Histomorphometric Analysis of Flaplessly Placed and Early Loaded One-Piece Mini Dental Implants in Overdenture Patients

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Mini dental implants (MDIs) are an affordable alternative for overdentures in medically compromised patients with reduced bone volume. This human study reports the histomorphometric analysis of early loaded and flaplessly placed tapered, one-piece MDIs (ILZ, Southern Implants; Sa: 1.5 µm) after 7 to 11 months in function. Patients agreed to have an additional MDI placed and removed for evaluation. MDI stability was assessed via Periotest prior to implant removal. Histologic sections of four mandibular and three maxillary MDIs with surrounding bone were processed, and the bone-to-implant contact (BIC) was analyzed. At retrieval, the MDIs were in function for more than 6 months, were clinically healthy, and had mean probing pocket depths of 1.4 mm and 1.6 mm in the maxilla and mandible, respectively. Periotest values were < 5.5, indicating clinical stability. Most of the screw threads were filled with bone and revealed an intimate BIC, without any signs of intervening fibrous tissue layer. In both arches, the mean BIC was 68.5%. Large osteocytes could be identified in the calcified tissue, indicative of mature peri-implant bone. It can be concluded that MDIs, when loaded within 2 weeks in either arch, provide proper clinical stability and high BIC after 6 months. Int J Periodontics Restorative Dent 2022;42:761–768. doi: 10.11607/prd.6309

In case of inadequate bone volume, limited financial resources, or the need for minimal invasive surgery, small-diameter implants are considered as a valuable alternative for standard diameter implants. The ITI (International Team for Implantology) consensus statement classified implants with a diameter of 3.5 mm or smaller as narrow-diameter implants, and they were divided into three subcategories by diameter: 3.3 to 3.5 mm, 2.5 to < 3.3 mm, and < 2.5 mm, with the latter defined as mini dental implants (MDIs). MDIs are mostly one-piece implants because an internal implant thread is technically impossible. Even with the observed higher MDI failure risk in the maxilla, an overall survival rate of 92.32% with acceptable marginal bone loss was observed. Important additional advantages are the reduced costs and the instant increase in oral health–related quality of life. Regardless of the positive outcome of MDIs, osseointegration initiated by an adequate bone tissue response is the first step toward success. Immediately upon implantation, a cascade of events starts at the bone-implant interface, beginning with the adsorption of proteins that originated from blood and tissue fluids at the wound site. Subsequently, bone formation is regulated by growth and differentiation factors that are released from

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the surrounding bone. Simultaneously, cellular responses are initiated through the infiltration of inflammatory and connective tissue cells. As such, osteogenic cells deposit a noncollagenous matrix layer on the implant surface. This early, calcified fibrillar layer provides a mechanism for optimal bonding between native bone and the implant. Bone formation starts either on the implant surface (contact osteogenesis) or from the surrounding bone towards the implant surface (distance osteogenesis). Finally, the immature peri-implant bone is replaced by mature bone, providing biologic (mechanical) stability, which is secondary to the primary fixation obtained during implant insertion. The essence of osseointegration is the direct contact between the implant surface and the surrounding bone: No intermediate layer of fibrous tissue may be present.

To qualify and visualize peri-implant bone responses, conventional microscopic evaluation of thin histologic sections and quantification of the percentage of bone-to-implant contact (BIC) are still widely used. In contrast to standard-diameter implants, the histomorphometric analysis of early loaded MDIs in humans is lacking. In most cases, the one-piece MDIs have been used for histologic assessment of bone on nonloaded implants in the context of material science. There is currently a knowledge gap in terms of qualitative assessment of osseointegration of MDIs under clinical functional loading conditions.

The aim of the present study is to report the histomorphometric analysis of flaplessly placed MDIs, early loaded with an overdenture, after at least 6 months in function.

Materials and Methods

Clinical Studies and Procedure

Different clinical studies have been designed by the present authors, aiming to evaluate the applicability of MDIs for early functional loading of mandibular or maxillary overdenture retention. In a maxillary study, 31 patients were included, in whom 6 MDI supporting overdentures were opposed by dentate mandibles. The clinical and radiographic outcomes were reported in detail after 2 years, and the clinical patient-centered outcomes after 4 years.

In the present study, subjects with uncontrolled systemic diseases, an immunocompromised status, previous treatment with oral or intravenous bisphosphonates, and history of radiotherapy were excluded. Participants were asked if they would allow the placement of an additional MDI to be removed as a biopsy sample during the final prosthetic phase, after 6 months of integration. All patients provided an informed consent before treatment. The studies were approved by the Ethical Committees of the General Hospital AZ ZENO Knokke-Blankenberge and the Ghent University Hospital (registration nos.: B670201422937 and B670201524211).

