Discrete Deposition of Calcium Phosphate Nanocrystals Promotes Bone-Bonding on Titanium Surfaces

Vanessa C. Mendes[1,2], Rahim Moineddin[3], John E. Davies[1,2]
Institute of Biomaterials and Biomedical Engineering[1], Faculty of Dentistry[2] and Department of Family & Community Medicine[3], University of Toronto, Canada

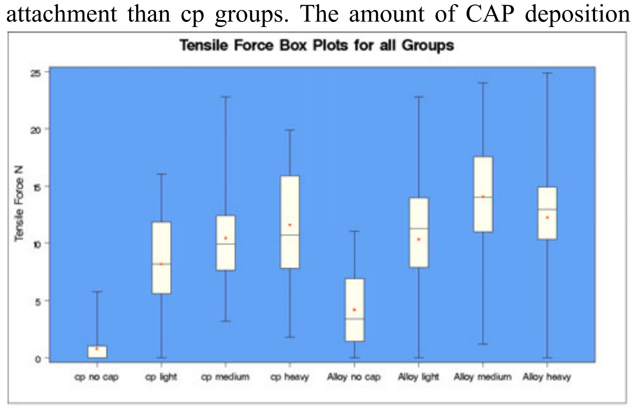
Statement of Purpose: The surfaces of titanium dental implants have evolved with a variety of microtextures that have been shown to accelerate early bone healing and increase implant stability [1,2]. Recently, it has been found that it is possible to modify an already clinically successful microtextured metallic surface by the discrete crystalline deposition (DCD) of nano-crystals of calcium phosphate (CAP). These deposited crystals have little effect on the micron-scale texture of the metallic surface, but do superimpose upon it a nano-scale topographical complexity. The purpose of the present study was to design an experiment to ask the questions: (a) Can such nanofeatures render a metallic implant surface bone-bonding? and (b) Does the amount of CAP deposition influence the degree of bone-bonding? To address these questions, we designed custom implants to measure the attachment of bone to candidate implant surfaces.

Methods: Custom designed rectangular implants, 1.3x 2.5x4mm, were fabricated by 3i Implant Innovations Inc. (Palm Beach Gardens, FL) from either commercially pure ("cp") or titanium alloy (Ti6Al4V or "alloy"). All implants were dual acid etched (DAE) [H_2SO_4/HCl or HCl/HF for cp and alloy respectively]. A total of 8 groups (2 non-DCD and 6 DCD) were generated and 13 implants were fabricated for each group. Non-DCD groups consisted of DAE cp and alloy without any CAP deposition. DCD groups comprised the original DAE cp and alloy implants modified by the CAP nanocrystals (nominal crystal size 20-80nm). Implant surfaces had different CAP crystals deposition and the groups (either cp or alloy) were: light (25% surface coverage), medium (60% surface coverage) and heavy (90% coverage). One implant of each group was submitted to Field Emission Scanning Electron Microscopy (FE-SEM) and 96 implants (12 per group) were placed into the distal metaphyses of both femora of male Wistar rats for 9 days. The femora of the sacrificed animals were trimmed to the width of the implant and the resulting samples consisted of 2 cortical arches of bone attached to each implant. For each arch, in turn, a nylon line was passed under the cortical, through the marrow space. The implant was attached to a sample holder and secured to an Instron™ testing machine and the arch was distracted at crosshead speed of 30mm/min. The force to rupture the sample was recorded and analyzed. FE-SEM was used as a qualitative method to analyze the bone/implant interface following the detachment assay.

Results/Discussion: The post-operative period was uneventful for all rats and none was excluded from the study. Two samples were compromised while being positioned in the Instron™ machine. Twenty-three arches (15 cp DAE, 1 cp-DCD light, 4 alloy DAE, 2 alloy-DCD light and 1 alloy-DCD heavy) were insufficiently attached to the surface of their implant to withstand sample handling. These data were included in the study. The resulting 169 arches were tested as described above. Distributions of tensile forces were not skewed except for group cp DAE which has 60% zero values for tensile forces. There were no significant differences between left and right leg, (p=0.2227) and between arches (p=0.0512). When comparing the cp and alloy groups, the mean for 'alloy' was higher than the mean of tensile forces for 'cp' ($p<0.0001$). The comparisons of 8 groups showed that the two non-DCD groups were the same (p=0.3925). The average of tensile forces for both non-DCD groups was statistically significant lower than for DCD groups ($p<0.01$). The comparison among DCD groups showed that the means of tensile forces for all groups were statistically the same except for group cp-DCD light (p=0.0384).

The bone-bonding phenomenon was demonstrated by visual inspection of the samples and FE-SEM. In samples with high "detachment" forces, the cortical bone arches had fractured while the bone in contact with the implant surface was not detached. Group cp-DCD light had the lowest amount of bone remaining on the surface of the implant. This finding corroborates the statistically significantly lower tensile force values for this group, which could be explained by a more fragile and less resistant bone-implant attachment at the interface.

Conclusions: The DCD surface treatment renders the implant surface bone-bonding, which was demonstrated by the fracture of the bone above the bone-implant interface. Alloy groups were able to promote a better bone-implant attachment than cp groups. The amount of CAP deposition



influences the detachment force, however, the failure force reaches a plateau beyond which increasing the deposited CAP has no effect.

References: 1. Buser D et al. J Biomed Mater Res. 1991, 25:889-902 2. Gotfredsen K et al. J Biomed Mater Res. 1995; 29:1223.

Acknowledgements: 3i Implant Innovations Inc., CIHR, ORDCF, Jian Wang.