Biodegradable functionalized membrane for bone and tissue regeneration

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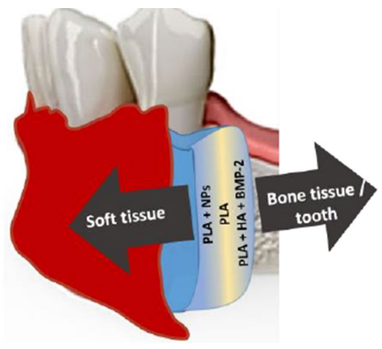
1 Motivation

Bone defects, whether caused by trauma, malformations, pathological degeneration, cleft palate defects, or medical interventions, often necessitate reconstructive bone augmentation procedures [1]. These treatments typically involve a range of surgical techniques, including the use of bone grafts and barrier membranes [2,3].

Project aim

Our project addresses this clinical need by developing a next-generation volume-stable barrier membrane made of biodegradable polylactic acid (PLA), enhanced with bioactive nanoparticles (hydroxyapatite, HAp) that supports bone regeneration in the alveolar ridge. We aim at making such membranes personalized, featuring improved mechanical properties, controlled biodegradation and targeted therapeutic effects (Fig. 1).



Fg.1 Schematic illustration of proposed PLA membrane.

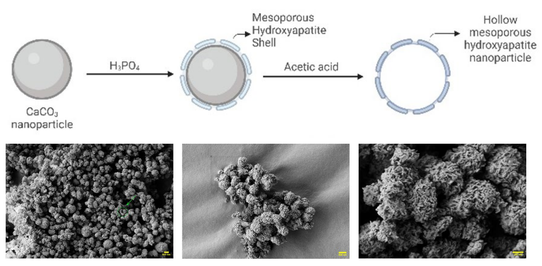
Proposed shaping methods

Following methods are tested for membrane development

- Electrospinning
- Dip coating
- Volumetric 3D Printing

2 Results

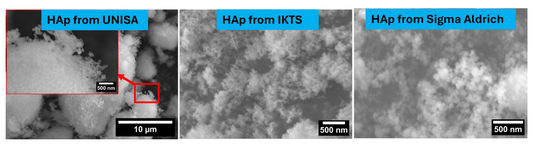
Mesoporous hollow HAp nanoparticles



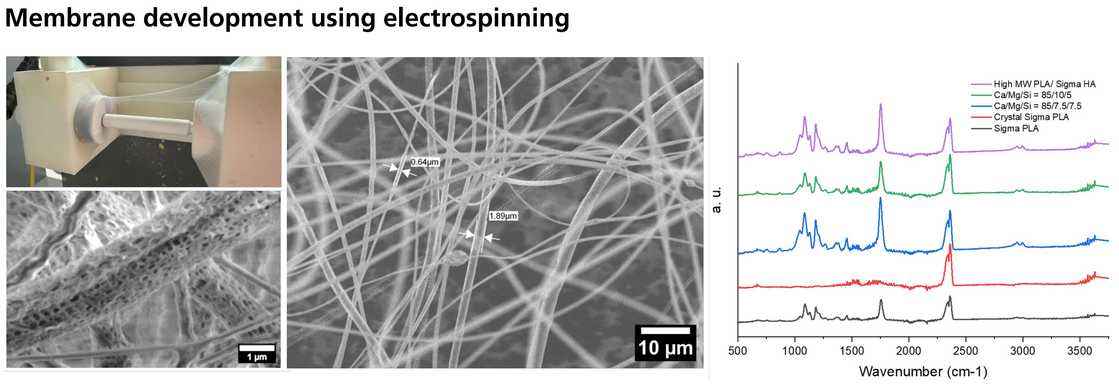
HAp modified by Magnesium and Strontium

Table 1. ICP-OES Analysis

	Ions Added (mol %)		
Material	**Ca**	**Mg**	**Sr**
HAp	100	0	0
HAp_10_5	85	10	5
HAp_7.5_7.5	85	7.5	7.5



Membrane development using electrospinning



Cell viability assessment via ATP production

- Human Osteoblasts: Cultivated with PLA extracts containing various nanoparticles (Fig 2).
- Mouse Fibroblasts (L929) and Macrophages (RAW 264.7): Cultivated with NP suspensions (Fig. 3).

