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Titanium Implant Characteristics after Implantoplasty

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Contents

Abstract

Background: One option to treat peri-implantitis is the combination of resective surgery with implantoplasty. The latter uses different rotary instruments and aims to reduce biofilm adhesion while enabling a more effective mechanical individual hygiene.

Objective: This study aimed to compare two common implantoplasty procedures and assessed the following parameters: a) the subjective assessment of quickness and ease of the whole implantoplasty procedure, b) lesions present at the approximal faces of neighbour teeth, c) residual wall thickness between implant surface and the abutment chamber and the abrasion depth and d) surface roughness.

Material and methods: Thirty titanium implants with a standardized 6 mm long rough implant surface exposed were embedded in position 16 and 26 in 15 maxillary plaster models. The models were then mounted in phantom heads and implantoplasty was performed by 15 dentists. The following two procedures were performed: i) Diamond group, i.e. a diamond sequence with Arkansas stone (Diamond burs of 106-, 40-, 15µm grit followed by Arkansas stone) and ii) Stone & Silicone group, i.e. abrasive stone and silicone polishers (Green abrasive stone, Arkansas stone, Brownie®, Greenie®). After resective implantoplasties, each dentist filled out a questionnaire with four VAS-scale items (abrasion, gloss, speed, tactility) to subjectively evaluate the two procedures. In addition, the approximal surfaces of the implant-neighbouring teeth were dichotomously checked for lesions. The residual wall thickness after implantoplasty between the treated implant surface and the abutment chamber was measured on digital x-ray images of each treated implant. Additionally, the weight of each treated implant was measured to determine weight loss and 3D-scans were performed in order to calculate the mean and maximal abrasion depths. Consecutively, each implant was scanned with a contact profilometer providing R_a and R_z values as a measure of surface roughness.

Results: The VAS showed significant differences regarding the abrasion and the gloss between the two implantoplasty procedures. The 15 dentists rated the stone & silicone procedures (4.6 ± 2.23, median 4) less abrasive than the diamond procedure (3.13 ± 1.3, median 3). The implants treated with the stone & silicone implantoplasty procedure (8.13 ± 1.41, median 8) were rated to be more glossy as compared to the diamond procedure (4.13 ± 2.07, median 4). There was, however, no significant difference between the two procedures regarding the speed and the tactility. No correlation was found between the implantoplasty procedure and the presence of a lesion on the surface of the neighbour teeth. Nevertheless, 63,3% of the neighbour teeth showed lesions on their approximal surface after implantoplasty. The diamond group had a significantly thinner remaining wall thickness mesially (0.2480 ± 0.0731µm, median 0.25µm) than the stone & silicone group (0.2967 ± 0.0461, median 0.32µm). No significant difference between the two groups regarding the mean and maximal abrasion depth was found. A mean roughness of R_a 0.38 ± 0.15µm and R_z 1.87 ± 0.69µm was achieved with the stone & silicone group under clinical conditions. The surface was statistically significant smoother than with the diamond group (R_a 0.76 ± 0.14µm, R_z 4.12 ± 0.72µm).

Conclusion: Considering the final surface roughness, present lesions at the approximal faces of neighbouring teeth, the residual wall thickness between the treated implant surface and abutment chamber, the mean und maximal depth of abrasion, and the subjective assessment of quickness and ease of the implantoplasty procedure, the group beginning with green abrasive stone, followed by Arksansas stone and ending up with the silicon polishers Brownie® and Greenie®, seems to be the best solution.

1. Introduction

Peri-implantitis is defined as a progressive destructive inflammatory process around osseointegrated implants in function. The disease may affect both, soft and hard tissues, resulting in mucosal inflammation (mucositis, reversible) and progressive loss of the supporting bone, which actually represents the irreversible peri-implantitis entity (Albrektsson&Isidor 1994, Mombelli, 1999). Left untreated, this process may lead even to implant loss due to extensive or complete loss of osseointegration. The prevalence of peri-implantitis varies, but is nowadays estimated to affect 10% of the implants and 20% of the patients 5 to 10 years after implantation (Mombelli et al 2012). Despite the fact that the primary etiologic factor of peri-implantitis are bacteria, which colonize the surfaces as biofilms, the disease progression is considered to be multifactorial and not only primarily related to poor oral hygiene, but also to the history of periodontal disease, smoking, diabetes and alcohol abuse (Heitz-Mayfield 2008).

It has been shown that there is a correlation between oral microbiota and peri-implant disease (Mombelli 1999, Lang et al 2000) and similar microbiota have been implicated, which are comparable to periodontitis (Mombelli 1999, Quirynen et al 2002). Therefore, the elimination of any established biofilm from the implant surface is still the main goal of mucositis and peri-implantitis.

