Evaluation of the Cleaning and Alterations in Titanium Surfaces with Different Mechanical Instruments Using an Artificial Calculus

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Abstract

Purpose: The aim of this study was to evaluate in vitro the degree of cleanness (removal) and the surface texture of titanium discs after exposure to plastic and metallic curettes, an air-powder abrasive system, and an ultrasonic scaler.

Materials and methods: Fifty titanium discs manufactured in the same conditions as implants were used. Half of the discs had a machined surface (group 1), while the other half had their surfaces treated with TiO_2 particles followed by acid etching (group 2). To remove the artificial calculus, four methods were tested: Method 1 (M1) - scraping with a Teflon curette; Method 2 (M2) – scraping with a titanium curette; Method 3 (M3) – cleaning with an air-powder abrasive system; and Method 4 (M4) – cleaning with an ultrasonic scaler with a metal tip. Evaluations were made using images captured on a digital microscope, and the surface condition of each group and method were described.

Results: The results showed that for the discs of group 1, the artificial calculus deposits on the surfaces were more effectively removed with all methods when compared to group 2. The best results with respect to calculus removal and minimal surface damage were with method M1 for group 1 and method M3 for group 2. The numerical results indicated that there is a statistically significant difference between the methods ($p<.05$).

Conclusion: Removal of calculus is more difficult on rough surfaces, and metal instruments can lead to major damage to titanium surfaces.

Key Words: Titanium discs, Peri-implantitis, Artificial calculus, Surface decontamination

Introduction

In the last decades, implant installation has become a routine procedure for the oral rehabilitation of partially or totally edentulous patients because of its high reliability and success rates: 88% in maxilla and 93% in mandible [1]. The failure of the host tissue to establish or maintain osseointegration around dental implants is caused by either occlusal or parafunctional forces, premature loading, ill-directed stress [2,3], or microbial infection [2,4].

Moreover, it is well established that the inflammatory response caused by the presence of biofilm in peri-implant tissues follows similar patterns to that of the periodontal tissues in a susceptible host [5,6]. The removal of plaque and calculus from an implant surface is necessary to achieve long-term success of the implant [7]. The mechanical procedures to clean the implant should ideally be capable of effectively removing bacterial deposits without altering the implant surface, which may negatively affect the implant's biocompatibility [8]. Roughness on titanium implant surfaces may alter the response of the surrounding soft tissues and may directly cause posterior dental biofilm formation, making its proper removal difficult [8,9]. On the other hand, scaling procedures may also alter the oxide layer on the implant surface, which can result in increased corrosion [10]. Therefore, one should attempt to maintain the integrity of the implant surface and prosthetic components during scaling procedures [11].

Different instruments have been proposed for the scaling of the implants. However, there is no consensus in the literature regarding which methods are more effective and less damaging. Instruments for cleaning dental implants should ideally be effective, cause minimum damage to the titanium surface, and show durability [12]. Several instruments and procedures have been proposed as alternatives to the removal of bacterial deposits of the supra- and subgingival, peri-implant area [13]. The mechanical scaling performed with the aid of hand curettes of different materials is one of these alternatives [14]. These instruments can be made of plastic, carbon fiber, stainless-steel, or titanium. Some studies have attempted to evaluate these different materials regarding their cleaning efficacy and potential to alter the implant surface and prosthetic component, which could affect the implant's biocompatibility, biofilm formation, and therefore the implant's longevity [15,16].

The purpose of this study was to evaluate in vitro, using an artificial calculus, the degree of cleanness (removal) and the surface texture of titanium discs after exposure to plastic and metallic curettes, an air-powder abrasive system, and an ultrasonic scaler with a metal tip.

