Mandibular Repositioning Appliance Following Resection Crossing the Midline- A3D Printed Guide

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Abstract:

Additive Manufacturing (AM) is one of the latest manufacturing processes which has evolved dramatically over the past three decades. The benefits of AM havesteadily stepped in to almost all modernindustries. The medical and dental industries may have benefitted the most in this regard. In the medical industry, every complex surgery has unique requirements in planning or execution, where it needs customized surgical guides or tools. In patients with mandibular tumors where a surgical resection is performed crossing the midline, currently there is no guide or tool available for repositioning the mandible to the patient's original anatomy. To overcome this, an attempt has been made to develop a customized repositioning appliance, which can be used for pre surgical planning and the same can be transferred to the patient during surgery. The repositioning appliance is developed using the patient's CT data which is then processed with the use of medical translation software. The final patient specific repositioning appliance is fabricated using AM technology. This guide has been used on the models of the jaws requiring resection to check their efficacy and the condylar repositioning has been seen to be close to the pre-surgical position.This appliance is useful for pre-surgicalplanning, pre-bending and adaptation of the reconstruction plate to the mandible and also to reposition the condyles to their original positions after the resection.

Keywords: Additive Manufacturing(AM), Mandibular Resection, Reposition Appliance, Complex surgery.

1. Introduction:

Technological advances in the field of medicine have revolutionized the diagnosis and treatment procedures in many ways. Use of CT scans, MRI and other advanced imaging modalities has brought about improved accuracy of diagnosis of the extent of lesions. The combination of CT scans with slicing software has made 3D printing a reality for today's surgical specialties. Additive manufacturing not only helps in diagnosis and treatment planning but also helps as an aid to teaching aspiring surgeons and educating patients about the outcome of the surgery. It also helps in virtual planning, mock surgeries and pre-adaptation of plates in maxillofacial surgery as well as reducing the intraoperative time. Another important application is the fabrication of surgical guides for orthognathic surgery and tumor resection which help in transferring the mock surgery to the actual surgical field improving accuracy and efficiency.

In maxillofacial surgery, one of the most challenging problems is the reconstruction of the anterior mandible. A defect in the anterior mandible region causes facial asymmetry, aesthetic disharmony, compromise in mastication and loss of tooth[1]. Reconstruction should focus on the anterior contour and repositioning of the temporomandibular joint (TMJ) into its original position so that the patient can maintain the same occlusion. In this article, the authors describe the concept of two customized 3D printed appliances which will help in repositioning into the pre-surgical position allowing aesthetic and functional reconstruction of the mandible.

Additive manufacturing(AM) has reduced human error in surgery by enabling meticulous virtual planning, mock surgery and pre-adaptation of reconstruction plates. The use of this technology in maxillofacial surgery has changed the conventional ways of approaching a surgical procedure. The anterior part of the mandible provides the shape and curvature of the lower third of the face. It provides attachment to the genioglossus muscle which is an important muscle of the tongue and to the geniohyoid muscle. It also provides attachment to the anterior belly of the digastric muscle.

Cancers of the oral cavity constitute the most common cancer group affecting the population of India. Use of tobacco in the chewable form causes most of the gingivobuccal sulcus carcinomas. Once the tumor invades the jaw bone, it will require resection of the bone along with the surrounding soft tissue. Large cysts and tumors invading the mandible may also warrant the resection of that segment of the jaw. Resection of the jaw especially the mandible causes a

profound impact on the quality of life of the individual and family[2]. This is because the mandible plays a significant role in supporting the tongue indirectly protecting the airway. It gives support to the lower dentition and maintaining the articulation, mastication and occlusion of the teeth.

The mandible is a parabola shaped single bone with the condyles on both sides constituting the joints to the cranial base. Resection of any part of the mandible causes a collapse of the bone medially due to the pull of the muscles attached on the lingual side. This disturbs the condylar position creating a disharmony in the muscle pull and movement of the jaw. Even a slight change in condylar position tends also to significantly change the occlusion. Resections of the anterior mandible or hemimandible crossing the midline poses a challenging surgery to the maxillofacial surgeon. Detachment of the genioglossus muscle causes the tongue to fall back creating respiratory distress in the supine position as shown in the Figure 1 below.

