

**How to Cite:**

Jamwal, S. S., Kant, K., Venugopal, K., Rajesh, D., & Khalid, I. (2022). Comparison of different plating systems in bilateral para symphysis fractures: An original research. *International Journal of Health Sciences*, 6(S6), 10311–10317.  
<https://doi.org/10.53730/ijhs.v6nS6.12723>

## **Comparison of different plating systems in bilateral para symphysis fractures: An original research**

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**Abstract**---Aim: The purpose of the present research was to evaluate the comparison of various plating systems used in treatment of bilateral para-symphysis fracture. Methodology: Fractures were generated in 3-dimensional finite element models, and were fixed with a single miniplate, parallel double miniplates, or perpendicular double miniplates. A 300 N perpendicular load was then applied on the left molar region, and a finite element analysis was performed. Vertical gaps between the fractured surfaces of bilateral para-symphyseal areas, maximum stress within the screw/plating system, and maximum stress around screw holes in the bone. Results: Compared to the single miniplate, both the parallel and perpendicular double miniplates demonstrated significantly less stress in the screw/plating

system and screw holes in the bone. In addition, the perpendicular double miniplates had significantly smaller vertical gaps between fracture surfaces when compared to the single miniplate. Comparing parallel and perpendicular double miniplate fixations, less stress was found around the screw holes of the perpendicular miniplate models than those of the parallel miniplate models. There were no differences in vertical gaps or maximum stress within the screw/plating systems between the 2 double miniplate fixations. Conclusion: Results suggest that perpendicular double miniplate fixation is more suitable for fixing mandibular symphysis fractures.

**Keywords**--finite element analysis, mandibular symphysis fracture, miniplate, mechanical stress.

## Introduction

The mandible is the most frequent site among facial fractures.<sup>1,2</sup> Fractures with displacements are often treated by open reduction and internal fixation using miniplates.<sup>1,3,4</sup> When planning a surgical strategy for mandibular fractures, it is most important to obtain a rigid initial fixation to bear the masticatory load. Mechanical analyses using a finite element analysis (FEA) have demonstrated that stability at the fracture interface differs with different plating strategies in both angle fracture models<sup>5,6</sup> and condyle fracture models.<sup>7</sup> Along with these fractures, the symphysis is one of the most frequent fracture sites,<sup>8-12</sup> making up 18–20% of mandibular fractures in adults.<sup>2,9</sup> Children experience a higher proportion of symphysis fractures (14.5–40%) due to a more fragile symphysis caused by overcrowding of unerupted teeth.<sup>10,11</sup> While stabilization is as important for symphysis fractures as other mandibular fractures, there has been relatively little study on an optimal method of internal fixation. This may be because, as the shape of the symphysis region is simpler than that of the angles or condyles, surgeons could assume that differences in fixation methods were less important. Little data exist on the selection of the number and positions of a plate, and these decisions are typically made empirically.

Two fundamentally different philosophies have evolved in the treatment of mandibular fracture using plates and screws. One in which Spiessl believed in rigid fixation sufficient to prevent interfragmentary mobility during active use of the mandible.<sup>12</sup> Large bone plates with bicortical screws were used and primary bone union by compression osteosynthesis was the goal of treatment. Bulky plates, difficult adaptation, stress shielding, scar formation due to extraoral approach, more operating time and increased chances of nerve injury were its disadvantages. Second in which Champy et al.<sup>13</sup> advocated a modification of Michelet et al.'s technique<sup>14</sup> of mandibular osteosynthesis, which consists of monocortical juxta-alveolar and subapical osteosynthesis, without compression and without IMF. The plates were placed near the tension zone produced by physiological strain. Since then, miniplates have been the preferred fixation method in craniomaxillofacial surgery because of their relatively small size, adaptability, ease of placement and intraoral approach.<sup>15</sup> Little data exist on the selection of the number and positions of a plate, and these decisions are typically

made empirically. To address this uncertainty, we used 3-dimensional FEA to investigate whether or not the stability of the fracture surface differs with different plating strategies.

### **Aim of the present study**

The purpose of the present research was to evaluate the comparison of various plating systems used in treatment of bilateral para-symphysis fracture.

