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# Number of Screws Affecting the Stability and Stress Distributions of Conventional and Locking Compression Plate: A Finite Element Study

Herman Tuminoh<sup>1</sup>, Mohamad Hafiz Mohamad Afandi<sup>1</sup>, Hong Seng Gan<sup>2</sup>, Mohammad Rafiq Abdul Kadir<sup>3,4</sup>, Muhammad Hanif Ramlee<sup>1,4\*</sup>.

<sup>1</sup>Medical Devices and Technology Centre (MEDITEC), Institute of Human Centered Engineering (i-Humen), Faculty of Engineering, Universiti Teknologi Malaysia, Skudai 81310, Johor, Malaysia

<sup>2</sup>Universiti Kuala Lumpur, British Malaysian Institute, Batu 8 Jalan Sg. Pusu, 53100 Gombak, Selangor, Malaysia

<sup>3</sup>Sports Innovation and Technology Centre (SITC), Institute of Human Centered Engineering (iHumen), Universiti Teknologi Malaysia, Skudai 81310, Johor, Malaysia

<sup>4</sup>Bio-inspired Innovation Group (BIOINSPIRA), School of Biomedical Engineering and Health Sciences, Faculty of Engineering, Universiti Teknologi Malaysia, Skudai 81310, Johor, Malaysia

\*Corresponding author: muhammad.hanif.ramlee@biomedical.utm.my

**Abstract.** The effectiveness of malleolar fracture fixation is still questionable. Internal fixator is the one of the treatment for treating this fracture. However, the analysis of various type of internal fixator is still lacking in the literature in terms of biomechanical characteristics and behaviour. Thus, the aim of the study was to compare the stability of locking compression plate (LCP) and one third tubular plate (OTT) in different configuration of screws. Computed Tomography (CT) images of bone was used to develop 3D model of fibula bone. The plate was constructed in Solidworks software and number of screws used were 3 and 5. Further, finite element study was conducted for both model. For LCP, the highest von Mises stress (VMS) observed at the plate for 3 screws was 484 MPa, whereas for 5 screws plate was 667 MPa. Besides, for OTT, the highest VMS at plate observed for 3 screws was 300.5 MPa, whereas for 5 screws plate was 127.5 MPa. Based on the results, it can be noted that the usage of 3 screws can causes a low VMS at plate compare to 5 screws. However, the relation is valid for LCP. For OTT, 5 screws constructs gave a low VMS than 3 screws constructs.

## 1. Introduction

From 2007 to 2011, hospital from the United States of America (USA) reported that the ankle has the highest number of fractures at lower limb which was 280 933 cases [1-2]. According to these numbers, it is shown that malleolar fracture has the highest ranking of occurrence specifically at the ankle joint [1-2]. In order to treat malleolar fracture, a surgery should be conducted to restore the fracture into the original formation of the structure. One of the method in restoring the ankle fracture is the open reduction and internal fixation method [3].



Conventional plating methods are based on the use of an adequate number of anchoring screws to press the plate against the bone with high compressive forces, creating a stable bone-implant connection. To date, there is no problem with the conventional plate, which is one third tubular plate (OTTP) if the patient's bone density is in normal condition. Another design that have been used to restore the ankle fracture is the locking compression plate (LCP). To be noted, the use of these two plates is favourable in treating ankle fracture specifically at fibula region [3].

In clinical practises, the complication from the application of plate fixation on the fibula fracture is 6.2% for the LCP fixation and 1.4% for the OTT plate fixation [4]. These cases will require medical surgeons to conduct second surgery for removing the implant. The complications reported in the literature are from various aspects such as implant loosening, infection, mal-union, non-union and misalignment [4-9]. As far as the authors are concerned, there is no study performed to evaluate the biomechanical properties of LCP and OTT in treating fibula fracture. Therefore, this study was conducted to compare the stability and stress distribution of LCP and OTT for better understanding on biomechanics principle of these two designs.

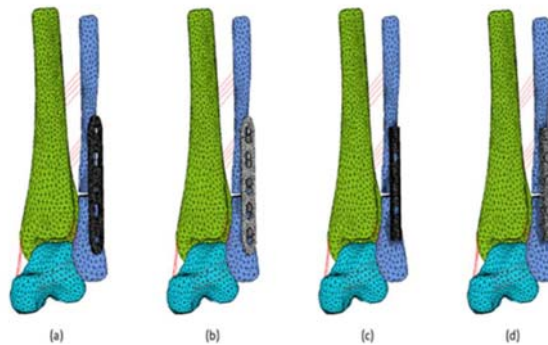
## 2. Methodology

### 2.1. Bone reconstruction

Computed Tomography (CT) images data set were used to reconstruct anklebone models which is fibula bone. The bone model images provided by CT scan were used to reconstruct the three-dimensional (3D) model of bone via Mimic software. Next, the 3D images of each bone model was made to undergo meshing process where the mesh was 3.0 mm sized tetrahedral. An opening of 2 mm gap was simulated by removing a cylindrical-shaped of bone from the distal part of the fibula.

The Conventional plate and Locking Compression plate were designed using a Solidworks software. All the parameters (size and distance) were determined following the techniques of MacLeod [8]. Both OTTP and LCP systems have 5 screws and 3 screws orientation while the screw type is kept constant which using cortical screw. Further, the process is continuing with fixing the bone plate to the fracture area using Mimic software.

