A Split-Mouth Study to Assess the Effect of Implant Surface Roughness on Implant Treatment Outcome After 5 Years

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The aim of current split-mouth study was to compare the implant treatment outcomes of hybrid-surface implants (minimally rough implant collar and moderately rough body) with moderately rough implants after 5 years in patients with a bar-supported mandibular overdenture. Fully edentulous patients were enrolled, and each patient received two implants: one moderately rough and one hybrid-surface implant. A total of 18 patients with 36 implants attended the 5-year recall, and the implant survival rate was 100%. The 5-year evaluation showed no significant difference in crestal bone loss or peri-implant health between the hybrid and moderately rough implants. Int J Periodontics Restorative Dent 2023;43:113–119. doi: 10.11607/prd.6264

Dental implants are a well-established treatment for tooth replacement. In general, implant treatment is a predictable procedure for partially or fully edentulous patients. Implant survival rates are high, yet implant failure still occurs in a small quantity of patients. Primary implant failure due to excessive surgical trauma, an impaired healing ability, premature loading, and/or infection occurs in 1% to 2% of patients within the first few months. Secondary implant failure develops several years after implant placement, affecting about 5% of patients, and is mainly caused by occlusal overload and/or progressive peri-implant bone loss. Recent evidence suggests that early bone loss is a predictor for future peri-implantitis development. Maintaining the initial crestal bone level is a key factor for long-term success. Initial crestal bone loss occurs immediately after soft tissue penetration due to the establishment of a soft tissue seal: the biologic width. Thus, initial crestal bone loss is a physiologic event, whereas late progressive crestal bone loss is more often a sign of pathology. As a consequence of progressive crestal bone loss, soft tissue recession around the implant neck could jeopardize the esthetic results and may also lead to thread exposure, plaque accumulation, and infection of the peri-implant tissues.
Peri-implant health should be taken into account together with implant survival and marginal bone stability. Presently, there is no consensus on how to define peri-implantitis. In general, signs of infection together with progressive crestal bone loss both characterize peri-implantitis. In a consensus report in 2017, peri-implantitis was defined as a combination of probing pocket depths ≥ 6 mm in combination with bleeding on probing or a bone level ≥ 3 mm apical to the most coronal portion of the intrabony part of the implant.8

Implant surface roughness enhances osseointegration by increasing the bone-to-implant contact area. This allows predictable treatment in more challenging conditions, such as immediate placement and immediate loading.9 However, it is generally accepted that implants with a smoother surface limit plaque accumulation, which could have a beneficial effect on peri-implantitis prevention.10 According to Albrektsson and Wennerberg, implant surfaces could be categorized into four different groups, depending on the surface roughness (Sa) value: smooth (Sa < 0.5 µm); minimally rough (Sa between 0.5 and 1.0 µm); moderately rough (Sa between 1.0 and 2.0 µm); and rough (Sa > 2.0 µm).11 The influence of implant surface roughness on crestal bone loss is still controversial. In a systematic review conducted by Doorenwaard et al, crestal bone loss after 5 years was greater at sites with moderately rough implants than sites with minimally rough implants.2 However, a recent systematic review by Zhang and Yue reported the opposite.6 Hybrid-surface implants have a minimally rough coronal part and moderately rough implant body. The minimally rough collar may reduce biofilm accumulation, minimizing the risk of peri-implantitis, and the moderately rough body could provide predictable osseointegration.12

The aim of the current prospective split-mouth study was to compare the implant treatment outcomes of hybrid-surface and moderately rough implants after 5 years in patients with a bar-supported mandibular overdenture.

Materials and Methods

Patient Selection

Fully edentulous patients were consecutively enrolled at a single center for treatment with implant-supported overdentures in the mandible. Inclusion criteria were as follows: (1) being totally edentulous for at least 4 months; (2) presence of a sufficient volume of residual bone to place two implants (4-mm diameter, 9- to 11-mm length); and (3) written informed consent. Exclusion criteria were as follows: (1) age < 21 years; (2) general contraindications for oral surgery; and (3) current smoking habit. Patients fulfilling these criteria received a new prosthesis in the maxilla and in the mandible prior to implant placement to achieve a correct occlusion, appropriate teeth position, and correct smile line. Patients were thoroughly informed about the treatment, and the study was conducted with approval of the ethical committee of the Ghent University Hospital (B670201422878).