Regarding the professional cleaning procedures and treatment protocols, there is no consensus yet (Renvert et al 2012). Different bone regenerative therapies have been used attempting to heal peri-implantitis defects. Based on animal studies, re-osseointegration is possible, but remains controversial at previously infected implant sites (Renvert S et al 2009). However, only limited data exist from controlled clinical trials. Complete bone fill using a GBR protocol with membrane and bone graft substitutes does not seem to offer a predictable outcome, although partial defect fills have been reported (Sahrmann et al 2009). In contrast, some early failures with pus secretion and consecutive loss of augmentation material have also been published (Behneke et al 2000, Schwarz et al 2009). Romeo and co-workers proposed an alternative treatment option, which combines resective surgery with implantoplasty. The goal of this rather invasive protocol is twofold: i) a pocket elimination is envisaged by adapting the peri-implant soft tissue more apically close to the bone level or even by soft tissue resection (mucotomy). In addition, osteotomy may also be indicated when reshaping of the bony anatomy is required to achieve a more favourable hard tissue situation. ii) the implant morphology is modified by reshaping the marginal surface. This includes the elimination of all implant threads with rotary instruments and smoothening and polishing of the rough surface (Romeo 2005, 2007). Thereby, not only the biofilm adhesion can be conceptually reduced, patients are also supposed to more effectively perform their individual mechanical hygiene. In a clinical study, bone loss with this technique was 0-0.01 mm as compared to 1.44-1.54 mm when a surgical debridement was performed without implantoplasty after a mean observation period of 3 years (Romeo et al 2005, 2007). Ever since, several studies have elucidated some advantages of this method and showed that a reduction of the titanium surface roughness was related to a decreased biofilm formation. The postulated average threshold value for roughness was found to be 0.2µm (Bollen et al. 1996, Quirynen et al 1996). Below this value, bacterial adhesion cannot be further reduced.

When performing implantoplasty, different rotary instruments such as carbide burs and diamond burs can be used. All instruments constitute a compromise of treatment time, easiness and accuracy. Important parameters, which influence the choice of treatment and applicability are the achievable surface roughness, existing lesions at the proximal aspects of the neighbour teeth and accessability, the residual wall thickness between the treated implant surface and abutment chamber and the maximal abrasion depth. The latter factors may significantly influence the fracture strength of the implant after implantoplasty.

A recent study compared six implantoplasty procedures and assessed the final implant surface roughness and treatment time (Ramel CF et al 2015). In conclusion, considering the treatment duration, production of debris and final surface roughness (mean R_a of 0.394µm) the authors recommended an implantoplasty procedure, which begins with a diamond bur of 106µm, followed by 40- and 15µm grit size and ending up with the Arkansas stone to be the most optimal solution (Ramel CF et al 2015).

Diamond burs, however, lack the possibility of shaping the instrument in order to adapt it to the implants' morphology and axis, which is more easily possible with abrasive rotary stones made of carborundum. In addition, the suggested Arkansas stone as a final instrument may leave still unpolished surfaces, which potentially leave niches for bacteria after every-day oral hygiene measures.

Despite the fact that implantoplasty seems to be a clinically promising treatment approach, there is still not much of an evidence regarding different surface qualities and effective abrasion characteristics.

The aim of this study was to compare the two most common implantoplasty procedures regarding substance loss and the resulting quality of the new surface. The still ongoing project will also assess the fracture resistance of these implants.

2. Materials and Methods

Implants

Thirty titanium implants (Camlog screw line, 4.3/13mm, Camlog Biotechnologies AG, Basel, Switzerlang) were embedded in 15 plaster models (white dental lab stone) in a way, that 6 mm of rough surface was exposed, simulating a horizontal peri-implant defect with only supracrestal aspects. Each of the 15 plaster models had two implants in position 16 and 26 (Figure 1 and 2).

Burs

The following materials were used under copious irrigation with water:

1. Bud-shaped diamond rotary instruments, short neck: 106-, 40-, and 15 µm grit; used in sequence (Intesiv SA, Montagnola, Switzerland) at 200’000 rpm (Figure 3)
2. Arkansas stone, as a cylindrically-shaped white aluminium oxide bur (Jota AG, Rüti, Switzerland) at 20’000 rpm (Figure 3)
3. Green abrasive stone, also cylindrically-shaped; green silicium carbide bur (Jota AG, Rüti, Switzerland) at 20’000 rpm (Figure 4)
4. Mini-point-shaped abrasive impregnated silicone polishers (Brownie®, Greenie®, Shofu Dental GmbH, Ratingen, Germany) at 20’000rpm (Figure 4)

Implantoplasty procedures

According to the bur systems and sequences used, the following two treatments were applied as describe in more detail before:

1. Diamond group = diamond sequence with Arkansas stone

   (Diamond burs 106- 40-, 15µm, Arkansas stone)

2. Stone & Silicone group = abrasive stone and silicone polishers

   (Green abrasive stone, Arkansas stone, Brownie®, Greenie®)

The implantoplasty procedures were performed by 15 dentists, which were well trained and are part of a Master program. Each dentist performed both implantoplasty procedures on the same plaster model. The decision which implant was treated first as well as the allocation of the different treatment type, was randomly allocated according to a computer-generated protocol.

