Finite element analysis of rhombic plate versus two miniplates in treatment of subcondylar fracture

Original Article

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ABSTRACT

Objective: This study aimed to compare by finite element analysis between rhombic condylar plate and standard two miniplate in subcondylar fixation through measuring the stresses on the plate, the stresses transmitted to bone and fracture displacement.
Material and methods : Two mandibular models were created through Mimics software. Model I: a five-hole Rhombic non locking Plate and model II: Two four-holes miniplates. The process of finite element analysis was done by ANSYS 18.0 software.
Results : The highest stress on the plates were in rhombic plate. While the stresses on screws was higher on screws A in rhombic plate while higher on screws B in miniplates. The maximal bone stress was the highest in the rhombic plated model. Displacement was slightly higher in the rhombic plate model.
Conclusion: The rhombic plate showed a higher stress than the two miniplates that was mainly because of the less hardware and numbers of screws in rhombic plate model.

Key Words: Subcondylar fracture, Three-dimensional plate, Rhombic plate, miniplates

Received: 13 October 2022, **Accepted:** 4 December 2022.

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ISSN: 2090-097X, October 2022, Vol. 13, No. 4

INTRODUCTION

Condylar fractures are one of the common mandibular fracture.[1] The management of such fractures is challenging and have many debates.[2]

The concepts for condylar fracture management have changed in the last decades. Open reduction and closed fixation has been considered the treatment of choice. [3] Several plates designs and configuration has been used in subcondylar fixation.

The two miniplates with a nonparallel configuration has been the standard fixation method used. [3- 4]

In an attempt to decrease the plates hardware, 3-dimensional plates have been invented. As a result, less surgical access and bone dimensions is required for fracture fixation.

Although some finite element studies proved superiority of two miniplates over all other hardware designs, The 3-dimensional designs have been reported to have a similar or better performance than 2 miniplates in form of clinically reliable fixation, less surgical access, shorter surgical time and less bone dimensions required with easier application.[5- 6] That provides the advantage of easier placement especially in the small proximal segments.[17]

Moreover, it offers reduction of the total treatment fees, as it has cheaper hardware and shorter operative time as less plate and screws are required.[18][7]

A rhombic 3D plate was introduced as a modification to the delta plate, changing the three sided delta shape into a four sided rhombic design and adding an extra screw to improve stability and biomechanical properties of the plate. The rhombic plate is also available in both non locking and locking forms.

The non-locking rhombic plate has screw adjustments in form of two gliding holes which compress the fracture, provide better interdigitation of the fracture ends and accelerate bone repair.[7]

The manufacturer mentioned that the most important feature that the plate take into account the various tensile and compressive forces.[8] Finite element analysis (FEA) is a computational method for predicting mechanical behavior of the plate and the bone.[9] Several studies compared different types of plates for condylar fractures internal fixation through FEA.

 DOI: 10.21608/OMX.2022.168591.1172

[10- 11] It can test different fixation systems to anticipates any future failure or complication before applying them to patients.[12] Rhombic plate has been compared to the gold standard two miniplates treatment by finite element analysis in few studies.[13- 14] In the current study, biomechanical assessment of the rhombic miniplates versus two miniplates in subcondylar fracture fixation using FEA in form of measuring stresses on plate, the stresses transmitted to bone and fracture displacement.

MATERIAL AND METHODS

A twenty-five-year-old male patient having a fully dentate was selected from the outpatient clinic, Oral and Maxillofacial Surgery Department, Faculty of Dentistry, Alexandria university. Computed Tomography (CT) scanning of the patient was used to obtain an accurate three dimensional (3D) digital model of the mandible through MIMICS software. Two models were used in this study in which subcondylar fracture was fixed by:

Model I: a five-hole Rhombic 3D Condylar Fracture* non locking plate.

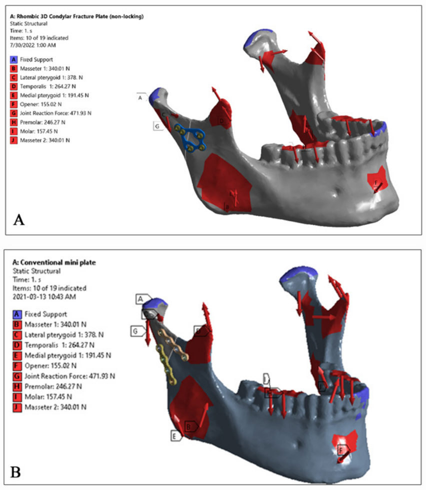
Model II: Two four-holes 2 mm miniplates*.