Surgical Procedure

The surgical site was anaesthetized, and a mucoperiosteal flap was reflected. Vertical implant position was defined by the soft tissue thickness counteracting the crestal bone loss due the biologic width. Each patient received two implants (Deep Conical Cylindrical [DCC], Southern implants): One had a hybrid surface (MSC) with a moderately rough sandblasted surface (Sa: 1.3 µm; Sdr: 60%) on the middle and apical parts and a minimally rough machined surface on the coronal 3 mm, which is comparable to the original Brånemark surface (Sa: 0.9 µm; Sdr: 34%). The other implant (DCC) had a moderately rough sandblasted surface (Sa: 1.3 µm; Sdr: 60%) over the entire implant length (Fig 1). These two implants were identical, with a 0.6-mm thread pitch, an integrated platform-shift with a smooth implant bevel, and an internal connection and microthreads on the implant neck. Randomization of the implant position was ensured using a closed envelope that was opened just before implant placement. Finally, nonengaging abutments (Compact Conical Abutments, Southern Implants) were placed during surgery. Antibiotics (amoxicillin, 2 g/day) and mouthrinse (chlorhexidine 0.12%, twice daily) were prescribed thereafter. Sutures were removed after 1 to 2 weeks, and the patients were instructed to maintain good oral hygiene.
Prosthetic Procedure

The dentures were adjusted with a soft reline material (Coe-Soft, GC), which was used as a buffer between the prosthesis and the abutment healing caps. This resulted in direct contact between the abutments and the prosthesis, and it can be considered an immediate functional loading with a removable denture. To avoid overload, the soft reline material was renewed every 2 to 3 weeks. During this visit, oral hygiene was checked and reinstructed whenever required. After a healing period of 3 months, conventional impressions were taken at the abutment level, and a titanium bar (designed and milled using CAD/CAM technology) connected the overdenture with the implants.

Follow-up Examinations

Baseline radiographs were taken immediately after surgery using an XCP Rinn-Sett (Dentsply Rinn). The patients were seen again after 3, 6, and 12 months, then annually thereafter. Periapical radiographs were taken to evaluate the bone level, defined as the distance between the reference point (implant bevel) and the crestal bone (Fig 2). If the bone level after implant placement was higher than the reference point, the bone level was set at zero. Bone loss was calculated using the bone level at follow-up compared to baseline (implant placement) (Fig 2). Each radiograph was analyzed and calibrated (Mediadent version 6.14.4.24, ImageLevel), and calibration depended on the implant length (9 or 11 mm) or the distance between the implant threads (0.6 mm). Periodontal pocket depth (PPD), bleeding on probing (BoP), and presence of plaque (PL) were measured. In the present study peri-implantitis was defined using the criteria of the Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions.
Statistical Analysis

All data were processed in SPSS (version 26, IBM). Bone loss measurements were performed twice. Intraclass correlation coefficient confirmed absolute agreement between the first and second measurements using a two-way mixed reliability analysis model ($r > 0.97$, $P = .000$), and the average of the two measurements was used for data analysis. Afterwards, bone loss was calculated as the average of the distal and mesial measurements. Normality test was performed for the bone loss data, and it was concluded that the data were not normally distributed at all time points; therefore, mean differences in bone loss between the DCC and MSC implants were compared using Wilcoxon signed-rank tests at different time intervals: baseline; 3, 6, and 12 months; and 2, 3, 4, and 5 years. Mean differences in bone loss between different time points, regardless of the implant type, were calculated using Kruskal-Wallis test. The level of significance was set at .05.

In addition, PPD, BoP, and PL were calculated as the average of distal, mesial, buccal, and palatal measurements. For the BoP and PL data, this resulted in discrete values. The mean differences between DCC and MSC implants in PPD, BoP, and PL were then performed using Welch’s $t$ test.

Results

Initially, 22 patients (10 women, 12 men) with 44 implants were included, but 4 patients were omitted from the final analysis: 1 patient did not attend the first year of follow-up, 1 patient admitted that he was a smoker, and 2 patients were lost during follow-up. Therefore, 18 patients with 36 implants were evaluated at the 5-year recall (8 women, 10 men). The overall implant survival rate was 100%, and the overall mean crestal bone loss was $0.42 \pm 0.83$ mm (range: 0 to 0.3 mm) and $0.34 \pm 0.55$ mm (range: 0 to 0.22 mm) in the DCC and MSC implants, respectively.

There was no statistically significant difference in crestal bone loss between the different implant surfaces at any of the follow-ups. After 3 months, $0.32 \pm 0.97$ mm and $0.30 \pm 0.48$ mm of mean bone loss was recorded in the DCC and MSC implants, respectively, which was significantly higher than baseline values ($0.02 \pm 0.07$ mm and $0.02 \pm 0.06$ mm, respectively) ($P < .05$ when comparing 3-month to baseline data, regardless of implant type). Bone loss values at all subsequent time points were also significantly different from the baseline measurements ($P < .05$) but were not significantly different from the bone loss values at 3 months ($P > .1$) (Fig 3). No statistical difference was found in bone loss between the DCC and MSC implants after 5 years of follow-up ($P > .05$) (Fig 4). The means, standard deviation, median, and range of the crestal bone loss values are reported in Table 1. There was no statistically significant difference in PPD, BoP, and PL between the different implant surfaces at any of the follow-ups ($P > .1$) (Table 2).

