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MDPI

MXENE-MODIFIED TI/HAP COMPOSITES AS A BIOMATERIAL PLATFORM FOR BONE TISSUE REGENERATION

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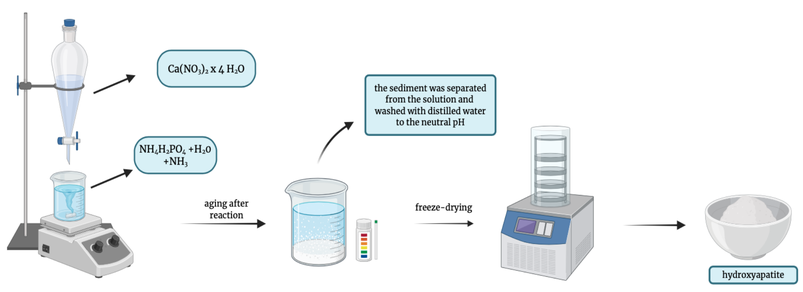
INTRODUCTION & AIM

Bone tissue regeneration remains a major challenge in modern medicine due to population aging and the increasing incidence of bone defects caused by trauma and degenerative diseases. Metal-ceramic composites combining the mechanical strength of titanium alloys with the bioactivity of hydroxyapatite (HAp) are considered promising materials for orthopedic implants. However, implants used in load-bearing applications are exposed to severe tribological conditions, leading to wear and reduced service life. Surface modification with MXenes, a family of two-dimensional materials, offers a potential strategy to improve both tribological performance and biological response owing to their lubricating properties, high surface area, and biocompatibility.

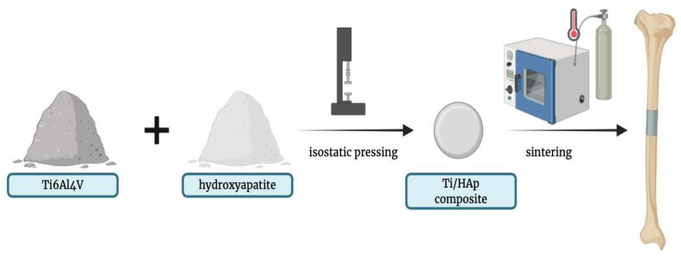
The aim of this study was to develop Ti/HAp composites modified with an MXene coating and evaluate their potential as biomaterials for bone tissue regeneration, with particular emphasis on improving surface properties, reducing friction and wear, and enhancing biological performance.

METHOD

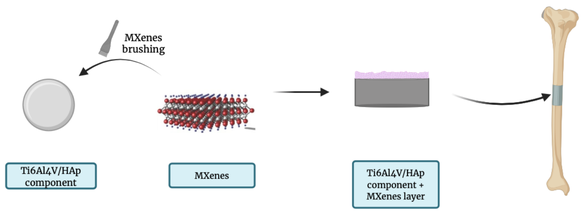
1 HYDROXYAPATITE SYNTHESIS



2 COMPOSITE MANUFACTURING



3 MXENE COVERING



HYDROXYAPATITE

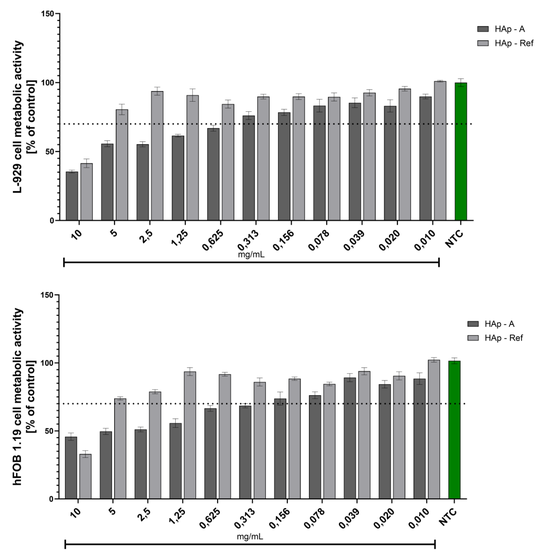


Fig. 1 Cytobiocompatibility of hydroxyapatite powders assessed using the MTT reduction assay.

