Surface Alterations of Several Dental Materials by a Novel Ultrasonic Scaler Tip

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Purpose: *To assess the effects of a recently developed ultrasonic scaler tip, composed mainly of copper, on the surfaces of several dental materials.* ***Materials and Methods:*** *Representative samples of dental materials, including titanium, type II gold, cobalt-chromium alloy, zirconia, and porcelain, were prepared. Three ultrasonic scaler tips of conventional metal (CM), carbon composite (CC), and copper alloy (CA) were prepared. To simulate ultrasonic scaling in an oral environment, 30 g of force was applied using a double-pan balance, and the scaler tip was allowed to move horizontally 5 mm for three consecutive cycles of 20 seconds each. The power of the scaler tip was set to intermediate according to the manufacturer's advice. The surface morphology of each dental material was examined using scanning electron microscopy and confocal laser scanning microscopy. Statistical analysis was performed through one-way analysis of variance and post hoc Scheffé test. All values were considered significant when* $P < .05$. ***Results:*** *Surface alterations of titanium, type II gold, and cobalt-chromium alloy by the CM tip were much greater than those caused by the CC and CA tips. No alterations were created on the zirconia surface by the CM, CC, or CA tips. On the porcelain surface, surface roughness (Ra) induced by the CM tip was 1.86 and 1.72 times higher than that produced by the CC and CA tips, respectively* ($P < .001$). ***Conclusions:*** *Within the limitations of this study, the surface alterations induced by CC and CA tips on the surfaces of dental materials were comparable. Therefore, this novel ultrasonic copper alloy scaler tip may possibly be used for the maintenance of implant prostheses.* Int J Oral Maxillofac Implants 2012;27:801–810.

Key words: *confocal laser microscopy, profilometry, surface alteration, surface topography, ultrasonic instrumentation, ultrasonic scaler tip*

According to long-term clinical studies, dental implant therapy has been recognized as a successful and predictable treatment modality for edentulous patients.[1] However, a small percentage of biologically related implant complications has also been reported.[2] The presence of plaque around implant-supported prostheses may cause peri-implantitis,[3] indicating that plaque removal is essential in implant-treated patients. Although patients can remove plaque with standard prophylactic agents, professional cleaning of implants is essential during the implant maintenance phase and can be carried out by various instruments.[4]

Ultrasonic scalers have a similar or greater efficiency than hand instruments in the removal of plaque and calculus on the surfaces of dental materials.[5–7] Accordingly, ultrasonic scalers have become an established tool for the removal of dental plaque and calculus.

However, instrumentation with a conventional ultrasonic scaler tip may damage the implant surface.[5,8–11] Improperly applied instruments adversely affect oral hygiene by damaging the surfaces of implants and prostheses, facilitating plaque formation, and creating a more conducive niche for the accumulation of plaque and calculus.[9] It has been suggested that nonmetallic instruments such as rubber cups, plastic curettes, graphite or nylon-type instruments, titanium curette, air-powder abrasive systems, or polytetrafluoroethylene-coated scaler tips have suitable features for implant

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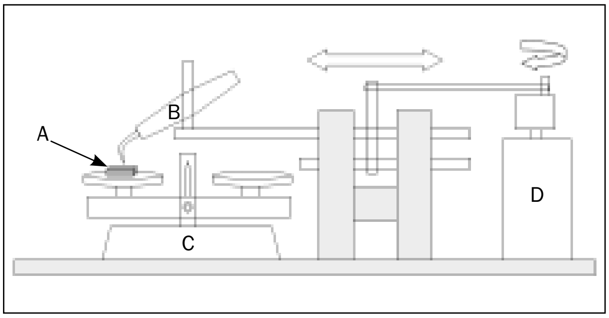

Fig 1 Diagram of the ultrasonic scaling apparatus. A = sample; B = ultrasonic scaler; C = double-pan balance; D = motor with control box.

maintenance. Nonmetallic instruments rarely produce significant surface damage, and they have been recommended for use in removing plaque from implants rather than metallic instruments.[10–15] However, nonmetallic tips are fragile and can be easily altered by force. As a result, there is a demand for an ultrasonic scaler tip that is not fragile and causes minimal changes to the implant surface.