The investigated MDI (ILZ, Southern Implants) was manufactured as a one-piece implant made of high-strength pure titanium (grade 4). The diameter was 2.4 mm coronally; on top, a coronal ball abutment with a diameter of 1.8 mm was attached. The hybrid surface consisted of a 4.8-mm-long machined coronal part (Sa: 0.4 μm), used as a transmucosal part, and a roughened apical screw threaded part (Sa: 1.5 μm) in contact with the bone (Fig 1a).

Preoperatively, a CBCT scan was taken of the patient wearing the existing denture with radiopaque markers at the mucosal surface, indicating the most optimal implant location for proper prosthetic rehabilitation. Before surgery, holes were drilled in the denture at the marked positions, transforming the denture into a surgical guide. Under local anesthesia, the MDIs were placed, freehand and flaplessly, mentally guided by the CBCT and the adapted denture in place (Figs 1b and 1c). No suturing was necessary.

Pain medication (600 mg ibuprofen and/or 1 g paracetamol [maximum of three times a day]) and antibiotics (875 mg amoxicillin or 300 mg clindamycin in case of allergy, 3 times a day for 5 days) were routinely prescribed. Detailed written postoperative instructions were discussed thoroughly and given to the patients. Patients were instructed to maintain normal daily oral hygiene beginning 2 days after surgery, brushing the ball abutment parts of the MDI twice daily with chlorhexidine gel (0.12%) using a soft toothbrush (TePe Surgical). Also, a soft diet for 6 weeks was advised. During the first postoperative week, patients were not allowed
to wear their conventional denture. Thereafter, the denture was relined with Coe-Soft gel (GC America), thereby creating an adequate fit and improved retention due to the transmucosal ball heads (Fig 1d).

All MDIs, including those scheduled for biopsy sample removal, involved an early loading protocol. After an osseointegration period of at least 6 months, the final housings were embedded into the resin part of the denture base. Prior to MDI removal, implant stability was assessed using Periotest (Medizintechnik Gulden). Originally, the Periotest was introduced to measure the damping characteristics of the periodontal ligament of teeth. In the literature, this device is also used to assess implant stability. Periotest values (PTVs) vary between –8 and 50. The lower the PTV, the greater the implant stability. According to the manufacturer, PTVs from –8 to 0 represent high stability; from 1 to 9 represent medium stability; and from 10 to 50 represent insufficient or low stability. In the present study, PTVs were measured to check whether the MDIs had a stable anchorage in the bone after 6 months of loading, which was essential for optimal interpretation of the histologic slides.

**Biopsy Sample**

After an integration period of about 7 to 11 months, a mucoperiosteal flap was elevated, and the extra MDIs were carefully retrieved under local anesthesia, using a trephine drill with a diameter of 4.4/5.2 mm (Nobel Biocare) at low speed and with copious cooling. The transmucosal part guided the drilling procedure, ensuring an intact bone biopsy sample that included approximately 1 mm of surrounding alveolar bone neighboring the implant threads. The surgical procedure is demonstrated in Fig 2. Subsequently, the specimen (Fig 3) was fixed in 4% formalin with 10% neutral buffered formalin solution, dehydrated in a graded series of ethanol (70% to 100%), washed with acetone, and embedded in methyl methacrylate for 4 weeks.

**Histomorphometric Analysis**

Histologic sections of implants and surrounding bone were processed and analyzed, and the percentage of BIC was calculated. After polymerization, three nondecalcified sections (10-µm thickness) were prepared in a plane parallel to the long axis using a modified sawing microtome technique. After staining with methylene blue and
basic fuchsin, light microscopic evaluation was performed using an automated Axio Examiner Z1 microscope (Zeiss) at ×10, ×50, and ×200 magnifications. Complete morphologic qualitative description and quantitative analysis of the hard tissue response were provided.

**Results**

In total, seven patients agreed to have an additional MDI placed: three in the maxilla and four in the mandible. As the diameter of the threaded part of the MID is limited to 2.4 mm, it was not feasible to cut three sections of good quality. Therefore, it was chosen to select the most representative section (ie, in the slide, the total MDI length could be identified). Characteristics of the patients, implant location, PTVs, and BIC are depicted in Table 1. The histologic examination showed that most of the screw threads were filled with bone, which presented with a uniform color and was in close contact with the titanium surface. Figures 4 and 5 show the histologic sections of a mandibular and maxillary MDI, respectively, at three different magnifications. No intervening fibrous tissue layer was observed between the implant and surrounding bone. In the calcified tissue, many large osteocytes were visible. Bone contact measurements were performed, extending from the most coronal aspect to the mandible. The mean pocket depths measured 1.4 mm (maximum: 1.9 mm) in the maxilla and 1.6 mm (maximum: 2.8 mm) in the mandible.