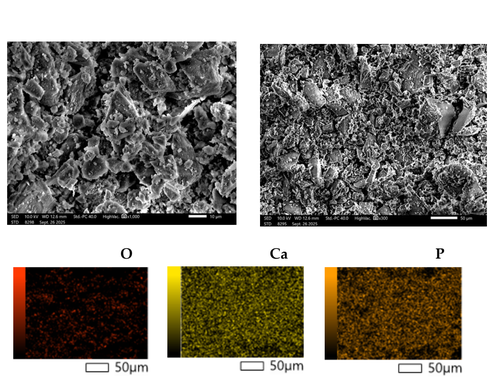
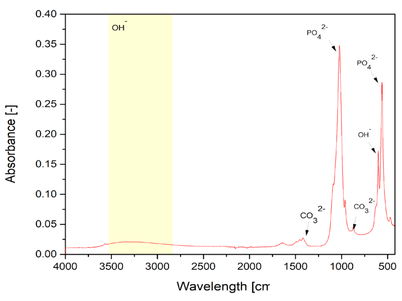


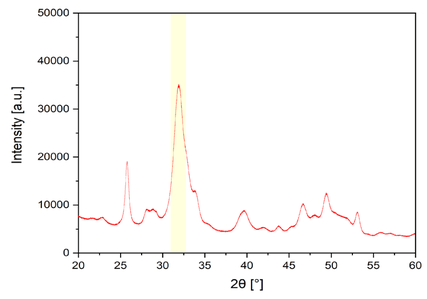
Fig. 2 Mapping of synthesized hydroxyapatite (HAp).

- ✓ HAp-A and HAp-Ref exhibit good, dose-dependent cytocompatibility in fibroblast (L929) and osteoblast (hFOB 1.19) models.
- ✓ Both materials meet the ISO 10993-5 criterion (≥70% viability) at low concentration ranges (<0.3 mg/ml).
- ✓ The decrease in metabolic activity at high doses is likely due to the physical effects of the suspension rather than the cytotoxicity of the material.
- ✓ Synthetic HAp-A exhibits cytocompatibility comparable to that of commercial HAp-Ref, confirming its potential for applications in biomaterials and regenerative medicine.