During the treatment, plaster models were mounted in phantom heads to simulate more realistically the clinical conditions. A handheld contra-angle hand-piece (at respective rpm) was used under copious water irrigation for diamond burs. For all the other instruments, a contra-angle hand-piece working was used, again with copious water irrigation.

With the first bur in both procedures, the threads of the exposed implant surfaces had to be removed. For this step a maximum time frame of 6 minutes was given. Afterwards, the smoothened implant surface was polished for three minutes with each of the three remaining rotary instruments, respectively. In total, each implantoplasty procedure had to be finished after 15 min.

Visual Analogue Scale

The visual analogue scale (VAS), a psychometric response scale was used to assess the subjective impressions of the operator during treatment.

After implantoplasty, each dentist responded to a questionnaire, which evaluated the two procedures. Four VAS-scale items were rated as follows:

- Abrasion: 0 = strong abrasion, 10 = no abrasion
- Gloss: 0 = dull, 10 = maximum gloss
- Speed: 0 = very slow, 10 = very fast
- Tactility: 0 = very easy, 10 = extremely difficult

Approximal contact damage of neighbouring teeth

After the implantoplasty procedures, the plaster models were examined in order to assess the approximal surfaces of the implant-neighbouring teeth, i.e. 15 distally, 17 mesially and 25 distally, 27 mesially. The surfaces were dichotomously checked for iatrogenic damages or lesions: "No lesion present" was rated as 0, a visible lesion as 1.

X-Ray imaging and measurement of residual wall thickness

An x-ray image was taken of each implant after treatment as well. For this purpose, standardized x-rays were taken with a paralleling technique. The exposure parameters were 65kV at 7.5mA a for 0.16s.

The x-ray images were calibrated using the known implant diameter of 4.3 mm (Adobe®Photoshop®CC 2015.5, Adobe Systems Incorporated, San Jose, USA) and the residual wall thickness after implantoplasty was measured between the treated implant surface and the abutment chamber (mesially and distally each). The manual distance measurement tool of the program was used for this analysis. At each site, the wall with the thinnest residual thickness was determined (Figure 5).

Afterwards, implants were cut out from the models and gypsum remnants were chemically removed (Firo Gips-Ex Plus, Fino GmbH, Switzerland).

Weight and weight loss

The weight of each implant was measured after treatment with a precision scale (Mettler AT 261 DeltaRange®, Mettler-Toledo GmbH, Switzerland). Every implant was weighed 3 times and the mean value was calculated. To determine the weight loss, 9 untreated implants were weighed 3 times each, and the resulting mean value was used as reference.

Three-dimensional scans, depth of abrasion

3D scans were performed with an inEos X5 scanner (Dentsply Sirona, Wals, Austria). The surface of the implant was first tarnished (Helling 3D, Laserscanning Entspiegelungsspray, Helling GmbH, Heidgraben, Germany) and fixed with putty. The surface was scanned at an inclination angle of 60° in order to adequately depict the complete surface. Each of the 30 treated implants was scanned as well as one untreated implant for reference. Data were processed with inLab 15.1 (Dentsply Sirona, Wals, Austria.).

With Geomagic Studio 12 Software (3D Systems, Rock Hill, USA), the scan of each treated implant was superimposed with the scan of the untreated implant. The scans were then manually aligned using the slots in the implant orifice as reference. Afterwards, the surface around the slots and the screw threads of the implant body were marked and aligned globally. The data of the aligned implants was saved for subsequent usage with the Geomagic Qualify 12 Software.

This software was also used to compare the 3D data of the treated and untreated implants. For this purpose, the treated implant was set as "test" and the untreated implant as a "reference". The surface area of interest was manually highlighted before the 3D comparison was initiated. A report of the comparison was created automatically, yielding the mean deviation of the depth of abrasion (Figure 6). For calculating the maximal abrasion depth, all deviations were exported in Excel 2017. The 5^{th} percentile was determined as the maximal depth of abrasion.

