COMPARING THE FIXATION OF A NOVEL HOLLOW SCREW VERSUS A CONVENTIONAL SOLID SCREW IN HUMAN SACRA UNDER CYCLIC LOADING.

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INTRODUCTION

Pedicle screw loosening in the sacrum is a significant mode of failure for lumbosacral fusions, particularly in long constructs (Carlson et al., 1992). The success of this procedure depends, in part, on the initial stability of the mechanical construct within bone. Currently, solid pedicle screws are the standard instrumentation used in the sacrum; however, use of a hollow screw has been proposed. The hollow screw increases contact area with the surrounding bone, both on the outer and inner surface of the screw, and thus may potentially improve fixation within the trabecular bone of the first sacral (S1) pedicle.

The purpose of this study was to determine if a hollow screw would be more resistant to loosening than a solid pedicle screw in the S1 pedicle under cyclic loading.

METHODS AND PROCEDURES

Seven fresh-frozen cadaveric sacra (mean age: 72 ± 4 years) were thawed and stripped of soft tissue. In each specimen, a solid 7.5 x 35 mm Xia® monoaxial titanium screw (Stryker Spine, Allendale, NJ) was placed in one S1 pedicle and a 12 x 34 mm MACS-TL HMA® (hollow monoaxial) titanium screw was inserted contralaterally. Insertion was performed under fluoroscopic guidance and the initial screw purchase was visualized using Computed Tomography (CT).

Figure 1. INSET: (A) Solid Screw, (B) Hollow Screw. APPARATUS: (C) Ball joint connected to the actuator of the Instron® materials testing machine, (D) Connecting rod between ball joint and screw, (E) Optical tracking beads, and (F) Sacrum potted within Denstone™ cement, with endplate exposed.

Each sacrum was potted in a custom-designed fixture. A standard fusion connecting rod was secured to both the screw and via a ball joint to the actuator of a materials testing machine (Instron 8872, Canton, MA) (Figure 1). Using load control, an alternating tension-compression load was applied in a sinusoidal pattern (frequency = 1Hz) to the connecting rod, such that the screw was subject to flexion and extension bending moments. Flexion moments started at 0.5 Nm (i.e. non-destructive level) for the first 1000 cycles, and increased by 0.5 Nm every 1000 cycles until the screw had visibly failed. Extension moments were maintained at 0.5 Nm...
throughout testing. Beads fixed to the rod and the sacrum were used to record screw rotation (flexion) relative to bone at 7.5 Hz using custom optical tracking software (Camera: Sony DFW-SX910, Japan; Software: Labview Vision Acquisition, National Instruments, TX). CT scans were repeated following experimental testing. Both the magnitude of the applied flexion moment and the number of loading cycles to cause loosening were analyzed using two-way repeated measures ANOVAs with post-hoc Student-Newman-Keuls tests ($\alpha=0.05$).

RESULTS

Loading of each screw continued until gross screw loosening was evident by visual inspection. It was determined post-hoc that visible failure corresponded to an average of 6° of screw flexion, by examining a graph of screw rotation versus time for each specimen. Relative performances of the two screws were therefore compared at both 3° and 6° of rotation.

![Figure 2](image.png)

Figure 2. Loading cycles required to reach both 3° and 6° of screw rotation.

Overall, the hollow screw required fewer loading cycles ($p=0.004$) (Figure 2) and less applied moment ($p=0.003$) to achieve the same magnitude of screw rotation as the solid screw. Post-loading CT scans showed the hollow screw tended to cut through trabecular bone, with a central core of bone remaining within screw, while the solid screw ‘swept away’ interior trabecular bone.

DISCUSSION

Sacral screw loosening continues to be a clinical problem due to the large cyclic bending moments applied at the screw-bone interface in the sacrum. Altering existing screw designs could improve fixation between the bone and screw in the early post-operative period, allowing a better chance for successful fusion. The in-vitro nature of this study is indicative of the initial fixation strength available in the bone-screw interface.

A previous study has shown the hollow screw to provide comparable results to bicortical fixation in an axial pullout test when used from an anterior approach in other vertebral bodies (Schramm et al., 2003). Subjected to cyclic flexion-extension loading in the present model, however, the hollow screw proved to be less effective at resisting screw loosening. The current findings are supported by the work of Ferguson et al. (2002) who also found the hollow screw to be ineffective under cyclic conditions in thoracolumbar vertebrae, which they attributed to cancellous bone cut-out.

SUMMARY

The novel hollow screw was less resistant to loosening when compared to a conventional solid pedicle screw in this sacral model under cyclic loading.

REFERENCES

Ferguson SJ et al. (2002). Eur Spine J, 11: 527-34.