Titanium Implant Characteristics After Implantoplasty: An In Vitro Study on Two Different Kinds of Instrumentation

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**Purpose:** To assess surface characteristics and implant stability after implantoplasty performed by two different instrument sequences regarding material loss, surface roughness, and fracture load resistance. Additionally, operators’ subjective experience during instrumentation and the damage to neighboring teeth were evaluated. **Materials and Methods:** Titanium implants were placed in the position of both first maxillary molars in models exposing 6 mm of their surface. Implantoplasty was performed in phantom heads: Exposed surfaces were instrumented with diamonds and Arkansas stones or abrasive stones and silicone polishers. Operators reported on abrasion, gloss, effectiveness, and tactility using a visual analog scale (VAS). Residual wall thickness of implants was measured on radiographs, material abrasion using three-dimensional (3D) scans, and surface roughness by contact profilometry. Maximum bending moments were measured. **Results:** Residual thickness and weight loss were comparable after both treatments (0.3 ± 0.1 and 0.25 ± 0.07 mm and 0.22 ± 0.01 g, and 0.03 ± 0.01 mm and 0.02 ± 0.01 g, respectively, P > .05). Mean surface roughness was lower (P = .0001) for the group with the silicone polishers (0.4 ± 0.2 µm) compared with the group employing diamonds (0.8 ± 0.1 µm). Maximum bending moments showed neither intergroup differences nor stability loss compared with untreated implants. The stone-and-silicone polisher group showed less abrasion (4.6 ± 2.2) and higher gloss values (8.1 ± 1.4) than the diamond-and-Arkansas group (3.1 ± 1.3 and 4.1 ± 2.1, respectively). Superficial tooth injuries at proximal neighbor teeth were common (73% and 80%). **Conclusion:** Implantoplasty did not weaken implant stability. The use of silicone polishers revealed lower surface roughness. Regarding surface smoothness, the instrumentation sequence employing silicon carbide and Arkansas stones followed by silicone polishers seems to be superior to the combination of diamond and Arkansas stones. **Keywords:** dental implants, fracture, implantoplasty, peri-implantitis, resective surgery, surface roughness

With a prevalence of 54% for peri-implant mucositis and 20% for peri-implantitis, inflammation around dental implants is a frequent pathology.¹,² which therefore constitutes a challenge to modern dentistry. If untreated, mucositis might progress to peri-implantitis,³ characterized by progressive loss of bone and, finally, implant loss.⁴ Based on the etiologic relevance of bacteria, treatment ultimately targets biofilm destruction and prevention of new colonization of the implant surfaces.⁵,⁶ Regarding peri-implantitis, clinical success and prognosis of current nonsurgical treatment concepts are still considered to be dissatisfactory,⁷ whereas surgical approaches show more promising outcomes.⁸ While intrabony peri-implant defects might be treated by a regenerative approach, cases with horizontal defects or patients with general contraindications for regenerative therapy might be treated by resective means: Marginal bone might get reshaped first in order to facilitate access to the implant surface during subsequent instrumentation, and to enable effective oral hygiene after the intervention. Then,
n a step called implantoplasty, implant threads of the no-longer-osseointegrated surface are removed, and the rough surface areas are polished. Finally, the peri-implant mucosa is repositioned apically in order to allow for better accessibility of the newly shaped surface areas during daily oral hygiene measures. The success rate of implantoplasty with regard to resolution of the inflammation—as proven by the absence of bleeding on probing and a stable bone level—is promising after 3 years of observation. However, implantoplasty has been discussed controversially due to a potential loss of stability in the shoulder area of implants treated with implantoplasty. Furthermore, the realization of a well-performed implantoplasty is clinically demanding, time-consuming, and, therefore, expensive. Moreover, a potentially damaging potential for neighboring structures such as teeth and surrounding bone has to be considered. Contamination of the surrounding soft tissues by titanium particles and remnants of the rotating polishers implies potential risks for wound healing and the immune system.

Whereas for the instrumentation of the surface, diamond burs in combination with Arkansas stones for the finishing have been proposed, the treatment with rotating stones and silicone polishers is a considerable alternative: Rotating silicium carbide stones develop less heat than diamonds, while the polishers allow for smoother surfaces. However, less rapid instrumentation and an increased danger of damaging neighboring teeth due to a bigger bur diameter are possible disadvantages. Nevertheless, reliable data regarding these clinically relevant issues are still missing.