Surface roughness measurements

Each implant was scanned with a profilometer (Form Taylsurf 50 Tayler Hobson, Rank Tayler Hobson Limited, Leicester, England) at three different lines. Using a diamond tip, the surface roughness was measured along a straight line at a constant speed (0.5mm/s) and a constant pressure. The implant was determined in such a way that the profilometer tip was set perpendicularly to the implant surface and the needle moved along the implant's longitudinal axis. The profilometer scanned along a length of 3 mm. The vertical movements of the tip, which was triggered by any surface irregularities, was transferred to a transducer, which in turn generated an electrical signal, which is then amplified, digitalized and recorded. The results were displayed on a screen and recorded as numerical values with a profile graph. Based on these charts, the relevant R_a and R_z values were determined and were defined as follows:

- R_a (arithmetic mean roughness): The mean of the absolute values of the modified roughness profile, based on the central line to a reference route,

- R_z (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.

Statistics

All statistical analyses were calculated with SPSS Statistics 21 (IBM, Armonk, USA). Nonparametric methods were applied due to non-normally distributed data. The absence of normality was checked after computing histograms.

With the exception of the parameter for approximal contact damage of neighbouring teeth, all parameters were analysed by using the Wilcoxon signed-rank test. The parameter for approximal contact damage of neighbouring teeth was analysed with the Chi-square Test.
Level of significance was set to $p < 0.05$.

3. Results

VAS

The results on the VAS (***Fehler! Verweisquelle konnte nicht gefunden werden.***) showed significant differences ($p<0.05$) regarding the abrasion and the gloss between the two implantoplasty procedures. The 15 dentists rated the stone & silicone procedure (4.6 ± 2.23, median 4) less abrasive than the diamond procedure (3.13 ± 1.3, median 3) (Figure 7). The implants with stone & silicone implantoplasty procedure (8.13 ± 1.41, median 8) was classified to be more glossy than after the diamond procedure (4.13 ± 2.07, median 4) (Figure 8). There was no significant difference between the two procedures regarding speed and tactility.

Approximal Contact Damage

No correlation was found between the mode of implantoplasty and the presence of a lesion at the surface of the assessed neighbour teeth. Lesions were found at 63,3% of the neighbour teeth at the approximal contact surface after the implantoplasty.

Minimal Wall Thickness

The diamond group had a significantly ($p<0.05$) thinner wall thickness remaining mesially (0.2480 ± 0.0731µm, median 0.25µm) as compared to the stone & silicone group (0.2967 ± 0.0461, median 0.32µm) (Figure 9). The remaining wall thickness distally was found to be slightly thinner in the diamond group, however, differences showed no statistical significance (***Fehler! Verweisquelle konnte nicht gefunden werden.***).

Weight Loss

Weight measurements were comparable in both groups and tests failed to reveal any significant differences (***Fehler! Verweisquelle konnte nicht gefunden werden.***).

Depth of Abrasion

No significant difference between the two groups regarding mean and maximal abrasion depth was found. However, the diamond group showed higher mean values of the measured mean and maximal abrasion depth values as compared the stone & silicone group. The maximal depth of abrasion was slightly higher in the diamond group, but the difference failed to show significance (p=<0.059) (***Fehler! Verweisquelle konnte nicht gefunden werden.***).

Surface roughness

The implant surfaces after treatment showed significant differences in terms of R_a and R_z values ($P<0.05$) (Figure 10 and 11). In this context, the diamond group yielded higher R_a and R_z values as well as rougher surfaces (***Fehler! Verweisquelle konnte nicht gefunden werden.***).

4. Discussion

Implantoplasty has become an effective technique to improve the prognosis after resective implant surgery (Romeo et al 2007, Schwarz et al 2011). The present assessed differences in relevant parameters after instrumentation with two implantoplasty procedures.

To simulate typical clinical conditions, the implants were embedded in plaster models of a maxilla. The latter were mounted in phantom heads and implantoplasty was performed by 15 dentists. The main focus of this project was the subjective attitude of the individual operators regarding the two implantoplasty procedures, i.e. the outcomes and the preferences. The analysis of the Visual Analogue Scale hypothesized, that there was no difference regarding the speed and manual tactility of the two procedures. The study found that, however, that the stone & silicone procedure was significantly less abrasive than the diamond procedure and that the resulting implant surface was significantly more glossy.

The roughness was measured with a profilometer. The R_a value is a common surrogate parameter to assess surface quality and describes roughness. However, R_a-values do not necessarily describe surface topography in all details. It captures surface topography only in one direction. Therefore, we decided to add additional descriptive data: In contrast to the R_z value, the R_a value has a large variance when performing multiple measurements. Only when taking both values into consideration, more reliable conclusions regarding the topography and roughness of a given surface can be provided.

