AffordBoneS
Personalized and affordable multi-substituted calcium phosphate scaffolds

Tampere University
Tampere University of Applied Sciences

Development of personalized and affordable multi-substituted calcium phosphate-based biomimetic scaffolds for bone regeneration applications

Antonia Ressler*, Erkka J. Frankberg, Roope Ohlsbom, Setareh Zakeri, Markus Hannula, Jari Hyttinen, Martin Schwentenwein, Susanna Miettinen, Erkki Levänen

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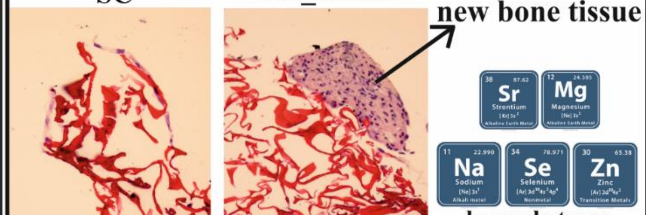
Personalized and affordable multi-substituted calcium phosphate scaffolds

MARIE CURIE ACTIONS



Objective 1/WP1

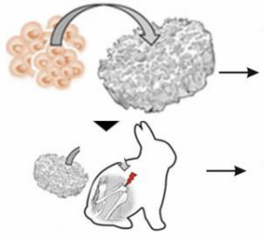
mCaP precipitation, design of mCaP scaffolds using CAD and scaffold fabrication

The mCaP scaffold properties accroding to the bone tissue engineering requirements:
-porosity: 50-90 %
-pore size distribution: 100-500 µm
-phase content: hydroxyapatite/tricalcium phosphate
-mechanical properties reqired for bone augmentation

Collaboration with : LITHOZ

Objective 2/WP2

***In vitro* and *in vivo* osteogenic properties of mCaP scaffolds**

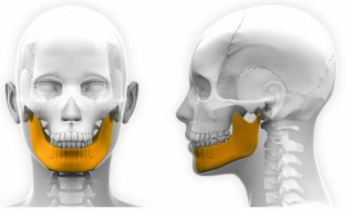


***In vitro* cell culture in static and dynamic conditions**
-live/ded assay, Cell Counting
-quantitative reverse transcription polymerase chain reaction
-imunocytochemical and immunohistochemical staining
-histological staining

***In vivo* characterization during three months in rats**
-micro-computed tomography
-inflammation detection

Objective 3/WP3

Obtaining a demonstration of personalized mCaP scaffolds in collaboration with Planmeca



-obtaining CAD design according to the real patient cases provided by Planmeca

-printing costumized scaffolds on CaraFab 7500 using previously optimized printing parameters

Collaboration with : PLANMECA

Prof. Erkki Levänen

Dr. Erkka Frankberg

Prof. Susanna Miettinen

LITHOZ

Dr. Martin Schweintenwein

Pontus Degerlund

PLANMECA

Dr. Antonia Ressler

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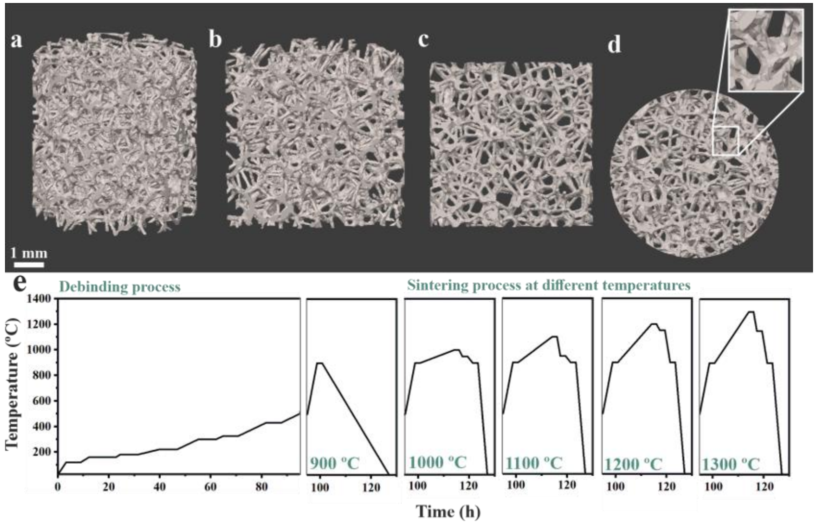
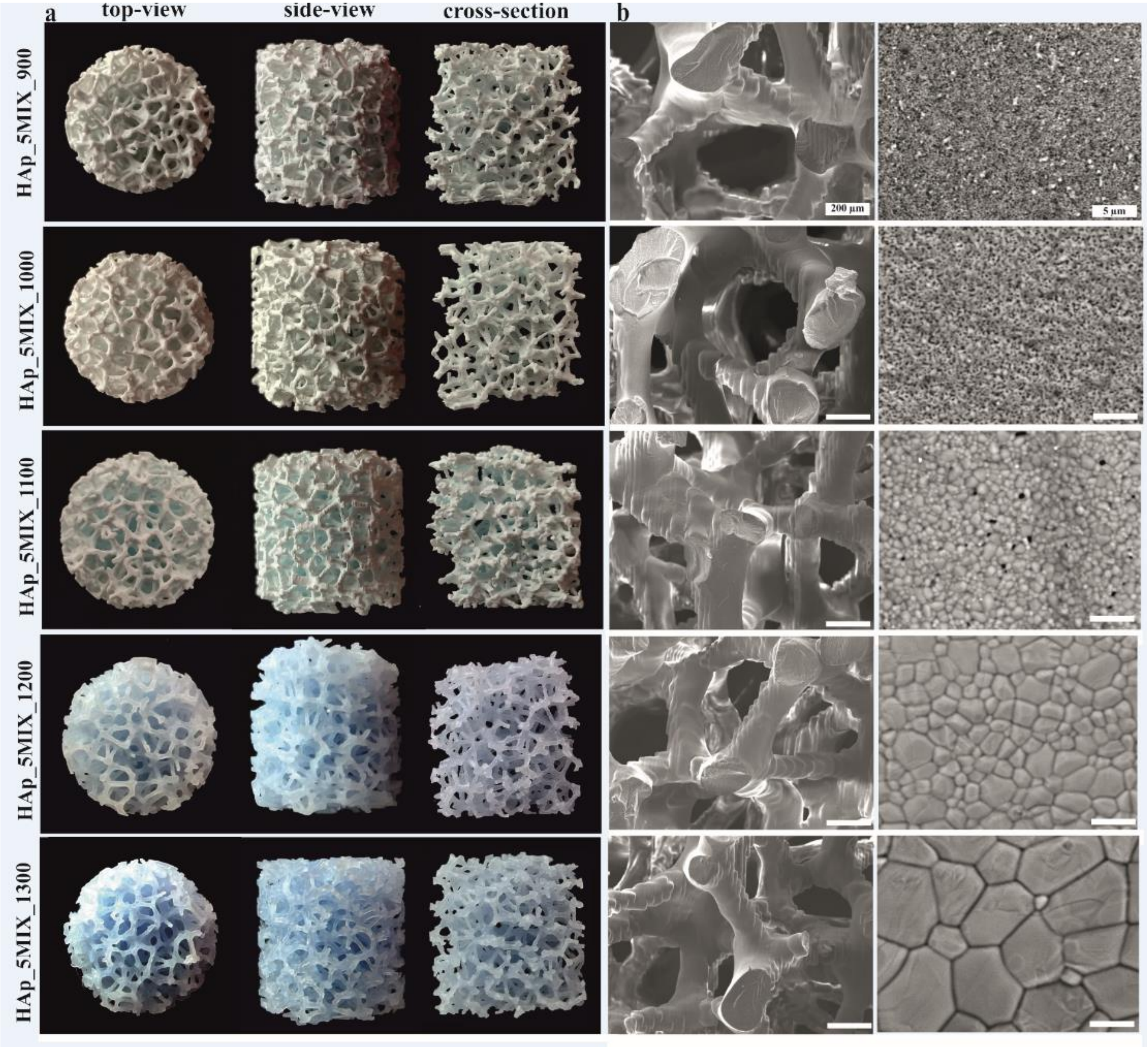
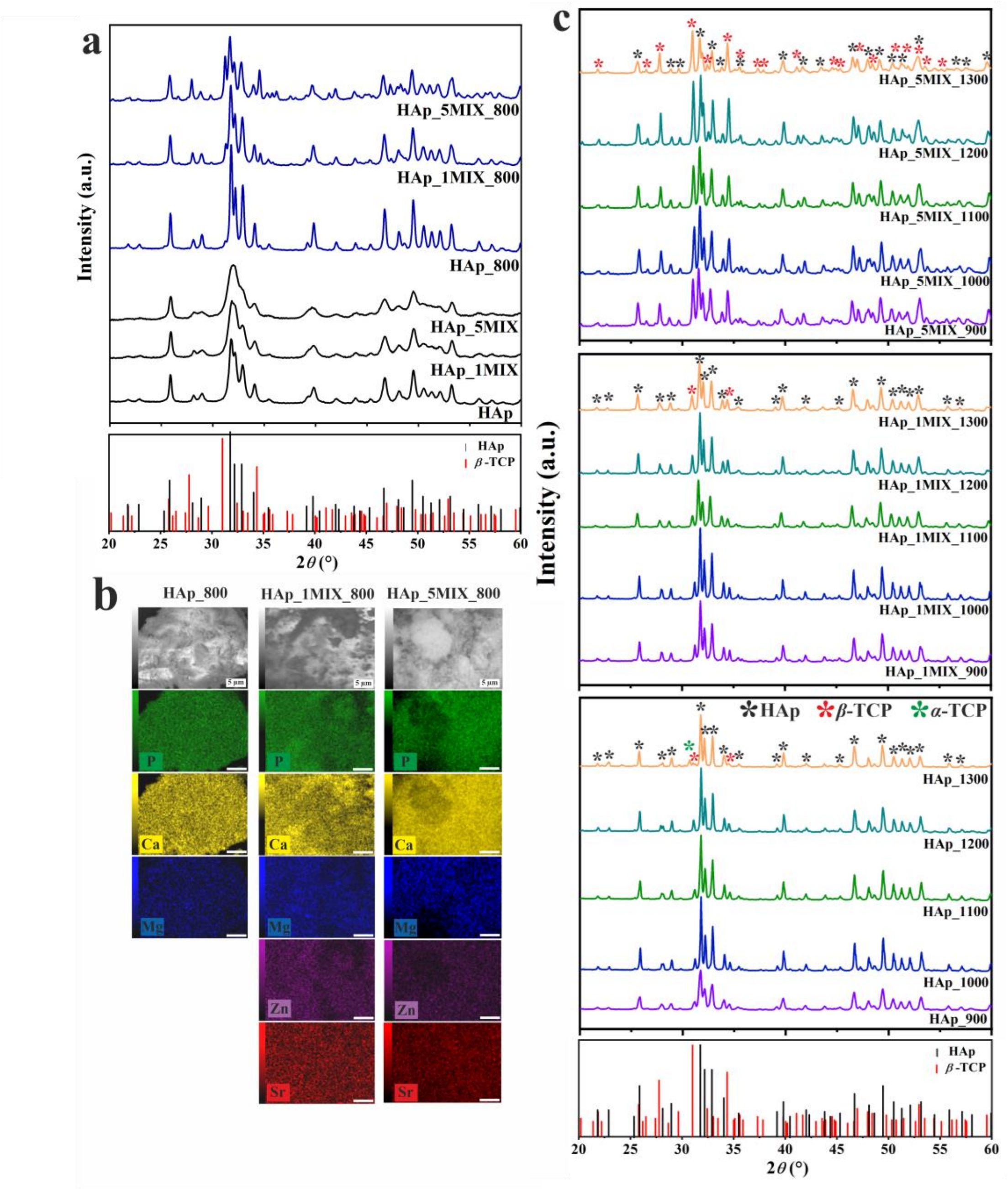
Ceramics International
Volume 50, Issue 15, 1 August 2024, Pages 27403-27415

