POROUS TITANIUM PARTICLES FOR APPLICATION IN IMPACTION GRAFTING: MECHANICAL STABILITY AND CEMENT PENETRATION IN CAVITARY ACETABULAR RECONSTRUCTIONS

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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]. Allograft bone particles are considered to be the gold standard although many alternative materials for allograft bone have been developed, most of them being ceramic based. Important properties of these synthetic materials are surgical handling characteristics (impactability) and stability of the reconstruction. Porous titanium particles (TiP; Hereford Metal Powder Company Ltd, Hereford, UK) have shown to be deformable and osteoconductive like bone particles and create a graft layer that is more stable [2]. In order to enable ingrowth of host tissue into the reconstructive graft layer like observed in reconstructions with BoP, cemented reconstructions with TiP should show limited cement penetration.

The goal of this study was to evaluate handling of TiP in acetabular impaction grafting and to compare graft layer stability and cement penetration in realistic acetabular in-vitro reconstructions.

Materials and Methods: Materials: Tests were performed in cylindrical synthetic acetabular models produced by Sawbones (Sawbones Europe, Malmö, Sweden). In these models, a central cavity (Ø 60 mm) was created. The defects in these models were comparable with AAOS type 2 defects [1].

Graft layers were created according to the impaction grafting technique (impactor Ø 20-45 mm). Polyethylene cups (Stryker Orthopaedics, Exeter Contemporary Cup, effective outer Ø 40 mm; inner Ø 28 mm) were inserted under displacement-controlled conditions, using an servo-hydraulic MTS machine (MTS® Systems Corporation, Minnesota, US) and Simplex® Bone Cement (Stryker Orthopaedics, Limerick, Ireland).

Methods: Radiostereometric analysis (RSA) was used to measure residual migration and rotation after cyclic physiological loading. Loading protocol:
1. 900 cycles, 1 Hz, 0-1500N, subsequently
2. 900 cycles, 1 Hz, 0-3000N, subsequently
3. 300 seconds without loading (recovery period)

Lever-out testing with a servo-hydraulic MTS machine was used to measure shear strength of reconstructions after loading.

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

Results: Handling: TiP sticked together very well during impaction and created a firmly entangled, macro-porous graft layer. Small titanium particles were generated during impaction.

Dynamic loading: All reconstructions showed residual cup migration less than 1.0 mm and rotation less than 1.5 degrees. Group B showed significantly more migration and rotation than all four other groups (p<0.004). Migration and rotation were not significantly increased by application of the coating (p=0.91, p=0.95 respectively) or by size (p=0.72, p=1.00 respectively).

Shear strength: Failure occurred within the graft layer. TiP reconstructions were about 3.5 times more resistant to shear stress than reconstructions in group B and B/T34 (p<0.001). All specimens in group B and B/T34 failed. The applied coating did not decrease shear strength (p=1.00).

Cement penetration: Bone cement intrusion was about 1.0 mm deeper in BoP graft layers than in TiP graft layers (p<0.02).

Discussion: A synthetic bone graft substitute for impaction grafting should provide initial mechanical stability and ensure ingrowth of host tissue to favor long term stability. From the data of this in-vitro test it can be concluded that from a mechanical point of view it seems safe to apply TiP for the reconstruction of large cavitory defects instead of using cancellous bone particles. Graft layers of TiP show excellent resistance to shear stress which results from impingement and could be a mechanical source of aseptic loosening [3]. Further, the application of a carbonate apatite coating showed only minor influence on stability and strength of TiP reconstructions.

The same cementation technique was used for all graft groups. Surprisingly the macro-porous graft layer of TiP showed less cement penetration than impacted BoP which should be beneficial to host tissue ingrowth. However, small titanium particles were generated during impaction. These micro-particles could interfere with tissue ingrowth and might cause third body wear. Further realistic in-vitro and in-vivo testing is warranted to observe the biological and mechanical effect of these micro-particles.

Conclusions:
1. Acetabular revision reconstructions made with TiP show very good initial stability and a macro-porous graft layer of TiP shows limited cement penetration.
2. The application of a coating does not decrease stability.
3. Realistic pre-clinical in-vivo testing should prove that TiP offer a safe alternative to the current gold standard.

References:

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![Figure 1a (left) and 1b (right): T34 specimen (left) and cross section after (right) cementation. Note the difference in graft layer thickness (10 mm supero-lateral vs. 4 mm infero-medial). Dotted blue arrows indicate local cement penetration. The firm blue arrow indicates mean cement penetration.](image)

![Table 1: Tested groups and corresponding materials. TiP had a porosity of 80-85%.](table)

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