Peri-implantitis has become an increasingly common condition among patients undergoing implant-prosthetic rehabilitations. In a recent retrospective cohort study, it was found that approximately one-third of the patients and one-fifth of all implants experienced peri-implantitis.1

Peri-implantitis is a complex multifactorial disease characterized by tissue inflammation and progressive bone loss. Though many factors are involved in disease pathogenesis, it is well established that the primary cause of peri-implantitis is the bacterial colonization of the implant surface.2–5 Therefore, biofilm removal is assumed to be crucial for peri-implantitis treatment. Different approaches have been proposed to eliminate bacterial biofilm from implant surfaces, including mechanical, chemical, and combined treatments. Mechanical treatments disrupt the biofilm by means of a direct physical action of the instrument, or a medium, on the implant surface. These include curettes of different materials, air polishing, and ultrasonic and rotary instruments (burs and brushes).6 Due to the intrinsic limitations of these instruments in achieving a complete biofilm removal, chemical agents are often used as an adjunctive treatment,7 including chlorhexidine, citric or orthophosphoric acid, and sodium hypochlorite.8

Efficacy of Combined Mechanical and Chemical Decontamination Treatments on Smooth and Rough Titanium Surfaces and Their Effects on Osteoconduction: An Ex Vivo Study

Marco Lollobrigida, DDS, PhD1/Luca Lamazza, MD, DDS1/Marisa Di Pietro, Mchem, PhD2/Simone Filardo, MD, PhD3/Mariangela Lopreiato, CTF, PhD4/Alessia Mariano, CTF, PhD Student2/Giuseppina Bozzuto, MBiolSci, PhD4/Agnese Molinari, MBiolSci4/Francesca Menchini, MPhys, PhD Student5/Adriano Piattelli, MD, PhD6/Alberto De Biase, MD1

Purpose: The aim of this ex vivo study was to assess the ability to remove oral biofilm by different combinations of mechanical and chemical treatments on smooth and rough titanium surfaces, as well as their impact on osteoconduction.

Materials and Methods: Forty-eight sandblasted acid-etched (SLA) and 48 machined titanium disks were contaminated with oral bacterial biofilm and exposed to the following treatments: (1) titanium brush (TB), (2) TB + 40% citric acid (CA), (3) TB + 5.25% sodium hypochlorite (NaOCl), (4) air polishing with glycine powder (AP), (5) AP + 40% CA, and (6) AP + 5.25% NaOCl. Residual bacteria and chemical contamination were assessed using viable bacterial count assay, scanning electron microscopy (SEM), and x-ray spectroscopy (XPS). Human primary osteoblast (hOB) adhesion and osteocalcin (OC) release were also evaluated.

Results: The microbiologic, SEM, and XPS analysis indicate a higher biofilm removal efficiency of combined mechanical-chemical treatments compared with exclusively mechanical approaches, especially on SLA surfaces. SEM analysis revealed significant alterations of surface microtopography on the disks treated with TB, while no changes were observed after AP treatment. OC release by hOBS was mainly decreased on disks treated with CA and NaOCl.

Conclusion: The combination of mechanical and chemical treatments provides effective oral biofilm removal on both SLA and machined implant surfaces. NaOCl and CA may have a negative effect on osteoblasts cultured on SLA samples. Int J Oral Maxillofac Implants 2022;37:57–66. doi: 10.11607/jomi.9105

Keywords: antiseptics, implant decontamination, peri-implantitis, surface decontamination
Differently from mechanical instruments, antiseptic agents have the ability to kill bacteria, thus exerting a synergistic action with conventional debridement techniques. However, only few studies have investigated the cleansing effectiveness of combined mechanical-chemical treatments in a preclinical setting.

Beyond the choice of treatment, the microtopographic characteristics of implants are a further reason of concern dealing with contaminated surfaces. If, on the one hand, moderately rough surfaces were demonstrated to enhance hard and soft tissue interfaces, on the other hand they favor bacterial colonization when an epithelial seal is missing around implants. Moreover, complete biofilm removal on rough surfaces is not easily feasible in most clinical situations, and for this reason, some authors even demanded to return to completely machined or hybrid implants.

This ex vivo study aimed to assess the ability to remove oral biofilm by different combinations of mechanical and chemical treatments on smooth and rough titanium surfaces, as well as their impact on osteoconduction.