For finite element analysis, axial loading was chosen to be tested on the model due to standing condition. The force was position axially to the fibula and tibia as the patient body weight was 70 kg, the load is distributed equally between two legs and further the load was distributed to tibia (93%) and fibula (7%) [10]. The load distributed between tibia and fibula was connected with link to imitate ligament. Besides, the model was also fixed at the bottom of talus surface to make sure the model is static. All friction coefficient values were set to 0.3. The analysis was done using commercial finite element software MARC with the equivalent von Mises stress (EVMS) and displacement of the model relative to the fibula. The Figure 1 below showed the finite element study of the model.



**Figure 1:** (a) 3 screws (LCP) (b) 5 screws (LCP) (c) 3 screws (OTT) (d) 5 screws (OTT)

### 3. Results and Discussion

The contour plots of von Mises stress (VMS) of the fibula and different configuration of screw for Locking Compression Plate (LCP) and One Third Tubular Plate (OTT) are shown in Table 1. In general, the contour plots of all the configurations showed that the bone had a high stress concentration at the pin-bone interface for stance phase.

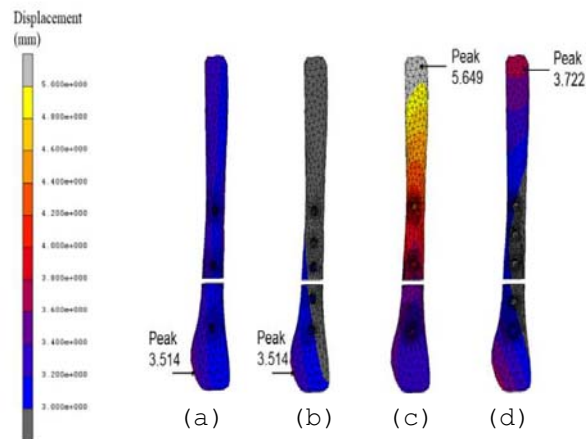
When the plate was placed towards the fracture side, 5 screws plate gave less stress to the bone in order to maintain the bone union. For LCP, the highest VMS was recorded for 3 screws with 183.7 MPa at the fibula pin-bone interface and then the 5 screws with 70 MPa was the lowest VMS. For OTTP, the highest VMS was observed for 3 screws (141.3 MPa) at the fibula pin-bone interface, whereas for 5 screws was 56 MPa.

The stress distribution at the plates is as shown in Table 1. The highest VMS of LCP plate for 3 screws (484 MPa) was observed lower than 5 screws plate (667 MPa). Besides, the highest VMS of OTTP plate for 3 screws was 300.5 MPa being higher than 5 screws plate (127.5 MPa). Even with the same pattern of stress distribution, the magnitude of each combinations was different.

From the results, a higher stress was seen at bone plate rather than fibula pin-bone interface. The stability of LCP depends on the number of screw plate where the reduction of screw number will reduce the stress distribution of implant. This is due to a low force required to achieve bone contact. The low force will minimize the effect of shielding force because the shielding effect need to be minimized is to reduce the bone resorption process that will weaken the bone structure [4, 7, 8].

The stresses at interface between the screw heads and the plate holes have been ignored due to the difficulty to accurate the modelling the threaded interfaces. The interfaces were not considered as the weakest part of system if screws are well aligned with plate hole and tightened with proper torque and not exceed the ultimate strength [11]. In this study, the use of LCP and OTT for treating malleolar fracture can be accept since the maximum stress at the bone when using LCP and OTT does not exceed the ultimate strength of the bone used (193 MPa) [12].

Figure 2 shows the displacement plot of the fibula bone. Generally, the displacement values were below 4 mm for all plates except for the 3 screws of OTTP (5.649 mm). When simulating the stance phase, the displacement of LCP for 3 screws (3.59 mm) and 5 screws (3.51 mm) were slightly close while the displacement of OTTP for 3 screws and 5 screws were 5.65 mm and 3.72 mm respectively.



**Figure 2:** The displacement plot of the fibula bone for different configuration of screw for Locking Compression Plate (a) 3 screws (b) 5 screws and One Third Tubular Plate (c) 3 screws (d) 5 screws.

**Table 1:** The contour plots of von Mises stress (VMS) of the (1) fibula and (2) plates for different configuration of screw for Locking Compression Plate (a) 3 screws (b) 5 screws and One Third Tubular Plate (c) 3 screws (d) 5 screws.

Contour plot	Maximum von Mises stress (MPa)				Ultimate strength (MPa)	
	(a)	(b)	(c)	(d)	3 screws	5 screws
	184	70	141	56	193	193
	484	667	301	128		

**4. Conclusion**

Based on the results, it can be noted that the use of 3 screws causing a low VMS at plate compare to 5 screws but the relation is only valid for LCP. However, for OTTP, the 5 screws plate gave a lower VMS than 3 screws construct. Furthermore, the result for VMS at bone is always lowest when using 5

screws construct. The stability in term of displacement, the value is quite close for both 5 screws and 3 screws construct for LCP.

### 5. Acknowledgement

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