Reusing Titanium Healing Abutments: Comparison of Two Decontamination Methods

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Purpose: To assess the amount of contamination remaining on used healing abutments after autoclaving and to compare the effectiveness of two additional decontamination methods.

Materials and Methods: After autoclaving, a total of 120 used healing abutments were divided equally into three groups: used healing abutments after autoclaving only (group 1); used healing abutments after autoclaving and air-flow polishing (Master Piezon, EMS) using erythritol powder (AIR-FLOW PLUS, EMS) (group 2); and used healing abutments after autoclaving and sodium hypochlorite (NaOCl; 25 g/L) treatment (group 3). Residual contaminants were stained using Phloxine B (400 g/mL), and healing abutments were photographed using a light microscope with digital capture system (Nikon SMZ800). The proportion of stained (ie, contaminated) areas on each healing abutment was then measured using imaging software (ImageJ). The healing abutments were also examined using scanning electron microscopy (SEM).

Results: Mean proportion of surface area affected by residual contaminants on the body, top (screwdriver-engaging), and bottom (implant-abutment interface) surfaces for group 1 was 38.2% ± 28.34%, 30.0% ± 19.55%, and 18.7% ± 17.87%, respectively; group 2 showed 3.5% ± 4.90%, 5.3% ± 3.74%, and 5.4% ± 8.49%, respectively; and group 3 showed 0.3% ± 0.16%, 1.9% ± 2.14%, and 0.7% ± 1.02%, respectively. Autoclaving alone was insufficient for successful decontamination, while additional decontamination procedures significantly reduced remaining contaminants. NaOCl was significantly more effective than air polishing. SEM analysis showed no detectable differences in the surface appearance of titanium healing abutments.

Conclusion: The results show that decontamination of used healing abutments is achievable, thus strengthening the feasibility of reusing healing abutments.


The practice of dentistry requires the use of highly specialized equipment and components that are frequently sterilized and reused. These items are continually in direct contact with human tissues and pose significant risks of cross-infection and tissue reaction if complete decontamination and sterilization are not achieved between patients.1–3

Healing abutments are intermediate components between the oral cavity and the dental implant during the healing period. They are usually composed of titanium (or titanium alloys) and are placed during healing of the peri-implant mucosa.1,2 Epithelial cells and fibroblasts colonize the area, resulting in adhesion and proliferation on the abutment surface as part of the healing process.1,2 The healing abutments also protect the internal aspect of the implant screw threads from contamination and ensure a complete seal between the implant and oral cavity.2 As healing abutments are used temporarily and sometimes for as short a time as only a few hours, the suitability of their reuse is worth exploration. The financial consideration, as well as the opportunity to reduce waste for an industry that consumes significant quantities of nonreusable resources, would be beneficial.1–3

The main issue surrounding the reuse of healing abutments is whether decontamination and sterilization can be achieved to the degree that completely eliminates risk to the patient.1–3 Furthermore, microbial contaminants and tissue debris on reused implant components can negatively affect the healing of the surrounding soft tissue and cause an unwanted inflammatory reaction.1,4 A few studies1,3 provide evidence of successful sterilization via biologic indicators; however, physical inspection noted the presence of residual contaminants following sterilization.2 In many instances, residual contamination remained on the healing abutments following various decontamination methods, including mechanical and chemical cleaning prior to autoclaving.1,2 Nevertheless, there
remains the potential for healing abutments to be safely reused after sterilization once the contaminants are effectively removed.1

An air-powder abrasion device using erythritol powder may be effective for removing residual contaminants from used healing abutments. This device is regularly applied to remove biofilms from tooth surfaces and has superior cleaning potential for debriding implant surfaces and components.5,6 By using the small particles of erythritol powder (D50 < 14 μm), air polishing has the advantage of accessing sequestered areas, with decreased abrasive effects and impeded biofilm activity via disruption of microanatomy and metabolism.5,6

Sodium hypochlorite (NaOCl) is another agent that may provide effective decontamination.7-9 The disinfection properties of NaOCl result from the release of powerful oxidizing agents, including reactive oxygen species, in the solution.7 Furthermore, hydroxide ions have the capacity to dissolve organic material to offer an additional cleaning action.7 The effectiveness of NaOCl for the removal of biofilms is also well established.8,9

The effect of decontamination methods on the surface characteristics of titanium healing abutments also requires consideration with respect to altering the surface wettability.1,2,4 Surface energies govern the adhesion of epithelial cells and fibroblasts required for healing of the peri-implant mucosa.1,2,4 Proposed decontamination procedures should thus maintain the surface characteristics present.

Therefore, the aim of this investigation was to assess the remaining contaminants on healing abutments after sterilization by autoclave and to compare the effectiveness of alternative decontamination methods; ie, air-flow polishing with erythritol powder and treatment with NaOCl.

### Materials and Methods

A collection of 120 used and autoclaved healing abutments were randomly divided into three groups. Each group consisted of 40 healing abutments from five different manufacturers: Astra Tech, Zimmer Biomet, Nobel Biocare, Southern Implants, and Straumann.