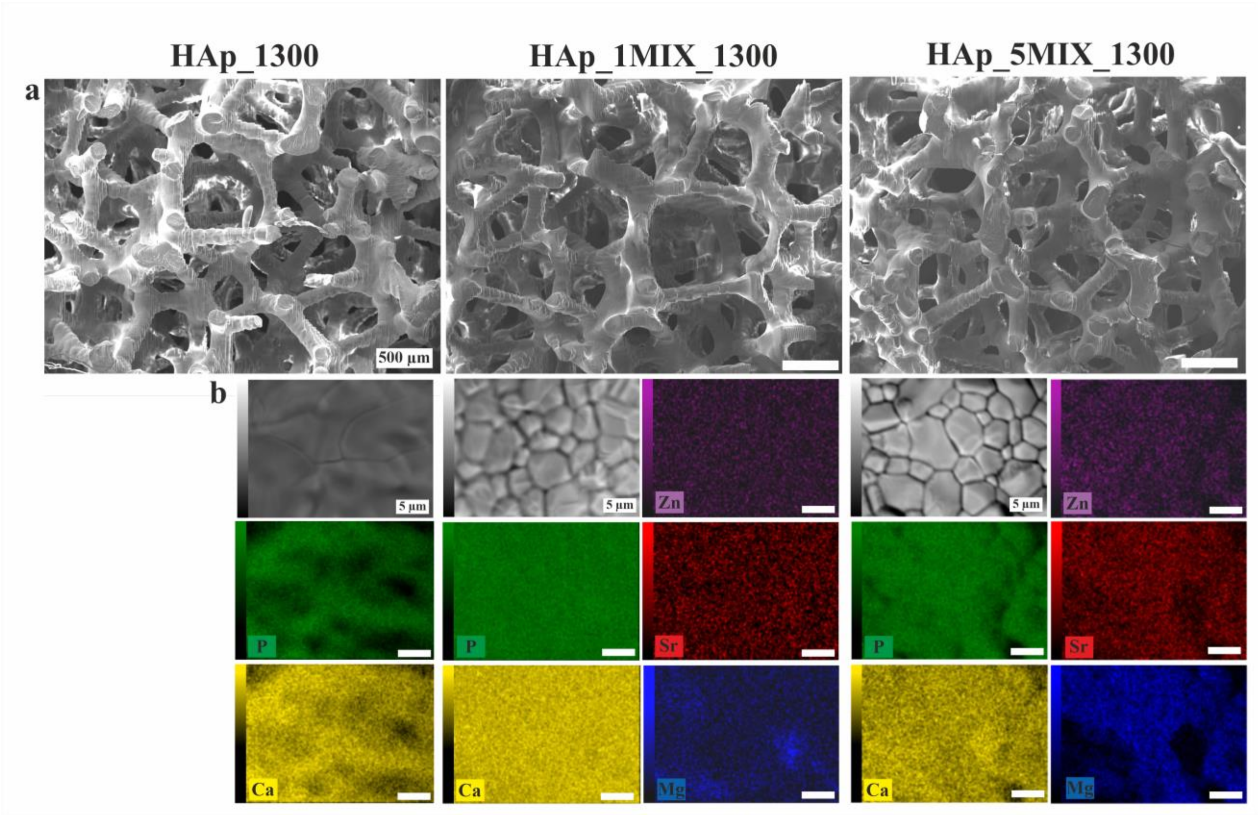
Vat photopolymerization of biomimetic bone scaffolds based on Mg, Sr, Zn-substituted hydroxyapatite: Effect of sintering temperature

Antonia Ressler [a], Setareh Zakeri [a], Joana Dias [b], Markus Hannula [c], Jari Hyttinen [c], Hrvoje Ivanković [d], Marica Ivanković [d], Susanna Miettinen [c e], Martin Schwentenwein [b], Erkki Levänen [a], Erkka J. Frankberg [a]

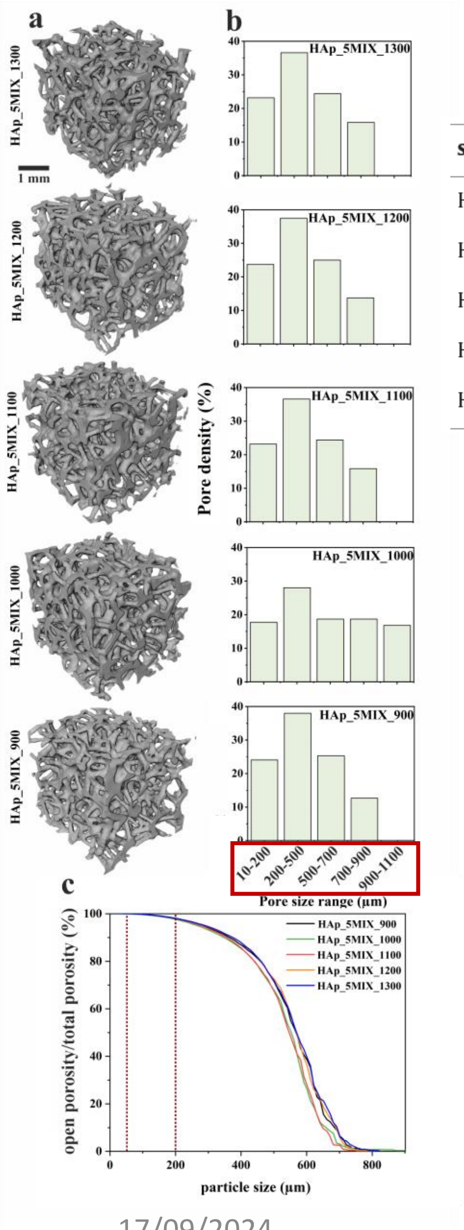








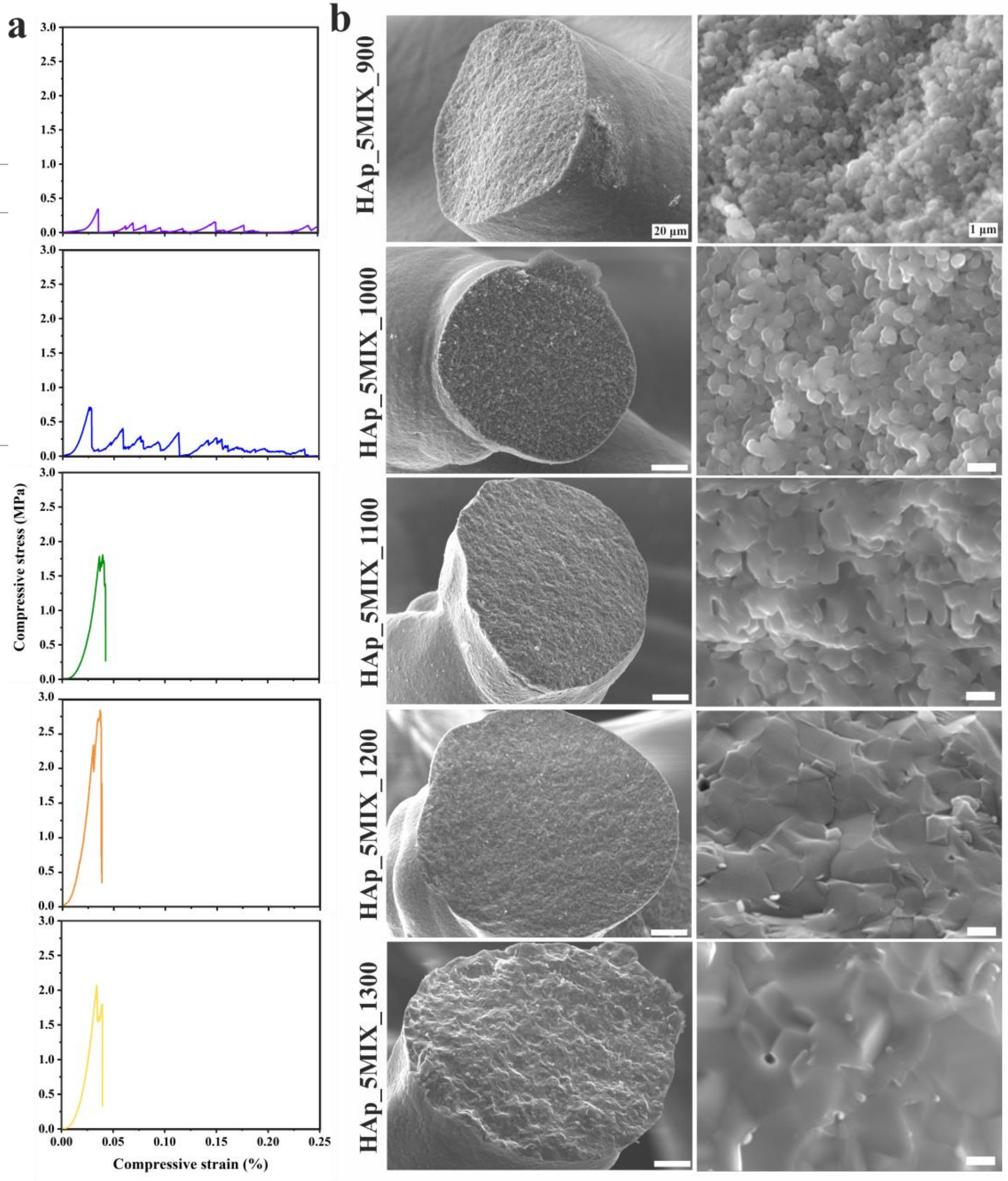
- Studies have shown that biphasic CaP systems composed of HAp and β-TCP are promising alternatives for achieving materials with improved biodegradation.

