Biomicroconcretes modified with gold nanoparticles and silicon

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INTRODUCTION

Bioactivity, appropriate mechanical strength, ease of handling, and antibacterial properties play a key role in the success of bone grafts. Due to the excellent biocompatibility and the chemical resemblance to the inorganic component of bone the calcium phosphate (CaP) based biomaterials have found a wide range of medical applications. Among others, calcium phosphate-based bone cements (CPCs) are a well-recognized group of modulable biomaterials for bone restoration and regeneration [1]. Recently biomicroconcretes, i.e. CPCs enriched with granules and/or microspheres, have gained much attention [2,3]. The granules can serve as delivery vehicles for therapeutics and antibacterial agents, such as silver, copper, and gold nanoparticles [4]. To improve biological features of biomaterials elements such as silicon, magnesium or zinc can be used [5]. Combining these strategies along with the idea of hybrid-type materials can lead to the development of bone grafts with some superior properties. The aim of our study was to obtain and examine hydroxyapatite/chitosan/tricalcium phosphate-based biomicroconcretes modified with gold nanoparticles (AuNPs) and silicon.

MATERIALS

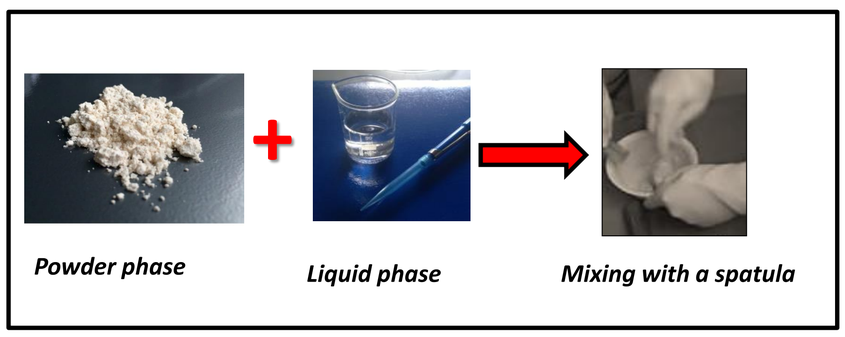
SOLID PHASES:

- αTricalcium phosphate (αTCP)- and Si-modified αTCP (Si-αTCP) - synthesized via the wet chemical method
- hybrid-type hydroxyapatite/chitosan granules modified with gold nanoparticles (0.1 wt% AuNPs) - synthesized using the wet chemical methods

LIQUID PHASES:

- 0.75 wt% of methylcellulose in 2.0 wt% Na_2HPO_4
- 2.0 wt% Na_2HPO_4 solution

Material preparation



METHODS

Setting time- Gillmore needle
Phase composition of the hardened samples, X-ray method (D2 Phaser diffractometer, Bruker), Rietveld method
Compressive strength (Instron 3345)
Microstructure of fractured surfaces (Nova NanoSem 200)
Antibacterial activity of the materials against *Staphylococcus epidermidis*, *Staphylococcus aureus,* and *Escherichia coli*

RESULTS

Initial composition

Table.1 Starting compositions of the studied biomicroconcretes.

Material	Solid phase		Liquid phase	L/P [g/g]
	Granules (40 wt.%)	Powder (60 wt.%)		
HT	HA/CTS	αTCP	0.75wt.% methylcellulose in 2.0wt.% Na_2HPO_4	0.6
Au-HT	Au-HA/CTS	αTCP		
Au,Si-HT	Au-HA/CTS	Si-αTCP		

Setting times

Gilmore Needle

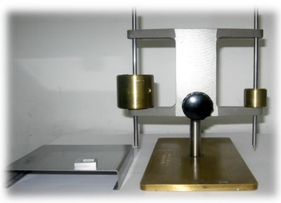


Table 2. Initial and final setting time of the studied materials.

Material	Settingtime [min]	
	Initial	Final
HT	7±1	20±1
Au-HT	6±1	16±1
Au,Si-HT	5±1	10±1

Compressive strength

Instron 3345

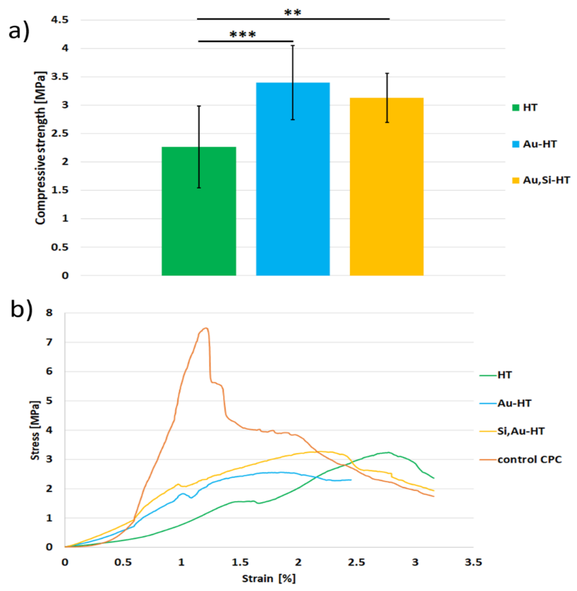


Fig.2. Compressive strength of the cements.

