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A Novel Mandibular Reconstruction Technique Using 3D Printed Titanium Implant with Functional Joint Component: A Case Series

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Abstract

Reconstruction of mandibular defect resulting from wide resection with a functional joint is one of the most challenging tasks faced by oral & maxillofacial surgeons because of the unique anatomy, presence of vital structures and diversity of defects. Surgical defect of mandible impacts both facial esthetics and oral functions such as mastication, speech, deglutition. Reconstruction modalities including reconstruction plates, nonvascularized bone grafting, vascularized free flap and alloplastic prosthesis have been reported to achieve optimal functions and aesthetic results. In large surgical defects, microvascular free flap is gold standard of mandibular reconstruction. But autogenous graft has its disadvantages, e.g., donor site morbidity, extended operation time and potential graft failure due to tissue necrosis. Recent development in three- dimensional (3D) printing technology enabled fabrication of customized

3D-printed titanium implant which can be designed according to defect size and morphology, which allows for reduced operating time and also recovers original contour of the mandible and functional integrity.

We hereby report two cases of ameloblastoma of mandible which underwent wide resection. The surgical defect was reconstructed by a novel technique using 3D printed custom made Titanium implant along with Temporo-mandibular joint component, without postoperative deformity or graft rejection during follow-ups until 18 months.

Keywords: Mandibular Reconstruction, 3D Printing, Customized Implant, Reconstructive Surgery, TMJ Replacement.

Introduction

The mandible is a major component of the human facial skeleton comprising of an individual's identity and orofacial function. Mandibular bone defects resulting from wide resection or hemi mandibulectomy may result in serious deficit of orofacial form and function, aesthetic disturbances and psychologic problems to the patient. Hence reconstruction of such defect with a functional joint is among the most challenging tasks faced by oral and maxillofacial surgeons because of the unique anatomy, presence of vital structures and diversity of defects.

Various reconstruction modalities have achieved optimal functional and aesthetic results. In large surgical defects, microvascular free flap is gold standard of mandibular reconstruction[1]. However, inability to rehabilitate a functional Temporo-Mandibular Joint functions remains a major drawback.

Recent advances and development in three-dimensional (3D) printing technology enabled fabrication of customized implant prosthesis according to the defect size and morphology, which can be fitted accurately in the defective site without interference. Customized impalnts with alloplastic TMJ components reduces operating time and donor site morbidity and increases efficiency in the maintenance of proper facial contour and stable occlusion [2].

Here, we used 3D Printing Technology to fabricate a titanium implant with a functional Joint component based on a series of pre-operative 3D computed tomography images. This novel technique provided an anatomically customized reconstruction material which provides excellent functional and esthetic results.

Case presentation

Case 1: A 29 years old male patient presented with a chief complaint of pain and swelling over the left side of face since 3 months with a history of unhealed socket following surgical removal of left mandibular third molar 2 years back. Medical history was non-relevant. Examination revealed a diffuse swelling over the left mandibular ramus region which was hard in consistency, non-tender with no local rise of temperature(fig.1).

Fig.1: Preoperative clinical images of Case 1.

Radiographic examination revealed a huge well defined multilocular radiolucency starting from the distal surface of 37 up till the left condyle region involving whole of the left coronoid process and the left ramus of mandible (Fig.2). Histopathological diagnosis was plexiform ameloblastoma.

