EXPULSION TESTING OF AN INTERVERTEBRAL FUSION CAGE: EFFECT OF TOOTH DESIGN ON PULL OUT RESISTANCE

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ABSTRACT

The effects of tooth design on the expulsion resistance of an anterior lumbar intervertebral fusion (ALIF) device were investigated in a synthetic cancellous bone model. Three tooth designs were tested. A design with teeth in the form of continuous ridges transverse to the direction of expulsion provided significantly more resistance to expulsion than two designs with discontinuous teeth. The designs with discontinuous teeth did not differ significantly.

INTRODUCTION

Cages are increasingly replacing bone graft in intervertebral fusion procedures. One of the potential complications in the use of both grafts and cages is migration. To retard migration, the cage surfaces in contact with the vertebral endplates are typically modified with “teeth” to increase friction. These modifications range from simple roughened surfaces to the addition of aggressively spiked features. The teeth in the present study were fabricated with shallow, parallel, V-shaped grooves in three arrangements.

The aim of this study was to determine which of these designs offered the highest resistance to anterior pull-out.

MATERIALS AND METHODS

This study used the Rhakoss™ Synthetic Bone Spinal Implant (Orthovita Inc., Malvern, PA). The Rhakoss device is generally oval in shape with an annular opening for bone graft augmentation. It is fabricated from a bioactive glass/ceramic composite with an elastic modulus similar to that of bone.

For this test, three tooth designs were tested. The “Basic” design consisted of parallel ridges running in the M-L direction, transverse to the direction of pull. The “Pyramidal” design consisted of two sets of parallel grooves, one in the A-P direction and the second M-L. The intersection of the grooves produced rows of pyramid shaped teeth aligned with the direction of pull. The third configuration was the “Oblique” design. It also consisted of intersecting rows of grooves, but in this case the grooves were set at oblique angles to the direction of pull. These angles were arranged so that the rows of teeth did not align with the direction of pull. The designs are shown in Figure 1.

The implants were tested between blocks of polyurethane foam synthetic cancellous bone (Sawbones, Pacific Research Laboratories, Inc., Vashon, WA). A foam density of 0.24 g/cc was used for all testing.

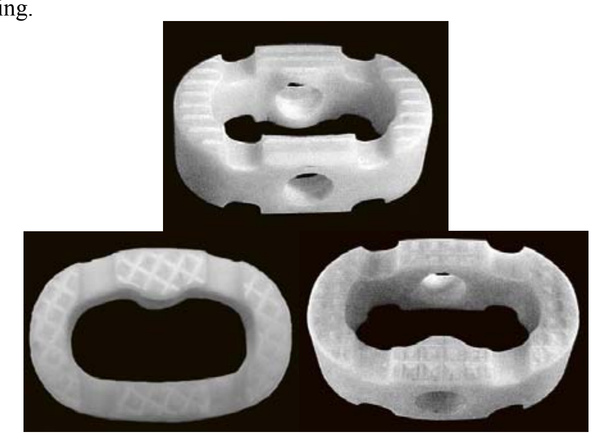

Figure 1. The Rhakoss™ ALIF device in the three tested tooth configurations. Clockwise from top: Basic, Pyramidal, and Oblique.

Testing was performed using a biaxial TestStar II Material Testing System (MTS system, Minneapolis, MN). The machine was fitted with a test fixture capable of constraining the foam blocks in the pull direction while applying a preload along the axis of the simulated spinal column, normal to the pull out. The specimens were sandwiched between the two foam blocks and the fixture was adjusted to produce a preload of 500 N. This preload was applied prior to testing and no provision was made to control it during the extraction.

The test fixture is shown in Figure 2. The implants were pulled using a threaded rod passing through holes drilled through both the anterior and posterior faces of the implants. Force was transmitted to the implant via a nut positioned at the posterior face of the implants, as shown in Figure 3. The implants were pulled at 0.4 mm/sec. Force and displacement data were collected at 10 Hz. The maximum pull force was taken to be the highest force recorded in the first 3 mm of implant displacement.

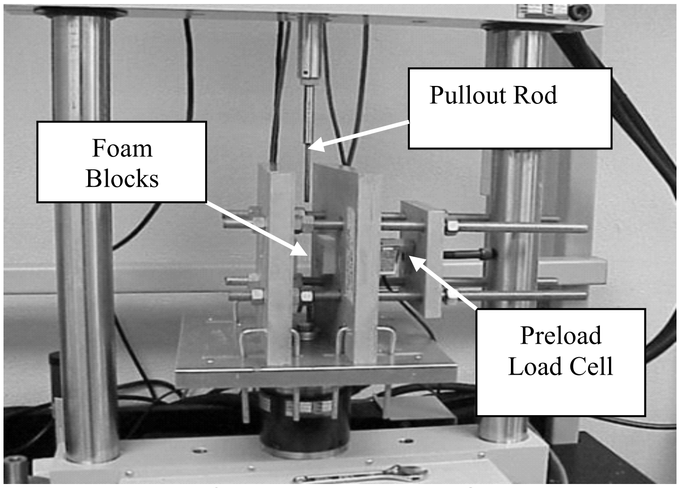

Figure 2. Test fixture mounted to MTS. Preload was applied by tightening the nuts on the four horizontal threaded rods.

