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Research Article

Alterations to Dental Implant Surfaces Produced by Different Methods of Mechanical Debridement. *In Vitro* Scanning Electron Microscope Study

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Abstract

Objectives: The purpose of this study is to compare the alterations to dental implant surfaces caused by classic methods of mechanical debridement compared with the recently introduced rotating titanium brush.

Methods: Four mechanical debridement methods were evaluated: stainless steel curettes (SSCs), conventional ultrasonic scaler (CUS), teflon ultrasonic scaler (TUS), and rotating titanium brush using a total of 16 titanium grade IV Straumann® soft tissue level implants with SLA® surface. Each implant was treated for one minute on one side and three minutes on the opposite side to compare the effects of treatment duration. Samples were prepared for analysis by scanning electron microscopy (SEM).

Results: Mechanical debridement with the rotating titanium brush produced the least alteration to the implant surface, followed by teflon ultrasonic scaler, stainless steel curettes, and conventional ultrasonic scaler, with statistically significant differences between the instruments ($p < 0.005$). Surface damage was shown to not be affected by the duration of treatment ($p = 0.476$) with the exception of SSCs, which shows statistical significant differences ($p = 0.04$) between 1 minute and 3 minutes of treatment.

Conclusions: Rotating titanium brush would appear to be gentler on the implant surface than all the others systems with statistically significant difference. Further clinical studies are needed to prove the effectiveness of rotating titanium brush for removing plaque and calculus from implant surfaces.

Keywords: *Debridement; Electron; Microscopy; Peri-implantitis; Surface Properties*

Abbreviations

SSCs: Stainless Steel Curettes; CUS: Conventional Ultrasonic Scaler; TUS: Teflon Ultrasonic Scaler; SEM: Scanning Electron Microscopy

Introduction

Peri-implantitis occurs in approximately 22% of all dental implants [1]. The disease is characterized by inflammatory processes and bone loss around the implant [2]. It is related to late implant failure and to the presence of bacterial plaque [3,4].

Treatment procedures for peri-implantitis are targeted at removing the existing biofilm and disinfecting the contaminated implant surface [5]. Nonsurgical techniques have failed to provide predictable and successful outcomes due to the difficulties of plaque removal from dental implants, which arise from the implants' macro- and microdesign, and the defect-specific characteristics of each case [6]. For this reason, it is often necessary to perform surgery to facilitate mechanical debridement [7].

It has been shown that mechanical debridement produces alterations to the implant surface which can hinder potential re-osseointegration.

Mechanical debridement methods should aim to create a surface that is not conducive to bacterial colonization, and does not affect the implant-soft tissue interface [8]. But if soft tissue attachment is disrupted, the instrumentation procedure needs to maintain a surface that is conducive to re-establishment of the soft tissue [9].

If treatment planning is oriented toward tissue regeneration and implant reintegration, rather than resective surgery, maintaining the integrity of the implant surface is crucial; damaging the surface and altering its specific characteristics can influence implant reintegration in unpredictable ways [10].

The degree of surface alteration will be influenced by the debridement instrument's characteristics as well as speed, direction, and handling pressure [11].

When applied to rough surfaces, a conventional ultrasonic scaler (CUS) with a metal tip has been shown, *in vitro*, to produce a smoother surface with reduced irregularities, and to remove bacteria more efficiently than ultrasonic scalers covered with a plastic tip [12]. Nevertheless, the application of non-metallic instruments would appear to produce insufficient bacteria elimination on rough surfaces [13].

In recent years, rotating brushes with titanium bristles (titanium brushes) have been introduced for the debridement of peri-implant osseous defects, which aim to be less time consuming, more efficient and gentler on the implant surfaces [5].

However, a direct comparison between different mechanical debridement methods was not assessed, and the problem of which method produces less changes at the surface of the implant and if the final state of the surface is influenced by the treatment time were also not addressed.

Therefore, the purpose of this study was to compare alterations to implant surfaces under scanning electron microscopy (SEM) caused by the classic methods of mechanical debridement comparing them with the rotating titanium brush. As secondary parameter the influence of treatment time was also assessed.

Materials and Methods

The study used a total of 16 titanium soft tissue level implants with grade IV titanium SLA® surface (Straumann®, Basel, Switzerland) and a 1.8 mm polished collar. Four mechanical debridement methods were evaluated: stainless steel curettes (SSC) (Deppeler®, Rolle,Switzerland), conventional ultrasonic scaler (Acteon® Merignac, France), teflon ultrasonic scaler (TUS) (Acteon® Merignac, France) and rotating titanium brush (TiBrush, Straumann®, Basel, Switzerland).