A number of split-mouth studies reported that a reduction of titanium surface roughness is related to a decrease in biofilm formation up to an average threshold roughness R_a of 0.2µm (Bollen et al. 1996, Quirynen et al 1996), below which bacterial adhesion cannot be further reduced. Rimondini and coworkers (1997) as well as Teughels et al. (2006) have shown, that the roughness of implant surfaces can significantly influence the initial biofilm adhesion. Berglundh et al. (2007) performed an experimental study in dogs and showed that an increased plaque formation and faster peri-implantitis progression rates were found in implants with a rough surface. The spontaneous progression of ligature-induced peri-implantitis was examined on standard SLA (R_a 2.29µm) and implants with polished surface (R_a 0.35µm).

In the present study, a mean surface roughness of R_a 0.38 ± 0.15µm and R_z 1.87 ± 0.69µm was achieved with the stone & silicone group under clinical conditions. The surface was statistically significant smoother than with the diamond group (R_a 0.76 ± 0.14µm, R_z 4.12 ± 0.72µm). This finding is related to the subjective attitude of 15 different dentists, who treated the implants. However, these roughness values were by far higher than the cut-off value, which has been reported to be relevant for plaque adhesion as mentioned above. Therefore, the aim of the implantoplasty should be rather considered to render oral hygiene measures more effectively (if performed). With this in mind, the stone & silicone group showed clearly better results, which could potentially affect the plaque index in a clinically relevant way.

Several in vivo studies used diamond burs and an Arkansas stone with or without silicon polishers as the instrument of choice to remove implant threads (Romeo 2005, 2007, Matarasso 2014, Schwarz 2011, 2014). However, these studies did not measure the final roughness of the treated implants. Only few laboratory studies have investigated surface roughness with different rotary instruments without silicon polishers (Meier et al 2012: mean roughness ranged from 0.39-4.75µm, De Souza Junior et al 2016: mean roughness ranged from 4.13-5.01µm). A previous in vitro study compared six implantoplasty procedures and recommend the implantoplasty procedure beginning with a diamond bur of 106µm, followed by 40- and 15- µm grit size and finishing up with the Arkansas stone to be the most optimal solution (Ramel CF et al. 2015: mean R_a of 0.394µm). In the present study, a much higher mean R_a 0.76µm was achieved with the same implantoplasty procedure. An explanation could be, that 15 dentists performed the implantoplasty procedure as opposed to one calibrated operator. Furthermore, the implantoplasty was performed under conditions, which simulated the clinical situation in the present study and hampered a perfect instrumentation, i.e. the plaster models were mounted in phantom heads, which rendered the implantoplasty more difficult.

The present study revealed, that there was no significant difference between the two groups regarding the mean and maximal abrasion depth. Consequentially there was also no significant difference for the residual weight of the treated implant. On the mesial and distal surface of the implant, respectively, the burs had less space and good care had to be taken not to damage the surface of the neighbouring teeth. The results showed a significantly thinner remaining wall thickness mesially in the diamond group as opposed to the stone&silicone group. The remaining wall thickness distally was found to be slightly thinner in the diamond group, failing to show significant differences, however. The 15 dentists considered the stone & silicone procedure to be significantly less abrasive than the diamond procedure. An explanation for the varying significance of the remaining wall thickness mesially and distally could be, that the individuals, who performed the implantoplasty had a better view on the mesial surface of the implant, when the plaster model of a maxilla was mounted in the phantom heads. The distal surface of the implant, in contrast, could only be treated indirectly under mirror control.

There was no correlation between the implantoplasty procedure and the presence of a lesion on the surface at the neighbour teeth. However, 63,3% of the neighbour teeth showed lesions after implantoplasty. Diamond burs lack the possibility of shaping the instrument in order to adapt it to the implants' morphology and axis, which on the other hand is was more easily possible with abrasive rotary stones like carborundum stones, which could be trimmed on shaping.

The significantly thinner remaining wall thickness at mesial sites in the diamond group as compared to the stone&silicone group could be potentially crucial for the fracture strength and behaviour of the implant. The latter was not part of this master thesis, but implants were investigated accordingly.

Gehrke SA et al. (2016) performed an in vitro study with 60 implants of 11 mm in length and 4 mm in diameter with 3 different implant connection designs. The test group underwent the implantoplasty with conical carbide cutter burs. Then all the implants were fixed simulating a 5mm bone loss and loaded with static compressive forces in implant angulation of 30 degrees. The three implant types showed an overall average of 833.5N fracture strength before, and an overall average of 566.8N after the implantoplasty, indicating a 32% reduction in resistance. Chan HL and co-workers (2013) performed a similar study using the same implant system but different diameter (3.75mm vs 4.7mmx10mm). This study found that the implantoplasty had no impact on the strength of the implant bodies with a thick diameter (4.7mm). However, Shemtov-Yona et al. (2014) showed that the implant strength indeed depended on implant wall thickness. Implant design and especially diameter were shown to be crucial to ensure long-term fatigue performance for dental implants and might be harmful for fatigue resistance especially in 3.3mm implants.