Therefore, the present study aimed to compare two common modalities for implantoplasty, ie, diamonds and Arkansas stones (DS) or abrasive stones with silicone polishers (SS). The null hypothesis was that both approaches would perform equally well, ie, that material abrasion, residual wall thickness, and mean surface roughness and the fracture load resistance would show no differences, and that operator-reported abrasion, gloss, effectiveness, and tactility using a visual analog scale (VAS) would not differ.

MATERIALS AND METHODS

Implant Models and Experimental Setup
Fifteen maxilla models were fabricated from white dental lab stone (Dentsply Sirona) with missing first molars in both quadrants. Titanium implants (Camlog screw line, 4.3/13 mm, Camlog Biotechnologies) were placed in the maxillary right and left first molar positions. Both sites harbored standardized horizontal defects with a marginal exposure of the rough surface over a length of 6 mm (Fig 1). Soft tissues were not simulated. Thus, implant surface treatment was possible with direct sight to the implant sites, imitating the surgical situation with deflected mucosa. The models were inserted in phantom head simulators (G20, KaVo) in maxillary position.

Implantoplasty was performed following two different instrumentation sequences. A computerized allocation list (www.random.org) defined which of the two implants had to be treated first and which of the two evaluated instrumentation sequences had to be performed:

- **Group 1**: Bud-shaped diamond burs with a grit size of 106 µm, followed by 40 µm at 200,000 rpm (Intensiv); afterward finishing and polishing with a pointed Arkansas stone (aluminum oxide) at 20,000 rpm (Fig 2a, Jota)
- **Group 2**: Conical silicon carbide stones (Jota) followed by a pointed Arkansas stone (Jota) and abrasive silicone polishers, ie, Brownie and Greenie (Fig 2b, Shofu Dental) at 20,000 rpm each

Accordingly, in each of the 15 jaw models containing two implants, one implant per group was instrumented.

Red and blue contra-angle parts were used at predefined rotational speed (200,000 and 40,000 rpm, respectively) with maximal water-cooling.

With the first bur in both groups, the exposed implant threads were removed within a maximum time frame of 6 minutes. Afterward, the resulting implant surface was smoothed and polished with further instrument(s) of the respective sequence for another maximal time frame of 9 minutes; thereby, the resulting total treatment time accounted for 15 minutes for each implant.

In the present study, implantoplasty procedures were performed as a part of a Master program (Master
of Advanced Studies in Periodontology, University of Zurich). In total, 15 experienced dentists performed the interventions with both techniques in the same jaw model.

Data Acquisition

Operators’ Evaluation. A VAS was used to determine the operators’ subjective ratings regarding the performance of the individual treatment sequences and the obtained results. Thereby, the following clinical aspects were assessed: pollution of the implant site (0: clean, 10: very dirty); quickness of the procedure (0: very slow, 10: very fast); tactility of the instruments (0: very comfortable, 10: extremely difficult); and gloss after instrumentation (0: dull, 10: perfect gloss).

Damage to Neighboring Teeth. After finishing all implantoplasty procedures, the plaster models were examined by an independent investigator (S.L.) in order to assess the approximal surfaces of the neighboring teeth, ie, maxillary right second premolar distally, maxillary right second molar mesially; and maxillary left second premolar distally, maxillary left second molar mesially. The surfaces were dichotomously rated with “no lesion” (0) or “lesion” (1) for iatrogenic damage.

Afterward, implants were cut out from the models. Maximum care was taken to avoid any injury of the implant surfaces. Plaster remnants on the implants were chemically removed (Fino Gips-Ex Plus, Fino).

Residual Titanium Thickness. In order to assess the remaining implant wall thickness at the implant shoulder area after treatment, standardized radiographic images of each implant were taken. For this purpose, implants were checked for eventual damage and horizontally fixed on the underlay in a way that no potential damage was present on the outer “left” and “right” margins, thus allowing later calibration. Digital radiographs (Digora, Soredex) were taken from a distance of 10 cm with a cathode voltage of 65 kV at 7.5 mA and an exposure time of 0.16 seconds using size 2 plates (Soredex).

Image size was calibrated using the known upper implant diameter of 4.3 mm (Adobe Photoshop CC 2015.5, Adobe Systems Incorporated). The residual minimal wall thickness after implantoplasty was measured between the outer implant surface and the abutment chamber (once mesially and distally, respectively) at the thinnest part, using the manual distance measurement tool of the program at 15× magnification (Fig 3).

