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Original Article

Distal fibula oblique fracture fixation using one-third tubular plate with and without lag screw – A biomechanical study of stability

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ABSTRACT

This laboratory-based study compared distal fibula simple oblique fracture fixation with one-third tubular plate with and without a single lag screw to determine which was mechanically more stable. A control group fixed with a limited contact dynamic compression plate was also tested. Biomechanical testing of 30 osteotomised saw bones under lateral bending and torsional forces was performed. There was no significant difference between the mean lateral bending and mean torsional stiffness between the fixation with tubular plate and lag screw and tubular plate alone. Limited contact dynamic compression plate conferred the best stability in lateral bending and torsion, as expected.

1. Introduction

Ankle fractures represent around 9% of all fractures constituting a large proportion of the trauma workload in trauma and orthopedics.[1,2] The most common type of ankle fracture pattern is the Weber type B or Lauge-Hansen mechanism type supination external rotation.[3,4] This involves fracture of the lateral malleolus (distal fibula) and medial malleolus. Lateral malleolar fractures can be treated operatively or non-operatively depending on fracture pattern, patient comorbidities and surgeon preference. The AO foundation recommends operative fixation techniques which involve the use of lag screws and plates, usually in combination.[5]

There have been a multitude of studies looking at the outcomes of various ankle fracture fixation techniques in terms of fracture healing, complications post-operatively and patient satisfaction.[6–10] There are fewer biomechanical studies that establish which fixation techniques are the most stable for a given fracture pattern. Some studies look at plate only fixation and compare different plates to each other. A cadaveric study of distal fibulae by Knutsen et al compared fixation with a five-hole compression plate and lag screw, five-hole locking plate and lag screw or six-hole tabbed plate with locking screws.[11] They concluded the plates had similar construct strength and stability. Eckel et al compared cadaveric fibulae fracture fixation with one-third tubular plates plus lag screw, LCP locking plates with lag screw, Orthohelix Maxlock extreme low-profile locking plates with lag screw and TriMed sidewinder non-locking plates.[12] They concluded no overall significant difference in plate performance. Both studies had to consider the variable bone quality of cadaveric specimens. There tends to be focus on plate choice depending on quality of bone, and locking plates are preferred for osteoporotic bone.[2,13,14] There has been a recent study by Misaghi et al that advocates lag screw only fixation in simple oblique distal fibula fractures.[15] Our literature search did not reveal any evidence comparing mechanical stability of fracture fixation between one-third tubular plate with and without lag screw.

Appropriate surgical fixation of fractures requires balancing the benefits of biomechanical fixation with the risks of operative complications. Hence, adequate and accurate knowledge of the stability conferred by each fixation technique is very important in making surgical decisions that impact patient outcomes. In our clinical practice, we routinely encounter simple oblique distal fibula fractures that are then fixed with one-third tubular plate plus lag screw, Limited Contact Dynamic Compression Plates (LC-DCP) or reconstruction plates. LC-DCPs are also recommended for transverse or oblique distal fibula fracture fixation by the AO Foundation.[16] Previous studies have not compared the use of one-third tubular plate with lag screw, one-third tubular plate without lag screw and LC-DCP plates for the fixation of distal fibula fractures. We were interested in determining which of these fixation techniques confers the most stability mechanically. The fracture pattern studied is a short oblique fracture of the distal fibula described as 44-C1 by the AO foundation.[17] Our aim was to measure the forces required to cause failure of each fracture fixation technique. We expected the LC-DCP plate to confer the best stability in keeping with previous mechanical tests, with thicker plates being more rigid and unlikely to deform. We hypothesised that the one-third tubular plate

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with lag screw would be more stable than the plate without lag screw. A mechanical laboratory-based experimental study was undertaken to compare stability of fracture fixation using each technique.

2. Material and methods

2.1. Materials

30 sawbones® (catalogue number 1127, solid foam full length fibula) were acquired from Pacific Research Laboratories Inc, Vashon, Washington, USA. The implants used were 9-hole 3.5 mm one-third tubular plates, 9-hole 3.5 mm Limited Contact Dynamic Compression Plates (LC-DCP), 20 mm length 3.5 mm cortical screws and 20 mm length 3.5 mm cancellous screws, supplied by Madura Orthosurge Pvt Ltd based in Paschim Vihar, New Delhi, India. The LC-DCP was 3.3 mm thick and one-third tubular plate was 1mm thick. A custom rig for mechanical testing was assembled in the Cardiff mechanical engineering lab. The rig constituted the MTS 858 Mini Bionix® 2 machine (MTS systems - Eden Prairie, Minnesota, USA) where the fixed sawbones® were mounted, a linear variable differential transformer (LVDT) to measure linear displacement, a 500 N Load cell, the MTS FlexTest® GT controller (MTS systems - Eden Prairie, Minnesota, USA) that controls machine software and the Vishay 7000® data logger (Vishay Precision Group - Malvern, Philadelphia, USA).

2.2. Design and set-up

The set-up for this study was adopted from Misaghi et al published in 2015 in the Journal of Foot and Ankle Surgery and modified to suit our experimental procedure.[15] This study was conducted after proposal review and approval from the Cardiff University School of Engineering.