Figure 1 (a) Muscles attached on the inner side of the mandible (b)Muscles attached on the inner side of Mandible causing condylar displacement(in the Figure red color represents muscle and white color represents bone.)

1.1 GeneralProcedure for medical AM

Patient's data from CT scan is the basis for AM medical model creation. Using the DICOM data's best restoration parameters, the scanned CT data is recreated. Software's like MIMICS, 3Matic and 3D Doctor are used to process the DICOM data. Three Dimensional CAD data of patient anatomy is obtained using these software's. Medical software's provides flexibility to manipulate the acquired CT data and converts to .stl file format. This .stl file is used to fabricate the AM medical model. The major steps involved in medical AM model as shown in the Figure 2 below.

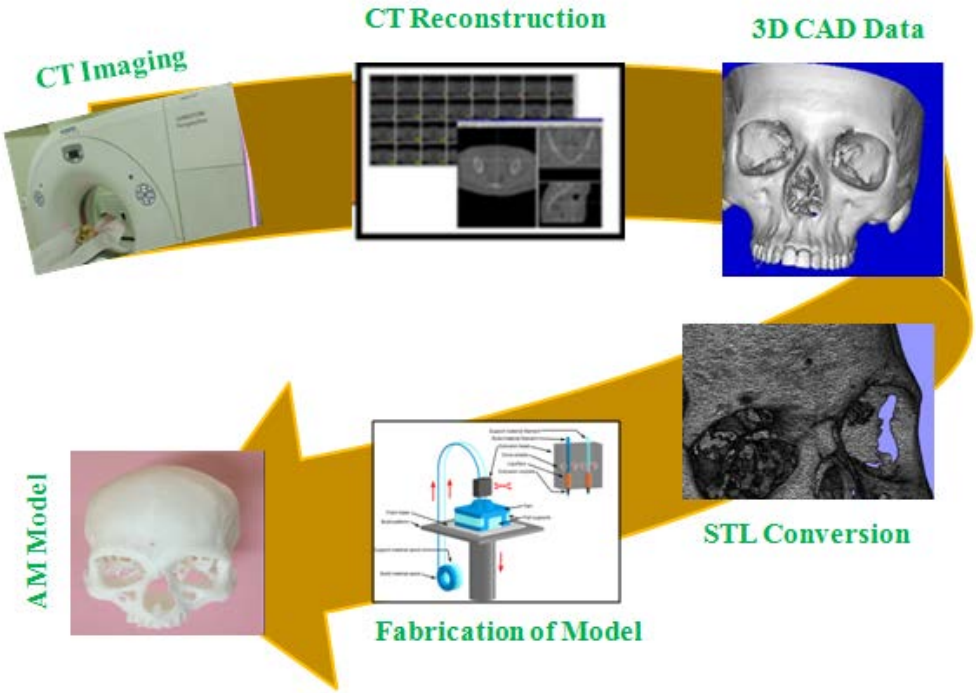


Figure 2: General procedure for Medical AM model

2. Materials and methods:

In the current work, two tumor cases were selected to design the condyle repositioningguides. For each case two versions of the guides are designed. The design and uses of each of these guides is described below.

2.1. Case Studies:

The DICOM images for the case studies were procured from the Navodaya Dental college and hospital Raichur, Karnataka, India. Both the cases selected for this study were anterior mandible tumors crossing the midline. In the first case, the tumor is involving more than 80% of the jaw as shown in Figure 3a below. In the second case, the tumor of the anterior mandible is involving more than 40% of the jaw as shown in Figure3b below. Resection of the jaw becomes the treatment of choice in these cases.

