A Simplified Digital Workflow for the Treatment of Pediatric Mandibular Fractures Using Three-Dimensional (3D) Printed Cap Splint: A Case Report

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Management of maxillofacial injuries in pediatric trauma patients needs special consideration due to the anatomical differences, skeletal and dentition developmental stages, differential growth patterns, and accelerated healing periods, as compared with adult patients.1 In hospitalized pediatric trauma patients, mandible is the most common fractured bone of the facial region.2

The treatment modalities for pediatric mandibular fractures differ markedly from that in adults. These differences are based on the presence of a relatively soft elastic bone, instability of deciduous or mixed dentition, the development of tooth germs, and the level of cooperation of the patient.3

Due to the aforementioned characteristic features, the management of pediatric mandibular fractures can range from simple observation and clinical follow-up, conservative treatment (closed reduction with nonrigid fixation) to surgical treatment open reduction with internal fixation (ORIF). ORIF in pediatric patients is avoided due to potential disruption of the periosteum and chances of damaging the tooth germs. Therefore, the accepted modality of treatment is conservative in most clinical scenarios, and the stabilization of fractured segments with splint retained by circummandibular wiring is the most commonly used treatment modality.4

In this case report, the authors describe a simpler preoperative digital workflow for the treatment of pediatric mandibular fractures. In this process, closed reduction is achieved with a three-dimensional printed cap splint stabilized with circummandibular wiring under general anesthesia.

Keywords
► pediatric mandibular parasymphyseal fracture
► CAD/CAM
► virtual surgical planning
► 3D printing
► circummandibular fixation

Abstract
Pediatric mandibular fracture needs special consideration by clinicians. The management of pediatric mandibular fracture differs from that in adults considering the presence of tooth germs and the potential for mandibular growth. One of the most common forms of conservative management for pediatric mandibular fractures is the use of cap splint along with circummandibular wiring. The conventional workflow prior to performing surgery with this technique is impression taking and dental model fabrication. Additionally, it is also recommended that mock surgery should be performed to achieve proper reduction before acrylic splint fabrication. However, these procedures are effortful and time consuming when performed under general anesthesia during surgery and require additional sedation if performed prior to surgery. The aim of this case report is to describe a simpler preoperative digital workflow for the treatment of pediatric mandibular fractures, in which closed reduction is achieved with a three-dimensional printed cap splint stabilized with circummandibular wiring under general anesthesia.
and Hospital, Raichur with a chief complaint of pain in the front region of his lower jaw. There was a history of trauma due to assault by his classmate 1 day prior. There was no history of loss of consciousness, vomiting, convulsions, or nasopharyngeal bleed. On clinical examination, a diffuse extraoral swelling measuring 3 × 2 cm was present over the right anterior region of the mandible. Intraoral examination revealed anterior and left-sided open bite with premature contact on the right posterior teeth of the mandible leading to an altered occlusion. In addition, there was a gap along with segmental mobility between the right mandibular permanent lateral incisor and canine region.

Based on the clinical findings, a provisional diagnosis of fracture of the right parasymphyseal region was made. Preoperative investigations included an orthopantomogram (OPG) and a computed tomography (CT) scan, which confirmed the unilateral fracture of the right mandibular parasymphyseal region. As the patient had mixed dentition, the treatment plan included closed reduction and stabilization of the fractured mandibular segments. Written informed consent was acquired from the patient’s parents.

For preoperative computational image and data acquisition, the skull of the patient was scanned using a high-resolution CT with the following parameters: (1) matrix of 128 × 128 pixels, (2) slice thickness of 1 mm, (3) seed per rotation of 1 mm, (4) gantry tilt of 0°, and (5) bone window setting.

The Digital Imaging and Communications in Medicine (DICOM) data of the two-dimensional image slices from CT scan were imported into a medical imaging and computer-aided design (CAD) proprietary software (Osteo3d). Following this, optimal bone thresholding values were applied, and a 3D virtual volumetric reconstruction of the patient’s skull anatomy was generated (Fig. 1A).