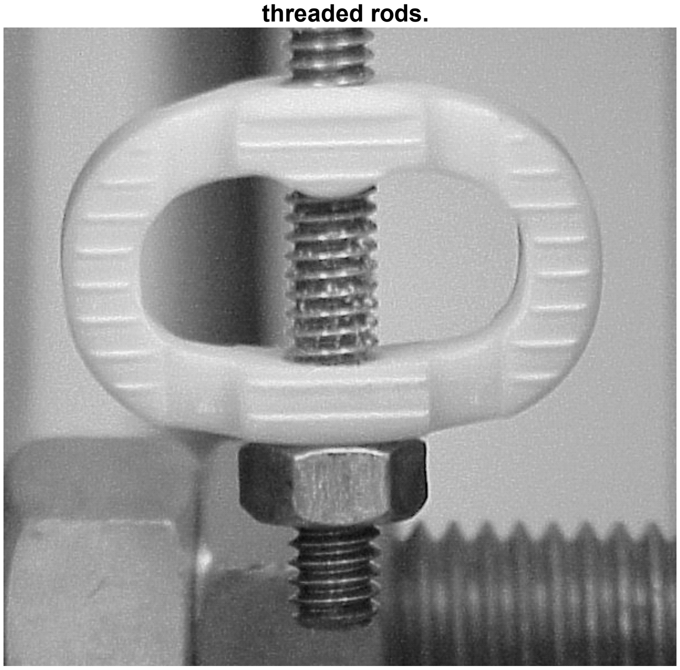

Figure 3. Detail of the method used to pull the implants. The direction of pull is upwards. For this testing, holes were added to the device to accommodate the rod.

RESULTS

Test results are shown in Table 1. The Basic tooth design generated significantly higher peak pull out forces than the other designs (two-tailed Student t-Test, $p \leq 0.05$). The Basic tooth design average of 864±141N was almost one third higher than those of the non-continuous tooth designs. There was no statistically significant difference between the other designs, which averaged 651±98N for the Oblique and 623±74N for the Pyramidal.

In all cases but one, failure consisted of gouging of the foam medium. The implant teeth did not show any visible wear or damage. In one case, involving a Basic tooth design, the implant failed at 813 N, breaking into four pieces. This failure initiated at the hole drilled in the implant to accommodate the pull rod. It is believed this failure was a result of the addition of this hole and the method of loading and not a function of implant design. All the implants developed cracks originating from the added hole during testing, but only one failed completely.

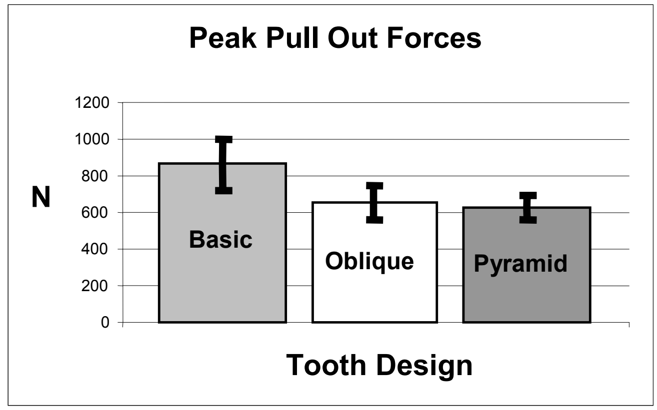

Table 1. Average peak pull-out forces for the three tested designs. Error bars indicate ± one standard deviation.

DISCUSSION

This study indicates that continuous transverse teeth may be superior to discontinuous teeth in cancellous bone. This design should also best distribute compressive loads across the vertebral endplates. More aggressive tooth designs may run an increased risk of subsidence by initiating failures of the endplates.

It should be noted that to execute this type of tooth design requires a relatively large implant footprint area. This favors a design, such as the Rhakoss, made of a material with an elastic modulus similar to bone. This material property allows for a larger cross sectional area without causing excessive stress shielding. Further studies are needed in cadaver models.

ACKNOWLEDGEMENT

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