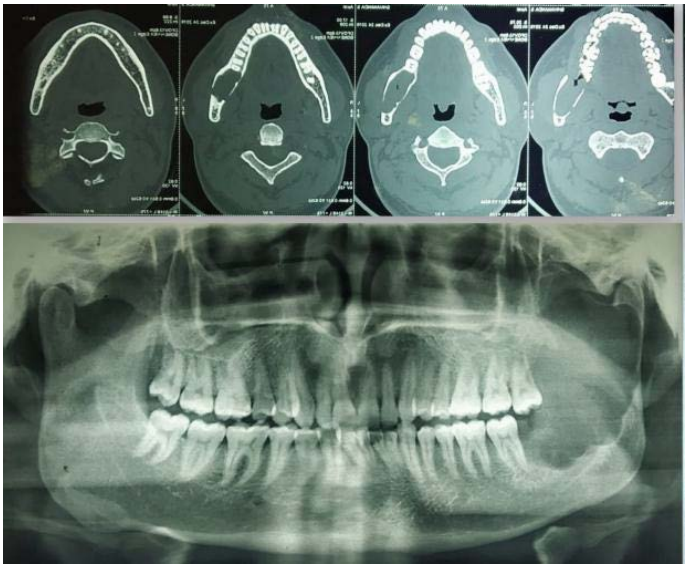

Fig.2: Preoperative radiological images of case 1.

Case 2: A 16 years old female patient presented with a chief complaint of swelling over the right side of face since 2 years with a history of enucleation of the lesion, extraction of 46 & 47 six months ago but the swelling did not subside. Medical history was non-relevant. Examination revealed a diffuse swelling over the right middle and lower third region of face which was hard in consistency, non-tender with no local rise of temperature (Fig.3).

Fig.3: Preoperative Clinical images of case 2.

Radiographic examination revealed well defined radiolucency starting from the distal surface of 45 upto the right condyle region involving whole of the right coronoid process and the left ramus of mandible leaving only a thin cortical plate left at the posterior border of ramus (Fig.4). Histopathological diagnosis was plexiform ameloblastoma.

Fig.4: Preoperative radiological images of case 2.

Treatment plan: Both cases were planned for resection and reconstruction under General Anesthesia.

Materials & methods:

Design Sequence: We've used two kinds of software to design the implant. A series of axial CT sections converted to 3D DICOM (Digital Imaging and Communications in Medicine) files and imported into MIMIC software (Materialise, Leuven, Belgium) (Fig.5) mirror imaging of the affected Side.

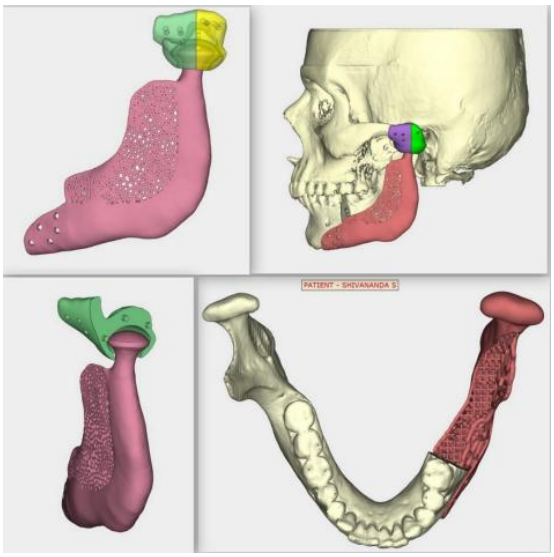

Fig.5: Design sequence.

The 3-matic software (Materialise) was used to build mesh arrays with geometries based on structural elements. The designed implant was manufactured using an A1 metal 3D printer (Arcam, Molndal, Sweden), with a biocompatibility material (Ti-6AL-4V-ELI medical grade powder) composed of titanium, aluminum, and vanadium.

Fabrication of Implant

The implant assembly consisted of three parts - 1. One Mandibular component which was analogous to the resected part of the mandible (Fig.6).

Fig.6: Mandibular Implant.

2. Two Glenoid Fossa component (made with titanium in case 1 and with medical grade polymer in case 2), which could be assembled together by key-keyway mechanism before placement of the implant assembly to provide the socket for the seating of the condylar head (Fig.7).