Recently, a novel ultrasonic scaler tip, mainly composed of copper alloy (CA) and plated with silver, was introduced. According to the manufacturer's data, the elastic modulus of a CA tip is higher than that of a carbon composite (CC) tip, and the hardness of the tip is lower than that of titanium grade II.[16] The purpose of this study was, therefore, to assess the effects of the novel CA ultrasonic scaler tip on the surfaces of several dental materials, including titanium.

MATERIALS AND METHODS

Fabrication of the Samples

The surfaces of following five dental materials (five samples per group) were used in this study.

1. Group 1: A commercially pure titanium disk (grade IV) with a diameter of 25 mm and a thickness of 1 mm (Warantec) was polished with 800-grit silicon carbide sandpaper (Struers A/S).
2. Group 2: A 10- × 10-mm^2 piece of type II gold (type II gold ingot, ISO 1562, Heesung Catalysts) was highly polished with a rubber point.
3. Group 3: A 10- × 10-mm^2 cobalt-chromium (Co-Cr) alloy (Elephant Dental BV) was cast and highly polished with a rubber point.
4. Group 4: A 10- × 10-mm^2 zirconia block (Cercon base, DeguDent) was polished with 800-grit silicon carbide sandpaper (Struers A/S) and then sintered with Cercon heat (DeguDent) at 1,350°C for 6 hours.
5. Group 5: Porcelain (Ceramco3, Dentsply) was built up onto a 10- × 10-mm^2 nickel-chromium alloy plate (Bellabond plus, BEGO) and glazed with Austromat 3001 (DEKEMA) at 600°C for 20 minutes.

Each sample was embedded in an acrylic resin block (Ortho-Jet, Lang Dental Mfg).

Ultrasonic Scaler Tips

The following ultrasonic scaler tips were used in this study:

1. A conventional metal (CM) tip (Piezon, EMS) made of stainless steel.
2. A CC tip (Periosoft, Satelec), which has been recommended for prosthesis maintenance because of its minimal scratching of the surface of the prosthesis.[11,14]
3. A CA tip (IS Tip, B&L Biotech) made of CA and plated with silver.[16]

Ultrasonic Scaler Apparatus

The samples were mounted onto a double-pan balance (Ohaus Harvard Trip Balance 1550-SD, Ohaus) using a magnet mold. An Implanet CSN ultrasonic scaler handpiece (CSN Industrie) was used throughout the experiment at an intermediate power setting (level 5 of 14 grades). The scaling tip was angled 90 degrees relative to the surface of sample. A constant force of 30 g was applied to the ultrasonic scaler tip by the vertical movement of a counterweighed balance. A standardized 5 mm horizontal movement and three consecutive cycles of 20 seconds each of the ultrasonic handpiece at a speed of 2 Hz was achieved and operated by the control box (Intermedi), which was similar to the devices described by Mengel et al[13] and Ruhling et al[4] (Fig 1).

The untreated adjacent surfaces served as control surfaces. All samples were rinsed with tap water, soaked in an ultrasonic water bath (Saehan Cleaner, Saehan Ultrasonic) for 10 minutes, and then dried with compressed air.

Surface Analysis

Scanning Electron Microscopy. The surface characteristics were viewed with a scanning electron microscope (SEM). All samples were coated with gold in a sputter coater unit and were introduced into the vacuum chamber of a field emission scanning electron microscope (S-4700, HITACHI) with an accelerating voltage of 15 kV and were observed with ×100 and ×1,000 magnification.

