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# Mini Fragment Fixation of Clavicle Fractures: A Biomechanical Study

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**INTRODUCTION:** When osteosynthesis of midshaft clavicle fractures is indicated plate fixation is a common mode of stabilization. Hardware irritation, skin problems, and implant prominence associated with open reduction and plate fixation have been reported [1]. It was suggested that the incidence of post-operative hardware irritation can be reduced to 0% with the use of precontoured plates as appose to 60% in their noncontoured counterparts [1]. A notable downside for using precontoured plates is the associated healthcare cost, and although they showed great results as demonstrated by Chandrasenan, et al. an effort for finding a cost effective alternative is needed.
This study looked at the 2.7mm locking compression plates (LCP) and reconstruction plates (RCP) as their thickness comes really close to that of precontoured plates. Plates were compared using locking and non-locking screws, in transverse and comminuted fracture models looking at stiffness and load to failure in bending and torsion. Composite Sawbone® clavicles were used. Also this study quantifies the cost differences between precontoured plates and 2.7 Compression plates over a 4 year period.

**METHODS::** 8 composite clavicle sawbones were used per group. All fractures were instrumented superiorly. Transverse fracture had compression plating adjacent to the osteotomy followed by locking or not locking screws. Comminuted models had 1cm of bone resected and were plated in similar fashion with a 2:1 screw plate ratio. Specimens allocated for four-point bend testing were potted at both ends. Four-point bending in load control in the elastic range of 5 – 50 N for each specimen was performed at a rate of 0.25 Hz employing a material testing machine (MTS 858 MiniBionix II). As soon as a steady state was reached the load/displacement curve was recorded in N/mm. After the stiffness had been collected, the specimens were loaded to failure in displacement control at a rate of 1 mm/sec.
Specimens undergoing torsional testing were secured to the base of the MTS and to the actuator and cycled in angular control in their elastic range ±4° at a rate of 0.25 Hz. As soon as a steady state was reached the torque/rotation curve was recorded in N-m/deg. After the stiffness had been collected, the specimens were loaded to failure in rotation control at a rate of 2 degrees/sec. Statistics performed by multi comparison ANOVA with Bonferroni correction for multiple comparisons.

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P values of x ≤ 0.05 were considered to be significant.
To review the fiscal impact of each plating construct the approval of the local institutional review board was obtained, and the number of mid-shaft clavicle fractures treated at a single academic level one trauma center was retrospectively obtained (cases from January 2008-February 2012). To determine the cost of clavicle fixation, company distributed 2013 price listings of for precontoured clavicle plates, cortical screws, and locking screws were obtained from Acumed®, Stryker®, and Synthes®, and the same information was obtained for Synthes® 2.7 LCP. A students T-test ($p<0.05$) was performed for statistical significance.
To maintain consistency, the biomechanical model used the same methods used in cases included in cost effectiveness analysis (1 plate/6 cortical screws & 1 plate/2 cortical/4 locking screws).

**Results:** In simple clavicle fractures employing LCP plates, the use of either cortical screws or locking screws showed no statistically significant difference in either strength of fixation or stiffness in 4-pt bending. Employing cortical screws in LCPs resulted in significantly stronger 4-pt bend ($p=0.011$) and torsion ($p=0.015$) results and stiffer ($p=0.018$) in 4-pt bend results than using them in RCP. Similarly locking screws in LCPs resulted in significantly stronger results in bending ($p= 0.037$) and torsion ($p<0.001$) and stiffer results in torsion ($p=0.013$) when compared to RCP.
In comminuted clavicle fractures the only statistically significant differences were between LCP plates with either locking screws or cortical screws vs. recon plates with cortical screws in bending and the locked LCP plates withstood significantly greater force with either locking screws ($p<0.001$) or cortical screws ($p<0.001$) than the RCP with cortical screws.
Three-hundred and sixty midshaft clavicles were identified for cost effectiveness analysis, of which 131 fractures where fixed with plate osteosynthesis. The average four year cost of precontoured, non-locking plates and non-contoured plates is $252,677.17 and $83,381.50 respectively $p<0.01$.