Discussion

The purpose of the present study was to report the 5-year implant
treatment outcomes of two implants with a similar macrodesign but different microsurface topography (hybrid and moderately rough). An intrasubject comparison was performed to control for confounding. The idea of the hybrid implant surface was to combine a moderately rough implant body and a machined coronal part, thus promoting rapid osseointegration and reducing peri-implantitis susceptibility.3

In the present study, fully edentulous patients were treated with

Table 1 Crestal Bone Loss of the DCC and MSC Implants at Different Time Points

<table>
<thead>
<tr>
<th></th>
<th>DCC</th>
<th>MSC</th>
<th>Paired difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Median</td>
<td>Range</td>
</tr>
<tr>
<td>Baseline</td>
<td>0.02 ± 0.07</td>
<td>0</td>
<td>0–2.62</td>
</tr>
<tr>
<td>3 mo</td>
<td>0.32 ± 0.97</td>
<td>0</td>
<td>0–1.70</td>
</tr>
<tr>
<td>6 mo</td>
<td>0.30 ± 0.67</td>
<td>0</td>
<td>0–3.94</td>
</tr>
<tr>
<td>12 mo</td>
<td>0.25 ± 0.62</td>
<td>0</td>
<td>0–1.71</td>
</tr>
<tr>
<td>2 y</td>
<td>0.27 ± 0.5</td>
<td>0</td>
<td>0–2.57</td>
</tr>
<tr>
<td>3 y</td>
<td>0.40 ± 0.53</td>
<td>0.20</td>
<td>0–3.53</td>
</tr>
<tr>
<td>4 y</td>
<td>0.45 ± 0.72</td>
<td>0.11</td>
<td>0–2.74</td>
</tr>
<tr>
<td>5 y</td>
<td>0.42 ± 0.83</td>
<td>0.07</td>
<td>0–0.30</td>
</tr>
</tbody>
</table>

CI = confidence interval; DCC = moderately rough implant; MSC = hybrid-surface implant.

P values were calculated between DCC and MSC at each time point using Wilcoxon signed-rank test.

Table 2 PPD, BoP, and PL of the DCC and MSC at Different Time Points

<table>
<thead>
<tr>
<th></th>
<th>DCC</th>
<th>MSC</th>
<th>P</th>
<th>DCC</th>
<th>MSC</th>
<th>P</th>
<th>DCC</th>
<th>MSC</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 mo</td>
<td>2.87 ± 0.75</td>
<td>2.81 ± 0.66</td>
<td>.81</td>
<td>0.26 ± 0.32</td>
<td>0.24 ± 0.26</td>
<td>.772</td>
<td>0.4 ± 0.34</td>
<td>0.4 ± 0.33</td>
<td>1</td>
</tr>
<tr>
<td>12 mo</td>
<td>2.6 ± 0.74</td>
<td>2.63 ± 0.69</td>
<td>.892</td>
<td>0.23 ± 0.33</td>
<td>0.25 ± 0.25</td>
<td>.869</td>
<td>0.4 ± 0.32</td>
<td>0.38 ± 0.32</td>
<td>.878</td>
</tr>
<tr>
<td>2 y</td>
<td>2.46 ± 0.59</td>
<td>2.33 ± 0.62</td>
<td>.578</td>
<td>0.27 ± 0.3</td>
<td>0.31 ± 0.38</td>
<td>.778</td>
<td>0.54 ± 0.35</td>
<td>0.48 ± 0.35</td>
<td>.677</td>
</tr>
<tr>
<td>3 y</td>
<td>2.1 ± 0.69</td>
<td>1.96 ± 0.59</td>
<td>.519</td>
<td>0.1 ± 0.15</td>
<td>0.07 ± 0.12</td>
<td>.541</td>
<td>0.36 ± 0.41</td>
<td>0.4 ± 0.38</td>
<td>.753</td>
</tr>
<tr>
<td>4 y</td>
<td>2.51 ± 1.38</td>
<td>2.36 ± 0.73</td>
<td>.681</td>
<td>0.49 ± 0.37</td>
<td>0.54 ± 0.37</td>
<td>.653</td>
<td>0.56 ± 0.38</td>
<td>0.51 ± 0.37</td>
<td>.74</td>
</tr>
<tr>
<td>5 y</td>
<td>2.81 ± 1.12</td>
<td>2.58 ± 0.6</td>
<td>.469</td>
<td>0.3 ± 0.26</td>
<td>0.41 ± 0.33</td>
<td>.305</td>
<td>0.55 ± 0.37</td>
<td>0.61 ± 0.32</td>
<td>.61</td>
</tr>
</tbody>
</table>

BoP = bleeding on probing; DCC = moderately rough implant; MSC = hybrid-surface implant; PL = plaque; PPD = periodontal probing depth.

