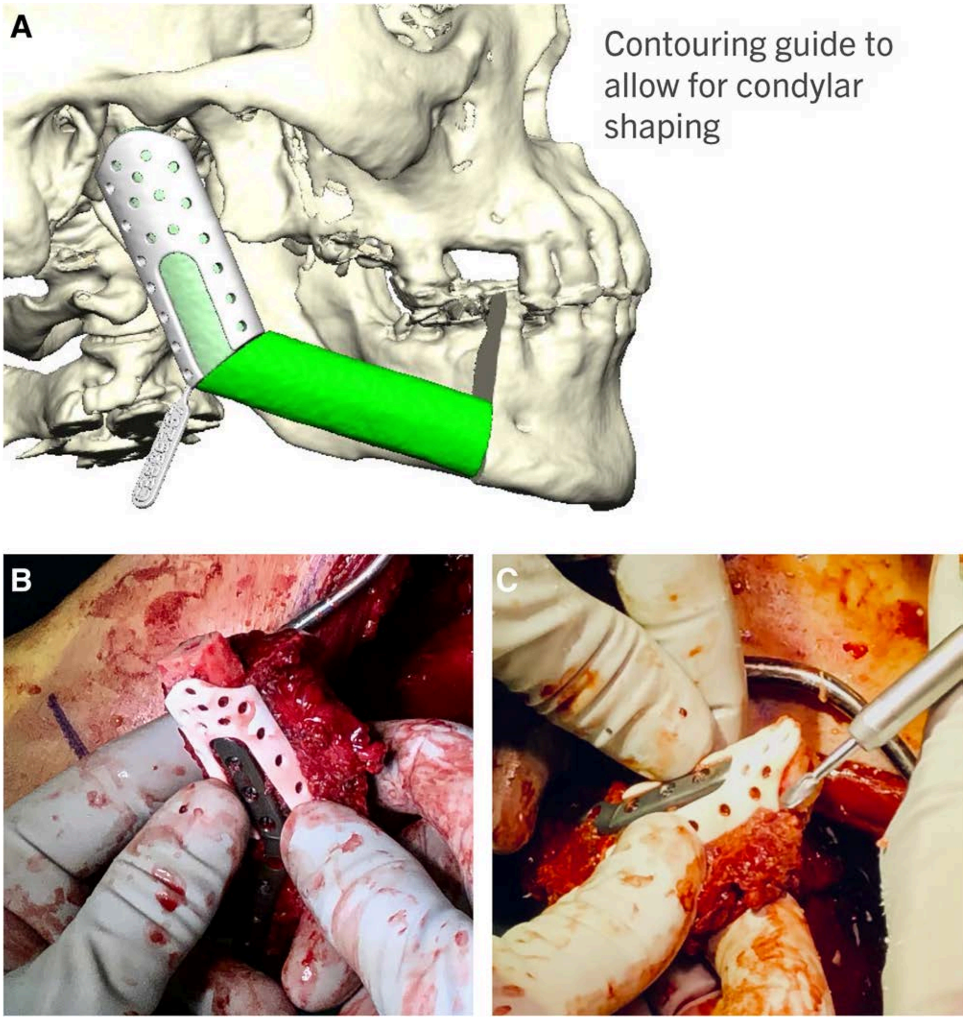

Fig. 2. Customized components for fabrication of the neo-condyle. A, CPSSP cutting-guide template for fabrication of neo-condyle. B, Placement of cutting guide on fibula for creation of neo-condyle. C, Contouring of fibula head with a carbide bur for the creation of a neo-condyle.