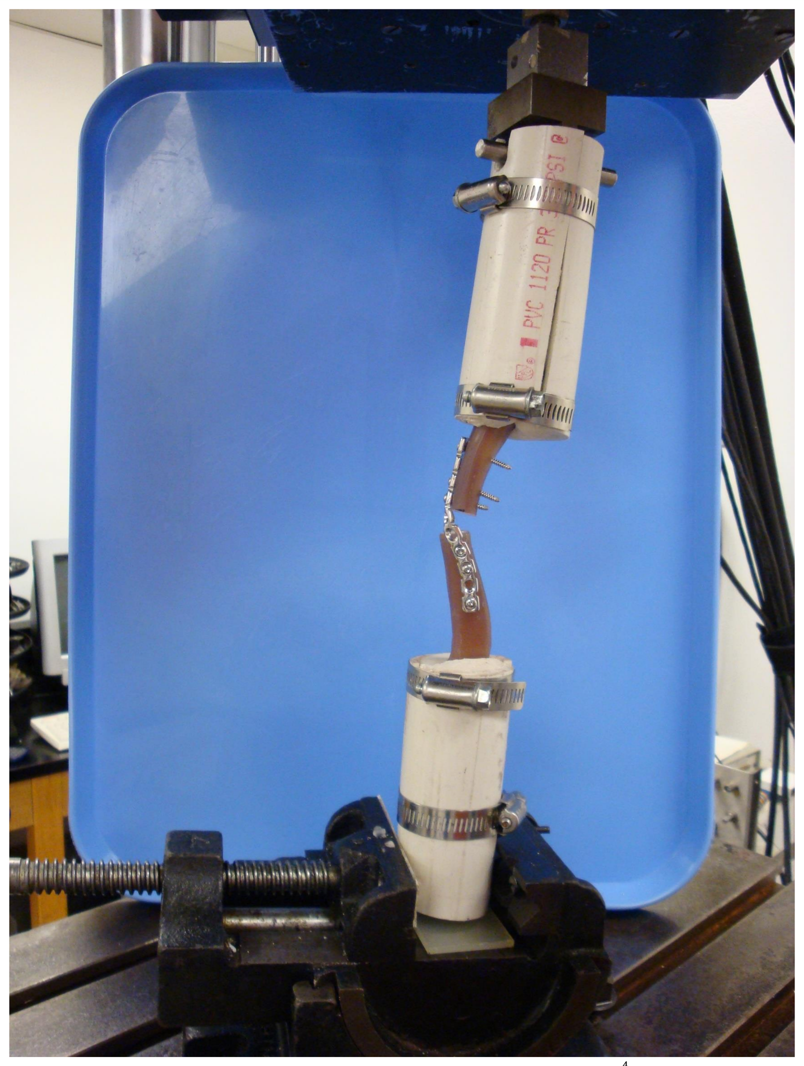

Figure 1: torsion test for gap model.

**Discussion**:
With the increase in popularity in clavicle plating, finding an ideal method for use is a worthwhile endeavor. Precontoured plates have shown to be dependable in the clinical setting [1], but their use is associated with high costs. The use of 3.5mm LCP or RCP is well established and their downfalls are known [1], their biomechanical properties have been tested on cadavers [2] and Sawbones® [3]. To our knowledge, no other studies tested 2.7mm LCP and RCP in locked and non-locked constructs biomechanically. Celectre et al. [3] tested 3.5 RCP in locking and non-locking constructs; but they used different methods of biomechanical testing. To compare our results to Celectre et al. we first looked at our bending stiffness test and calculated the “effective cross-sectional stiffness” to have comparable data. Using a 4-point bend test in this study and 3-point bend test by Celectre et al, meant our no gab model can’t be used in the comparison since their 3-point bend test opened, rather than closed, the osteotomy site. Our gap model constructs on the other hand were a close comparison since in both models (gap 4-point bend and 3-point bend) had no interaction between the bone fragments. Torsion tests done in both studies had similar loading set up and constructs, and our no gap model was a fair comparison in this instance. It wasn’t surprising to find the 3.5mm plates used by Celectre et al. 2009 more rigid and stronger than our 2.7mm plate constructs since the bend tests used in both studies are mostly a test of plate stiffness and strength. The 2.7mm thickness is a biomechanically viable option and is close in thickness to that of precontoured plates. It should reduce the common complaints seen with the 3.5mm plates, but authors realize the lack of clinical studies needed to test this hypothesis.

