Biomimetic surface functionalization of clinically relevant metals used as orthopaedic and dental implants

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E García-Gareta[1,2], J Hua[1], A Orera[3], N Kohli[2], JC Knowles[4,5], GW Blunn[1]

[1]John Scales Centre for Biomedical Engineering, Institute of Orthopaedics and Musculoskeletal Science, University College London, Royal National Orthopaedic Hospital, UK.
[2]Regenerative Biomaterials Group, RAFT Institute of Plastic Surgery, Mount Vernon Hospital, UK.
[3]Instituto de Ciencia de Materiales de Aragón, CSIC and Universidad de Zaragoza, Spain.
[4]Eastman Dental Institute, University College London, UK.
[5]Department of Nanobiomedical Science & BK21 Plus NBM Global Research Center for Regenerative Medicine, Dankook University, Republic of Korea.

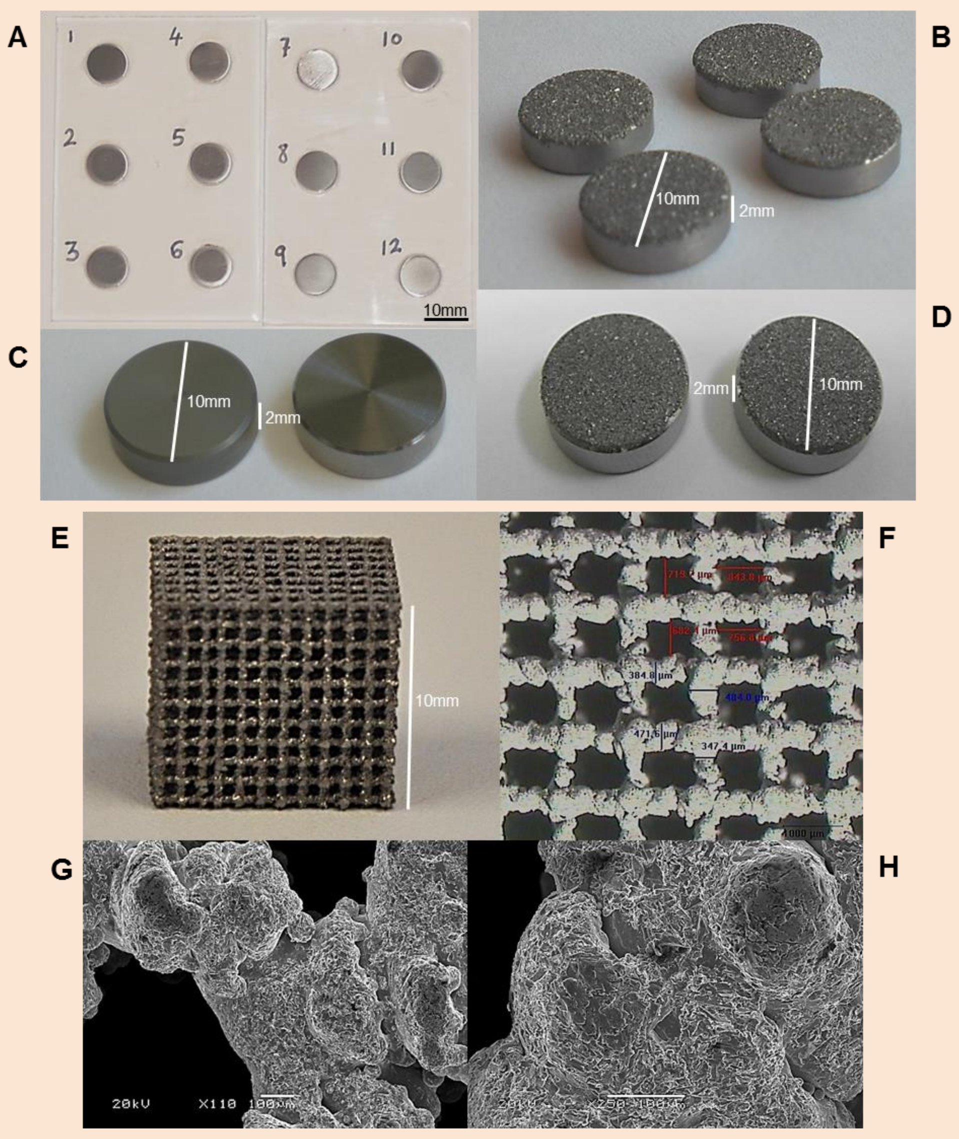
BACKGROUND

- Titanium and its alloys or tantalum (Ta) are widely used in orthopaedic and dental implants due to their excellent mechanical properties and biocompatibility.
- Metals present insufficient bioactivity: research focuses on metals' surface modification and functionalization for rapid and stable integration with bone tissue.
- Surface functionalization can be achieved through deposition of an uniform coating of calcium-phosphate (CaP). However, they can lead to flaking and delamination.
- We hypothesized that metal surfaces can be functionalized with CaP deposits composed of amorphous nano-particles using a biomimetic soaking method with simulated body fluid (SBF) solutions without a pre-treatment of the metal surfaces.

