A NOVEL SURFACE TREATMENT ON POROUS METAL IMPLANTS THAT IMPROVES THE RATE OF BONY ONGROWTH

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INTRODUCTION
Biological fixation of porous coated metallic implants is a complex phenomenon, involving the processes of osteoconduction and osteoinduction. Porous ingrowth options in current use require both mechanical and chemical modifications of the metallic surface for optimal success. Attachments of beads, wire mesh, and plasma coatings are straightforward processes, but chemical treatments, such as hydroxyapatite (HA) coatings, are more complex and expensive.

The purpose of this study was to evaluate the efficacy of using a beaded surface treated with a new chemical process (Orthobond) that renders the surface osteoinductive. This relatively easy and inexpensive process is a chemical surface treatment that creates a monolayer of phosphonate molecules covalently bonded to the naturally occurring metal oxide surface. A variety of biologically functional molecules can be bonded to the monolayer, an example of which is RGD peptide, a known modulator of cell adhesion and initiator of cell signaling.

We hypothesized that Orthobond coating would enhance mechanical fixation of porous coated metallic implants beyond that achieved with HA treatment.

MATERIALS & METHODS
Sixty skeletally mature New Zealand white male rabbits had beaded titanium cylinders (5mm diam, 25mm long) inserted retrograde bilaterally into their distal femora. The cylinders were treated with one of three coatings: Orthobond alone, Orthobond and an RGD peptide, or HA alone. Fifteen rabbits were sacrificed at each of 4 time intervals: 2, 4, 8, and 16 wks with 10 specimens of each coating randomly assigned to femora for each time point. All femora were harvested and subjected to either mechanical (7 specimens per group) or histological analysis (3 specimens per group).

Mechanical pull-out tests were performed on an MTS servo hydraulic load frame. Specimens were prepared by carefully removing the distal femur around the uncoated portion of the implant and creating a cable loop that would attach to the testing machine. A 2 mm K-wire was inserted perpendicularly through the proximal femur and supported by bone cement; the wire was attached to a custom fixture that ensured uniaxial loading. Tests were conducted at 2mm/minute, and maximum failure load was recorded.

Histological specimens were fixed in 70% alcohol immediately after sacrifice. Using a diamond blade, two cross sections through the implant and cortical bone were taken at the proximal and distal ends of the implant. These sections were analyzed by scanning electron microscopy (SEM), morphometry, and bone formation rates using fluorescence microscopy.

Statistical analysis was performed using a two-way ANOVA, followed by a Student-Newman Keuls post-hoc test. The type I error rate was set at 0.05. The study was approved and monitored by the IACUC.

RESULTS
For all groups, failure load increased over the study period. Both Orthobond groups had significantly higher failure loads when compared to HA at 4 wks (p<0.05) suggesting a more rapid fixation process. The Orthobond alone group had significantly higher failure loads when compared to HA at 16 wks (p<0.05) (Fig. 1).

SEM demonstrated new bone formation around all three groups as early as 2 wks, though the trabecular characteristics in the epiphyseal region differed among the groups (Fig. 2). Cortical bone bridging was noted in the metaphyseal region between the rod and the endosteal cortex in the Orthobond treated rods; in the HA group, only trabecular bone bridging occurred in this region. In the distal sections, trabecular bone was found surrounding the rod even though trabecular bone was lost in all samples in the anteroposterior direction within the metaphysis. In the proximal sections, bone was formed from the endosteal surface to surround the implanted rod. The rate of new bone formation was similar in all three groups.

DISCUSSION
Our biomechanical and histomorphometric analyses of this novel coating are encouraging. The mechanical results show that the Orthobond process enhances bony fixation of porous coated titanium implants by achieving greater fixation strength more rapidly than conventional HA coating. The histological analysis was supportive, but not conclusive, of a more rapid integration of bone onto the implant. The load sharing with the Orthobond implants as compared to HA can be seen with trabecular resorption medially and laterally, thickening anteriorly and posteriorly, and the presence of new trabeculae peripherally around the bond. At four weeks, these phenomena were much less developed in HA specimens. Although few specimens were analyzed histologically, this remodeling is suggestive of earlier bone ingrowth and fixation.

One of the limitations of this study is the large variability in mechanical and histological results. This is most likely explained by a varied implant fit in all femora. This was a pilot study powered off previous published HA data using the same animal/implant model 3. Further work with a bilateral control to lessen the impact of this variable, as well as to evaluate the longer term properties of this coating is necessary.

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REFERENCES

Figure 1: Mechanical pull-out test results (* represents significant difference, p<0.05).

Figure 2: Cross section of rod (white) surrounded by new bone formation in distal femur: A) Orthobond + RGD, B) Orthobond Only, and C) hydroxyapatite (Mag: 15X).