Confocal Laser Scanning Microscopy. Confocal laser scanning microscopy (CLSM) (LSM 5 Pascal, Carl Zeiss) was performed to measure the depths and widths of the scratches in groups 1, 2, 3, and 4 and

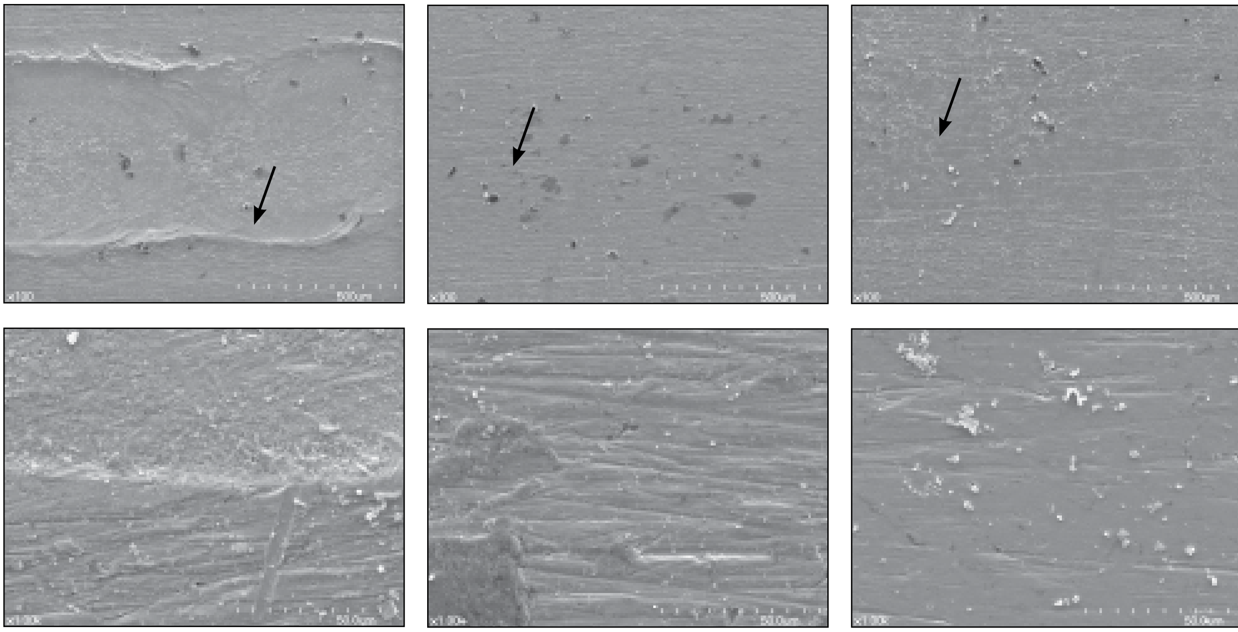

Fig 2 SEM images of group 1 (*left to right*: CM tip, CC tip, CA tip). *(Top row)* Magnification ×100. *(Bottom row)* Magnification ×1,000. Black arrows indicate the area that is magnified in the corresponding higher-magnification image.

the surface roughnesses of group 5. A 543 nm (1 mW) helium-neon laser was used as a light source, and the samples were observed at ×70 magnification. The measuring area was 1,300 × 1,300 μm^2, and the height of the z-stack was 80 μm in 1.6 μm intervals.

The CLSM images were analyzed using a Zeiss LSM Image Examiner (version 3.1, Carl Zeiss).