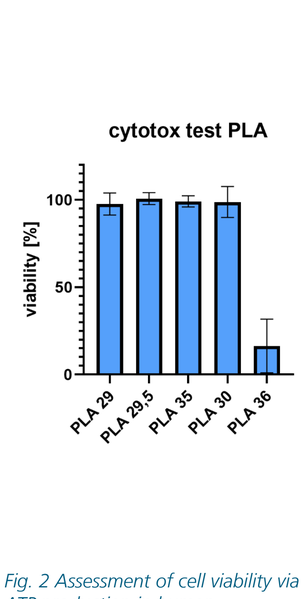


Fig. 2 Assessment of cell viability via ATP production in human osteoblasts cultured with various PLA nanoparticle extracts.

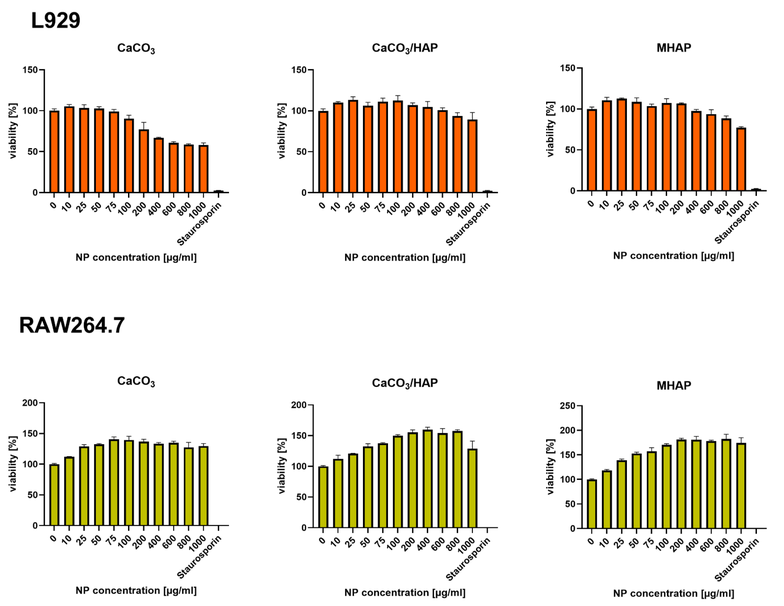


Fig. 3 Assessment of cell viability via ATP production in mouse fibroblast and macrophage cell lines cultivated with NP suspensions.

In vitro degradation tests

- Static immersion tests at 37°C in HBSS, apple juice, and tooth paste solution for 8 days (Fig. 6).
  - Samples developed with dip coating were used for this experiment.
  - SEM analysis were conducted before (Fig. 4) and after the degradation tests (Fig. 5).
  - Percentage of mass variation was calculated to quantify the degradation.

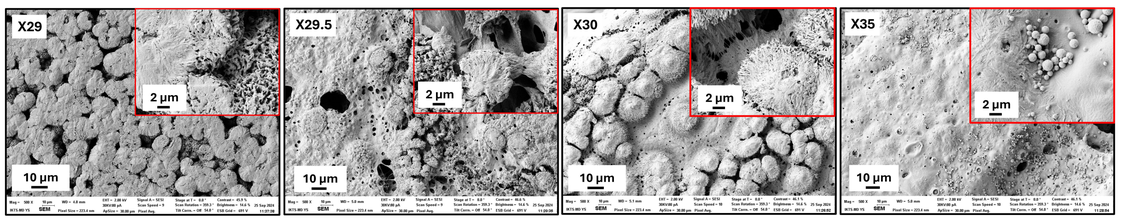


Fig. 4 SEM images of four sample surfaces X29, X29.5, X30, and X35 before degradation tests. Only X35 is fabricated with HAp NPs.

