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Humerus Compression Plate Analysis Using ANSYS Software

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Abstract

A compression plate is a type of orthopaedic implant used to fix bone fractures. It is a metal plate that is screwed onto the surface of the bone to hold the broken pieces together and promote healing. They are available in different shapes and sizes to fit the specific bone and fracture pattern. Certain aspects of the humerus, such as overall length and the angles of curvature, can vary among individuals. Additionally, the size and prominence of muscle attachment sites on the bone can differ based on factors like genetics, age, and lifestyle. The study addresses the absence of research on the load applied to the design of humerus compression plates at 0º and 30º. Existing Finite Element (FE) studies on proximal humeral plates have predominantly focused on aspects such as screw configuration, bone cement augmentation, and optimization of implant design and properties. This study employs ANSYS software to conduct a thorough analysis of humerus compression plates with 30º and 0º configurations, focusing on equivalent von Mises stress and displacement under various loading conditions. Results indicate that the 0º abduction load yields significantly lower equivalent von Mises stress compared to adduction, extension, flexion, and axial compression, suggesting superior biomechanical performance. Additionally, the investigation reveals that the 30º compression plate exhibits the most favourable displacement characteristics during axial compression, emphasizing its potential as the preferred design for enhanced stability in clinical applications. These findings contribute valuable insights to the optimization of humerus compression plate design, guiding advancements in orthopaedic implant technology and ultimately improving patient outcomes.

1. Introduction

The humerus bone, situated in the upper arm between the shoulder and the elbow, plays a crucial role in arm and shoulder mobility, being the longest bone in the arm. Fractures are common, often resulting from direct impacts (Seladi-Schulman, 2022). Among young patients, humerus fractures account for 4 to 6% of all fractures, while in the elderly, the figure is 1 to 3%, potentially leading to permanent disability (Attum, 2022 and Roland, 2018). Surgical intervention, particularly plate fixation, is reserved for specific cases, such as open fractures or those involving multiple traumas (Nowak et al., 2018). Compression plates, usually made of titanium or surgical-grade stainless steel, are employed in stable fractures to eliminate interfragmentary motion and provide

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absolute stability (International Center for Limb Lengthening, 2023). However, the specific study of humerus compression plate designs at 0° and 30°, crucial for understanding their mechanical behavior, has been lacking.

The research aims to fill this gap by utilizing Finite Element Method (FEM) analysis through ANSYS software to explore the stress on the plate under various mechanical loads. The study focuses on 0° and 30° metal plate designs, employing static analysis to measure stress without arm movement. The investigation extends to assessing the structural integrity of the plate under a cracked humerus bone, analysing equivalent Von Misses stress and displacement. This project's significance in contributing to the orthopaedic sector, particularly in plate fixation surgeries for humerus fractures, offering insights into the performance of compression plates under different loading scenarios. The anticipated results include a comprehensive analysis of equivalent Von Misses stress and displacement on the compression plate under varied mechanical loading conditions. Social sustainability is a key consideration, aligning with the principle of "Putting people first" in development processes, addressing the needs of individuals with broken arms and emphasizing the societal benefits of this study (Tadeusz Stolarski et al., 2006).

This paper focusing on the humerus bone, fractures, and various compression plates used in surgical interventions. It begins by explaining the anatomy of the humerus bone and the significance of compression plating for stable bone healing. Two commonly used compression plates, Locking Compression Plate (LCP) and Dynamic Compression Plate (DCP), are introduced, with details on their design and applications (Sommer et al., 2003). The review delves into types of humerus fractures, such as proximal, midshaft, and distal fractures, providing insights into their characteristics and classifications. The chapter also explores the Finite Element Method (FEM) as an analytical tool, emphasizing its application in understanding the mechanical behaviour of compression plates. Three types of finite element compression plates such as LCP, DCP, and Limited Contact Dynamic Compression Plate (LCDCP) are detailed, along with their features and materials.

The Standard Plate Technique, guided by the principles of the AO (DePuySynthes, 2021). The steps involve fracture reduction, plate bending, positioning, and screw insertion, with variations for neutral and eccentric drill guide positions. The literature review concludes with an overview of FEM studies, highlighting specific research models and findings related to compression plates' stress distribution in humerus fractures. Overall, this chapter serves as a foundation for the subsequent research, providing a comprehensive understanding of the anatomical and biomechanical aspects related to humerus fractures and compression plate applications.

