Effect of Coating and Pre-coating Techniques on the Compressive Strength of Fluorapatite Glass-ceramic Scaffolds

Ourania-Menti Goudouri[1], Jeffrey Harless[1] and Isabelle Denry[1]

[1] Dows Institute for Dental Research, University of Iowa College of Dentistry, Iowa City, IA, USA

Statement of Purpose: Ceramic scaffolds produced by the foam replica technique often lack adequate compressive strength. Therefore, the aim of this study was to investigate the effect of different pre-coating and coating approaches on architectural characteristics and mean compressive strength of fluorapatite glass-ceramic scaffolds.

Methods: Fluorapatite glass-ceramic scaffolds were prepared by the polyurethane (PU) foam replica technique. The control group (A) was prepared by impregnation of non-coated PU foam cylinders (10x12mm) with a fluorapatite-based glass slurry, followed by sintering under vacuum at 795ºC for 2min. at a heating rate of 55ºC/min. Scaffolds in Group A were coated twice and sintered a second time using the same heat treatment. Scaffolds in Group B received a third coat and identical heat treatment. Scaffolds in Group C were prepared as in group A and further coated with a 1 wt.% gelatin aqueous solution . Scaffolds in groups D and E were pre-coated with either gelatin (Group D) or 40 wt.% colloidal silica aqueous solution (Group E) and then coated twice with glass slurry and sintered as for group A. The rationale for pre-coating with gelatin or colloidal silica is to round the sharp angles of the PU foam struts prior to glass slurry application[1], while coating as-sintered ceramic scaffolds with gelatin has been shown to improve their strength[2]. Architectural characteristics of the scaffolds were investigated by SEM. The porosity was determined via helium pycnometry. The mean compressive strength was measured using a Universal Testing machine. Crystalline phases were analyzed by x-ray diffraction (XRD) on powdered scaffolds.

Results: XRD confirmed the presence of a small amount of fluorapatite for all groups. Groups B, D and E presented an interconnected porous network with no significant difference ($p>0.05$) in percent porosity, mean strut thickness or mean pore size compared to control group A (Table 1). The mean compressive strength of groups C (2.64 ± 0.78 MPa) and D (3.44 ± 0.98 MPa) was significantly higher than that of the control group (1.32 ± 0.20 MPa). The higher mean strength value for Group C was tentatively attributed to a significantly higher mean strut thickness ($p< 0.001$). In the case of group D, it can be hypothesized that the gelatin layer successfully rounded the sharp angles of the PU foam struts prior to applying the glass slurry, thereby resulting in a stronger strut structure, free of sharp internal angles.

Table 1. Architectural characteristics and mean compressive strength for the various groups (±SD).

	St (μm)	Pd (μm)	P (%)	σ (MPa)
A	187 ± 52	496 ± 133	72 ± 3	1.32 ± 0.20
B	210 ± 38	395 ± 113	65 ± 3	2.18 ± 0.44
C	403 ± 99	416 ± 138	66 ± 5	2.64 ± 0.78
D	267 ± 48	511 ± 115	64 ± 4	3.44 ± 0.98
E	216 ± 59	445 ± 159	70 ± 3	1.52 ± 0.58

St = Strut thickness, Pd = Pore diameter, P = Porosity, σ = Compressive strength

Conclusion: Application of a gelatin coating or pre-coating the PU foam with gelatin are both promising techniques for the fabrication of stronger fluorapatite glass-ceramic scaffolds while keeping a high level of interconnected macroporosity.

Acknowledgements

Supported by NIH-NIDCR R01DE19972.

References:

1. Kim SM, Yi SA, Choi SH, Kim KM, Lee YK. Nanoscale Res Lett. 2012; 7: 78-82
2. Jun IK, Kong YM, Lee SH, Kim HE, Kim HW, Goretta KC. J Am Ceram Soc 2007; 89: 2317-2319