**SIGNIFICANCE:** In this biomechanical Sawbone® model, we were able to demonstrate the viability of using 2.7mm LCP to achieve stability in both fracture models. This theoretically offers the advantage of a rigid construct while minimizing hardware prominence. Further study will be needed to quantify our secondary hypothesis of a more favorable soft tissue profile when using the 2.7mm plates.

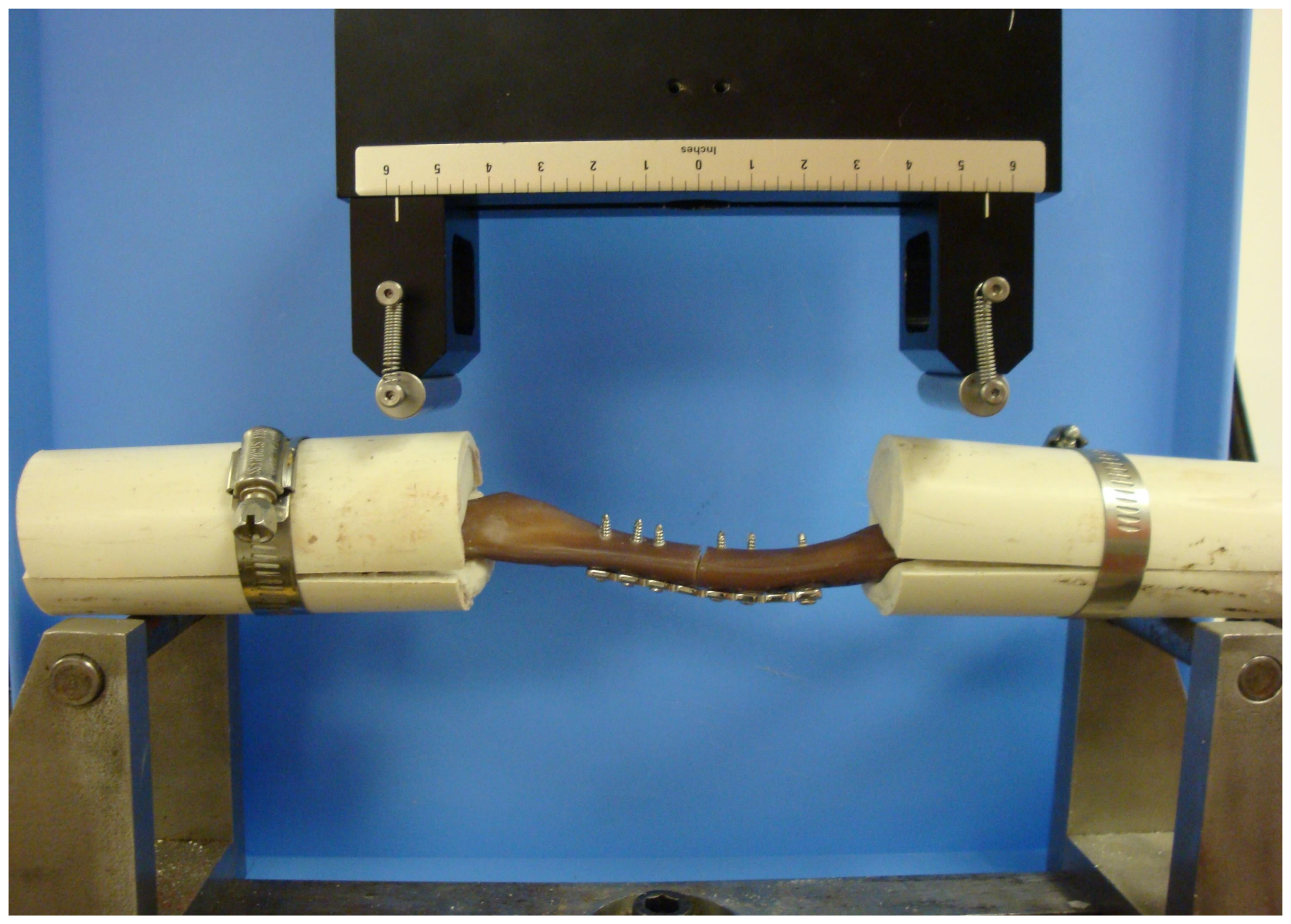

Figure 2: four-point bend test for no gap model.