

Case Report

Neocondylar Formation with Vascularized Fibular Free Flap: A Report of Three Rare Cases and Review of Literature

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Abstract: Background: Neocondylar formation is an uncommon finding that can result after the reconstruction of a vascularized free flap. Three case reports were presented in the current article. (1) A 64-year-old male presented with clear cell Odontogenic Carcinoma to the left mandible. (2) A 14-year-old male presented with an ameloblastoma to the right mandibular associated with tooth 48. (3) A 13-year-old female presented with an ameloblastoma to the right mandible. Methods and Results: All three cases required a surgical resection of the mandible involving the temporomandibular joint. Reconstruction was performed using a vascularized free flap, and Neocondylar formation was observed during the healing process in all three cases. Neocondylar formation after a vascularized free flap reconstruction can improve anatomical functions such as mastication and decrease post-operative complications. Knowledge of this finding can improve future surgical treatment planning and outcome. Conclusion: This report contributes to the existing literature by offering new insights into neo-condylar formation following mandibular reconstruction with vascularized free fibular flap, particularly in complex resective surgeries, and highlights its potential clinical implications.

Keywords: neocondylar formation; vascularized fibular free flap; temporomandibular joint



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1. Introduction

The temporomandibular joint (TMJ) is a complex anatomical region that plays a critical role in craniofacial function. The TMJ consists of an articular surface between the condyle of the mandible and the temporal glenoid fossa, connecting the mandible to the skull base. It is supported by a fibrocartilage disk and encased in a fibrous capsule. The position of the condyle is primarily maintained by the articular ligaments and the articular disc, while the lateral pterygoid muscle plays a more dynamic role in controlling condylar movement. The TMJ is essential for dynamic functions of the mandible, including chewing, phonation, and respiration. Additionally, it contributes significantly to maintaining a lower facial profile and facial symmetry through its influence on craniofacial growth [1–5].

Large benign or malignant tumors and other bone lesions such as osteonecrosis, osteomyelitis, vascular lesions, trauma, or severe TMJ ankylosis that invade bone involving the condyle require extensive ablative surgery. A large resection with wide resection margins for definitive treatment may also be considered. Resection of the mandible can result in a large defect that can involve the whole TMJ. The patient's life quality can be critically affected by this condition. TMJ disorders can cause the deterioration of facial asymmetry, retrusion of the mandible, airway compromise, difficult nutrition intake, poor oral hygiene, and detrimental psychological issues [3,6]. These consequences highlight the importance of addressing TMJ dysfunctions in clinical practice, as they can severely impact a patient's quality of life. Because of the complex anatomy and function of the TMJ, this can make reconstruction difficult. Achieving optimal functional and aesthetic results is a big challenge in oral and maxillofacial reconstructive surgery [3,7]. Different reconstructive options are available to reconstruct mandibular condyles, such as autologous reconstruction (vascularized free tissue transfer, non-vascularized free tissue transfer, distraction osteogenesis, ramus osteotomies) and non-autologous reconstruction (alloplastic TMJ prosthesis) and future advances (computer-aided design, 3D printing, biomimetic structures, and tissue engineering). Meanwhile, non-vascularized free tissue transfer includes costochondral, sternoclavicular, iliac crest, and calvarium graft. The vascularized free tissue transfer includes fibula, descending circumflex iliac artery free flap, and scapula [1,3,8–11]. Vascularized free tissue transfer has been imperative to oral and maxillofacial reconstructive surgery by solving the major postoperative problems and the functional impairment related to resection over the decades. Vascularized Fibular Free Flap (VFFF) was first termed by Taylor et al. [12] in 1975 and then by Hidalgo [13], who presented it for mandibular reconstruction in 1989. Now, it has been widely used by surgeons, and it has been the gold standard for TMJ reconstruction because of its advantages, including the large size of the graft, large vessel diameter, strength, tubular shape, and adaptability to the glenoid fossa. In addition, the VFFF has the capability to join skin, muscle, and bone structures. These features help promote neo-condylar formation and prevent ankylosis postoperatively [3,7,9,14–16]. Recent studies, such as the one by Pyne et al. [11], have demonstrated the successful functional and quality of life outcomes of mandibular reconstruction with vascularized free fibula flap (FFF) and alloplastic TMJ prosthesis, utilizing Surgical Design and Simulation (SDS), highlighting its potential in addressing both mandibular and TMJ defects effectively.

The neo-condylar formation is a critical biological process that occurs following mandibular reconstruction with a VFFF and is associated with the reshaping of the condyle in the temporomandibular joint. This phenomenon has the potential to enhance joint function, accelerate healing, and improve postoperative recovery by increasing joint mobility and reducing complications. In this study, three cases are presented where neo-condylar formation was observed during the healing process, highlighting its clinical significance. It is hypothesized that neo-condylar formation plays a key role in optimizing surgical outcomes, enabling the use of less invasive methods, and refining surgical treatment strategies for patients with temporomandibular joint disorders and jaw deformities.

