The Effect of Hydroxyapatite (Endobon) Particles on Implant Osseointegration in Osteoporotic Trabecular Bone

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Introduction: In osteoporotic bone, remodelling is altered, whereby bone resorption exceeds bone formation and consequently bone volume and bone contact decreases in the peri-implant region. As a result, implant loosening and/or failure may occur. Current approaches to reduce the effect of remodelling on secondary implant stability are based on pharmaceutical methods (e.g. bisphosphonates, parathyroid hormones). The objective of this study was to determine if a simple alternative could also preserve the bone mantle around a screw implant. Endobon® (Biomet) is a non-resorbable osteoconductive hydroxyapatite (HA) ceramic which is being used clinically as filling material for the management of bone defects. We hypothesized that implanting such particles in the peri-implant region in an osteoporotic rat model could maintain a more dense and functional peri-implant bone structure, by shift remodelling events.

Materials and Methods: Sixty-five 12 week old female Wistar rats were examined. The rats were ovariectomized (OVX) 4 weeks prior to implantation for osteoporosis induction. The osteoporotic state of each animal was verified with in vivo bone mineral density (BMD) measurements of the distal femoral metaphyses at the time of ovariectomy and implantation using a novel high-resolution peripheral quantitative computed tomography (pQCT) system (XtremeCT, Scanco Medical, Bassersdorf, Switzerland). The animals were randomly separated into five groups representing the different time-points of euthanasia after implantation. Each animal received two self-tapping titanium screws (Ø 1.7 x 5 mm), one in each proximal tibia. For reproducible screw positioning, a custom made surgical aiming device was used. Prior to screw implantation in the right tibia, the drill-hole was filled with 6 mg HA ceramic particles with an average size of 63 to 100 μm. The left tibia was used as a control, whereby the screw was implanted without any HA particles. Animals were euthanized 1 hour, 2, 4, 6, and 8 weeks post implantation. The proximal tibiae were explanted and scanned with a micro-computed tomography system (μCT40, Scanco Medical, Bassersdorf, Switzerland) at 16 μm isotropic resolution. Thereafter, 9/13 tibiae of each group were preserved for histomorphometric analysis (primary outcome) while the remaining 4/13 animals were used for biomechanical pull-out tests (secondary outcome).

A constrained Gaussian filter with sigma of 1.2 and a support of 1 was used to suppress the noise in the μCT40 data. Subsequently, segmentation was used to digitally separate bone, HA, and implant in the images. For this purpose, special image processing was applied to the direct vicinity of the implant to remove imaging artifacts from the Ti implant. For quantitative analysis, a volume of interest (VOI) was defined in a 200 μm thick peri-implant region. Bone and HA volumes were analyzed in a region including 130 slices (approx. 2 mm) in axial screw direction, starting at the fully threaded region of the screw tip. In the HA-implanted side, the peri-implant bone mantle was analyzed as the (BV+HAV)/TV %, whereas only BV/TV % was taken into account for the control side.

For mechanical testing each bone was partially embedded in PMMA, i.e. not including the implant head, to hold it firmly in a custom made jig of the testing machine (Instron, Darmstadt, Germany). The implant was then pulled under displacement control (1 mm/min) until failure and ultimate force was determined.

Finally, a one-way ANOVA with Tukey HSD post-hoc testing was used to determine if the difference between HA-implanted and control side changed over time, with a significant threshold of p < 0.05.

Results: Ovariectomy in rats caused a mean decrease in cancellous bone volume of 28.9% (±7% SD) at the distal femoral metaphyses after 4 weeks. Results of the tibia used for mechanical testing indicated that peri-implant mantle % volume decreased slightly over time (Fig. 1). There was a more dense peri-implant mantle with HA-implantation with respect to the control side, and this difference did not change over time (p = 0.118). Despite this higher density, there was no difference with HA-implantation in the pull-out force which increased over time for both groups (p = 0.389). No correlation between the pull-out force (N) and the peri-implant material was found. Further analyses regarding the biological effects of HA on the delay in remodelling as well as the mineralization state of the bone are still pending. Histological analysis will also elucidate these aspects in more detail.

Discussion: The absence of correlation between peri-implant mantle % volume and pull-out force is most likely due to the fact that BV/TV resp. (BV+HAV)/TV represents the amount of material in the ROI but does not take into account other properties, e.g. mineral content of the newly formed bone, its structural organization, or the effect of HA. The difference in the peri-implant material volume between the control and the HA-implanted side reflects the amount of implanted HA particles.

In conclusion, the present results of this study suggest that HA particles do not increase osseointegration of implants in osteoporotic bone. Further exploration on bone-implant contact area and bone quality will allow us to determine if this was simply due to the HA having no effect on bone remodelling or if there was a lack of this effect on osseointegration due to some other phenomenon, especially in the high turn-over trabecular bone.

References: