Latest Technology for Efficient Mandibular Reconstruction: A Case Series

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Abstract

Three-Dimensional (3D) printing has been increasingly adopted in maxillofacial surgeries to improve results and reduce operation time. This report presents the benefits of 3D-printing technology in extensive mandibular reconstruction surgery. Two extensive ameloblastoma cases were indicated for segmental mandibular resection. The diagnosis was reached after conducting clinical assessments, 3D-CT scan, and biopsy. Segmental mandibular resection was carried out under general anesthesia according to the set standard operating procedure. Following the resection, a prepared mandibular plate was adapted and fixated in the affected area, precisely mirroring the opposite mandibular segment without needing to bend the plate intraoperatively or choosing the appropriate plate size and/or type.

The plate was preoperatively bent according to the 3D- printing model, which saved around two hours of operation time. The operation time overall took around two hours, as opposed to the usual four to five hours. The utilization of 3D-printing greatly reduced operation time, enabled preoperative planning which improved the surgeon's confidence and prevent stress fatigue, and facilitated a more accurate adaptation. Using outsourced 3D-printing services allowed affordability.

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Introduction

Certain pathological conditions involving the maxillofacial region, including trauma or malignant neoplasm, could prompt the need of surgical management of affected areas, followed by a reconstructive surgery. Reconstruction of the maxillofacial region is a challenging task due to its complicated anatomy, especially considering the pressing need of both aesthetical and functional result in the facial region.[1–3] Conventionally, surgical planning of maxillofacial reconstruction is based on two-dimensional (2D) radiographic imaging, commonly panoramic or cephalometric view, clinical assessment, and dental cast of the patient. However, 2D analysis has an increased risk of error in identifying certain structures, superimposed images that might cause confusion, and projection errors.[4,5]

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Recent advances in digital technology have allowed the utilization of a three-dimensional (3D) technology to assist a more predictable and detailed examination as well as surgical application in the maxillofacial surgery field. Magnetic resonance imaging (MRI), computed tomography (CT), cone-beam computed tomography (CBCT), or computer-aided design (CAD) software could be employed to obtain 3D-image of related craniofacial structures, to be analyzed for diagnosis and treatment planning.[1,3] The obtained 3D-image could also be modified with a software, then printed three-dimensionally afterwards, to produce a customized contour model, surgical guides, or splints to later be used during the surgical reconstruction of the maxillofacial defect, allowing a quicker and more precise procedure.[3–7]

Specifically, in mandibular reconstruction, post-surgical defect could alter patients' appearance, confidence, and quality of life.[6,7] Facial asymmetry and sunken cheeks are one of the most common outcomes of unreconstructed mandibular defects. Improper reconstruction could lead to malocclusion and temporomandibular disorders.[2,3,7] This case

report discusses the procedure, challenges, and benefits of 3D-printing technology in mandibular reconstruction of two extensive ameloblastoma cases.

CASE REPORT

Case 1

A 17-year-old Deutero-Malay male patient was referred to Wangaya Regional Hospital with chief complaint of facial asymmetry due to a large swelling and a slow-growing intraoral mass in the right mandible region. The swelling started around five years ago and progressively increased in size. The patient denied history of pain or difficulty in breathing, only slight disturbance during mastication.

Figure 1. Pre-operative condition of the first patient with a large swelling on the right lower jaw.

Clinical examination showed a firm swelling on the right side of the face extending from the parotideomasseteric, buccal region, and inferior border of the mandible (Figure 1). A large mass was found, covering the buccal vestibule of the lower right region. Three- dimensional computed tomography imaging showed a large, well-defined multilocular lesion with a typical soap-bubble appearance associated with the destruction of surrounding bony structures (Figure 2). Histopathological biopsy confirmed the diagnosis of intraosseus ameloblastoma.