Assessment of Scratch Depth and Width. In groups 1, 2, 3, and 4, the three-dimensional topographic surfaces were converted into profiles along the x-axis, and a Gaussian filter with a low-pass of 24 μm was applied to each profile of the series to remove very small peaks and unrepresentative noise.[4,17] Five measurements were made of each sample, and the depths and widths of the scratches were measured using the topography measurement mode of the Zeiss LSM Image Examiner according to the method of Sánchez-Brea et al.[18]

Examination of Surface Roughness. In group 5, the three-dimensional topographic surfaces were converted into profiles along the y-axis, and a Gaussian filter with a high-pass of 8 μm was applied to each profile of the series to eliminate the deviation and waves.[17] The average surface roughness (R_a) was then calculated using Zeiss LSM Image Examiner, considering the arithmetic mean deviation of all profile height values, using the equation:

$$R_a = \frac{1}{N_y} \cdot \sum_{j=1}^{N_y} \cdot \left[z\left(x, y_j\right) - R_c \right]$$

where N_x, N_y... indicate the number of pixels in the x- and y-directions, respectively, and R_c indicates the mean height of all profile height values. R_a was calculated along the y-axis in two and three different areas for the control and test sites, respectively.

Statistical Analysis

Statistical analysis was performed using a one-way analysis of variance and a multiple-comparison Scheffé test using PASW Statistics (version 18, SPSS, IBM). Differences at $P < .05$ were considered statistically significant.

RESULTS

Surface Photography

SEM images of each sample are shown in Figs 2 to 6. The group 1 samples (commercially pure titanium disks with polished surfaces) showed significant alteration of the surface following treatment with the CM tip, but no surface alterations were observed following use of the CC or CA tips (Fig 2). In group 2 (type II gold with a highly polished surface), significant alterations from the CM tip were evident, but no surface alterations were observed with the CC or CA tips (Fig 3). Group 3 specimens (Co-Cr alloy with a highly polished surface) showed alteration after application of the CM tip, but no surface alterations by the CC or CA tips were

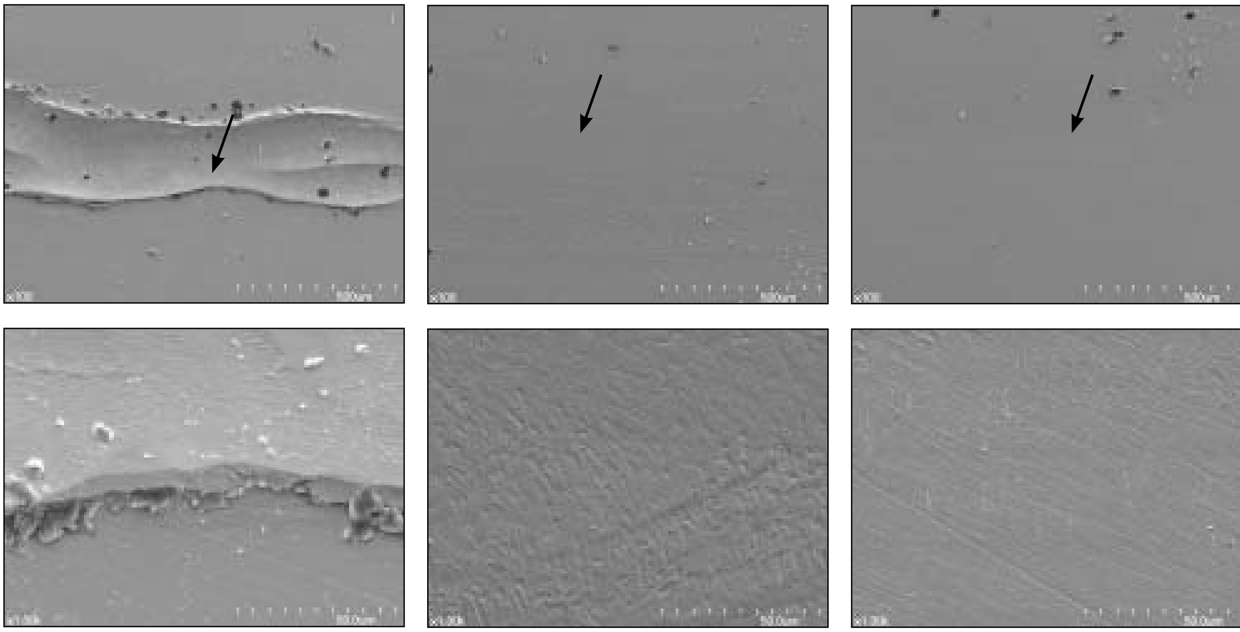

Fig 3 SEM images of group 2 (*left to right*: CM tip, CC tip, CA tip). *(Top row)* Magnification ×100. *(Bottom row)* Magnification ×1,000. Black arrows indicate the area that is magnified in the corresponding higher-magnification image.

