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Dentistry Section

Case Report

Customised 3D Printed Guides for Mandibular Fracture Management-A Report of Two Cases

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ABSTRACT

In treating mandibular fractures, accurate anatomical reduction and reconstruction remains quite challenging and arduous for the oral maxillofacial surgeon using traditional devices and methods. Therefore, advanced techniques have become essential to simplify and achieve safe and desirable anatomical reduction with lesser operative time. Introduction of 3 Dimensional (3D) printed guides helps to achieve bony consolidation in the correct anatomic position to facilitate standard mouth opening and restore the pretrauma occlusion. In the following case reports (7-year-old male, 35-year-old male), the preoperative surgical planning began with the construction of 3D imaging in both the cases after radiographic examination. For virtual reconstruction, the images from the multiplanar Computed Tomography (CT) scan were converted into Digital Imaging and Communications in Medicine (DICOM) format. The present reports have proposed using an inexpensive customised 3D printed cast metal surgical guide in the treatment of two cases of mandibular fracture. A customised 3D printed surgical guide and an occlusal stent were designed and fabricated to assist in placing screws and plates for approximation of fractured segments and to guide the occlusion during surgery. They also highlight the efficacy and functionality of a customised 3D printed cast metal surgical guide in increasing the reduction accuracy, reducing surgical difficulties, and improving clinical outcomes with a lesser operative time in treating mandibular fractures.

Keywords: Additive manufacturing, Cast metal guide, Mandibular trauma, Occlusal splint, Virtual surgery

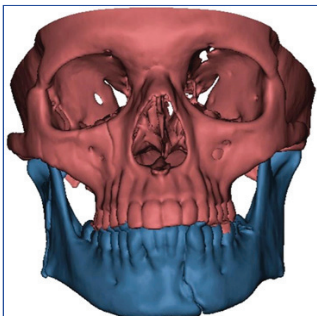
CASE REPORTS

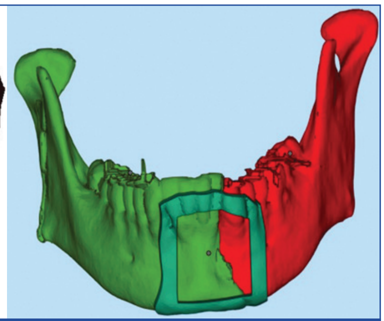
Case 1

A 27-year-old male patient with extraoral diffuse swelling on the lower third of the face and difficulty in mouth opening and pain in lower front tooth region with a history of fall from bike two days ago reported to Department of Oral and Maxillofacial Surgery (OMFS). Clinical and radiological examination revealed displaced left parasymphysis and undisplaced right mandibular ramus fracture. In addition, intraoral anterior open bite and right posterior crossbite were observed, along with step deformity palpable between lower left lateral incisor and canine [Table/Fig-1]. Therefore, the elected treatment choices were an open reduction with internal fixation using lag screws for parasymphysis and closed reduction for ramus fracture.

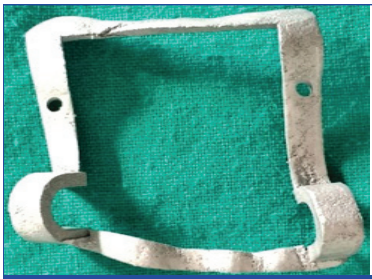
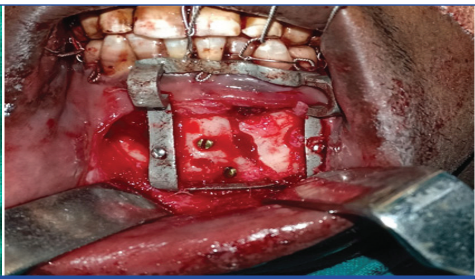
[Table/Fig-1]: Preoperative clinical image showing posterior cross bite and step deformity.

Preoperative surgical planning began with the construction of 3D imaging after the radiographic examination. For virtual reconstruction, the images from patients multiplanar CT scan (Ingenuity core 128-Phillips multislice CT) with a slice thickness of 1 mm were taken [Table/Fig-2] and imported as data files in the DICOM format. A virtual 3D volumetric reconstruction by segmentation of fracture fragments was done in 3D Slicer 4.11.0 and converted to Standard Tessellation Language (STL) file format [Table/Fig-3]. Often during the reduction of a fractured mandible, since the clinical visualisation is only from buccal aspect, an accurate anatomical reduction of the lingual and inferior cortex is not achieved leaving a postoperative occlusal discrepancy. With the use of virtual surgical planning and 3D printing technology, researchers have found a definitive advantage in visualising the mandible in all dimensions. After virtual reduction, transferring the portion of reduced mandible to the operating table was possible with the fabrication of guide. The accurate occlusal intercuspation was ensured using a customised 3D printed splint. To make this technology affordable for outpatients, they have used a hybrid technique where the virtual design was 3D printed using castable wax and then fabricated using Cobalt-Chromium (Co-Cr) alloy in a furnace using the "lost wax" technique. No specific post processing was required. These guides were rigid and could be autoclaved. After the virtual surgical planning, the occlusion was also accessed virtually. Using a Boolean operation, the maxillary and mandibular teeth position were replicated in the occlusal splint [Table/Fig-4]. This was then fabricated using a Surgical Guide (SG) (power resin) resin in a form 2 Stereolithography (SLA) 3D printer.





