Original Article

Management of Mandibular Fractures with Pre-adapted versus Intraoperatively Adapted Mini Plates-A Comparitive Study

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Abstract

Background: Pre-operative planning on 3D models and pre-adapted miniplates in the maxillofacial trauma helps to achieve better anatomic reduction and decrease the operating time. This study aimed to compare the management of mandibular fractures by open reduction and internal fixation (ORIF) with pre-adapted versus intraoperatively adapted miniplates. **Material and Methods:** A total number of 10 patients were taken to compare pre-adapted miniplates (Study group or Group A) to Intraoperatively adapted miniplates (Control group or Group B) in ORIF of mandibular fractures for volumetric analysis of fracture reduction and intraoperative time. **Observations and Results:** There is a statistically significant difference among Group A and B ($P < 0.05$) when mean values of time taken for ORIF and volumetric analysis of fracture reduction in Group A and Group B are compared. **Conclusion:** We conclude that pre-adaptation of miniplates using 3D prototyping models reduces intraoperative time and interfragmentary distance during ORIF of mandibular fractures.

Keywords: Open reduction and internal fixation, 3D prototyping models, Volume analysis, Pre-adapted miniplates.

Introduction

Craniomaxillofacial traumatic injuries are difficult to manage. Restoring a patient's form and function to their pre-injury state can be challenging, even for an established oral and maxillofacial surgeon. Over the past few decades, innovations in diagnostic imaging technology, open reduction and internal fixation (ORIF) have improved treatment benefit in trauma patients. However, when standard procedures are used, the issue of optimally re-establishing the maxillofacial skeleton in three dimensions persists. This is especially true for injuries involving complicated three-dimensional (3D) anatomy. Numerous factors may play a role in achieving these best results. These include difficulty visualizing the deep skeletal outlines directly during surgery and difficulty visually appraising the intraoperative result for optimal position, projection, and symmetry.[1] In treating maxillofacial trauma, surgeons generally perform osteotomy and approximate the bone segments to their original position and fix them with plates and screws. Previously, surgeons used to judge the anatomical position of bone segments based on their clinical experience, which usually resulted in poor post-operative facial symmetry and functional recovery.[2]

Recent technological advancements with pre-operative planning on rapid prototyping (RP) 3D models, stereolithography (SL), laser lithography or laser technology, skull replicas, computer-aided design and manufacturing, intraoperative navigation, and intra-operative imaging can aid in increasing the reliability and efficiency of the outcomes.[1] Nowadays, this technique of pre-operative model planning and simulation surgery is preferred.[2] Pre-operative 3D planning can reduce operating time and cost. Due to the decrease in intra-operative time, the period of hospitalization, cost of the treatment, and rate of infection are reduced.[3] This research aimed to evaluate whether pre-adaptation of miniplates for ORIF for fracture management using 3D printing is advantageous over intraoperatively adapted miniplates.

A comparative study was designed on 10 Patients and divided into two groups of five patients in each group to compare the pre-adapted mini plates on 3D printed models over intraoperatively adapted mini plates in ORIF for mandibular fractures.

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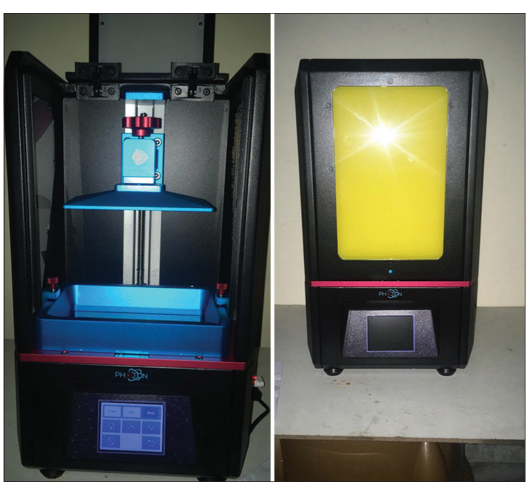
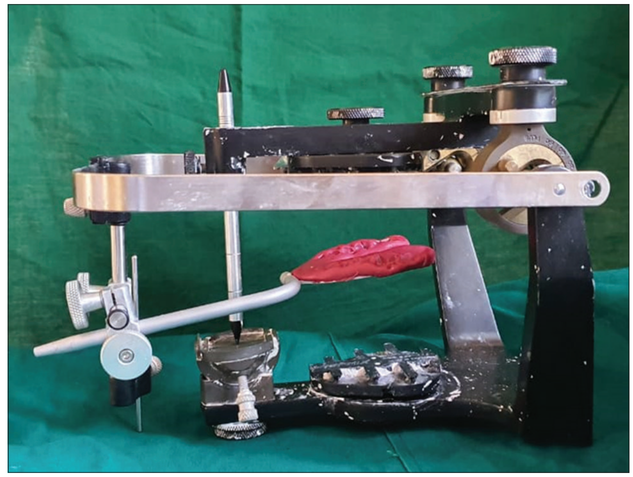
Materials and Methods