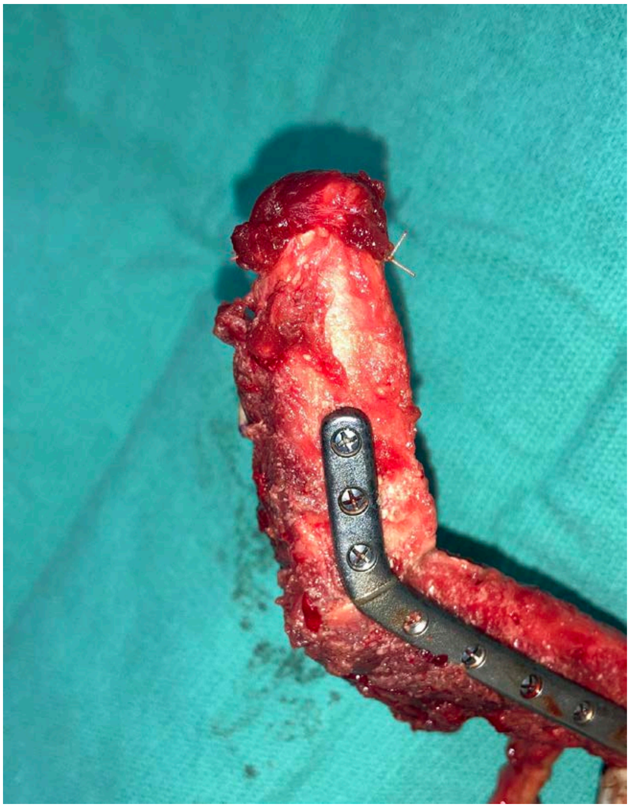

Fig. 3. Coverage of the articulating surface of the neo-condyle with redundant soft tissue from fibula pedicle.

ascending ramus. The approach for the mandibular resection was via an intraoral mandibular labial vestibule access only (Figs. 8–10).

4. *Case 4*—The patient is a 59-year-old man who presented with a remote history of an oropharyngeal SCCa, which was treated with chemoradiation who subsequently developed ORN of his left mandibular body and ascending ramus. He eventually developed chronic osteomyelitis of the irradiated mandible with progressive loss of osseous structure. The approach for the mandibular resection was via an intraoral mandibular labial vestibule access only (Figs. 11, 12).
5. *Case 5*—The patient is a 73-year-old man with a medical history significant for HIV and a right tonsil SCCa subsequently treated with chemoradiation who later developed severe trismus secondary to fibrosis associated with more than 7500 cGy of radiotherapy to the head/neck, with a maximal interincisal opening of approximately 2 mm, ORN, and a pathologic fracture of the mandible. Due to his significant trismus and radiation scarring, the approach to the mandibular resection was via a classic Risdon submandibular percutaneous incision (Figs. 13, 14).

RESULTS

The Duke University Medical Center Institutional Review Board approved this study. All treatment recipients were men, with a mean age of 62 years (range, 44–72 years). At the time of the mandibular resection, care was taken in all cases to dissect only the inferior head of the lateral pterygoid muscle, leaving the superior head of the lateral pterygoid attached to the temporomandibular disk. This technique maintained the disk as a biological barrier between the glenoid fossa and the neo-condyle of the fibula in an attempt to prevent the development of bony ankylosis. When performing the resection via an external approach, the medial pterygoid and masseter muscles were separated at the inferior border of the mandible before resection for reconstruction of the pterygomasseteric sling at closure. If an intraoral approach

