INTRODUCTION

34 million Americans suffer from low bone mass and another 10 million have been officially diagnosed with the more severe condition of osteoporosis. This degenerative disease substantially increases risk of bone fractures, the majority of which occur in the spine (1). Unique challenges arise when osteoporosis patients develop spine conditions requiring surgery. When lumbar fusion is the indicated treatment, surgeons must proceed with the diminished bone density of their patient in mind. One means of fusion is anterior lumbar interbody fusion (ALIF) surgery, first described in 1932 by Capener for treatment of spondyloolisthesis, and is currently also indicated for other degenerative spine conditions, congenital abnormalities, and traumatic injuries (2).

The unique challenges posed by fusion candidates with osteoporosis have stimulated research into the area of instrumented spinal fusions. Because of its practicality, many of researchers use polyurethane (PU) foam as biomechanical models for human bone (3-5). This foam provides both a practical and suitable means in which to test the biomechanical properties of normal and osteoporotic cancellous bone (3, 4). Prior studies have shown that an increased foam density yields increased bone screw pullout strength (3, 5). However, the relationship between density and ALIF plates remains ambiguous, despite the frequency of the procedure.

The goal of this study was to determine the relationship between density and ALIF plate pullout strength using a polyurethane foam model. Based on prior data (5), our hypothesis was that pullout strength increases with higher density. Additionally, we predicted that this relationship would remain constant amongst clinically relevant screw angles.

METHODS

Polyurethane foam blocks of low density (0.08 g/cm³), medium density (0.16 g/cm³), and high density (0.24 g/cm³) (Sawbones, Inc., Vashon, WA, USA) were used to model severely osteoporotic, mildly osteoporotic, and normal cancellous bone, respectively (4). Self-tapping screws (20mm x 5.5mm) were used to affix an ALIF plate (LANX, Inc., Broomfield, CO, USA) onto the foam block. Custom made guides were fabricated, allowing pilot holes to be predrilled into the foam blocks with the desired fixed angles (Table 1). The screws were then inserted into the holes by a single investigator and tightened to a predetermined torque for each respective foam density. Three groups of each density were tested with the following angle configurations: (1) 0 degrees in both the sagittal and coronal directions; (2) 12 degrees diverging in the sagittal direction and 6 degrees converging in the coronal direction; (3) 6 degrees diverging in the sagittal direction and 4 degrees converging in the coronal direction (Table 1).

<table>
<thead>
<tr>
<th>Group</th>
<th>Low Density (.08 g/cm³)</th>
<th>Medium Density (.16 g/cm³)</th>
<th>High Density (.24 g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0° x 0°</td>
<td>0° x 0°</td>
<td>0° x 0°</td>
</tr>
<tr>
<td>2</td>
<td>12° x -6°</td>
<td>12° x -6°</td>
<td>12° x -6°</td>
</tr>
<tr>
<td>3</td>
<td>6° x -4°</td>
<td>6° x -4°</td>
<td>6° x -4°</td>
</tr>
</tbody>
</table>

Table 1. Description of screw angles for each group. (+/- indicate convergence/divergence; “Sagittal angle x Coronal angle”)

After the ALIF plate was affixed, it was attached to the actuator of an Instron 8521 materials testing machine. Pullout tests of the plate constructs were performed, and load and displacement data were obtained during each test. Maximum pullout force was defined as the maximum load recorded prior to screw failure. Ten samples were tested in each group. Statistical comparison of the groups was done using a two-factor ANOVA and a one-way ANOVA with Tukey multiple comparisons test.

RESULTS

A comparison of pullout forces between each density showed a significant increase as PU foam density increased (p < .05). On average, there was a three-fold increase in pullout strength between the low density foam (.08 g/cm³) and the medium density foam (.16 g/cm³), and five-fold increase between the low density foam and high density foam (.24 g/cm³) (Figure 1). This increase in pullout strength was consistent between each angle configuration as density increased. Although significant differences were found between groups 1 and 3 in the low density group, and groups 2 and 3 in the medium density group, these were only on the order of 4% and 12%, respectively (p < .05).

![Figure 1. Comparison of maximum pullout loads of varying density PU foams. Asterisks indicate significant differences between groups.](image)

DISCUSSION

This study was performed to establish the influence of density on ALIF plate pullout strength. It is unique in that it is the first study to examine the effect of density on ALIF plate pullout strength, rather than on pullout of a single screw. Our results showed that greater densities yield significant increases in plate pullout strength, thus confirming prior screw pullout data (5). The trend in pullout strength due to density was consistent despite any change in screw angle. This is clinically relevant in that it would be of more interest to insert the screws into an area with denser bone than at a specific angle to ensure maximum plate stability. As age-related, density-lowering structural changes begin in the center of the vertebral body and subsequently move superiorly and inferiorly (6), one can infer that surgeons can obtain optimal ALIF plate fixation by inserting the screws toward the vertebral body endplate.

In conclusion, our results show that for this particular plate design, it may be more advantageous to focus on inserting the screws in areas of denser material than attempting to insert it at a certain angle. The pullout strength that may be gained or lost by screw orientation is surpassed by what is gained or lost by inserting the screw in more dense or less dense material.

REFERENCES

1. (National Institute of Arthritis and Musculoskeletal and Skin Diseases, 2009), vol. 2010.