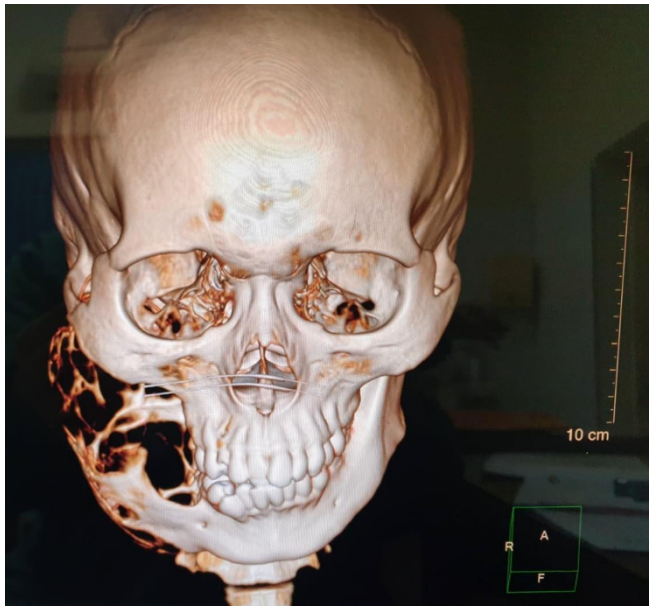

Figure 2. Computed tomography imaging showing a multilocular lesion with typical soap-bubble appearance.

Case 2

A 34-year-old Deutero-Malay female patient was referred to Wangaya Regional Hospital with chief complaint of facial asymmetry due to a massive swelling and an extensive intraoral mass in the right mandible region. The swelling started around eight years ago and progressively increased in size. The patient denied history of pain or difficulty in breathing, only slight disturbance during mastication.

Clinical examination showed a firm swelling on the right side of the face affecting the buccal region, extending beyond the border of the right mandible (Figure 3). A large mass was found, covering the whole posterior buccal vestibule up to the labial vestibule of the lower right region. An axial computed tomography imaging showed a massive, well-defined multilocular radiolucent lesion, which resorbed the alveolar bone and caused expansion of the right ramus with presence of bony erosion in the outer cortical plate (Figure 4). Facial asymmetry is evident. Histopathological biopsy confirmed the diagnosis of peripheral ameloblastoma.

Figure 3. Pre-operative condition of the second patient with a massive swelling on the right lower jaw.

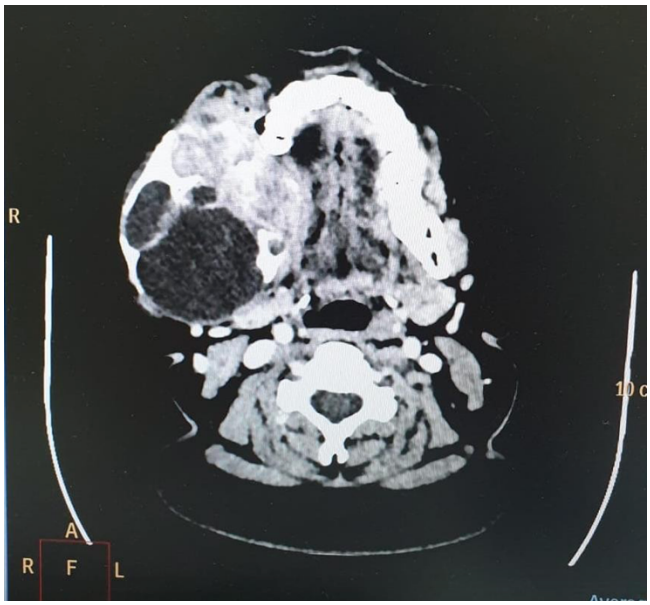

Figure 4. Axial computed tomography imaging showing a multilocular lesion with ramus expansion and destruction of surrounding bony structure.

Surgical management was planned to be undertaken with general anesthesia according to the set standard operating procedure. A segmental mandibular resection was performed in both patients via submandibular approach. The three-dimensional computed tomography imaging was sent to an outsourced manufacture (Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia) to be modified and 3D-printed. A customized contour model for each patient was produced by duplicating the opposite healthy mandibular region with a software (ultimaker cura software) at the manufacturer (Figure 5A, B).