A randomized prospective comparative clinical study in 10 patients who visited the Department of Oral and Maxillofacial Surgery for the management of mandibular fractures are categorized into Group A (ORIF of mandibular fractures with pre-adapted mini plates) and Group B (ORIF of mandibular fractures using Intraoperatively adapted mini plates). Adult patients with mandibular fractures from angle to symphysis region and patients who are medically fit to undergo Open reduction and internal fixation are included in this study. Comminuted, Edentulous fractures, patients with bone tumors, cysts and other bony pathologies, and Condylar fractures are excluded from the study. After detailed case history, routine blood and radiographic investigations were done. Informed consent was obtained from the patients to participate in the study. Institutional Ethical Committee clearance was obtained for the study.

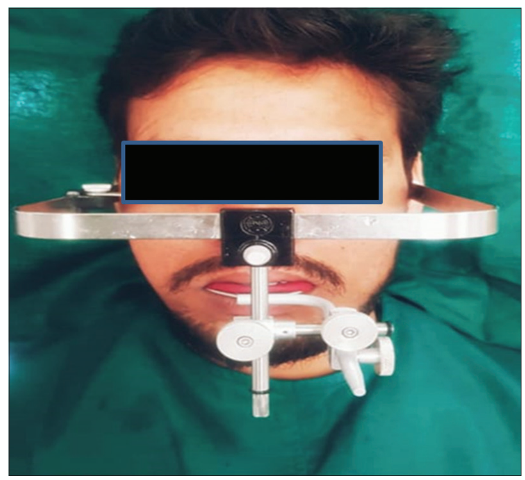
In the study group (Group A), maxillary dental arch impression was taken, and the model was made using dental stone. A pre-operative CBCT scan of the mandible was made, and the distance between the two fractured fragments was measured in volume (mm^3). 3D model of mandible was obtained from the CBCT scan data and is printed with an Enycubic photon printer (Photograph 1). The patient's occlusion is transferred to the Hanus Semi-adjustable Articulator (Photograph 2) using a Face bow (Photograph 3). The maxillary model (Photograph 4) is articulated onto the semi-adjustable articulator. Mandibular 3D model (Photograph 5) was osteotomized at the fracture fragment, and mock surgery (Photograph 6) was performed. 3D printed mandibular model (Photograph 7) was also articulated (Photograph 8) accordingly. Miniplates were adapted (Photograph 9) using plate bender following the anatomical landmarks on the 3D model in a functionally reduced position. This functional reduction of fracture is attained using face bow transfer and mock surgery performed on Hanus semi-adjustable articulator. Pre-adapted plates were sterilized and fixed to the patient at the fractured site during surgery (Photograph 10). In Control group (Group B), ORIF is performed in conventional method of adapting miniplates during the surgery. In both the groups, Intra-operative time, that is, the time taken from the exposure of fracture site to the last screw placement is measured. Post-operative Volume analysis of fracture reduction is done using IDDS software.



Photograph 1: Enycubic photon 3D model printer



Photograph 2: Transfer of occlusion to Hanus Semi-adjustable Articulator

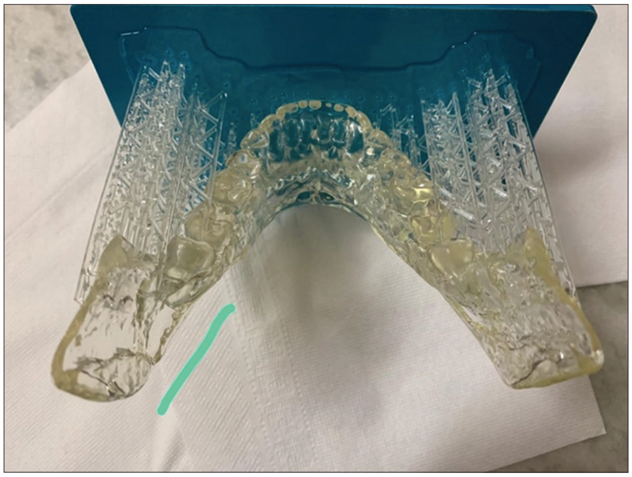


Photograph 3: Face bow transfer

Photograph 4: Maxillary Impression and maxillary model is done using dental stone