The Stainless Steel Curettes were used doing apico-coronal movements mimicking a clinical situation where the implant surface is covered by plaque, calculus and granulation tissue and the objective of the treatment is produce a debridement of these deposits. Applying in each movement the same pressure and the same angulation of the instrument.

The conventional ultrasonic scaler and teflon ultrasonic scaler were operated at medium power (level 6 of 14 available power levels) under profuse water irrigation. In CUS and TUS the contact between the surface of the implant and the instrument was soft without making pressure over the implant. In teflon ultrasonic scaler were used the same device than conventional ultrasonic scaler changing only the stainless steel tip for a Teflon tip.

The rotary brush instrument operated at 300 rpm under saline irrigation. Alternating the placement of the brush perpendicular and parallel to the implant.

Treatment procedure

The 16 implants were divided into 4 groups according to the different instrumentation used to treat surfaces. Each implant was evaluated for 1 minute on one side and 3 minutes on the opposite side, side A and B respectively (Table 1).

Group	Number of implants	Minutes of treatment	
		Side A	Side B
Stainless Steel Curettes	4	1 min.	3min.
Conventional Ultrasonic Scaler	4	1 min.	3min.
Teflon Ultrasonic Scaler	4	1 min.	3min.
TiBrush®	4	1 min.	3 min.

Table 1: *Distribution of implants by treatment group.*

The treated area was limited to the polished-rough interface from the beginning of the SLA surface to 3 mm below. All implants were treated by a single operator (MG). The movements mimicked those that would be performed in a real clinical situation (Figure 1).

a b c d

Figure 1: *Treatment of implant surfaces: a) Stainless steel curettes; b) Conventional ultrasonic scaler; c) Teflon ultrasonic scaler; d) TiBrush Straumann®.*

Scanning electron microscopy

To prepare samples for analysis of surface morphology resulting from treatment by mechanical debridement, the implants were gently rinsed in pure water, and dehydrated with increasing concentrations of acetone (40 - 100% in steps of 10%). After drying with hexamethyldisilazane, the implants were sputter coated with gold and examined with a SEM (S-3000N; Hitachi®, Pleasanton, CA, USA) at 30x, 300x and 600x, capturing and saving images for later analysis.

Surface morphology

SEM images of each of the four groups and an untreated control implant surface were taken. The SEM images were examined only at x600 magnification because was considered the minimum augmentation level to perceive the small alterations. SEM images were evaluated by 16 postgraduate students (International Master's program in Oral Surgery and Implant Dentistry, International University of Catalonia, Spain), all blinded to the group assignation of each sample. Damage to each implant surface was rated using an intervals staircase whereby observers evaluated the grade of surface alteration in comparison with the control images (Table 2).

Score	Assessment of the level of alteration
0	0%
1	> 0% to ≤ 25%
2	> 25% to ≤ 50%
3	> 50% to ≤ 75%
4	> 75 % to < 100%
5	100%

Table 2: *Alterations to implant surface morphology.*

Statistical analysis

An estimate of the necessary evaluations was conducted in order to correct the obvious correlation between examiners (p Spearman = 0). Subsequently in a pilot study with 3 examiners a level of correlation of $\rho = 0.4$ was estimated, which was then used to correct the required sample size, and the need of 4 to 5 implants for each group was obtained.

A nonparametric model of Brunner-Langer for longitudinal data was considered. The degree of alteration is the dependent variable, the factor intra-implant is the treatment time, and the factor between-implant is the debridement method.

Data were analyzed, clustering by examiner. ATS (type-ANOVA) test was performed to evaluate the main effects and the interaction. The significance level of analysis is 5% ($p < 0.05$).

Furthermore, once all implants were observed the concordance between observers of the degree of alteration was done using the Kappa index with linear weighting.

Results

SEM images (Figure 2 and 3) show how each debridement system altered the surface structure.

