Cement Augmentation of Sacral Pedicle Screw Fixation

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INTRODUCTION

Instrumentation failure in the S1 pedicles as a result of the screw loosening created by large cyclic bending loads is well documented. Biomechanical studies have shown that pedicle screw augmentation with Polymethylmethacrylate (PMMA) can result in improved screw-bone interface strength [1].

As an alternative to PMMA, a newly developed calcium triglyceride bone cement (CTBC) (Kryptonite, Doctors Research Group, USA) has been reported to have osteoconductive properties [2]. In addition, CTBC is adhesive, non-toxic, and low exothermic, all of which would be advantageous in vivo. It has also been shown to have a modulus of elasticity very similar to bone, which is drastically different than the much stiffer PMMA. These properties provide a theoretical advantage of CTBC compared to PMMA for use in vivo. However, to date, there is no peer-review published literature biomechanically comparing the screw fixation strength in CTBC versus PMMA.

The aim of this study is to determine if pedicle screw fixation augmented with CTBC would be more resistant to loosening than the conventional technique using PMMA when inserted into the S1 pedicles and tested under cyclic loading in a cadaveric model.

MATERIALS & METHODS

Six fresh-frozen cadaveric sacra (mean age: 72 ± 12 years) were thawed and stripped of soft tissue. Using a standard posterior technique and fluoroscopic guidance, a Xia® monoaxial titanium screw (Stryker Spine, Allendale, NJ) was placed into the S1 pedicles of each specimen. Screw sizes were chosen based on specimen geometry and matched contralaterally. A controlled volume (i.e., 2.5 ml) of PMMA or CTBC was injected into the screw tract after removal of the normally inserted screw. The same screw was then immediately reinserted after cement injection. The cement was allowed to cure overnight for at least 12 hours before testing.

Figure 1. (A) Sacrum potted within Denstone™ cement, with endplate exposed; (B) Ball joint connected to the actuator of the Instron® materials testing machine; (C) Connecting rod between ball joint and screw; (D) Optical tracking markers.

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 1 Nm every 1000 cycles until the screw had reached six degrees of rotation. Extension moments were maintained at 0.5 Nm throughout testing. Custom tracking markers were fixed to the rod and the sacrum 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).

Both the magnitude of the applied flexion moment and the required number of loading cycles to cause screw loosening was analyzed using two-way repeated measures analyses of variance (ANOVAs), with factors of augmentation type and magnitude of screw motion (three and six degrees), followed by post-hoc Student-Newman-Keuls tests (α = 0.05).

RESULTS

Every screw loosened within the pedicle to at least six degrees of rotation under the defined loading protocol, without screw fracture or failure. This value of screw flexion corresponds to a previous study by our lab performed using a similar in vivo nature of this study is indicative of the initial fixation strength available in the bone-screw interface; however, it does not allow for any of the potential in vivo benefits or drawbacks to be compared.

The PMMA augmented screw required an average applied moment of 15.3 ± 2.2 Nm, which was significantly larger (p=0.041) than 10.5 ± 1.7 Nm for the CTBC augmented screw (Figure 2). The PMMA also required an increase in cycles to failure (p=0.007) of 15464 ± 2526 cycles compared to 10277 ± 1762 cycles for the CTBC.

Figure 2. Applied moment (Nm) required to reach both 3° and 6° of screw rotation (i.e., flexion) within the S1 pedicle.

DISCUSSION

While pedicle screw loosening in the sacrum continues to plague the success of long fusion constructs, the use of PMMA to augment screw fixation is mainly limited to existing screw failures or in serious cases of osteoporosis, as a result of its known drawbacks. CTBC offers potentially revolutionary capabilities for spine surgery if the biomechanical properties can be shown to be similar to that of PMMA. The in vitro nature of this study is indicative of the initial fixation strength available in the bone-screw interface; however, it does not allow for any of the potential in vivo benefits or drawbacks to be compared.

Both the PMMA and CTBC provided a substantial increase in fixation over unaugmented pedicle screws in the sacrum in comparison to a previous study performed by our lab performed using a similar methodology [3]. However, in the current model, the PMMA augmented screw was shown to be more effective at resisting screw loosening compared to the CTBC augmentation.

REFERENCES