2. Methodology

There are two software that are used to complete this project, which are ANSYS and SolidWorks. ANSYS software is being used to analyse stress and SolidWorks software to design new compression plate. The stress data related for this project is gathered from the previous research and will be compared with new plate design analyse. There are two main software involved in this project which are SolidWorks and Ansys. The SolidWorks focus on the design of the compression plate and the Ansys focus on the analysis of the plate with the bone. In this project, SolidWorks software is used to design and draw the compression plate. The compression plate is also attached to the humerus bone in the SolidWorks shown in Fig. 1. Fig. 2 shows the compression plate and humerus bone imported from SolidWorks into the Ansys software to do the analysis of von Mises stress on the plate. By using this ANSYS software, the data of equivalent Von Misses stress and displacement will be extracted and compared.

Fig. 1 *Compression Plate with Humerus*

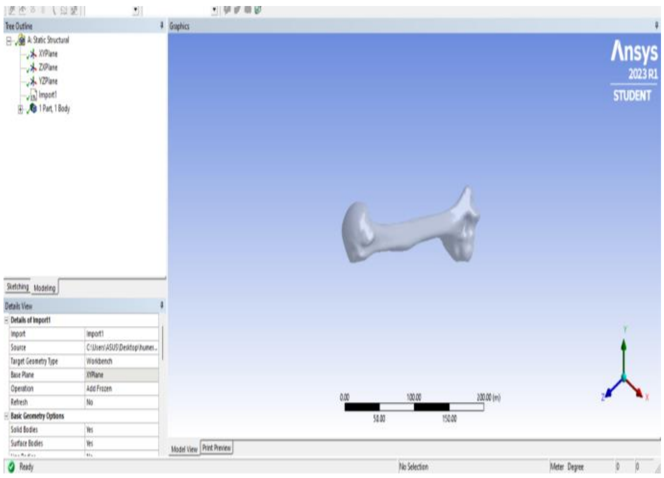


Fig. 2 *Humerus Bone in Ansys Software*

Based on Fig. 3, the dimension of compression plate is 110×12×2.5mm. Both compression plate designs, which are 0º and 30º, have the same density, mass, and volume for this research. The density of both plates is 0.008027g/mm³, while mass is 17.8g and volume of 2216.98 m³. However, the plate design is different in terms of surface area due to the degree on the plate. The material chosen for the plate in this project is stainless steel because of its cost-effectiveness. Table 1 shows the stainless-steel parameters that being used during the analysis. The 0-degree compression plate design is a flat plate shown in Figure 4(a) and 4(b). This compression plate surface area is 3246.88mm^2 with 36811 nodes in finite element. The 30º compression plate design is slightly bent from 0º plate design, which is shown in Figure 4(c) and 4(d). This compression plate surface area is 3250.53mm^2 with 4511 nodes in finite element.

Table 1 *Stainless Steel Parameters*

Parameter	Value
Young Modulus	1.93×10^5 MPa
Yield Strength	207 MPa
Poisson's Ratio	0.3
Mesh Size	3mm