Weight Loss. The weight of each implant was measured after treatment with a precision scale (Mettler AT 261 DeltaRange, Mettler-Toledo). Every implant was weighed three times, and the respective mean value Wt was calculated. To determine the mean weight loss Wl of each implant, nine untreated implants were weighed three times each, and the mean weight of untreated implants Wu was calculated. The mean weight loss of each implant was calculated by the formula:

\[ Wl = Wu - Wt \]

Three-Dimensional Assessment. In order to characterize the treatment-related material loss, the implants were assessed three-dimensionally (3D). For this purpose, implants were apically fixed on the ground and matted with a scan spray (Helling 3D, Laserscanning Entspiegelungsspray, Helling). Then, 3D scans were performed using an inEos X5 scanner (Dentsply Sirona) with an inclination of 60 degrees to the implant axis in order to adequately depict the complete surface. One new untreated implant and each of the 30 treated implants were scanned, and data were processed with inLab 15.1 (Dentsply Sirona). Scans of each treated implant were superimposed with the untreated one using Geomagic Studio 12 Software (3D Systems). The scans were then manually aligned using the slots at the implant orifice as reference areas. The treated area was manually marked before the 3D comparison was initiated, and a report of the comparison was automatically created, reporting the mean and standard deviation of the abrasion depth (Fig 4). The 5th percentile was determined as the maximal depth of abrasion.

Surface Roughness Measurement. The roughness of each implant was determined using a profilometer.
Surface irregularities were recorded, and the relevant Ra and Rz values were calculated and defined as follows:

- **Ra (arithmetic mean roughness):** The mean of the absolute values of the modified roughness profile, based on the central line to a reference route.
- **Rz (averaged roughness):** The arithmetic mean of the differences between the five highest and five lowest points of a profile within a sample route on the surface measured.

**Bending Moment.** Finally, implant stability was tested assessing the bending moment. For this purpose, implants were fixed according to the international standard for fatigue tests for endosseous dental implants ISO 40801 as follows: Implants were embedded in acrylic resin (Paladur, Heraeus Kulzer, Degussa) leaving the treated coronal 6 mm free from resin, before they were fixed in a gypsum tray. Standard abutments (Camlog 4.3 mm, Camlog Biotechnologies) were screwed on the implants with a standardized torque of 25 Ncm. The specimens were then mounted in a 30-degree angle steel holder, and static load was applied on the palatal side of the specimens until fracture or deformation occurred (Zwick 1445 RetroLine, Zwick). Bending moments were measured for each of the treated specimens. Sixteen untreated specimens of the same type and brand served as a reference.

**Statistics**

All statistical analyses were calculated with SPSS Statistics 21 (IBM). Nonparametric methods were applied in case of non-normally distributed data. The absence of normality was checked by the analysis of computed histograms.

With the exception of the approximal contact damage potential of neighboring teeth, all intergroup parameters were analyzed by Mann-Whitney U test and, therefore, displayed non-normally distributed data. The difference for approximal contact damage at neighboring teeth between the groups was analyzed with the chi-square test. For all tests performed, the level of significance was $P < .05$.

**RESULTS**

**Visual Analog Scale**

Based on the VAS scores obtained from the operators, the diamond sequence was considered to leave a less polluted implant site (VAS $3.13 \pm 1.3$) than the stone and silicone sequence ($4.6 \pm 2.23$, $P = .03$). The gloss after the sequence involving silicone polishers was perceived as more shiny with $8.13 \pm 1.41$ compared with the group finished with Arkansas stones ($4.13 \pm 2.07$, $P = .001$). The operators did not notice any difference between the groups regarding speed and tactility (Table 1 and Fig 5).

**Damage of the Adjacent Tooth Surface**

No correlation was found between instrumentation sequence and the presence of a lesion at the adjacent tooth surface. After implantoplasty, lesions in terms of superficial scratches in the surfaces of adjacent plaster teeth were generally found in 63% of the adjacent tooth surfaces. These scratches were always localized in the area of the supposed approximal contact.

**Residual Wall Thickness**

Assessment of the residual wall thickness around the abutment chamber revealed for the mesial aspect a significantly thinner wall thickness measurement for the sequence involving diamonds (group 1) compared to the one with stones and silicone polishers (group 2) ($0.25 \pm 0.07$ mm and $0.30 \pm 0.05$ mm, respectively). For the distal aspect, no difference was found (Table 1).

**Weight Loss**

Weight loss after implantoplasty accounted for $0.025 \pm 0.01$ g and $0.02 \pm 0.01$ g for the sequence involving diamond burs (group 1) and the group using stones and silicone polishers (group 2), respectively, revealing no significant intergroup weight loss after instrumentation. Likewise, weight was comparable for instrumented and pristine implants (Table 1 and Fig 5).

