Compressive fracture behaviors of fluoridated calcium phosphate coated Ti6Al4V lattice structures

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Introduction. The recent advances in manufacturing such as selective laser melting (SLM) have allowed the fabrication of complex geometries and lightweight 3D components. Lattice structure serves as an alternative design to existing implants by reducing the stiffness thereupon eliminate the stress-shielding effect whilst improving osseointegration process. In order to reinforce the osseointegration with the adjacent tissue after the surgery, the porous scaffold is coated with fluoridated calcium phosphate by using plasma electrolytic oxidation (PEO) technique. Ti6Al4V has been material of choice for medical application and it is viable for SLM technology and PEO technique. The aim of this study is to determine the effect of PEO treatment on the compressive fracture behavior of fluoridated calcium phosphate coated lattice scaffolds. This paper will discuss the compressive properties of as-built and coated porous scaffolds with following parameters; plateau stress, quasi-elastic gradient, compressive offset stress and energy absorption rate.

Materials and Methods.
1) Porous scaffold fabrication

There are three different processes involved for porous scaffold fabrication namely; pre-processing, build-up process and post-processing. Before starting the build-up process, the porous scaffolds are designed in nTopology software, create STL file and transfer to the SLM 280HL machine. Then, a batch of scaffolds are fabricated layer-by-layer by completely melting the Ti6Al4V powder and produce the scaffolds on the metal platform. All scaffolds are cylinder with a porous structure with similar strut diameter (0.3mm) but two different porosity (80% and 85.8%) designated as HEX2 and HEX3. Heat treatment is required for SLM-fabricated Ti6Al4V scaffolds prior to removal of scaffolds from the platform to increase the ductility of the scaffolds. Finally, the scaffolds are removed from the platform by using a cutting machine with a diamond blade.

2) Plasma electrolytic oxidation coating

Phosphate electrolyte is prepared by using 5g/l tri-sodium orthophosphate (Ajax Finechem), 3 g/l calcium fluoride (Sigma Aldrich) and 2 g/l potassium hydroxide and diluted in 1000 ml distilled water. Two different treatment times are considered for each group. The porosity of the scaffolds, voltage threshold, current and treatment time which are used during the experiment is shown in Table 1.

<table>
<thead>
<tr>
<th>Voltage threshold (V)</th>
<th>HEX2-5</th>
<th>HEX2-7</th>
<th>HEX3-5</th>
<th>HEX3-7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current (A)</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Treatment time (mins)</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 1 List of PEO coated scaffolds

3) Mechanical test

Universal material testing machine Autograph AG250kND is used for compression test of the uncoated and fluoridated calcium phosphate coated scaffolds. Compression test is carried out according to the ISO standard 13314:2011.

Results. The quasi-static test results demonstrate the high effect of porosity percentage on its mechanical properties. Fig 1 shows the PEO coating does not reduce the mechanical properties. On the other hand, it enhances the mechanical strength of the scaffold possibly because of the growth of coating increase the density of the scaffold. The result is comparable to Karaji et al. [1] study where the PEO technique would barely affect mechanical properties of the coated porous scaffold namely maximum stress, yield stress, plateau stress and energy absorption. Therefore, the technique could be an alternative to design a better orthopedic and dental implants.

Fig1 Maximum stress for all scaffolds

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References.