Values are presented as mean ± SD. BoP and PL were recorded as dichotomous variables (0 if absent, 1 if present). P values were calculated between DCC and MSC at each time point using Welch’s t test.

Fig 4 Crestal bone loss 5 years after placement of the hybrid-surface implants (MSC) and the moderately rough surface implants (DCC).
mandibular overdentures supported by two implants, and no implant failures occurred during the 5-year follow-up. This is comparable with a study by Doornewaard et al, in which 52 moderately rough implants were placed in 26 patients for the same prosthetic indication; after 5 years of function, a 100% implant survival rate was reported. Research on survival rates of hybrid-surface implants is more scarce, but the reported implant survival rates range from 95.8% to 100%, suggesting that osseointegration and survival of hybrid implants are comparable to those of full moderately rough implants.

Crestal bone loss is a multifactorial process, dependent of both implant and biologic factors. The presence of a platform shift limits initial crestal bone loss. Another factor affecting initial crestal bone loss is the soft tissue thickness. In an intra-subject comparison by Vervaeke et al, 158 implants were placed in 79 patients to support a mandibular overdenture. In each patient, one implant was placed equicrestal and the other implant was placed with the soft tissue thickness taken into account. Initial crestal bone loss was significantly higher at the equicrestal implants, suggesting that subcrestal implant placement is mandatory in cases with thin soft tissues. As described in a recent meta-analysis by Vatēnas and Linkevičius, multiple disconnections of the abutment could increase crestal bone loss. In the present study, all implants were platform-shifted and placed according to the soft tissue thickness. Moreover, final abutments were immediately placed, limiting multiple disconnections; this could contribute to the limited crestal bone loss reported herein. Randomized clinical trials comparing crestal bone loss of implants with a hybrid surface or a fully moderately rough surface are rare. Spinato et al placed 37 sandblasted moderately rough implants and 38 hybrid implants (minimally rough implant collar and moderately rough implant body) in 75 patients. After a follow-up of 1 year, no difference in crestal bone loss between these two implant types was reported. This is in line with Serrano et al’s study, in which 20 hybrid and 20 fully moderately rough implants were compared in 40 periodontally compromised patients; clinical parameters (PPD, BoP, and PL) were also reported, and no difference between the two surfaces was found after 12 months of follow-up, which is comparable to the present study. Zetterqvist et al compared dual-acid-etched implants to hybrid-surface implants with a machined collar and described long-term outcomes of hybrid-surface implants: After 5 years, statistically significantly more crestal bone loss was found at the hybrid-surface implants, and this difference was already present after 1 year. The hybrid implants used by Zetterqvist et al had a very low Sa value (0.18 μm), which is close to a polished implant collar. Alternatively, the hybrid surface in the present study yielded an Sa value of 0.9 μm. When compared with Zetterqvist’s results, the present findings suggest that some roughness is needed to preserve the crestal bone.

Reduced peri-implantitis susceptibility could be a potential benefit of the minimally rough implant collar. In the present study, only one patient yielded bone loss > 2 mm. After 1 year, mean crestal bone losses of 1.41 mm and 2.62 mm were found for the MSC and DCC implants; after 5 years, these values were 2.32 mm and 3.53 mm, respectively. Because of an absence of a PPD > 6 mm, these implants could not be defined as peri-implantitis, but progressive crestal bone loss was seen nonetheless. As seen in this particular patient, increased crestal bone loss was already present at the 1-year follow-up. This is in line with a recent study conducted by Windael et al, where 1,482 implants with a moderately rough surface were placed in 407 patients and evaluated after 10 years. Early bone loss was clearly identified as a risk factor for peri-implantitis, emphasizing the importance of limiting the initial crestal bone loss.

From the present study, it can be concluded that hybrid implants can be used predictably and are capable of preserving the crestal bone. Indeed, the strict follow-ups and high level of maintenance in this prospective study minimizes the chances to assess peri-implantitis. However, it is suggested that a smooth-surface implant yields less peri-implant bone loss after 5 years. It is thus tempting to suggest that the hybrid surface may prevent peri-implant bone loss equally in patients with a history of periodontitis.
However, this needs to be further investigated.

Conclusions

This 5-year evaluation of the patients who received both hybrid implants (minimally rough implant collar and moderately rough implant body) and implants with a moderately rough surface showed no significant difference in crestal bone loss and peri-implant health.

Acknowledgments

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References