

Simulated damage of two implant debridement methods: Nonsurgical approach with Teflon and stainless steel hand scalers

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Abstract:

Background: Mechanical scaling is the most common treatment of periodontal and peri-implant tissue infections. **Aims:** This study aimed to evaluate the effect of mechanical prophylactic therapy on the residual stresses in the implant and hand scaler. **Settings and Design:** For finite-element analysis, an implant-supported prosthesis was created using modeling software with 3 mm of exposed threads. For simulation of a prophylactic mechanical debridement, the active face of the shank was disposed of in contact with the last thread exposed at a 90° angle. **Materials and Methods:** In the analysis software, the contacts were defined as rough between the instrument and the implant. The cortical bone was fixed and a load of 10 N was applied to the instrument cable. Two simulations were performed according to the instrument material: stainless steel or Teflon. Von-Mises results were obtained. **Statistical Analysis Used:** No statistical test was used, but, the 500 higher stress peaks in the implant and in the instrument were analyzed for qualitative comparison. **Results:** Mechanical prophylactic therapy generates higher residual stress on the implant with a stainless steel instrument. There was no difference between the materials for the active tip of the instrument, and the active portion of the shank was the region which concentrated more stress. **Conclusions:** It is suggested that hand scalers in Teflon are less damaging to the implant, but more susceptible to deformation and possible early failures.

Key words:

Cleaning instruments, dental/oral implants, hand instruments, implant surfaces, peri-implantitis

INTRODUCTION

The oral cavity is colonized by approximately 750 species of microorganisms that form dental biofilm when organized and involved in an extracellular polysaccharide matrix.^[1,2] The biofilm can adhere to soft, solid,^[3] natural, or artificial surfaces of the oral cavity^[4] such as dental implants, leading to pathologies relevant to dentistry. Among oral pathologies, dental caries and periodontitis are the two most common diseases related to dental biofilm action.^[5]

In patients with dental implants, biofilm accumulation in the peri-implant region may develop an inflammation reaction called peri-implantitis,^[6] which is similar to periodontitis.^[7] This inflammatory process promotes progressive bone loss, thus exposing more threads and allowing more bacterial proliferation.^[8] Exposed threads in contact with the oral environment provide a favorable niche to bacterial adherence.

Mechanical scaling with periodontal hand scalers and ultrasonic tips is the most common treatment of periodontal and peri-implant

tissue infections.^[7,9,10] Periodic scaling and cleaning of biofilm accumulation niches are a noninvasive option, acting in prevention and production of excellent clinical results.^[7,11-13] In general, the combination of this control therapy associated with instruction and patient hygiene motivation culminates in preventing the disease progression.^[13,14] Despite the similarities, implant prostheses need extra care, since titanium surface damages could facilitate the accumulation of bacterial biofilms^[7,15,16] due to the increase in surface roughness.

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Some studies suggest the use of plastic tips for hand scalers and ultrasonic instruments for plaque removal due to their less structural damage in implants and components in comparison to metallic instruments.^[11,12,15-17] Using scanning electron microscopy it has been reported that the use of metal hand scalers is capable of damaging the titanium surface^[6,17] so that results of surface roughness by optical profilometry demonstrate greater depth and width of the defects caused by the instrumentation performed with these hand scalers compared to plastic hand scalers.^[15] In spite of this, there are no reports in the literature of the residual stresses generated between the friction of the implant surface and the different instrument tips, which could aid in visualizing mechanical problems and in preventing plastic deformations.

Among the methods used in implantology,^[18,19] computational mathematical analysis using the finite-element method is widely used which can demonstrate the effect of contact between materials.^[20] Thus, the purpose of this study was to compare the effect of mechanical prophylactic therapy on residual stresses on the implant surface and on the active tip of the instrument, varying the type of hand scaler material. The hypotheses of the study were that: (1) the rigid hand scaler would concentrate more stress in the implant and (2) there would be no difference in the stress concentration in the hand scalers.

MATERIALS AND METHODS

Tridimensional modeling

For this study, a previously validated bone-level tapered implant model (Straumann Institute, Waldenburg, Switzerland) of 4.1 mm × 10 mm was used.^[20] The complete three-dimensional (3D) model presented a cemented fixed prosthesis on solid abutment and the implant was inserted into a slice of cortical and medullary bones. Each geometric structure of the components of this system was represented, including a fixing screw and cement line between the crown and abutment. Following ISO 14801, the implemented 3D model presented 3 mm of the exposed threads representing a bone defect of 4 walls with insertion loss. For simulation of a prophylactic mechanical debridement, a generic model of periodontal hand scaler was created based on the shank geometry of Gracey's hand scaler. The active face of the shank was disposed of in contact with the last thread exposed at a 90° angle. Each solid was considered a 3D volumetric body and exported in STandard for the Exchange of Product model data format for the analysis software.