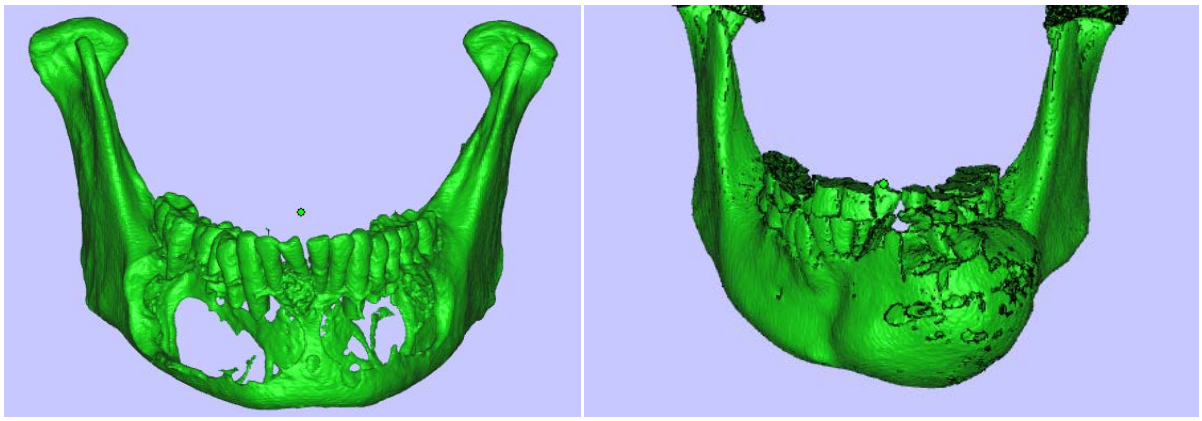


Figure 3(a). Mandible with 80 percent tumor(case study1). (b). Mandible with 40 percent tumor(case study2).

Since in case 1 all the teeth are removed with the tumor, guidance for the occlusion, which comes with adequate repositioning of the condyle, becomes a challenging task.

2.2. Design of Repositioning Guides:

The DICOM data is imported into the Mimics (Materialise, Belgium)medical processing software to create the 3D CAD data of the patient's bony anatomy. This anatomy is used to design the repositioning guides. The objective of thisguide is that it has to perfectly adapt to the patient'sanatomy. This ensures maintaining the jaw position and condylar position after resection. The model is also used to pre bend and adapt the reconstruction plate. To achieve the above, the guide is designed in two versions. The first has provision to accommodate the reconstruction plate and maintain the original condyle position and the second design with minimal surgical exposure to maintain the original condyle position.

2.3 Guide design 1:

The guide design has 3 main features. The 2 C-shaped vertical limbs on either side adapt perfectly to the buccal contour slightly extending on to the lower border. This vertical limb was designed to accommodate the reconstruction plate which is to be fixed after the resection. A horizontal limb which connects both the vertical limbs was also designed. This limb extended along the lower border of the resection area of the mandible. This limb is very rigid and helps in maintaining the contour. It also forms a guide for positioning of the pre-adapted reconstruction plate. The plate will be adapted to follow the contour of the horizontal limb. The slot on the vertical limb on both sides provides adequate space for placing a reconstruction plate with at least 3 screws bilaterally as shown in Figure 4 below.

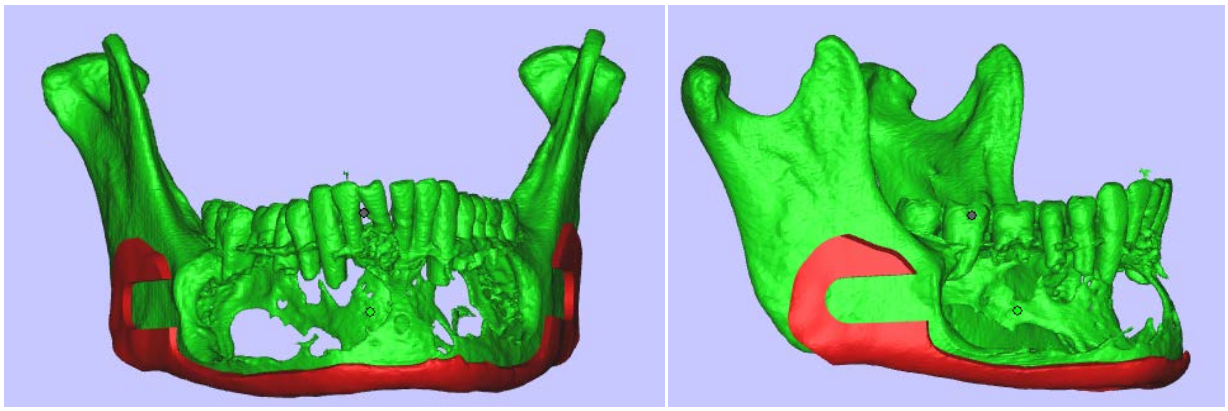


Figure4.3D CAD Mandible with repositioning Guide design one with provision for holding surgical plate.

