CHAPTER 02

Osseointegration of a zirconia implant: a case report and review

• PART A •

This chapter is an extended version of:

The aim of this study was to describe the histological and histomorphometrical features of a retrieved, functional zirconia endosseous implant in a human subject and relate the findings to information available from literature on osseointegration in other explanted zirconia and titanium implants in man.

A maxillary zirconia implant in a 52-year old male patient (Zv3, Wolfratshausen, Germany) was retrieved and prepared for light microscopic evaluation. It had functioned successfully without objective or subjective concerns for approximately two years.

Histological examination demonstrated that most of the screw threads were filled with bone, showing a uniform colour, which was in close contact with the zirconia surface. No intervening fibrous tissue layer was observed between implant and the surrounding bone. In the calcified tissue many large rounded osteoblasts and osteocytes were visible. Bone contact measurements measuring from the most coronal aspect until the lowest thread revealed a mean percentage of bone to implant contact of 55.8% (SD 3.8%). This is comparable to findings regarding retrieved implants in the literature, although these show a wide range.

The histological data are coherent with a well osseointegrated zirconia implant after 2 years of functional loading. This provides further evidence of the potential of zirconia to osseointegrate to a more or less similar degree as titanium implants in man.
Introduction

Titanium (Ti) is seen as the ‘gold standard’ ground material for dental implants and has been widely and successfully used for decades. Nevertheless, it has some potential drawbacks, among which blue-greyish shimmering of the implant itself or implant components in cases of thin overlying mucosa. Also, the high prevalence of peri-implant mucositis and peri-implantitis is of concern. Titanium has relatively little resistance against wear and fretting. Submicron titanium particles that can evolve from implant bending, induce inflammatory cytokines secretion in vitro and are observed in soft tissues adjacent to sites with peri-implantitis. In addition, concerns regarding the potential hypersensitivity towards titanium were raised which however, was seen in only a limited number of susceptible patients. Therefore, some patients prefer a metal-free solution.

High strength ceramics such as Yttria-stabilized zirconium dioxide (Y-TZP) could form an alternative for titanium as implant material. Y-TZP being white, entails better light dynamics, especially in cases with thin overlying mucosa. It can be milled according to individual specifications by means of a Computer Assisted Design and Computer Assisted Manufacturing (CAD-CAM) production process. Both bone and soft tissues respond favourably to Y-TZP. In a 3-year retrospective study clinical gingival parameters around zirconia implants compared to natural teeth demonstrated less bleeding and smaller probing pocket depths around the implants. However peri-implantitis and peri-implant mucositis were also reported for zirconia implants which did not always respond favourably to treatment either. In a recent systematic review 19 clinical studies with zirconia implants could be included. Most were biased because of methodological shortcomings, resulting in only a low evidence level. Nevertheless, the authors concluded that to date zirconia implants are inferior to titanium implants in terms of implant survival. This is in agreement with a consensus statement from a few years previously in which the use of Y-TZP implants was discouraged. Comparison of osseointegration between Y-TZP and Ti implants is almost exclusively done in animal studies. The results are consistent as comparable percentages of bone-implant contact between Ti and Y-TZP implants were reported in mandibles, maxillae and femur heads of rats, minipigs, dogs, rabbits and goats. In one study in goats, multinucleated giant cells were seen in association with zirconia and not with titanium implants, however, without a difference in the percentage of bone contact.

The aim of this case report is to describe the histomorphometrical and histological features of a retrieved, functional zirconia implant in a human subject and relate the findings to the limited amount of information available from literature on osseointegration from other explanted implants.
Materials and Methods

A zirconia (Y-TZP) implant (dimensions 5 mm wide x 11 mm long) in a 52-year old male patient at the position of the first upper right molar (ZV3, Wolfratshausen, Germany) was damaged and unsalvageable as a result of an intubation procedure necessary for unrelated treatment in general anaesthesia. The proximal crown of a natural abutment tooth was also injured. The implant was immobile and had functioned successfully without objective or subjective concerns for approximately two years. After informed consent was obtained, it was carefully retrieved using a trephine drill at low speed and copious cooling, including approximately 1 mm of surrounding alveolar bone. The specimen was stored in a cool place and eventually fixed in buffered formaldehyde (pH 7.4) 10% for 24 hours and subsequently dehydrated in ethanol.

After embedding in methyImethacrylate, following polymerization, three non-decalcified, 10-µm-thick, longitudinal sections of the implants were prepared in a plane parallel to the long axis of the implant using a modified sawing microtome technique and subsequently stained with methylene blue and basic fuchsin.

Light microscopical evaluation of all sections was executed using an automated Axio Imager Z1 microscope (Carl Zeiss Micro Imaging GmbH, Göttingen, Germany) at 10x as well as 200x magnification and consisted of a complete morphological qualitative description and quantitative analysis of the hard tissue response.