**MATERIALS AND METHODS**

**Study Population**

Three healthy male volunteers, aged between 25 and 30 years, were enrolled in the study. Inclusion criteria were the absence of periodontal disease, good general health, and no antibiotic treatment in the last 6 months. They were asked to wear an intraoral splint carrying six titanium disks for 24 hours (Fig 1). The volunteers kept the splints in place for the duration of the experiments, except during meals, maintaining a regular Mediterranean diet.

Before the experiment, all the volunteers underwent a professional oral hygiene session and provided written informed consent. The protocol was approved by the Ethics Committee of the Sapienza University of Rome (prot. N. 756/17, REF. CE 4621).

**Titanium Disks**

Disks of commercially pure titanium (grade 4 ASTM, 5-mm diameter with 3-mm thickness) were used for the study. The disks were divided into two groups: (1) disks with moderately rough (Sa [average roughness] 1.30 μm) sandblasted and acid-etched (SLA) surface (Camlog Promote) and (2) disks with machined (turned) surface. Each disk was sterilized by autoclaving before the experimental procedure.

**Treatment Procedures**

The contamination of the disks was obtained by wearing the splints and suspending any oral hygiene maneuver. After 24 hours of biofilm accumulation, the disks were aseptically removed from the splints using sterile plastic instruments, gently washed with sterile saline solution (NaCl 0.9%), and immediately treated.

Combinations of titanium brush (TB; TiBrush, Straumann), air polishing (AP; Easyjet Perio, Mectron Medical Technologies) with glycine powder (25 μm granulometry, Mectron Glycine Powder, Mectron Medical Technologies), 5.25% liquid sodium hypochlorite (NaOCl; Chloraxid 5.25%, Cerkamed), and 40% liquid citric acid (CA; Cerkamed) were tested, and the disks were randomly assigned to one of the following treatment groups:

1. TB
2. TB+NaOCl
3. TB+CA
4. AP
5. AP+NaOCl
6. AP+CA

All procedures were performed by the same operator (M.L.). Mechanical treatments were performed for 20 seconds on each side of the disks. TB was used with a contra-angle handpiece, in continuous rotation at a speed of 600 rpm, parallel to the surface, under continuous irrigation of sterile saline solution (20 mL). The procedure was performed manually applying gentle pressure. Considering the dimensions of the disk with respect to the brush dimensions, each brush passage covered the entire disk surface; 10 brush passages were performed for each surface (1 passage every 2 seconds). As for the AP procedure, a mechanical positioner was used to maintain a constant 2-mm distance between the nozzle and the disks and a 90-degree angle of incidence. With the nozzle in fixed position, the disks were moved manually by the operator using thin sterile tweezers, thus obtaining a relative motion of the nozzle over the disks. At the end of the treatments, the disks were washed with 20 mL of sterile saline solution to remove debris. As for the combined treatments (TB+NaOCl, TB+CA, AP+NaOCl, and...
AP+CA), the disks were first treated with TB and AP as described earlier, then immediately immersed in 1 mL of test solutions (NaOCl and CA) for 2 minutes in sterile 24-multiwell plates.

**Microbiologic Analysis**

For the microbiologic analysis, a total of 48 machined and 48 SLA disks were treated. Each experimental group included four disks in two independent experiments, for a total of eight disks per group. As controls, a total of 24 machined and 24 SLA untreated disks were used. Of the six disks mounted on each splint, four were used as tests and two as untreated controls.

The treated and untreated disks were transferred to sterile tubes containing 2 mL of sterile D/E neutralizing broth and glass beads and vortexed for 2 minutes. Ten serial dilutions of the resuspended biofilm solutions were then performed in sterile saline solution, and two aliquots (1 mL) were plated in Columbia Blood Agar (CBA, OXOID) supplemented with 5% sheep blood for aerobic bacteria, and two aliquots in Anaerobe Basal Agar (OXOID) supplemented with 5% horse blood for anaerobic bacteria. The plates were incubated at 37°C for 1 to 2 days under aerobic or anaerobic conditions using the Anaerocult A (Merck) system. The viable bacterial count was performed and expressed as total colony-forming units (CFUs)/disk. The neutralizing activity of D/E neutralizing broth was verified according to DIN EN 1040.

**Scanning Electron Microscopy (SEM) Analysis**

Two disks for each experimental group and two untreated disks were fixed with 2% glutaraldehyde in 0.1 M cacodylate buffer (pH 7.4) at room temperature for 2 hours, post-fixed with 1% OsO₄ in the same buffer for 1 hour, dehydrated through a graded ethanol series, critical point dried with CO₂ (CPD 030 Balzers device, Bal-Tec, Balzers), and gold coated by sputtering (SCD 040 Balzers device, Bal-Tec). The disks were analyzed at different magnifications using a field emission gun scanning electron microscope (FEG-SEM; Inspect FTM, FEI) with a potential difference of 10 kV.

