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FINITE ELEMENT MODELING OF PATIENT-SPECIFIC MANDIBULAR PLATES FOR CONDYLAR FRACTURE

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Abstract: *Condyle fractures are the most common type of mandibular fracture. This study aims to evaluate the biomechanical performance of four proposed designs and ensure the optimum plate design. Four models were constructed using CAD software (Plates A, B, C, and D). A normal chewing force (100 N) was applied to the first molar location of the non-fractured site. Stresses in plates and reaction forces at the left and right mandibular necks were evaluated using finite element method. Results showed that the lowest peak von Mises stress was in plate D (217 MPa), while the highest stress was with plate A (351 MPa), followed by plate C (250 MPa), then plate B (287 MPa). Higher reaction forces were on the left side non-fracture side. Plate B showed the highest reaction force in the fracture side (33 N), while the lowest value was with plate A, followed by plate C and D (20 N). For the mandibular movement, plate B showed less displacement. It was concluded that among the four designs, plate D demonstrated lower stress distribution and lowest micromotion at the fracture gap compared to the other plates.*

Keywords: Condyle fracture, Plate, Finite element, Stress, Biomechanics

1. Introduction

The mandible forms the lower portion of the face and is essential not only for facial aesthetics but also for key functions such as chewing, speaking, and keeping the airway open. As a result, damage to the mandible can severely impact both appearance and overall quality of life (Conforte et al., 2016). Mandibular fractures are grouped based on location into symphysis, parasymphysis, body, angle or ramus, and condylar process fractures. Fractures at the top of the condyle are called intracapsular or diacapitular, and those at the bottom are called subcondylar fractures. About 20 to 40% of all mandible fractures happen in the condyle. Various techniques for osteosynthesis have been proposed for the surgical treatment of condylar fractures, ranging from miniplates (Brito et al., 2025)(Leonhardt et al., 2025) to various types of screw and resorbable polylactide pins (McLeod & Saeed, 2016), as well as titanium-based cannulated headless bone screws (Franke et al., 2025). This can be considered as an open reduction and internal fixation technique for mandibular condyle fracture, which is beneficial for restoring the jaw functions, and it is the standard treatment approach so far (Alyahya et al., 2020). However, the management of fractures involving the mandibular condyle is a subject of significant debate within the field of maxillofacial trauma (Bhatti et al., 2025).

In the present study, our primary aim was to compare various bone plate designs that can be planned preoperatively using patient-specific CAD/CAM technology for the osteosynthesis of subcondylar fractures. By using finite element analysis, we aimed to evaluate the biomechanical performance of the four plate designs and ensure the optimum one.

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2. Materials and methods

2.1. Construction of 3D models

Cone beam computed tomography (CBCT) scan model of the mandible was obtained from 3D Slicer 5.8.0 software (CBCT-MR library). The datasets were donated to 3D Slicer by medical institutions for public access and are available without restrictions, ensuring compliance with ethical standards (Fedorov et al., 2012). As these datasets do not contain private or identifiable patient information, the study adheres to ethical guidelines for using open-access medical data. Semi-automatic segmentation was performed to reconstruct the STL file of the mandible. The 3D geometry was offset by 1.5 mm to create the internal architecture of the cancellous bone, while the external layer was considered as cortical bone. The bone was split with a 0.5 mm gap (Mehboob et al., 2025) to create a condyle fracture. The plate thickness was modeled as 1 mm with a length of 20 mm (Jung et al., 2020), as shown in Fig. 1(a). The length and diameter of the screw were 6.0 mm and 2.0 mm, respectively. Four plate models were constructed with the same thickness but different shapes, as shown in Fig. 1(b). Mechanical properties of bones, screws, and plate was taken from a previous study conducted by Jung et al. (Jung et al., 2020).

2.2. Computational modelling

Chewing and biting forces can vary significantly with age, with younger individuals typically exerting lower forces compared to adults. In this study, a normal chewing force of 100 N (Orassi et al., 2022) was applied at the first molar location, as shown in Fig. 1(c). Muscle forces were not considered in this work. The tie contact was applied between the screws and the plate, as well as between the screws and the bone, assuming full osseointegration. The proximal ends of the left and right mandibular necks were fully constrained in all directions to simulate fixation and eliminate rigid body motion. All components in the model were meshed with tetrahedral elements using ABAQUS 2017 (Dassault Systemes, France, Abaqus), except for the plates, which were meshed with hexahedral elements.