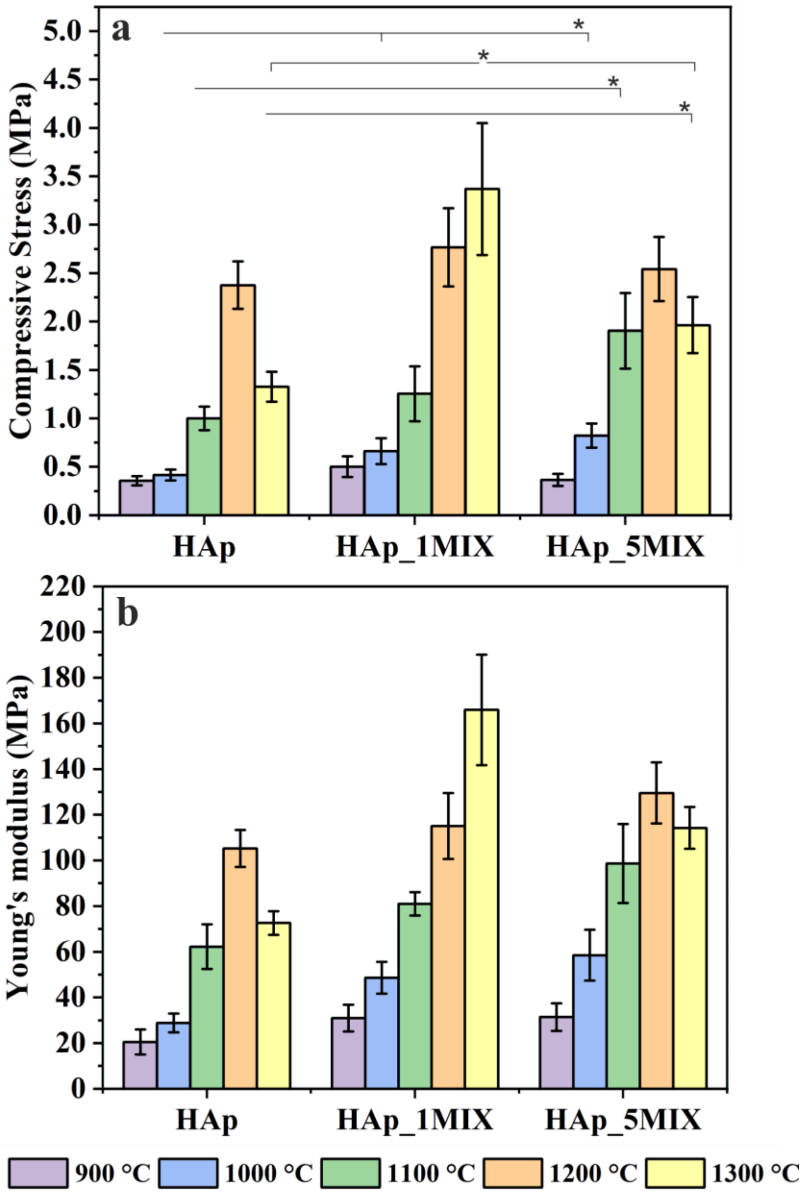


scaffold	porosity (%)	average pore size (μm)	wall thickness (μm)
HAp_5MIX_900	75.55	551.94±133.55	216.16±52.81
HAp_5MIX_1000	74.83	536.05±135.45	214.59±52.31
HAp_5MIX_1100	75.54	532.79±126.94	208.24±55.60
HAp_5MIX_1200	77.43	554.54±131.01	201.21±48.98
HAp_5MIX_1300	77.84	555.93±133.41	194.93±42.33

The size of mesenchymal stem cells is in the range of 15–30 μm. Particle sizes up to 200 μm are of primary relevance. This size range allows migration of small cell aggregates in the seeding process.

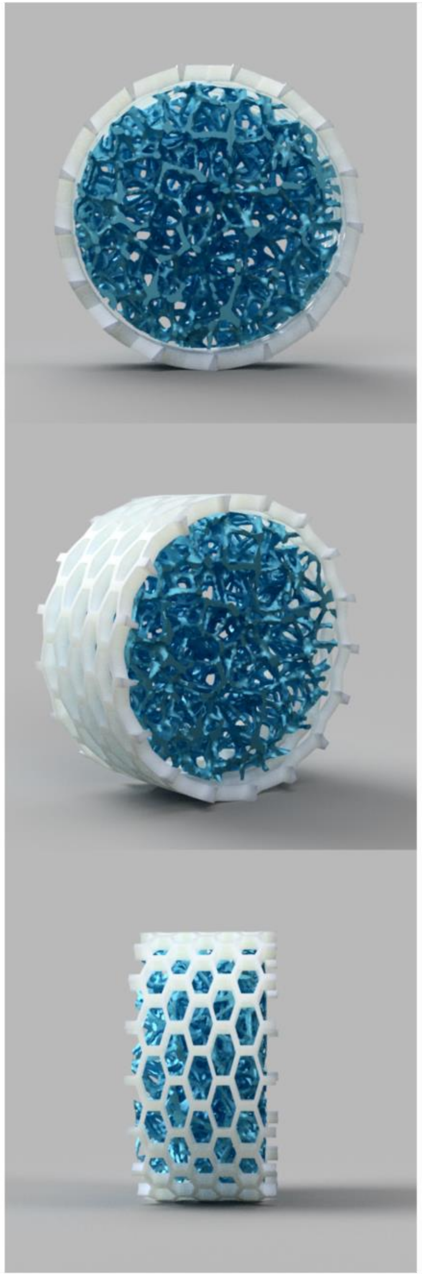
-50 μm particle is able to infiltrate into all pores in fabricated scaffolds
-200 μm particle is able to infiltrate into 98 % of the pores





It is worth noting that the mechanical properties of bone exhibit a wide range of reported values, influenced by factors such as local tissue density and testing conditions.

Cancellous (trabecular) bone exhibits the Young's modulus in the range of 0.1–1.0 GPa and the strength that varies from 1 to 10 MPa.