**Discussion**

In the present study, the mean percentage of BIC was 68.5% in both the maxilla and mandible. For mandibular implants, this is in line with the review and meta-analysis by Sağırkaya et al,6 who reported a mean BIC of 69.8% in the mandible and 56.7% in the maxilla for standard-diameter implants. Sağırkaya et al’s6 maxillary BIC result is 10% lower than the maxillary BIC in the present study.

Although the systematic review by Sağırkaya et al6 mainly addressed standard-diameter implants, the outcome for experimental small implants with a diameter between 2 and 2.5 mm was briefly mentioned in four of the reviewed studies.11–14 These MDIs were placed exclusively to test various surface modifications. Those experimental implants had a minimally rough surface (machined surface),11–13 had a moderately rough
Experimental MDIs have also been used to calculate the BIC under various clinical circumstances (such as when iliac crest blocks are fixated to the maxillary alveolar process\textsuperscript{15} or the effect of applied bone substitutes (such as anorganic bovine bone particles,\textsuperscript{16} collagenated corticocancellous porcine bone,\textsuperscript{17} or platelet-rich plasma\textsuperscript{18} after sinus floor elevation). Furthermore, the effect of the lateral window size in sinus floor elevations was tested using experimental MDIs, evaluating large (8 mm) and small (4 mm) antrostomies.\textsuperscript{19} In the same way, the optimal antrostomy location was also inventoried: closer to the original alveolar process (base) vs 4 mm cranially (standard)\textsuperscript{17} (Table 2).

The aforementioned experimental evaluations of MDIs cannot

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Gender</th>
<th>Age, y</th>
<th>Location (site\textsuperscript{a})</th>
<th>Time of biopsy sample</th>
<th>Mean PTV upon retrieval</th>
<th>Maximum BIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>68</td>
<td>Mandible (32)</td>
<td>7 mo</td>
<td>–4.5</td>
<td>82%</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>66</td>
<td>Mandible (32)</td>
<td>7 mo</td>
<td>4.1</td>
<td>71%</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>59</td>
<td>Mandible (31)</td>
<td>7 mo</td>
<td>4.5</td>
<td>72%</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>84</td>
<td>Mandible (32)</td>
<td>8 mo</td>
<td>0.7</td>
<td>49%</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>63</td>
<td>Maxilla (24)</td>
<td>8 mo</td>
<td>–1.4</td>
<td>72%</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>70</td>
<td>Maxilla (21)</td>
<td>11 mo</td>
<td>5.3</td>
<td>62%</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>70</td>
<td>Maxilla (15)</td>
<td>10 mo</td>
<td>0.5</td>
<td>72%</td>
</tr>
</tbody>
</table>

\textsuperscript{a}FDI tooth-numbering system.

Table 1 Patient, Implant, and Biopsy Sample Data for Each Patient

\[ \begin{array}{cccccc}
\text{Patient no.} & \text{Gender} & \text{Age, y} & \text{Location (site\textsuperscript{a})} & \text{Time of biopsy sample} & \text{Mean PTV upon retrieval} & \text{Maximum BIC} \\
1 & M & 68 & Mandible (32) & 7 mo & –4.5 & 82% \\
2 & M & 66 & Mandible (32) & 7 mo & 4.1 & 71% \\
3 & M & 59 & Mandible (31) & 7 mo & 4.5 & 72% \\
4 & F & 84 & Mandible (32) & 8 mo & 0.7 & 49% \\
5 & M & 63 & Maxilla (24) & 8 mo & –1.4 & 72% \\
6 & M & 70 & Maxilla (21) & 11 mo & 5.3 & 62% \\
7 & F & 70 & Maxilla (15) & 10 mo & 0.5 & 72% \\
\end{array} \]

M = male; F = female; PTV = Periotest value; BIC = bone-to-implant contact.