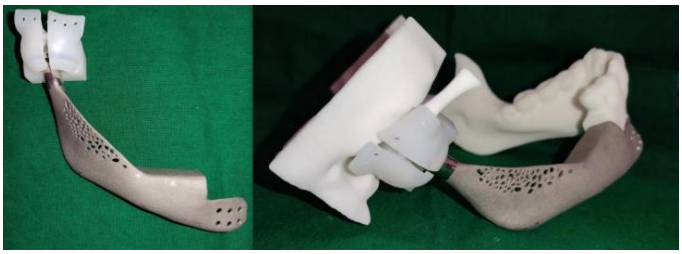

Fig.7: Assembled mandibular prosthesis with glenoid fossa component

Surgical Sequence: Incision was placed 1 cm below the lower border of mandible antero-posteriorly from the midline of the chin till the mastoid process through skin and subcutaneous tissue to the level of platysma (Fig.8).

Fig.8: Submandibular Incision.

Layered dissection was carried out to expose the pathological site. An additional pre-auricular incision was placed for disarticulation of the condyle and fixation of the fossa component (Fig. 9)

Fig.9: Preauricular Incision.

Vestibular incision was placed extending from premolar region to angle of mandible and all muscle attachments were stripped. Prefabricated cutting template was placed. Osteotomy marking was given (Fig.10). Resected fragment of affected side of mandible along with tumour mass was completely removed.

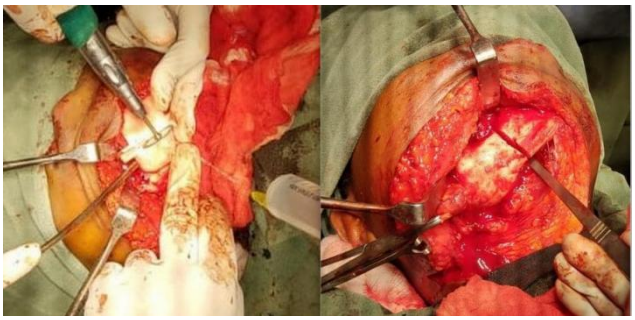

Fig.10: Installation of surgical guide and osteotomy.

All three components of the titanium implant i.e., two glenoid fossa component & one mandible component were assembled together and approximated using of long wire exiting through the pre-auricular incision (Fig.11).

Fig.11: Glenoid fossa components assembled together and approximated using of long wire exiting through the pre- auricular incision

Glenoid fossa component was first approximated to articular eminence following which complete bone to implant contact without soft tissue interference was ensured. Glenoid fossa component was fixed to posterior most part of zygomatic arch using 1.5×8 mm Titanium screws. Mandibular component fixed into position by using 2×8 mm Titanium screws at the base of the mandible (Fig.12). All the fixations were done with the help of surgically guided stents.

Fig.12: Fixation of Implant assembly.

Final position of the fixed implant assembly with functional joint component is shown in (Fig.13).

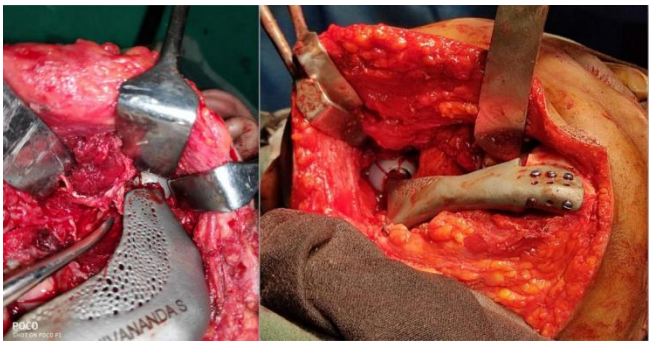

Fig.13: Final position of the fixed implant assembly with functional joint component.

After achieving hemostasis, Closure was done in layers. Negative pressure drainage device was placed in the submandibular region & secured into position by sutures.