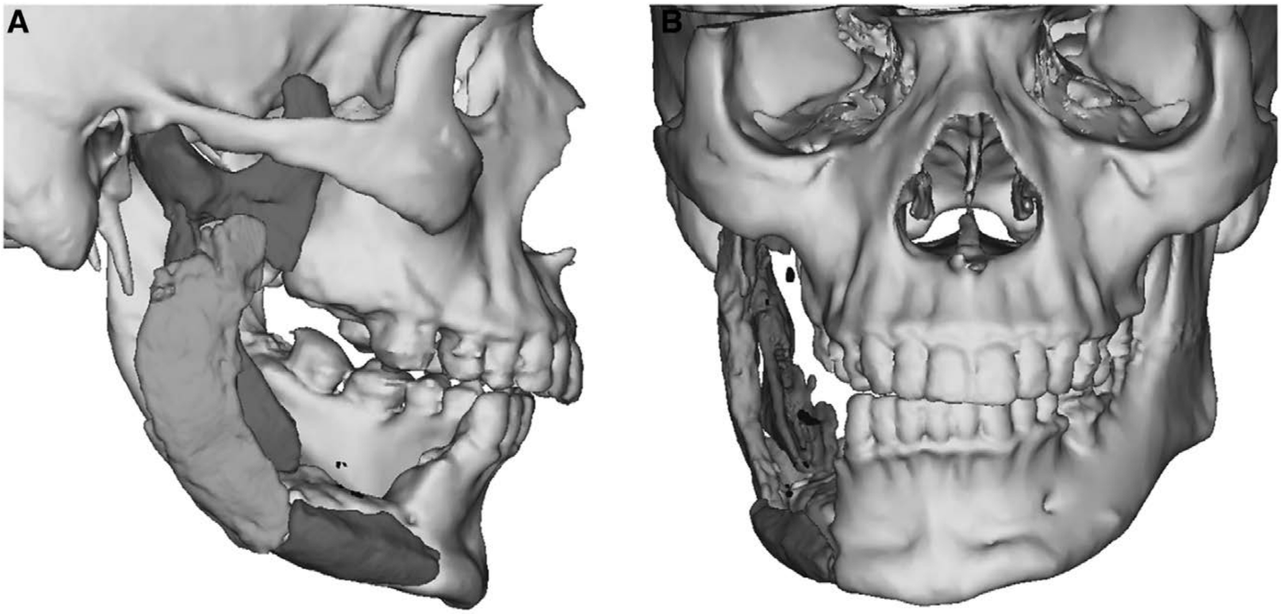

Fig. 4. Preoperative findings for case 1 indicating extent of ORN and pathologic fracture of the mandible. A, Lateral view. B, Frontal view.

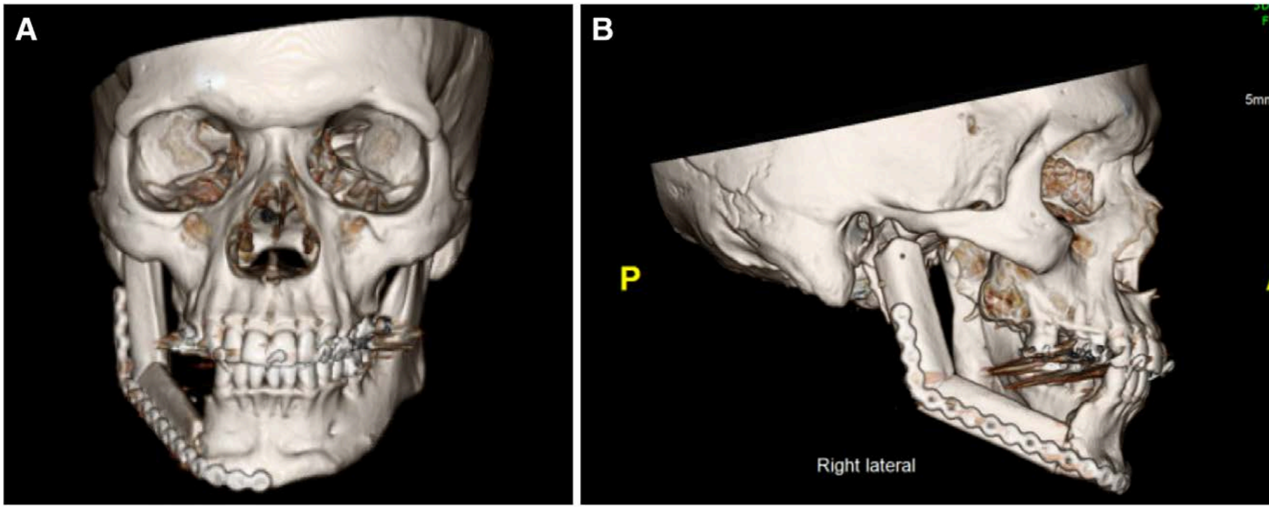

Fig. 5. Postsurgical views of mandibular reconstruction for case 1 with CPSSP neo-condyle. A, Frontal view. B, Lateral view.

was used, stripping of the pterygomasseteric sling at the inferior border of the mandible was performed with an Obwegeser J-stripper similar to a sagittal split osteotomy. All cases were performed with surgical implants from KLS Martin (Jacksonville, FL/Tuttlingen, Germany). The KLS Martin Individual Patient Solutions software program was utilized to create a neo-condyle for the resected side, which reproduced the vertical height of the native mandibular anatomy. All patients were maintained in intermaxillary fixation/restricted opening for 7–14 days and then immediately transitioned to both active and passive range of motion (ROM) exercises. Our protocol focuses on visual reinforcement of neurocognitive rehabilitation via observation of mandibular function in active ROM, specifically exercises such as observing themselves in a mirror while manually keeping their chin position midline on function. Passive ROM is reinforced with the use of different commercial devices, such as a TheraBite device (Atos Medical, Malmö, Sweden). Dietary recommendations were soft mechanical for 6 weeks with progression to a regular diet after that time. Case 1 used a patient-specific prebent 2.5 mm conventional mandibular reconstruction plate and custom fabricated polyamide cutting template for the neo-condyle fabrication. Cases 2–5 utilized patient-specific laser-sintered 2.5 mm mandibular reconstruction bars and polyamide neo-condyle cutting templates similar to case 1. No patients have been lost to follow-up, and the overall length of time for supplemental examinations since initial surgery has been 29.2 months (range, 6 –46 months). Four of the five patients have maximal interincisal openings more than 40 mm with no alternation in their native occlusal relationship. (**See table, Supplemental Digital Content 1**, which displays patient demographics, diagnosis, and treatment, http://links.lww.com/PRSGO/C135.) (**See table, Supplemental Digital Content 2**, which