2.4. Guide design 2:

In some circumstances the guide 1 discussed earlier may be too bulky. This guide is generally only possible when the soft tissue resection around the tumor is not required. In these cases a slight modification of the guide can be used. This also has 2 rigid vertical arms perfectly adapted to the buccal cortex and to the lower border of the mandible on both the proximal and distal aspects of the tumor resection. These vertical arms extend only a short distance on to the buccal cortex adequate for holding the mandible in position. It also has a provision for placing screws to fix this guide to the mandible to keep it in position during resection and fixation of the pre-adapted reconstruction plate. A horizontal arm will be made extending all along the lower border in the region of the resected mandible connecting the 2 vertical arms as shown in the Figure 5 below.

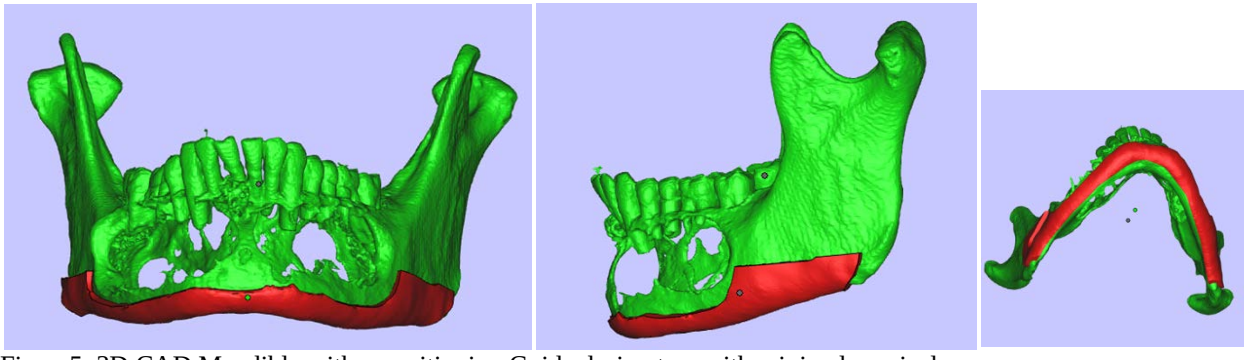


Figure5. 3D CAD Mandible with repositioning Guide design two with minimal surgical exposure.

2.5 Fabrication of Additive Manufacturing Medical models

The above designed guides and mandible models for both the cases are converted into an .stl file format, which is globally accepted by any AM machine. To fabricate the physical AM models Flashforge Finder machine usingFused Deposition Modelling (FDM) technique was utilised.

PLA material at 210^0C is used for all the AM models in the current work, some of the AM models are shown in the Figure 6 below.