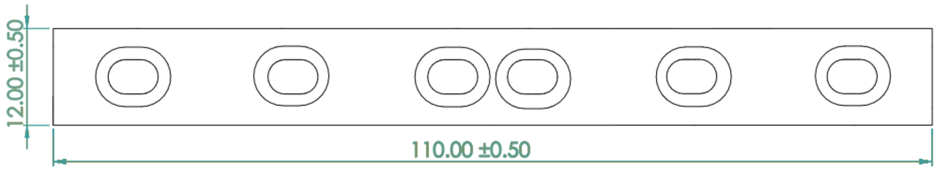


Fig. 3 *Top View of Compression Plate*

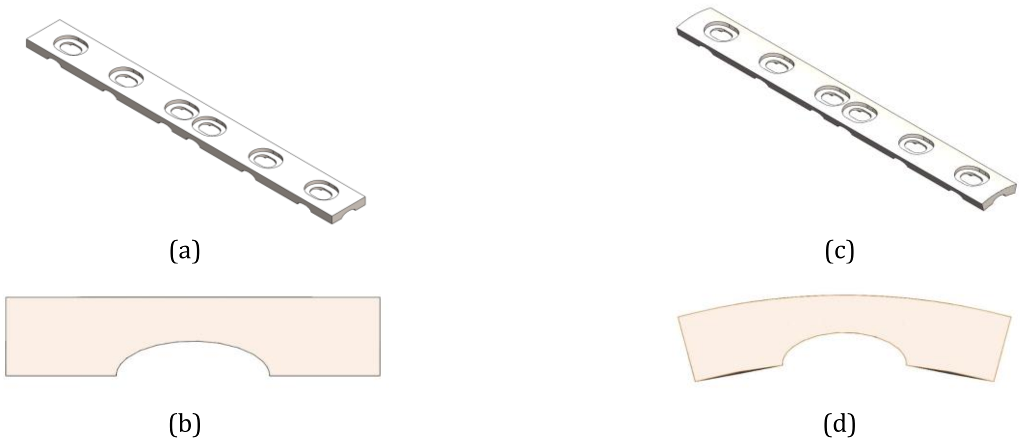


Fig. 4 0º compression plate, *(a) isometric view; (b) right side view and* 30º compression plate, *(c) isometric view; (b) right side view*

2.1 Bone Specifications

Compressive loads were applied to the humerus model to replicate the flexion, extension, abduction, and adduction as well as the axial compression illustrated in Fig. 5. To replicate the effects of muscle abduction, adduction, flexion, and extension, 100N loads were applied to the humerus shaft in four different directions. Furthermore, axial compression was simulated by applying 200N loads to the humerus' ends. Table 2 shows the humerus bone parameters that undergoes Ansys analysis. The distance between humerus proximal and humerus distal is 1mm which is in midshaft area.

Table 2 *Humerus Bone Parameters*

Parameter	Value
Young Modulus	1.3GPa
Poisson's Ratio	0.3
Mesh size	10mm

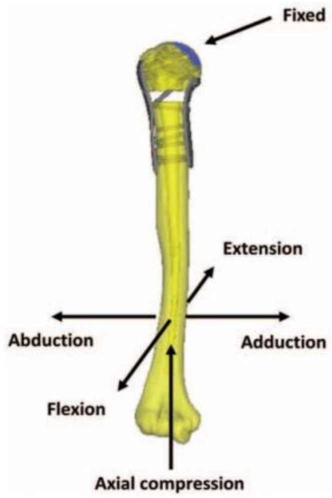
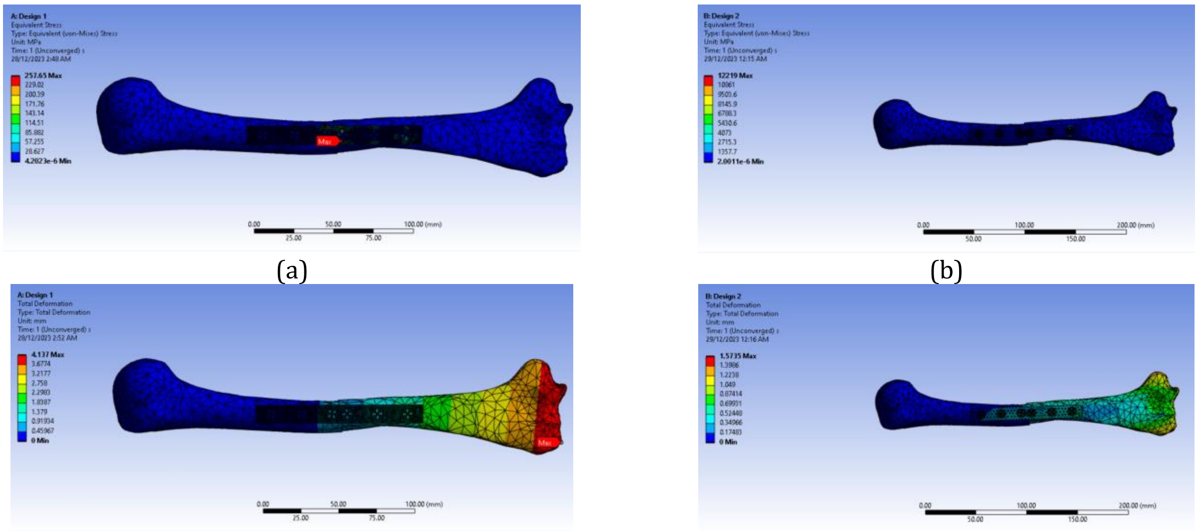


Fig. 5 *The shoulder joint's functions, including abduction, adduction, flexion, extension, and axial compression, were simulated using compressive loads on the humerus model.* (He et al., 2025).

