BIOMECHANICAL COMPARISON OF SCREW HOLDING POWER FOR DIFFERENT PEDICLE SCREW AUGMENTATION TECHNIQUES IN SEVERE OSTEOPOROSIS

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SUMMARY
Pedicle screws with PMMA cement augmentation have been shown to significantly improve the fixation strength in a severely osteoporotic spine. However, the efficacy of screw fixation for different cement augmentation techniques, namely solid screws with retrograde cement pre-filling versus cannulated screws with cement injection through perforation, remains unknown.

Conical and cylindrical pedicle screws with solid or cannulated designs were installed using the aforementioned cement augmentation techniques. Uniform synthetic bones simulating severe osteoporosis was used to provide a platform for each screw design and cement augmentation technique. Pedicle screws were then tested for axial pullout failure using a mechanical testing machine.

The results revealed the following 1) Regardless of the screw outer geometry (conical or cylindrical), solid screws with retrograde cement pre-filling exhibited significantly higher pullout strength as compared to that of cannulated screw with cement injection ($p = 0.0129$ for conical screws; $p = 0.005$ for cylindrical screws). 2) For a given cement augmentation technique (cannulated screw with cement injection or solid screw with cement pre-filling), no significant difference in pullout strength was found between conical and cylindrical screws ($p > 0.05$).

INTRODUCTION
PMMA augmentation is regarded as an efficient method to enhance screw strength in osteoporotic bones [1]. Traditionally, in order to improve the anchoring strength of screws in osteoporotic bone, PMMA is injected directly into the prepared pilot hole of the vertebral body prior to screw insertion. The pedicle screw is then inserted into the cement to enhance the screw anchoring strength. Another insertion technique is the usage of expandable screw, which allows flange expansion at screw tip and hence increases the screw holding power [2]. Recently, works have focused on the perforated screw with PMMA augmentation, which allows the injection of cement through the perforation to achieve the improvement of screw anchoring strength [1]. Although numerous studies address the improvement in pullout strength with various screw augmentation techniques, a comparison of screw insertion techniques between solid screws with retrograde cement pre-filling and cannulated screws with cement injection is lacking.

METHODS

Synthetic bone samples
Synthetic bone made from polyurethane foam was used as substitute for cadaveric spinal bone. The material was open-cell rigid polyurethane foam with a density of $0.09 \text{ g/cm}^3$ to simulate a cadaveric spinal bone with extreme osteoporosis.

Bone screws
Four screw designs were employed in the present study: conical-solid, conical-cannulated, cylindrical-solid and cylindrical-cannulated screws. The cylindrical screws maintained a constant diameter from hub to tip. The conical screws tapered 20%, from 6.0 mm at the hub (major diameter) to 4.8 mm the tip. The thread pitch was 2 mm and the thread depth was 0.8 mm for both screws. The thread contour was identical for both screws. For the cannulated screws, two radial holes with a diameter of 2 mm were located at 5-mm increments along the length of screw starting at the screw tip. Figure 1 illustrates the conical and cylindrical screws in the cannulated design.

Allocation of the specimens
The allocation of specimens to experimental groups is shown in Table 1.

Specimen preparation
For cannulated screws (both conical and cylindrical), PMMA cement was injected into the test block after screw insertion. Pilot hole was drilled into the test block using a 3-mm drill, and cannulated screw was then inserted into the test block through the prepared pilot hole. Following the cannulated screw insertion, Osteobond bone cement (Zimmer, Warsaw, IN) was mixed at room temperature and introduced.
into the cannulated screws using a self-designed cement injector system that exerts pressure on the cement. For all specimens, a total of 3 ml of cement was injected into the cannulated screw.

For solid screws (both conical and cylindrical), the solid screw was inserted into the test block through the prepared pilot hole and then removed to create a hole with identical dimension as the screw contour. A total of 3 ml of cement was then retrogradely injected into the created hole using a 4-mm diameter bone biopsy needle.

**Biomechanical tests**

The individual specimen was tested for failure in axial pullout using an Instron testing machine. Pullout force was applied at a constant crosshead rate of 5 mm/min. The force acting on the screw during the testing was continuously recorded in 0.1-mm increments. Six trials for each screw fixation configuration were performed, and the mean value of the maximum pullout strength of the six trials was determined. Unpaired two-tailed Student’s *t*-tests were performed for the intergroup comparison. Differences were considered significant for *p* < 0.05.

**RESULTS AND DISCUSSION**

The radiological and physical examinations of the screws inserted into the test blocks and specimens after the pullout tests are shown in Figure 2. The radiological photographs (Figure 2, top) indicated that the area of the cement/screw interface was greater for solid screws with retrograde cement pre-filling than for cannulated screws with cement injection. Observations of the failed specimens after pullout test (Figure 2, bottom) indicated that cement infiltration into the open cell of the test block led to a (cement/bone) composite structure. All the failures occurred at the composite/bone interface, however, the composite remained well bonded to the screws.

The average ultimate pullout strengths of conical and cylindrical pedicle screws for the different cement augmentation techniques are shown in Figure 3. Regardless of the screw outer geometry (conical or cylindrical), solid screws with retrograde cement pre-filling exhibited significantly higher pullout strength as compared to that of cannulated screw with retrograde cement pre-filling (*p* = 0.0129 for conical screws; *p* = 0.005 for cylindrical screws); whereas solid screws without cement augmentation exhibited the lowest pullout strength (*p* < 0.001). For the conical screws, the solid type provided a 23 % increase in the pullout strength compared to the cannulated type (*p* = 0.005). For a given screw augmentation technique (screw without cement augmentation, cannulated screw with cement injection or solid screw with cement pre-filling), no significant difference in pullout strength was found between conical and cylindrical screws (*p* > 0.05).

**Figure 2**: (A) A conical solid screw with cement pre-filling, (B) a cylindrical solid screw with cement pre-filling, (C) a conical cannulated screw with cement injection and (D) a cylindrical cannulated screw with cement injection.

**Figure 3**: Average ultimate pullout strength of conical and cylindrical screws with various screw fixation techniques.

**CONCLUSIONS**

We conclude that solid screws with retrograde cement pre-filling offer an improved initial fixation strength compared to cannulated screws with cement injection.

**REFERENCES**


<table>
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<tr>
<th>Group</th>
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<td>6</td>
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