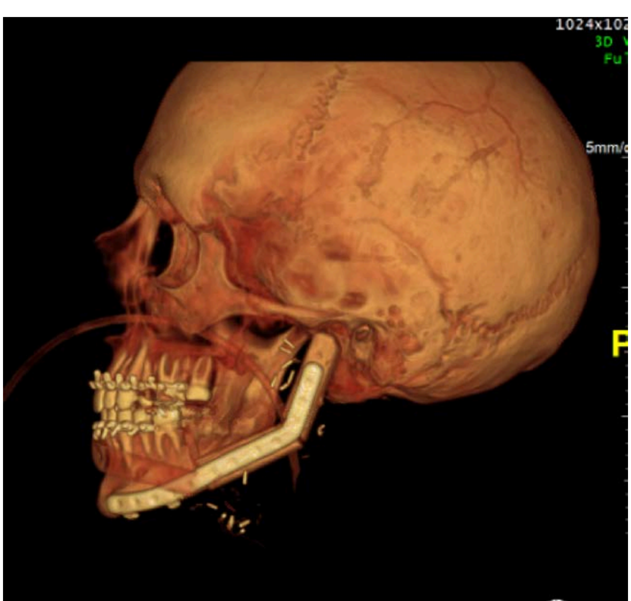

Fig. 6. Postsurgical views of mandibular reconstruction for case 2 with CPSSP neo-condyle.

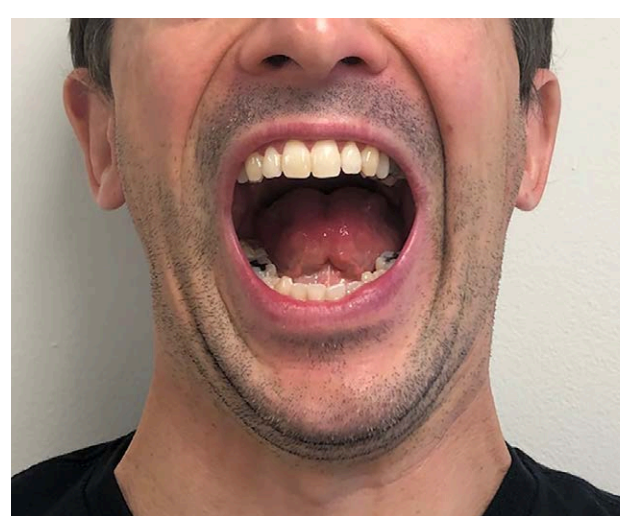

Fig. 7. Maximal interincisal opening postoperatively for case 2.

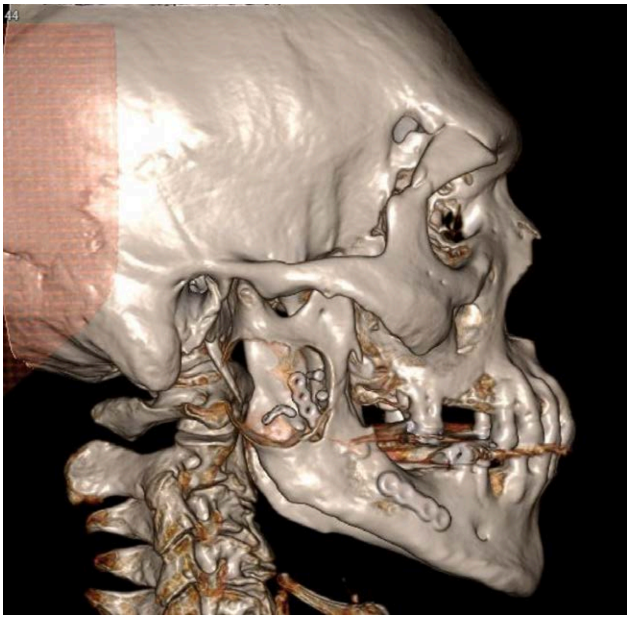

Fig. 8. Preoperative findings for case 3 indicating extent of pathological expansion of mandible and fractured surgical hardware.

displays patient follow-up and the mandibular opening, http://links.lww.com/PRSGO/C136.)

