TAPERED PEDICLE SCREW PULL OUT STRENGTHS: EFFECT OF INCREASING SCREW HEIGHT OUTSIDE THE PEDICLE

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INTRODUCTION

It is often necessary to back out the screw to increase its height above the pedicle after initial insertion. This is done to achieve alignment with other hardware elements. While the subsequent loss of embedded screw length would be expected to reduce holding power, there is a concern that tapered screws would be more affected than cylindrical designs. This study investigated the impact on pull out strength of backing fully inserted screws out one and three turns. Three screw taper profiles were tested in an artificial cancellous bone model. Each taper profile was tested with three screw thread shapes and pitches.

METHODS

Screws were custom made with three taper profiles and three thread shapes, for a total of nine designs. The major/minor (thread tip/thread root) diameter combinations tested were cylindrical/cylindrical (CC), cylindrical/tapered (CT), and tapered/tapered (TT). For each taper profile, screws were made with buttress (B), square (S), and "V" (V) thread shapes.

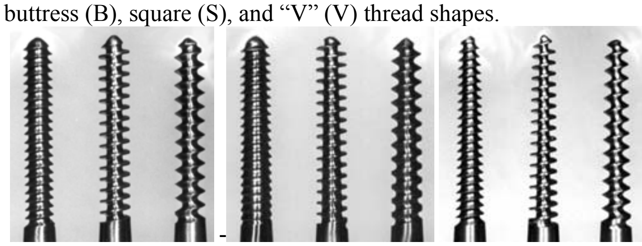

Figure 1. Screw designs tested. The panels show, from left to right, the CC, CT and TT taper designs. Within each panel the thread shapes are, left to right, Buttress, Square, and "V".

The B, S, and V threaded screws had pitches (the distance between threads, or the distance the screw will advance in one revolution) of 1.8, 2.375, and 3.0 mm respectively. All screws had a base major diameter of 6.5mm and a threaded length of 40mm. The screws are shown in Figure 1.

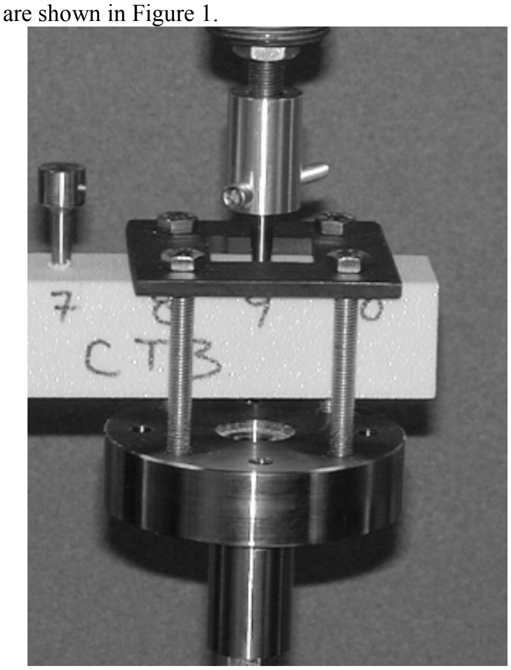

Figure 2. The test fixture. The screw was pinned to the MTS ram and the foam block restrained by a clamp plate. The plane of the clamp plate was adjustable to accommodate any screw misalignment.

Polyurethane foam synthetic cancellous bone (Sawbones, Pacific Research Laboratories, Inc., Vashon, WA) was used as a test medium. Foam test blocks of 0.08, 0.16, and 0.24 g/cc densities were used to simulate a range of cancellous bone densities. Holes were prepared by pilot drilling to the minor diameter of each screw tip. The holes were not tapped. The screws were fully inserted and pulled out axially using an MTS testing machine. Testing was repeated twice more in new foam blocks with the screws backed off first one and then three revolutions from fully inserted.

RESULTS

Three samples of each screw design were used for all testing, with five trials made at each condition of screw design, foam density, and back-out position. The standard deviation for each condition averaged 6.4% of peak force across all testing. Failure was by shearing of the foam at the thread tip diameter. Failure always occurred within one thread pitch of displacement.

For the full insertion case, the CT taper profile and the Buttress (and finest pitch) design produced the highest peak pull forces, with the CTB producing the highest forces at each foam weight. The S and V threads were generally very close, as were the CC and TT profiles. Differences between screw designs became more pronounced as the foam density increased, especially for the thread shape. At the lowest foam weight, the thread shape/pitch made no significant (two tailed *t*-test, $p < 0.05$) difference.

All screws showed significant increases in force with each step in foam density, with six-fold increases typical over the tested range. When the results were plotted vs. foam shear strength (as determined from the measured density and the manufacturer's published density/strength data) peak pull force vs. density was found to be highly linear for all screws.