Microstructure

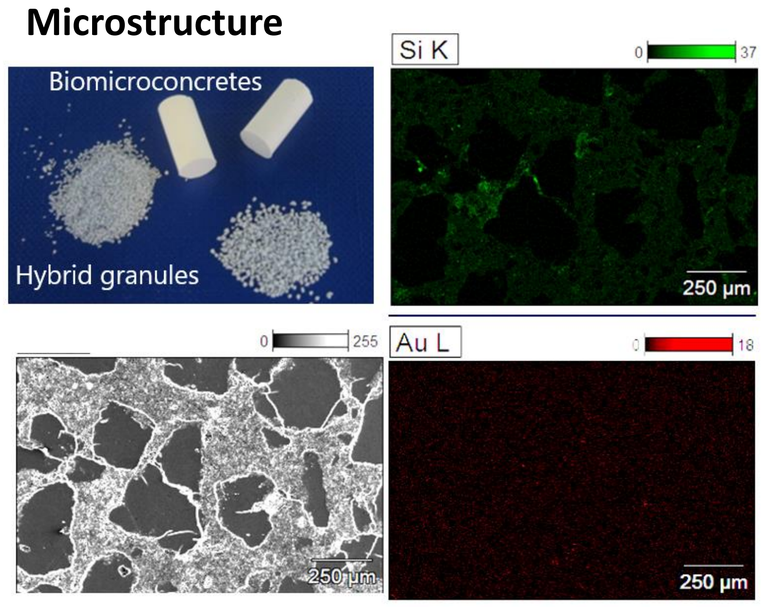


Fig.1. The photography, SEM image and elemental mapping of AuNPs and silicon modified biomicroconcrete..

Phase composition

Table 3. Phase compositions of the initial powders, granules and set biomicroconcretes

Material		αTCP [wt.%]	HA [wt.%]
Powders	αTCP	98±2	2±2
	Si-αTCP	97±1	3±1
Granules	HA/CTS	--	100±0
	Au-HA/CTS	--	100±0
Biomicroconcretes	HT	54±4	46±4
	Au-HT	62±2	38±2
	Au,Si-HT	62±2	38±2

Antibacterial properties

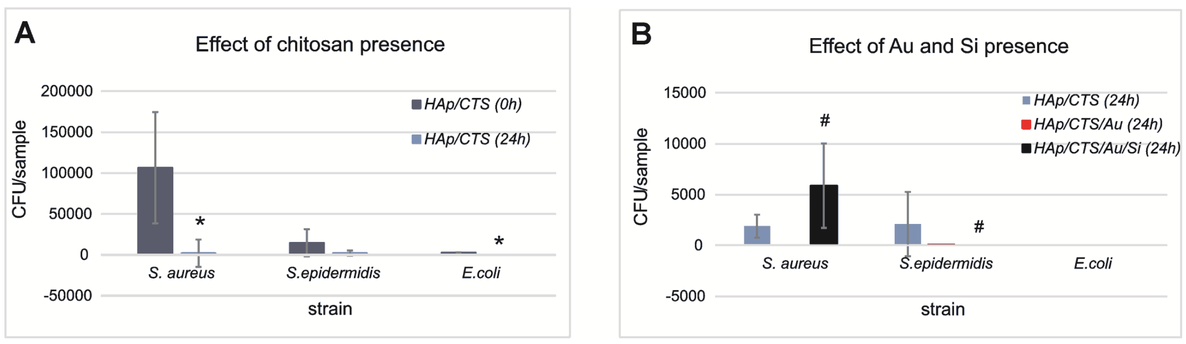


*Fig.3. Effect of chitosan presence in the material (A) and effect of Si and Au presence in biomicroconcretes (B) observed after 24 h incubation with 3 bacterial strains. * significance compared to control at 0h (Mann Whitney test); # significance compared to control at 24h (One-way ANOVA followed by Dunnett's post-hoc test).*

CONCLUSIONS

The developed biomicroconcretes combine the dual functions of antibacterial action and bone regeneration. Gold nanoparticles and silicon have been proven to be effective modifiers of the chemically bonded biomaterials. Moreover, the beneficial impact of AuNPs and silicon, enhancing the antibacterial activity of chitosan, was demonstrated. Further biological studies are needed.

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