Results

At the time of retrieval, after having raised a muco-periosteal flap, the implant appeared clinically healthy and was fully surrounded by alveolar bone. Characteristic histological sections are presented as figures 1a-b.

Histological examination demonstrated that most of the screw threads were filled with bone, showing a uniform colour, which was in close contact with the zirconia surface. No intervening fibrous tissue layer was observed between implant and the surrounding bone. In the calcified tissue many osteocytes were visible.

Bone contact measurements were performed, measuring from the most coronal aspect until the lowest thread. The mean percentage of bone to implant contact as seen in the 3 sections was 55.8% (SD 3.8%), taken into consideration that coronally some alveolar bone seems to have been severed from the implant. This percentage of bone to implant contact lies in the same range of magnitude or perhaps somewhat less than the percentages of bone to implant contact that have been reported in literature regarding human histology around implants with a titanium or hydroxyapatite surface (table 1).
Figure 1a
Characteristic histological section showing intimate contact between the zirconia implant (gray) and the red colored adjacent bone (magnification 10x).

Figure 1b
Histological section; the depicted area (see framework in picture 1a) emphasizes the intimate contact between the zirconia implant (gray) and the red colored bone (magnification 200x). The vital bone is bounded by osteoblasts.
<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Location</th>
<th>Type</th>
<th>Reason for Retrieval</th>
<th>Years</th>
<th>Bone to implant contact (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Zirconia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Nevin et al, 2011</td>
<td>26</td>
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<td>Y-TZP</td>
<td>Planned</td>
<td>0.5</td>
<td>Not provided</td>
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<tr>
<td>Kohal et al, 2016</td>
<td>19</td>
<td>Mandible</td>
<td>Y-TZP</td>
<td>Peri-implantitis</td>
<td>4.1</td>
<td>76.4% (range 58.1–93.7%, SD 9.7%)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Maxilla</td>
<td>Y-TZP</td>
<td>Peri-implantitis</td>
<td>4.5</td>
<td>77.2% (range 73.6-81.9%, SD 4.3%)</td>
</tr>
<tr>
<td><strong>Current study</strong></td>
<td>1</td>
<td>Maxilla</td>
<td>Y-TZP</td>
<td>Fracture</td>
<td>2</td>
<td>55.8% (SD 3.8%)</td>
</tr>
<tr>
<td><strong>HA-coated</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominici et al, 1997</td>
<td>1</td>
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<td>HA-coated</td>
<td>Post-mortem</td>
<td>3</td>
<td>75.3%</td>
</tr>
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<td>2</td>
<td>Maxilla</td>
<td>HA-coated</td>
<td>Post-mortem</td>
<td>3</td>
<td>47%</td>
</tr>
<tr>
<td>Romanos et al, 2005</td>
<td>3</td>
<td>Mandible</td>
<td>HA-coated</td>
<td>In function</td>
<td>0.5</td>
<td>80.6%</td>
</tr>
<tr>
<td>Trisi et al, 2005</td>
<td>2</td>
<td>Mandible</td>
<td>HA-coated</td>
<td>Post-mortem</td>
<td>10</td>
<td>37.6%</td>
</tr>
<tr>
<td>Iezzi et al, 2007</td>
<td>2</td>
<td>Maxilla</td>
<td>HA-coated</td>
<td>Fracture abutment</td>
<td>14</td>
<td>28%-60%</td>
</tr>
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<td>Mandible</td>
<td>HA-coated</td>
<td>Fracture</td>
<td>15</td>
<td>77.6% (SD 5.1%)</td>
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<td>Maxilla and mandible</td>
<td>HA-coated</td>
<td>Prosthetic reasons</td>
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<td>35%-95%</td>
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<td>Iezzi et al, 2013</td>
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<td>HA-coated</td>
<td>Peri-implantitis</td>
<td>10</td>
<td>36.3% (SD 1.2%)</td>
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<tr>
<td><strong>Titanium</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Dominici et al, 1997</td>
<td>1</td>
<td>Mandible</td>
<td>Ti</td>
<td>Post-mortem</td>
<td>3</td>
<td>72.2%</td>
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<td>Ti</td>
<td>Post-mortem</td>
<td>7</td>
<td>65%</td>
</tr>
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<td>Degidi et al, 2003</td>
<td>11</td>
<td>Maxilla and mandible</td>
<td>Ti</td>
<td>In function</td>
<td>10/12</td>
<td>60%-65%</td>
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<tr>
<td>Roccì et al, 2003</td>
<td>2</td>
<td>Class III / IV bone</td>
<td>Oxidized Ti</td>
<td>In function</td>
<td>0.5</td>
<td>84.9% (SD 0.9%)</td>
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<tr>
<td>Bolind et al, 2005</td>
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<td>Maxilla and mandible</td>
<td>Oxidized Ti</td>
<td>In function</td>
<td>0.5</td>
<td>81.4% (SD 10.6%)</td>
</tr>
<tr>
<td>Romanos et al, 2005</td>
<td>16</td>
<td>Maxilla</td>
<td>Ti</td>
<td>In function</td>
<td>0.6</td>
<td>62.4%</td>
</tr>
<tr>
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<td>10</td>
<td>Mandible</td>
<td>Ti</td>
<td>In function</td>
<td>0.4</td>
<td>66.8%</td>
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<tr>
<td>Coelho et al, 2009</td>
<td>23</td>
<td>Maxilla and mandible</td>
<td>Ti</td>
<td>Prosthetic reasons</td>
<td>8-13</td>
<td>62.2%</td>
</tr>
<tr>
<td>Degidi et al, 2011</td>
<td>9</td>
<td>Maxilla and mandible</td>
<td>Ti</td>
<td>In function</td>
<td>0.1</td>
<td>59.9%</td>
</tr>
<tr>
<td>Iezzi et al, 2012</td>
<td>2</td>
<td>Mandible</td>
<td>Ti</td>
<td>Abutment fracture</td>
<td>5</td>
<td>89.8%</td>
</tr>
<tr>
<td></td>
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<td>Maxilla</td>
<td>Ti</td>
<td>Abutment fracture</td>
<td>5</td>
<td>76.6%</td>
</tr>
<tr>
<td>Iezzi et al, 2014</td>
<td>8</td>
<td>Maxilla and mandible</td>
<td>Ti</td>
<td>Prosthetic/psychologic</td>
<td>5-22</td>
<td>94-100%</td>
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<tr>
<td>Mangano et al, 2015</td>
<td>1</td>
<td>Mandible</td>
<td>Ti</td>
<td>Fracture</td>
<td>5</td>
<td>47.2%</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Maxilla</td>
<td>Ti</td>
<td>Fracture</td>
<td>10</td>
<td>NR</td>
</tr>
</tbody>
</table>
Discussion