Statistical analysis method

Data will be entered in MS-Excel and analyzed using SPSS V25. Descriptive statistics will be represented with Mean with SD. Independent *t*-test, Paired *t*-test will be applied based on the nature of the distribution. $P < 0.05$ is taken as statistically significant.



Photograph 5: Printed 3D model

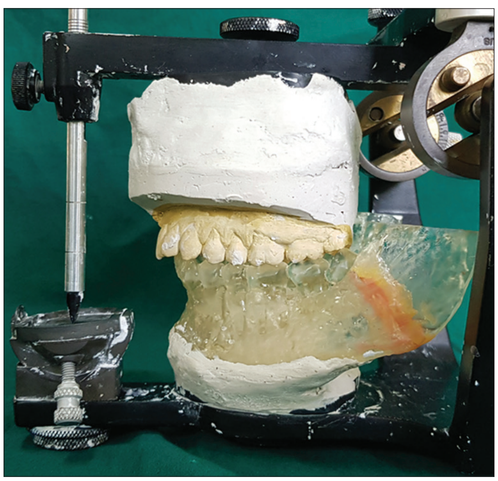
Results and Findings

A total of 10 patients were randomly divided into two equal groups. In this study, Intraoperative time (i.e., time taken from the exposure of surgical site to the last screw placement) during ORIF of mandibular fractures and Volumetric analysis of fracture reduction were compared in both Group A and Group B.
Group A: Pre-Bended plates.

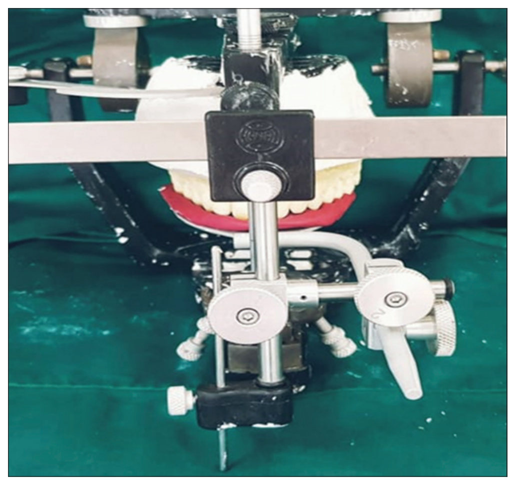
Group B: Intraoperatively bent plates.

Intra-operative time

Table 1 and Diagram 1 show a comparison between the intra-operative time taken for ORIF using pre-bended miniplate Group A and Intraoperatively bended miniplates Group B. There is a statistically significant difference among Group A and B ($P < 0.05$) when mean values of time taken for ORIF in Group A and Group B are 20.60 s and 35.20 s are compared. It