3. Result and Discussion

3.1 Flexion Load

Fig. 6(a) shows the result of equivalent Von Misses stress based on flexion load on 0° compression plate and Fig. 6(b) shows the result of flexion load on 30° compression plate. Based on Figure 6, the equivalent Von Misses stress on 0° compression plate is lower (257MPa) than 30° compression plate (12219MPa). This result shows flexion load on 0° compression plate is better compared to 30° compression plate as the difference between these two plates is 11961.35 MPa. This result concludes that 30° compression plate is not suitable for flexion load. Fig. 6(c) shows the result of displacement based on flexion load on 0° compression plate and Fig. 6(d) shows the result of flexion load on 30° compression plate. Based on the Fig. 6, the displacement on 0° compression plate is higher (4.1mm) than 30° compression plate (1.5mm). This result shows flexion load on 30° compression plate is better compared to 0° compression plate as the difference between these two plates is 2.5635mm. In conclusion, 30° compression plate is suitable for flexion load.



(a) (b)

(c) (d)

Fig. 6 *(a) 0° Compression; (b) 30⁰ Compression, (c) 0° Compression Plate and (d) 30° Compression Plates.*

3.2 Extension Load

Fig. 7(a) shows the result of equivalent Von Misses stress based on extension load on 0° compression plate and Fig. 7(b) shows the result of extension load on 30° compression plate. Based on Fig. 7, the equivalent Von Misses stress on 0° compression plate is lower (2592MPa) than 30° compression plate (4552MPa). This result shows extension load on 0° compression plate is better compared to 30° compression plate as the difference between these two plates is 1960MPa. This result concludes that 30º compression plate is not suitable for extension load. Fig. 7(c) shows the result of displacement based on extension load on 0º compression plate and Fig. 7(b) shows the result of extension load on 30º compression plate. Based on Fig. 7, the displacement on 30º compression plate is higher (4.2mm) than 0º compression plate (2.1mm). This result shows extension load on 0º compression plate is better compared to 30º compression plate as the difference between these two plates is 2.1mm. In conclusion, 30º compression plate is not suitable for extension load.

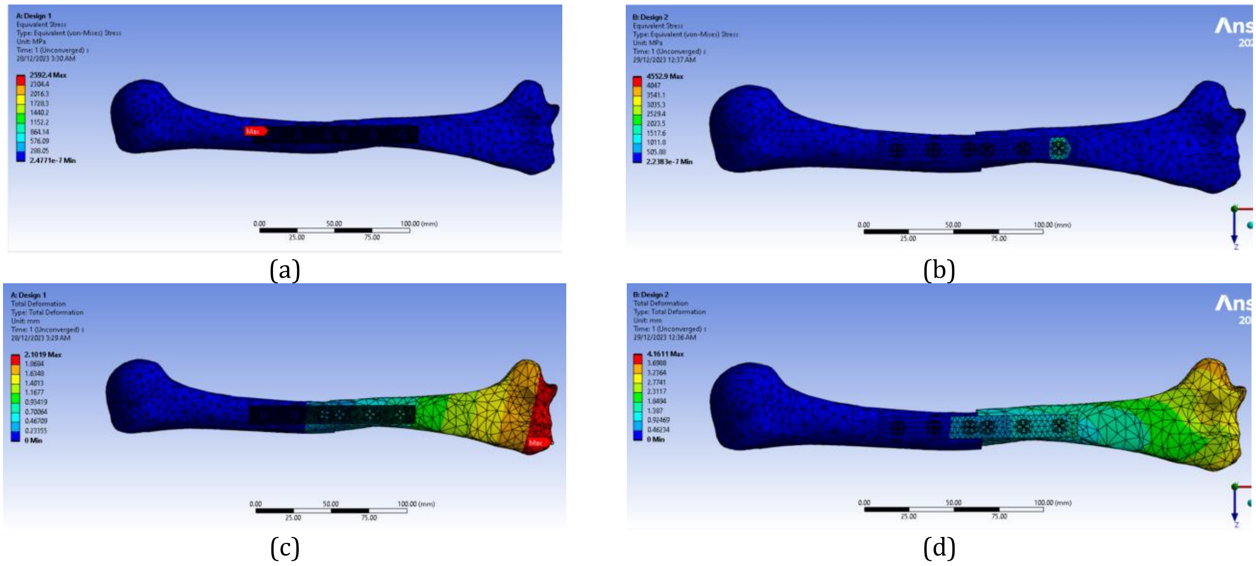


Fig. 7 *(a) 0º Compression; (b) 30⁰ Compression, (c) 0º Compression Plate and (d) 30º Compression Plates.*