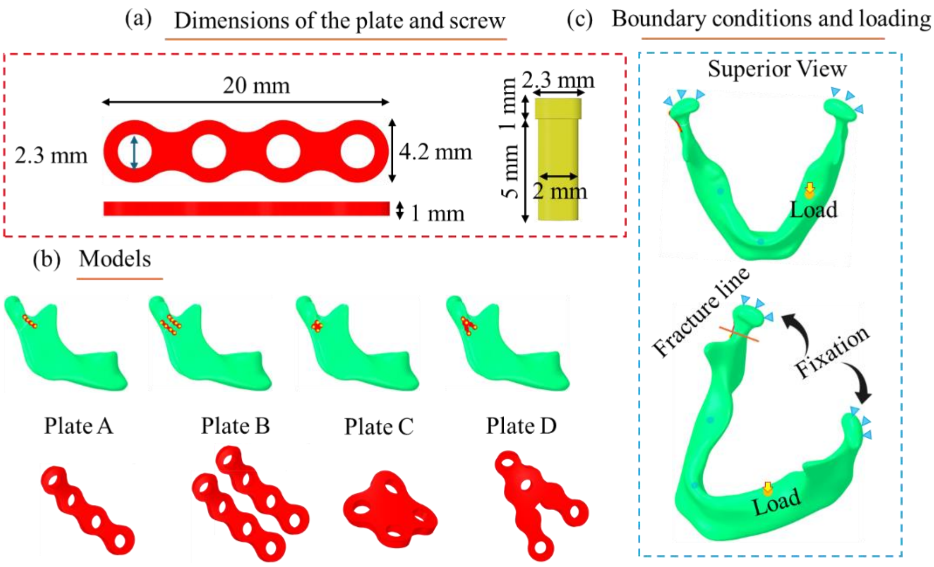

Fig. 1: Finite element models. (a) Dimensions of the plate; (b) Various plate models and (c) loading and boundary conditions.

3. Results and discussion

von Mises stress distribution in the plates is shown in Fig. 2(a). The highest von Mises stress of 351 MPa was observed in plate A, the straight single plate, with stress concentrated at the center of the plate, where it maintains the gap between the bones at the gap location. In contrast, plate D exhibited the lowest von Mises stress of 217 MPa. This plate features a lambda-shaped structure, which helps to distribute the load more effectively. Plate B, consisting of two straight plates, had a maximum stress of 287 MPa, while plate C, with a square structure, showed a maximum stress of 250 MPa.

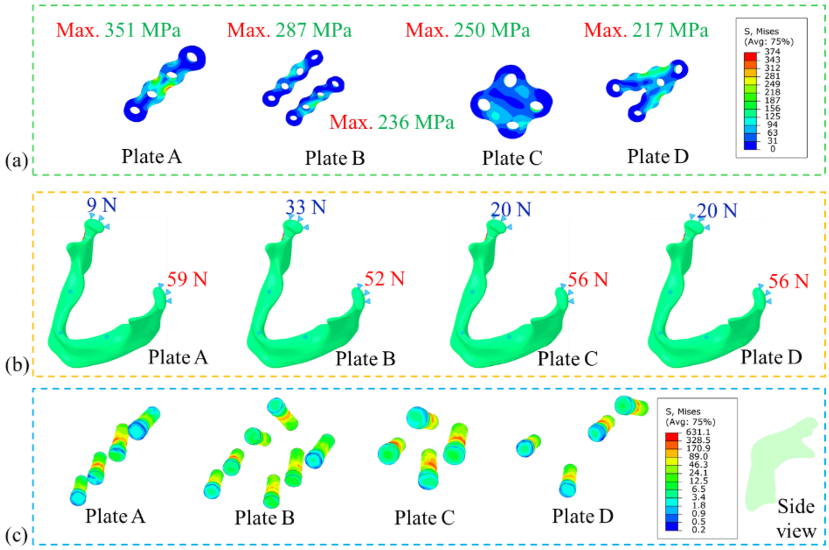

Fig. 2: (a) von Mises stress distribution in all plates; (b) reaction forces at mandibular neck and (c) von Mises stress in screws.

