In Vivo Evaluation of Custom-made Dental Implants through Electron Beam Melting

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Statement of Purpose: Electron Beam Melting (EBM) is a novel processing method that uses a computer-controlled heating source to create three-dimensional (3D) objects from metal powders to replicate the 3D profile from a Computer-Aided-Design (CAD) program or patient's computer tomography (CT) data. EBM has been used to make porous Ti-6Al-4V titanium structures for orthopedic and dental applications. By scanning a tooth with computer tomography and then converted the data to a computer-aided design file, the root form and the abutment were made by EBM as one piece to reproduce the shape of the patient's tooth (Chahine et al., 2008). Though the feasibility of producing dental implants by EBM has been demonstrated, there has been very limited information about the *in vivo* performance of these implants. The objective of this study is to evaluate the *in vivo* performance of the novel dental implants fabricated via EBM and compare them to the commercially available porous-coated press-fit dental implants (Endopore). This study is important as a preliminary study to examine the bone to implant integration of EBM and the potential application of EBM. This study is also unique in that this is one of the few studies that use push-out test for the evaluation of mechanical properties and SEM for the evaluation of the bone-implant interface in porous-coated dental implants.

Methods: Twelve commercial conical shape porous-coated implants (Endopore™, Innova Corp.) of 3.5 mm wide and 5 mm long were used as controls. Twelve implants with the same geometry were made by EBM using Ti6Al4V ELI alloy at Southern Methodist University and used as the experimental group. Samples were implanted in the tibia of New Zealand white rabbits for six weeks. Calcein green (10 mg/kg) and alizarin red (20 mg/kg) were injected to the rabbits at 2 weeks and one week before sacrifice. At six weeks, the samples were retrieved and six specimens from each implant type were embedded undecalcified, sectioned, stained and evaluated using an automated histomorphometry system (Bioquant, Nashville, TN). Bone to implant contact (BIC) was obtained by dividing the total perimeter by the length in direct contact with bone. Paired t-test was used for statistical analysis (α=0.05). Fluorochrome analysis was performed on the unstained sections. Mineral apposition rate (MAR) was calculated by measuring the distance between the edges of two consecutive labels divided by the number of days between injection. On the six remaining samples from each implant type, the mechanical properties were evaluated by push-out test using a custom jig device on a material testing machine at a loading rate of 1 mm/min. The push out load and shear stiffness were measured.

Results: For both EBM and Endopore implants, gross examination of the light microscopic sections revealed periosteal and endosteal callous in close proximity to the implant. In the both implants, bone was seen to grow into the porous space between the beads. In EBM implants, some loose metal beads were seen trapped in the tissue (Figure 1). The mean BIC for the Endopore implant was approximately 35% ± 6% while the mean BIC for the EBM implant was 32% ± 9%. There were no significant statistical differences in the MAR and BIC between the two implants. The peak push-out force for Endopore and EBM implants has an average of 198.80 ± 61.29N and 243.21 ± 69.75N. The apparent shear stiffness between bone and implant for the Endopore and EBM has an average of 577.36 ± 129.99 N/m and 584.48 ± 146.63 N/m. Neither the peak push-out force nor the apparent shear stiffness of the implants was statistically different between the two groups. SEM images for the Endopore implant surface after removing the bone at the implant bone junction show parts of bone attached between the implant beads. On the opposing bone surface a replica of the implant beads can be seen indicating that bone grows around the titanium spherical beads. SEM images of the EBM implant surface show areas where beads have been pulled away when the bone was fractured and areas where bone is attached between the beads. On the fractured bone surface, many implant beads were seen remaining on the surface as well as areas that showed the replica of the implant surface (Figure 2). In the histology section of the EBM fracture specimen we can see part of bone attached to the implant at the area of fracture as well as parts of the implant that are still attached to bone.

Conclusions: Preliminary histological and biomechancal results from this study suggest that the implants manufactured by EBM perform equally well with the commercial implant Endopore in this current animal model.

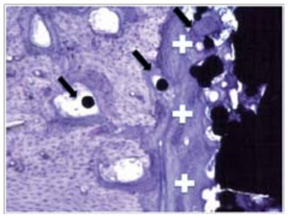

Fig. 1 Histology showing new bone layer (+) formed. Loose metal particles can be seen in the tissue.

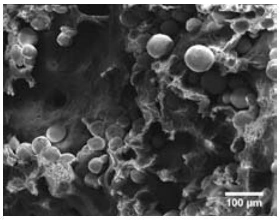

Fig. 2 SEM image of the fractured bone surface opposing the EBM implant. Many titanium beads can be seen attached to the bone surface

References: Chahine G, et al (2008) JOM 60(11):50-55.

This study was funded by Baylor College of Dentistry.