The Comparative Effect of Ultrasonic Scalers on Titanium Surfaces: An In Vitro Study

Shuichi Sato,*† Mamoru Kishida,‡ and Koichi Ito*†

Background: Professional maintenance is as important for patients with dental implants as it is for patients with natural teeth. However, no proper maintenance instruments have been available for implant patients. The purpose of this in vitro study was to compare the effects of a new ultrasonic scaler (VR), a conventional ultrasonic scaler (SP), and a plastic scaler (PS) on titanium surfaces.

Methods: To simulate subgingival conditions, the implant healing abutments were connected to acrylic resin blocks with artificial gingiva using silicon impression material. The abutments were painted with ink as an artificial form of debris. The ink was removed with the VR, SP, or PS scaler for 60 seconds under standardized conditions, and the removal rate was calculated. The roughness of the abutment surface was measured with a profilometer and observed by scanning electron microscopy (SEM).

Results: The removal rate using the VR and SP scalers was higher than that using the PS scaler. No significant differences in the surface roughness or SEM observations were found among the VR, SP, or PS scalers.

Conclusions: In this preliminary study, the new ultrasonic scaler and conventional ultrasonic scaler were shown to be useful for removing artificial debris and produced no significant damage to titanium surfaces compared to plastic scalers. We concluded that new and conventional ultrasonic scalers with a non-metal tip would be suitable for implant maintenance. J Periodontol 2004;75:1269-1273.

KEY WORDS
Comparison studies; scaling/instrumentation; titanium; ultrasonics/instrumentation.

Plaque accumulation and formation of pockets have been reported to occur following placement of titanium implants.¹,² Therefore, to achieve a successful outcome for titanium implants, it is necessary to perform professional maintenance and to ensure that home oral hygiene is adequate. Furthermore, the peri-implant area seems to be more susceptible than the periodontium to bacteria,³ indicating that early plaque removal is essential in patients with dental implants.⁴

The main problem in removing plaque from implants relates to possibly damaging the implant surface. In particular, conventional sonic and ultrasonic scalers cause considerable changes to implant surfaces.⁵-⁷ Thus, plastic curets, graphite or nylon-type instruments, rubber polishing cups, brushes with abrasive paste, or air-powder abrasive systems have been recommended.⁵-²⁰ On the other hand, conventional sonic and ultrasonic scalers are considered to be rapid and efficient cleaning tools with potential to reach areas not readily accessible by other instruments.

A recently developed ultrasonic scaler generates ultrasonic vibration at a frequency of 25 kHz that is converted to horizontal vibration by a resonating ring. As a result, the instrument tip moves only parallel to the surface and thus causes only minimal damage to the implant surface. However, the value of ultrasonic scalers in implant maintenance has not been clarified. Some studies have shown that non-metallic ultrasonic tips or modified ultrasonic tips may be useful for implant maintenance,²¹-²⁴ but there is little consensus as to which instruments are
most appropriate for use on implant surfaces. The purpose of this in vitro study was to compare the effects of a new ultrasonic scaler, conventional ultrasonic scaler, and plastic scaler on titanium surfaces.

MATERIALS AND METHODS

Fifteen (five per group) new 7-mm titanium implant healing abutments were used in this study. To simulate subgingival conditions, each healing abutment was attached to an acrylic resin block, and the exposed area was covered with silicon impression material to form a gingival mask (Fig. 1A). One side of each healing abutment was painted with ink as an artificial form of debris as a test surface (Fig. 1B). The resin block was mounted on a force gauge, while mechanical treatment was carried out under standardized conditions. The VR and SP scalers were used at 40 g pressure for 60 seconds at 25 kHz set on medium power. The PS scaler was used at 300 g pressure for 60 seconds. Non-instrumented abutments served as controls. All instrumentation was performed by one investigator (SS).

Evaluation of Cleaning Efficacy

After treatment, the healing abutments were removed from the resin blocks. Photographs of the test surfaces were taken using a stereomicroscope at 4× magnification. The area of artificial debris was recorded using a computerized image analysis system. Slides taken at 10× magnification were digitized using a solid-state 35 mm slide scanner and CCD linear photo diode array interfaced to a computer, and the measurements were extracted from the digital images using an image-processing software package. The removal rate of artificial debris was calculated using the following formula: area of removed debris/area of test surface × 100 (%).

Evaluation of Surface Roughness

Average surface roughness (Ra) and the mean roughness profile depth (Rz) were measured using a profilometer. In each case, the measurement was

---

\[ Ra = \frac{1}{L} \int_{0}^{L} \left| z(x) \right| \, dx \]

\[ Rz = \frac{1}{L} \int_{0}^{L} \left( z(x) - \frac{1}{L} \int_{0}^{L} z(x') \, dx' \right)^2 \, dx \]

---

5 Steri-Oss, Newport, CA.
6 Gracin, Supraso, Satelec, La Ciotat, France.
7 Model SZC, Olympus, Tokyo, Japan.
8 NIH Image version 1.44, Bethesda, MD.
9 Surfcom 1400A, Tokyo Seimitsu, Tokyo, Japan.
performed with a 0.25 mm cutoff and 1.25 mm measurement length. Each abutment was measured five times at 0.5 mm intervals length-wise and width-wise; then the average for each specimen was recorded.