[Table/Fig-2]: Preoperative CT scan (3D reconstruction) showing parasymphysis fracture and step deformity. **[Table/Fig-3]:** Surgical planning by virtual reduction of fracture fragments. (Images from left to right)


[Table/Fig-4]: 3D Printed cast metal surgical guide. **[Table/Fig-5]:** Customised fixation guide in place for lag screw fixation of mandible. **[Table/Fig-6]:** 3D printed occlusal splint to guide the occlusion. (Images from left to right)

An intraoral vestibular incision was placed and passed submucosally in layers. Mentalis muscle was incised and bilateral tunnelling of submucosa was done up to premolar region to expose of fracture fragments after reflection of the periosteum. The customised cast metal surgical guide with thickness of 3 mm was placed to engage the mandible along the inferior-lingual border. This guide was stabilised using 2 mm screws in slots provided on the guide which enabled a perfect reduction of the mandible and adaptation of the guide along the labial, inferior and lingual surface of the mandible giving it a snug fit [Table/Fig-5]. The 3D printed occlusal splint was then placed to establish the occlusion [Table/Fig-6]. After confirming satisfactory reduction into anatomical position, two 2×20 mm lag screws (SK Surgical) were fixed perpendicular to the fracture line keeping the guide and occlusal splint in place. After fixation, the guide and occlusal split were removed and occlusion reconfirmed. The wound was closed in layers using 3.0 vicryl (Ethicon) after copious irrigation. Postoperative CT scan was taken which showed a perfect continuity of lower border [Table/Fig-7].

The postoperative recovery was uneventful, with no major complications [Table/Fig-8]. The wound healing was satisfactory and maximum occlusal intercuspation was achieved. CT scan taken three months postoperatively showed a perfect anatomical reduction of inferior and lingual cortex similar to what was achieved in preoperative virtual planning.

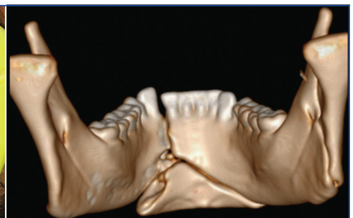
[Table/Fig-7]: Postoperative CT scan (3D reconstruction) showing good occlusion and continuity of lower border.

[Table/Fig-8]: Postoperative occlusal image showing maximal intercuspation.

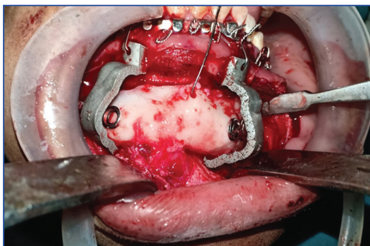
Case 2

A 35-year-old male patient, with a history of road traffic accident three days back presented with swelling in lower left side of the face and difficulty in chewing. Clinical and radiological examination showed displaced and comminuted fracture of the left parasymphysis and an undisplaced incomplete fracture of the right ramus [Table/Fig-9]. Virtual surgical planning was done and STL reconstruction showing displaced mandibular fracture accordingly [Table/Fig-10] and fracture reduction surgical guide was contrived to bring the inferior border and lingual cortex into anatomical approximation. The guide, in this case, was fabricated in a manner that it could be attached superiorly to arch bar and inferiorly hooked around the inferior border of the mandible to bring lingual cortex into approximation. The visible buccal cortex was also reduced, 2 Titanium 2.0 mm four holed mini plates with gap (SK Surgical) were fixed superiorly and 1 Titanium 2.0 mm three holed with gap miniplate was placed near the lower border of mandible [Table/Fig-11] to maintain precision and accuracy of the reduced segment. Good postoperative occlusal contact was achieved [Table/Fig-12].

The postoperative recovery was uneventful, with no major complications. Patients were followed-up three months later, and postoperative CT scan was taken [Table/Fig-13].