1.1. Case Reports

1.1.1. Case-1

Clinical and radiological findings: 63-year-old male with a history of intermittent pain over the past year on the left side of his jaw (Table 1). The patient noticed over the past 5 weeks that the symptoms have gotten significantly worse, and he began noticing swelling. The patient then went to a general dentist, thinking he needed a root canal treatment. The patient was then referred to the Oral and Maxillofacial Surgery Department at the University of Mississippi Medical Center (UMMC) for further evaluation. The

patient medical and surgical history revealed hypertension, obstructive sleep apnea (OSA), cardiac catheterization, and mitral valve replacement. The patient has no known allergies. Cone-beam computed tomography (CBCT) was taken, which showed a soap-bubbled hypodense lesion with the well-defined, sclerotic, and scallop peripheral margin of the mandible extending from tooth 36 to mid-ramus. Tooth 36 also presented with significant root resorption (Figure 1).

Table 1. This table summarizes the clinical characteristics and postoperative outcomes of three cases.

Cases	Age	Gender	Diagnosis	Surgical Procedure	Outcomes	Neocondyle Formation	Follow-Up Duration
Case 1	64	Male	Clear cell odontogenic carcinoma	Mandibular resection with VFFF	Reduced pain, better mouth opening	Observed	35 months
Case 2	14	Male	Ameloblastoma	Mandibular resection with VFFF	Improved chewing and occlusion	Observed	30 months
Case 3	13	Female	Ameloblastoma	Mandibular resection with VFFF	Reduced pain, better mouth opening	Observed	10 months

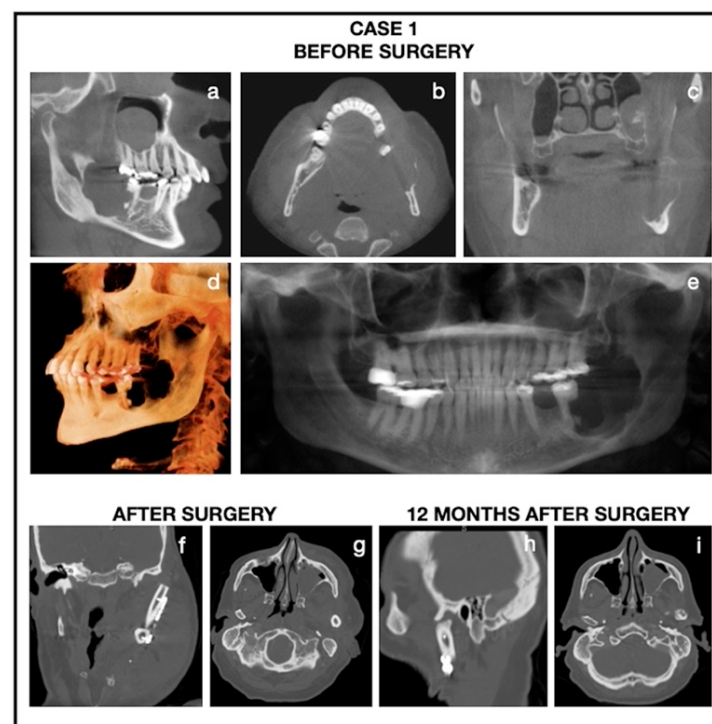


Figure 1. CBCT images of case 1. (a) Parasagittal, (b) Axial, and (c) Coronal slice of CBCT showed that a hypodense intraosseous lesion in the mandible has scallop and sclerotic peripheral margin and showed buccal-lingual cortical expansion and perforation in before surgery. (d) 3D reconstruction view of CBCT image before surgery. (e) CBCT reconstructed the panoramic image before surgery. (f) Coronal, (g) Axial, (h) Sagittal, and (i) Axial slices of CBCT image showed that continued bone growth was noted on subsequent follow-up CBCT imaging to the condylar surface 12 months after surgery.

Histopathological examination: An incisional biopsy of the left mandibular lesion was performed, and it revealed Clear Cell Odontogenic Carcinoma (CCOC). Congo Red stain was performed to rule out the clear cell variation of the calcifying epithelial onto-

genic tumor (CEOT). Mucicarmine and Alcian Blue stains were performed to eliminate an intraosseous mucoepidermoid carcinoma. It revealed multiple sections of a specimen composed of a malignant tumor arising from odontogenic epithelium with a supporting dense fibrous connective tissue stroma. The tumor infiltrates throughout the connective tissue in the form of strands, cords, and islands. The individual cells have hyperchromatic and irregular nuclei but are not mitotically active. The tumor cells have abundant clear and occasional eosinophilic cytoplasm. The connective tissue contains a myxoid stroma with chronic inflammatory cells and a few eosinophils. Where intact, the surface epithelium is composed of parakeratinized stratified squamous epithelium and appears to maintain a normal maturational pattern. In other areas, it is focally discontinuous with a prominent acute and chronic inflammatory infiltrate (Figure 2).