Materials and Methods

Titanium discs and artificial calculus deposition

Fifty (50) C.P. Titanium (Titanium grade 4) discs with a 6mm diameter and 3mm thickness were fabricated from the same bars used to manufacture titanium dental implants. Half of the discs had a machined surface (group 1 – *Figure 1a*), while the other half had their surfaces treated with acid-etch process was controlled to create a homogeneous disc surface topography. The discs were blasted with 50-100μm TiO_2 particles. After

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sandblasting the discs were ultrasonically cleaned with an alkaline solution, washed in distilled water and pickled with maleic acid ($HO_2CCH_2CHOHCO_2H$) (group 2 – *Figure 1b*). Ten discs (five per group) were used for roughness measurements using a Mitutoyo Surftest 211 Profilometer (Mitutoyo Corporation, Tokyo, Japan). The discs were produced by the company Implacil De Bortoli (São Paulo, Brazil).

A mixture were used of cyanoacrylate (Super Bonder Locatite, Itapevi, Brazil) and toluidine blue 1% (Cinética, Jandira, Brazil), in equal parts, for to reproduce an artificial calculus that had similar consistency, thickness, and adhesion to the surface of titanium as natural calculus (*Figure 2*). Then, the mixture was applied onto the disc with a spatula.

Methods for calculus removal

To remove the artificial calculus, four methods commonly used by dentists were tested: Method 1 (M1) - scraping with a Teflon Gracey curette 1/2 (American Eagle Instruments, Missoula, USA); Method 2 (M2) – scraping with a titanium Gracey curette 1/2 (Salvin, Charlotte, USA); Method 3 (M3) – blast cleaning with sodium bicarbonate (Ultra-Jet Olsen, Palhoça, Brazil); and Method 4 (M4) – cleaning with an ultrasonic scaler with a metal tip (Cavitron® JET Plus Ultrasonic Scaler, York, USA). For each method, five discs in each group were used. All procedures for each method were performed by the same specialist in periodontics who had approximately 10 years of clinical experience. The details of each method are described below:

Method 1 (M1) and Method 2 (M2): Scraping in one direction at an angle of approximately 45° until the artificial calculus was completely removed (by visual inspection).

Method 3 (M3): The jet with sodium bicarbonate particles was applied at an average distance of 2 to 3 cm at an angle of 45° relative to the discs at a pressure of 80 pounds per square inch (psi) in accordance with a previously reported study [17], until the artificial calculus was completely removed (by visual inspection).

Method 4 (M4): The ultrasonic tips were applied on the surface of the disc at an angle of 45°, until the artificial calculus was completely removed (by visual inspection).

For all of the proposed methods, the discs were fixed in a vise-grip. Images were captured with a digital microscope (DinoLite AM413ZT, São Paulo, Brazil) at a magnification of 50 x, and evaluations were made outlining the completeness of calculus removal and damage to the disc surface for each method. Using the software Image Tool 5.02 for Microsoft Windows™ was measured the total area of the disks and then, the total area with residues of calculus on the surface (*Figure 3*) and, an average was performed for each method in the groups and converted to percentage.

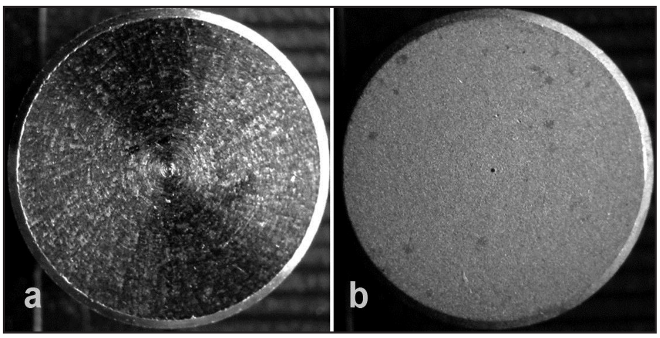

***Figure 1**. Images of the surface characteristics of the discs used. Machined disc (group 1) and surface-treated disc (group 2), respectively.*