But not only the implantoplasty is able to reduce the fracture strength of the implant. Gherke and co-workers (2014) simulated a bone loss of 3- and 5 mm around four different implant types (diameter 3.30 – 3.50mm, length 13mm) and determined their fracture strength. A 3mm loss of bone level results in an average reduction in strength of 37.2 %, whereas a 5 mm loss in insertion results in an average reduction in strength of 53.8 %.

An additional aspect, which yet remains to be investigated is the biotoxicity of the generated debris during implantoplasty and the potential effect on the clinical outcome. Diamond and carbide burs cause a pollution of the surgical field with titanium particles. In addition, the silicone polishers wear off themselves resulting in an additional pollution of silicone debris. Schwarz et al. (2011) revealed in an implantoplasty study in dogs a slight to moderate deposition of titanium particles in the adjacent tissues, which was associated with a localized chronic inflammatory cell infiltrate. However, previous clinical studies have shown that these depositions were not associated with any adverse events (Romeo et al. 2007: Implantoplasty with diamond bur, Arkansas stone, Brownie®, Greenie®, Schwarz et al. 2011: Implantoplasty with diamond bur, Arkansas stone), which indicated a clinical safety and efficacy of implantoplasty to serve as an alternative approach for the treatment of supracrestal defect components.

5. Conclusion

In conclusion, considering the final surface roughness, present lesions at the approximal faces of neighbouring teeth, the residual wall thickness between the treated implant surface and abutment chamber, the mean und maximal depth of abrasion, and the subjective assessment of quickness and ease of the implantoplasty procedure, the group beginning with the green abrasive stone, followed by Arkansas stone and ending up with the silicon polishers Brownie® and Greenie®, seems to be the best solution.

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7. Appendix

Figure 1. Picture of a plaster model holding two implants in the positions 16 and 26.

Figure 2 Picture of an implant in the position 16 with a horizontal peri-implant defect.

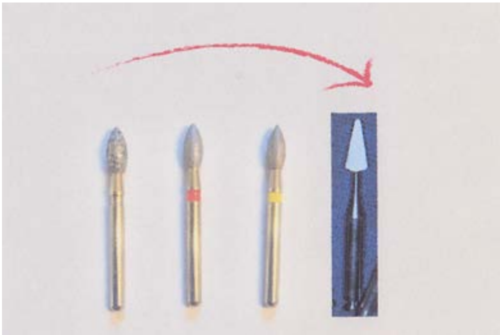

Figure 3. Picture of the diamond sequence with Arkansas stone. From left to right: Bud shaped diamond rotary instrument 106 µm; 40 µm; 15 µm; Arkansas stone.

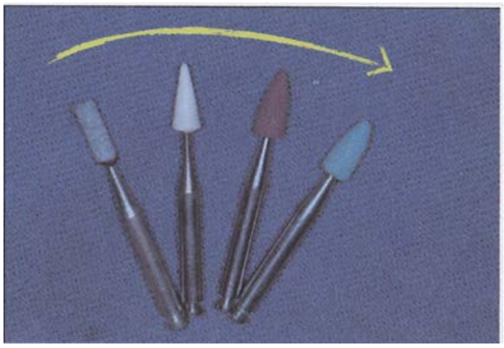

Figure 4. Picture of the abrasive stones and silicone polishers. From left to right: Green abrasive stone; Arkansas stone; Brownie; Greenie

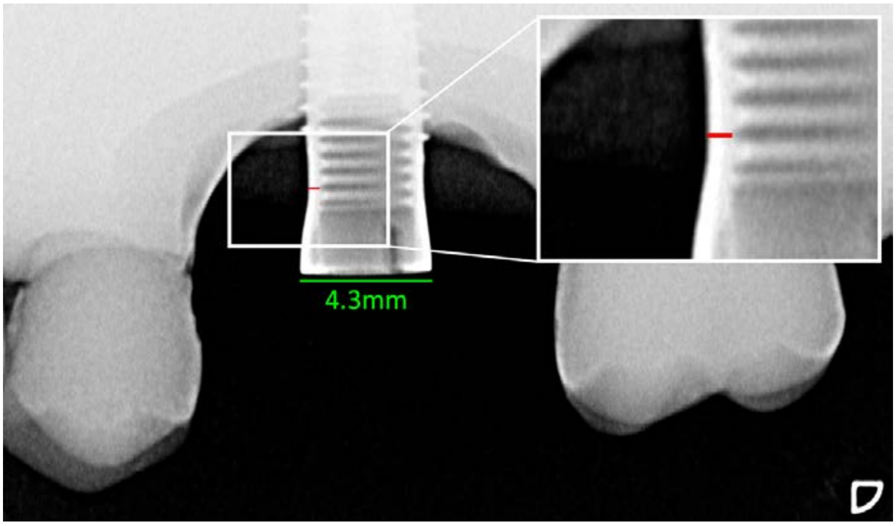

Figure 5. Measuring the min. remaining wall thickness (red) on an x-ray image after implantoplasty on Adobe®Photoshop®CC 2015.5.