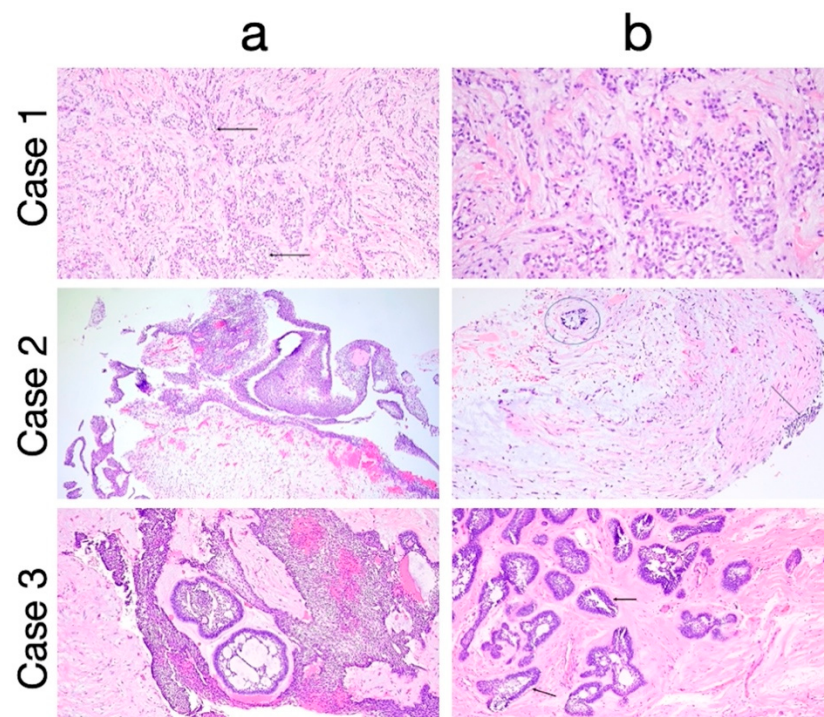


Figure 2. Histopathology images of the cases. Case 1. (a) Photomicrograph from the incisional biopsy sample demonstrating infiltrating odontogenic islands and cords with a clear-cell presence (arrows) (H&E $\times 10$ magnification). Case 1. (b) Photomicrograph at higher magnification showing clear cells within odontogenic islands and cords (H&E $\times 20$ magnification). Case 2. (a) Photomicrograph demonstrating fragmented hyperchromatic odontogenic epithelium resembling stellate reticulum (H&E $\times 4$ magnification). Case 2. (b) Numerous ameloblastic islands were observed within the connective tissue stroma (circle). Cystic lining (arrow) depicts basophilic columnar-cuboidal cells exhibiting focal reverse polarization (H&E $\times 10\times$ magnification). Case 3. (a) Photomicrograph from the incisional biopsy sample demonstrating anastomosing cords of odontogenic epithelium exhibiting columnar differentiation, reverse polarization, and central zones resembling stellate-like reticulum (H&E $\times 4$ magnification). Case 3. (b) Photomicrograph demonstrating islands of mural invasion within the connective tissue stroma highlighting reverse polarization with arrows (H&E $\times 10$ magnification).

Surgery procedure: The surgical procedure began with a tracheotomy to secure the airway. Following this, a left segmental mandible resection and left neck dissection were performed, along with a tracheotomy for airway management. Reconstruction was carried out using a fibula-free flap, with a recon bar placed to secure the flap. After harvesting the fibula, anastomosis to the neck vessels was performed. The oral surgery team then fitted the fibula into predrilled holes, securing it with titanium and bicortical screws in the

anterior mandible, while monocortical screws were used in the fibula. The soft tissue was sutured intraorally to the floor of the mouth and buccal mucosa using 3.0 Vicryl sutures. The procedure was concluded with appropriate closure and postoperative care.

Following up: The patient subsequently had radiation therapy post-operatively. Initial post-operative CT imaging taken 1 month after surgery showed a fibula with hardware intact extending to the left glenoid fossa; 7 months after surgery, the CT image showed bony growth to the medial surface of the superior portion of the fibula graft, replicating the condylar head. Continued bone growth was noted on subsequent follow-up CT imaging to the condylar surface 13, 21, and 29 months and panoramic radiographs 35 months after the surgery (Figures 1 and 3).

