**Bulk Mechanical Properties of a Novel Titanium Foam**

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**Statement of Purpose:** Titanium metal foam is a prospective material for orthopedic implants and implant coatings.

In this study, mechanical properties of a novel open porous titanium foam material were determined. The effect of percent porosity on compressive strength of the bulk titanium foam was investigated and flexural properties were evaluated.

**Methods:** Metal foam parts of varying percent porosity were manufactured from commercially pure titanium by Wright Medical Technology, Inc. The pore cell size is around 530µm and the diameter of interconnection pores is around 200µm. Commercially available porous tantalum parts (Trabecular Metal™, Zimmer Inc., Warsaw, IN) were obtained for comparison. The porous tantalum has been reported to have pore sizes around 430µm and 75-80% porosity [1].

The compression tests were performed per ASTM D695. Cylinders measuring 8mm diameter by 12 mm long were machined from bulk foam parts using electric discharge machining (EDM). The aspect ratio of the cylinders was chosen to obtain accurate strength measurements and was below the suggested ratio for determining compressive modulus. A total of 15 cylinders were obtained from three lots of titanium foam with a bulk porosity of 68-69%. An additional 17 cylinders were obtained from three bulk foam lots ranging from 67% to 71% porosity. A total of 7 cylinders were machined from the porous tantalum parts using EDM. The specimens were tested using an MTS 858 Bionix Test Systems load frame at a strain rate of -0.333mm/sec. The percent porosity was estimated for each cylinder based on the cylinder's weight and volume and the published densities of pure titanium and tantalum.

Four-point bend testing was performed on 7.5 x 7.5 x 75 mm titanium foam blocks per ASTM D790. A total of 15 samples were cut from the same three 68-69% porosity lots used to obtain the compression test cylinders, using EDM. Each part was weighed to determine the percent porosity. Testing was conducted in a MTS 858 Bionix Test Systems load frame at a strain rate of 0.333 mm/second, using a four point bend fixture (Wyoming Test Fixtures) with the inner rollers set to a distance of 25 mm and the outer rollers to a distance of 60 mm.

**Results/Discussion:** Figure 1 shows a scatter plot of compressive strength of titanium foam as a function of porosity. Over the porosity range investigated, it was found that the relationship between porosity and compressive strength was linear.

Table 1 shows the compressive strength, elastic limit and modulus for the three lots of titanium foam at 68-69% average porosity, as well as the porous tantalum parts. Even though the metal foam had a higher average compressive strength, analysis of variance failed to show statistical significance (P-value = 0.154).

Results for four point bend testing of the same three lots of titanium foam are given in Table 2.

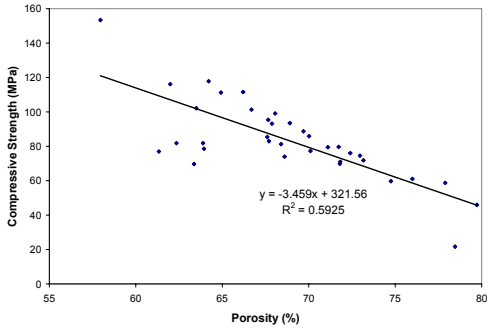


Fig. 1. Compressive strength as a function of % porosity for titanium metal foam.

Table 1. Compressive properties of Ti foam & porous Ta

| | Average Sample Porosity [st.dev] | Compressive Strength MPa [st.dev] | Elastic Limit MPa [st.dev] | Compressive Modulus GPa [st.dev] |
|---|---|---|---|---|
| Lot1 | 69% [2%] | 89 [9] | 60 [9] | 2.5 [0.4] |
| Lot2 | 69% [2%] | 79 [6] | 62 [4] | 2.5 [0.1] |
| Lot3 | 68% [4%] | 93 [22] | 66 [14] | 3.1 [0.5] |
| Porous Tantalum | 74% [1%] | 76 [15] | 65 [14] | 3.2 [0.5] |

Table 2. Flexural properties of titanium foam.

| | Average Sample Porosity [st.dev] | Flexural Strength MPa [st.dev] | Flexural Modulus GPa [st.dev] |
|---|---|---|---|
| Lot1 | 70% [2%] | 106 [10] | 8.2 [1.5] |
| Lot2 | 69% [1%] | 106 [4] | 9.6 [0.8] |
| Lot3 | 67% [3%] | 134 [20] | 9.7 [2.3] |

The flexural strength and modulus were found to be higher compared to the compressive properties. Since reticulated metal foams consist of a 3-dimensional network of ligaments, the calculated properties are not representative of a pure state of loading.

**Conclusions:** As expected, lower percent porosity resulted in greater compressive strength of the titanium foam. Titanium foam in the range of 68-69 % porosity showed equivalent compressive strength and modulus compared to the porous tantalum parts.

All porosity ranges of the titanium foam as well as the porous tantalum demonstrated excellent mechanical integrity and showed sufficient strength to be used in many load-bearing orthopeadic applications.

**References:**

1) Bobyn J. JBJS 1999; 81B: 907-914