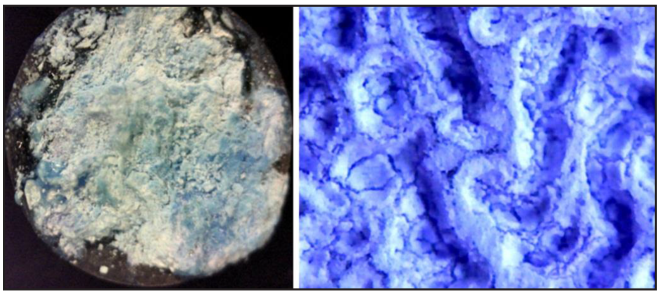

***Figure 2**. Images of the characteristics of the artificial calculus deposited onto the discs surface.surface.*

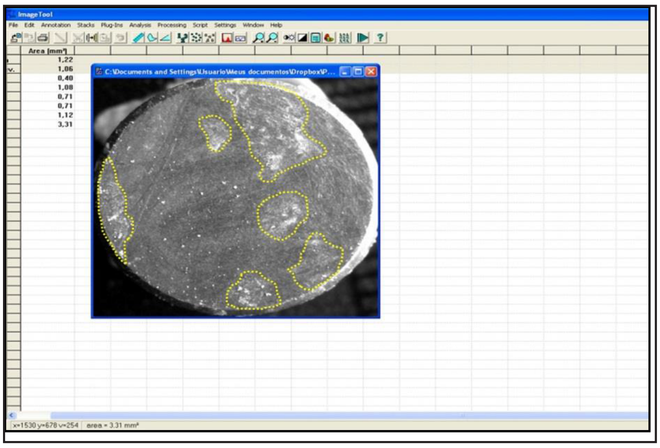

***Figure 3.** Image of software measurements on the disks surface to evaluate the effectiveness of each cleaning method.*

Statistical analysis

The analyses were performed on the results obtained from the measurements residues of calculus on the discs surface; statistical analyses were performed using a one-way Analysis of Variance (ANOVA) to determine the differences between the three four methods in the groups.

Results

The preparation process provides a discs surface with a surface roughness with the mean and standard deviation of the absolute values of all profile points (Ra) was 0.14 ± 0.033 µm for group 1 and 0.59 ± 0.056 µm for group 2. The total area of the disc measured and used as a parameter was 26.8 mm^2, considered as 100%.

Images obtained after the removal of the artificial calculus from the surface of the discs, regardless of the method used, revealed superior cleaning of the surfaces in group 1 with 88,4 % of general effectiveness versus 72% in the surface of the discs in group 2. For a one-way ANOVA test, the fact that *F* crit (2,312741) is smaller than *F* calc (27.86279) indicates that the test is highly significant, enabling the conclusion that there is an important effect among the groups at a significance of $p < .05$ (*Table 1*). The average values converted to percentage for each method in the groups are shown in the bar graph of *Figure 4*.

In group 1, the one-way ANOVA test demonstrated a significant difference between the methods (p = .000329). The use of Teflon curettes (M1) resulted in effective calculus

Table 1. *ANOVA test.*

Source of variation	SQ	gl	MQ	F	value-P	F crítico
Between groups	1438,336	7	205,4766	27,86279	6,78E-12	2,312741
Inside of groups	235,9868	32	7,374588			
Total	1674,323	39				

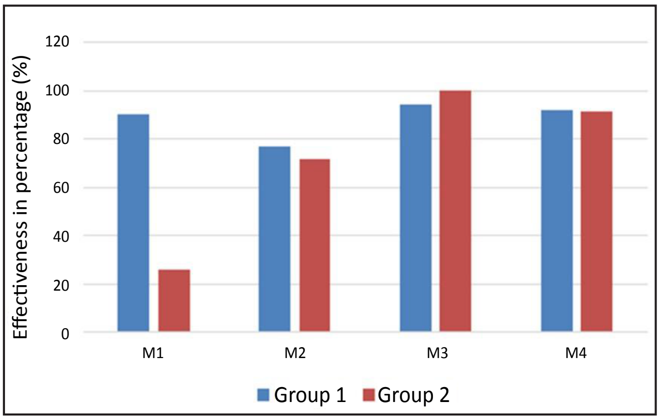

Figure 4. *Bar graph of the effectiveness in percentage of each method in the groups.*

removal (media = 90.3 %) and caused minor damage (marks) to the surface, while the use of metal curettes (M2) resulted in minor effectiveness in calculus removal among all studied methods with the smooth surface (media = 76.9 %). Removal by blast cleaning (M3) resulted in quasi-complete calculus removal (media = 94.4 %) but also left a rough surface. Similar results were observed with the use of ultrasonic tips (M4), which had a high effectiveness in the calculus removed (media = 91.8 %), but significantly damaged the surface of the discs. The results of group 1 are shown in *Figure 5*.