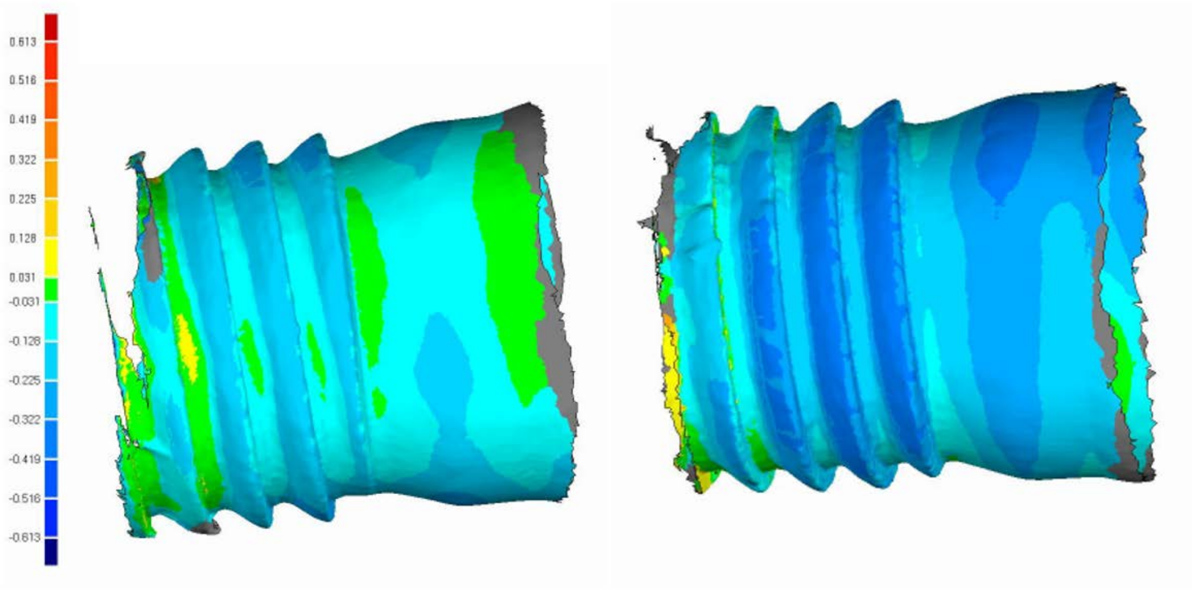

Figure 6. Superimposed implants as derived from Geomagic QUALIFY 12 Software. The software calculates the 3D comparison of the treated and untreated implant. The depth of abrasion is color-coded: green (identical to untreated implant; no abrasion), light blue to dark blue (abrasion), yellow to red (additional material compared to untreated implant; in this case a result of the application of tarnishing spray), and gray (punctual mismatch of the highlighted areas of the treated and untreated implant). (left) Depth of abrasion after implantoplasty with stone & silicone. (right) Depth of abrasion after implantoplasty with diamond.

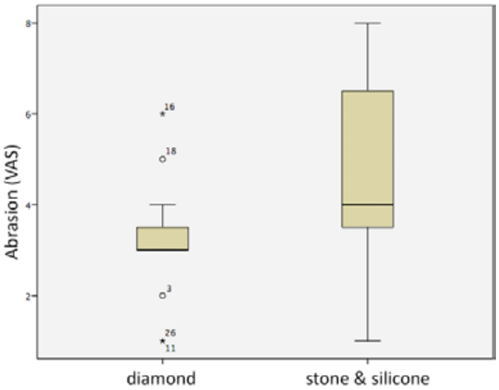

Figure 7. Box plot of abrasion VAS data. Significant differences between the groups.

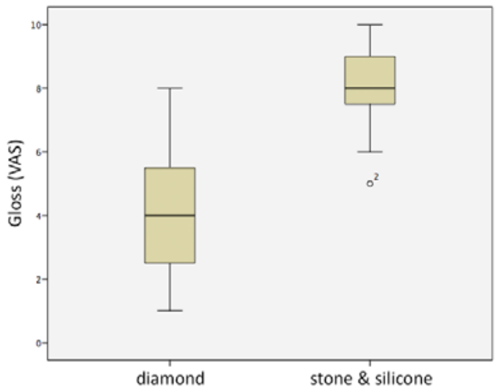

Figure 8. Box plot of gloss VAS data. Significant differences between the groups.

