Are HA coatings actually hindering osseointegration of THA femoral stems?

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INTRODUCTION: Uncemented fixation of joint replacement components relies on osseointegration. Hydroxyapatite (HA) coatings have found broad use [1]. It is thought to accelerate and improve bone on-growth [2]. The use of HA coatings was mainly driven by the success of the Corail stem. HA may however delaminate and cause specific complications, as any coating may do due to the creation of another interface [3]. Data from a recently published case study suggests the persistence of residual HA from the coating remaining underneath ongrown bone [3]. The objective of this study was to determine the potential presence of HA coating residues and the consecutive effect on osseointegration in a consecutive cohort of HA coated stems retrieved at revision THA in a single center.

METHODS: We analyzed 16 retrieved plasma spray HA coated Ti6Al4V stems (n=8, AMI Stem-H, Medacta; n=4 Quadra-H stem, Medacta; n=3, Avenir, Zimmer Biomet; n=1, Corail Revison, DePuy Synthes) consecutively retrieved by the same surgeon at the Cantonal Hospital Winterthur (Winterthur, Switzerland). The median time *in situ* was 7.5 years (0.1, 16.4), patient age at revision was 72.9±11.7 years, patient sex was 8 female and 8 male. The reasons for revision were periprosthetic fracture of the femur (n=10), malpositioning (n=2), periprosthetic joint infection (n=2), aseptic loosening (n=1), and pathologic stress concentration (n=1). Samples were first viewed under digital light microscopy at a magnification of 100 to 200x to determine the extent of bone on-growth and presence of HA coating residues. Cases with apparent HA coating remaining underneath on-grown bone were chosen for cross-section analysis. Cross-section samples were sectioned using a cut-off machine (Secotom, Struers) at a quarter position from the distal end of each stem. Samples were embedded in epoxy resin using a hot embedding press (CytoPress, Struers), and the section surface polished to a 9 µm finish. Finally, each polished sample was sonicated in 75% ethanol bath separately and air dried. Polarized light microscopy was used to characterize the general morphology of potential interfaces between bone, coating, and implant. The chemical composition of the different interfaces was determined by Raman micro-spectroscopy (Horiba) using a 50x objective and 785 nm laser with ND filter set to be 25%. The data were plotted in Origin for comparison.

RESULTS: Examination under the digital light microscope revealed likely residual HA coating among bone in eleven cases, while three exhibited nonidentifiable and two had questionable findings. Among the likely and questionable cases, 8 (6 female, 2 male) had a time *in situ* of at least 5 years and qualified for further analysis. All remaining cases failed due to periprosthetic fracture and had an average time in situ of 121 months (89 - 197). Cross-section analysis revealed the prominent presence of HA coating underneath the bone in multiple locations. Mostly, coating residues had the same thickness as product specifications, apparently no dissolution or resorption occurred in presence of ongrown bone. **Figure 1** A-H demonstrates bone on-growth at different locations on the stem surface. The white markers indicate bone, while the black markers indicate the residual HA coating. The representative Raman spectra were plotted for areas with bone and HA coating, respectively (**Fig. 1** I). The HA coating consists of purely inorganic minerals and has no Raman spectral features above 1200 cm^{-1} wavenumber, where proteins and lipids exhibit various characteristic peaks. Areas with bone clearly demonstrate a rich presence of organic constituents. Also, newly formed bone could be observed on top of the coating in some cases (inlet, **Figure 1** J). Strong signals of various organic components were found by Raman suggesting the undergoing bone formation.

CONCLUSIONS: This study shows that the initial osteointegration was successful, yet the HA coating can still be present even after a long time *in situ* beneath the bone. Even beyond 10 years, the HA coating remained mostly unchanged. Apparently, no dissolution or resorption of the HA coating occurs in presence of ongrown bone. This finding could be concerning as the interface between the implant and the coating can be a mechanically weak link, leading to delamination [3]. This study further raises the question whether the HA coating has prevented bone ongrowth in the long-term and may at least be inconsequential for successful osseointegration of the stem. As some large studies showed no difference in revision rates between identical implants with and without HA coatings [4-6], such coatings are at least not relevantly detrimental for the patient.

SIGNIFICANCE: As no advantage of HA coatings could be identified, their use should be questioned as a cost-driver and potential source of complications. Despite their popularity [1], both the preclinical and clinical evidence for HA coatings is rather weak. Any potential benefit in osseointegration is mainly driven by the rougher topography, compared to sandblasted metal surfaces, not by chemical characteristics [7]. Traditional HA coatings are rather thick (~100 µm). Very thin (<1 µm) coatings may offer advantages which yet need to be clinically proven.

REFERENCE: [1] Wellauer et al. EFORT Open Rev 2023. [2] Soeballe et al. J Orthop Res 1992. [3] Schönweger et. al, Materials 2020, 13, 4713. [4] Lazarinis et al. Acta Orthop 2011. [5] Hailer et al. Acta Orthop 2015. [6] Flatoy et al. Acta Orthop 2016. [7] Hacking et. al. 2002, 405, 24–38.

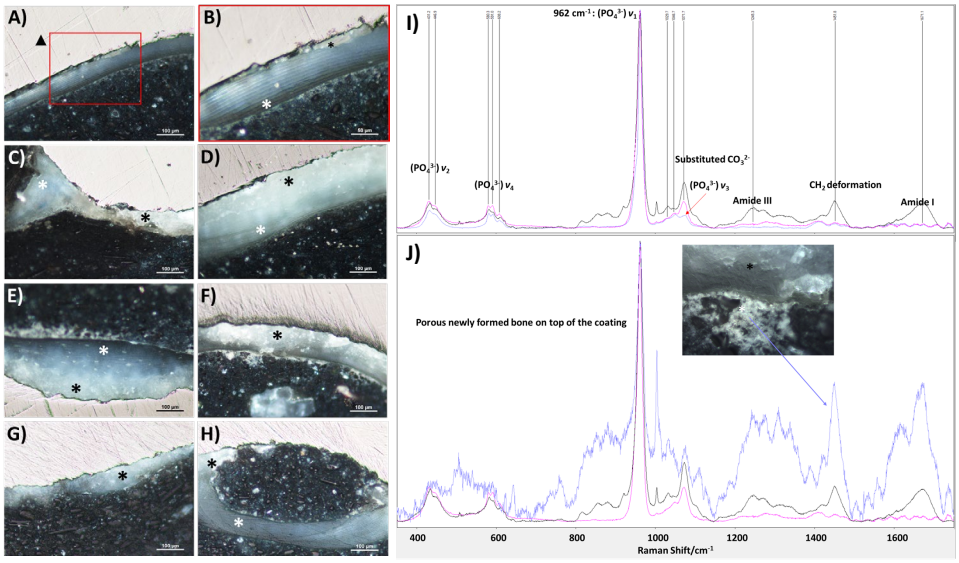

Figure 1 *A-H) Light microscopy of areas with residual HA coating with bone on-growth. The white markers indicate bone, while the black markers indicate the residual HA coating. I) Spectral comparison between bone (black) and HA coating (magenta & purple). Both share several vibrational modes of PO_4^{3-}, but bone has organic constituents (i.e., Amide I and III for proteins. CH_2 for lipids) which do not occur within the HA coating. J) In an area with dense coating still present, newly formed bone was observed.*