In group 2, the one-way ANOVA test demonstrated a significant difference between the methods (p = 7.47^{-10}). Teflon curettes (M1) were the least effective in removing calculus (media = 25.7 %), leaving a great deal of waste calculus on the surface of the discs. The use of metal curettes (M2) resulted in medium effective calculus removal (media = 71.6 %), leaving few calculus particles on the surface, but also left the surface badly damaged with deep grooves. Method M3 (application of an abrasive jet of sodium bicarbonate) had the best results with the complete removal of the calculus in all samples (media = 100%). The use of ultrasound (M4) resulted in very effective in removing calculus (media = 91.4 %), but with the badly damaged disc surfaces. The results of group 2 are shown in *Figure 6*.

Discussion

The purpose of this study was to test the surface decontamination of titanium discs and to compare four different surface decontamination methodologies. Finding an appropriate protocol for the surface decontamination of dental implants was of the utmost importance because several strategies for surface decontamination have been reported in the literature with inconclusive evidence. Nearly 10 million dental implants are placed each year, and studies report that a substantial number of these implants will be affected by peri-implantitis [17,18].

There is very limited evidence for one specific treatment strategy for peri-implantitis, but there is a general consensus that implants affected by peri-implantitis need to be decontaminated if re-osseointegration shall occur [5]. It is important to find a methodology that will decontaminate dental implants but at the same time leave the original surface intact, as damaged surfaces will affect tissue recuperation. Thus, after developing the artificial calculus, the contaminant particles were applied onto titanium discs with two surface characteristics, namely machined and rough, and four surface decontamination methods were tested.

It was difficult to standardize the decontamination methodology. Mechanical debridement with a titanium curette was utilized using regular hand force. This force was much higher than what is typically used with a brush, which had a major impact on the results. It is of the utmost importance to develop a methodology to standardize the force used. Furthermore, in this study, the amount of scraping and application time of the cleaning the methods were determined visually.

Rough implant surfaces speed up the rate of osseointegration and favor bone-to-implant contact as well as biomechanical stability [19,20]. On the other hand, it appears that more implants with rough surfaces are affected by peri-implantitis [21]. The implant's superficial roughness favors bacterial plaque adhesion when the surface is exposed to the oral environment, although there is no correlation between the