AIM

To functionalise clinically relevant metal surfaces with CaP apatite-like mineral deposits

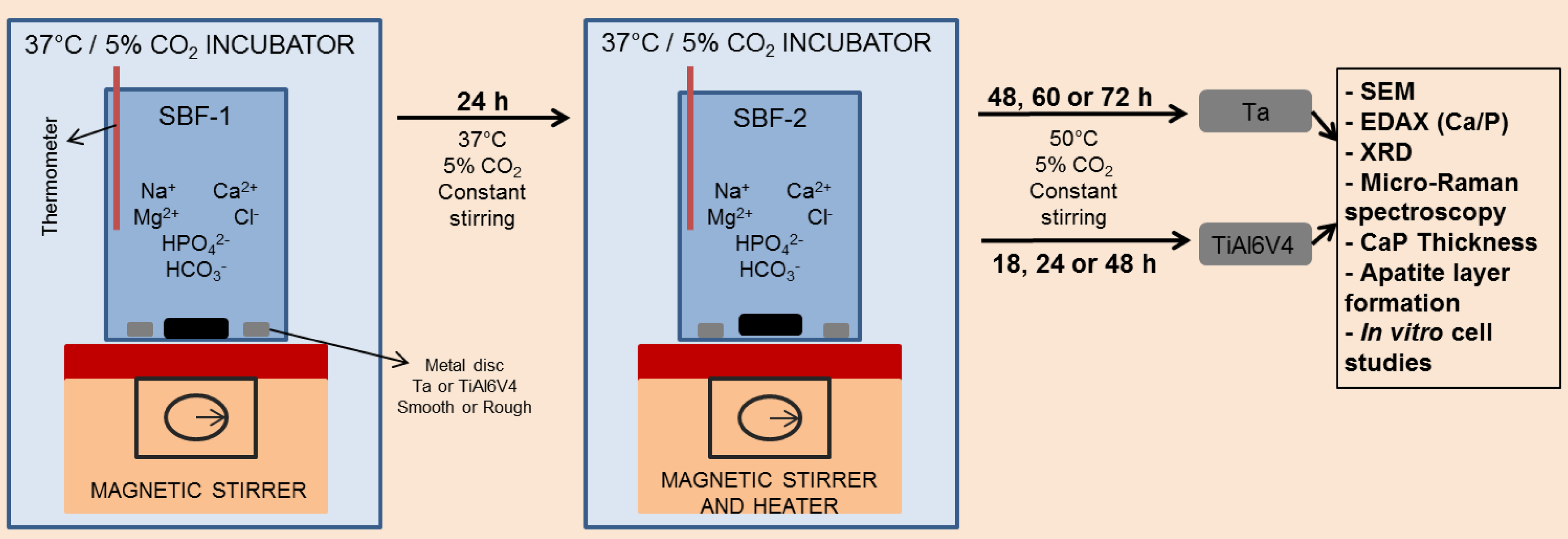
MATERIALS AND METHODS



Materials:

A) Ta discs after being polished showing a smooth surface
B) Sand-blasted Ta discs (Ra=4.0μm)
C) TiAl6V4 discs before being polished to obtain a smooth surface
D) Sand-blasted TiAl6V4 discs (Ra=4.0μm)
E) Macroscopic image of porous TiAl6V4 cubes (70% porosity)
F) Microscopic view of the porous TiAl6V4 material as supplied by the manufacturer
G and H) SEM images of the porous TiAl6V4 material revealing a rough surface.