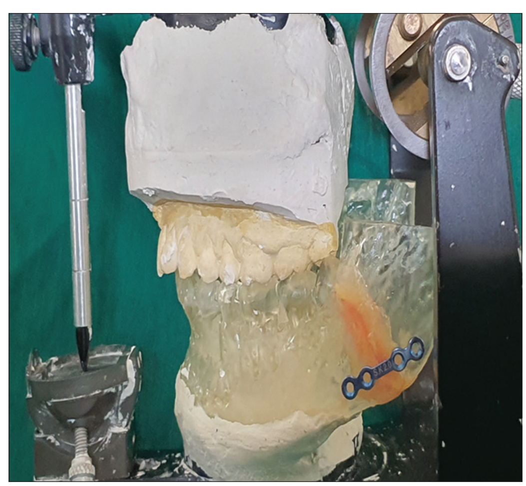


Photograph 6: Mock surgery performed



Photograph 8: Articulating maxillary cast onto the articulator

Photograph 7: 3D printed mandibular model



Photograph 9: Adaptation of miniplates

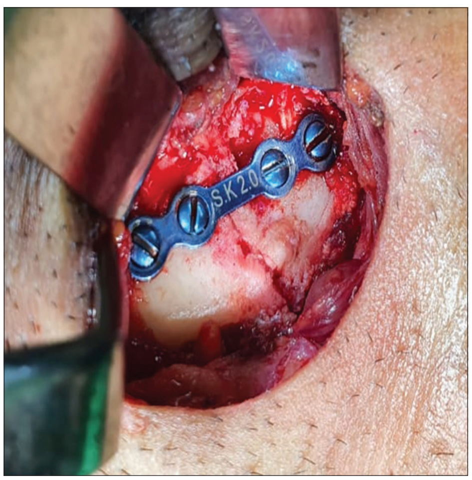
can be said from the above result that ORIF with Pre-bended miniplates is quicker than conventional method of bending plates intraoperatively.

Pre- and post-operative volume

Table 2 and Diagram 2 show a comparison of mean post-operative volume between Group A and Group B which are 180.76 and 345.68, respectively. There is a statistical significance ($P < 0.01$) seen when mean values of post-operative volume between Group A and Group B are compared. It can be said from the above result that the distance between the fractured fragments is reduced better using pre-adapted miniplates compared to the conventional method of intraoperatively adapted miniplates.

Volumetric analysis of fracture reduction

Table 3 and Diagram 3 show a comparison of the amount of volume reduced post-operatively between Group A and Group B. There is a statistical significance ($P < 0.05$) seen when mean values of amount of reduced volume in Group A and Group B, which are 58.42 and 18.24, respectively. It can be said from the above result that the fracture reduction is better with pre-adapted miniplates compared to conventional technique of adapting miniplates intraoperatively during ORIF of mandibular fractures.



Photograph 10: Miniplates are sterilised and fixed at fracture site

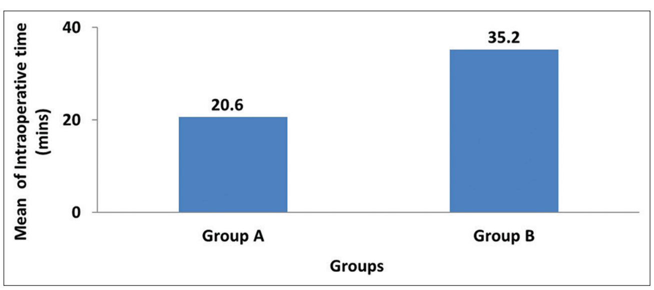


Diagram 1: The mean Intraoperative time in Group A and Group B

Table 1: Comparison of mean between the groups (Group A and Group B) in the parameters (Intraoperative time) using independent *t*-test

	Group A		Group B		*P*-value
	Mean	SD	Mean	SD	
Intra-operative time (min)	20.60	4.56	35.20	6.38	0.003*

Discussion

The face is the most vulnerable area of our body, making it highly susceptible to traumatic injury. Maxillofacial injury is one of the most common injuries seen in trauma patients that report to the emergency room, and it is the leading cause of death among them. These are the most commonly occurring among all other injuries in road traffic accidents. Maxillofacial injuries involve skeletal, dental, and soft tissues of the maxillofacial region.[3] The lower part of the face is formed by the mandible, the only movable bone in the maxillofacial region.[1] In the present study, it is observed that among ten mandibular fractures, four are parasymphysis fractures, three are symphysis, two are angle, and one combined fracture. Because of the prominence of the symphysis, it is the most vulnerable region to be hit during an assault. As a result, mandibular fractures are among the most prevalent injuries in the maxillofacial region.[4]

Adult patients with mandibular fractures from the angle to the symphysis region were included in the present study since these are the most common fractured areas in the mandible.[3] The primary goal of treating mandibular fractures is to return the patient to pre-injury form and function by restoring the patient to pre-injury occlusion, obtaining anatomic reduction when possible, and achieving osseous union predictably.[3] The best way to treat mandibular fractures is to create the ideal environment for bone healing, enough blood supply, immobilization, and appropriate alignment of the teeth and fractured segments.[5]