In case 5, our most recent reconstruction, the patient is currently undergoing intensive physical therapy for his mouth opening. His preoperative maximal interincisal opening was 2 mm secondary to soft tissue-induced radiation-induced contracture. At the time of this article preparation, it is 22 mm, with a stable and reproducible occlusal relationship. There have been no complications with the consolidation of the fibula osteocutaneous flap, neo-condyle construct, or tolerance of the reconstruction plates.

DISCUSSION

An accurate assessment of the number of hemimandibular resections performed annually is impossible to determine due to the variability associated with trauma, benign tumor, or oncologic treatment needs. However, a recent study confirmed that the number of alloplastic temporomandibular joint replacements fabricated by a single manufacturer was 1004 in 2014, which would indicate that the number of cases of this type worldwide is not insignificant.[16] As noted previously, the lifespan of alloplastic TMJ replacements is unknown, but the consensus is approximately 20 years, understanding it is influenced by patient activity choices,

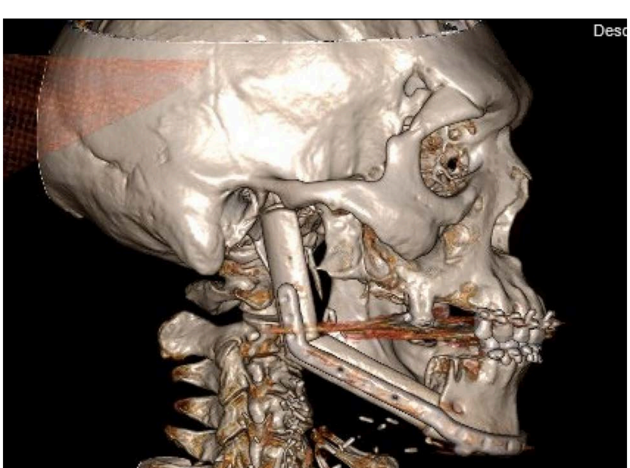

Fig. 9. Postsurgical view of mandibular reconstruction for case 3 with CPSSP neo-condyle.

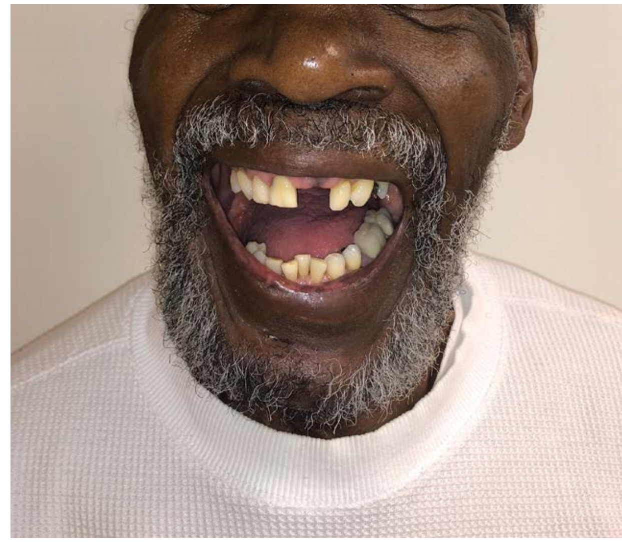

Fig. 10. Maximal interincisal opening postoperatively for case 3.