Fig 4 Histologic view of a section from a mandibular MDI biopsy sample. (a) Overview of the complete section (\times 10 magnification). The green arrows reflect the pocket depth. (b) Closer view of the yellow section identified in Fig 4a (\times 50 magnification). (c) Closer view of the blue section identified in Fig 4a (\times 200 magnification). No intervening fibrous tissue layer was observed between the implant and surrounding bone. In the calcified tissue, many large osteocytes were visible (white arrows), as well as marrow spaces (black arrows).
be compared with the clinical reality reported in the present study. Although many reports were written about the survival rate of MDIs, the present paper is quite unique in that it reports the histomorphometric analysis of regular, available MDIs after early loading. At the time of retrieval, the implants appeared clinically healthy and immobile, as all PTVs were < 5.5 (Table 1). PTVs are mainly determined by bone density, location, and the abutment and implant lengths. Low PTVs indicate successfully integrated implants, while high/increasing PTVs indicate ongoing disintegration and/or marginal bone loss. For regular, standard-diameter implants, PTVs vary between −6 and 0, irrespective of maxillary or mandibular placement. In the present study, two MDIs scored < 0, indicating high stability. The other five implants in the present study had PTVs between 0.5 and 5.3, indicating medium stability. These results are comparable to other studies that measured PTVs for MDIs after 6 months, reported between −3 and 1 and between −8 and 9. Thus, regarding the decision to choose immediate or early loading, a threshold or ideal cutoff PTV for MDIs is still unknown.

The present histomorphometric study has some limitations that should be recognized. The limited number of retrieved specimens, although unique, is maybe too small for firm evidence. Retrieval after 7 to 11 months showed bone morphology and stability after the defined integration period, but it cannot define a final, long-term outcome.

Conclusions

MDIs showed a mandibular BIC comparable to standard-diameter implants, and the maxillary BIC was
even 10% higher than reported elsewhere. Thus, 6 months after early loading, MDIs elicit a histologic response and stability outcomes comparable to those of standard implants.

**Acknowledgments**

Luc Van Doorne reports material support from Southern Implants. Hugo De Bruyn, on behalf of Radboud University Medical Center, reports a research and educational collaboration agreement with Southern Implants, who provided material support for the clinical studies.

Dr Van Doorne conceptualized the project idea, performed the surgery and retrieved the MDIs, and drafted the article. Dr Meijer performed data analysis/interpretation, article drafting, and critical revision of the article. Dr Cuijpers sectioned the biopsy samples and prepared and analyzed the specimens. Dr De Bruyn initiated the study, critically reviewed and revised the manuscript, approved the article, and provided funding.

**References**


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**Table 2 BIC Results of the Present Study and other Mini Dental Implant Studies**

<table>
<thead>
<tr>
<th>Study, y</th>
<th>Implant surface</th>
<th>Research topic</th>
<th>Time of biopsy sample, mo</th>
<th>Maximum BIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present study</td>
<td>Alumina-blasted</td>
<td>Flaplessly placed, early loaded, native bone</td>
<td>7–11 mo</td>
<td>Maxilla: 72% Mandible: 82%</td>
</tr>
<tr>
<td>Tellemann et al,15 2010</td>
<td>DAE</td>
<td>DAE</td>
<td>3</td>
<td>8.7%</td>
</tr>
<tr>
<td>Menicucci et al,16 2013</td>
<td>DAE</td>
<td>DAE + CaP</td>
<td>12</td>
<td>48%</td>
</tr>
<tr>
<td>Menicucci et al,16 2013</td>
<td>DAE</td>
<td>DAE + CaP</td>
<td>12</td>
<td>37%</td>
</tr>
<tr>
<td>Hirota et al,17 2020 a</td>
<td>Moderately rough surface</td>
<td>Collagenated cortico-cancellous porcine bone after SFE</td>
<td>3</td>
<td>Base: 41% Standard: 48.5%</td>
</tr>
<tr>
<td>Aimetti et al,18 2008</td>
<td>DAE + CaP</td>
<td>After SFE filled with anorganic bovine bone</td>
<td>6</td>
<td>+PRP: 46.8% −PRP: 20.5%</td>
</tr>
<tr>
<td>Imai et al,19 2020 b</td>
<td>Moderately rough surface</td>
<td>Collagenated cortico-cancellous porcine bone after SFE</td>
<td>6</td>
<td>Large: 41.1% Small: 42.8%</td>
</tr>
</tbody>
</table>

BIC = bone-to-implant contact; CaP = calcium phosphate; DAE = dual acid-etched; PRP = platelet-rich plasma (+ = with; − = without); SFE = sinus floor elevation.

aBase = antrostomy located close to the original alveolar process; standard = antrostomy located 4 mm more cranially.
bLarge = 8-mm antrostomy height; small = 4-mm antrostomy height.