The management of facial fractures is very challenging due to its unique 3D contours and nonlinearity of the facial skeleton. To reduce the operating time in the OT, the 3D models can serve as a template on which pre-contouring of the fixation plates can be done. They can be preferred over conventional implants and reduce the surgical time. To reconstruct the multitude of craniomaxillofacial defects of mandible, zygoma, midface, and orbit, these pre-bent technologies are very helpful.[4]

According to the studies conducted by Lye[6] *et al*., the pre-bent titanium plates are used to minimize or significantly reduce the necessity for repeated plate bending and contouring of the plates, which causes strains and microcracks in the material, which weakens the plates. Advantages of PBA plates give the best resistance to displacement, permanent deformation, and force for breaking. Using these plates has a number of benefits, such as reduced bending of plates decreasing the need to sacrifice the plate's integral strength, and less contouring decreases the operating time. As a result, the prebent plates improved strength that comes from both their increased bulk and their absence of weakness due to decreased need for contouring.[6]

Table 2: Comparison of mean between pre-operative and post-operative volume in groups (Group A and Group B) using Paired *t*-test

Parameters	Group A		Group B	
	Mean	SD	Mean	SD
Pre-operative volume (mm^3)	239.21	42.80	363.82	167.38
Post-operative Volume (mm^3)	180.76	18.11	345.58	147.33
P-value	0.019*		0.129	

Table 3: Comparison of mean reduced volume between the groups (Group A and Group B) using independent *t*-test

Parameters	Group A		Group B		*P*-value
	Mean	SD	Mean	SD	
Pre-operative volume (mm^3)	239.21	42.80	363.82	167.38	0.145
Post-operative volume (mm^3)	180.76	18.11	345.58	147.33	0.038*
Reduced volume (mm^3)	58.42	34.55	18.24	21.40	0.05*

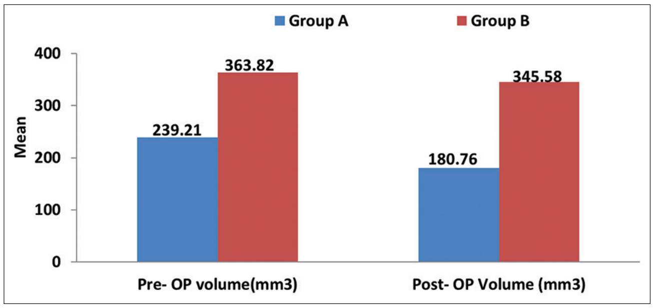


Diagram 2: The Comparison of mean between Pre-OP and Post-OP volume

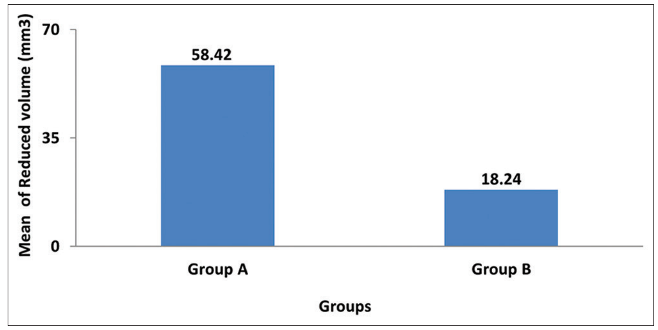


Diagram 3: Comparison of mean reduced volume between the groups (Group A and Group B) by using independent *t*-test

According to studies conducted by Loukota and Shelton,[7] Loukota and Shelton bending the plates five times increased the final bending load while lowering the mean bending stiffness. Because of plate bending, the fracture toughness has decreased, indicating that some damage has occurred in the bridging region. Repeated bending of plates results in increased chances of plate deformation and fracture due to the masticatory load exerted at the screw-plate interface.[7]

In studies conducted by Lauria *et al*.[8] in 2016, the act of bending to adapt plates could be a cause of fracture of plates as a result of the residual tension generated. Prebent plates are commonly used in orthognathic surgery, as manual bending of fixation plates can considerably increase operating time and may also weaken the material during its adaptation to bony tissue. They concluded that prebent plates could be used to reduce the intra-operative time and reduce the chances of plate fracture, restoring plate integrity.