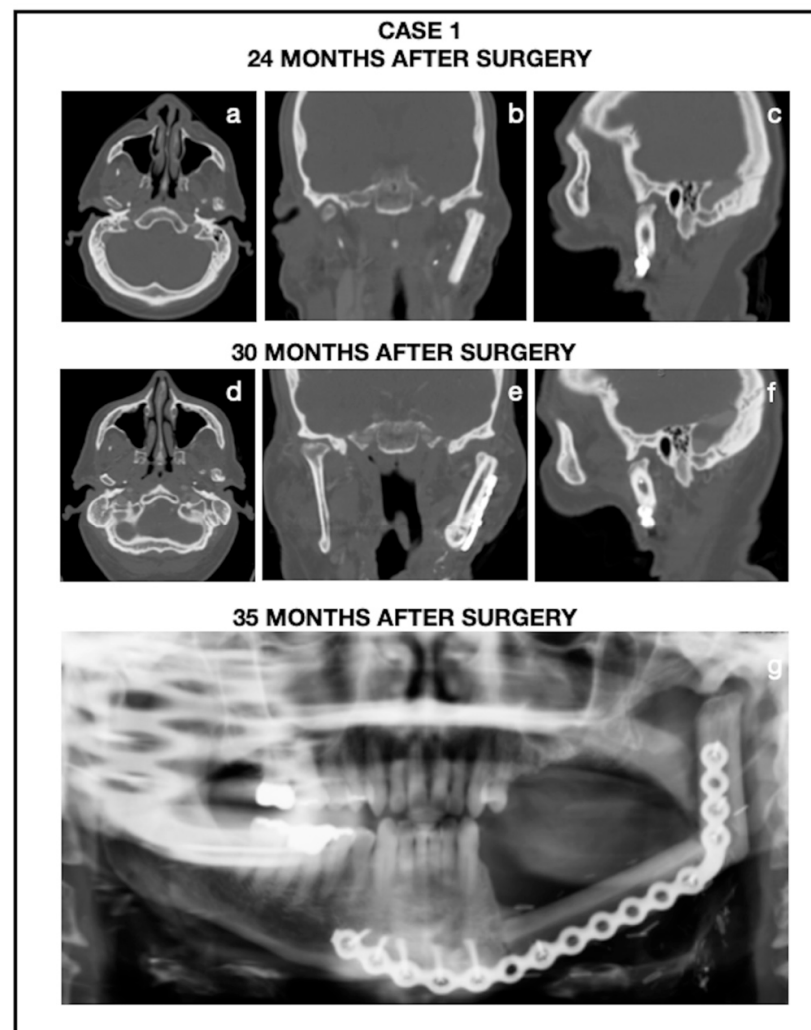


Figure 3. CBCT images of case 1. (a) Axial, (b) Coronal, and (c) Sagittal slice of CBCT image showed that continued bone growth was noted on subsequent follow-up CBCT imaging to the condylar surface 24 months after surgery. (d) Axial slice (e) Coronal and (f) Sagittal slice of CBCT image showed that continued bone growth was noted on subsequent follow-up CBCT imaging to the condylar surface 30 months after surgery. (g) Panoramic image 35 months after surgery.

1.1.2. Case-2

Clinical and radiological findings: A 14-year-old male with a right mandibular lesion associated with tooth 48 was found during a routine dental examination (Table 1). The patient denied a recent history of facial swelling, fevers, chills, nausea, emesis, dyspnea, dysphagia, or paresthesia. The patient was then referred to the Oral and Maxillofacial Surgery Department at UMMC for further evaluation. The patient medical and surgical

history revealed sinusitis, tonsillectomy, and cochlear implant placement. CBCT was taken, which showed a large right mandibular hypodense lesion with a well-defined, sclerotic peripheral margin that extends to the coronoid and body of the right ramus. Impacted tooth 48 was noted to be displaced inferiorly with no root formation. The lesion also involved impacted tooth 47, which had mature root formation (Figure 4).

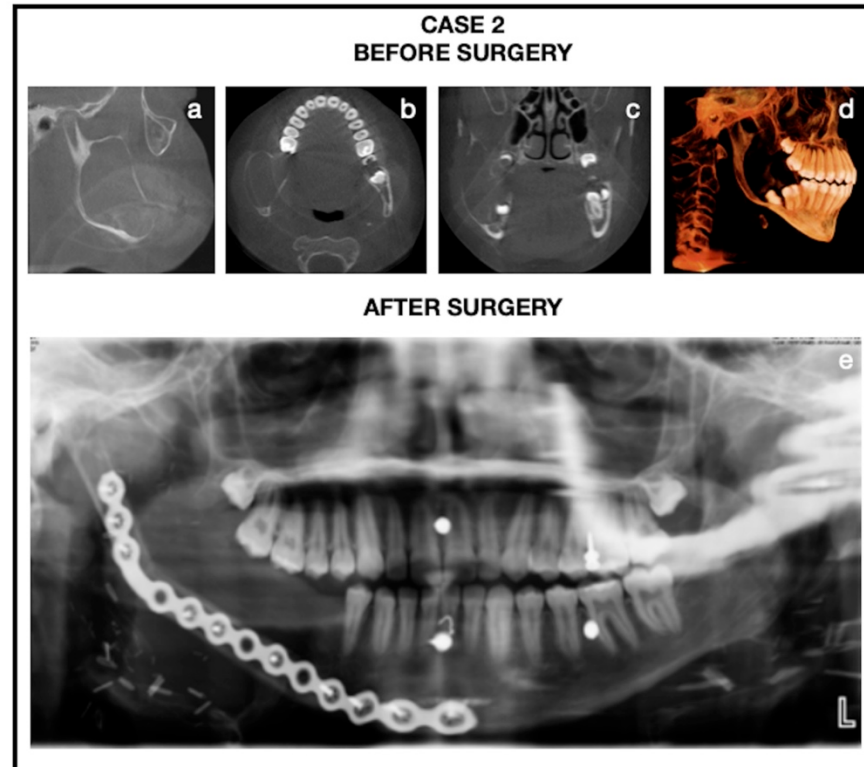


Figure 4. CBCT images of case 2. (a) Parasagittal (b) Axial (c) Coronal slice of CBCT image before surgery. (d) 3D reconstruction view of CBCT image before surgery. (e) Panoramic image after surgery.

Histopathological examination: Incisional biopsy and extraction of tooth 48 was performed. Microscopic examination reveals a benign neoplastic proliferation composed of hyperchromatic basophilic odontogenic epithelium distributed in a fibrous connective tissue stroma. The neoplasm is fragmented throughout the entire specimen and consists of numerous anastomosing cords and nests of odontogenic epithelium with occasional tumor islands extending into the connective tissue stroma. The majority of these cords are of the “plexiform pattern” consisting of sheets and cords lined by columnar-cuboidal ameloblast-like cells surrounding more loosely arranged epithelial cells, resembling stellate reticulum. The supporting stroma is loosely arranged with areas of prominent vasculature. Aggregates of viable bone are noted to be in close association with the ameloblastic epithelium. Areas of mural involvement are observed. A biopsy of the lesion revealed an ameloblastoma with a predominate plexiform pattern. The histopathologic and immunohistochemical profile was consistent with the diagnosis of Ameloblastoma (Figure 2).