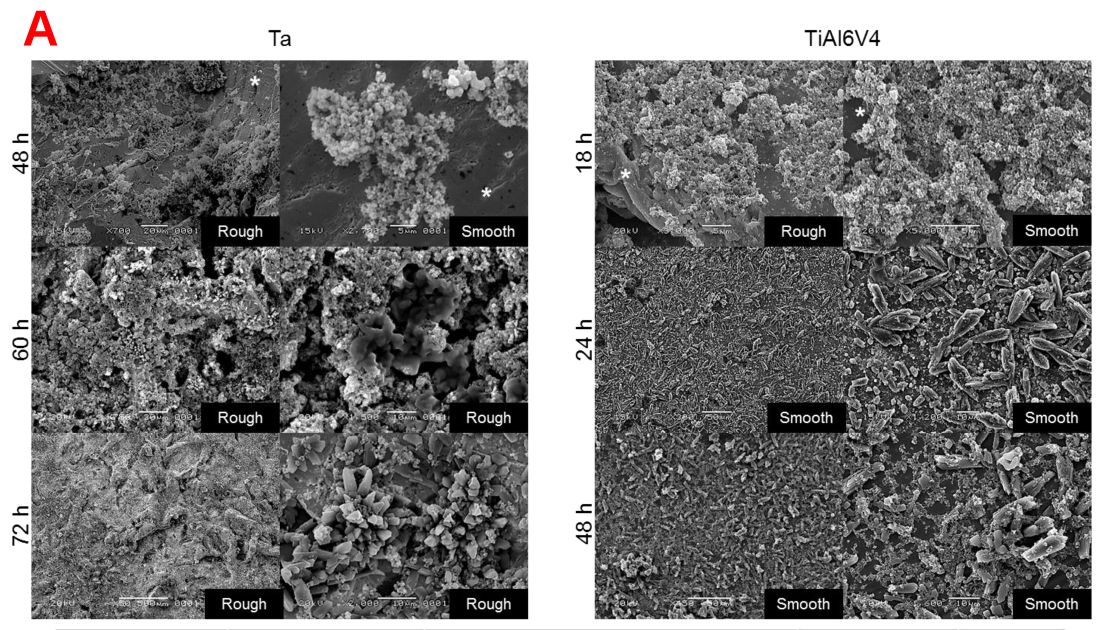
Method:



RESULTS

- Immersion times in SBF-2 of 48 h and 18 h for Ta and TiAl6V4 respectively produced CaP deposits composed of amorphous globular nano-sized particles that contained Ca, P, Mg, C and O **(A, B)**.
- Longer immersion times in SBF-2 produced uniform coatings as well as an undesired calcite ($CaCO_3$) mineral phase **(A,B,C)**.

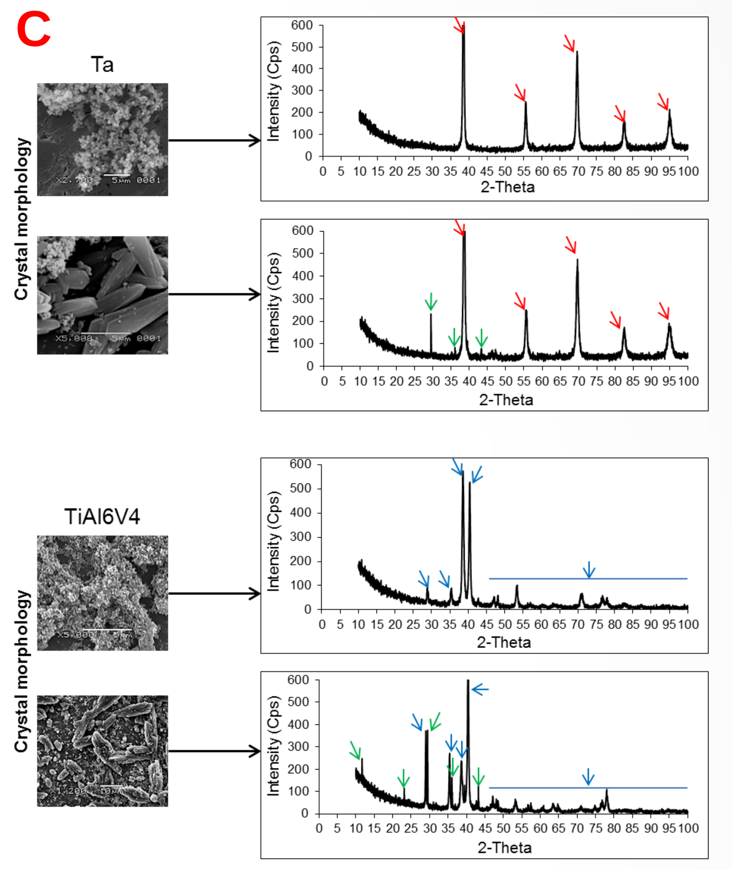
A



B

METAL	Time in SBF-2 (h)	Ca/P (Average ± Standard Deviation)	C and O Peaks	Mg Peak
Ta	48	1.43 ± 0.08	YES	YES
Ta	60	1.99 ± 0.11	YES	YES
Ta	72	-	YES	-
TiAl6V4	18	1.48 ± 0.03	YES	YES
TiAl6V4	24	2.01 ± 0.04	YES	YES
TiAl6V4	48	2.07	YES	YES