Martola *et al*.[9] found that the act of bending to adapt plates could be a source of plate fracture as a result of the residual tension generated, which can impact the mean tension during the cyclic load. According to studies related to facial injuries,[9] excessive bends in plates, when adjusted for bony morphology, can lead to strain and micro-fissures in the material, causing fragile points and fractures associated with fatigue.[9]

Lye *et al*.[6] reported that as a result of the bending, the material becomes more fragile and less resistant and fails to function during the adaptation and manual bending of plates for bone tissue. According to Loukota and Shelton,[7] bending plates more than five times utilized in the craniofacial region lessens their rigidity to flexion.

According to the studies cited above,[5-7] frequent bending of plates increases the probability of plate fracture and lowers the fracture toughness. Pre-bent plates are used to circumvent these constraints. Thus, in the present study, plates are pre-adapted using 3D models to decrease operating time as well as the risk of plate fracture. With the above advantages of the pre-bent plates, the present study aims to compare the conventional plates to the prebent plates in treating mandibular fractures.

To achieve the goal of pre-adaptation, a variety of mini plates are pre surgically adapted utilizing 3D SL models, surgical guides, and templates. Over the last two decades, numerous novel technological advancements have created a new era in the field of Oral and Maxillofacial Surgery. One such technique is the use of 3D models.[10] Hounsfield, in 1973 pioneered the use of computed tomography (CT) to produce accurately sliced sections of the human anatomy. Alberti, in 1980 recognized its significance and proposed the construction of 3D models from CT images.[11] Since then, 3D printing, which is also known as 3D SL or RP, has gradually revolutionized surgical planning and simulation via Computer Assisted Design and Manufacturing software.[12] It has become the gold standard in current practice from pre-operative model planning and simulation surgery in craniomaxillofacial trauma, tumor surgery, reconstructive surgery, orthognathic, pre-prosthetic surgery, and sophisticated treatment like congenital abnormalities.[12] Skull replicas were created utilizing SL or laser lithography, or laser technology to produce transparent, high-precision anatomical facsimile models that reproduce thin bone layers and closed spaces.[13] One can simply plan soft tissue incisions and surgical resection margins, as well as examine bony defects for grafting, plate adaption, pre-bending, and manufacture of custom prostheses.[10]

Bui *et al*.,[1] in their study, stated that the fabrication of stereolithographic models using virtual reconstruction data allows pre-operative plate contouring, osteotomies planning, and intraoperative bone graft contouring.

According to studies conducted by Mehra *et al*.,[10] The advantages of 3D and SLA models include improved diagnosis, treatment planning, direct visualization of anatomic structures, surgical practice/Mock surgery, planning incisions, resections and surgical evaluation of bone defects for grafting purposes, pre-bending/adaptation of reconstruction plates, reduced operative time and anesthesia, duration of wound exposure, fabrication of Guides or templates for surgery, custom prostheses, TMJ prostheses, distraction devices, fixation devices, which increases the chances of predictable outcomes, and for better communication between colleagues and patient education.

Mankovich *et al*.[14] defined Medical Rapid prototyping (MRP) in 1990 as the process of creating physical models of human anatomy from medical imaging. These surgical guides improved precision in jaw osteotomies. Creating medical models involves obtaining high-quality volumetric (3D) imaging data of the anatomy to be modeled, region of interest, data preparation for RP model production, and model quality assessment.[15]

Winder and Bibb[15] in his studies, described the technique for fabrication of 3D Models. Specialized volumetric or 3D picture data is necessary for MRP. Using the well-known Digital Image Communications in Medicine format is standard for medical imaging, and CT data are transferred to the printer in this format. The two commonly used technologies are SL and Fused deposition modeling (FDM). Many researchers conclude that SL is the method of choice for prototyping. FDM generates models layer by layer using Acrylonitrile Butadiene Styrene as model material.[15] In the present study, the above described SLA method is used for 3D model printing. Once the 3D prototyping model is fabricated, the adaptation of miniplate and transferring the same to the operating site can be comparable to the study done by Wagner[16] *et al*., who discussed the method of repairing a craniofacial fracture utilizing a quick 3D prototyping approach. The above authors, in the management of acute maxillofacial injuries, suggested employing 3D models to recreate fracture lines, decrease interfragmentary distance and contour reconstruction plates.