Little information is available with respect to the osseointegration of zirconia implants in humans. The best indication of their potential for osseointegration is obtained from animal studies or compromised situations (i.e. retrieval after peri-implantitis). Therefore, the current observations are of interest.

The clinical performance of the particular implant type in the present study was described in a retrospective evaluation involving 74 patients, 121 implants, which observation time stretched up to 3 years. Implant survival was 96.5% with healthy peri-implant conditions, both clinically and radiographically. It is a 2-piece implant (figure 2) with a surface roughness with a Ra of 20-40 µm that is accomplished by blasting with zirconia grid before sintering (figures 3a-b).

Figure 2
Zv3 standard implant with a prepared glass fiber post (Wolfratshausen, Germany, bottom) and an implant with a personalized epi-gingival profile and unprepared glass fiber post (top).

The histological and histomorphometric data associated with the retrieved implant demonstrate a well osseointegrated, zirconia implant, concurrent with a healthy situation, ample bone to implant contact and no apparent signs of fibrous or granulomatous tissues adjacent to the implant after 2 years of clinical functional loading.

Comparison to literature is provided by the data from Kohal et al. who retrieved a relatively large number of zirconia implants. Peri-implantitis prompted their removal (n=22). The form as well as differences in surface characteristics makes comparison troublesome. They report compact bone at
the apical regions and state that the remaining bone that was attached to the implants contained a regular lamellar structure with osteons and osteocytes. Approximately 20% more bone to implant contact was observed compared to the present findings, despite the compromised condition that had required removal of the implants. This may be because of individual variation. However, the retrieved implants by Kohal et al were mostly mandibular implants for which a higher bone to implant percentage may be anticipated than for a maxillary implant. The current study evaluated only a single maxillary implant.

**Figure 3a**
REM image of the Zv3 implant surface.

**Figure 3b**
Detail of figure 3a, focused at the centre of the image.
In another study a female patient agreed to have a maxillary 2-piece zirconia implant (Ziterion, Ziterion GMBH) and to have it removed after 6 months for histological evaluation. It was not been functionally loaded. There were no signs of implant mobility. Both light microscopy and back scatter electron microscopy were performed. Histological analysis revealed close bone apposition with the combination of newly formed and native bone, with areas of mineralized bone contact to the implant surface as well as areas where bone marrow spaces were adjacent to the implant surface. No quantitative data with respect to the amount of bone-to-implant contact were presented and the authors state that they ‘expect it to be sufficient for clinical service, but not as strong as expected’.

Information with respect to the implant surface was not provided in the article. The human studies providing evidence of osseointegration of titanium and HA-coated implants report a wide range of percentages of bone-to-implant contact and the data from the present study lie in that range (table 1).

The histological data presented in this case report are coherent with a well osseointegrated zirconia implant after 2 years of functional loading. It is concluded that the observations from the retrieved implant in this study provide further evidence of the potential of zirconia to osseointegrate to a more or less similar degree as titanium implants in man.

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References