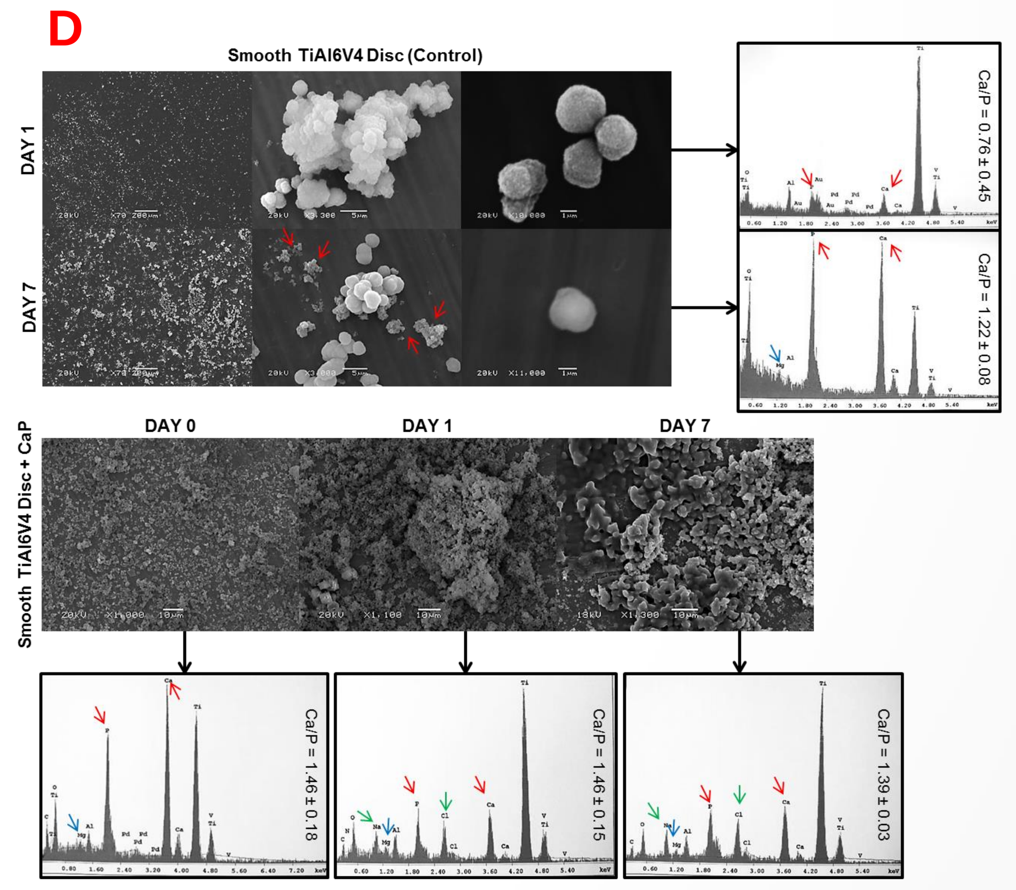
C



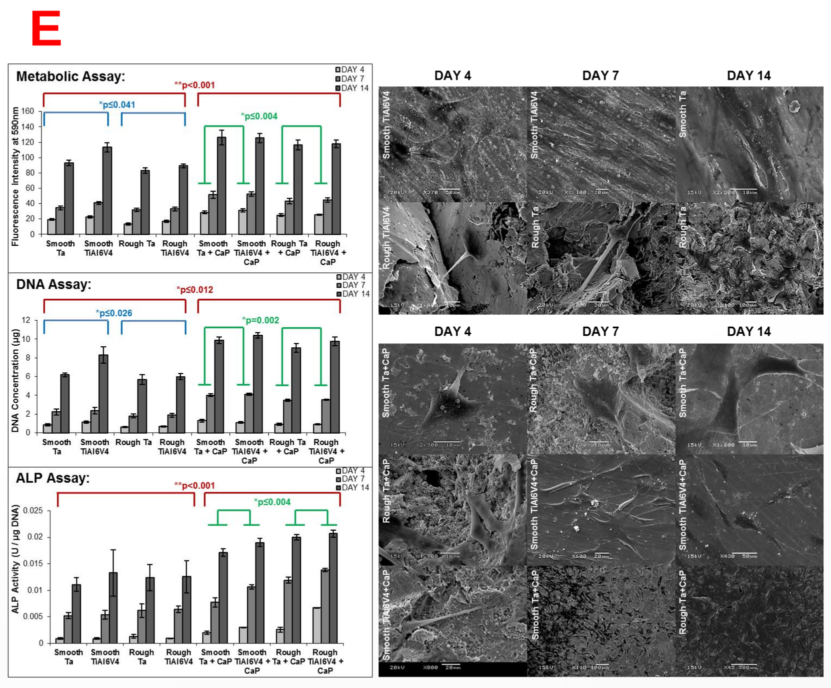
(Red arrows : Ta peaks / Blue arrows: TiAl6V4 peaks / Green arrows: $CaCO_3$ peaks)

- Prediction of *in vivo* behaviour (immersion in SBF) showed that the CaP deposits would act as a catalyst to rapidly form a Ca deficient CaP layer that also incorporates Mg demonstrating their bioactivity **(D)**.
- *In vitro* cell work **(E)** showed that the amorphous CaP apatite-like deposits promote initial cell attachment, proliferation and osteogenic differentiation.
- Finally, we used our method on 3D porous structures **(F)**.