### **Methodology**

Computer models of adult human edentulous mandibles were created from CT scans of 8 dry human mandibles. Every fifth coronal plane slice (1 mm each in thickness) was picked, and the outer edge of the cortical bone and the boundary between the cortical bone and the cancellous bone were traced. Twenty to 30 points on the traced line were plotted on XYZ coordinates, and these points were then combined with straight lines to produce a wire frame. Then, adjacent wire frames were connected to each other. Therefore, 3-dimensional mandibular models composed of cortical bone and cancellous bone were created. The 8 mandibular models had different heights and widths. And, all surgical simulations and analyses were performed using finite element analysis software (ANSYS Ver. 8.0). Models were assigned with an orthogonal X-Y-Z coordinate system: the X-axis was assigned as medio-lateral, the Y-axis cranio-caudal, and the Z-axis antero-posterior.

Next, we configured complete para-symphysis fractures that run on the midline in the sagittal plane, with fractured surfaces apposing each other. Models of titanium fixation plates (4 holes, thickness 1 mm) were positioned in 3 different ways as described later on the buccal cortical bone surfaces, and fixed with unicortical cylindrical screws (diameter 2 mm). Although these screw models were designed without a groove, screws were united to the plates and buried in bone so that screw models were designed to be mechanically the same as actual screws. These plates were curved along with mandibular contour and connected to the mandible only by screws. So, forces in the plates were transmitted to bones only by the screws. The comparative conditions of miniplates were as follows:

- Single miniplate
- Parallel double miniplates
- Perpendicular double miniplates

The upper screws in both double miniplate models were positioned at the same location as those of the single miniplate model. The lower screws in the parallel miniplate models were positioned parallel to the upper ones at the inferior margin of the mandible. In other words, the long axis of all screws in the parallel miniplate model was parallel to the Z-axis. In the perpendicular miniplate model, the lower screws were driven into the inferior surface of the mandible. The long axis of the lower screws was parallel to the Y-axis. Screws were labelled #1: posterosuperior, #2: anterosuperior, #3: posteroinferior, and #4: anteroinferior. A 4 mm-diameter titanium dental implant was imbedded vertically into the left molar region. The head of the implant was given a cubic shape to simplify

masticatory load calculations. Four models (intact mandible, para-symphysis fracture with single miniplate fixation, parallel double miniplate fixation, and perpendicular double miniplate fixation) from 8 individuals, a total 32 models, were created for the analyses. Each model was divided into 59,000– 79,000 elements.

Each element was tetrahedron-shaped, iso-parametric, and contained 10 nodes. (Table 1) All materials in this model were accounted for as isotropic, homogenous, and linearly elastic. Six regions including condylar processes, coronoid processes, and mandibular angles, were fixed to zero displacement. A masticatory load on the left molar region was simulated with a 300 N force perpendicular to the dental implant, which is the mean single molar bite force in healthy young adults. It was assumed that the maximum masticatory load was applied to the molar region through the implant during mastication and clenching. The vertical gaps between the upper surfaces of the bilateral mandible fragments at the fracture site, the maximum stress within the screw/plating system, and the maximum stress around the bone screw holes were evaluated. All stress values were recorded in MPa (Mega Pascals  $\frac{1}{4}$  N/mm<sup>2</sup>). Data were compared for significant differences using the Mann-Whitney U test, with P values < 0.05 being significant.

## Results

Von Mises stresses decreased gradually with distance from the loading region; little stress was found at the para- symphysis region. In para-symphysis fracture models, von Mises stresses were concentrated within the #2 and #4 screws, regardless of fixation patterns. Each fixation method had a gap at the upper border of the fractured surfaces (Z-axis). The perpendicular miniplate models demonstrated significantly smaller gaps than the single miniplate models ( $p \frac{1}{4}$  0.028), but there was no significant difference in the gaps of the upper border of the fractured surface between the parallel and perpendicular miniplate models. Comparing the 3 fixation models, mechanical stress within screw/plating systems differed. In the single models, the maximum stress was found within screw #2. In the parallel models, the stress within screw #2 was reduced and appeared to be dispersed to screw #4. In the perpendicular models, the maximum stress was found in the middle of the inferior plate. Among these models, there were no statistically significant differences in stress within screw #2, although there was a trend for the stress to be lowest in the perpendicular models and highest in the single models. The lowest maximum stress around screw hole #2 was found in the perpendicular models, followed by the parallel models, and finally the single models; these differences were significant. (Table 2)