**Spectroscopic Analysis**

Surface chemical analysis of treated and untreated SLA disks was carried out using x-ray photoelectron spectroscopy (XPS; Escalab MKII, Vacuum Generators). The disks were treated according to the procedures described earlier and located in the pre-chamber of the XPS, in a vacuum of approximately 10⁻⁷ mbar. To analyze photoelectron spectra, the disks were excited with MgKα non-monochromatic radiation at 1,253.6 eV. All disks were analyzed within 6 hours to reduce possible contamination.

**Cell Culture**

Human primary osteoblasts (hOBs) were isolated from patients undergoing total knee and hip arthroplasty surgery, as previously described,¹⁵ and used to assess cytocompatibility of previously contaminated disks. For each experimental group, treated disks were sterilized by autoclave and placed in a 96-well plate. hOBs were seeded at a density of 4 × 10³/disk and incubated at 37°C and 5% CO₂.

Osteocalcin (OC) levels in culture medium were determined after 3, 7, and 14 days of incubation by an enzyme-linked immunosorbent assay kit (FineTest ELISA, Fine Biotech) according to the manufacturer’s instructions. Optical density absorbance was measured at 450 nm using a microplate reader (Appliskan, Thermo Fisher).

Lastly, SEM analysis was performed on 7-day hOB cultures, as described earlier, to analyze cell adhesion and spreading on the treated surfaces. Two disks for each experimental group were observed.

**Statistical Analysis**

Given the difference between the effects of the decontamination treatments on machined and SLA disks as the primary endpoint, with an estimated effect size f = 0.5, eight disks per experimental group (six treatment groups, namely, TB, TB+NaOCl, TB+CA, AP, AP+NaOCl, and AP+CA) are needed for a statistical power of 80% with a significance level of α = .05.

Experiments to determine the OC production by hOBs, through ELISA assay, were replicated three times, performing three independent experiments, each performed in duplicate.

Data were expressed as means ± SD of at least three replicates from two independent experiments. Statistical analysis was performed using two-way analysis of variance (ANOVA) with a Tukey multiple comparisons test. P values were considered statistically significant when P < .05. Statistical analyses and graphs were produced in GraphPad Prism software v. 7.05.

**RESULTS**

**Microbiologic Analysis**

The antibacterial effect of different combinations of mechanical and chemical treatments against human oral biofilm formed on machined and SLA disks was investigated via the viable count of aerobes and anaerobes (Table 1). All treatments were effective against 24-hour biofilm on both surfaces compared with the control (P < .00001). The combined treatments (TB+NaOCl, TB+CA, AP+NaOCl, and AP+CA) were significantly more effective than the mechanical treatments alone (TB and AP, P < .05), as evidenced by a higher reduction of the...
viable bacterial count. No significant differences in the decontamination activity were found between the mechanical treatments alone. TB had more effective results on the machined disks compared with the SLA disks ($P = .033$). By contrast, the combined treatments showed no significant differences in the antibacterial activity when applied on machined or SLA surfaces.

**SEM Analysis**

The microscopic analysis (Fig 2) showed that all treatments were able to dislodge the biofilm from the disk surface compared with the untreated controls, as evidenced by the absence of organized biofilm. However, following TB treatment, large amounts of organic debris and residual bacteria, isolated or in clusters, remained

---

**Table 1**

Viable Counts (Log CFU/disk) of Aerobic and Anaerobic Bacteria Following Physical or Chemical-Physical Treatments on Human Oral Biofilm Formed on Machined and Rough SLA Disks After 24 Hours