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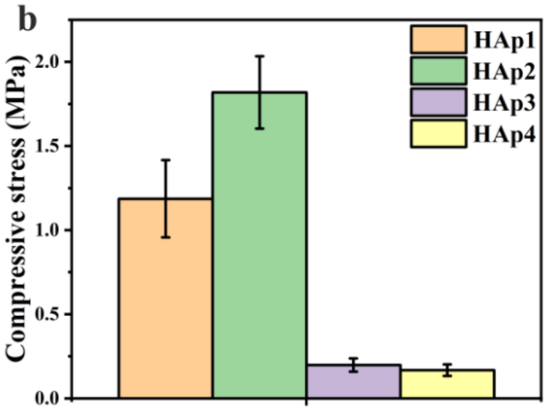
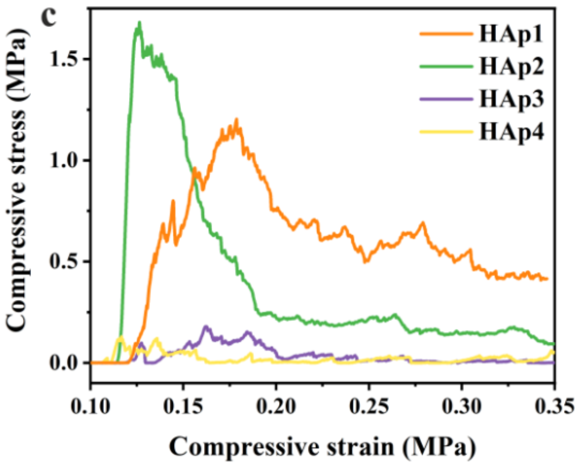
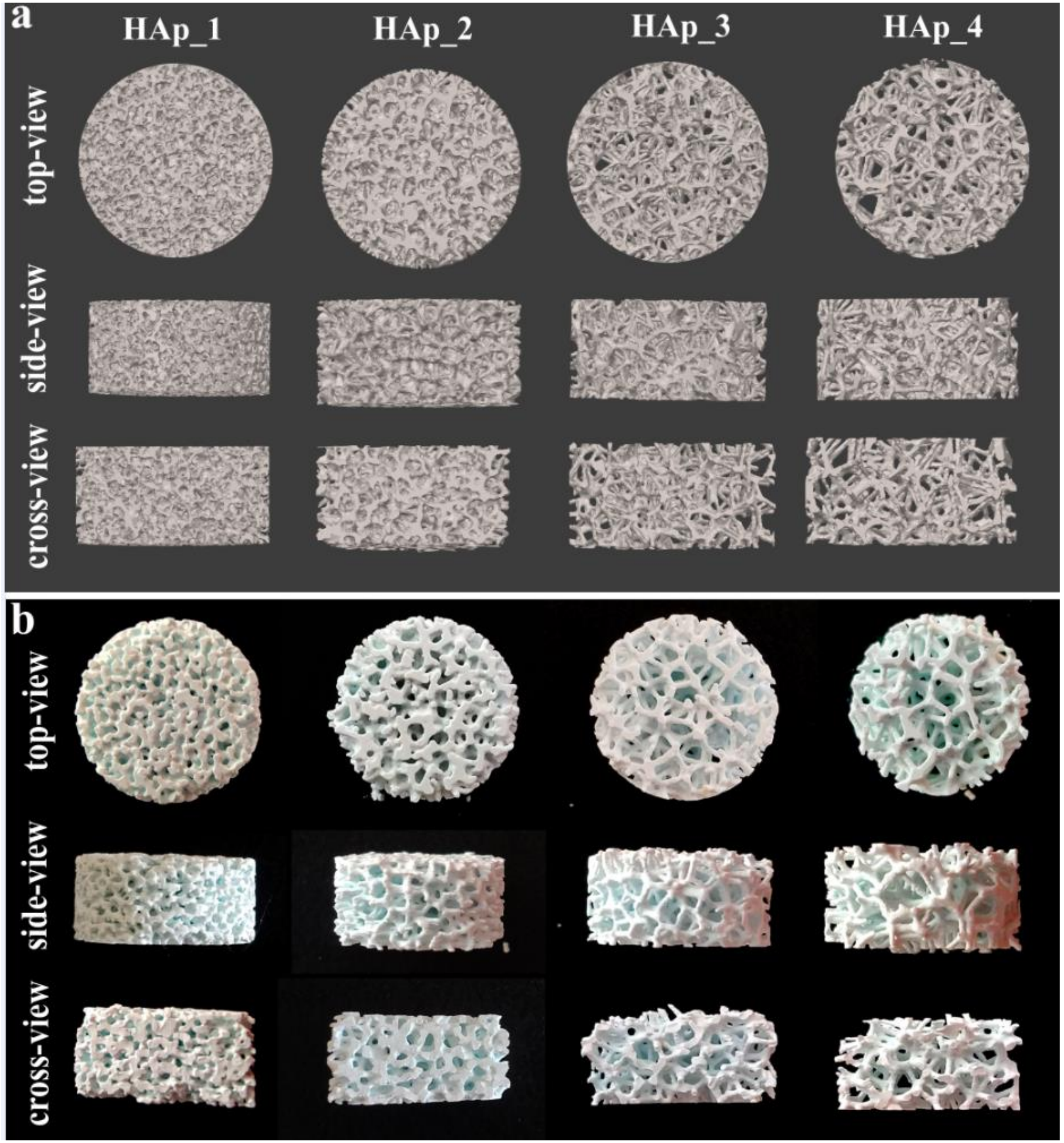
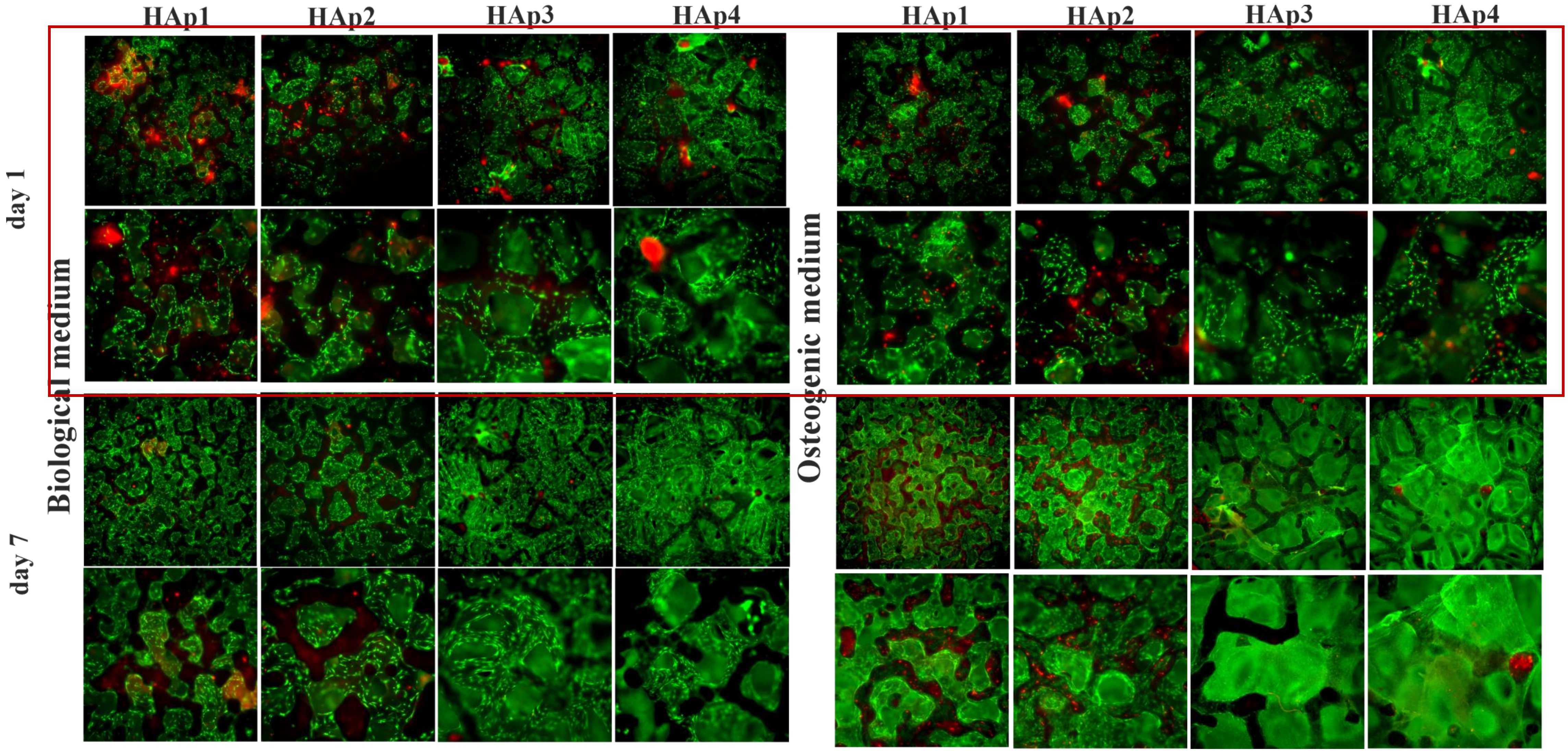
Effect of pore size and porosity

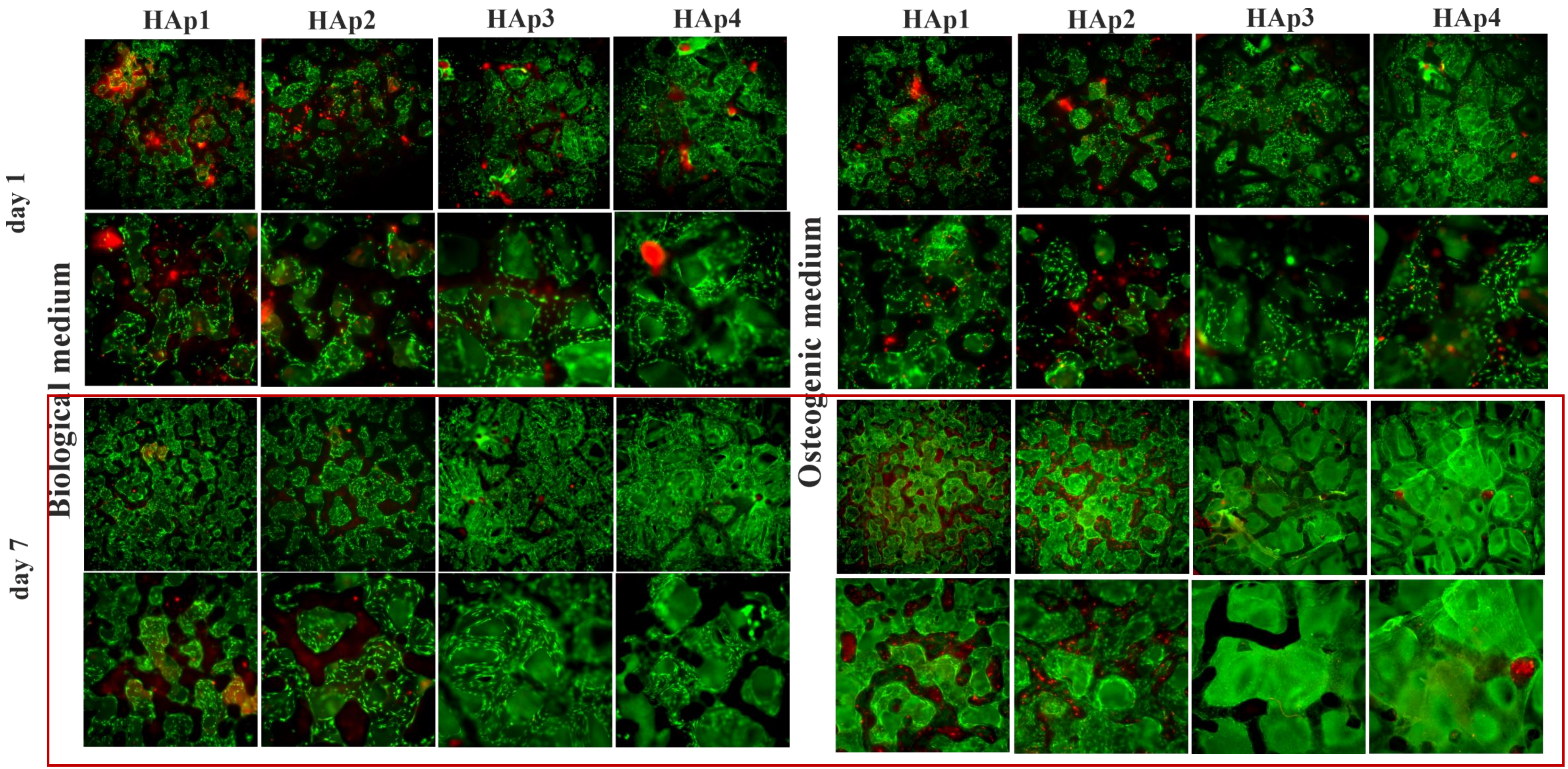
scaffold	porosity (%)	average pore size (µm)	wall thickness (µm)
HAp1	42.930	267.643	291.965
HAp2	45.605	396.535	354.771
HAp3	76.749	707.331	260.536
HAp4	78.701	850.795	292.394








HAp1
HAp2
HAp3
HAp4
HAp1
HAp2
HAp3
HAp4
day 1
day 7
Biological medium
Osteogenic medium


HAp1
HAp2
HAp3
HAp4
HAp1
HAp2
HAp3
HAp4
day 1
day 7
Biological medium
Osteogenic medium