#### Table 1  Mean ± Standard Deviation (SD) Proportion of Pink-Stained Surface Area Measured on Unused Healing Abutments as a Result of Reflective Background Coloration

<table>
<thead>
<tr>
<th>Surface</th>
<th>Mean ± SD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>0.2 ± 0.13</td>
</tr>
<tr>
<td>Top</td>
<td>0.8 ± 0.73</td>
</tr>
<tr>
<td>Bottom</td>
<td>0.4 ± 0.30</td>
</tr>
</tbody>
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**Group 1 (Control): Used Healing Abutments After Autoclaving (132°C for 7 Minutes)**

In order to assess residual contaminants, autoclaved healing abutments were placed individually in micro-centrifuge tubes (1.8 mL) with 0.5 mL Phloxine B (400 μg/mL) (Sigma-Aldrich).2 The samples were vortexed (VX100, Labnet) for 10 seconds. Each healing abutment was rinsed twice in 40 mL of distilled water at room temperature and then dried at 37°C.

Healing abutments were photographed using a light microscope and digital capture system at ×2 magnification (SMZ800, Nikon). Six images of each healing abutment were captured: four of the body rotated at 90 degrees, one from the top (screwdriver-engaging part), and one from the bottom (implant-abutment interface).

Images were digitally analyzed (ImageJ 2.0.0-rc-43/1.50e, ImageJ) to measure the stained (ie, contaminated) surface area. Manual manipulation of the “color threshold” function allowed for the selection of the stained surface area, and the number of pixels within this selected area was calculated. Surface area contamination was expressed as a fraction (%) of total surface area by dividing the number of pixels within the selected area by the total number of pixels comprising the image. To appreciate the two-dimensional nature of the images, the reflective lines generated on images of the circular three-dimensional body were used to outline the area selected for analysis. As the current methods to detect and measure Phloxine B–stained material produced false positives due to the reflective background coloration, the proportion of pink-stained surface area measured from the reflective background coloration of unused healing abutments without the Phloxine B staining was taken into consideration (Table 1).

#### Group 2: Used Healing Abutments After Autoclaving and Mechanical Debridement with Air-Flow Polishing Using Erythritol Powder

The Air-Flow Master Piezon (EMS) was loaded with erythritol powder (Air-Flow Plus, EMS), and the handpiece was mounted on a customized device (Fig 1). Both power and liquid were set to “nine lights,” and function set on “Air-Flow.” A corresponding implant analog and healing abutment were fixed to the device with the handpiece positioned 5 mm away and at a 60-degree angle to the healing abutment. The device was activated for 15 seconds per surface (six surfaces/healing abutments in total), after which the healing abutments were rinsed with water from the handpiece for 5 seconds. Healing abutments were debrided individually and dried at 37°C. The protocol for staining and quantification of debris was the same as the control group.
Group 3: Used Healing Abutments After Autoclaving and Chemical Decontamination with NaOCl

Each healing abutment was placed into individual microcentrifuge tubes with 1 mL NaOCl (25 g/L) (QualChem Products). Microcentrifuge tubes were then loaded onto a customized putty mold secured to a vortex table (Fig 2). The vortex (Genius 3, IKA) was activated for 10 minutes at 2,000 rpm, after which the NaOCl was removed. Each healing abutment sample was rinsed twice in 40 mL distilled water, dried at 37°C, and stained and imaged as above. The same methodology was used to quantify the remaining debris.

Potential effects on the titanium surface characteristics caused by the varying protocols were examined using scanning electron microscopy (SEM).

All procedures were undertaken by a single operator (M.C.). Due to the differences in morphology of the body, top (screwdriver-engaging), and bottom (implant-abutment interface) surfaces, these surfaces were analyzed and reported independently.

Statistical Analyses

The data were analyzed using the Kruskal-Wallis test with unadjusted post hoc Dunn tests. Significance was established at \( P < .05 \).

Results

Of the 120 healing abutments, 116 samples were analyzed for residual contamination with Phloxine B staining. An inherent pink coloration of the remaining four healing abutments prevented their analysis by the ImageJ software color threshold function. The resulting sample sizes of the three groups were: \( n = 40 \) in group 1; \( n = 38 \) in group 2; and \( n = 38 \) in group 3.

Autoclaving alone was insufficient to achieve adequate decontamination (Figs 3 and 4), whereas additional decontamination with both air-flow polishing

Fig 3 Comparison of residual debris following three decontamination procedures by surface type: (a) body surface; (b) top surface; and (c) bottom surface. Group 1 (control) = used abutments after autoclaving; group 2 = used abutments after autoclaving followed by air polishing; group 3 = used abutments after autoclaving followed by NaOCl treatment. \( P < .001 \) for all comparisons.
using erythritol powder (Figs 3 and 5) and NaOCl treatment (Figs 3 and 6) resulted in significantly better results. Decontamination with NaOCl was more effective than air-flow polishing for all surfaces (Fig 3). These differences were consistent for the body, top, and bottom surfaces (Fig 3). The body surfaces of healing abutments were more readily cleaned, followed by the bottom and then the top surface (Fig 3).

