

## COMPARISON OF THREE DIFFERENT HYDROXYAPATITE COATINGS IN AN UNLOADED IMPLANT MODEL - EXPERIMENTAL CANINE STUDY

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### INTRODUCTION

Treatment of osteoarthritis and rheumatoid arthritis by total joint replacement generally shows a high success rate, however challenges (e.g. revision joint replacement) remain. Clinically and experimentally, plasma sprayed hydroxyapatite (HA) coating on porous implant surfaces has been shown to enhance mechanical implant fixation and bone ongrowth in the primary and revision settings. In this study we compare the well-documented plasma sprayed HA coating to two alternative thinner HA coatings: electrochemical deposition of HA and electrochemical deposition of HA mixed with mineralized collagen. Uncoated plasma sprayed Titanium (Ti) was the negative control. We hypothesize that the electrodeposited HA's (HA alone, and collagen mixed with HA) will achieve the same fixation as traditional plasma sprayed HA, with Ti being inferior to all three HA's.

### METHODS

A paired and controlled experimental canine study was carried out following approval of our institution's Animal Care and Use Committee. Cylindrical plasma sprayed titanium (Ti-6Al-4V) implants 10 mm long x 6 mm were used (Fig.1). Four different implant surfaces were investigated in each of 7 skeletally mature animals: (1) plasma spray titanium, (2) HA-plasma spray, (3) electrochemical HA-deposition (36C and pH 6.4) and (4) HA-mineralized collagen coating. Two implants surrounded

by a 1 mm gap were inserted alternately in two unloaded extraarticular cancellous bone sites bilaterally in the proximal humeri. Specimens were obtained at 4 weeks and were frozen until testing. Sections (3.5 mm thickness) were cut perpendicular to the implant axis, using a diamond saw (Exact) and implant-based alignment post.

**Figure 1:** Implant placement (bilateral; 4/animal)



#### Mechanical testing

Mechanical pushout testing was performed on transverse sections, using an Instron test machine UK (5 mm/minute).

Load versus displacement was recorded and ultimate shear strength (MPa), apparent shear stiffness (MPa/mm) and energy absorption to failure ( $J/mm^2$ ) were derived. Histomorphometry Using stereological methods, vertical sections were obtained after random rotation of the 6.5 mm blocks. Computer assisted histomorphometry was performed blindly using a CAST-grid system (Olympus Denmark). Tissue ongrowth was defined as tissue directly at the implant surface, and was determined using the linear intercept technique and tissue volumes were obtained using point counting. Statistics: Non-parametric analysis was applied since differences between pairs did not follow a normal distribution. After Kruskal-Wallis on Ranks, the Wilcoxon sign ranks test was used to compare specimens pairwise. P-values < 0.05 are considered statistically significant. Data are accordingly presented as median and interquartile ranges.

## RESULTS AND DISCUSSION

Table 1. Mechanical pushout properties

Median and interquartile range	Ultimate shear strength (MPa)	Apparent stiffness (MPa/mm)	Energy absorption (J/m <sup>2</sup> )
Titanium	0.0 (0.0-0.3)	0.0 (0.0-1.3)	0 (0-45)
HA plasma	2.1 (1.5-3.2) ab	7.8 (4.2-17.9) ab	535 (213-574) ab
HA elec.depos.	1.97 (0.7-3.4) a	9.0 (2.7-16.6) a	339 (92-618) a
HA Collagen	0.51 (0.1-2.1)	2.5 (0.6-8.9)	73 (7-456)

a: p<0.05 compared to Titanium.

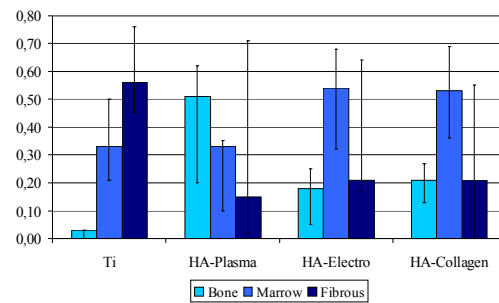
b: p<0.05 compared to HA/collagen

Mechanical fixation of the electrochemically deposited HA was not statistically different than the plasma sprayed HA or the electrochemically deposited HA-collagen, and was significantly increased compared to the titanium control. The traditional HA-plasma sprayed implants achieved better mechanical fixation compared to electrodeposited HA-collagen and titanium controls (significant). In the histomorphometric analysis, significant differences were only seen directly at the implant interface (ongrowth). All HA coated implants demonstrated significantly higher bone ongrowth compared to the titanium control. The traditional plasma sprayed HA showed 2-fold higher bone ongrowth fraction (not significant, p=0.06) compared to the electrodeposited HA's. There was a tendency for more marrow at the surface of the electrodeposited HA's, (not significant).

Electrochemical deposition of HA does not require high temperature for application, can be thinner than plasma sprayed (retaining the macro roughness of the titanium plasma spray surface), and can achieve full three-dimensional coverage not possible with the line-of sight plasma spraying process. Conceptually, adding collagen to the HA could present a more "bone-like" surface.

Some of the findings could be related to differences in coating thickness, surface

Fig 2. Fraction of implant tissue ongrowth



Bone ongrowth: p<0.05 for all coatings compared to titanium

morphology, composition, and dissolution rate of the mineral phase, with the electrodeposited HA's having a thinner coating and smaller crystallites, and the high temperature plasma sprayed HA having a thicker coating and larger crystallites. From our previous experience, the low fixation for the titanium surface is not unexpected in a 1 mm gap at 4 weeks.

These results are limited to the plasma spray implant surface and unloaded gap setting, in a 4-week observation period. The potential for electro-deposited HA to be as good as (or to improve upon) plasma sprayed HA warrants further experimental study.

### SUMMARY

Mechanical fixation of electrodeposited HA was not different than the traditional plasma spray method of HA coating, although there was a tendency for bone ongrowth to be less. Adding collagen to the mineral phase of the coating to create a surface that more closely imitated the natural bone setting did not improve fixation in this model.

### REFERENCES

- i Roessler S et al. J Biomed Mater Res 64A:655-663, 2002. ii Roessler S et al, J.Mat Sci, 12:871-877, 2001.

### ACKNOWLEDGEMENTS

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