[Table/Fig-9]: Preoperative clinical image.
[Table/Fig-10]: Preoperative Standard Tessellation language (STL) reconstruction showing displaced mandibular fracture. (Images from left to right)




[Table/Fig-11]: Fixation guide in place for miniplate fixation.
[Table/Fig-12]: Postoperative clinical image taken after 15 days. (Images from left to right)

DISCUSSION

Mandible is a unique and only movable bone of facial skeleton, having complex role in aesthetics of the face and functional occlusion. Regardless of being the largest and strongest facial bone, mandibular fractures constitute 36-59% of all maxillofacial fractures serving as the most commonly diagnosed fractures in the maxillofacial region

[Table/Fig-13]: Postoperative CT scan taken after 3 months.

after nasal bone fractures [1-3]. Due to its prominent position in the craniofacial region with multiple muscle attachments, mandible fracture can occur at one or multiple locations depending on the direction and magnitude of the traumatic force [4,5].

Accurate restoration of mandibular fracture involving multiple sites with complex morphology, muscular attachments, or loss of occlusal relationships sometimes can be challenging even for an experienced surgeon [6]. It is now possible to treat such arduous cases with assistance of significant advances in technology, giving more reliable and predictable therapeutic outcomes. Among different new technological advances that have been developed in the last few years, 3D printing has gained tremendous popularity in field of Oral Maxillofacial Surgery. With this novel technology, various surgical guides and templates can be easily fabricated that serve diverse applications like harvesting bone grafts, plate bending, tailoring bioprosthetic implants, osteotomies guides, intraoperative occlusal splints, etc., giving favourable results [7]. Furthermore, compared to the traditional approach, it offers the advantage of providing greater accuracy with reduced operative time [8,9].

In different case studies, 3D surgery was used to obtain a direct and clear view about the morphology of fractured sites by virtually manipulating bone fragments at any angle giving adequacy of the required reduction process, and 3D printed customised cast metal guides to transfer this precise reduction intraoperatively. This digital software and preoperative CT scans can also assess the cortical bone thickness, bone density, and fracture location [10]. This virtual preoperative surgical planning enabled the operator to have a 3D visualisation of the fracture segments and their spatial relationships to surrounding structures, thus leading to the best possible restoration of the fractured segments. In addition, accurate proximity of the fracture segments as planned in mock surgery was achieved during the treatment procedure using 3D printed surgical guides. It also helped shorten the intraoperative time by 30 minutes for each case, reducing the patient's exposure to general anesthesia by one hour for both the cases. According to Hanason M and Skoracki B, 3D printing could reduce surgery duration up to 1.4 hours compared to conventional methods [11]. Postoperatively, it also yielded acceptable esthetic and functional treatment outcomes gaining maximum patient satisfaction.

Three-dimensional printing techniques often included additional costs and a more prolonged preparation phase with elaborate infrastructure requirements. To allay the above concerns, in the present case scenario, researchers have proposed using Co-Cr cast metal alloy to fabricate digital surgical guide plates as an alternative to other costly metal guides such as Titanium Vitallium, making it a more affordable and cost-effective approach for the patients. An approximate cost of INR 10000 has been spent each for surgical planning and fabrication of both customisable 3D printed guides and models. An inexpensive, hybrid manufacturing technique using SLA was adopted to fabricate cast metal surgical guides that combined 3D printing and investment casting technologies with a shorter duration [6]. This method enabled 3D printing of casting wax pattern, providing a smooth surface and perfect adaptation to the 3D printed anatomical model requiring no further adjustments. These guides facilitated a precise reduction of the inferior and lingual cortex with relative ease and no requirement of an additional hand to support the reduced mandible during fixation.

Limitation(s)

However, certain limitations were observed in this present study using 3D printed customised guides plates. Firstly, the fabrication of these guide plates was technique sensitive and required a proficient software engineer to carefully and accurately merge the relevant fracture fragments before printing them, which was time consuming. Any lapse or inaccuracy during this virtual 3D reconstruction in simulating the required anatomy could cause errors in treatment planning, jeopardising treatment outcomes. Secondly, the implantation of these 3D customised surgical guide plates required a long incision and more reflection of the soft tissues. On an average the time taken for these surgeries was around one hour. Hence, there is a need to modify the design of these guide plates to avoid expanding incisions and excessive reflection of the soft tissue during the placement of the guide plates.

CONCLUSION(S)

The present case report highlights how virtual surgical planning empowers the surgeon to visualise the reduction process preoperatively and guide the similar intraoperatively, making it less time consuming and more accurate. In addition to this, using a 3D custom fabricated cast metal guide enabled the operator to optimise lag screws position in different mandibular fracture sites, minimising injury to dentoalveolar and other anatomical structures leading to better therapeutic outcomes and providing a cost effective approach with a more favourable patient response. Currently, this 3D printing technology is trending and growing popular in different fields of OMFS for its ability to yield customised guides and devices with higher precision and fit consequently, providing a better healthcare service in the 21st century.

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