* KLS Martin

Finite element analysis process was carried out by ANSYS 18.0 software. All the materials used in the model including the bone, miniplates and screws were assumed to be isotropic, homogenous and linearly elastic. During this process each model was divided into small parts called elements connected together at points called nodes forming an unstructured mesh.

The forces exerted by contracting muscles were represented by vectors. Following the creation of the 3D meshes and defining the loads, a boundary condition was defined in such a way that all movements at the condyles of the mandible were restrained during load application and only rotational movement was allowed for the analysis purpose (Figure 1).

Figure 1: Showing muscular force (red arrow) and constraints (blue colored) applied in finite element simulation (A) rhombic plate (B) two miniplates.

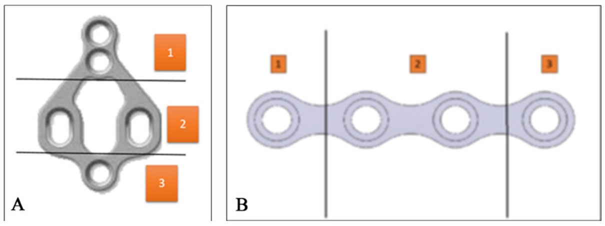


Analysis of the study models was performed regarding two major parameters ; stress (Von Mises Stress and Maximum principal stress) and displacement. A color scale for the von Misses stress (MPa) and displacement (μm) was used.

RESULTS

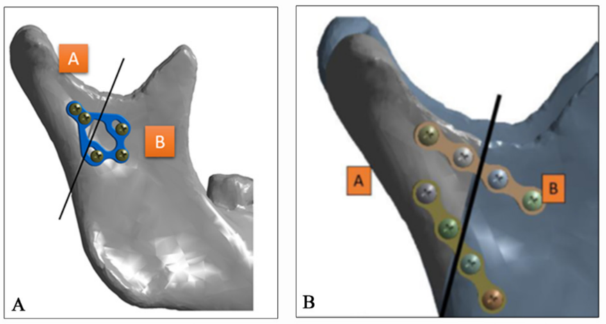
FEA findings indicate that stress distribution on miniplates and screws showing various values for von misses stress, so to make it easier the model was divided into three regions upper, middle and lower as shown in (Figure 2).

Figure 2: Showing region distribution for (A) rhombic plate (B) miniplate.



The screws on the plate were separated as well to an upper screws (A) and lower screws (B) as shown in (Figure 3).

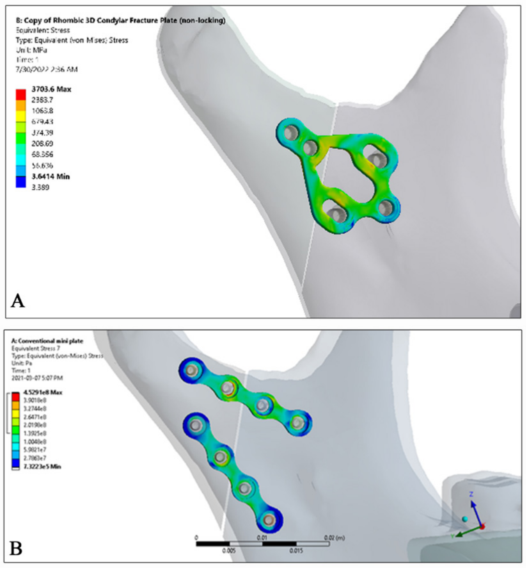
Figure 3: Showing screws regional distribution for (A) rhombic plate (B) miniplate.



a.Stresses induced on the two miniplates and screws:

The results of this study revealed that there was a significant difference in the values of Von Mises stresses induced on Rhombic 3D Condylar Fracture on all three areas during the clenching task. The highest stress in both rhombic plate and miniplates was at the middle area [2] of the plate (457.7 MPa in rhombic model and 269.55 MPa in two miniplate model). (Figure 4)

Figure 4: Showing Von mises stresses induced on plates (A) rhombic plate (B) two miniplate during clenching task application.