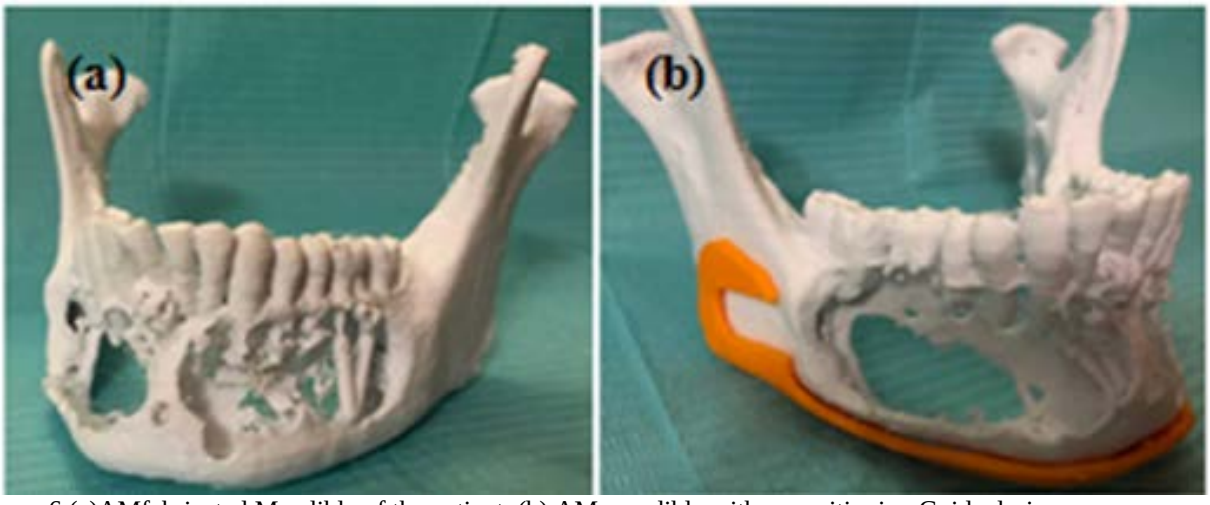


Figure6.(a)AMfabricated Mandible of the patient. (b) AM mandible with repositioning Guide design one

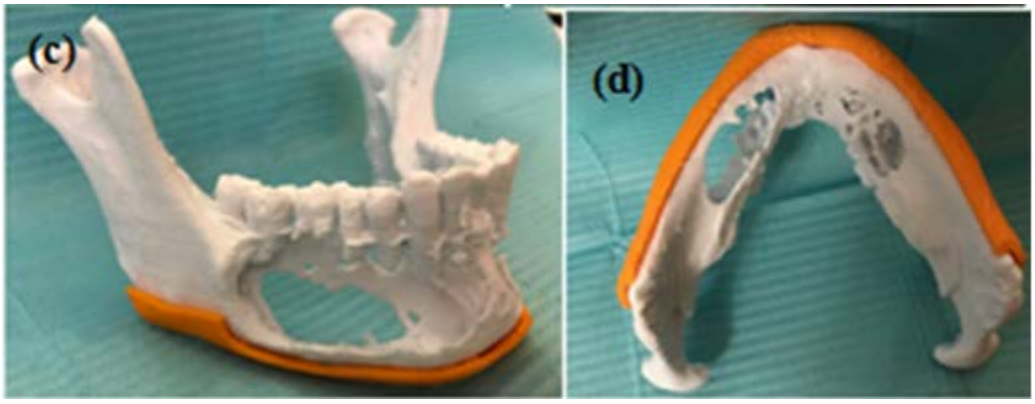


Figure6(c) AM mandible with repositioning Guide design two(d) Bottom contour of the Mandible and Guide.

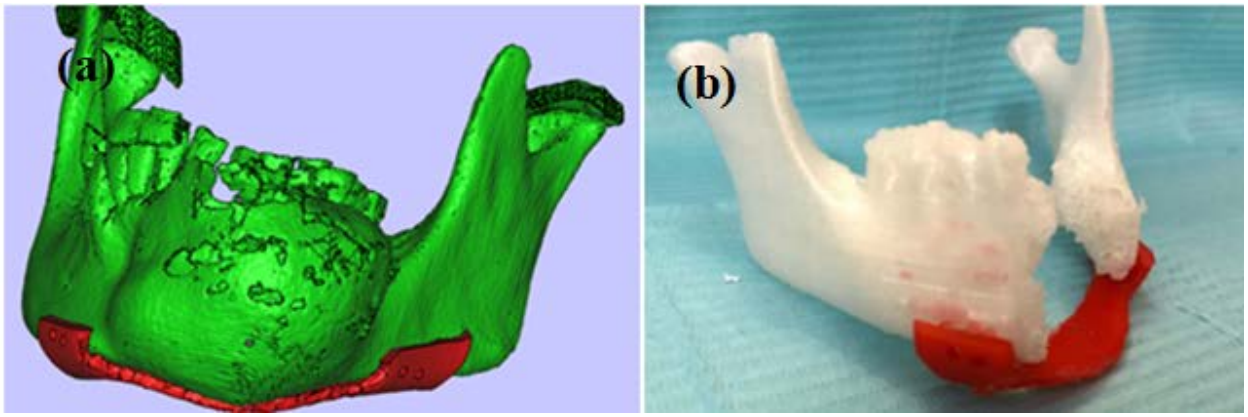
2.6 Mock surgery on AM medical models.