The plates are used to support fractures as well as serve as templates for fracture reduction during surgery. Model surgery is carried out to determine the location and pattern of each fracture.[16] Chew[12] *et al*. in 2021 assembled these osteotomized fractured model segments in "anatomic reduction" using fast-acting medium consistency cyanoacrylate glue that allowed for pre-bending and adaptation of mini plates,[12] which was used in the present study. In this study, face bow transfer is used to replicate premorbid occlusion to achieve intermaxillary fixation and centric relation. The mini plates are then adapted to the reduced fracture site on a 3D model. The surgical plates are sterilized and transferred to the surgical site intraoperatively. There are several advantages of reducing fractures on models of the maxillofacial region before surgery which include maintenance of intra-arch width of the maxilla and mandible, which enables to examine 3D symmetry of reconstruction. The ability to examine the alignment of mandibular segments based on mirror imaging of the contralateral side considerably improves fracture reduction. 3D models can plan fracture reduction and contour mini plates in optimal conditions. Presurgical planning based on the use of 3D prototyping models may reduce the surgical time required for fracture reduction and plate contouring. Adapting rigid reconstruction plates is done accurately during pre-surgical planning rather than during surgery as the fracture site is hidden by soft tissue. This improves the precision and reduces the time taken for mandibular fracture management.[16]

In the present study, the procedure followed in the study group described is in coherence with the above technique[12,15,16] for fabrication of 3D models, Mock surgery, and adaptation of miniplates.

In the present study, the operating time taken is measured intra-operatively from exposure of the fractured site to the placement of the last screw. In this study (Table 1 and Diagram 1), mean values of time taken for ORIF in Group A and Group B are 20.60 s and 35.20 s, respectively. Hence it is found that the intra-operative time taken for pre-adapted mini plates is significantly lesser than that of intraoperatively adapted mini plates ($P < 0.05$) due to adaptation of plates priorly on 3D models and performing mock surgery. According to studies conducted by Lye *et al*.,[6] Loukota and Shelton,[7] Lauria *et al*.,[8] Mehra *et al*.,[10] King and Park[17] pre-adaptation of mini plates using 3D models significantly reduced surgical operating time, the time spent under general anesthesia, and wound exposure time which is in coherence with the present study.

In this study (Tables 2 and 3, Diagrams 2-4), mean values of volume reduction in Group A and Group B are 58.42 and 18.24, respectively. Hence, it is found that the fracture reduction is slightly more significant in pre-adapted mini plates compared to the conventional technique of adapting mini plates intraoperatively during ORIF ($P < 0.05$), which is statistically significant. Comparing Group A and Group B, it can be inferred that fracture reduction is better when using pre-adapted mini plates during ORIF than intraoperatively adapted mini plates, which are in accordance with the studies conducted by Wagner *et al*.,[16] Mehra *et al*.,[10] Lye *et al*.,[6] Kermer *et al*.[13]

Thus pre-adapted miniplates have certain advantages over the conventional method of adapting mini plates intraoperatively. The traditional method of adapting mini plates during ORIF of mandibular fractures is time-consuming and challenging to achieve optimal anatomical and functional reduction.[16] In the management of acute maxillofacial injuries, surgeons can employ 3D models to recreate fracture lines, decrease interfragmentary distance, and pre-adapt mini plates in the functionally reduced position, which significantly reduce surgical operating time, time spent under general anesthesia, and wound exposure time.[10] In this study, intraoperative time and interfragmentary distance are compared among Group A and Group B, which concludes that there is a significant decrease in the Intra-operative time[15] and interfragmentary distance[16] when using pre-adapted mini plates in ORIF of mandibular fractures.

It can be hypothesized from the present study that pre-bent mini plates would reduce intra-operative time and achieve good reduction, which can be confirmed by the volumetric analysis pre and post-surgery. In this study, various anatomical sites of the fracture have been considered, such as parasymphysis (40%), symphysis (30%), angle fractures (20%). So this brings an advantage of observing the parameters to different fracture sites in a single study. Preparation of 3D models, transferring of articulation between the skull to the mandible and osteotomising the 3D model, errors in the models are some of the problems encountered in the study. Unfavorable fractures of the angle of the mandible are avoided in the study group because of the above-mentioned technical limitations.

Conclusion

It can be concluded that pre-adapted mini plates may be recommended for ORIF of mandibular fractures having the advantages of better functional reduction and reduced intraoperative time. Further studies can be done under the following recommendations, such as including unfavorable and displaced fractures, segregating the groups depending upon the site of fracture, favorability or unfavorability, displaced or undisplaced, with or without condylar fractures.

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