3.3 Axial Compression Load

Fig. 8(a) shows the result of equivalent Von Misses stress based on axial compression load on 0º compression plate and Fig. 8(b) shows the result of axial compression load on 30 degrees compression plate. Based on Fig. 8, the equivalent Von Misses stress on 0º compression plate is lower (2000MPa) than 30º compression plate (16425MPa). This result shows axial compression load on 0º compression plate is better compared to 30º compression plate as the difference between these two plates is 14425MPa. This result concludes that 30º compression plate is not suitable for axial compression load. Fig. 8(c) shows the result of displacement based on axial compression load on 0º compression plate and Fig. 8(d) shows the result of axial compression load on 30º compression plate. Based on Fig. 8, the displacement on 0º compression plate is higher (3.5mm) than 30º compression plate (0.8mm). This result shows axial compression load on 30º compression plate is better compared to 0º compression plate as the difference between these two plates is 2.7mm. In conclusion, 30º compression plate is suitable for axial compression load.

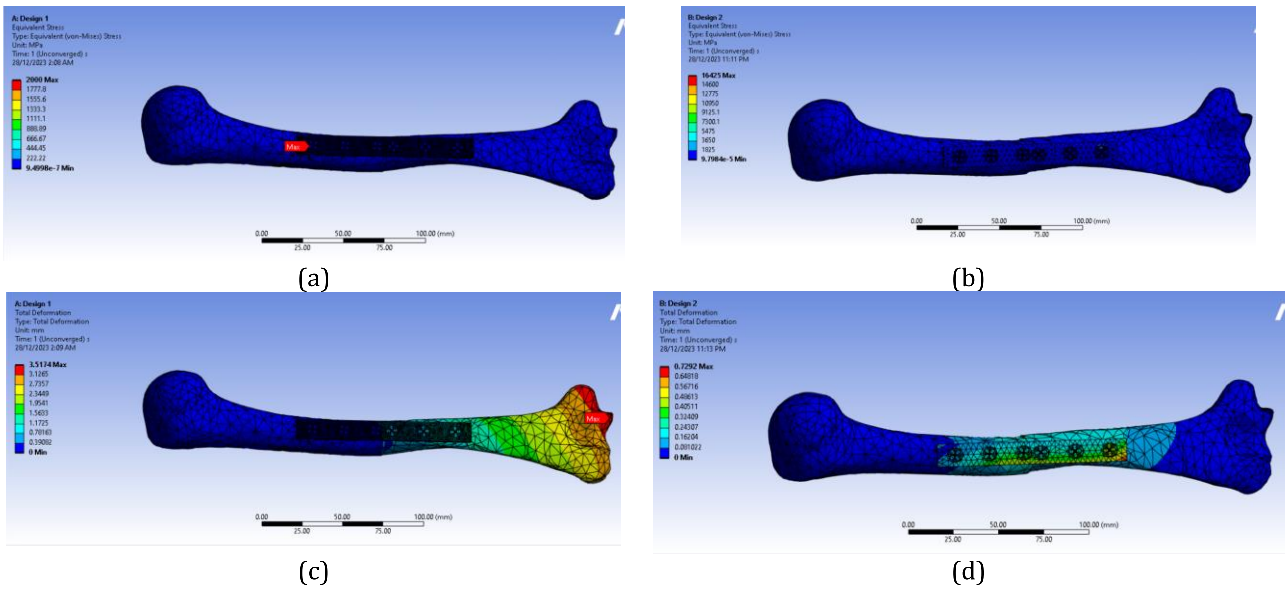


Fig. 8 *(a) 0º Compression; (b) 30⁰ Compression, (c) 0º Compression Plate and (d) 30º Compression Plates.*

3.4 Adduction Load

Fig. 4.7 (a) shows the result of equivalent Von Misses stress based on adduction load on 0-degree compression plate and Fig. 4.7(b) shows the result of adduction load on 30 degrees compression plate. Based on Fig. 4.7, the equivalent Von Misses stress on 0-degree compression plate is lower (2376MPa) than 30^{o} compression plate (6249MPa). This result shows adduction load on 0-degree compression plate is better compared to 30 degrees compression plate as the difference between these two plates is 3873MPa. This result concludes that 30 degrees compression plate is not suitable for adduction load. Fig. 4.8(a) shows the result of displacement based on adduction load on 0-degree compression plate and Fig. 4.8(b) shows the result of adduction load on 30 degrees compression plate. Based on Fig. 4.8, the displacement on 0^{o} compression plate is lower (1.1mm) than 30^{o} compression plate (2mm). This result shows adduction load on 0-degree compression plate is better compared to 30^{o} compression plate as the difference between these two plates is 0.9mm. In conclusion, 0^{o} compression plate is suitable for adduction load.