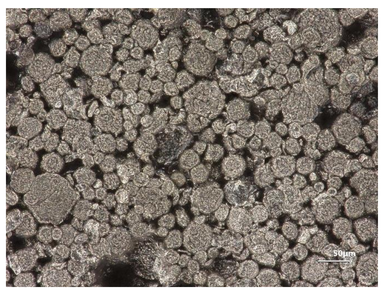
FTIR

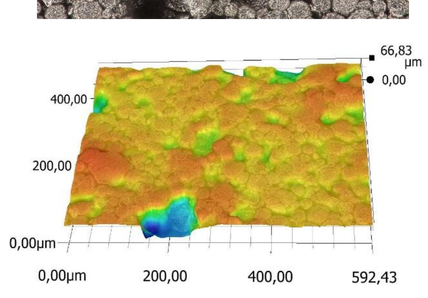
XRD

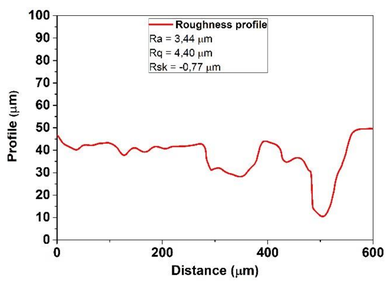


SURFACE CHARACTERIZATION

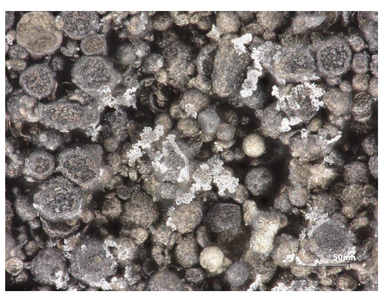
5%HAp10%CMC

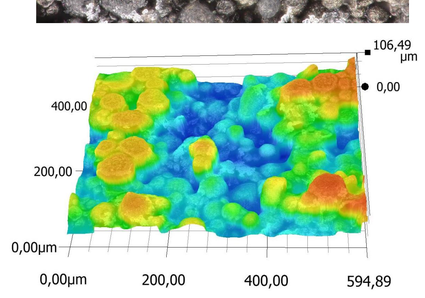


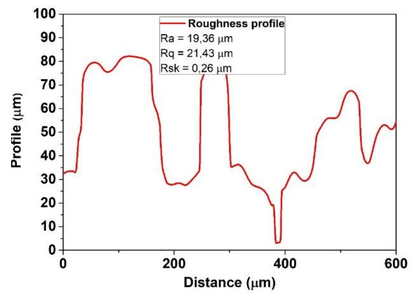




10%HAp10%CMC







5%HAp10%CMC

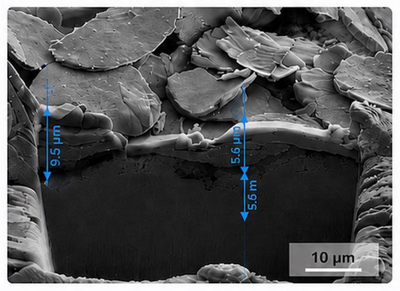
- ✓ Uniform granular morphology
- ✓ Lower roughness (Ra = 3.49 µm; Rq = 4.40 µm)
- ✓ Valley-dominated surface

10%HAp10%CMC

- ✓ Coarse agglomerated morphology
- ✓ Higher roughness (Ra = 13.98 µm; Rq = 21.43 µm)
- ✓ Pronounced surface protrusions (Rsk = 0.28)

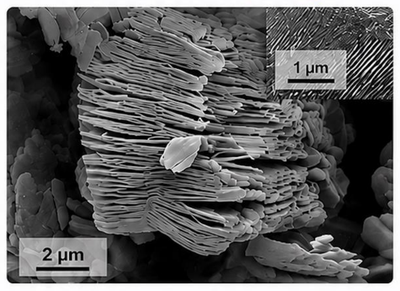
MXENE SURFACE MODIFICATION

Cross-sectional SEM image



Uniform MXene coating deposited on Ti6Al4V/HAp composite surface.
Coating thickness: ~5–10 µm.

Lamellar MXene morphology



Characteristic multilayered MXene nanosheets.
Lamellar architecture beneficial for tribological performance.

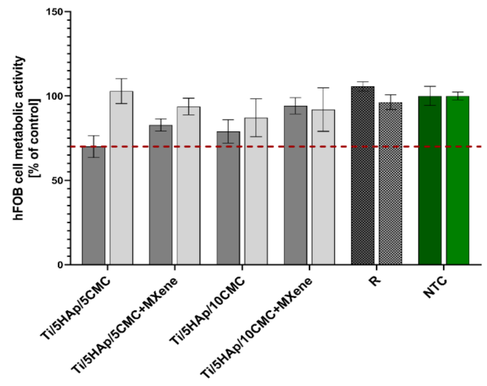


Fig. 3. Cytocompatibility of composite materials and post-incubation solutions with human osteoblasts (hFOB 1.19); R – reference material, NTC – untreated control; data are presented as mean ± SD.

- ✓ All tested materials meet the ISO 10993-5 criterion (≥70% viability) and demonstrate good biocompatibility.
- ✓ The addition of MXene increases cellular metabolic activity, achieving up to 94% viability compared to composites without MXene.
- ✓ The post-incubation fluids were biocompatible (87–103% viability), confirming the absence of cytotoxic degradation products.

ACKNOWLEDGMENT

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