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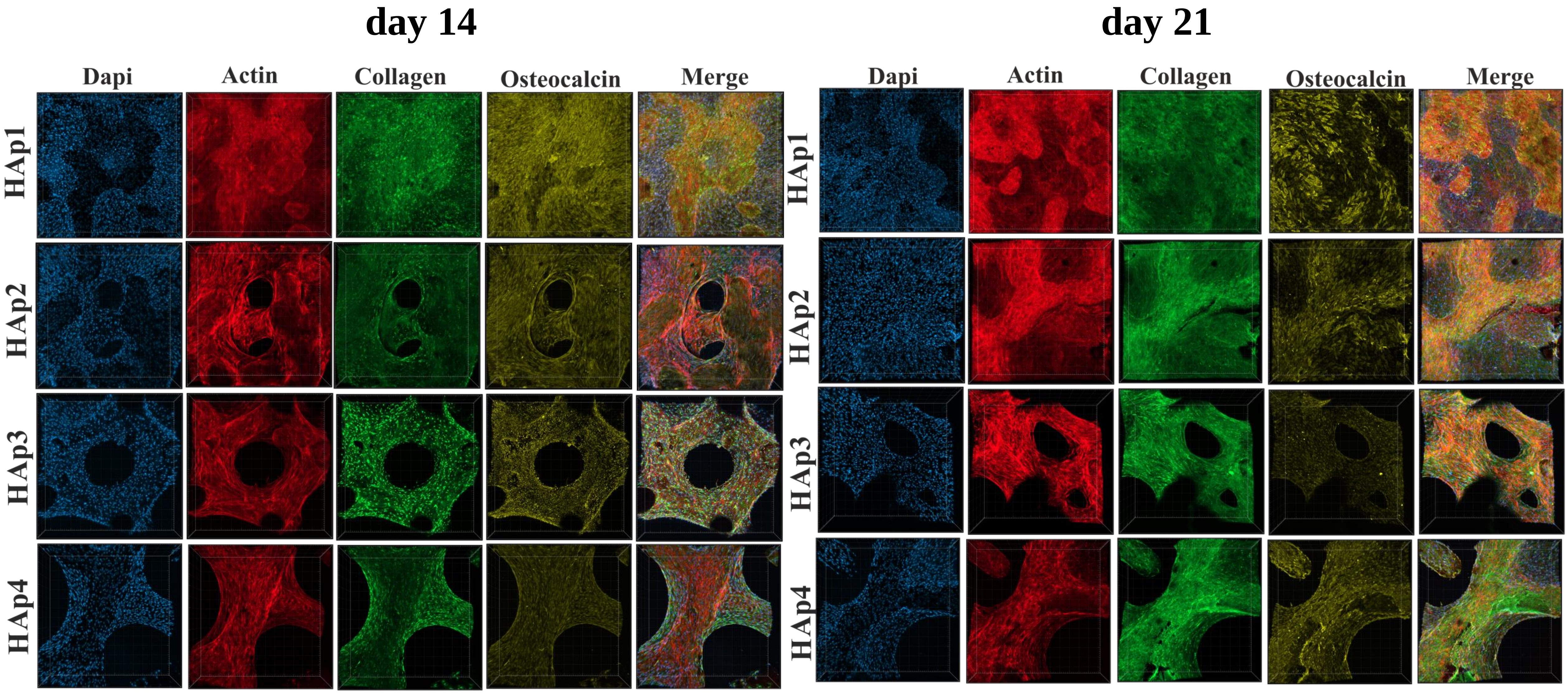
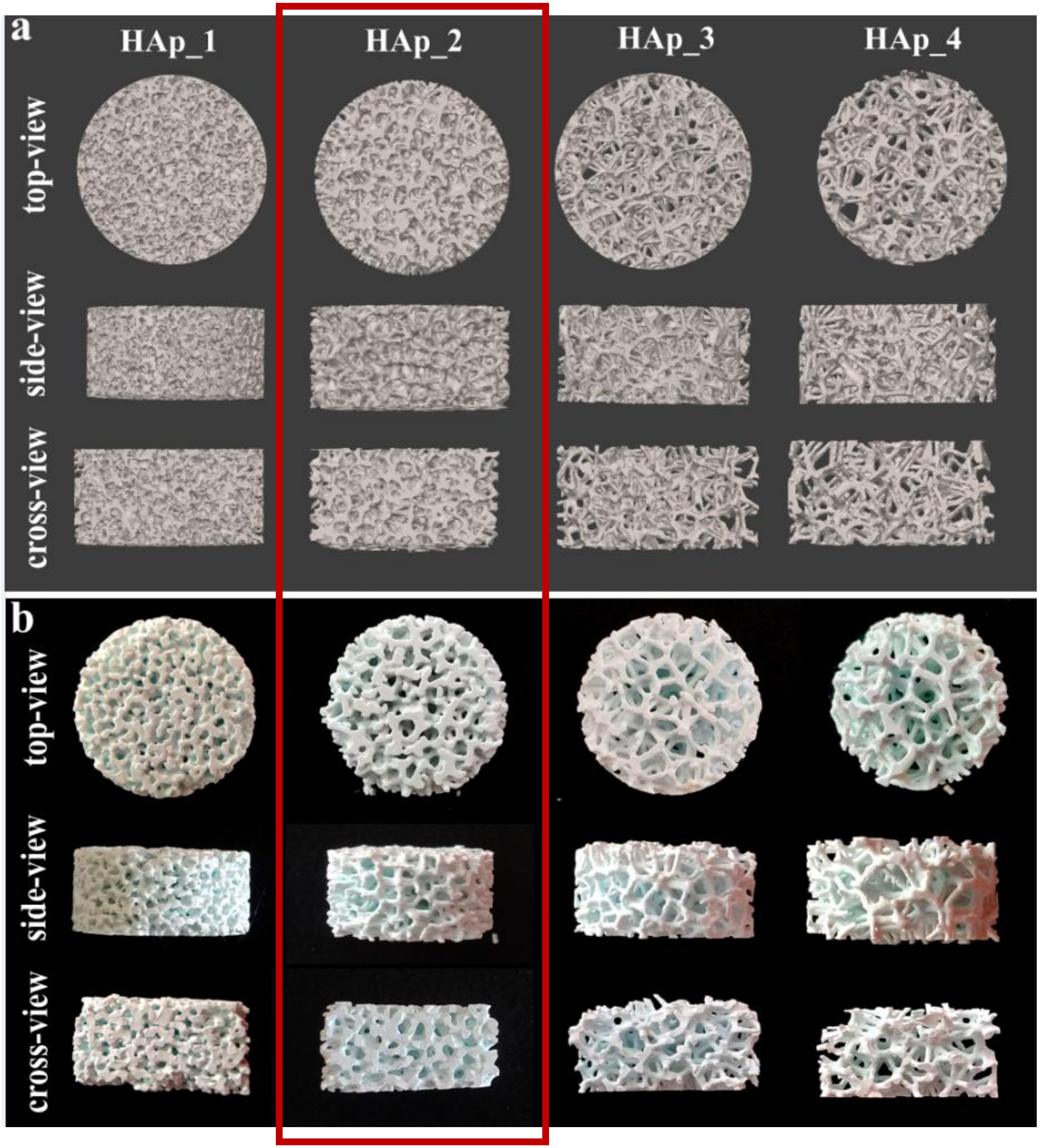
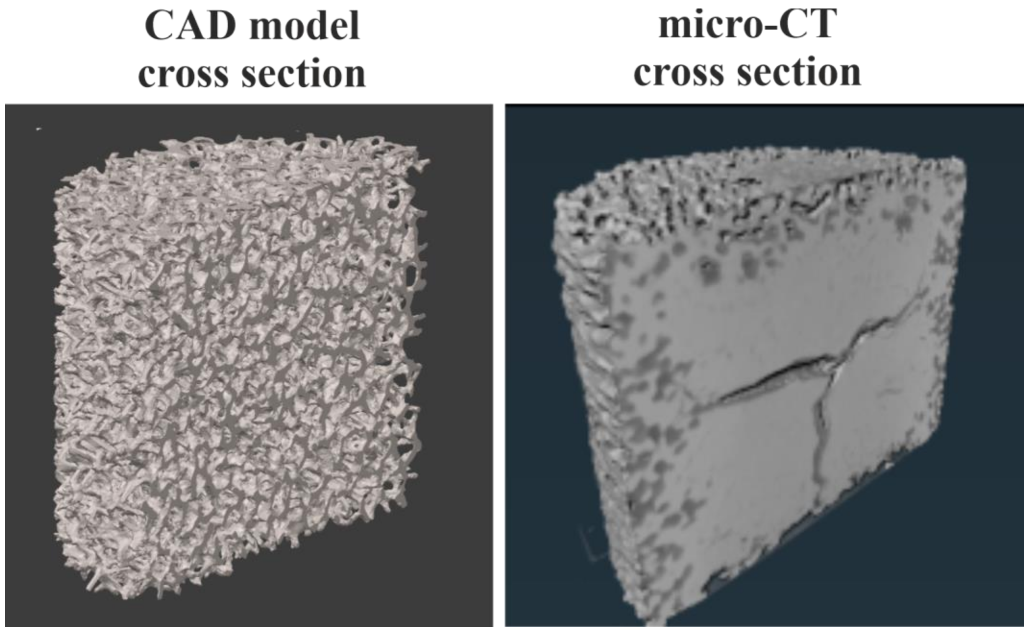
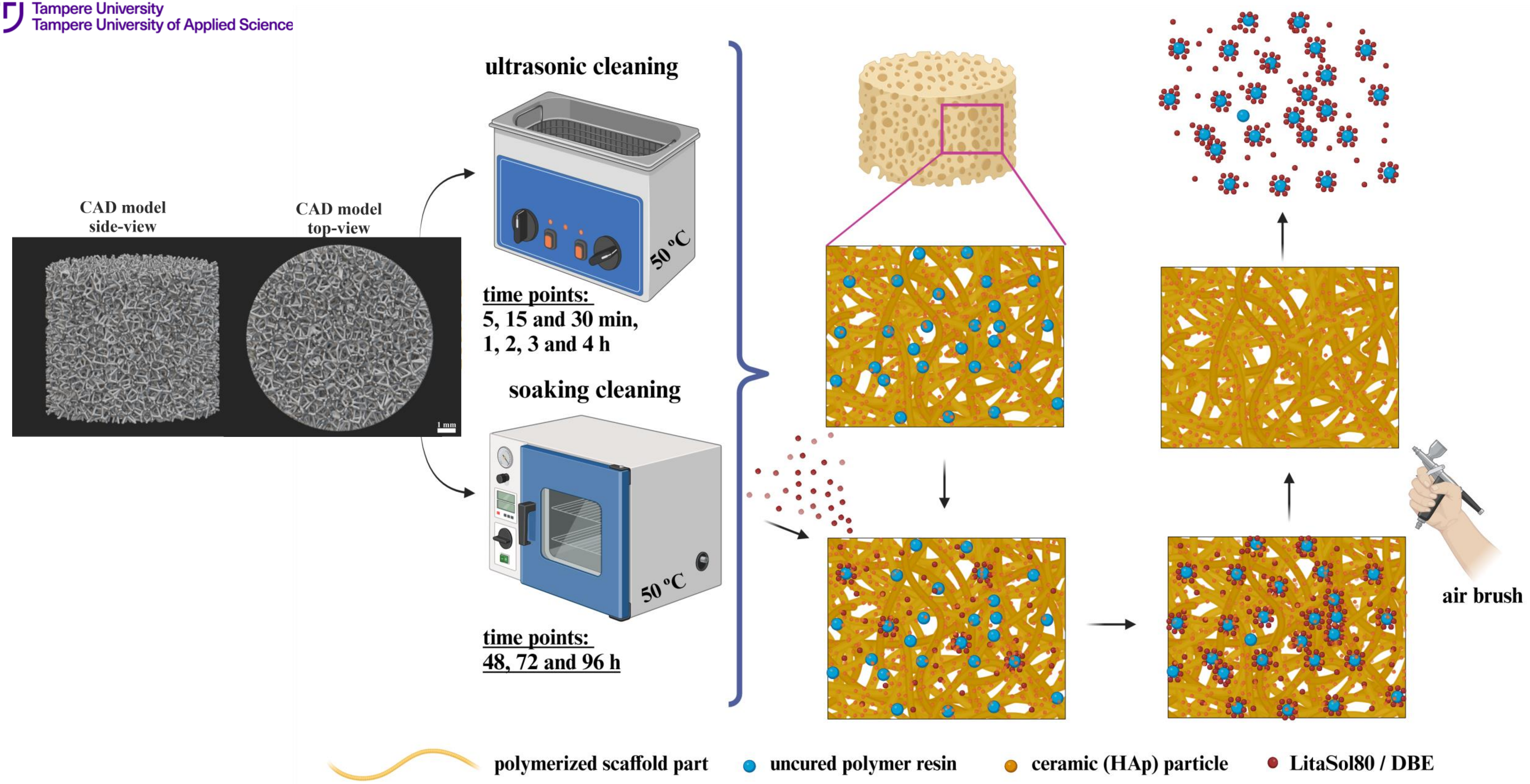



