The Effect of Screw Type on the Fixation of Depressed Fragments in Tibial Plateau Fractures

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Abstract

The ability of various screw types to stabilize depressed tibial plateau fractures was determined in a biomechanical study using a Sawbones® model. Two sizes of both cancellous and cortical screws were evaluated for both support from below and through the depressed fragment. As a general trend, cancellous bone screws provided a greater resistance to fragment displacement than cortical bone screws, and screws with a smaller thread diameter provided greater resistance to displacement than screws of the same thread type with a larger diameter. These results agree with the accepted standard that cancellous screws provide better fixation for tibial plateau fractures, but also are counterintuitive in that smaller screws provided greater fixation than larger screws of the same type.

Tibial plateau fractures are relatively common, accounting for 1% of all fractures and 8% of fractures in the elderly.1,2 There is controversy concerning the optimal treatment method for these fractures, whether it be surgical or non-operative,1,3 and the selected method of treatment actually depends on a number of patient, injury, and surgeon factors.1 Still, AO/ASIF principles are generally accepted for the surgical management of these fractures.3,4 According to these guidelines, fixation with screws alone is generally sufficient to transfix or support Schatzker Type 35 (AO/ASIF type B2.25) fractures to prevent collapse.1 The advantage of using screws alone without plate fixation is that the amount of periosteal dissection can be minimized.3,9

Previous studies have shown that successful fracture reduction does not depend on the arrangement or number of screws.10,11 However, there are no studies that indicate whether a particular screw diameter or screw thread type provides a more stable construct. The most commonly used screws for fixation of tibial plateau fractures are 6.5 mm and 7.0 mm cancellous bone screws,1,2,7,10-15 yet it has not been clearly established that these screws provide a more stable fixation than cortical bone screws or smaller diameter cancellous screws.

This study evaluated the stability of cancellous and cortical bone screws of two sizes by assessing the stability of the fixation both when the screw was either transfixed through or supporting from below the simulated depressed fragment of Schatzker Type 3 fractures (pure central depression fractures).

Materials and Methods

Cellular Rigid Polyurethane Foam (7.5 pcf, Pacific Research Laboratories, Vashon, WA), manufactured as an alternative test medium for human cancellous bone, was selected to simulate the depressed bone fragment. It was chosen because its material properties and cell structure resemble that of cancellous bone found in the proximal tibia,16 and its use eliminated any variability that the use of human cadaveric bone might incur.16 Cylindrical plugs 33 mm in diameter by 25 mm thick were cut from the foam and divided into 8 groups of 20 specimens. One group was used for the transfixed position and another group for the supported position for each of the four screws used. The screw types used are listed in Table 1 and shown in Figure 1. As a control to evaluate the ef-
fect of screw threads on the polyurethane foam, a smooth pin of the same root diameter as the 6.5 mm screw was evaluated for its resistance to displacement, and the results compared to those of the 6.5 mm cancellous screw.

A hollow cylinder of Solid Rigid Polyurethane Foam (40 pcf, Pacific Research Laboratories), intended to simulate cortical bone, was machined to support the screws in both configurations during testing (Fig. 2). The testing device was made to simulate a worst-case scenario, in which the depressed fragment is supported only by the screw, with none of the load being transmitted through the sides to adjacent bone. For the transfixed groups, the screw was inserted into a hole in the center of the side of the foam piece which was pre-drilled according to the accepted standard for that screw, and the specimen was placed into the custom device for testing. In the supported group, the screw was simply put in the device and the foam piece placed on top of it. Compressive loads were applied to the top of the foam pieces at a rate of 0.05 mm/s to a maximum of 12.5 N with an MTS machine (model 810, MTS Corp, Minneapolis, MN). Test data were obtained as load-deflection curves using an analog chart recorder and their slopes calculated as a measure of resistance to displacement.

Statistical significance was determined by a one-way analysis of variance (ANOVA), followed by Fisher’s PLSD post-hoc analysis for pair-wise comparisons. Statistical significance was set at $p < 0.05$.

### Results

All the load-deflection curves obtained possessed a characteristic shape, consisting of a short initial region followed by a sharp increase in slope, which was linear until the load was removed at 12.5N (Fig. 3). The displacements and slopes during this initial region were calculated, as it was thought they corresponded to the screw threads sinking into the polyurethane foam as the system stabilized. However, no relation between the size of the screw thread and the initial displacement was observed. Further, there was no significant difference in the initial displacement between the 6.5 mm cancellous screw and the smooth pin of the same diameter, suggesting that the initial region could not be explained by the settling of the screw thread into the foam.

