Do "Cancellous Metal" Shells Provide Adequate Stability for Press-Fit Fixation in the Revision Acetabulum?

Introduction:

In revision THR, acetabular fixation can be problematic due to acetabular rim defects. Although press-fit fixation is often augmented by bone screws, long-term retrievals have shown that screw holes expose the pelvis to particulate debris leading to the formation of granuloma along screw threads. Moreover, conventional ingrowth coatings allow excessive interface motion at sites removed from points of screw fixation. These concerns have led to the development of shells with high porosity “cancellous” metal coatings to increase the fixation and biologic incorporation of acetabular cups. These materials have potential in expanding the indications for press-fit fixation in revision THR without the use of dome screws. This study was performed to determine whether a “cancellous” metal coating provides adequate strength of fixation for use in the deficient revision acetabulum without adjunctive fixation.

Materials and Methods:

A surrogate model of the revision acetabulum was fabricated from a composite construction of low-density polyurethane foam with rigid polymeric reinforcement simulating the cancellous bone bed and the periacetabular cortex respectively. The model replicated critical anatomic features of the bony acetabulum, including the acetabular notch, the external chamfer of the bony margin, and reinforcing columns representing the ilium, ischium and pubis. The hemispheric cavity within each surrogate was prepared using custom milling fixtures which held the internal diameter of the implantation site to a tolerance of 55 ± 0.15 mm. A Paprosky Type IIb defect spanned 100° and was located 230 ± 0.5° from the center of the notch to replicate the discontinuity in rim contact in the revision acetabulum. The stiffness profile of the surrogate was matched to stiffness of the cadaveric acetabulum. In pilot experiments, the response of the surrogate to implantation of a press-fit shell was validated through comparison against experiments performed with 7 unilateral cadaveric hemi pelvises (mean age 75.1 years).

To evaluate the performance of a “cancellous” metal coating for press-fit applications, 27 forged, hemispherical, titanium (Ti6Al4V) shells were coated with one of three coatings: “cancellous” metal, conventional plasma-spray coating, and titanium alloy beads. The highly porous (55-65%), sintered titanium coating of the “cancellous” cup consisted of interconnected, open pores ranging in size from 250-400µm. In contrast, the lower porosity arc-deposited plasma coating (2-15%) and sintered beaded (30-35%) coatings had closed pores ranging in size from 400-600µm and 90-125µm respectively.

Results:

The average cyclic load at 150µm of permanent interface displacement for the “cancellous” coated shell (675±103N) was the same as the plasma-sprayed component (674±113N, p=0.99) but 87% greater than the beaded implant (363±82N, p<0.01). The ultimate spin-out force of the “cancellous” metal shell (1088±250N) was 18% greater than the plasma-sprayed (921±134N, p=0.05) and 189% greater than the beaded implant (377±97N, p<0.01). Given the minimum spin-out threshold of 400N, the fixation of 67% of the beaded cups was unacceptable while the fixation of the “cancellous” metal and plasma-sprayed cups demonstrated 100% acceptability (p<0.01).

Upon visual examination of the surrogates following ultimate spin-out, the “cancellous” metal implants were observed to undergo cohesive failure of the foam in which the foam substrate failed as indicated by the presence of foam interdigitated with the implant coating. The plasma-sprayed implants failed in a combination of interface failures where a) the cup surface slipped past the foam and b) cohesive failure of the foam. The beaded coating appeared to fail solely at the cup-foam interface as no foam was removed from the acetabulum during spin-out. Cohesive failure of any of the coatings was believed to be improbable due to the discrepancy in strength of the coatings relative to the foam of the surrogate.

Discussion:

- Initial fixation of “cancellous” metal coatings are superior to that of conventional plasma-sprayed and beaded components when permanent interface displacement (150µm), resistance to ultimate spin-out or a minimum fixation threshold (400N) are compared in the deficient surrogate acetabulum.
- The superior initial stability of the “cancellous” metal coatings may be attributed to the cohesive failure of the foam in the surrogate acetabulum in contrast to the mixed mode failure of the plasma-sprayed coating and the slip of the cup-foam interface of the beaded coating.
- These results suggest that these new “cancellous” metal coatings provide improved fixation which, with further testing, may prove to be adequate to warrant their use without dome screws in revision THR.

Figure 1

A ramped (100 N/s) implantation load of 1500 N was used to press-fit each cup in a surrogate with 1.0 mm of interference. Each cup was subsequently subjected to cyclic edge loading utilizing a ramped amplitude function (50N/cycle) in which the cup was loaded at 50N/s to a peak load. The cup was then unloaded and held for 20 seconds until the next loading cycle was initiated. The cyclic loading procedure continued until ultimate spin-out of the cup from the surrogate. The relative motion of the implant with respect to the foam surface was continuously monitored by a displacement transducer mounted on the crosshead of the testing machine and following the motion of the foam surface adjacent to the point of load application. Failure of implant fixation was defined at two points:

1) The edge load corresponding to 150µm of permanent interface displacement, as defined by interpolation of the peak edge load versus the residual interface displacement proceeding the corresponding load cycle
2) Ultimate spin-out of the implant from the acetabulum where the permanent interface displacement was greater than 4mm.