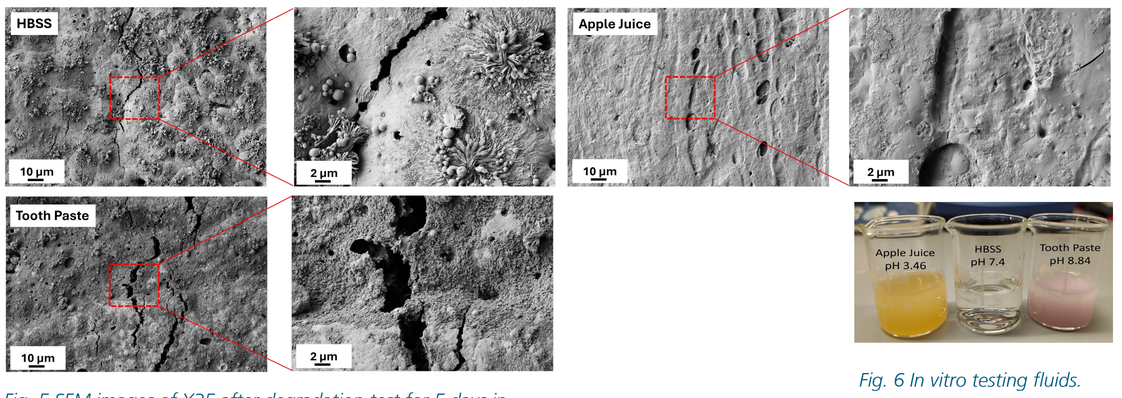


Fig. 5 SEM images of X35 after degradation test for 5 days in HBSS, apple juice and tooth paste solution.

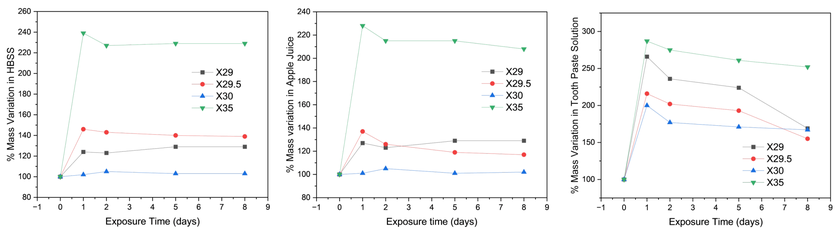


Fig. 7 Percentage of mass variation in the dip coated membranes after 1, 2, 5, 8 days in HBSS, apple juice and tooth paste solution.

Fig. 6 In vitro testing fluids.

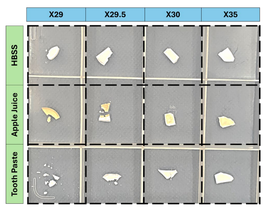
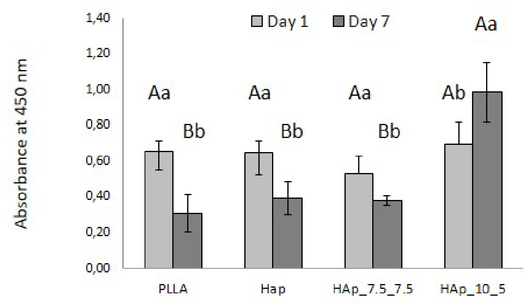


Fig. 8 Physical evaluation of degradation of dip-coated membranes after 8 days in HBSS, apple juice and tooth paste solution.

Cell proliferation

- Proliferation of human periodontal ligament stem cells (hPDLSCs) in clonogenic medium was assessed on PLLA and modified HAp (Tab. 1) at 1 and 7 days using the Cell Counting Kit-8 (CCK-8) proliferation assay (Fig. 9).



Fg. 9 Cell proliferation at 1 and 7 days of hPDLSCs in clonogenic medium using CCK-8 assay. Aa, Bb, and Ab indicate comparisons among materials at the same time point and vice versa.

3 Conclusions

- Structural characterization via SEM with EDX, Raman spectroscopy and FTIR confirmed the membranes desired morphology, composition and functional integration.
- In vitro degradation tests conducted in acidic, basic and physiological pH environments showed membranes in basic medium degrading faster compared to acidic or physiological pH.
- First in vitro cytotoxicity tests showed good biocompatibility with fibroblasts.

4 Outlook

With these first results we are getting closer to the overall goal of achieving membranes that support guided bone and tissue regeneration (GBR/GTR) by maintaining stability within defect sites while promoting controlled biodegradation and cellular response. Challenges must be tackled regarding better distribution of particles within the scaffold material, effectively loading the payloads and realizing personalized shapes.

5 References

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