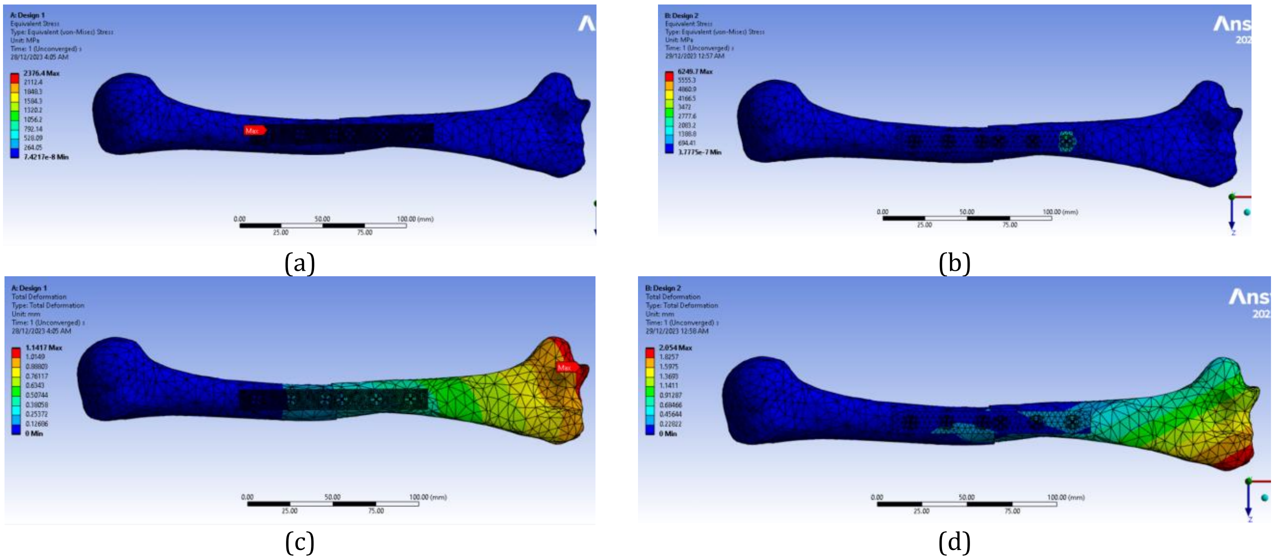


Fig. 9 *(a) 0^{o} Compression; (b) 30^{0} Compression, (c) 0^{o} Compression Plate and (d) 30^{o} Compression Plates.*

3.5 Abduction Load

Fig. 10(a) shows the result of equivalent Von Misses stress based on abduction load on 0-degree compression plate and Fig. 10(b) shows the result of abduction load on 30^{o} compression plate. Based on Fig. 10, the equivalent Von Misses stress on 0^{o} compression plate is lower (102MPa) than 30^{o} compression plate (5253MPa). This result shows abduction load on 0^{o} compression plate is better compared to 30^{o} compression plate as the difference between these two plates is 5151MPa. This result concludes that 30^{o} compression plate is not suitable for abduction load. Fig. 10(c) shows the result of displacement based on abduction load on 0^{o} compression plate and Fig. 10(d) shows the result of abduction load on 30^{o} compression plate. Based on Fig. 10, the displacement on 0^{o} compression plate is lower (1.1mm) than 30^{o} compression plate (6.2mm). This result shows abduction load on 0^{o} compression plate is better compared to 30^{o} compression plate as the difference between these two plates is 5.1mm. In conclusion, 0^{o} compression plate is suitable for abduction load.