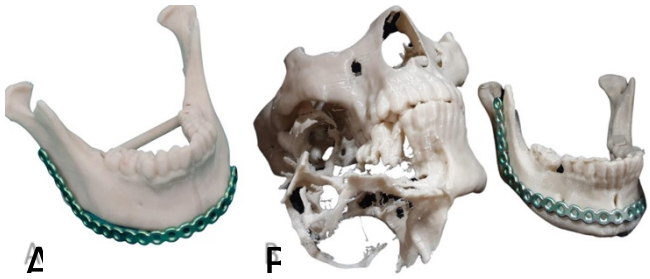

Figure 5. a) 3D-printed mandibular contour model of the first patient and adaptation of the pre-bent titanium plate, b) 3D-printed maxillofacial model of the second patient, composed of one original modeland one modified contour model.

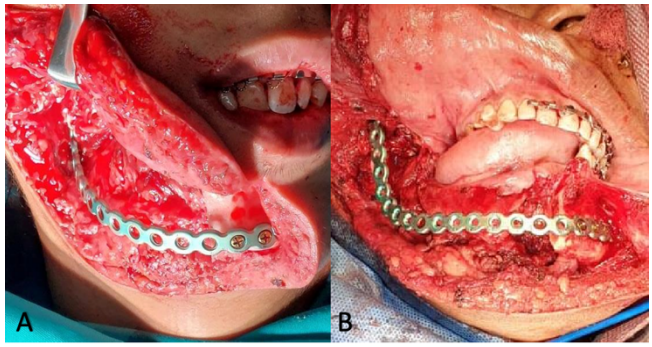

Figure 6. Prepared titanium plate was sterilized and then placed in the mandibular defect of the a) firstpatient and b) second patient with ease.

A titanium plate was used for reconstruction of the mandibular defect. The plate was preoperatively bent according to the 3D-printed model. The prepared plate was sterilized according to the standard procedures, then adapted and fixated into the mandibular defect, precisely mirroring the opposite healthy mandibular segment (Figure 6A,B). An intermaxillary fixation was carried out with arch bars. The operation time overall took around two hours.

Both patients experienced uneventful recovery with a stable healing progress. Both patients expressed satisfaction of the surgical result (Figure 7A, B). There were no signs of disease recurrence clinically not radiologically

throughout the one-month follow-up period. Both patients were referred to a prosthodontist to create dental prosthetics.

Figure 7. One-month post-operative follow-up, patients (a. b) exhibited stable recovery with decent wound closure and facial symmetry.

Discussion

Surgical management of maxillofacial tumors commonly leave a large defect on the facial structures of the patient. Reconstruction of said defect could be gruesome and complicated, especially when all reconstruction procedures have to be performed intraoperatively.[2,3,6–8] A 3D imaging (CT, CBCT, CAD/CAM) and 3D-printing technology could be utilized in effort to achieve a more straightforward and quick procedure. The rapid advances in 3D technology could facilitate a wider utilization in the medical field, including virtual surgical planning and fabrication of individualized models and devices via 3D-printing.[1,5,9]