Preprocessing

In computer-aided engineering software (ANSYS 17.2, ANSYS Inc., Houston, TX, USA), the 3D model was subdivided into a finite mesh of quadratic tetrahedral elements totaling 651,239 nodes and 390,818 elements. A mesh convergence test with 10% coherence was used for this.^[21] Next, the contacts between the bodies were defined as being bonded to all components of the implant prosthesis. The type of contact selected for the hand scaler and implant was rough. The system fixation occurred at the cortical bone base and the applied force was in the Z (occlusal) direction with an intensity of 10 N in the hand scaler cable. Displacement of the hand scaler in the X and Y directions was prevented from

occurring by lateral movements between the hand scaler and the implant [Figure 1]. The structural information required to perform the mechanical structural analysis was the elastic modulus and Poisson ratio, as based on previous studies [Table 1].^[22-27] Two different simulations were performed: the hand scaler (1) presenting the mechanical properties of stainless steel or (2) Teflon.

RESULTS

The results required for the implants and for the shank of the hand scaler were in von-Mises stress (KPa). A qualitative stress map was photographed in these structures and the 500 largest stress peaks in these structures were exported and plotted in bar charts for qualitative comparison. In the implant body [Figure 2], it is possible to notice greater residual stress accumulation on the titanium surface which was debrided with a metal hand scaler. Thus, in the bar graph of Figure 2, it is possible to notice a superior ability of the Teflon hand scaler to soften damage. Considering the hand scalers themselves, the most stressful region was the active portion of the shank, highlighted with circles in Figure 3. A great similarity can be seen between the stress distribution of both instruments, as well as the magnitude of the stress peaks [Figure 3].

DISCUSSION

The purpose of this study was to compare the effect of mechanical prophylactic therapy on residual stress on the implant surface and on the active tip of the hand scaler, varying the type of hand scaler material. The results of the present study demonstrate that the residual stress generated by the debridement can be modified depending on the instrument material, thus accepting the first hypothesis.

Figure 3 shows that the implant surface can be impacted by more stress from the stainless steel hand scaler, justifying why some studies have found greater roughness and grooves in the titanium when this instrument is used. Von-Mises stress demonstrates possible failure regions in metal structures through finite-element analysis, and it can be extrapolated as a predictor that the more stressed regions will fail earlier. Despite this, the results of the present study serve to illustrate how two-hand scalers indicated for the same treatment and with the same contact force can induce different results in the implant. As the literature already reports the full capacity for prophylaxis with plastic hand scalers,^[7,11-13,15,17] it is clear that its indication is less harmful for use on delicate surfaces. However, the present study did not simulate a

Table 1: Mechanical properties of each material and structure used in the study: Elastic modulus in gigapascal and Poisson ratio (adimensional)

Material/structure	Elastic modulus	Poisson ratio
Titanium ^[22]	110	0.35
Lithium disilicate ^[23]	95	0.30
Resin cement ^[24]	5.1	0.27
Medullar bone ^[25]	1.37	0.30
Cortical bone ^[25]	13.7	0.30
Teflon ^[26]	0.3	0.41
Steel ^[27]	200	0.33

series of oscillatory movements, such as what was promoted by using an ultrasonic device. The literature reports that ultrasonic prophylaxis is more efficient and practical by removing biofilm more easily in a shorter clinical time.^[13,28] As the ultrasonic tips can be found in plastic and metal,^[28] the results of the present study can serve as a theoretical basis for selecting plastic tips, due to its less aggressive behavior on the implant. In the same way, metal instruments and burs are only recommended in cases requiring the smoothing of surface roughness.^[6]

Several studies have been conducted with the purpose of analyzing the effect of different prophylactic treatments on titanium implant surfaces.^[7,15,13,28] The surface roughness method stands out as predominant, which, in association with photomicrography, show the different potential of damage in the implant structure. Thus, the present study is notable for bringing information regarding superficial residual stresses in both implant and periodontal instruments.

An important point of the results generated in the present simulation is the analysis of the hand scaler active tip. In Figure 3, both tips of the instruments presented similar stress distribution. Thus, instrument geometry was more important than the structural property reported for the final result. Therefore, a plastic hand scaler under the same conditions will generate as much stress as a metal hand scaler. In this way, plastic hand scalers require more attention from the clinician because, as the resistance of the plastic is inferior, failures such as shape loss and fractures can occur more easily by modifying the active tip of the instrument. Therefore, the second hypothesis was also accepted.