At one turn back, most screws showed a significant drop in strength, with an average loss of five to nine percent. At three turns back, all screws recorded a significant drop, with average losses ranging from 18 to 22 percent. Much of this drop was directly due to the loss of embedded screw length as the screws were backed out. Also, this loss of embedded length varied, with the screws backing out different amounts for a given number of turns depending on pitch.

To correct for this variation, the pull forces were normalized with respect to the length of screw remaining in the foam block. This was calculated as the total length minus the number of back off turns multiplied by the screw pitch. A graph of normalized forces for one foam weight is given in Figure 3. After this normalization, most of the CC designs showed no significant loss for either one or three turns. The tapered designs were mostly unchanged at one turn. At three turns, they generally lost strength, with the losses averaging less than eight percent. An exception was the TT design, which lost strength in the two lighter foams but actually gained some strength (two to four percent) at one turn back in the 0.24 g/cc foam. No screw design lost more than 11% per unit length.

The effect of thread shape and pitch did not appear to change with back-out, as the screws generally maintained their relative rankings as they were turned back.

DISSCUSION

While the CT designs did lose more strength with back-out than the CC screws, they were still equivalent to the CC designs after three turns out. The TT designs dropped relative to the CC in the medium density foam, but the loss was small. And, in practice, the performance of TT screws may be improved through the use of larger base diameters than possible with the other designs. Pedicle screw diameter is constrained by the inner diameter of the pedicle isthmus, so a TT screw sized for the isthmus would be larger at the base than a cylindrical screw.

Overall, these tests indicate that the CT taper profile compares favorably to cylindrical designs even after three turns of back-out, with the TT taper profile only slightly lower in performance.

A surprising observation was the small but statistically significant increases that the TT designs all demonstrated at one turn back in the highest density foam. This may have been due to the hole preparation technique. Since the pilot holes were drilled to the minor diameter at the screw tip, these tapered screws produced radial compression of the foam as the screw widened towards the base. This compressive stress may have contributed to early failure. When the screws were backed off this stress was reduced, resulting in increased apparent pull strength.

Finally, although screw pitch was not an independent variable in this experiment, the best performing screws also had the smallest pitch. A further advantage of finer screw pitch, at least with uniaxial screws, is better control over screw height. To maintain hardware alignment these screws must be rotated in half turn increments, and finer pitch results in smaller possible height adjustments.

ACKNOWLEDGEMENT

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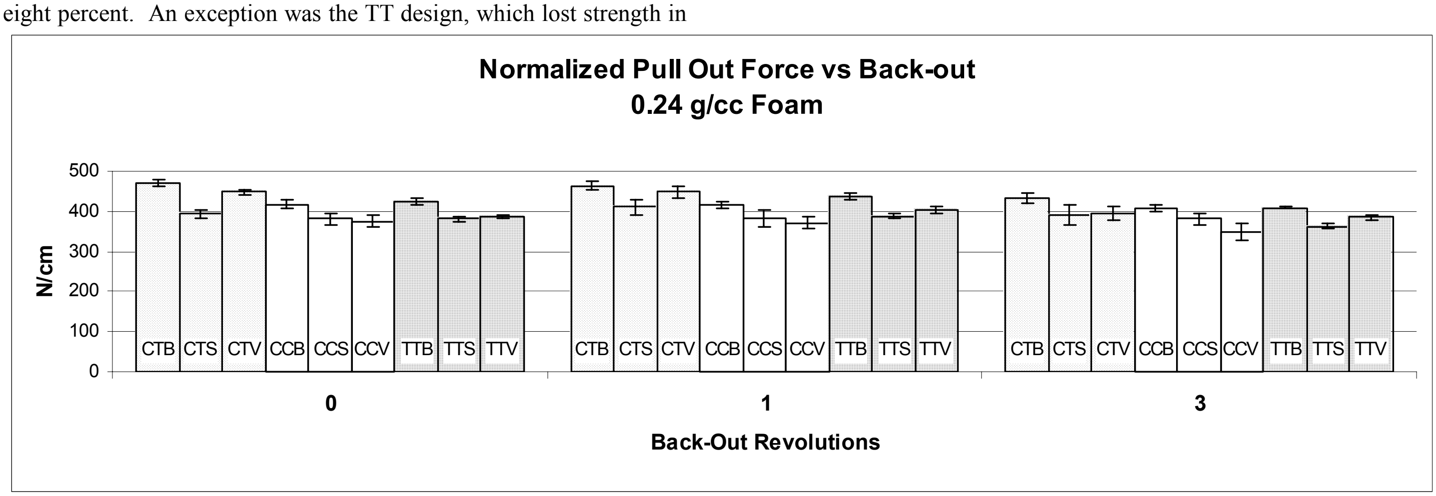

Figure 3. Peak pullout forces vs. revolutions of screw back-out in 0.24 g/cc Foam. Forces normalized to embedded screw length. Error bars represent ± one standard deviation.