3.6 Equivalent Von Misses Stress

In Fig. 11, abduction load is better than other load because it has the minimum equivalent Von Misses stress, which is 102MPa. However, extension load has the maximum equivalent Von Misses stress with 2592MPa. This load is not preferred on 0^{o} compression plate, as it undergoes huge stress. In Fig. 12, the extension load is better than other load because it has the minimum equivalent Von Misses stress, which is 4552MPa. However, axial compression load has the maximum equivalent Von Misses stress with 16425MPa. This load is not preferred on 30^{o} compression plate, as it undergoes huge stress.

3.7 Displacement

Fig. 13 reveals the abduction load is better than other loads because it has a minimum displacement, which is 1.1mm. However, flexion load has a maximum displacement of 4.1mm. This load is not preferred on 0^{o} compression plate, as it undergoes huge displacement on the plate. In Fig. 14, the axial compression load is better than other loads because it has the minimum displacement, which is 0.8mm. However, abduction load has a maximum displacement of 6.2mm. This load is not preferred on 30° compression plate, as it undergoes huge displacement on the plate. In nutshell, the equivalent Von Misses stress of abduction load on 0° compression plate is the best because it does not exceed the yield strength of stainless-steel compression which is 207MPa. The axial compression load on 30° plate shows the minimum displacement which is the greatest result among others load. This is because lower displacement values suggest better stability and indicate that the plate is more effective in maintaining the alignment of the fractured bone. Based on the results, 0° compression plate shows the best design with lowest Von Misses stress and low displacement when compared with 30° compression plate.

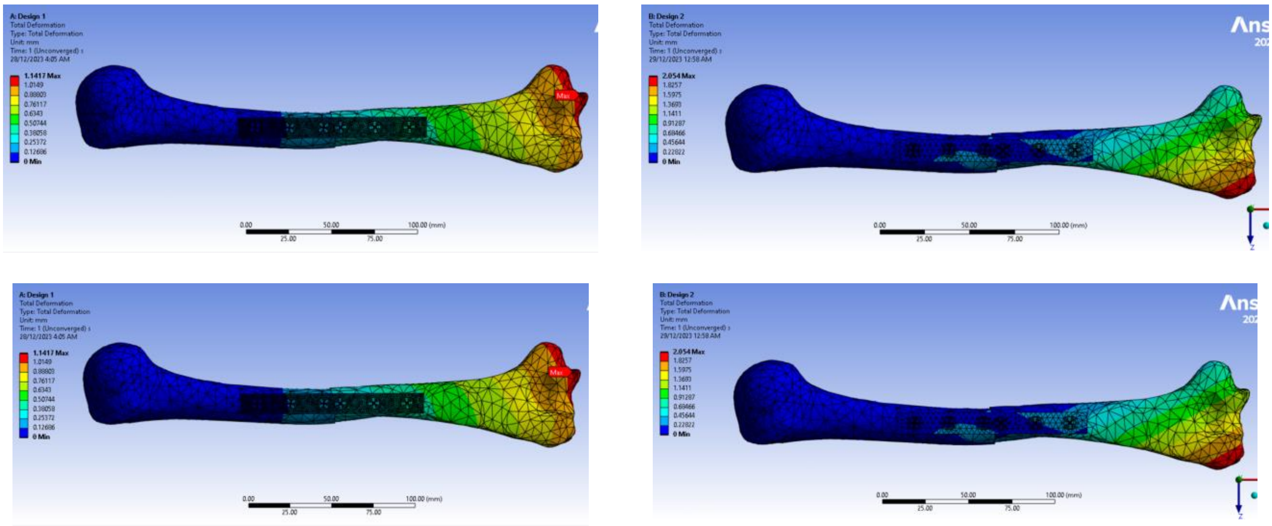


Fig. 10 *(a) 0° Compression; (b) 30⁰ Compression, (c) 0° Compression Plate and (d) 30° Compression Plates.*

