Elastic Modulus Characterization of Porous Titanium TrellOss™ Structure

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Introduction

PEEK (polyetheretherketone) is the most commonly used material for interbody fusion devices.[1] One reason for this is that PEEK has an elastic modulus value greater than cancellous bone but less than cortical bone, providing a greater resistance to subsidence than solid titanium cages.[1]

However, PEEK has several other properties not conducive to osteogenesis and fusion, such as a hydrophobic nature and a smooth surface.[2] For this reason, new alternatives are being developed. One of these is TrellOss, an additive manufactured or 3-D printed titanium (Ti6Al4V) device platform. This device not only is hydrophilic, but also, due to the 3-D printed nature, possesses an elastic modulus lower than traditionally manufactured titanium.[3] In this study, we set out to characterize the elastic modulus of this material and assess its axial compression stiffness.

Materials and Methods

Elastic Modulus Characterization:
Six cubes measuring 10 mm on each side were tested. Each cube was made of additively manufactured titanium Ti6Al4V, in a structure identical to the TrellOss-TS, 26D x 9W x 10H, 0°. Each specimen was measured using a calibrated caliper to determine the exact height and cross sectional area. Then, each specimen was loaded using a servo-hydraulic uniaxial test frame in static axial compression. The samples were loaded in displacement control at 0.1 mm/s until 5 mm or 15 kN (3375 lbs) was reached (Figure 1a). The compressive elastic modulus was computed by fitting a line to the linear region of the stress-strain curve. The average elastic modulus value was compared to other materials commonly used for spinal arthrodesis devices (PEEK and Ti6Al4V) and biological tissues (cancellous and cortical bone).

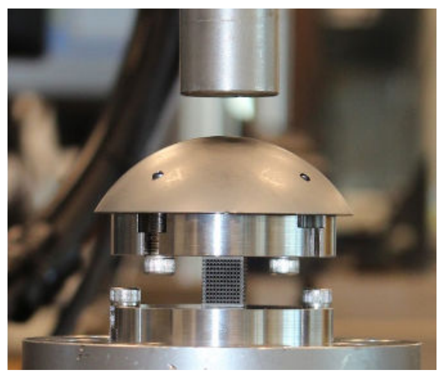

Fig. 1a *Elastic Modulus Characterization Cube*

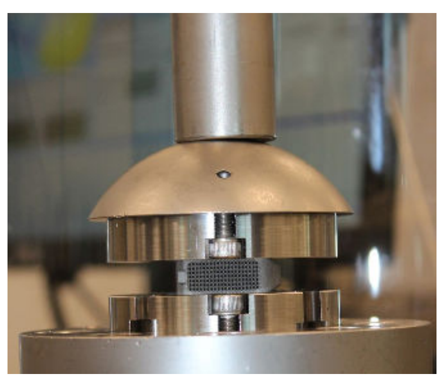

Fig. 1b *TrellOss-TS 26 L x 9 W x 10 H,0°*

Implant Compressive Stiffness Testing:
Six TrellOss-TS, 26D x 9W x 10H, 0° cages were tested in axial compression. The cages were loaded in displacement control at 0.1 mm/s until 5 mm or 20 kN (4500 lbs) (Figure 1b). Analysis of the load displacement curve was performed to determine whether or not plastic deformation (irreversible damage) occurs in this loading range.

Results and Discussion

Each elastic modulus sample was loaded to 15 kN with no plastic deformation or yielding. The average elastic modulus for all samples was 2.97 ± 0.05 GPa (Figures 2 and 3).

For the implant samples tested, each experienced purely linear elastic deformation up to 20 kN.

Elastic modulus of spinal implants is important. Higher elastic modulus leads to greater risk of subsidence.[1,2] Early iterations of interbody designs involved solid machined titanium with sharp edges and pinpointed stress risers. These design features allowed for a greater risk of bony endplate penetration and subsidence.[4] PEEK cages followed these early designs. These cages possess elastic modulus values greater than cancellous bone but less than cortical bone, existing in the ideal range for fusion devices. The problem with PEEK cages is the smooth surface and hydrophobic nature, both of which inhibit osteogenesis.[2] With these results, the TrellOss material demonstrates the ability to tune an additively manufactured or 3D printed Ti6Al4V structure to match the ideal elastic modulus value.

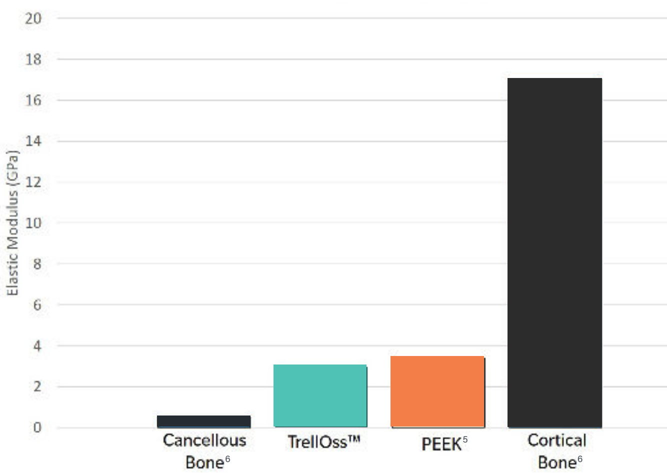

Fig. 2 *Elastic Modulus of Spine Device Materials*

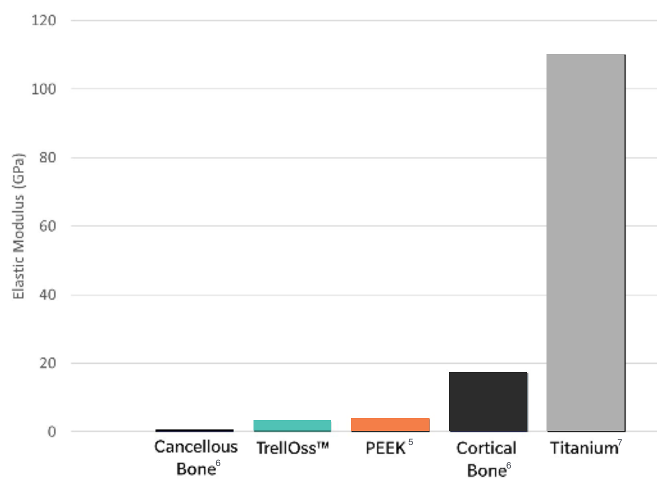

Fig. 3 *Elastic Modulus of Spine Device Materials*

CONCLUSION

The TrellOss structure possesses an elastic modulus greater than cancellous bone, less than cortical bone, and similar to PEEK. This property gives it an excellent ability to prevent subsidence. In addition, a standard TrellOss-TS cage was shown to withstand loads up to 20 kN (4500 lbs) without plastic deformation, demonstrating the strength of the implants.

References:

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