Surgery procedure: The patient was then taken to the operation room for surgery for a right hemi-mandibulectomy, recon bar placement, right submandibular gland excision, right Inferior Alveolar Nerve (IAN) graft with conduit repair, and free fibula flap reconstruction. The extraction of tooth 48 and tracheostomy were performed in conjunction with a plastic surgeon who performed the right fibula free flap reconstruction on the right mandible. Next, the nerve grafting procedure was performed. The right facial vessels were isolated, and the right submandibular gland was then removed. At this point in time, the

procedure was turned over to the Plastics reconstructive team for the anastomosis and placement of the fibula flap.

Following up: Post-operative CT imaging taken after 10 days showed a fibula graft with hardware intact extending to the right glenoid fossa. Panoramic radiographs taken after 25 days and 70 days showed no acute changes to the condylar surface. The first bony growth to the new condylar head was noted on a CT scan taken after 3 years, which showed bony growth on the lateral surface of the condylar head (Figures 4 and 5).

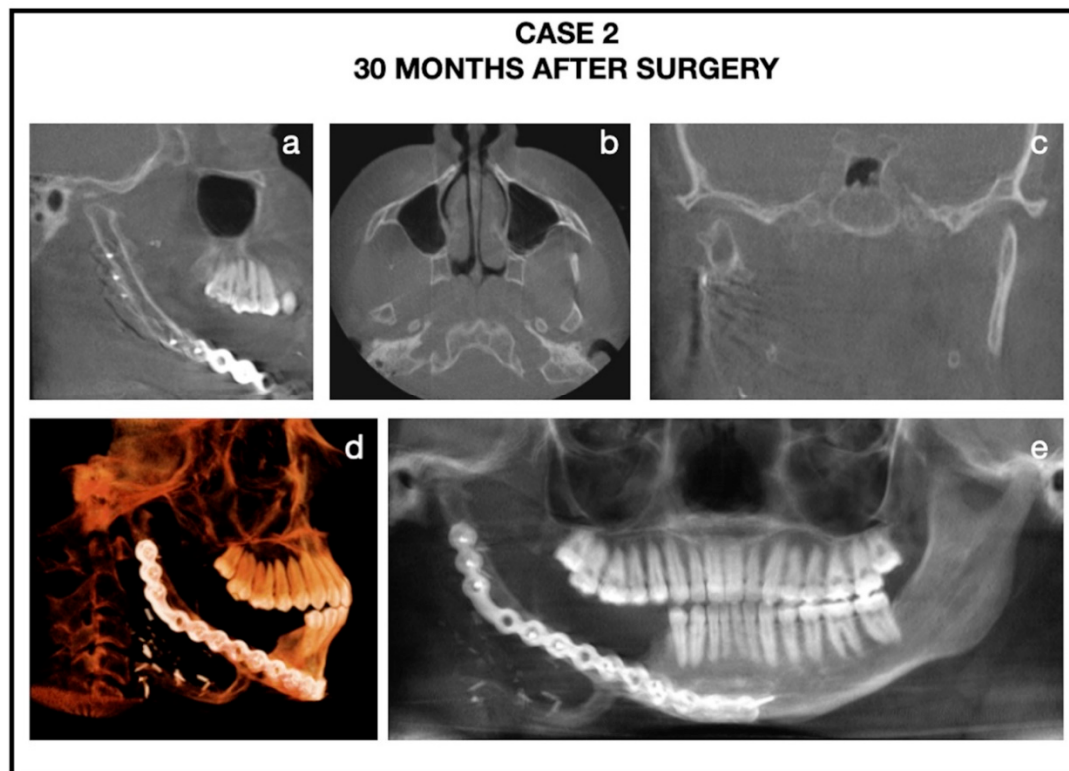


Figure 5. CBCT images of case 2. (a) Parasagittal, (b) Axial, (c) Coronal slice of CBCT image showed bony growth to the new condylar head 30 months after surgery. (d) 3D reconstruction view of CBCT image 30 months after surgery. (e) CBCT reconstructed the panoramic image 30 months after surgery.

1.1.3. Case-3

Clinical and radiological findings: A 13-year-old female with a history of the right mandibular lesion that was found 6 months ago by her dentist on a routine dental examination (Table 1). The patient denies facial swelling, numbness, and pain associated with radiolucent lesions. The patient was then referred to the Oral and Maxillofacial Surgery Department at the UMMC for further evaluation. The patient has no pertinent past medical and surgical history. The patient has no known allergies. A panoramic radiograph was taken, which showed a unilocular radiolucent lesion with the well-defined, sclerotic, and scallop peripheral margin to the right mandible involving the extending to ramus and the coronoid from the anterior ramus to the body of the mandible. The lesion was noted to be displacing tooth 48 inferiorly to the inferior border and just posterior to tooth 47 (Figure 6).