a
HAp_1
HAp_2
HAp_3
HAp_4
top-view
side-view
cross-view
b
top-view
side-view
cross-view

Cleaning challenge of porous scaffolds

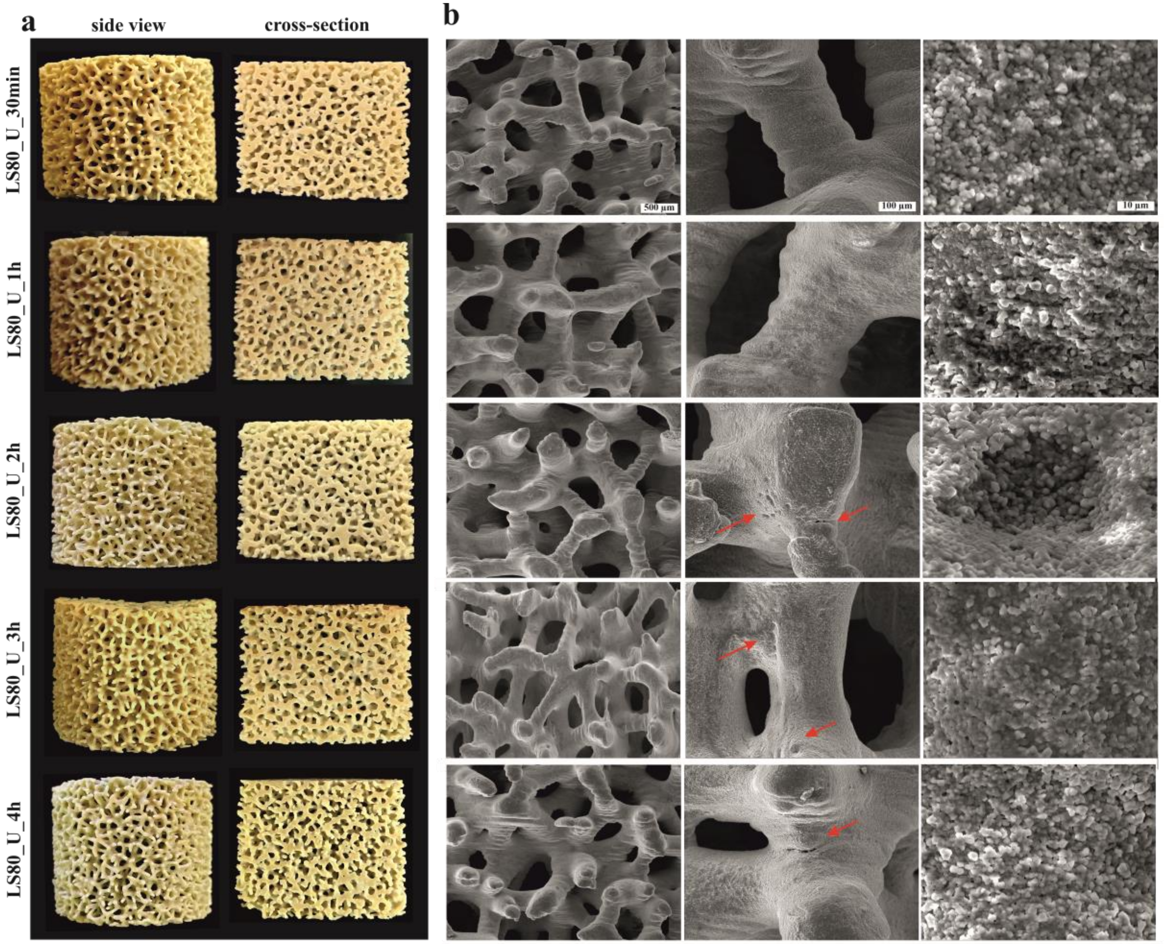
- porous structures where the interconnected pores are intentionally designed to remain uncured
- the uncured slurry in these porous regions can become intricately trapped between the cured layers, complicating the cleaning process
- effectively removing the uncured slurry from within the intricate and porous geometries of the printed structures becomes a critical task as the presence of residue within the structure can obstruct pores during sintering
- biomedical implants → pore characteristics are crucial for tissue integration and substance exchange.



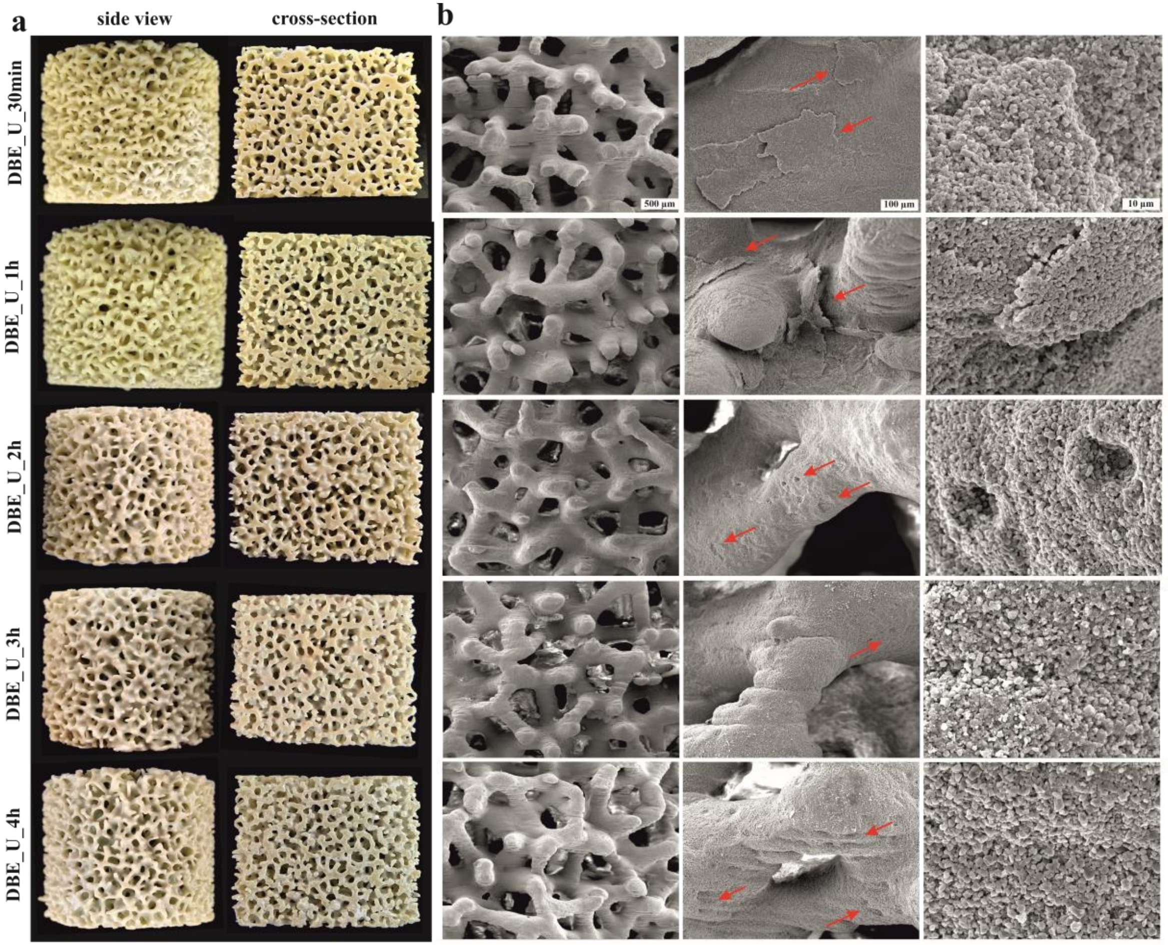

CAD model
side-view
CAD model
top-view
1 mm
ultrasonic cleaning
50 °C
time points:
5, 15 and 30 min,
1, 2, 3 and 4 h
soaking cleaning
50 °C
time points:
48, 72 and 96 h
air brush
polymerized scaffold part
uncured polymer resin
ceramic (HAp) particle
LitaSol80 / DBE

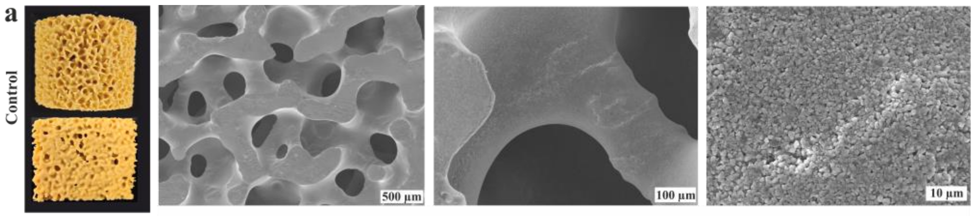
Morphological characterization - ultrasonication