Figure 2(b) shows the reaction forces at the left (non-fractured) and right (fractured) sides of the mandibular neck. It can be observed that the non-fractured side, where the load was applied, generally exhibited higher reaction forces. In some cases, patients may be unable to bite or chew on the fractured side, which can affect the movement of the mandible and stress transfer to the plate. Notably, plate B demonstrated a higher reaction force on the fractured side compared to the other designs, likely due to its double straight-plate configuration. Additionally, the patient's mandibular geometry, which is not perfectly symmetrical between the left and right sides, may also influence the biomechanical performance of the plates.

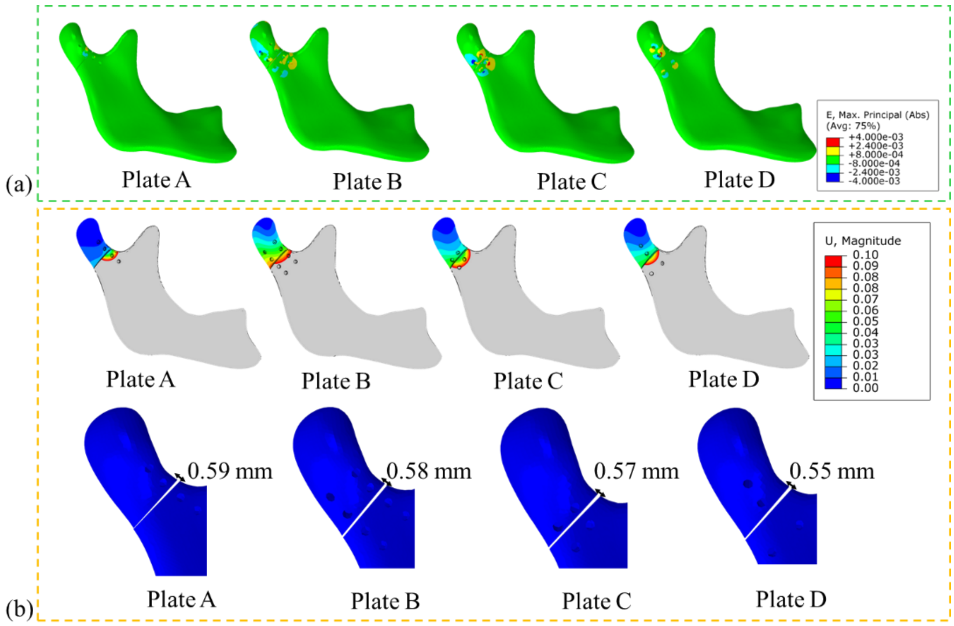

Fig. 3: (a) Maximum principal strain in mandible and (b) displacement within the mandibular condyle.

Figure 2(c) showed von Mises stress in screws. The stress values in all screws remain below the yield strength of titanium, indicating that the screws are safe under the applied loading conditions. Figure 3(a) shows the maximum principal strain in mandible. Plate A showed lower strain at the bone–screw interface, indicating reduced fixation stability. In plate B, the strain exceeded 0.4%, the typical strain limit of human cortical bone (Liokatis et al., 2021), in only one screw region. Plate C exhibited higher strain at all bone–screw interfaces, whereas plate D showed increased strain in only one screw region. Figure 3(b) shows the displacement within the mandibular condyle. Plate A showed a larger gap between the two bone segments at the fracture site, while plate D showed less compared to other plates, this suggests better approximation of the bone segments and potentially improved load sharing between the bone and the fixation plate and screws.

This study compared four different plate designs for condylar fractures. The analysis has certain limitations, including the exclusion of muscle forces and the assumption of linear elastic properties for the bone tissue. Moreover, the cortical bone of the mandible does not have uniform thickness across its anatomical regions, which may influence the stress distribution in the screws and plates. Future studies should focus on callus gap healing, topology optimization of bone plate designs, and validation through in-vitro experiments.