Previous studies have found success in the utilization of 3D technology in orthognathic surgery cases, post-cancer removal jaw reconstruction, orbital surgeries, and even in cranial surgeries.[3,9,10] In this case, 3D technology was used to produce a contour model. Contour model is one of the most common types of 3D technology utilization in maxillofacial surgeries. Contour model allows the fabrication of a patient-specific model, precisely mimicking each individuals' unique anatomy, which then would be used for surgical planning or pre-bending titanium plates.[1–3,7] Pre-operative manipulation of the titanium plate allows easier handling and visualization, without obstruction from surrounding soft tissue or blood.[2,3,7,11] Contour model also allows operator to simply adapt the plate to the model with confident, without needing to worry whether the plate is properly positioned in relation to the opposite segment or not.[1,3,7,12] A prepared plate also saved surgery time and prevent stress fatigue because the operator could place the plate right away without needing to manipulate it intraoperatively.[1,4,6,12] Specifically in this case, the utilization of 3D-printed contour model facilitated a quicker surgery of only two hours period as opposed to the usual four to five hours. The use of 3D-printed contour model ensured that the plate is adapted in a symmetrical manner, which results in a more aesthetic outcome.[1–3,7,8] A previous study of a similar extensive ameloblastoma case also reported successful result, in which the authors stated that a 3D-printed contour model greatly reduced operation time, simplify the procedure, allowed a better visualization of the size and extend of the tumor, and helped achieving an aesthetic reconstruction.[2,8,10,12] The authors also stated that the 3D-printed contour model served as a surgical design simulation mold which allowed the operators to predict possible challenges that might arise during the actual procedure and plan a proper response.[2,8,12] It is also a great tool during pre-operative consultation with the patient and guardians, especially regarding the difficulty of the case and related treatment planning, which helped eliminate doubts, increase coordination and trust, and reduce the risk of post-operative disputes.[12] Other studies with similar case of mandibular reconstruction showed an overall good result and positive outcomes by performing virtual planning and 3D- printed model during the

procedure.[2,8,10,12]

Other 3D technology implementation in maxillofacial and orthognathic surgery includes; fabrication of surgical wafer or occlusal splint, osteotomy and repositioning surgical guides, and customized 3D-printed dental implants or plate.[3,7,13–16] In surgical wafers or occlusal splint, a 3D design is virtually created with a CAD/CAM technology to stimulate the final postoperative position of the related bony structure and occlusion, before the procedure is carried out, instead of the conventional way where the positioning is done during the surgery. This method has shown to have a higher accuracy, reliability, consistency, control, and efficiency in comparison to the conventional way.[3,4,6,7,15] As surgical guides, a 3D-printed individualized template of the negative space around related bony structure is made. This patient-specific template is useful in making sure that the procedure (*e.g.,* osteotomy), is positioned exactly as the established virtual planning. It is also useful in guiding operators during drilling or cutting procedures. This template allowed a precise and efficient handling, reduced operation time, and give aesthetic results.[1,3,7,13] Recently, 3D technology has also been utilized to create patient-specific biomedical dental implant or plate. A Ti6AlV4 pre-alloy powder could be utilized via layer-by-layer technique to produce a biocompatible, light, and corrosion-resistance dental implant or plate. A custom produced implant or plate enable a more precise placement and fixation.[3,7,13,14,16] Previous study has shown successful result with good strength and stability with 3D-printed plate in a Le Fort 1 osteotomy case.[3,7]

The main drawback of utilization of 3D technology in maxillofacial surgery is presumably cost and accessibility.[6] Patient usually have to be referred to a larger hospital to gain access for a 3D imaging procedure (CT, CBCT, CAD/CAM). Hospitals or medical center with an in-house 3D-printing services are even more limited.[5,6] However, specifically in regards of the 3D-printing services, it is possible to access the service via an outsourced manufacturer.[4,7] Operators could simply send the 3D images obtained from CT scan or CBCT or CAD/CAM in a digital file to the manufacturer, and then request the images to be 3D- printed. The produced 3D-printed models would then be sent via standard expedition and should arrive in 1-5 business days depending on the types of chosen logistic service. Outsourcing 3D-printing services allows operator to access this technology without the concern of expensive instruments needed.[1,3,5,7,16] In this case, the 3D-printed contour models were relatively affordable, costing IDR500.000,00 (around US$ 33.84) for one modified mandible model and one original maxillofacial model. Other authors have also used this trick to reduce unit cost and increase accessibility in regards of 3D-printing technology.[1,3–5,7,11,16,17]

Conclusions

3D technology is a significant asset with a vast potential to be incorporated in the maxillofacial and reconstruction surgery field. Proper utilization of 3D technology printing greatly reduced operation time, enabled preoperative planning which improved the surgeon's confidence and prevent stress fatigue, and facilitated a more accurate adaptation. Outsourcing 3D-printing services is one trick to ease cost and encourage accessibility.

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Declaration of Interest

The authors report no conflict of interest.

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