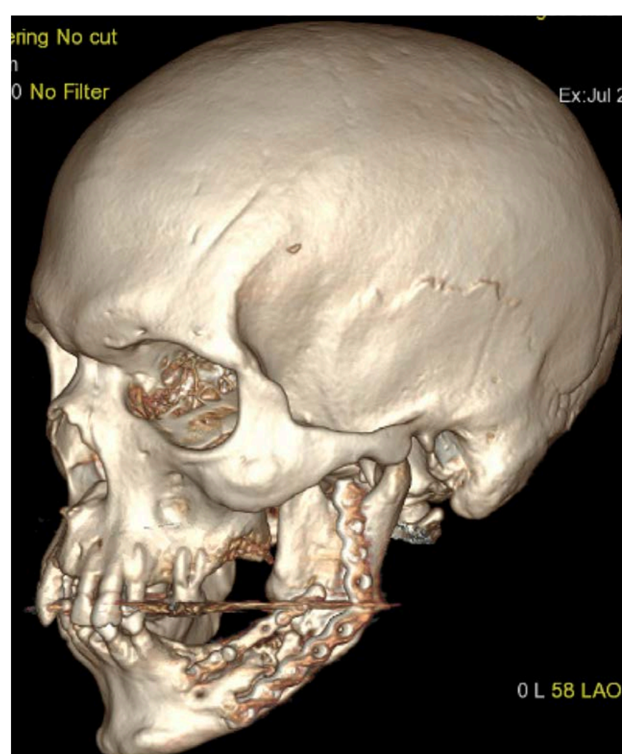

Fig. 11. Preoperative findings for case 4 indicating extent of ORN and suboptimal positioning of existing surgical hardware.

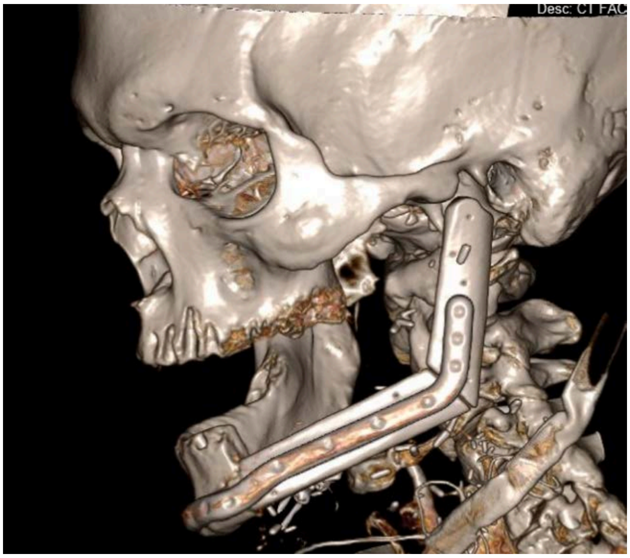

Fig. 12. Postsurgical view of mandibular reconstruction for case 4 with CPSSP neo-condyle.

body type, gender, and diet.[8,17,18] However, what is known is that alloplastic TMJ replacement, in conjunction with a hemimandibulectomy, will likely require an area of interface between the fibula reconstruction and the alloplastic materials. This interface is an additional site of potential complication or component failure. Reconstruction of the condylar head of the resected mandible with a fibula osteocutaneous flap has been well reported in the literature for many years, with various modifications noted to improve long-term success, negating the need for alloplastic materials in the temporomandibular joint region.[19–22] Recently, there have been reports of condylar reconstruction integrating CPSSP in surgical care.[23–26] A critical review of those publications notes several differences between our protocol

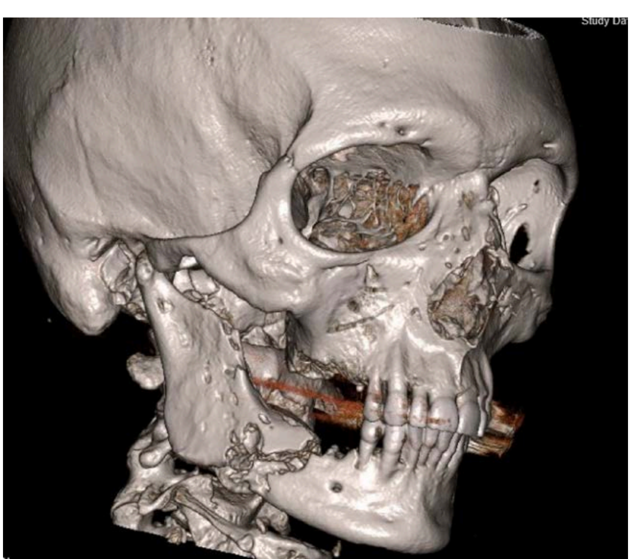

Fig. 13. Preoperative findings for case 5 indicating extent of ORN and pathologic fracture of the mandible.