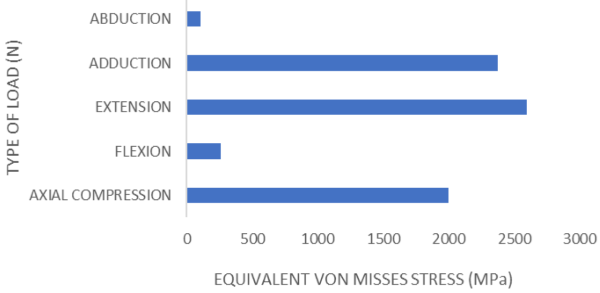


Fig. 11 *Equivalent Von Misses Stress of 0°*

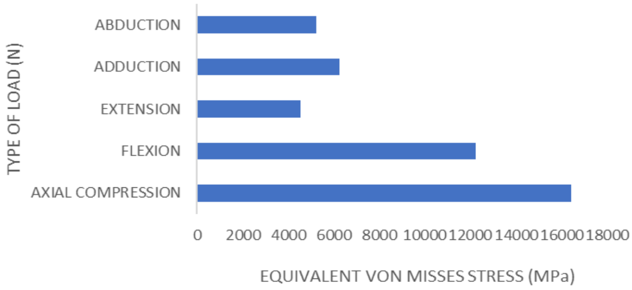


Fig. 12 *Equivalent Von Misses Stress of 30°*

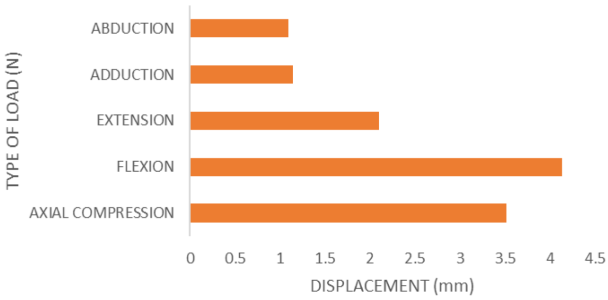


Fig. 13 *Displacement of 0°*

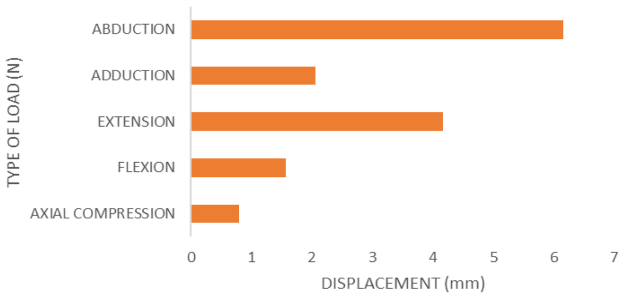


Fig. 14 *Displacement of 30°*

4. Conclusion

In summary, this research paper effectively achieved its goals by thoroughly examining the behavior of current compression plates under varied mechanical loading conditions, specifically assessing their structural integrity when subjected to a cracked humerus bone. The study's findings offer crucial insights into compression plate performance, highlighting the superiority of the abduction load with the lowest equivalent Von Misses stress at 102MPa, while cautioning against the use of the extension load on 0° plates due to its high stress of 2592MPa.

Additionally, the unsuitability of 30º compression plates for axial compression loads, with a stress of 16425MPa, was established.

The investigation of displacement patterns emphasized the superior stability of the abduction load for axial compression plates, displaying a minimal displacement of 0.8mm, whereas the flexion load proved unsuitable for 0^0 plates due to its maximum displacement of 4.1mm. Overall, these findings underscore the critical importance of considering both displacement and stress factors in the selection of compression plates for specific loading scenarios, with the abduction load on 0º plates standing out as optimal, remaining below the yield strength of stainless-steel compression at 207MPa, and the axial compression load on 30º plates showing superior stability by minimizing displacement and effectively maintaining bone alignment. The findings indicate that, when compared to a 30º compression plate, a 0º compression plate exhibits the best design with the lowest Von Misses stress and minimal displacement.

5. Future Work on The Study

This research provides opportunities for further investigation into orthopedic implant design. Prospective studies could investigate long-term biocompatibility, dynamic loading scenarios, and advanced materials. Furthermore, patient-specific customization using computational modelling and advanced imaging has potential. The incorporation of sophisticated simulation methods, such as finite element analysis such as adding more load and more degree of compression plate design, would improve the accuracy of the stress distribution understanding. A clinical validation study conducted in conjunction with medical experts is necessary to move from laboratory testing to practical implementations. Future studies can help improve compression plates by addressing these aspects and maximising their biomechanical performance and patient-specific fit. This will ultimately advance fracture fixation techniques and enhance patient outcomes in general.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Khairun Nisa Mahfuzah Haidir;* ***data collection:*** *Khairun Nisa Mahfuzah Haidir;* ***analysis and interpretation of results:*** *Khairun Nisa Mahfuzah Haidir; Al Emran Ismail;* ***draft manuscript preparation:*** *Khairun Nisa Mahfuzah Haidir; Al Emran Ismail. All authors reviewed the results and approved the final version of the manuscript.*

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