LithaSol 80

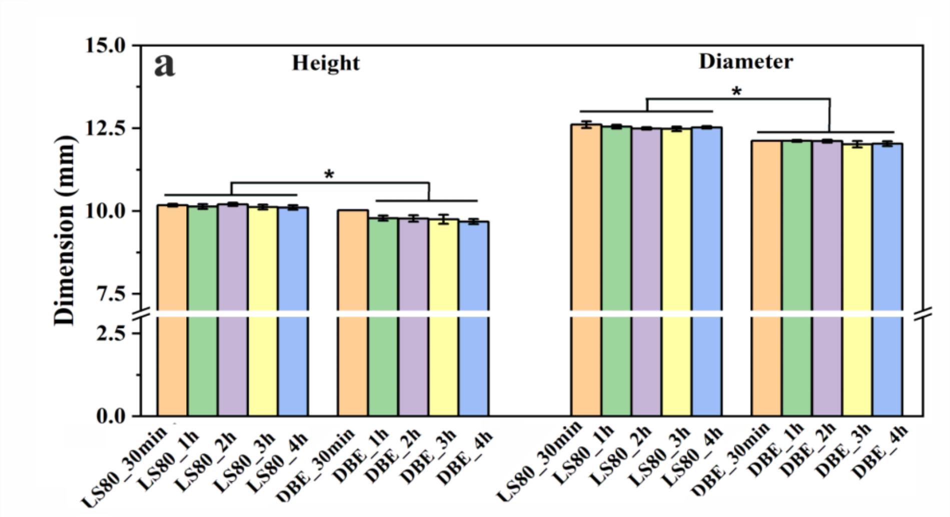


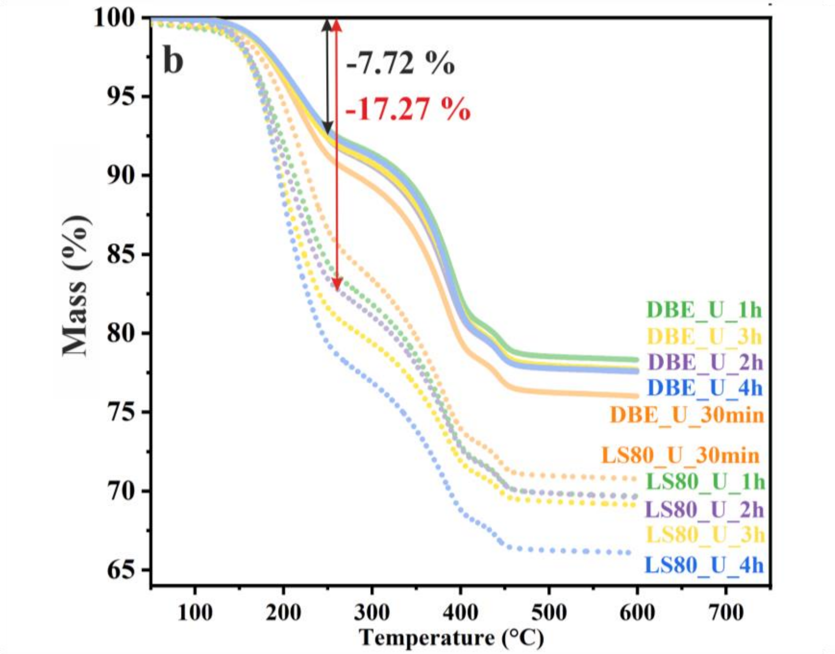
DBE





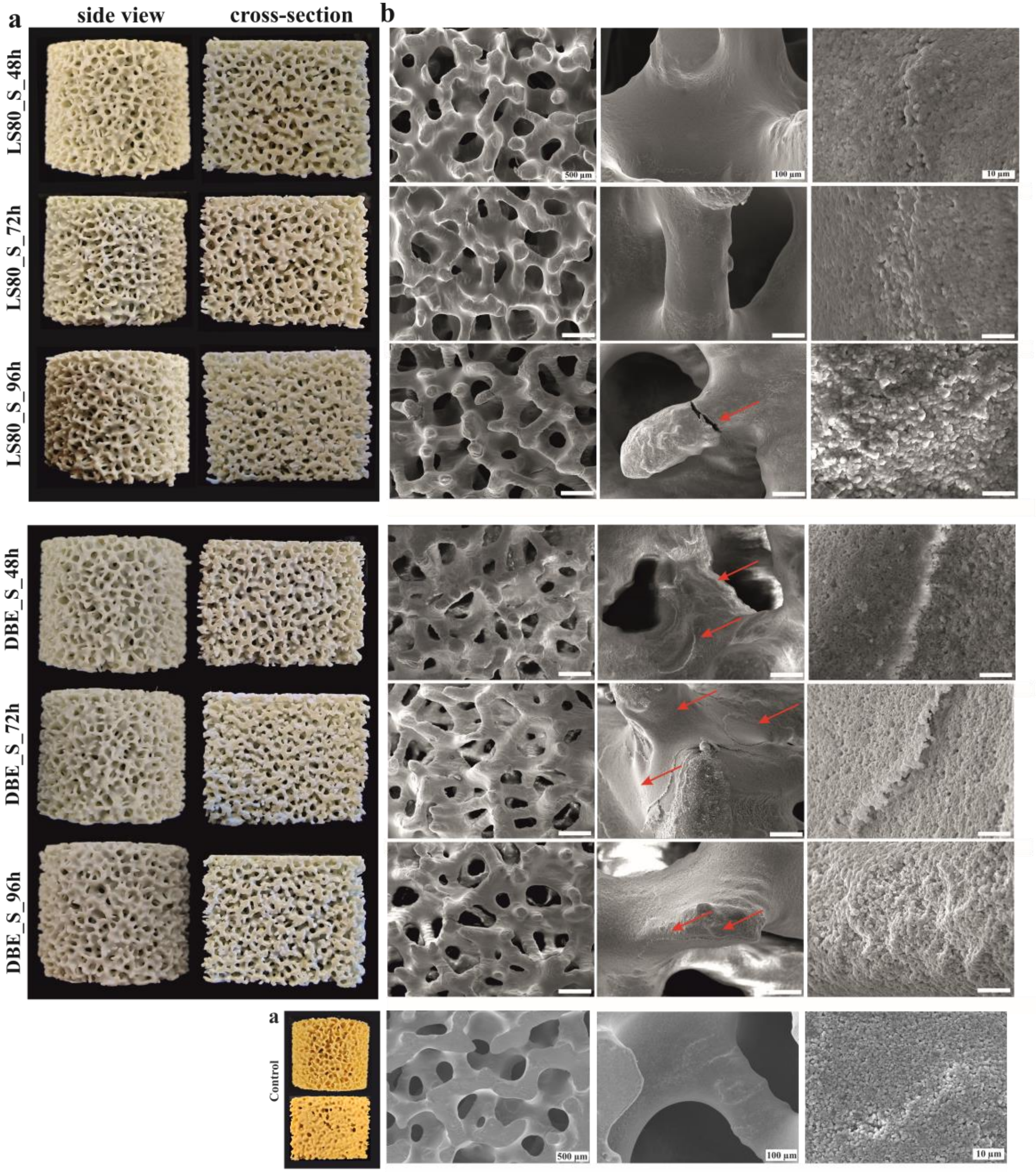
Scaffolds dimensions and thermal stability