<table>
<thead>
<tr>
<th></th>
<th>CTRL</th>
<th>TB</th>
<th>TB+NaOCl</th>
<th>TB+CA</th>
<th>AP</th>
<th>AP+NaOCl</th>
<th>AP+CA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Machined</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerobes</td>
<td>6.0 ± 0.2</td>
<td>4.4 ± 0.7*</td>
<td>0.0*§</td>
<td>0.0*§</td>
<td>3.7 ± 0.4*</td>
<td>0.0*§</td>
<td>0.0*§</td>
</tr>
<tr>
<td>Anaerobes</td>
<td>5.9 ± 0.3</td>
<td>4.3 ± 0.8*</td>
<td>0.0*§</td>
<td>0.0*§</td>
<td>3.6 ± 0.5*</td>
<td>0.0*§</td>
<td>0.0*§</td>
</tr>
<tr>
<td><strong>SLA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerobes</td>
<td>6.2 ± 0.3</td>
<td>5.8 ± 0.3*</td>
<td>0.0*§</td>
<td>0.0*§</td>
<td>4.5 ± 0.6*</td>
<td>0.0*§</td>
<td>0.0*§</td>
</tr>
<tr>
<td>Anaerobes</td>
<td>6.1 ± 0.3</td>
<td>5.7 ± 0.2*</td>
<td>0.0*§</td>
<td>0.0*§</td>
<td>4.4 ± 0.5*</td>
<td>0.0*§</td>
<td>0.0*§</td>
</tr>
</tbody>
</table>

CTRL = control contaminated disks; TB = titanium brush; NaOCl = sodium hypochlorite; CA = citric acid; AP = air polishing.

* $P < .05$ vs CTRL.
§ $P < .05$ vs TB and AP.

---

**Fig 2** SEM images of intraorally contaminated disks with machined and SLA surface after 24 hours of intraoral contamination (600×) and after treatment with TB, TB+NaOCl, TB+CA, AP, AP+NaOCl, and AP+CA (10,000×).
on the SLA disk, while only few organic debris were observed on machined disks. AP machined disks did not show residual contamination, while few organic debris were detected on SLA disks. As for the combined treatments, NaOCl was demonstrated to dissolve residual bacterial cells to a higher extent than citric acid on both machined and SLA disks after TB treatment. By contrast, CA seemed to be more effective than NaOCl in dissolving residual organic debris after AP treatment.

Spectroscopic Analysis

The qualitative analysis (Fig 3) revealed the presence of titanium on all treated disks. The peaks related to oxygen and carbon were also clearly detected on all disks. By performing higher-resolution scans in the energy ranges corresponding to the main elements, it could be noted that carbon was present both in an adsorbed atomic form and bonded to other elements. Oxygen occurred in a chemically bonded form with other elements, differently for each disk. The results of the semi-quantitative analysis are reported in Table 2. Interestingly, the disks treated with NaOCl had the highest percentage amount of titanium, while the samples treated with CA showed a lower amount. TB and TB+CA treated disks had a high amount of carbon, while lower content was detected on TB+NaOCl, AP, AP+NaOCl, and AP+CA treated disks. The analysis also revealed the presence of silicon on all the disks treated with AP.
To determine which combination of mechanical and chemical treatments was less detrimental for biologic activity of cells, the amount of OC was measured in the cell culture medium of osteoblasts seeded on disks and cultured for 3, 7, and 14 days by ELISA assay. The amount of OC produced at 3, 7, and 14 days by osteoblasts seeded on cell culture plates was used as the control (Fig 4).

At 3 days, a lower OC amount was detected in both machined and SLA TB and AP combination compared with the control. At 7 days, a significantly higher amount of OC was detected in smooth TB+CA, smooth AP, and smooth AP+NaOCl ($P < .001$), whereas a statistically lower amount was measured in SLA TB+CA, SLA AP+CA, and SLA AP+NaOCl. At 14 days, a significantly higher amount in OC production was detected in SLA TB, smooth TB+CA, smooth TB+NaOCl, smooth and SLA AP, smooth AP+CA, and smooth AP+NaOCl, whereas a statistically lower amount was measured in smooth TB, SLA AP+CA, and SLA AP+NaOCl.

SEM analysis of cells seeded on disks after 7 days of culture showed that osteoblasts adhered to all samples (Fig 5). On TB machined disks, cells exhibited a more rounded shape morphology compared with TB SLA disks, where cells had a polygonal morphology, more spread extremities characterized by microvilli, and cell protrusions anchoring to the substrate. In the AP machined samples, cells showed a more flattened morphology compared with cells seeded on AP SLA. Cells did not reach confluence in any sample. Overall, hOB cells apparently had a lower proliferation rate on SLA disks TB+NaOCl and AP+NaOCl compared with SLA disk TB and AP, while they exhibited a scarce poor adhesion on the AP+CA sample.

