Enhancing Osseointegration

Optimal Surface Chemistry. Optimized Nano-Roughness


Aim

Osseointegration is dependent on several factors, such as the surface chemistry and topography of the implant. Since HA\textsuperscript{nano} Surface is added to an implant surface, the biological response of HA\textsuperscript{nano} Surface modified implants was evaluated in two \textit{in vivo} studies employing implants with different surface roughnesses.[A, B]

Method

Study A\textsuperscript{[A]}: Half of the 20 turned electropolished cylindrical implants were modified with HA\textsuperscript{nano} Surface. The surfaces were analyzed using optical interferometry, Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM) and X-ray Photoelectron Spectroscopy (XPS). The biological response was evaluated after 4 weeks of healing in rabbit tibia by histomorphometric analysis (BIC).

Study B\textsuperscript{[B]}: A total of 20 threaded titanium implants were blasted with TiO\textsubscript{2}. Half of the implants were modified with HA\textsuperscript{nano} Surface. The surface of the implants was analyzed using optical interferometry, Scanning Electron Microscopy (SEM) and X-ray Photoelectron Spectroscopy (XPS). The biological response after 4 weeks of healing in rabbit tibia was evaluated by histomorphometric analysis (BIC) and biomechanical testing (removal torque).

Results

Analysis of the surface topography of electropolished implants using interferometry revealed a very smooth surface. Addition of HA\textsuperscript{nano} surface was shown not to affect microroughness, Table 1. However, an increased surface roughness in the nanometerscale was observed, as determined by interferometry and AFM, Figure 1 and Table 1. Interferometry measurements of blasted implants showed a moderately rough surface (see Figure 2 and Table 2). As for the electropolished implants, surface modification with HA\textsuperscript{nano} Surface did not affect the microroughness of the blasted implants (Figure 2 and Table 2).

SEM images at high magnification of implants modified with HA\textsuperscript{nano} Surface showed presence of nano-sized particles which was not observed on the reference implants. The XPS analysis showed presence of calcium and phosphorous in addition to the oxygen, titanium and carbon residing from the underlying substrate.

Irrespective of surface roughness and topography, presence of HA\textsuperscript{nano} Surface resulted in an increased biological response after 4 weeks of healing. Electropolished implants modified with HA\textsuperscript{nano} Surface showed significantly higher BIC values compared to unmodified implants. For moderately rough surfaces, significantly higher removal torque values were observed for HA\textsuperscript{nano} Surface modified implants.

Conclusion

Surface topography analysis showed that HA\textsuperscript{nano} Surface did not affect the surface microroughness irrespective of initial surface treatments (blasting or electropolishing). In both \textit{in vivo} studies, the presence of HA\textsuperscript{nano} Surface resulted in a significantly enhanced biological response. The results indicate that the combination of surface chemistry and added nano-topography has a positive effect on osseointegration.
Table 1. Surface roughness values of electropolished titanium surfaces with and without HA\textsuperscript{nano} Surface obtained by optical interferometry and Atomic Force Microscopy (AFM).

<table>
<thead>
<tr>
<th>Implant</th>
<th>S\textsubscript{a} (µm)</th>
<th>S\textsubscript{dr} (%)</th>
<th>S\textsubscript{ds} (µm\textsuperscript{2})</th>
<th>AFM</th>
<th>S\textsubscript{a} (nm)</th>
<th>S\textsubscript{dr} (%)</th>
<th>S\textsubscript{ds} (µm\textsuperscript{2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electropolished titanium</td>
<td>94.2</td>
<td>71.6</td>
<td>0.06</td>
<td>0.9</td>
<td>0.2</td>
<td>0.0</td>
<td>0.0 115 25</td>
</tr>
<tr>
<td>Electropolished titanium with HA\textsuperscript{nano} Surface</td>
<td>134.4</td>
<td>55.4</td>
<td>0.32</td>
<td>2.3</td>
<td>1.5</td>
<td>0.4</td>
<td>0.3 90 23</td>
</tr>
</tbody>
</table>

Table 2. Surface roughness values of blasted titanium surface with and without HA\textsuperscript{nano} Surface obtained by optical interferometry.

<table>
<thead>
<tr>
<th>Implant</th>
<th>S\textsubscript{a} (µm)</th>
<th>S\textsubscript{dr} (%)</th>
<th>S\textsubscript{ds} (µm\textsuperscript{2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blasted titanium</td>
<td>1.42</td>
<td>0.22</td>
<td>30.1</td>
</tr>
<tr>
<td>Blasted titanium with HA\textsuperscript{nano} Surface</td>
<td>1.36</td>
<td>0.18</td>
<td>30.3</td>
</tr>
</tbody>
</table>

Figure 1. AFM 10x10 µm images of electropolished (left) and HA\textsuperscript{nano} Surface modified implants (right). On both images grain boundaries (GB) can be observed.

Figure 2. Optical interferometer images of HA\textsuperscript{nano} Surface modified (left) and blasted (right) implants.