**SEM Analysis**

The analysis of the contaminated healing abutments allowed the visualization of biofilm. Contamination of the body surface was more concentrated around the coronal (top) region (Fig 7a) compared to that around the apical (bottom) region (Figs 7b and 7c), probably due to more exposure of the coronal region to the oral cavity. Under higher magnification, the complex multicellular population within the biofilm was apparent (Fig 8).

Investigation of titanium healing abutments under SEM further revealed the insufficiency of autoclaving alone in removing residual contaminants when compared to new healing abutments (Figs 9a, 10a, and 10b). The vast improvements in surface decontamination after either air polishing or NaOCl treatment were evident under SEM (Figs 9b and 9c). The visual analysis of the titanium healing abutments under SEM revealed no surface alterations following either air-polishing or NaOCl treatment (Figs 10c and 10d).
Reusing titanium healing abutments has environmental and economic merits. However, patient protection in terms of preventing cross-infection and facilitating healing must be prioritized. The findings of this study concur with those of a recent study: Used healing abutments after sterilization by autoclaving are not sufficiently decontaminated for reuse. The current study also found that more than half of the surface area may remain contaminated. The additional decontamination methods significantly reduced residual contamination, with NaOCl being significantly more effective than air polishing on all surfaces.

The various surfaces on each healing abutment (ie, body, top, and bottom) also responded differently to the decontamination procedures. Body surfaces were more readily decontaminated, followed by the bottom surfaces and then the top surfaces. This is likely due to the differences in accessibility of certain areas of the healing abutments; the top part (screwdriver-engaging area) has fairly limited surface area for the decontamination particles to access.

None of the protocols removed the contaminants completely, but this does not translate to an unacceptable decontamination protocol. The color threshold function calibrated to detect pink-stained debris also detected pink hues of light reflected from the titanium surfaces, resulting in false positives. To adjust for this reflective background coloration, a threshold above 0 was established. The corrected data demonstrate that additional air-polishing treatment does not completely decontaminate; however, treatment with NaOCl produced very encouraging results. The average proportion of residual contamination on surfaces treated with NaOCl are within the range of unused healing abutments, indicating that the NaOCl protocol can achieve complete decontamination, which emphasizes its current use as a disinfectant in many industries.

Biofilms that develop on the surfaces of titanium healing abutments are complex multicellular structures, and the action of NaOCl to hydrolyze this material is dependent on its contact and penetration into the biofilm. In the current study, the use of a vortex table to continuously agitate the preparations and expose sequential biofilm layers could enhance effectiveness. However, within the NaOCl protocol, the proportion of stained surface area peaked beyond the values obtained for reflective background coloration. This means that the current protocol does not achieve a 100% success rate. Although not ideal, these results are promising, as they show the possibility to decontaminate used healing abutments after autoclaving. Further improvements to the NaOCl protocol, such as increasing the concentration of NaOCl or exposure time in the solution, may achieve the desired outcome of complete decontamination.
When considering sterilizing and decontaminating used healing abutments, the potential effects these procedures have on the titanium surface characteristics must also be considered. The titanium oxide layer on healing abutments offers biocompatibility while surface roughness contributes to its wettability, which regulate adhesion of epithelial cells and fibroblasts required for healing of the peri-implant mucosa. SEM analysis of the titanium surfaces revealed no visible changes in surface roughness after the additional decontamination procedures, indicating that treatment with air polishing and treatment with NaOCl had no significant detrimental effects. Chemical changes to the oxide layer on titanium discs and implant components can occur as a result of steam autoclaving, but this was not assessed in the present study and warrants further investigation.

Treatment of surgical instruments with NaOCl has shown to decrease the infectivity of prions. However, the recommended time of application is much longer than what has been implemented in this study. It is also appreciated that, in conjunction with the high concentration required, NaOCl treatment can be damaging to instruments and constitutes a hazard to operators. Risk of prion transmission by dental procedures is extremely low and associated predominantly with the reuse of endodontic files in direct contact with peripheral nerves in pulpal tissue. Taking this into consideration, the reuse of healing abutments poses a very low risk of prion transmission, and the suggested treatment with NaOCl further reduces the risk.

Incineration is a decontamination method that ensures denaturation of all organic material. Thermolysis of organic material was assessed in a pilot study in which used healing abutments were heated to 400°C for 90 minutes (data not shown). Evidence of thermolysis of debris was minimal, and at 400°C the healing abutment surface started to oxidize, even though this temperature was well below the α/β phase transformation (882.5°C) of titanium. For these reasons, the thermolysis protocol was not pursued.

Conclusions

Currently, there is no decontamination procedure for used healing abutments that guarantees a successful outcome. The current results support the use of NaOCl in addition to autoclaving to achieve effective decontamination; however, further development, such as increasing the concentration or exposure time to NaOCl, is warranted. This study also supports the use of NaOCl to decontaminate used titanium healing abutments, as the chemical had no significant adverse effects on titanium surface characteristics.

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References