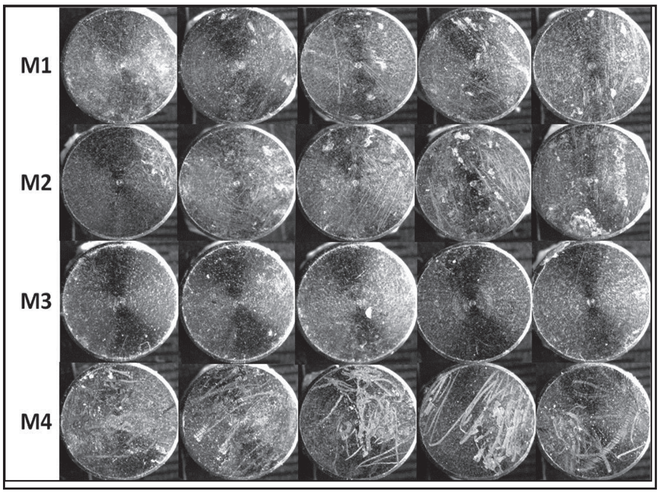

Figure 5. *Images of the discs in group 1 treated with each method.*

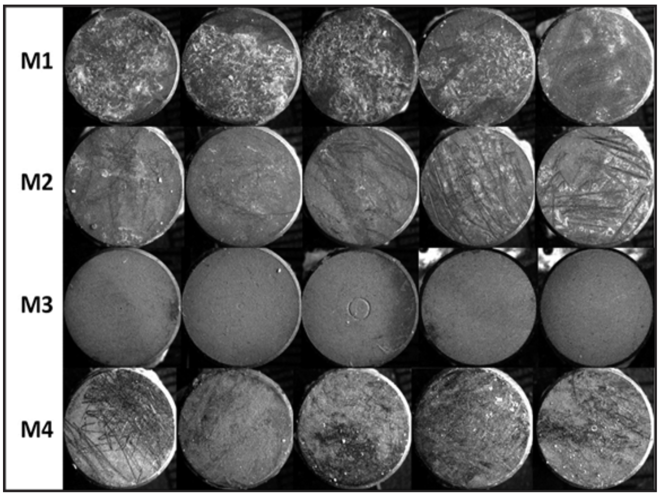

Figure 6. *Images of the discs in group 2 treated with each method.*

type of surface and the type of aggressive colonizing bacterial species [22]. The bacteria start growing and form biofilm after they have attached firmly onto the surface. This is a disadvantage of having a roughened surface. Many studies have shown the effect of roughened surfaces on increased bacterial adhesion for multiple surfaces including restorative material, teeth, and titanium [23]. In this study, the differences and difficulties in removing artificial calculus were compared, and the results showed that a rough surface complicates the decontamination process.

The majority of studies indicate that a rough surface in general creates a friendlier environment for microbial adhesion and report that abutments with rough surfaces harbor 25 times more bacteria subgingivally when compared to smooth abutments [24]. Tanner et al. (2005) tested four different materials with Ra values ranging from 0.05 to 0.51 μm bonded to the buccal surface of a molar and reported that after 24 hours intra-orally, the roughest surface had the highest colony-forming units of total facultative bacteria and plaque formation [25], a trend also observed in other studies [26]. The surface roughness significantly influenced the adhesion of the artificial calculus. For the discs in group 1, which had a surface roughness of 0.159 μm, calculus was more easily removed and was damaged less by the instruments used. However, for the discs in group 2, which had a surface roughness of 0.699 μm, there was greater difficulty in removing calculus and more surface damage.

For the removal of calculus and other contaminants from the surface of titanium, methods such as implantoplasty [27], using an air powder abrasive with different materials [28], using an ultrasonic scaler with metal tips [29], and using metal [30] or nonmetal [31] curettes are proposed. The most common method of physically removing bacteria, plaque, or calculus from a surface in the oral cavity is the use of a metal curette. However, the potential damaging effect of a curette to the titanium surface is of great concern [32]. Similarly, ultrasonic devices with metallic tips cause pronounced traces and remove substantial material from a titanium surface [33], which was demonstrated in the samples tested in this study. Moreover, these methods do not remove calculus very effectively, most likely because, as the inspection was visual, marks caused on the surface were mistaken as calculus removal by the operator. Therefore, some authors advise the use of plastic curettes or air abrasive systems [33]. The air abrasive system was demonstrated to be a good method of decontamination[51] and resulted in no damage to the underlying titanium surface. However, other authors showed the altered morphology of machined implants after administration of air powder abrasion [34], which was also observed in the samples of group 1. In addition to altering implant surfaces, there are additional concerns over the possibility of particles remaining after administration and the application of compressed air intra-orally. On the other hand, curettes made of Teflon showed adequate calculus removal from the machined surface with no surface damage but were ineffective on the rough surface. A cleaning method should fulfill the important criteria of not causing damage to the implant surface.

In conclusion, removal of calculus is more difficult on rough surfaces, and the use of metal instruments can lead to major damage to the titanium surface. For smooth surfaces (machined), the use of plastic curettes was suitable, while for rough surfaces, the use of an air abrasive system resulted in the most effective calculus removal with the least damage.

Clinical Relevance: Regardless of the method used by professional and surface characteristics (smooth or rough) of the components in rehabilitation with implants, cleaning is very difficult and should be performed with the aid of a microscope or loupes.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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