Based on the 3D volumetric virtual model, the fractured margins were accurately defined by the operating surgeon, in consultation with an engineer via web-conferencing. The fractured mandibular segments were virtually segmented and reduced along the fracture line, thereby maintaining the native bone continuity and contours of the mandible (Fig. 1B). Following reduction, a cap splint was modeled over the mandibular teeth extending bilaterally around the first deciduous molar region. The cap splint was designed 2 mm supragingivally and was modeled to a thickness of 3 mm with a 0.1 mm clearance from the mandibular teeth (Fig. 2A).

After approval by the operating surgeon, the digital file of the cap splint was exported in a standard tessellation language (STL) format (Fig. 2B). The “.stl” file was imported into the software for 3D printing and the cap splint was fabricated in a translucent photopolymeric resin using Stereolithography 3D printing technology (ISO:13484 certified). Following preanesthetic clearance for the patient, treatment plan was performed as planned, under general anesthesia. The mandibular parasymphyseal fracture was reduced and stabilized with the 3D printed cap splint. Circummandibular wiring was done by placing bilateral stab incisions on the inferior border of the mandible ~5 mm from the midline. Mandibular bone awl (Kelsey-Fry) was used to enter lingually along the body of the mandible, and piercing the lingual mucosa. A 26 gauge stainless steel wire was then passed and secured to the awl. The tip of the awl was withdrawn until it reached the lower border of mandible without penetrating through the skin and was then carefully passed onto the buccal sulcus along the body of the mandible. The wires were held together and the 3D printed cap splint was stabilized by winding the wires (Fig. 3).

Postoperative OPG was taken with circummandibular wires in place (Fig. 4). Oral hygiene maintenance regime
Fig. 2  (A) Virtually designed cap splint over reduced mandibular fractured segments. (B) Final .stl file of the cap splint.

Fig. 3  Three-dimensional printed cap splint secured by circummandibular wiring.

Fig. 4  Postoperative orthopantomogram with cap splint in situ.
was explained to the patient’s parents and the patient was discharged after 2 days. On the fourth postoperative week, the circummandibular wiring and the splint were removed. Postoperative recovery was uneventful, and the occlusion was found to be satisfactory.

Discussion

The goal of treatment in pediatric mandibular fractures is the stable restoration of the fractured bony segments to its pre-injury position with minimal manipulation of the traumatized hard and soft tissues without causing any functional impairment. Due to concerns related to dentition development and mandibular growth, management of pediatric mandibular fractures requires a more conservative approach.9

Several studies in literature have recommended the use of splints with circummandibular wiring as a viable option for treating pediatric mandibular fractures.6–8 The conventional splint fabrication approach, while being cost effective and providing ease of application and removal, has certain shortcomings such as intensive preoperative laboratory procedures as impressions taking, creation of dental stone models, and finally the fabrication of splints based on dental stone model surgery. As these procedures are manual in nature, they may carry potential human errors that may eventually result in an inaccurate treatment plan.9

With the advent of technologies in 3D imaging, CAD, and computer-aided manufacturing, the strategy to maneuver the preoperative planning in maxillofacial surgeries has since been substantially improved. The combination of CT datasets (DICOM) with an appropriate CAD software makes virtual surgical planning (VSP) achievable. Additionally, consolidation of VSP with 3D printing technologies further aids in providing an accurate translation of the desired treatment plan to reality.10–13

On the basis of assimilation of the aforementioned technologies, the possible application of a patient-specific digital cap splint for treating pediatric mandibular fractures was described in this case report. This preoperative digital workflow eliminated the discomfort and the need of sedation in the patient during impressions. In addition, the surgical time under general anesthesia was also considerably reduced. During the design process of the 3D printed cap splint, dental contours and morphologies were integrated. These occlusal undersurfaces of the splint acted as a guiding plane by providing an accurate positional control for the restoration of mandibular arch to its preinjury shape. The 3D printed esthetically pleasing cap splint was also of a perfect fit requiring no intraoperative trimming or adjustments. Furthermore, the splint had a more aesthetically pleasing feel compared with the traditional acrylic cap splint.

Conclusion

Management of pediatric fractures is challenging as the cooperation of the patient is very important in most cases. The workflow explained in this case makes the accurate management of such cases easier when compared to the making of impressions, casts, and cap splints manually. Overall, this preoperative workflow and 3D printed patient-specific cap splint were found to be beneficial in this case report with respect to reduced operative time and minimal trauma to the adjacent anatomical structures.

Conflicts of Interest
None declared.

References