Stability of the Proximal Humeral Fracture Treated with Compression, Locking Plating and Inlay Allograft Struts

Stability of the proximal humeral fracture can be difficult to achieved if osteoporosis or severe loss of bone stock is presented. Recently, locking plate technology has included these fractures, but appears that may not be predictable as hoped. Recent studies have demonstrated the importance of both reduction and mechanical support of the medial column in proximal humerus fracture fixation. Although the open reduction and internal fixation with a compression plate in conjunction with autogenous bone grafting is the most successful management, however, it was found that fractures without medial column support was obtained, reduction loss and articular screw penetration occurred in 29% of cases. Therefore, the medial column mechanical support of these fractures could play a significant role. This study experimentally compares the strength and fixation stability for proximal humeral fractures treated with cloverleaf conventional, locking plating and inlay strut allografts. The results are intended to lead to a better understanding of the load transfer and inlay graft technique in proximal humeral fracture stabilization.

MATERIALS AND METHODS:

Twenty humeral sawbone specimens (Synbone 5011, Swiss), conventional and locking cloverleaf plating system (Synthes 3.5 mm cloverleaf plate), with and without augmented inlay strut allograft, were experimentally compared in this study. All specimens were divided into four groups: (I) specimens were fixed with a conventional (compression) plate; (II) with a locking plate; (III) a conventional plate and augmented with an inlay allograft strut; and (IV) a locking plate with an inlay allograft strut. All plates were seated over the greater tuberosity then positioned and fixed with two holes (middle stem) and four in the shaft (two cortex). A 10-mm gap transverse osteotomy was performed at the level of the surgical neck to simulate the nonunion. The mid-shaft of the specimen was cut and inserted into a circle trough and then embedding this end in cement. The humeral head was smeared butter oil then semi-inserted in the cement to mold a partial cup.

Each construct was installed and statically tested in a material testing machine (Universal testing machine, HT-2402, Hungta, Taiwan). Increasing axial load was applied through a ball bearing with a displacement rate of 5 mm/min until the load displacement curve showed a clear decay (screw loosening/construct failure) or the osteotomy gap of the specimens closed (the fracture site contacted). The axial stiffness was then defined as the load divided by displacement and to be evaluated according to the slope of linear portion of the load-displacement curve. SigmaStat17 (SPSS, Chicago, IL) statistics package was used for analysis. One way ANOVA was performed with stiffness and ultimate load as the outcome variable, post-hoc test compared the statistical significance between groups as p≤0.05.

RESULTS:

Table 1 listed the experimental results of stiffness and ultimate strength for four groups. We can find that the locking plate with inlay allograft provided the highest axial stiffness and the axial ultimate strength. The strength of the specimens that fixed with inlay strut allografts obtained to be about 3 times of those of conventional and locking specimens without allograft struts augmented. In the conventional plate system, there is no significant difference in stiffness between the conventional plate and conventional plate with inlay allograft. However, the locking plate conjunction with inlay strut showed about two times of the locking plate system in stiffness and ultimate strength.

Table 1 Experimental results of averaged stiffness and ultimate strength

<table>
<thead>
<tr>
<th>No</th>
<th>Conv.</th>
<th>Conv. + Inlay strut</th>
<th>Locking</th>
<th>Locking + Inlay strut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stiffness (N/mm)</td>
<td>194.91 (252.05)</td>
<td>204.48 (373.90)</td>
<td>149.16 (221.27)</td>
<td>336.47 (500.38)</td>
</tr>
<tr>
<td>Ultimate Strength (N)</td>
<td>496.58 (4118.92)</td>
<td>955.81 (5797.57)</td>
<td>582.40 (1576.61)</td>
<td>1051.71 (291.12)</td>
</tr>
</tbody>
</table>

Fig. 1 compared the averaged stiffness between groups. The graphs revealed that the locking plate with inlay allograft strut group was significantly greater than other groups in stiffness (356.5 N/mm versus 186.7, 227.5 and 169.4). Fig. 2 also showed the locking plate with inlay allograft strut which provided higher loading resistance when compared to other groups (1130.4 versus 496.6, 955.8 and 582.4).

DISCUSSION:

This study provides quantitative, comparative and descriptive data for four different fixed approaches to treat distal radius fractures. Houwelingen reported that onlay allograft struts can provide an effective collateral support to weakened osteopenic/osteoporotic bone. This technique has been successfully employed in treating of periprosthetic femoral fractures around the inserted implant. In a recent study, Wang and Weng reported a union rate of 100% with all of the nonunions achieving union within 6 months of surgery. Our study biomechanically compared the stability and strength of conventional, locking plating and the plating combined with inlay allograft strut. The experimental results showed the highest stiffness and strength for plating with inlay strut. It provided an internal support to resist the axial loading and the bending moment due to eccentric load that induced by lateral plating. It is worth to note, the fracture pattern and screw configuration are also the important factors on the effects of biomechanical comparisons between different humeral fracture fixations. Within the limitations of the study, we conclude that for nonunion proximal humeral fractures, the locking plate combined with inlay allograft strut may offer a mechanically superior construct than conventional, and locking fixing system, however, this study mainly focused on results with static testing, the cyclic loading effects should be considered in the mechanical behavior of the construct.

SIGNIFICANCE:

This study experimentally demonstrated that locking plate augmented with humeral tubular allograft struts can provide inlay support to strengthen the stiffness and maximum load, increasing the stability of the construct for nonunion of humeral fracture. It provided useful information for the treatment of proximal humeral fracture.

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ABSTRACT INTRODUCTION:

Stability of the proximal humeral fracture can be difficult to achieved if osteoporosis or severe loss of bone stock is presented. Recently, locking plate technology has included these fractures, but appears that may not be predictable as hoped. Recent studies have demonstrated the importance of both reduction and mechanical support of the medial column in proximal humerus fracture fixation. Although the open reduction and internal fixation with a compression plate in conjunction with autogenous bone grafting is the most successful management, however, it was found that fractures without medial column support was obtained, reduction loss and articular screw penetration occurred in 29% of cases. Therefore, the medial column mechanical support of these fractures could play a significant role. This study experimentally compares the strength and fixation stability for proximal humeral fractures treated with cloverleaf conventional, locking plating and inlay strut allografts. The results are intended to lead to a better understanding of the load transfer and inlay graft technique in proximal humeral fracture stabilization.