4. Conclusion

Among the four plate designs evaluated for condylar fractures, plate D (lambda-shaped) demonstrated lower stress distribution and lowest micromotion at the fracture gap compared to the other plates.

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References

Alyahya, A., Bin Ahmed, A., Nusair, Y., Ababtain, R., Alhussain, A., & Alshafei, A. (2020). Mandibular condylar fracture: a systematic review of systematic reviews and a proposed algorithm for management. *British Journal of Oral and Maxillofacial Surgery*, *58*(6), 625–631. https://doi.org/10.1016/j.bjoms.2020.03.014

Bhatti, N., Mohamedbhai, H., Poon, X., Khan, P., der Cruyssen, F. Van, & Holmes, S. (2025). Open management of condylar head fractures. The first 50 cases: What have we learnt and where are we going? *British Journal of Oral and Maxillofacial Surgery*, *63*(1), 19–24. https://doi.org/10.1016/j.bjoms.2024.08.005

Brito, G. C., de Assis, A. F., & de Moraes, M. (2025). Assessment of the trapezoidal miniplate with posterior extension for open management of condylar fractures: Can it be used instead of straight miniplates? *Oral Surgery*, *18*(2), 159–168. https://doi.org/10.1111/ors.12934

Conforte, J. J., Alves, C. P., Sánchez, M. delP. R., & Ponzoni, D. (2016). Impact of trauma and surgical treatment on the quality of life of patients with facial fractures. *International Journal of Oral and Maxillofacial Surgery*, *45*(5), 575–581. https://doi.org/10.1016/j.ijom.2015.11.022

Franke, A., Matschke, J. B., Sembdner, P., Seidler, A., McLeod, N. M. H., & Leonhardt, H. (2025). Long-term outcomes of open treatment of condylar head fractures using cannulated headless bone screws—a retrospective analysis. *International Journal of Oral and Maxillofacial Surgery*. https://doi.org/10.1016/j.ijom.2025.01.018

Jung, B. T., Kim, W. H., Park, B., Lee, J.-H., Kim, B., & Lee, J.-H. (2020). Biomechanical evaluation of unilateral subcondylar fracture of the mandible on the varying materials: A finite element analysis. *PLOS ONE*, *15*(10), e0240352. https://doi.org/10.1371/journal.pone.0240352

Leonhardt, H., Matschke, J. B., Bräuer, C., Remschmidt, B., McLeod, N. M. H., Lauer, G., & Franke, A. (2025). Treatment of mandibular condyle fractures with a rhombic 3D condylar fracture plate – Does the surgical approach matter? *Journal of Cranio-Maxillofacial Surgery*, *53*(5), 533–542. https://doi.org/10.1016/j.jcms.2025.01.029

Liokatis, P., Tzortzinis, G., Gerasimidis, S., & Smolka, W. (2021). Finite Element Analysis of Different Titanium Plates for Internal Fixation of Fractures of the Mandibular Condylar Neck. *Journal of Oral and Maxillofacial Surgery*, *79*(3), 665.e1-665.e10. https://doi.org/10.1016/j.joms.2020.09.038

McLeod, N. M. H., & Saeed, N. R. (2016). Treatment of fractures of the mandibular condylar head with ultrasound-activated resorbable pins: early clinical experience. *British Journal of Oral and Maxillofacial Surgery*, *54*(8), 872–877. https://doi.org/10.1016/j.bjoms.2016.05.027

Mehboob, A., Barsoum, I., Mehboob, H., Ouldyerou, A., & Abu Al-Rub, R. K. (2025). Computational modelling and optimization of porous plates for mandibular fracture fixation accounting for bone healing. *Materials & Design*, *254*, 114060. https://doi.org/10.1016/j.matdes.2025.114060

Orassi, V., Fischer, H., Duda, G. N., Heiland, M., Checa, S., & Rendenbach, C. (2022). In Silico Biomechanical Evaluation of WE43 Magnesium Plates for Mandibular Fracture Fixation. *Frontiers in Bioengineering and Biotechnology*, *9*. https://doi.org/10.3389/fbioe.2021.803103