**Three-Dimensional Assessment**

Despite the fact that the mean values and the maximum abrasion depth were slightly higher in the group using diamond burs compared...
with the group using stones and silicone polishers (–0.098 ± 0.020 mm vs −0.088 ± 0.025 mm and –0.21 ± 0.03 mm vs −0.19 ± 0.04 mm, respectively), the 3D evaluation failed to show significant differences between the treatment groups (Table 1).

**Surface Roughness Measurement**
The implant surface after treatment showed Ra values of 0.76 ± 0.14 µm and 0.38 ± 0.15 µm and Rz values of 4.12 ± 0.72 µm and 1.87 ± 0.69 µm for the group employing diamonds and Arkansas stone and the group with stones and silicone polishers, respectively. The significant differences \( P = .0001 \) reflected rougher surfaces after application of the DS group (Table 1).

**Bending Strength**
Evaluation of the bending forces showed no intergroup differences with obtained values of 10.0 ± 3.7 Nm for the group using stones and silicone polishers vs 10.2 ± 4.0 Nm for the group involving diamonds and Arkansas stone. These results did not significantly differ from the bending strength that was obtained from the untreated implants (12.4 ± 4.9 Nm).

**DISCUSSION**
The results of the present study showed that a combination of abrasive stones and silicone polishers resulted in better gloss but likewise in dirtier implant sites as rated by the operator. In the laboratory evaluation, a lower surface roughness was found for the latter. In addition, the residual wall thickness of the abutment chamber showed less material loss at the mesial sites when the stone and silicone sequence was applied. Other parameters such as abrasion, minimum wall strength, and material loss, however, did not seem to depend on the choice of instruments. The present study thereby found the null hypothesis rejected in part. It was noteworthy that fracture resistance was not negatively influenced when implantoplasty was performed, showing no significantly different bending strength after the application of either instrumentation sequence. It is important to note that damage of the teeth neighboring the instrumented implant was—even if only superficially in the plaster surfaces—a frequent finding.

In the present study, the combination of stones and silicone polishers showed superior results, but only in

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Visual Analog Scores During Instrumentation and Morphologic Characterization of Implants After Resective Therapy</th>
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<tbody>
<tr>
<td></td>
<td>Group 1</td>
</tr>
<tr>
<td></td>
<td>Mean ± SD</td>
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<tr>
<td>Abrasion (VAS)</td>
<td>3.13 ± 1.30</td>
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<tr>
<td>Gloss (VAS)</td>
<td>4.13 ± 2.07</td>
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<tr>
<td>Speed (VAS)</td>
<td>5.93 ± 2.22</td>
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<tr>
<td>Tactility (VAS)</td>
<td>5.40 ± 1.99</td>
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<tr>
<td>Minimal thickness mesial (µm)</td>
<td>0.248 ± 0.073</td>
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<tr>
<td>Minimal thickness distal (µm)</td>
<td>0.285 ± 0.053</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>0.411 ± 0.009</td>
</tr>
<tr>
<td>Weight loss (g)</td>
<td>0.025 ± 0.009</td>
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<tr>
<td>Abrasion depth (µm)</td>
<td>–0.098 ± 0.020</td>
</tr>
<tr>
<td>Maximum depths (µm)</td>
<td>–0.211 ± 0.032</td>
</tr>
<tr>
<td>Ra (µm)</td>
<td>0.76 ± 0.14</td>
</tr>
<tr>
<td>Rz (µm)</td>
<td>4.12 ± 0.72</td>
</tr>
</tbody>
</table>

Group 1 = diamond and silicone polisher; group 2 = stone and silicone polisher; SD = standard deviation.
terms of reduced surface roughness, consistently represented by significantly lower Ra and Rz values and by higher gloss, based on VAS values. Since Ra values capture surface topography only in one direction, Rz analysis was performed in order to validate the surface quality more comprehensively.

The findings from the present study are in good accordance with the results of a previous study, which assessed titanium surface roughness of implants after different approaches for implantoplasty. Quirynen et al and Bollon et al showed that on differently rough titanium surfaces, Ra values below 0.2 μm would not further affect the adhesion of biofilm, while with a roughness of 0.8 μm, plaque adhesion was found to be 80-fold higher. Therefore, surfaces treated by the diamond group are at risk of facing enhanced plaque adhesion, considering the standard deviation of the present data. Accordingly, the difference in roughness between the two instrumentation modalities might be of clinical impact.