Depending on the type of device used and the prophylactic method, changes can be made on the surface of the implant,^[7,13,15,28] especially when using a metallic instrument.^[7,15] This assertion is in accordance with the

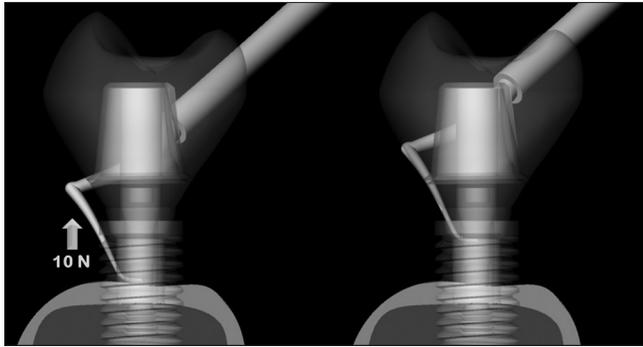


Figure 1: Boundary conditions: Load applied to pull the hand scaler in an occlusal direction with 10 N

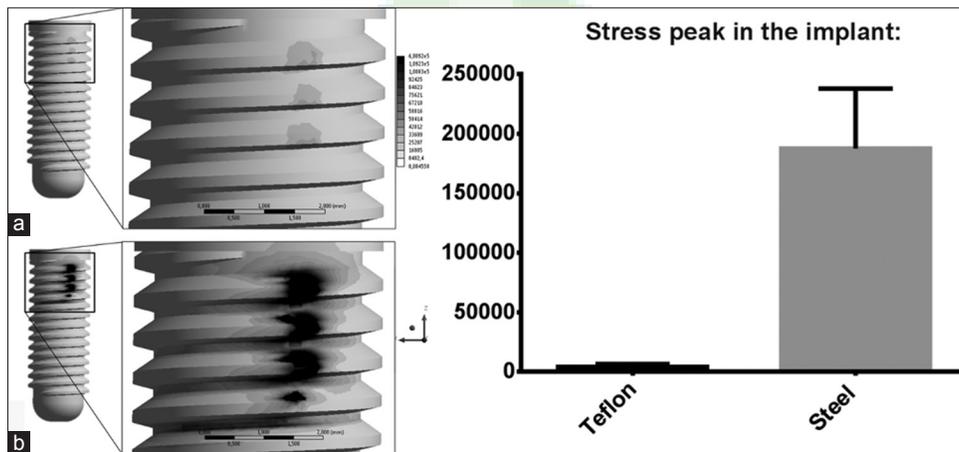


Figure 2: Residual stress on the titanium surface according to the hand scaler material used in the computational test load application: (a) Teflon; (b) Steel

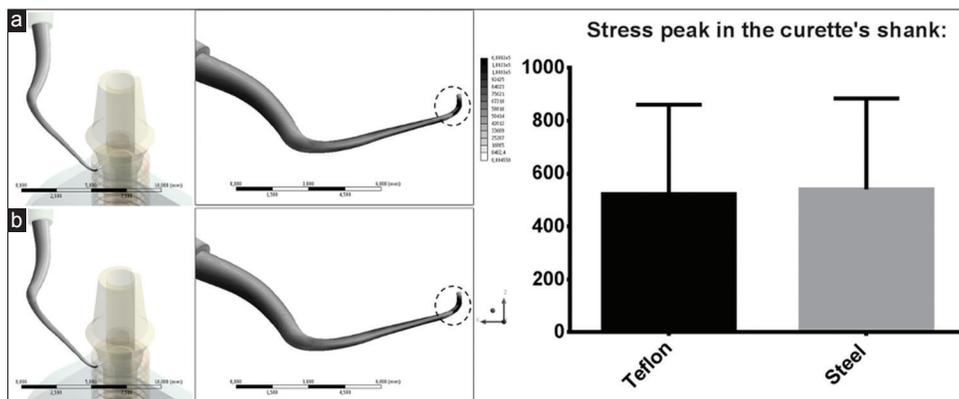


Figure 3: Residual stress in the hand scaler according to the material type: (a) Teflon; (b) Steel

findings of the present study, which demonstrate an increase in the noxious stresses for this therapeutic modality when using metal hand scalers. Although the oral environment presents a variety of anatomy in each clinical case due to the pathogenicity of the microbiota and host response, the bone defect herein was created to allow the hand scaler complete freedom of movement. This should be taken into consideration when choosing the prophylactic method to be used, since anatomical modifications may hinder the treatment.^[17] In addition, the materials simulated herein are isotropic and homogeneous, without defects or considering ideal contacts.^[20] Therefore, this study serves as a complement to the *in vitro* and *in vivo* studies in the aspect of elucidating the mechanical behavior generated by the friction between instrument and osseointegrated implant.

CONCLUSIONS

Among the limitations of this computational study, it can be concluded that the residual stresses during mechanical prophylactic therapy in the implant and in the hand scaler vary according to the type of instrument material. Moreover, the hand scaler in Teflon is less damaging to the implant, yet more susceptible to deformations and possible early failures.

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Conflicts of interest

There are no conflicts of interest.

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