Results

Both the cases underwent hemi mandibulectomy of the respective side and the mandibular surgical defect was reconstructed with 3D printed custom-made Titanium implant along with Temporo-mandibular joint component, without postoperative deformity or graft rejection during follow-ups, until 18 months for case 1 and 12 months for case 2.There was excellent acceptance to the implant, adequate mouth opening with all ranges of mandibular movements, acceptable occlusion, very little or no deviation on mouth opening and no signs of infections or rejection around the implant with very minimal scar formation. The clinical and radiological follow-up pictures of both the cases are shown in (Fig.14-17).

Fig.14: 18 months postoperative clinical pictures of case 1.

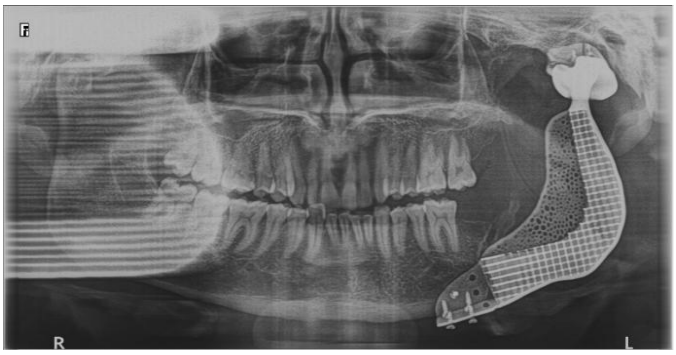

Fig.15: 18 months Postoperative radiological picture of Case 1.

Fig.16: 12 months postoperative clinical pictures of case.

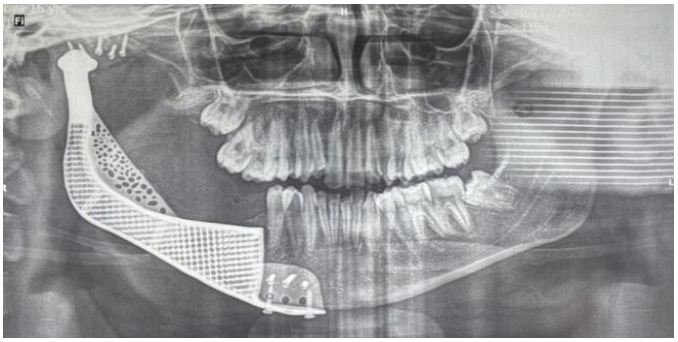

Fig.17: 12 months postoperative radiological picture of case 2.

Discussion

This clinical case series presents a novel mandible reconstruction technique after hemi mandibulectomy, using 3D-printed mirror imaged titanium implant with a functional Temporo-Mandibular Joint component to improve esthetics and mandibular function. Mandibulectomy is a procedure used to eradicate disease that involves the lower jaw or mandible. Its indications include, infectious etiologies (e.g., osteomyelitis, osteoradionecrosis), a benign (e.g., ameloblastoma) or malignant neoplastic process (e.g., invasive squamous cell carcinoma), bisphosphonate-related necrosis of the mandible or severe oral and maxillofacial trauma. It can either be full thickness (segmental), in which both cortices in addition to the upper and lower surfaces of the mandible are removed en bloc, or partial thickness, in which either the inner or outer cortex of the mandible is spared for maintenance of some mandibular continuity.

Cases where the excision of benign tumour of the mandible might precipitate to a pathological fracture, a full-thickness segmental mandibulectomy is the best option.

Both the cases, were diagnosed with plexiform ameloblastoma of mandible, i.e., a benign odontogenic tumour with an aggressive growth pattern. It has potential for malignant transformation especially in long

standing cases and in cases that are treated with incomplete enucleation. On the basis of the size of the lesion and extensive destruction of mandible and on absence of any co-morbidities or other contraindications, a treatment plan of hemi mandibulectomy under general anesthesia was undertaken.

Now the biggest challenge was, reconstruction of the surgical defect. In craniofacial reconstruction, restoration of appearance and function is the primary goal [3]. Considering both the patients were young and unmarried, restoration of the continuity with proper facial contour and most importantly re-establishment of proper orofacial function were must.