## Discussion

The main goal in the treatment of any fracture is to predictably restore pre-injury anatomical form with associated aesthetics and function. The concept of bone plating has changed over time, with the introduction of various modifications. Sequentially, bone plates such as compression plates, dynamic compression plates, eccentric, dynamic compression plates, miniplates, and microplates have been introduced, but miniplates are the ones most commonly used.<sup>16,17</sup> There are two fundamentally different philosophies for the treatment of mandible fracture

using plates and screws: rigid fixation using compression plates, semi-rigid fixation using miniaturized malleable plates. Luhr felt that mini plates did not offer adequate stabilization of the fractures, thereby necessitating the need for further inter-maxillary fixation.<sup>18</sup> The purpose of surgical fixation for mandibular fractures is to secure the reduced fragments during osteogenesis to permit sound healing. Inevitable frequent masticatory loads can cause motion at the fracture site, and interfere with the healing process.

As a result, non-union can occur in symphysis fractures, the rate of which has been reported to be 3.7%.<sup>19</sup> Inadequate stabilization or reduction was an important cause of nonunions.<sup>20</sup> Therefore, we sought the most effective fixation method to stabilize a fracture, which results in less mechanical stress on the mandible, in this study. The para-symphysis is one of the most frequent sites of mandibular fractures in children, and comprises about 20% of adult mandibular fractures. Para-Symphysis fractures with displacement are often fixed with 1 or 2 miniplates. Although there have been some reports on mechanically appropriate positions for miniplates in mandibular angle and condyle fractures, few such studies exist for para-symphysis fractures.<sup>21</sup> In this study, we created 3-dimensional mandibular models to simulate the 3 fixation techniques. In vivo strain gauge measurements are alternatives to FEA,<sup>22</sup> but stress-measuring areas and the number of measuring devices are limited due to the volume of the gauge. FEA permits an analysis of stress from arbitrary points, and provides other useful information such as on distances, stress, and behaviour of the whole model. The parallel miniplates models demonstrated significantly less stress than the single miniplate models in both the screw/plating system and bone screw holes, but no significant difference was found in the gap at the upper borders of the fractured surfaces. The perpendicular miniplate models also demonstrated less stress than the single miniplate models in both the screw/plating system and bone screw holes, while having significantly smaller gaps at the upper border of the fractured surfaces. These data indicate that double miniplate fixation can lead to better stability regardless of plate position, however, more stress would occur around bone screw holes in parallel miniplates fixation.

## **Conclusion**

Therefore, in the perpendicular models, less stress occurred around bone screw holes, despite no difference being found within the screw/plating systems between the perpendicular models and the parallel models.

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## Tables

Table 1  
Material Properties Used for the Calculations

	Elastic Modulus (MPa)	Poisson's Ratio
Cortical Bone	8700–15000	0.3–0.33
Cancellous Bone	500–1500	0.3
Titanium	105000–110000	0.34–0.35

\*MPa; Mega Pascal.

Table 2  
Maximum von Mises Stresses at #2 Screws and Screw Holes and Gaps between the Fractured Surface in the Different Plates Fixation

Fixation <i>Positions of plates</i>	Single plate		Double plates			
	<i>Median</i>	<i>Range</i>	Parallel		Perpendicular	
			<i>Median</i>	<i>Range</i>	<i>Median</i>	<i>Range</i>
Maximum stress at #2 screw (MPa)	15.50	8.7–16.4	10.32	4.6–17.0	7.97	6.2–12.5
Maximum stress at #2 screw hole (MPa)	13.91	7.0–21.4	6.6	3.8–8.8	2.61	1.2–4.4
Gap between the upper borders of the fractured surface (mm)	0.293	0.22–0.6	0.255	0.14–0.42	0.171	0.01–0.31