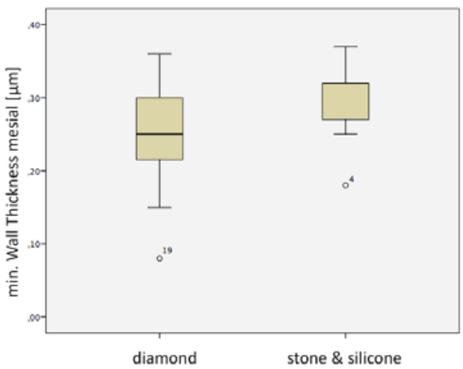

Figure 9. Box plot of min. wall thickness mesial data. Significant differences between the groups.

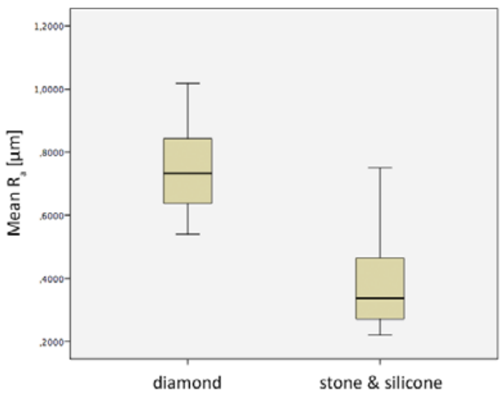

Figure 10. Box plot of mean R_a values in µm.

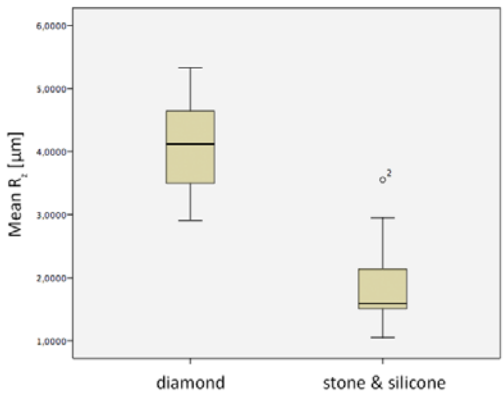

Figure 11. Box plot of mean R_z values in µm.

Table 1. VAS of abrasion, gloss, speed and tactility of Diamond and Stone & Silicon group.

Group	Abrasion		Gloss		Speed		Tactility	
	Mean $\pm$ SD	Median	Mean $\pm$ SD	Median	Mean $\pm$ SD	Median	Mean $\pm$ SD	Median
Diamond	3.13 $\pm$ 1.3	3	4.13 $\pm$ 2.07	4	5.93 $\pm$ 2.22	6	5.40 $\pm$ 1.99	5
Stone & Silicone	4.60 $\pm$ 2.23	4	8.13 $\pm$ 1.41	8	5.40 $\pm$ 1.96	5	4.60 $\pm$ 1.35	5

Table 2. Min. wall thickness mesial & distal values stated in µm.

Group	Min. thickness mesial		Min. thickness distal	
	Mean $\pm$ SD	Median	Mean $\pm$ SD	Median
Diamond	0.2480 $\pm$ 0.0731	0.25	0.2853 $\pm$ 0.0529	0.28
Stone & Silicone	0.2967 $\pm$ 0.0461	0.32	0.3027 $\pm$ 0.0427	0.31

Table 3. Weight and weight loss values stated in µm.

Group	Weight		Weight loss	
	Mean $\pm$ SD	Median	Mean $\pm$ SD	Median
Diamond	0.4106 $\pm$ 0.0085	0.4119	0.0246 $\pm$ 0.0085	0.0233
Stone & Silicone	0.4159 $\pm$ 0.0078	0.4171	0.0194 $\pm$ 0.0078	0.0181

Table 4. Mean and max. depth of abrasion values stated in µm.

Group	Mean depth		Max. depth	
	Mean $\pm$ SD	Median	Mean $\pm$ SD	Median
Diamond	0.0984 $\pm$ 0.0202	0.0920	0.2106 $\pm$ 0.0323	0.1997
Stone & Silicone	0.0882 $\pm$ 0.0248	0.0840	0.1912 $\pm$ 0.0397	0.1819

Table 5. R_a and R_z values stated in µm.

Group	R_a		R_z	
	Mean $\pm$ SD	Median	Mean $\pm$ SD	Median
Diamond	0.76 $\pm$ 0.14	0.73	4.12 $\pm$ 0.72	4.12
Stone & Silicone	0.38 $\pm$ 0.15	0.34	1.87 $\pm$ 0.69	1.59

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