| Table 2 Semi-quantitative Analysis of Samples Following Physical or Chemical-Physical Treatments on Human Oral Biofilm Formed on SLA Disks After 24 Hours |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 | CTRL (Contaminated disk) | CTRL (sterile disk) | TB              | TB+NaOCl        | TB+CA           | AP              | AP+NaOCl        | AP+CA           |
| N (1s)          | 5.7              | 1.3              | 9.3             | 1.2             | 7.0             | 6.6             | 3.8             | Traces          |
| Na (1s)         | –                | –                | –               | Traces          | –               | 7.0             | Traces          | –               |
| C (1s)          | 75.8             | 48.4             | 66.1            | 47.4            | 66.4            | 39.1            | 43.7            | 47.7            |
| O (1s)          | 18.5             | 37.7             | 22.9            | 40.9            | 25.3            | 39.5            | 41.7            | 32.3            |
| Ti (2p)         | –                | 12.6             | 1.7             | 10.5            | 1.3             | 4.5             | 5.9             | 2.1             |

CTRL = control disk; TB = titanium brush; NaOCl = sodium hypochlorite; CA = citric acid; AP = air polishing.
DISCUSSION

In this ex vivo study, the biofilm removal efficiency of various combinations of mechanical and chemical treatments was assessed on both machined and SLA titanium surfaces, indicating a higher biofilm removal of combined mechanical-chemical treatments compared with exclusively mechanical approaches, especially on SLA surfaces. It has been reported that rough surfaces can affect the progression of peri-implantitis as well as long-term results of surgical therapies by promoting plaque accumulation and proliferation at higher rates than smooth surfaces. On the other hand, rough surfaces play a pivotal role during the first stages of peri-implant bone healing and, accordingly, may enhance re-osseointegration after the surgical therapy of peri-implantitis. The identification of effective decontamination procedures for rough implant surfaces thus represents a high road to improve the long-term results obtained by the surgical treatment of peri-implantitis.

Several studies have assessed the efficacy of titanium brushes in cleansing infected implants compared with other treatments but with a similar mechanism of action (ie, manual curettes). In an ex vivo study on intraorally contaminated titanium disks with a machined surface, Al-Hashedi et al reported the highest decontamination with titanium brush and metal curettes compared with plastic curettes and erbium:yttrium-aluminum-garnet (Er:YAG) laser. Using a similar study design but on an SLA surface, John et al reported significantly higher decontamination for titanium brush compared with metal curettes. Interestingly, the aforementioned studies did not report any alteration on the implant surface, in contrast with the findings of the present study and the present authors’ previous observations. Another remarkable finding of the present study is the observation of large amounts of residual bacteria on SLA disks treated with TB. Translating this result to a clinical situation with long-standing plaque accumulation and difficult access to the implant surface as often found in deep bone defects, it follows that TB alone cannot be considered a proper approach to peri-implantitis.

In the present study, air polishing with glycine powder has proven to be particularly indicated for both its oral biofilm removal efficiency and the limited impact on the implant surface. Several in vitro studies have investigated the effects of air polishing on contaminated implant surfaces, reporting encouraging results under ideal in vitro working conditions. Sodium bicarbonate and glycine are currently the most-used powders for air polishing. It has been observed that...
hard and large-sized powders, like sodium bicarbonate, present the highest cleaning capacity. However, they can alter implant microtopography as well. Low-abrasive powders, like glycine, have a limited impact on the implant surface, though a lower decontaminating efficacy was reported. In the present study, AP demonstrated a higher cleaning capacity compared with TB, though some organic debris remained on SLA disks. Moreover, as already noted for TB, proper surgical access is also necessary when using air polishing in vivo, since as the nozzle’s angle of incidence varies, the cleaning action of air polishing significantly decreases, falling to zero at the level of undercuts between the implant threads. These data support the idea that, in a clinical context, air polishing may not be sufficient as a single treatment approach for peri-implantitis.

For several years, the complementary use of antiseptics has been advocated to compensate the limits of mechanical treatments discussed earlier. In the present study, the association of both the approaches yielded the highest oral biofilm removal, as indicated in the microbiologic and SEM analysis. The present observations also seem to suggest the use of NaOCl in case of abundant residual biofilm (eg, after TB treatment), due to its high antimicrobial activity. Translated to a clinical setting, this would be the case of infected implants with difficult access to mechanical instruments. In any other case, CA treatment may be indicated due to its lower toxicity and possible positive impact on the bone. Indeed, CA has been shown to be effective against oral bacterial biofilms on titanium surfaces, though to a lower extent than NaOCl. In the present authors’ previous study, a similar antimicrobial activity of CA and NaOCl against the biofilm formed by specific oral pathogens, such as Porphyromonas gingivalis and Streptococcus mutans, was also reported. Notwithstanding, in the present study, residual bacteria were still visible on TB+CA disks; however, no viable bacteria were observed on all disks that received combined treatments, and hence, it can be assumed that these residual cells might be dead. Similarly, for the SEM analysis, the implants treated by AP+CA showed the highest decontamination, as already observed by Hakki et al, who found the highest decontamination with air polishing with glycine powder followed by citric acid, compared with eight different debridement modalities tested on failed implants.