Histopathological examination: An incisional biopsy of the right mandibular lesion was performed, which revealed ameloblastoma with a predominant follicular pattern and mural invasion. Microscopic examination reveals a benign neoplastic proliferation composed of hyperchromatic basophilic odontogenic epithelium distributed in a fibrous connective tissue stroma and surfaced by superficial stratified squamous epithelium. The surface epithelium maintains a normal pattern of maturation. The neoplasm is fragmented

throughout the entire specimen and consists of numerous anastomosing cords of odontogenic epithelium exhibiting peripheral columnar differentiation with reverse polarization. These cords and islands have a follicular pattern consisting of central zones resembling the stellate reticulum with focal cystic degeneration. The supporting connective tissue stroma is dense and fibrous with areas of prominent vasculature. Mural invasion is observed in multiple foci (Figure 2).

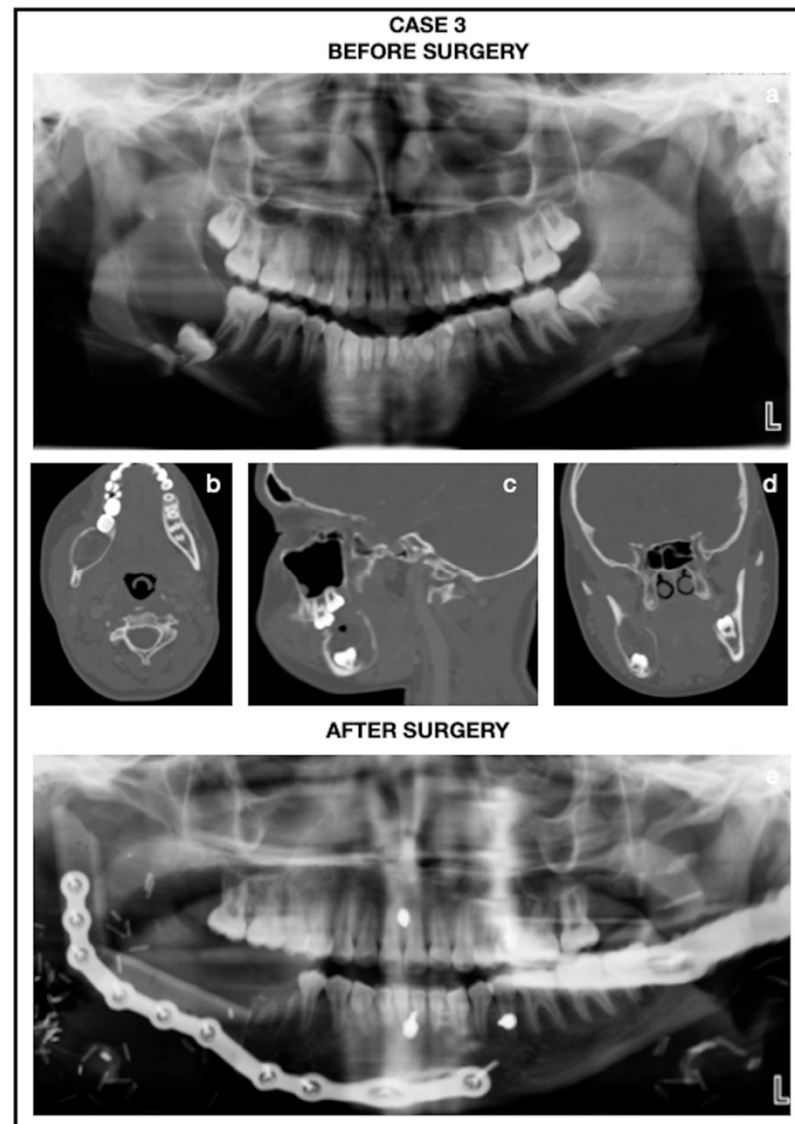


Figure 6. CBCT images of case 3. (a) Panoramic image before surgery. (b) Axial, (c) Parasagittal, and (d) Coronal slice of CBCT image before surgery. (e) Panoramic image after surgery.

Surgery procedure: The patient was then taken to the operation room for surgery for a right segmental mandibulectomy, tracheostomy, inferior alveolar nerve graft with axogen allograft, dental extractions, removal of the right submandibular gland, and reconstruction with fibula free flap by plastic surgery.

Following up: Post-operative panoramic radiograph showed a fibula graft with hardware intact extending to the right glenoid fossa. CT imaging revealed an appropriately healing fibular graft, but no new condylar bony growth was noted on imaging. Panoramic radiograph showed bony growth to the tip of the fibula graft with neo-condylar formation (Figures 6 and 7).