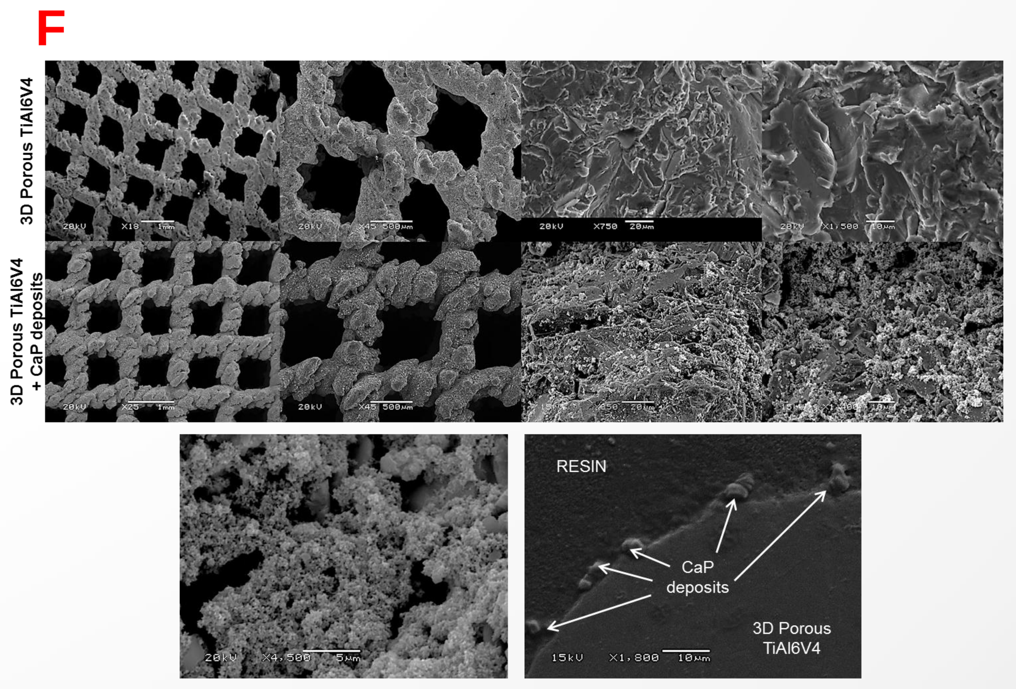
D



E



F



METAL	STRUCTURE	MAXIMUM THICKNESS OF CaP DEPOSITS (μm)	Ca/P (Average ± Standard Deviation)	C and O PEAKS (EDAX)	Mg PEAK (EDAX)
TiAl6V4	3D Porous	7	1.49 ± 0.02	YES	YES

CONCLUSIONS

- We present a novel and cost-effective approach to functionalize clinically relevant metal surfaces to increase their bioactivity, which could improve their clinical performance.
- Our method can be used on 3D porous structures, which have bone ingrowth potential.
- Due to its simplicity and cost-effectiveness, this method could be easily applicable in the coating prostheses industry.