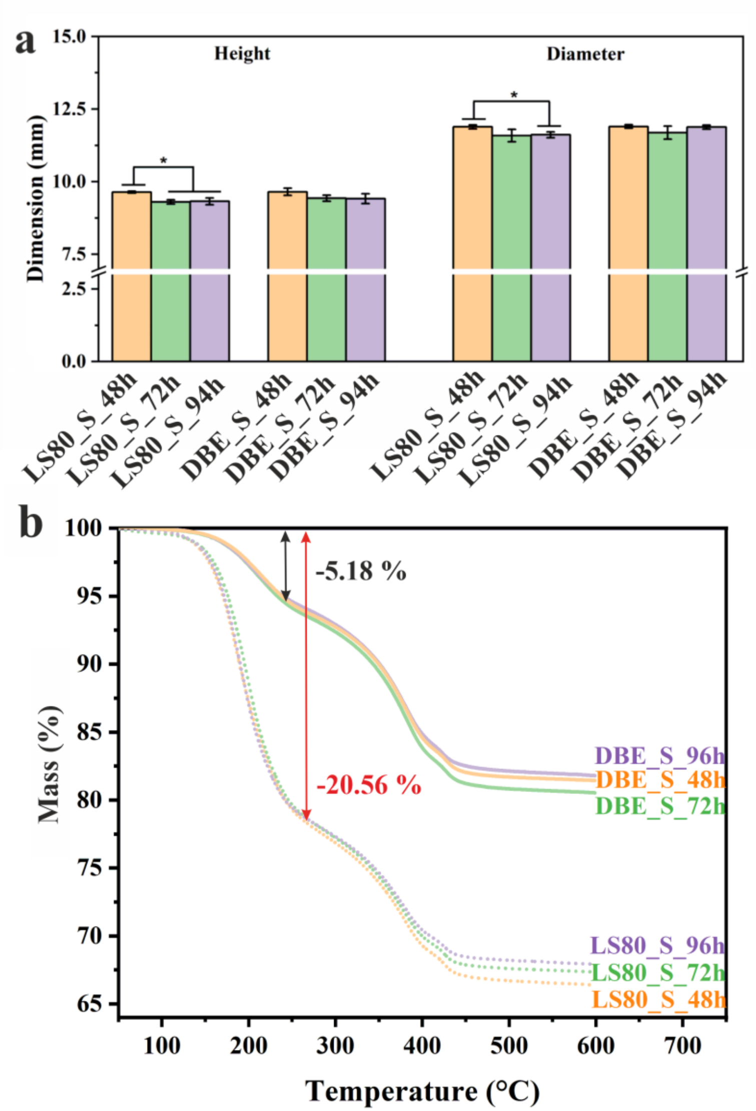


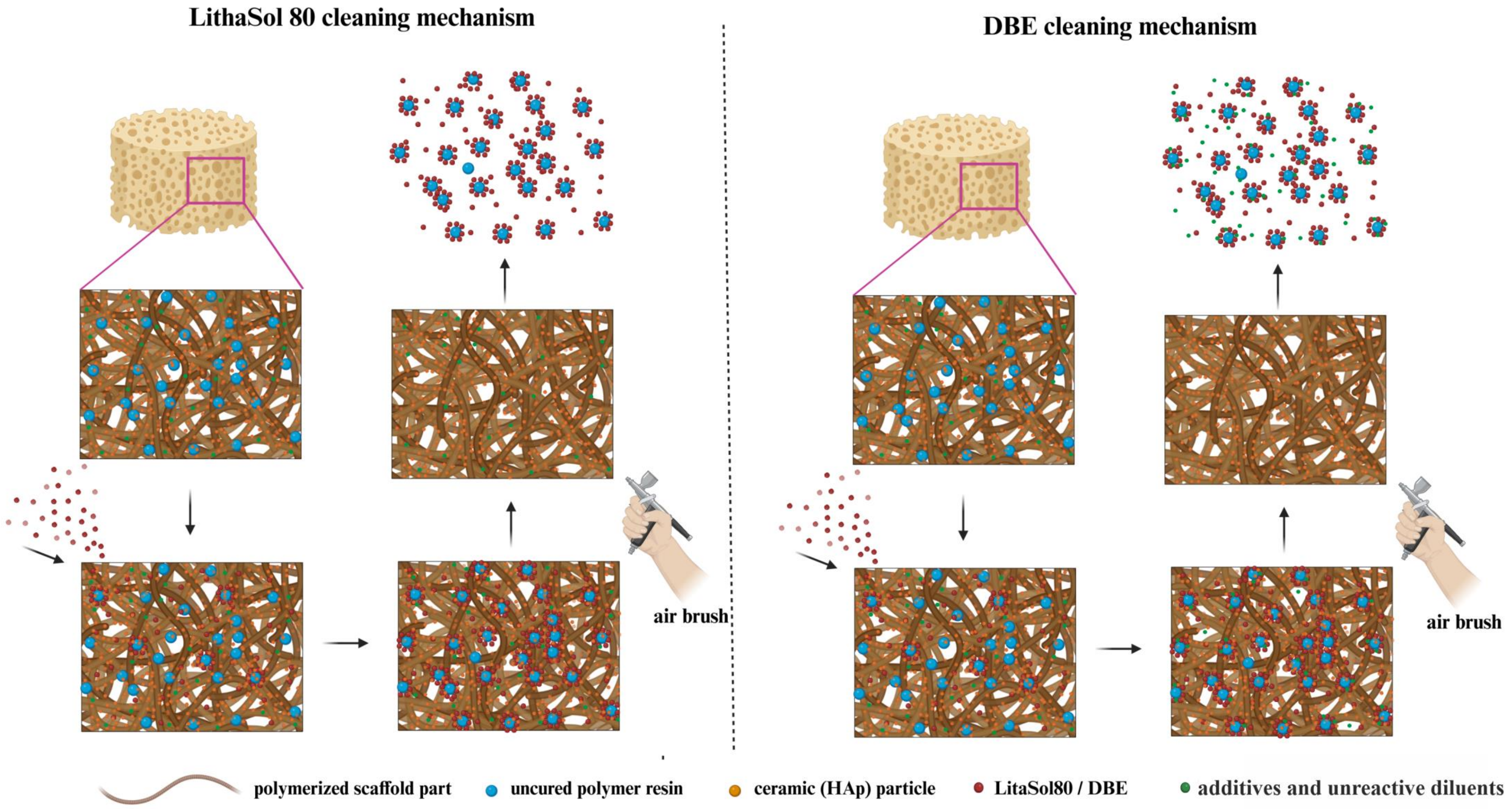


- mass loss started at approximately 150 °C, primarily attributed to the diffusion and evaporation of additives, unreactive diluents and uncured slurry
- the degradation of the major cured organic components initiated around 250 °C
- the significant contrast in the TG curves between scaffolds treated with LithaSol 80 and DBE primarily lies in the initial stage of weight loss
- the observed difference in total mass loss (14.15%) between samples treated with Lithasol 80 and DBE implies the potential occurrence of chemical debinding during cleaning with DBE. However, further detailed examination is required to provide conclusive evidence

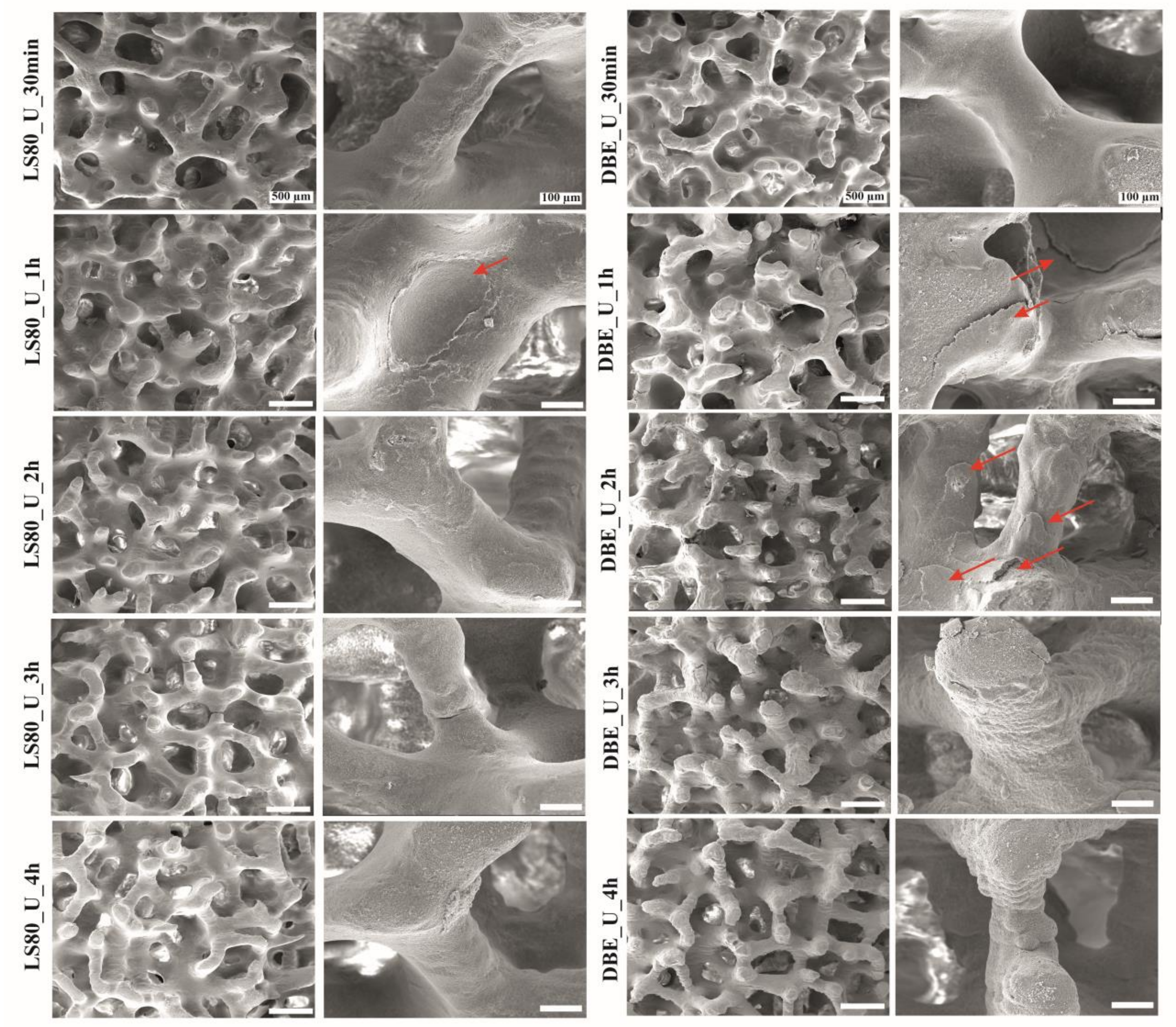
Morphological characterization - soaking

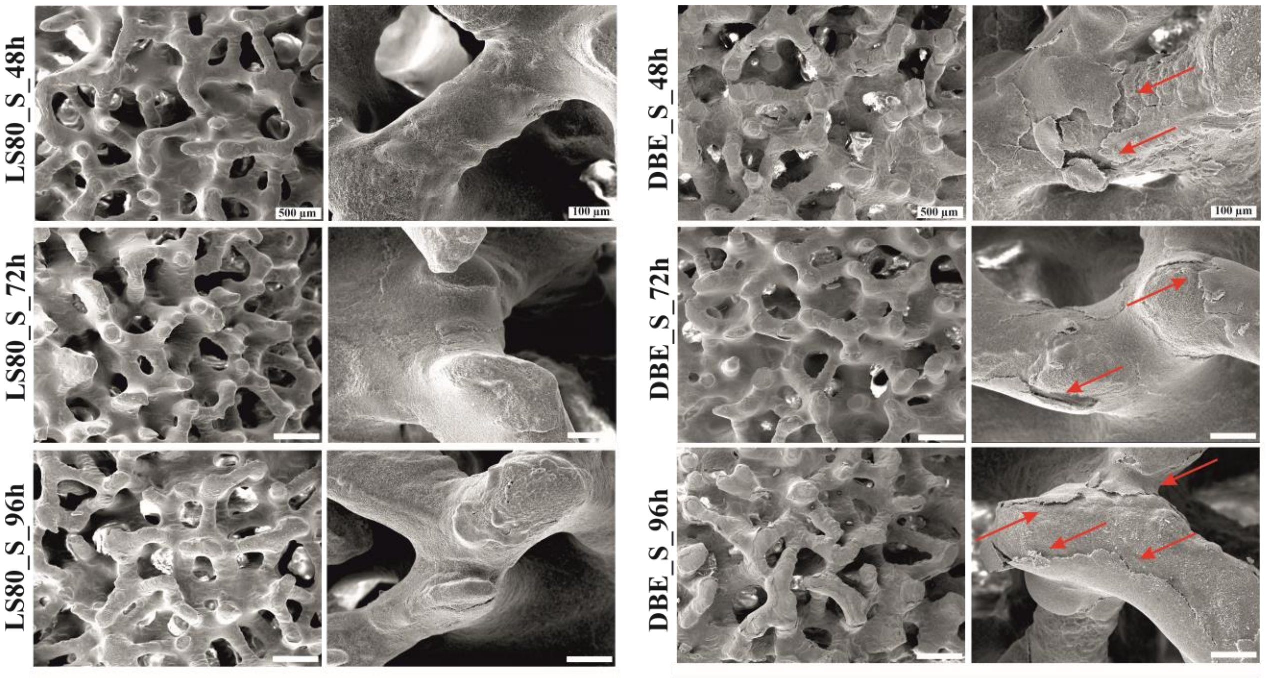





LithaSol 80 cleaning mechanism
DBE cleaning mechanism
air brush
air brush
polymerized scaffold part
uncured polymer resin
ceramic (HAp) particle
LitaSol80 / DBE
additives and unreactive diluents

Morphological characterization – sintered samples





Conclusion…

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Thank you for your attention!

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