The slope of the linear region of the load-deflection curve was calculated in N/mm and assumed to reflect resistance of the passage of the screw through the foam. Values for this resistance to displacement ranged from 119 to 246 N/mm for the transfixed groups, and from 80 to 188 N/mm for the supported groups. For the transfixed group, the 4.0 mm cancellous screw provided a significantly greater resistance to displacement than any of the other three screws (Fig. 4, $p < 0.05$). None of the remaining screws were significantly different from each other in this transfixed configuration, and there was no significant difference between the screws in the supported configuration. However the trend in both cases

<table>
<thead>
<tr>
<th>Screw</th>
<th>Root Diameter (mm)</th>
<th>Thread Diameter (mm)</th>
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<tbody>
<tr>
<td>3.5 mm Cortical</td>
<td>2.55</td>
<td>3.50</td>
</tr>
<tr>
<td>4.5 mm Cortical</td>
<td>3.10</td>
<td>4.50</td>
</tr>
<tr>
<td>4.0 mm Cancellous</td>
<td>2.15</td>
<td>4.00</td>
</tr>
<tr>
<td>6.5 mm Cancellous</td>
<td>3.25</td>
<td>6.50</td>
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</table>

Figure 1 Four bone screws used. (top to bottom) 3.5 mm cortical, 4.5 mm cortical, 4.0 mm cancellous, 6.5 mm cancellous.
was that the cancellous screws provided a greater resistance to displacement than the cortical screws, and further that the smaller diameter screws provided a greater resistance to displacement than the larger diameter screws of the same thread type. For all four screws, the transfixed configuration was more stable than the supported configuration (p < 0.05).

Discussion

This study provides a biomechanical assessment of the resistance to displacement for four different types of bone screws used to stabilize Schatzker Type 3 tibial plateau fractures. The findings indicate that a 4.0 mm cancellous bone screw provides a significantly greater resistance to displacement for stabilizing Schatzker Type 3 fractures through transfixation than do the other three screws. Aside from this single screw configuration, none of the results for the other tested screws were significantly different. Yet there was a general trend that cancellous screws provided a greater resistance to displacement than cortical screws, and also that smaller diameter screws provide a greater resistance to displacement than larger diameter screws of the same type.

Even though not significant, the finding that cancellous screws were more stable on average than the cortical screws is consistent with their predominant use for stabilization of tibial plateau fractures.\textsuperscript{1,2,7,10-14} They have larger threads that provide more purchase in soft cancellous bone and are therefore better suited to use in metaphyseal areas.\textsuperscript{17} However the result that smaller-diameter screws provide a greater resistance to displacement than larger diameter screws, a finding which was significant in one case and a trend elsewhere, is seemingly counterintuitive and goes against the accepted standard of a larger 6.5 mm or 7.0 mm cancellous screw being used almost exclusively for this procedure.\textsuperscript{1,2,7,10-14} It contradicts Dirschl’s\textsuperscript{15} argument that the use of cancellous screws with a larger root diameter is desirable for stabilization of depressed fractures.

The greater resistance to displacement achieved by smaller-diameter screws in this study may be due to the manner in which the cell structure of the polyurethane foam is disrupted as it fails. While this is a possible explanation for the current results, the same relationship that exists for the foam may not exist for the trabecular structure in bone. In addition, there are other factors important to fracture healing besides the resistance to displacement. Even if these results also held true for trabecular bone, the advantages gained by an increased resistance to displacement in switching from a 6.5 mm to a 4.0 mm diameter screw may be offset by other variables such as those described by Koval.\textsuperscript{10}

The results of this study are intriguing in that they suggest that a 4.0 mm cancellous bone screw will provide a greater resistance to displacement than is currently being achieved with the 6.5 mm or 7.0 mm cancellous screws. However one obvious limitation to this study is that the Sawbones model might not accurately simulate actual bone. Further, only one screw is used in this model, whereas multiple screws are used clinically. There might be some sort of non-additive synergism that occurs when using multiple screws together that is not apparent in this study, such as that described by Beris.\textsuperscript{3} The use of bone grafts,\textsuperscript{1,2,5,7,11-13,15} or potentially even calcium phosphate bone cements,\textsuperscript{2} in conjunction with screws to support the depressed fragment is also common, yet the additional effects that may be due to these factors were neglected in this experiment. Finally, this study was limited to screws; other hardware options such as K-wires are used for stabilization of tibial plateau depression fractures,\textsuperscript{3} which depending on their arrangement may provide a more stable fixation than even screws.
Conclusions
The results of this study indicate that cancellous bone screws provide a greater resistance to displacement than cortical bone screws for fixation of Schatzker Type 3 tibial plateau fractures, and that smaller diameter screws provide a greater resistance to displacement than larger diameter screws of the same thread type. These findings agree with the current standard of using cancellous bone screws, but contradict the assumption that larger screws provide greater fixation stability. Further study is needed to investigate whether these same findings are reproducible using cadaveric bone.

References