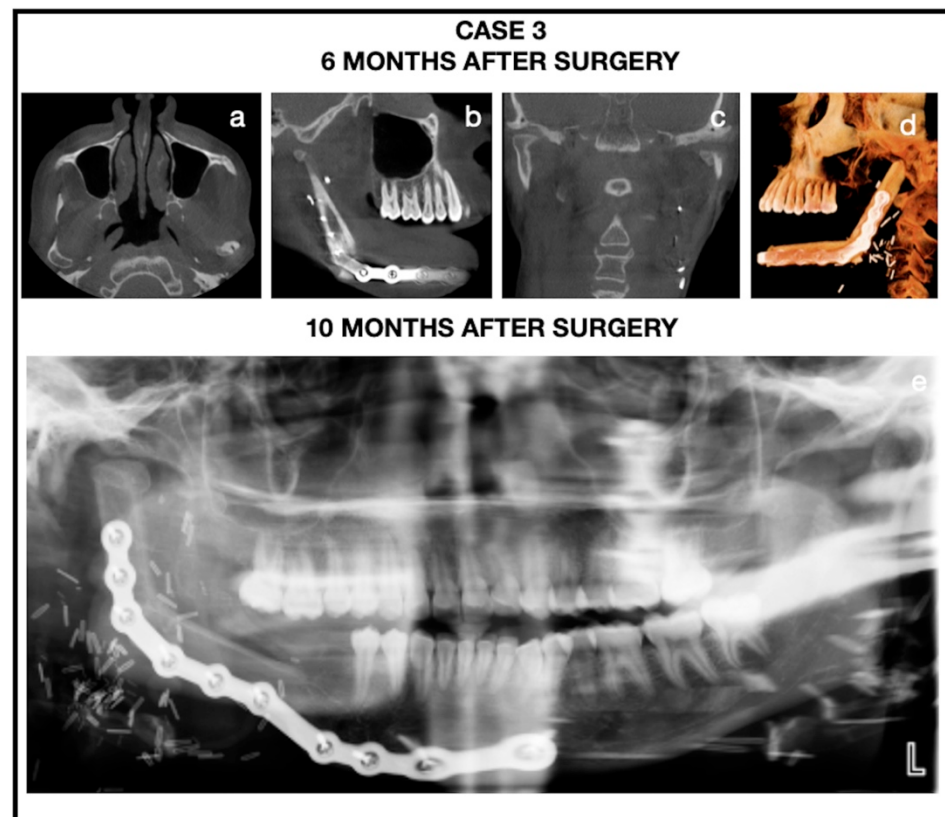


Figure 7. CBCT images of case 3. (a) Axial, (b) Parasagittal, and (c) Coronal slice of CBCT image 6 months after surgery. (d) 3D reconstruction view of CBCT image 6 months after surgery. (e) Panoramic image showed a fibula graft with hardware intact extending to the right glenoid fossa and bony growth to the tip of the fibula graft with neo-condylar formation 10 months after surgery.

2. Discussion

Large ablative and resective surgery can include partial or complete resection of the TMJ. It has a complex anatomy, so recreation of the TMJ is challenging. Large mandibular resections can result in disarticulation of the mandibular condyle from the temporal bone. Some major purposes for mandibular reconstruction include maintaining facial symmetry, rehabilitating occlusion, and preserving mouth opening. If reconstruction cannot be made sufficiently, facial abnormality and functional complications can occur related to TMJ structures. The VFFF has completely changed the treatment view by reducing major post-operative despair and functional problems related to the resection [7,9,10]. Since Hidalgo presented it for mandibular reconstruction, this procedure has been widely accepted for complex cases [13]. VFFF has many advantages for mandibular reconstruction termed in the literature. Some advantages of the VFFF are that it has a tubular anatomy, long bone length, and is suitable to the shape of the glenoid fossa. This allows many osteotomy sites because of the rich periosteal blood supply. Also, the rate of donor site morbidity is low, which can be combined successfully with skin, muscle, and bone components and easily osseointegrated with dental implants. In addition, a 2-team view can be applied for each case [3,9,10]. To reconstruct the TMJ, autogenic reconstruction with a costochondral graft has commonly been used. However, it has some problems, including growth changes and resorption [15]. The reconstruction plates with titanium condylar prosthesis were used to reconstruct condylar structure after large, ablative surgery, which has recently been seen in the literature. However, it has some drawbacks, which include short-term use, hardware failure, dehiscence, or intracranial migration [7]. In the literature, some authors supported the preservation of the native condyle during surgery by removing and

freely grafting it to the fibular construct. However, this opinion is not logical because the tumor has a recurrence risk, and the disease can show progression. This adds an extra procedure to the complex reconstruction period [9]. In the presented study, findings of three different cases, including Clear Cell Odontogenic Carcinoma and ameloblastoma, that were reconstructed with VFFF after the large resection were presented. In these cases, VFFF was used with subsequent follow-ups showing successful neo-condylar formation. All three cases demonstrated significant functional improvement, including increased mouth opening and a reduction in pain, highlighting the positive impact of the vascularized free fibula flap (VFFF) reconstruction on postoperative outcomes.