The Jewer classification classifies mandibular defects and reflects the complexity of the reconstructive problem. Central defects including both canines are designated ‘‘C’’, and lateral segments that excludes condyle are designated ‘‘L’’. When the condyle is resected together with the lateral mandible, the defect is designated ‘‘H’’, or hemi mandibular. Eight permutations of these capital letters—C, L, H, LC, HC, LCL, HCL and HH—are encountered for mandibular defects [4]. In our cases, after the resection we were left with a ‘H’ type mandibular defect.

Various modalities for reconstruction include reconstruction plates, nonvascularized bone grafting and vascularized free flaps. Irrespective of their high success rates, they have got their drawbacks.

Non-vascularized bone grafts include iliac bone graft, costochondral bone graft and bone graft substitutes e.g., autologous free bone grafts, irradiated or cryopreserved mandible, bone graft substitutes and xenogenic bone mineral and recombinant human bone morphogenetic protein (BMP). But these are done for small defects of mandible with insignificant loss of soft tissue with disappointing overall success rate. Other complications include wound dehiscence, material exposure, postoperative infection and resorption of graft or existing bone leading to partial or total loss of the graft.

Vascularized free flaps include fibular free flap, radial forearm free flap, scapula free flap, anterolateral thigh flap, pectoralis major myocutaneous flap, metatarsus osteocutaneous flap, iliac crest free flap, Clavipectoral Osteomyocutaneous Free Flap. Fibular free flap has been the gold standard for reconstruction of extensive mandibular defects apart from achieving optimal functional and aesthetic results. Their disadvantages includes, donor site morbidity, extended operation time, and potential graft failure due to tissue necrosis. For overcoming the above-mentioned disadvantages, the reconstruction modality chosen here was 3D printed custom-made titanium implant with a functional Temporo-Mandibular Joint Component. It’s recent application to medicine allows precise patient-specific preoperative design of implants based on a series of pre-operative three- dimensional (3D) computed tomography (CT) images. It’s advantages includes its ability to fabricate complex structures, its improved customization and its time efficiency. It has been used in various fields of facial reconstruction including the mandible, but the principal challenge faced by us was reconstruction of the Temporo- Mandibular Joint.

The success of TMJ prosthesis depends on the provision of a good imitation of the function of the joint, a close fit between the prosthesis and host bone, and a reasonable durability [5]. Theoretically, according to the development of the TMJ prosthesis, the functioning surfaces of TMJ prosthesis should have low wear, flow, and fatigue coeffcients [6]. Hence, two Glenoid Fossa component were included, which when assembled together can provide the socket for the seating of the condylar head and could be fixed to the posterior most

part of the zygomatic arch. This reconstruction assembly overcame the disadvantages of other modalities such as inadequate reproduction of proper lower facial contour and mandibular functions, donor site morbidity, prolonged operation time etc. and thus the patients were provided with an excellent reconstructive option without any signs of post-operative deformity or graft rejection. Similar attempts of temporomandibular joint reconstruction have been documented in a few orthognathic cases. To our knowledge, in pathological cases, reconstruction of such extensive mandibular defect with a functional joint component has not been attempted before and therefore is a novel surgical technique.

The only drawback of this technique was non-inclusion of dental implant fixtures to the implant for the prospect of future dental rehabilitation. Here an extensive part of the mandible was being reconstructed including the posterior tooth region which bears the highest amount of occlusal force and the fossa component was supported on the zygomatic arch region which provides a comparatively thinner bony buttress. Therefore, considering the risk- benefit ratio, a calculated surgical decision was taken not to include dental implant fixtures for maintenance of the integrity of the functional temporo-mandibular joint component.

Conclusion

This case series is a proof of the fact that the 3D-printed titanium implant with a functional joint component, would be a novel and one of the most suitable treatment modalities for mandible reconstruction considering all the aspect of esthetics and functions. Both the patients are extremely satisfied with the outcome and returned to their normal lifestyle without much obstacle. As surgeons, we were also very satisfied having provided the patients with a much better quality of life.

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