**Scanning Electron Microscopy**
The surface roughness was viewed with a scanning electron microscope (SEM). Photomicrographs of the treated area on each abutment were taken at 200× magnification. The SEM photographs were evaluated using modified roughness scores developed by Hallmon et al. and determined by three masked investigators (examiners 1-3). Roughness was scored as follows: 0 (smooth – comparable to untreated titanium surfaces), 1 (slightly rough), 2 (moderately rough), or 3 (severely rough). The average for each specimen was recorded.

**Statistical Analysis**
The data were analyzed using one-way factorial analysis of variance (ANOVA) and Scheffé’s test, and a difference at \( P < 0.05 \) was considered significant.

**RESULTS**

**Cleaning Efficacy**
The rate of debris removal by the VR (61.2% ± 4.6%) and SP (45.8% ± 3.5%) scalers was higher than that for the PS scaler (20.3% ± 1.6%) (Figs. 3A through 3C, Fig. 4). The VR scaler removed debris significantly better than the SP scaler. The removal rate of the VR scaler was almost three times higher than that of the PS scaler.

**Surface Roughness**
There were no significant differences in surface roughness (Ra and Rz) among the VR, SP, and PS scalers and the controls (non-instrumented) (Fig. 5).

**SEM Observations**
SEM images showed no marked differences in surface morphology among the VR, SP, and PS scalers and the controls (Figs. 6A through 6D). There were no evident differences in roughness scores among the abutment surfaces treated with any of the scalers when plotted by examiner (Fig. 7).
DISCUSSION

The results of this study revealed no significant differences in the surface roughness or SEM observations among the two ultrasonic scalers and plastic scaler. In vitro studies have demonstrated that instruments used to clean teeth cause varying degrees of damage to implant surfaces.9-12,14-17 Sonic and ultrasonic scalers with metal tips cause considerable changes to implant surfaces.5-7 Rühling et al.22 using Teflon-coated tips, Gantes and Nilveus24 using plastic tips, and Bailey et al.23 using non-metallic tips noted minimal damage to implant surfaces.

In the present study, we used one ultrasonic scaler with a carbon tip and one with a plastic tip. It was thought that these materials would be suitable for use on implant surfaces.

The tip movement of ultrasonic scalers is sometimes thought to damage implant surfaces.5-7 The tip movement is generated by different mechanisms, resulting in varying amplitudes and patterns of movement, some of which may damage implant surfaces. We used two piezoelectric-type scalers because the tip movement is parallel to the surface25 and would cause minimal damage to the abutments. In particular, the VR scaler uses a ring-shaped oscillating resonance body that is ultrasonically driven and is attached to the working end at an angle of 90 degrees. The resultant movement eliminates the usual ellipsoid vibration.

Bain measured the mean scaling time for one abutment in a clinical setting, using a plastic scaler, as approximately 60 seconds.11 Thus, we applied instruments for 60 seconds. However, other studies5,20 used a longer scaling time.

The advantage of using ultrasonic instruments is that they can remove plaque and calculus effectively and efficiently from implants21 and from titanium implant surfaces.24 One study showed no significant differences in the effectiveness of plaque removal between ultrasonic and plastic scalers.20 However, the current study showed that the two ultrasonic scalers removed a higher percentage of artificial debris than a plastic scaler. This could be due to the differences between removing artificial debris and removing plaque.

We fabricated a holding device for the abutment and used silicone impression material as artificial gingiva to simulate subgingival conditions. The peri-implant tissue is frequently difficult to access with scalers and other instruments because the implant neck is smaller than those of natural teeth. The VR scaler removed artificial debris significantly better than the SP scaler. The shape and materials of the tip could be a factor in the debris removal rate. We used a VR scaler with a probe-shaped, fiber-reinforced composite tip, and an SP scaler with a curet-shaped plastic tip under standardized conditions. The flexibility of the plastic curet seems to prevent its secure placement and application. The fiber-reinforced composite tip seems to have sufficient stiffness for removing implant debris. The SP and PS scalers
we used are of similar shape and dimensions as the stainless-steel cures used for natural teeth. The shape of instruments used for cleaning implants should be proportionally smaller and finer, especially for cleaning the subgingival area. A probe shape and the use of fiber-reinforced composite material for the tip would be desirable features in an instrument used for cleaning the subgingival area of implant abutments.

The new and conventional ultrasonic scalers with non-metal tips used in this study appear to be useful for removing artificial debris with no significant damage to titanium surfaces when compared to the plastic scaler, removing artificial debris with no significant damage to non-metal tips used in this study. A probe shape and the use of a fiber-reinforced composite material for the tip would be desirable features in an instrument used for cleaning the subgingival area of implant abutments. The shape and proportionality of the titanium surfaces were carried out in standardized in vitro conditions. Thus, our results cannot be applied directly to clinical situations. Further study is necessary to evaluate the efficacy of plaque and calculus removal from implant abutments in vivo.

REFERENCES


Correspondence: Dr. Shuichi Sato, Department of Periodontology, Nihon University School of Dentistry, 1-8-13, Kanda Surugadai, Chiyoda-ku, Tokyo 101-8310, Japan. Fax: 81-3-3219-8349; e-mail: sato-su@dent.nihon-u.ac.jp.

Accepted for publication January 21, 2004.