POROUS TITANIUM PARTICLES FOR APPLICATION IN IMPACTION GRAFTING: BASIC MECHANICAL CHARACTERISTICS AND IN-VIVO TESTING OF OSTEOCONDUCTIVE POTENTIAL.

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Introduction
Bone impaction grafting (BIG) is a surgical technique to restore the bone stock loss in revision hip arthroplasty by impaction of allograft bone particles (BoP) in the bony defects [1]. There are many alternative materials for allograft bone developed of which most of them are ceramic based materials (HA/TCP). Important properties of these synthetic materials are: 1) surgical handling characteristics (impactability), 2) initial stability of the reconstruction and 3) long-term stability. In terms of the latter aspect the resorption characteristics of the synthetic material are crucial and may jeopardize implant stability during the remodeling phase if resorbed material is not directly replaced by living bone. This problem may be overcome by using synthetic materials that remain in-situ, are non-resorbable and are osteoconductive. Porous titanium particles (TiP; Hereford Metal Powder Company Ltd, Hereford, UK) may be such a deformable, non-resorbable and osteoconductive material. The goal of this study was to compare impactability and graft layer stability and elasticity of TiP, bioceramic particles (CeP; BoneSave®, Stryker Howmedica Osteonics, Limerick, Ireland) and BoP. In addition, an in-vivo model was used to study the osteoconductive potential of impacted TiP.

Materials and Methods
In-vitro testing: TiP, CeP and BoP were subjected to standardized impaction to measure impactability (impaction strain) (Figure 1). Subsequently a confined compression test was used to measure deformation (loading strain) and stiffness of the graft layer (MPa) at the end of cyclic physiologic loading (0.1-2.5 MPa, 900 cycles at 1 Hz).

In-vivo testing: Twelve goats were operated on both knees. Six different graft materials were impacted in each goat (corresponding to a clinical degree of impaction) in cylindrical defects (Ø 8 mm, depth 10 mm): BoP, CeP and four groups of TiP. The four groups of TiP consisted of uncoated TiP (TiP, constituted of commercially pure titanium), uncoated TiP mixed with BoP (TiP/BoP), and TiP with two different ceramic coatings (TiPc1, TiPc2). Goats were killed twelve weeks after operation. Fluorochrome labeling at four (tetracyclin) and eight weeks (calcein) after operation and Goldner staining of undecalcified slices (30 micrometer) were used to measure time-dependence of bone ingrowth. Bone ingrowth distance (mm) from the periphery to the center of the defect was quantified by interactive computer controlled image analysis (AnalySIS®, Soft Imaging System GmbH, Munster, Germany).

Statistics: Multivariable analysis of variance was used to study differences between groups. An alfa level of 0.05 was used for significance. Results were expressed as mean ± standard deviation.

Results
Impactability

Figure 1: From left to right: TiP, CeP and BoP before (top) and after impaction (below). The bar indicates 10 mm.

Discussion
Although materials were impacted and loaded in a relative simple model (cylindrical metal test chamber), we can conclude that TiP are at least as impactable as BoP and therefore probably do not cause high peak stresses during impaction like seen with CeP. After impaction, TiP create a very coherent and stable graft layer that has about the same elasticity as a graft layer of a mixture of BoP and CeP [2]. Osteocondution of impacted materials in a relatively unloaded goat model showed that uncoated TiP have a lower osteoconductive potential than BoP and biphasic CeP. However, bone ingrowth distance in TiP with a bioceramic coating and BoP was comparable.

Conclusion: TiP with a bioceramic coating seem to be a suitable bone substitute for impaction grafting. However, more realistic preclinical testing of reconstructions, both in-vitro and in-vivo, should prove that TiP offer a stable and safe alternative to the current gold standard.

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References