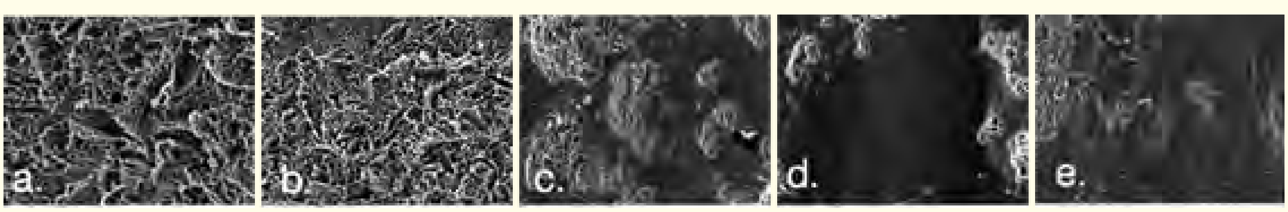


Figure 2: *SEM images at 600x after 1 min. of treatment: a) untreated control implant showing no surface damage; b) TiBrush; c) TUS; d) SSC; e) CUS.*

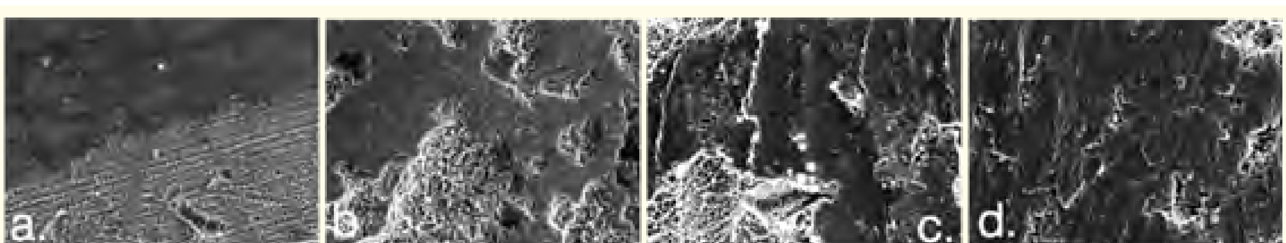


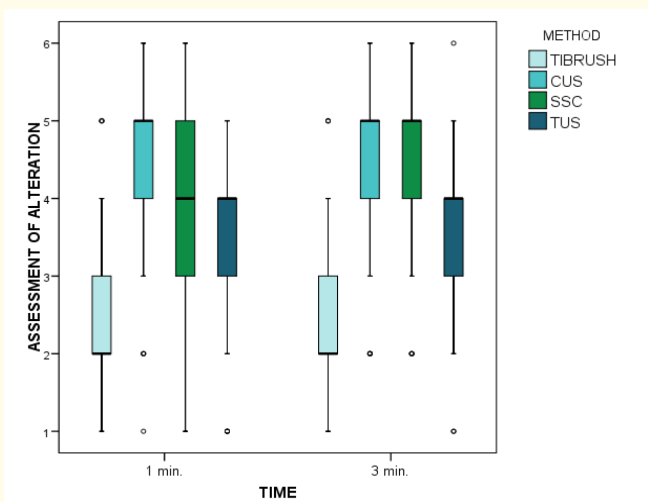
Figure 3: *SEM images at 600x after 3 min. of treatment: a) TiBrush; b) TUS; c) SSC; d) CUS.*

The rotating titanium brush showed statistically significant differences (p < 0.001) in comparison with all other mechanical debridement systems showing the lowest mean surface damage scores, followed by the Teflon ultrasonic scaler, stainless steel curettes, and the conventional ultrasonic scaler (Figure 4).

It was shown that surface damage was shown to not be affected by the duration of treatment (p = 0.476) as statistical analysis identified similar results between side A and B (1 and 3 minutes respectively) for all the methods with the exception of Stainless steel Curettes which shows statistical significant differences (p = 0.04) between 1 minute and 3 minutes of treatment (Figure 4).

The stainless steel curettes and teflon ultrasonic scaler have a similar level of surface alteration at 1 min., but when the treatment time is prolonged to 3 minutes SSCs produces much more alterations to the implant surface than TUS at 3 minutes, although there are important differences between them, these are not statistically significant (p = 0.087).

The increased alteration that produces stainless steel curettes over time makes SSCs significantly better than conventional ultrasonic scaler (p = 0.045) over a short time, but when the time is increased to 3 minutes both method produce similar levels of alterations over the implant surface.



Despite the examiners agree on which method produces fewer alterations, there is not a high concordance level between the examiners and the rest methods of mechanical debridement.

Discussion

Since there is no established a gold standard method in mechanical debridement of oral implants it is of interest to scientifically assess what method is best maintaining the integrity of the implant surface to facilitate their reintegration in cases where the peri-implantitis treatment is approached with mechanical debridement and regenerative surgery.