The XPS analysis provided further information on the effectiveness of the treatments in cleaning the contaminated surface of the disks. By assuming carbon as an index of residual contamination and the amount of titanium as an index of effective decontamination, the spectra analysis confirmed the findings of the SEM analysis. In particular, the high amount of carbon detected on TB and TB+CA treated disks reflects the presence of residual cell debris observed with the SEM on these disks. Interestingly, CA seems to have a role in reducing detectable oxygen. The detection of silicon on the AP disks reveals the presence of residual particles of glycine powder, which in turn, according to the manufacturer specification, contain traces of silica. It was reported that residual chemical agents can negatively affect cell adhesion, proliferation, and differentiation on decontaminated implant surfaces. Surface biocompatibility may be altered by either a direct action of the antimicrobial agents on the surface or by the permanence of traces of the chemical agents themselves. In this regard, prolonged rinsing is crucial to minimize possible effects related to residual particles or traces of chemical agents. However, no data are available in the literature on the rinsing time to completely eliminate chemical residues from the implant surface, if ever possible. Future investigations should also elucidate the specific impact of each antimicrobial agent on the titanium surface.

Osteoblast cultures also demonstrated that previously contaminated surfaces are still biocompatible after treatments, allowing for adhesion and metabolic activity. However, SEM images showed a lower cell proliferation on SLA disks treated with combined treatments, indicating a possible negative effect of chemical residues from the decontamination procedure. Accordingly, OC release at 7 and 14 days was lower on all SLA disks treated with combined treatments. Interestingly, this trend was not observed for the machined disks. This could be explained by the major absorbability of rough surfaces with respect to the chemical agents. Only few in vitro studies have compared osteoblast or fibroblast response on titanium surfaces treated with different decontamination protocols, but with inconclusive results. By contrast, it has been demonstrated in animal models that re-osseointegration of previously contaminated surfaces is possible and is considered a prerequisite for long-term results. It was also observed that rough surfaces have higher chances to re-osseointegrate compared with smooth surfaces, while no conclusive results have been reached on the impact of decontamination procedures. As a proof of concept, the results of the present study demonstrate that metabolically active osteoblasts can adhere on all treated surfaces, though with some difference related to the type of surface and the decontamination protocol. The observation of a lower proliferation of osteoblasts and OC release on rough surfaces treated with combined mechanical-chemical approaches, however, highlights the importance of an accurate rinsing of the treated surface to eliminate possible chemical residues. Further studies should better elucidate the specific effects of organic and inorganic residues.
on osteoblast response following decontamination procedures.

This study has some limitations. The oral bacteria collected from the volunteers are not representative of all the conditions associated with peri-implantitis, where long-term structured biofilms with a significant anaerobic component are present along with calculus. Moreover, the number and characteristics of volunteers could also affect the representativeness of collected bacteria. Lastly, the presence of residual contaminants might be overestimated or underestimated, since XPS is a semi-quantitative analysis, with an error of 10% to 15%, although this approach has already been used to evaluate the efficacy of the treatments to clean contaminated disks. Future studies should corroborate the findings of this study in vivo and with long-term follow-up, assessing the impact of treatments, surface characteristics, and their mutual relations, as well as other patient-related factors that cannot be considered in a preclinical setting.

CONCLUSIONS

Combined mechanical and chemical decontamination can be equally effective on both machined and SLA surfaces. A specific chemical agent seems to be indicated to enhance the decontamination process, namely, NaOCl following TB and CA following AP, although chemical residues may negatively affect osteoblast proliferation and metabolism. The characteristics of implant surfaces as well as the biofilm removal capacity of mechanical and chemical treatments should be considered together to select the most effective and less-invasive therapeutic approach.

ACKNOWLEDGMENTS

The authors wish to acknowledge the contribution of Dr Lorenzo Fortunato, Dr Giorgio Serafini, and Dr Giulia Tranquilli to the microbiologic study. This research was funded by the Oral Reconstruction Foundation grant number ORF-11701. The authors declare no conflict of interest. The funder had no role in the study design, collection, analysis, and interpretation of data; writing of the report; or decision to submit the article for publication.

REFERENCES