The screws at the condylar area (A) of the rhombic plate has higher stresses 293.35 MPa than miniplate 209.49 MPa. The screws at the ramus area (B) of the rhombic plate has lower stresses 233.26 MPa than at miniplate 274.18 MPa.

b. The maximum principal stresses on bone:

At area (A), the maximum principal stresses transmitted to the bone at the rhombic model was 319.79 MPa and two miniplates generated 79.48 MPa. At area (B), rhombic plate showed 286.56 MPa stress while two miniplate generated 69.7 MPa

c. Displacement:

Rhombic model reflects a displacement with 218.75 µm around the fracture line during the clenching task, while two miniplates model had a slightly less displacement with 207.3 µm. (Figure 5)

Figure 5: Showing displacement distribution induced on the fracture surface of (A) rhombic plate (B) two miniplate during the maxillofacial tasks.

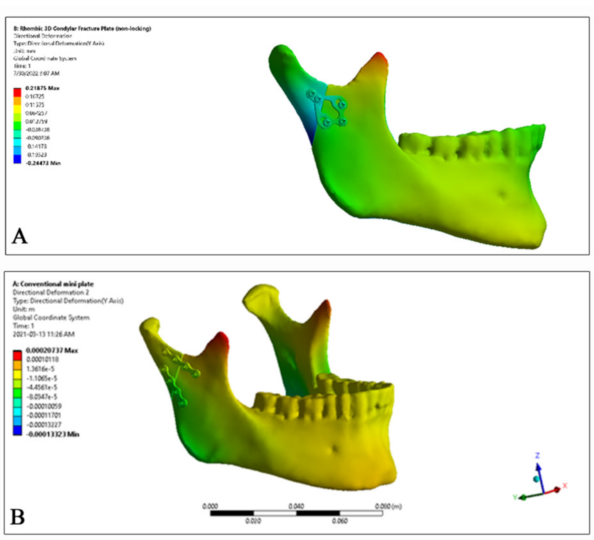


Table 1: finite element analysis values of von misses stress (Mpa) and displacement (µm)

	tow miniplate	Rhombic
von misses (plate)		
Area 1	89.5	380.41
Area 2	269.55	457.7
Area 3	54.59	210
von misses (screws)		
A	209.49	293.35
B	274.18	233.26
Maximum principal stresses on bone		
Bone surrounding (A)	79.48	319.79
Bone surrounding (B)	69.7	286.56
Displacment		
clencling	207.3	218.75

DISCUSSION

In condylar fracture there are different fixation systems used. It is well proven that two miniplates with an non parallel position provide a stable fixation to the fracture.[4]Nowadays, there are the 3D condylar plating system that provides a satisfactory stability with some extra advantages related to the less material and size in addition to resisting the stresses in three dimensions.[15]Conflicts of interest

Finite element analysis studies the internal stress of bones and plates by a biomechanical analysis which cannot be obtained from in vitro studies.[16]Our FEA results have shown that the use of rhombic plate in condylar fracture does not exceed neither the yield stress nor the fatigue limit of titanium. The yield stress of titanium is 934 MPa and fatigue limit is 9001000- MPa .[14]That means that the rhombic plate can withstand different masticatory stresses during the healing of the fracture.

The maximum stress for both models were concentrated at the middle area. The rhombic plate showed much higher stress but more homogeneous distribution than two miniplates same as what Abdelwahab et al [14] was found in his study.

That may be due to the smaller size of the rhombic plate.

The screws stresses at the condylar area (A) were higher at the rhombic model than the two miniplates model that may be due to the vertical configuration of the upper part of rhombic plate and the concentration of the stresses on only 2 screws versus 4 screws in the miniplates model. While at the ramus area (B) the rhombic plate has lower stresses than at miniplate as the configuration and the screws number were nearly equivalent on both models.

The highest maximal bone tension was on rhombic plate and the least tension was in the two miniplate model same as Ergezen et al.[13] The displacement was slightly higher with only 10 µm in the rhombic plate system than the two miniplate model same as other studies. [13-14]

The displacement between the proximal and distal segments indicates of the stability of osteosynthesis. That indicates that the rigidity of the rhombic plates was satisfactory despite the higher stresses found in the plate and bone. In conclusion, Rhombic plate shows higher stresses than two miniplates. Regarding the rigidity,

rhombic plate provides a satisfactory stability for subcondylar fracture. In addition, the other advantages in the clinical setting due to the practical small size which needs a smaller approach and bone area to be applied intraoperatively.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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