It has been reported that debridement of dental implant using mechanical techniques such as scaling with metal, plastic or ultrasonic instruments, rubber cup polishing, air-powder abrasion or brushing with a conventional or rotating brush are used to achieve complete removal of all calcified and bacterial deposits from implant surfaces to halt the progression of disease [13,14].

The use of SEM for evaluating surface topography and assessing of the state of implant surfaces has been widely used in previous studies [5,11,13,15,16].

When considering implant cleaning instruments, in addition to their efficacy, it is important to assess the potential damage they may cause to the implant surface.

Conventional ultrasonic devices have been shown to be effective for periodontal preventive treatment and are much in use [13]. However, they suffer the disadvantage that, like any metal-to-metal contact, they can produce implant surface alterations during active contact [13].

Sharp metal curettes are the standard instruments for scaling and root planning procedures, used to treat roots affected by periodontal disease, although this involves substantial loss of cementum from the root and they could possibly damage the implant surface [27].

An *in vitro* study using a surface profilometer showed that metal curettes made of stainless steel alloys reduce the degree of roughness of rough-surfaced implants and decrease *Streptococcus sanguinis* attachment [8], which is an important early colonizer of the oral cavity. However, a systematic review of re-osseointegration of implants with previously contaminated surfaces found that open debridement including decontamination of the surface may result in re-osseointegration but that such re-osseointegration is greater for rough surfaces than smooth surfaces [18]. Smooth surfaces accumulate less plaque than rough surfaces but in turn produce poorer implant osseointegration. Moreover, if the rough surface of the implant is reduced when performing implantoplasty, this will make the implant more susceptible to fracture, especially when implants have a diameter of less than 3.75 mm [19].

This has led to the development and introduction of instruments that are less aggressive to the implant surface, such as the ultrasonic scaler with teflon tip. Nevertheless, the application of non-metallic instruments would appear to produce insufficient bacteria elimination on rough surfaces [13].

In this regard, the results of this study showed be partially in agreement, showing significant differences in the degree of surface alteration, being more aggressive the conventional ultrasonic scaler and stainless steel curettes than plastic instrument (teflon ultrasonic scaler) but the titanium brush was the most respectful with the implant surface of all the analyzed methods.

In agreement with other studies SEM image observation in this research showed that the plastic hand curette produced similar results to those reported in other studies that also assayed conventional stainless steel curettes, ultrasonic scaler, and a teflon ultrasonic scaler and confirmed excessive damage was observed with the CUS [5,11].

The rotating brush with titanium bristles has been designed to be gentler on the implant surfaces and to offer easier access to implant threads, an advantage that also reduces treatment time [15].

Consequently, it is possible to suggest that an effective cleaning of the surface with a respectful instrument could improve the levels of the re-osseointegration of the implant with a regenerative technique. However clinical studies are needed to affirm this hypothesis.

When choosing the most appropriate instruments for mechanical debridement, the alterations produced by instrumentation and the effect of instrumentation on the treated surface's biocompatibility must be taken into account [8].

The evaluation of SEM images revealed similar alterations to surface morphology when the treatment time was increased from 1 min. to 3 min., with the exception of stainless steel curettes. Considering that the stainless steel curettes are a completely manual method, they may require more treatment time to achieve the complete disappearance of the treated surface, or they may require a longer treatment time for the alterations to become invisible to the observer.

It is important to keep in mind that all examiners agree on which method produces fewer alterations, although there is a low concordance level between examinators. For a greater concordance between observers, it has been suggested to develop a classification, which unifies the criteria for the evaluation of the implant surface.

Since titanium rotating brush have tested to be very respectful to the implant surface, further research is needed to evaluate the efficiency and the efficacy of the titanium rotating brush on removing the contaminants and adhering bacteria and the effect over different types of implant surface in a clinical aspect.

Conclusions

- Within the limitations of this *in vitro* study, the method of mechanical debridement has a significant influence to the degree of alteration of the implant surface. Rotating titanium brush is the method that produces less alterations to the implant surface since it shows statistically significant differences when compared with a teflon ultrasonic scaler, stainless steel curettes, and a conventional ultrasonic scaler.
- Instrumentation time would not appear to be key factor in relation to alterations to implant surface with the exception of stainless steel curettes which increases the degree of alteration when increase the treatment time.
- To test the clinical effectiveness of rotating titanium brush removing plaque and calculus of the implant surface further Randomized Clinical Trials comparing this rotatory brush against other mechanical debridement methods are needed.

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Conflict of Interest

The authors report no conflict of interest related to the present study.

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