An electric saw was used to create a 4cm long oblique, antero-inferior to postero-superior osteotomy/fracture in each bone model. The antero-inferior edge of the fracture was initially marked at a constant distance from the distal fibula tip and the fracture was made at an angle of 45° to fibula surface. These models were then randomised into 3 groups of 10 sawbones per group. The first group of osteotomised sawbones® was fixed with one-third tubular plates in compression. In the second group of 10 sawbones, each fracture was fixed with a single cortical fully threaded lag screw with one-third tubular neutralisation plate. The lag screw was applied perpendicular to the fracture plane. The third group of osteotomised sawbones® was each fixed with an LC-DCP plate. This was used as a control as we saw no value in testing the osteotomised models with no fixation applied. The results we obtained for the other 20 constructs could be verified against the expected results with the LC-DCP fixation.

Each plate was secured onto the fractured fibula with 3 proximal cortical screws and 3 distal cancellous screws. The plates were not bent or re-shaped in any way and were applied directly onto the lateral surface of the fibula. The central screw hole (fifth hole in the 9-hole plates) was aligned with the mid-point of the fracture site. All screws were applied bi-cortically to maintain a degree of uniformity.

Each model with fracture fixation was mounted and tested in lateral bending first. The proximal fibula was secured in the linear actuator and the distal end was supported on a pin attached to the load cell. The supports were 150 mm apart for each saw bone tested. The proximal fibula was displaced at 0.5 mm per second for 3 mm as measured by the LVDT and the load-displacement data was monitored at 100 Hz. The lateral bending aspect of the testing was non-destructive in nature. Once the lateral bending testing was concluded, each saw bone was then subjected to a torsional force to failure. The proximal and distal ends of the fibula were secured in the rig with the distance between the supports standardised at 150 mm. The load-displacement data was again monitored at 100 Hz and the fibula rotated at 2° per second to failure. We defined failure as either a fibula fracture or a decrease in maximum torque, whichever occurred first (Fig. 1).

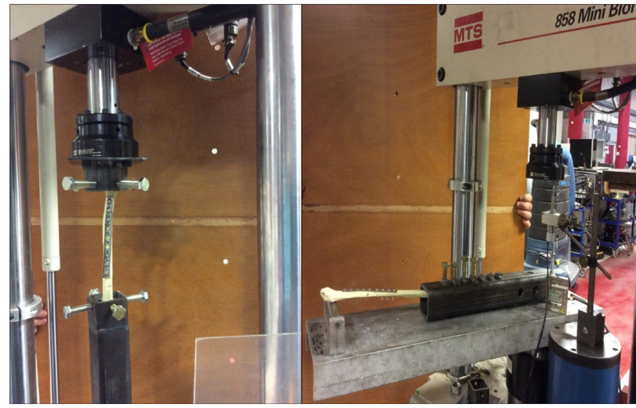

Fig. 1. MTS 858 Mini Bionix rig with sawbone construct for torsion testing (left) and lateral bending (right).

2.3. Statistical analysis

The Statistical Package for Social Sciences (SPSS) was used for our data analysis. The mean values with standard deviation for maximum lateral bending force (Newton), lateral bending stiffness (Newton/millimetre) and torsional stiffness (Newton metre/degree) for each fixation technique were calculated. The data were checked for normality using the quantile-quantile (q-q) plot which is a graphical analysis. The data were then analysed using the one-way analysis of variance (ANOVA) with pair-wise comparisons using the Tukey test. The alpha level was set at 0.05 to be considered significant. A post-hoc power analysis was undertaken although the sample size utilised in this study is consistent with that employed by Misaghi et al and also Eckel et al.[12,15]

3. Results

The mean values with standard deviation for maximum lateral bending force (Newton), lateral bending stiffness (Newton/millimetre) and torsional stiffness (Newton-metre/degree) for each fixation technique are presented in the Table 1. It can be observed that the mean values for the one-third tubular plate fixation without lag screw and one-third tubular plate with lag screw fixation are very similar, with the latter being marginally higher. Fig. 2 clearly demonstrates these differences. The one-way ANOVA with TUKEY tests did not demonstrate any significant difference between one-third tubular plate and one-third tubular plate with lag screw for maximum lateral bending force required to give a displacement of 3 mm ($p = 0.99$). The same applies to the lateral bending stiffness with no significant difference between the one-third tubular plate and one-third tubular plate with lag screw fixation ($p = 0.96$).

With respect to the torsional stiffness, there was no significant difference between the one-third tubular plate and one-third tubular plate

Table 1
Mean values +/- standard deviation for each fracture fixation technique (N = 30 patients).

Fixation Technique	LATERAL BENDING Maximum Force (N)	LATERAL BENDING Stiffness (N/mm)	TORSION Stiffness (Nm/degree)
1/3rd tubular plate	16.07 +/− *0.94*	5.17 +/− *0.56*	0.04 +/− *0.01*
1/3rd tubular plate with lag screw	15.97 +/− *1.55*	5.25 +/− *0.56*	0.05 +/− *0.01*
LC-DCP plate	23.81 +/− *2.97*	7.08 +/− *0.89*	0.08 +/− *0.01*

Abbreviations: LC-DCP - Limited contact Dynamic Compression Plate; N - Newton; N/mm - Newton/millimetre; Nm/degree - Newtonmetre/degree.