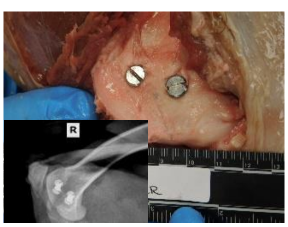
Solution deposited hydroxyapatite on 3D printed titanium reveals contact osteogenesis in a sheep gap-defect model

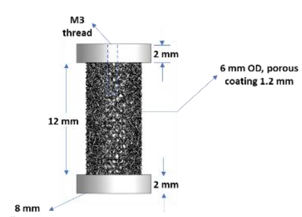
Rajendra Kasinath, Stephanie Vass, Danny Ettensohn, and Bryan Smith
DePuy Synthes Joint Reconstruction

Statement of Purpose: Endosseous healing has been thought to occur either through distance or contact osteogenesis. [1-2] Distance osteogenesis occurs when new bone is formed on old bone in the peri-implant site and contact osteogenesis proceeds by bone first forming on an implant surface. While these concepts are not new, it is challenging to observe clear evidence of contact osteogenesis in animal models since the two types cannot be easily deconvoluted after osseointegration. In this study, we report contact osteogenesis on hydroxyapatite (HA) coated 3D printed (3DP) porous titanium (Ti) implants implanted in a 1 mm gap format, into bony defects in skeletally mature sheep.

Methods: Bilateral pair-wise implantation was performed in the distal femoral condyles at 2 locations (anterior and posterior). Implants consisted of a 6 mm OD, 12 mm long porous metal portion, and endcaps that were 8 mm OD and 2 mm thick. 8 mm diameter by 16 mm long defects were drilled at these locations after the periosteum was carefully removed. Implants seated in these defects produced a 1 mm gap between the porous metal portion and surrounding bone. 3DP printed porous implants were coated with hydroxyapatite employing a previously reported technique. [3] Two 7-8 µm thick conformal coatings were tested: (a) as coated, and (b) 2-hour hydrothermally treated. Sheep were survived for 8 weeks, and implants were recovered at necropsy. Explants were sectioned, fixed and subsequently impregnated for further histological preparation. Histological sections were prepared, and H&E stained for soft tissue and Stevenel blue for histomorphometry. Bone in-growth and bone-in-contact (BIC) with the implant, and fibrous tissue formation were assessed.



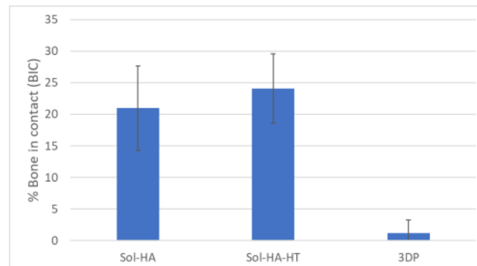
(a)



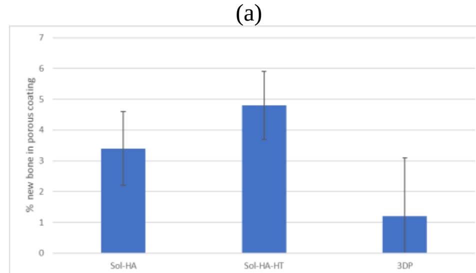
(b)

Figure 1 (a) Implant location and placement at surgical site, (b) implant design and dimensions.

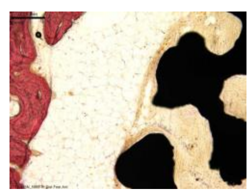
Results: Histology/histomorphometry revealed that at 8 weeks BIC for solution deposited HA implants was ~25%, and substantially higher than bare metal controls, ~2% ($p<0.001$). In-growth, characterized by the amount of new bone in the porous coating, was minimal (5%) but higher for the HA coated implants ($p=0.001$). HA coated implants revealed ~25% fibrous tissue vs ~45% for uncoated 3DP controls. The micrographs clearly indicated that the 8-week time point was sufficient to enable some healing to take place but not sufficient to bridge the 1 mm gap. This is likely a consequence of the more gradual healing response in sheep relative to dogs or rabbits. However, implants with HA coating clearly indicated the presence of bone in contact with porous sections, but not bridging from the surrounding native bone, hence suggesting contact osteogenesis. It is likely that the unique combination of porous architecture and our solution deposited HA at the porous peri-implant interface seemed to create the necessary conditions for potentiation and adhesion of osteoprogenitor cells. Furthermore, it is expected, given time, that bone will continue to oppose and fill this gap.



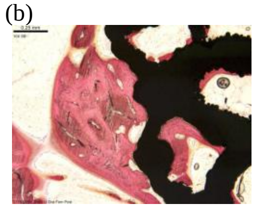
(a)



(b)



(c)



(d)

Figure 2 (a) BIC, (b) new bone %, and representative histology of (c) 3DP control and (d) HA coated 3DP implant.

Conclusions: The results suggested that our solution deposited HA coating induced contact osteogenesis for 3DP implants in cancellous bone.

References:

1. Osborn JF, Newesely H. Dynamic aspects of the implant bone interface. In: Heimke G, ed. Dental implants: materials and systems, 1980, p111-23.
2. Davies, JE, Understanding Peri-Implant Endosseous Healing, J of Dent Edu, 67 (8), 2003, p932-949.
3. C. Ernsberger et al., High throughput solution deposited hydroxyapatite coatings for orthopedic implants, Society for Biomaterials 2018 Meeting, Abstract 218.