Abrasion and Frictional Properties of a Porous Titanium Foam

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Statement of Purpose: The purpose of this study was to measure abrasion and friction characteristics of a novel titanium (Ti) porous metal foam. The material is presented as a coating for fixation of cemented and cementless orthopedic implants. In addition to other bulk mechanical properties, the *in vivo* performance is affected by its mechanical interaction with bone.

Methods: Four coating types, shown in Table 1, were bonded to Ti6Al4V substrates (30x30x6 mm). Metal foam surfaces were textured by wire electro-discharge machining to create shallow grooves in the surface (x-hatch).

Table 1: Coating specimen groups

Group	Description	% Porosity
A	3-layer CP Ti porous beads	30-40%
B	0.5 mm CP Ti plasma spray	0%
C	Ti metal foam w/ x-hatching	72%
D	Ti metal foam w/ x-hatching	67%

Abrasion testing was performed per the FDA guidance for modified metallic surfaces. A hardened cylinder (l=25 mm, r= 0.5 mm, 51 Rockwell C min) was cycled back and forth, normal to its axis, over the same 25x25 mm of specimen surface for 10 cycles. The specimen was oriented downward such that debris would fall away from the surface. The minimum load, (the lowest load that produces a detectable loss in the specimen surface), and the maximum load, (the load that removes at least 50 percent of the specimen surface or causes significant plastic deformation), were determined. Three specimens were then tested at five loads equally spaced between the established minimum and maximum loads. Abrasive wear is reported as percent height change. Friction properties were measured based on a prior study with cadaver tibiae[1]. Blocks (25.9x25.9x12.7 mm) of 10 pcf foam bone (SAWBONES, Inc. Vashon, WA) were selected to represent tibial cancellous bone[2]. The test was conducted on a biaxial test machine with a linear bearing attached to the vertical load cell. Alignment adjustments were made to ensure the opposing surfaces of the specimens were parallel to one another and a vertical load of 65 N was applied normal to the contacting surfaces, producing a contact pressure of 0.1 MPa. Horizontal displacement was applied to the foam bone at a rate of 0.025 mm/sec and vertical load, horizontal load, and horizontal displacement were sampled and recorded at 10 Hz with data acquisition software (ENDURATEC, Inc., Eden Prairie, MN). The coefficient of friction was calculated by dividing peak horizontal load by the nominal normal force (65 N).

Results/Discussion: Abrasion test results are shown in Fig. 1. Groups C and D showed higher abrasion resistance than Group B (ANOVA, P<0.01). There was no significant difference between Groups A and D (P=0.9788), however, Group C was found to have greater abrasive wear than Group A (P<0.001).

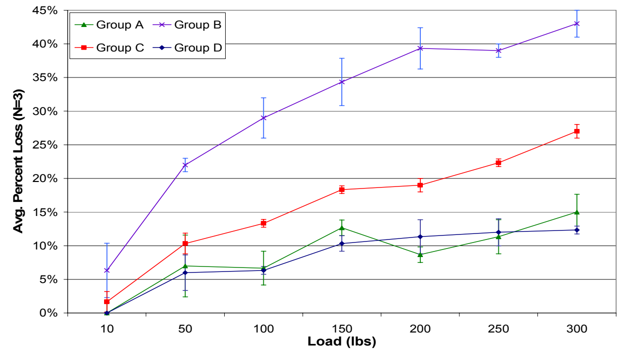

Figure 1. Percent of coating height loss

The coefficient of friction for each group is shown in Fig. 2. The average coefficient of friction obtained for both Groups C and D were greater than that of Group A (two sample t-test, P=0.006 and P=0.004, respectively). Group C had higher friction values than Group B (P=0.007), however, the difference between Group D and Group B was not significant (P=0.054).

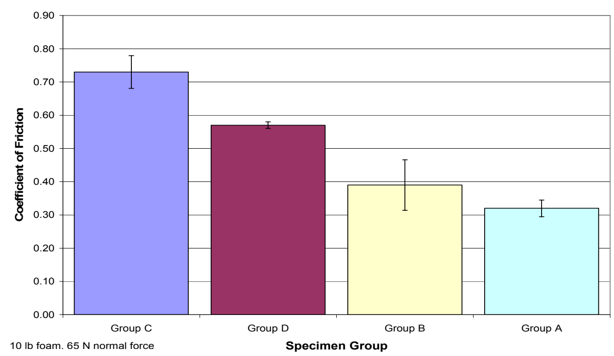

Figure 2. Average coefficient of friction (N=3)

Conclusions: The ability to withstand abrasion in a manner similar to other coatings while increasing the porosity compared to those materials is a benefit of the subject material. The results also indicate the Ti metal foam is capable of providing equivalent or greater resistance to motion against cancellous bone than the other biomaterials considered in this study. Property variability is consistent with the controls. From an abrasive wear and frictional stability standpoint, this material provides excellent surface properties to function in the intended manner as an orthopedic implant coating.

References: (1) Shirazi-Adl, A., JBMR, Vol. 27, pp 167-175, 1993.
(2) Goldstein, SA, J Biomechanics, Vol. 16, No. 12, pp 965-969, 1983.