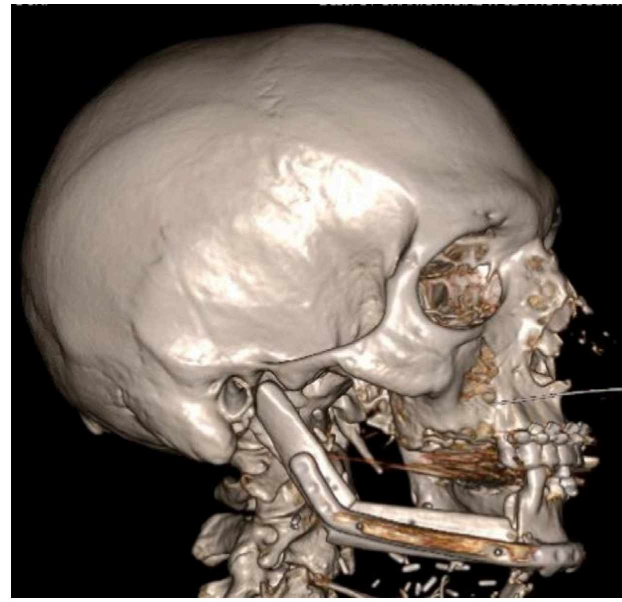

Fig. 14. Postsurgical view of mandibular reconstruction for case 5 with CPSSP neo-condyle.

and some recommendations from these reports. First, we strongly advocate maintaining the native temporomandibular disk as a biologic spacer that allows for the reduced potential for ankylosis, as reported in some case series, and functional remodeling of the neo-condyle within the articulating fossa.[20,26] Second, our neo-condyle is fabricated to the anatomic height of the existing condylar head before resection, which we feel helps preserve the posterior vertical dimension of occlusion and allows for functional and physiologic positioning of the condylar head within the articulating fossa. Our long-term follow-up mirrors the finding of Yu et al[25] that migration of the condylar head is a physiologic adaptation of the position of the neo-condyle to the articulating fossa. By accurately positioning the neo-condyle within the confines of the articulating fossa at the outset of reconstruction with CPSSP, migration and change in position are minimized. Third, using a custom cutting guide to create an articulating contour of the neo-condylar head facilitates the smooth and complete translation of the mandible, which results in superior maximal interincisal opening. Finally, custom fabrication of a low-profile, high-strength titanium mandibular reconstruction bar is paramount to success. Manufacturing the reconstruction bar via additive manufacturing processes, where titanium molecules are bonded under laser guidance to the osseous template, reduces postdeformational plate changes to fit anatomy creating a stronger implant with smaller size. In our experience, the low-profile plate affords increased soft tissue coverage and neovascularization to the fibula graft, which we feel reduces resorptive changes. Our belief is the added strength and increased soft tissue attachments additionally result in a lack of either subluxations or dislocations of the neo-condyle from the temporomandibular joint. Concerns with increased costs have likely resulted in some surgeons being hesitant to adopt CPSSP into their operative repertoire. Published reports indicate that the cost range for integration of this technology into mandibular reconstruction varies from $4000 to $12,000, which is consistent with our experience.[27–30] The variability in costs is determined by the specific materials requested, such as titanium versus polyamide cutting guides or laser-melded plates versus prebent conventional plates. In our estimation, the costs associated with these materials are easily recouped with the savings in operative time and the consistency of the results obtained. Research shows fixed OR costs are between $60 and $100 per minute, which does not include variable/hourly salary costs (anesthesia providers, OR nurses, and surgical technicians), nor the increased physical costs of anesthetic agents used in cases of longer duration.[31,32] Although true time savings are impossible to calculate with any degree of certainty, all three authors uniformly agree our efficiency is improved dramatically with CPSSP, well in excess of 90 minutes. With the highlighted points listed above, our protocol represents a new contribution to the literature related to the performance of mandibular reconstruction with CPSSP. Utilization of this technology allows the patient to have an autologous reconstruction option of their acquired craniomaxillofacial defect that offers similar, if not identical, benefits to the fabrication of a custom-fabricated alloplastic TMJ replacement in patients. If possible, preserving the temporomandibular disk serves as a biological spacer, minimizing resorption of the neo-condyle and preventing the development of bony ankylosis. Long-term follow-up of this treatment modality is necessary to confirm success, but our initial results seem promising.

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