The guide is placed prior to the resection of the mandible to determine the position. It can be fixed to the jaw so that the same position can be retrieved after the resection. This will allow the surgeon to estimate the pre-surgical condylar position. After the mock surgery a reconstruction plate is adapted on the resected model to get aninitial approximation. This will help the surgeon to save intraoperative time. Pre adaptation of reconstruction plate also helps to get a better contour of the mandible with the help of the developed guide. Since the guide follows the exact contour of the mandible, it repositions the condyles bilaterally. It also maintains the resected gap in the same dimensions to allow reconstruction to be done to replicate as much of the pre-surgical contour as possible. Maintaining the condyles in their original position enables the patient to maintain jaw movements and have an occlusion of the posterior teeth replicating the

pre operative occlusion. The anterior contour can be reconstructed with the guide in place to get a good aesthetic reconstruction. This guide is thus meant to reproduce the pre surgical mandible both aesthetically and functionally as shown in the Figure 7 below.

Figure7. (a)AM fabricated Mandible of the patient with Guide after resection. (b) AM mandible of the patient with Guide and surgical plate adoption after resection

Based on the observations from the mock surgery, it was inferred that each of the repositioning guides had their particular uses in different situations. Design 2 had certain advantages over design 1 as it required lesser surgical exposure of the soft tissues and could be used in cases of tumor resection not requiring too much soft tissue excision. Also, making a provision for two 2mm screw fixations on both sides proved beneficial as it allowed removal of the guide during resection if required and easy replacement in the same position again. These stabilization screws can be placed in both the guide designs as shown in Figure 8 below.



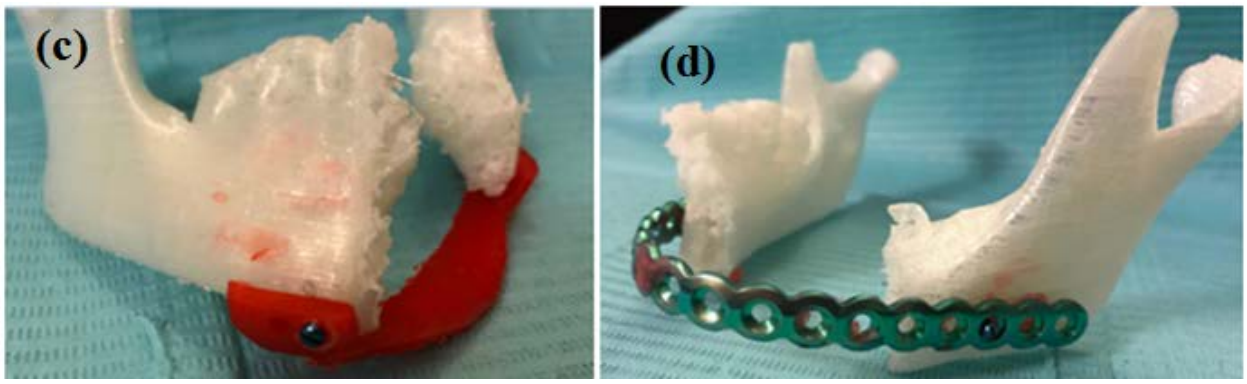


Figure 8(a) 3D CAD Mandible of the patient with Guide. (b,c) AM mandible of the patient with Guide after resection. (d)AM mandible with surgical plate adoption after resection

Reconstruction of the resected mandible requires that the mandible be brought back to its original dimension. This will provide rehabilitation to the patient both in terms of esthetics and functionality. Choices for reconstruction of the jaw include use of a reconstruction plate or bone grafts. Microvascular free flap reconstruction is the method of choice in most cases[3,4]. It is important to help reattach the tongue muscles to prevent stridor. It is equally important to maintain the position of the condyle to prevent collapse of the free segments. This helps in maintaining contour as well as occlusion.With these points in mind, these repositioning guides have been fabricated.Guides that have been fabricated previously for repositioning of the mandible have served the purpose but have been inconvenient to use as they are bulkyand complex in design[5-12].

3. Conclusion:

The current work presents a simple and easy design for repositioning the mandible after tumor resection. This guide helps in establishing the condylar position and maintaining the resected gap after surgery. This aids the surgeon to get a patient's initial contour of the reconstructed mandible. They are rigid and can be fixed to the patient’s mandible with the help of screws to keep it in position through the procedure. Further modifications can be made to this guide after use in the patient to get the most convenient design for the maxillofacial surgeon.

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