The residual thickness of the abutment chamber was another parameter that was assessed in this present study. Though the mean mesial and distal values in the radiograph showed no difference between the groups, a subgroup analysis for the mesial wall thickness revealed thinner walls when instrumentation had been performed with diamonds. This finding might indicate a potential problem for the diamond sequence: Since abrasion works more quickly with diamonds, operators might miss the exact moment when windings are removed but the implant body itself is not yet injured. The difference between the groups, however, does not seem to be crucial when considering intergroup comparison of data for abrasion, minimum wall strength from 3D analysis, and material loss as determined by weight loss. Regarding the latter, a reduction of 20 to 25 mg seems to be a surprisingly low value. Considering the total weight of a 13-mm virgin implant of 435 mg and the fact that ideally only the windings that line the cylinder on the outer surface (over a length of only 6 mm) were removed, these values appear reasonable.

Maximum bending forces were not changed by implantoplasty, and no significant intergroup differences were found. This finding is corroborated by several studies. One study by Tribst et al assessed the stress distribution in implants after implantoplasty and loading by an occlusal force of 300 N. Respective data did differ for less than 10% between implants with and without implantoplasty. Generally, a weakening of implant strength after implantoplasty over a length of 5 mm was found in this study. In a subgroup analysis, however, implants with Morse Taper connections—like the ones used for the present study—showed significantly better results compared to those with external or internal hexagon connections. In several clinical studies, the effect of implantoplasty was assessed, but implant fracture was never observed. This fact was also corroborated by findings of a recently published laboratory study, which aimed to assess possible weakening of the implant due to implantoplasty-related material removal: Regarding stress distribution in implants, groups with and without implantoplasty did not vary significantly. The same study also showed that exposure of the threads seemed to be the most critical issue regarding stress pattern development irrespective of whether implantoplasty was performed or not. The authors concluded that implantoplasty might therefore be considered a safe treatment option.

An important finding was the frequent damage at neighboring teeth. Obviously, none of the performed techniques was superior in preventing according injuries at the interproximal face of the anatomical crown. Though in all cases superficial and thus unlikely to lead to consequential damage worse than potentially less-strong contacts after repolishing these areas, the resulting defects run contrary to any exclusively implant-related and generally conservative approach.

Future clinical studies should further assess the damaging potential of implantoplasty, and aim for possibilities to protect the vulnerable neighboring areas.

A limitation of the present study is the fact that the instrumentation was performed in vitro; thus, operators were not disturbed by blood or saliva, tongue, and patients' behavior. Nevertheless, the aim of the present experimental setup was to simulate the best possible clinical situation by performing implantoplasty on original implants in "dentured" maxilla models placed in phantom heads.

VAS is an assessment tool that would not generate completely objective and unbiased data but is subjected to the operators' clinical impression. Validating the data of the present study, the authors found a considerably narrow range for VAS scores and a satisfying agreement between laboratory parameters as represented by operators' rating of gloss and the abrasiveness of the instruments on the one hand, and the roughness parameters and 3D analysis on the other hand.

Furthermore, radiographic analysis was performed from one direction only. Midfacial or midlingual could thereby not be assessed by this technique, but only by the 3D analysis. The respective areas are of particular interest, since clinically the oral section is especially difficult to reach, while the vestibular aspect is of utmost importance for esthetic considerations.

For both techniques, a potentially harmful effect of loose titanium particles has to be considered: The latter has been suspected to play a—so far not totally clarified—role in the etiology of peri-implantitis on one hand and, on the other hand, these particles...
might just have a negative impact on the postinterventional wound healing. Though wound contamination with polishing particles is an undesired effect for sure, little is actually known about potentially impeded negative effects such as wound healing. In an animal study involving implantoplasty, Schwarz et al. found residual titanium particles in the adjacent soft tissues, which provoked localized chronic inflammatory cell infiltrates. Clinical studies by Romeo et al did not show any adverse effects in relation with these particles. The problem, however, is clinically resolvable by either previous application of sticky nonhazardous pastes approved for oral use, which easily get washed out together with the remnants as soon as polishing is finished, or the use of low-abrasive airflow devices that easily remove residual particles from the wound.

CONCLUSIONS
Within the limitations of this study, it can be concluded that implantoplasty seems to be a safe treatment modality for implants with exposed windings. On the other hand, there seems to be a high risk for injury of the neighboring teeth. With regard to surface smoothness, the instrumentation sequence employing silicon carbide and Arkansas stones followed by silicone polishers seems to be superior to the combination of diamond and Arkansas stones. This study thereby found the null hypothesis of an equal performance of both instrumentation modalities rejected in part.

ACKNOWLEDGMENTS
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