At this time, conventional freehand methods and virtual reality techniques like Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) have been used to flap harvesting in VFF. The CAD/CAM method has pros and cons versus the freehand method. VFFF planning with the CAD/CAM method is expensive, but it allows detailed pre-planning evaluations in mandibular reconstruction like bone contouring and positioning of the harvested flap. This allows the relationship between neocondyle and glenoid fossa to be evaluated preoperatively to produce a patient-specific reconstruction plate. This reduces operation time and post-operative complications, which improves post-op patient satisfaction. This technology presented to surgeons provides positive results in overcoming large mandibular defects [2,7,8]. A study by Tang et al. [17] evaluated the association between condylar position changes and functional results after condylar reconstruction by VFFF. In this study, 43 patients reconstructed by freehand method and 5 patients reconstructed by computer-assisted three-dimensional (3D) methods were reviewed retrospectively. Study results showed that the maximum mouth opening range was found as ≥ 35 mm in 76.7% of patients and < 35 mm in 23.3% of patients in the conventional group; 4.7% had pain during jaw movement, and 7% disliked treatment outcomes in clinical examination at 1 year after the surgery. All patients had a maximum mouth opening range exceeding 35 mm, none had pain, and all were satisfied with functional outcomes in the 3D method group [17]. CAD/CAM and conventional reconstruction methods of the mandibular condyle using a fibula-free flap were evaluated by Maurer et al. [8] clinically with imaging. They concluded that mandibular reconstruction by using VFFF reliably reconstructed TMJ function with no pain, adequate mouth opening, good chewing capability, and proper occlusion. The CAD/CAM methods provided a more accurate result, and they also reduced the operation time when compared to the conventional free-hand method [17]. In the present study, we used virtual surgical planning (CAD/CAM) for flap harvesting. After the first year of surgery, patients had no pain and a maximum mouth opening range exceeding 35 mm with satisfactory treatment outcomes.

A study conducted by Yu et al. [3] evaluated the regeneration of the neo condyle after a free fibular flap reconstruction of the mandibular condyle. Among the 26 patients, only 11 patients had neo-condylar regeneration at follow-up. Neocondylar regeneration was found to be statistically significantly related to patient age [3]. 3D imaging, such as CT scans, are powerful tools and is a reliable resource to help evaluate and assess Neocondylar formation, which can also aid in the direction of bone growth due to the traction of the lateral pterygoid muscle [6].

In a study by Park et al., neocondyle regeneration following mandibular reconstruction using a VFFF was evaluated [18]. The authors observed remodeling of the distal end of the free fibula in two patients following condylectomy or mandibulectomy, highlighting the potential for neocondyle formation in the absence of ankylosis, provided that the articular disc is preserved and proper occlusion is maintained. Similar to our findings, neocondylar formation was noted in all three of our cases after reconstruction with a VFFF, suggesting that this phenomenon can contribute to the functional restoration of

the TMJ. The preservation of the articular disc and the alignment of the condyle are critical in ensuring both anatomical and functional success. These observations further support the concept that neocondylar formation can play a significant role in improving mastication and minimizing postoperative complications following complex mandibular reconstructions [18].

Alternative reconstruction methods for mandibular and TMJ defects include autogenous grafts, alloplastic TMJ prostheses, and other flaps like the radial forearm free flap. Autogenous grafts, while biologically advantageous, can face issues with growth and resorption. Alloplastic prostheses offer predictable outcomes but may be more expensive with limited functionality. The radial forearm free flap is adaptable but can have more complexity in achieving optimal function. Compared to these, the VFFF is preferred for its ability to reconstruct both bone and soft tissue effectively, with good functional outcomes and low donor site morbidity, despite its higher cost and technical complexity [19].

Additionally, the surgical challenges of VFFF reconstruction differ between age groups. In elderly patients, issues such as decreased bone density, reduced vascularity, and slower healing may complicate recovery. Conversely, in adolescent patients, the ongoing growth and development of facial structures must be considered, as it may affect the long-term stability and function of the reconstruction. These age-specific factors necessitate tailored surgical approaches to optimize outcomes. However, the literature suggests that elderly patients may tolerate free fibula flap reconstruction as well as younger patients [20]. In light of these findings, it is important to consider the age factor when evaluating cases and planning surgeries.

One limitation of this study is the lack of MRI scans for the TMJ, which would have provided more detailed information on the newly formed condyle. While CT scans were utilized to assess the general condition of the lesions and condylar changes, MRI imaging could have offered a more comprehensive understanding of the soft tissue involvement and the dynamic changes in the condyle. This gap in imaging data should be considered when interpreting the findings of this study. Additionally, variability in follow-up imaging and long-term functional outcomes among the reported cases should be acknowledged, as this may impact the generalizability of the results.

In conclusion, the VFFF remains a reliable method for reconstructing mandibular defects, offering satisfactory functional results and promoting neo-condylar formation. This approach minimizes donor site complications and long-term sequelae. Additionally, the physiological processes driving neo-condyle formation, primarily through revascularization and bone remodeling at the TMJ site, are crucial in achieving functional recovery. The vascularized tissue from the flap enhances blood supply, supporting bone regeneration and contributing to improved TMJ function. Future directions should explore advanced imaging techniques to better understand neo-condylar formation and the role of patient-specific factors, such as age and pre-existing conditions, which may influence the outcomes of mandibular reconstruction.

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Institutional Review Board Statement: Ethical approval was not required for this study, as it is a case report. The University of Mississippi Medical Center exempts case report studies from the Institutional Review Board (IRB) process. All patient information was anonymized to ensure confidentiality, and this study adhered to ethical guidelines for case report publication.

Informed Consent Statement: Written informed consent was obtained from the patient for publication of this article and accompanying images.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare that there are no conflicts of interest related to this research or the publication of this paper. All authors have disclosed any potential financial, professional, or personal affiliations that could be perceived as influencing our research outcomes. This research was conducted in an unbiased manner, with the integrity of this study being the primary focus.

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