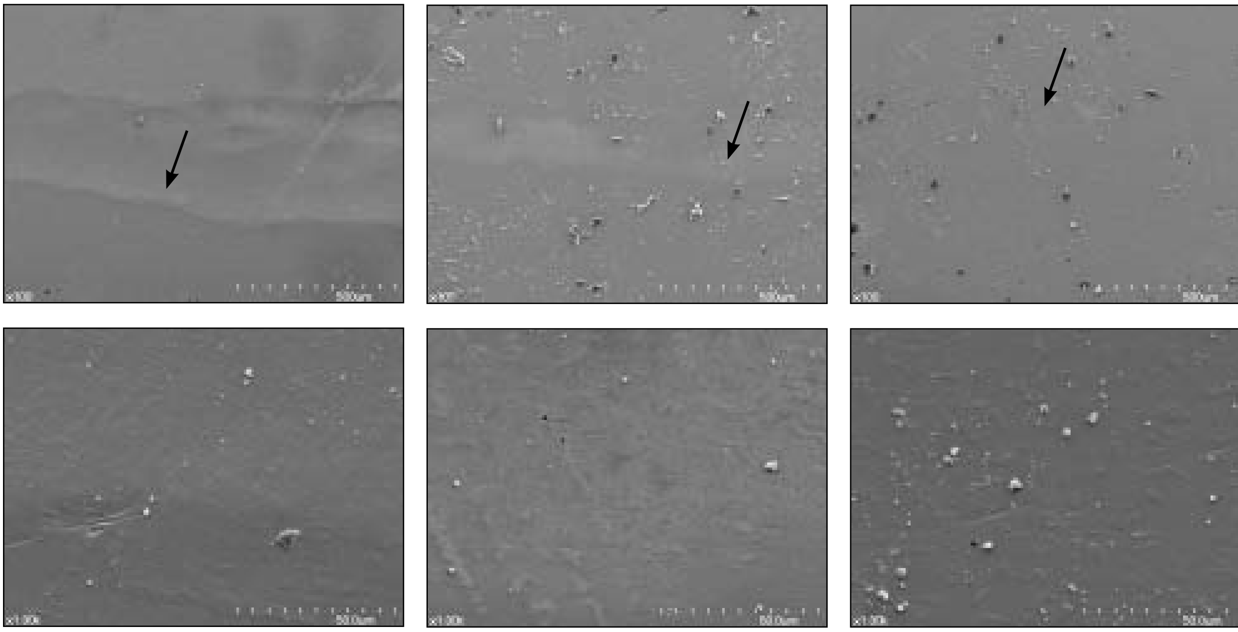

Fig 4 SEM images of group 3 (*left to right*: CM tip, CC tip, CA tip). *(Top row)* Magnification ×100. *(Bottom row)* Magnification ×1,000. Black arrows indicate the area that is magnified in the corresponding higher-magnification image.

observed (Fig 4). In group 4 (zirconia), no alterations of the surface were observed with CM, CC, or CA tips (Fig 5). In group 5, a fracture of the porcelain was observed following treatment with a CM tip, but no surface alterations caused by the CC or CA tips were observed (Fig 6).

Surface Defect Analysis

The surface defects of each group were measured using CLSM. In group 1, surface alteration by the CM tip was observed, but changes were not observed following use of the CC or CA tips (Fig 7). In group 2, surface alterations by the CM tip were observed. Surface alterations

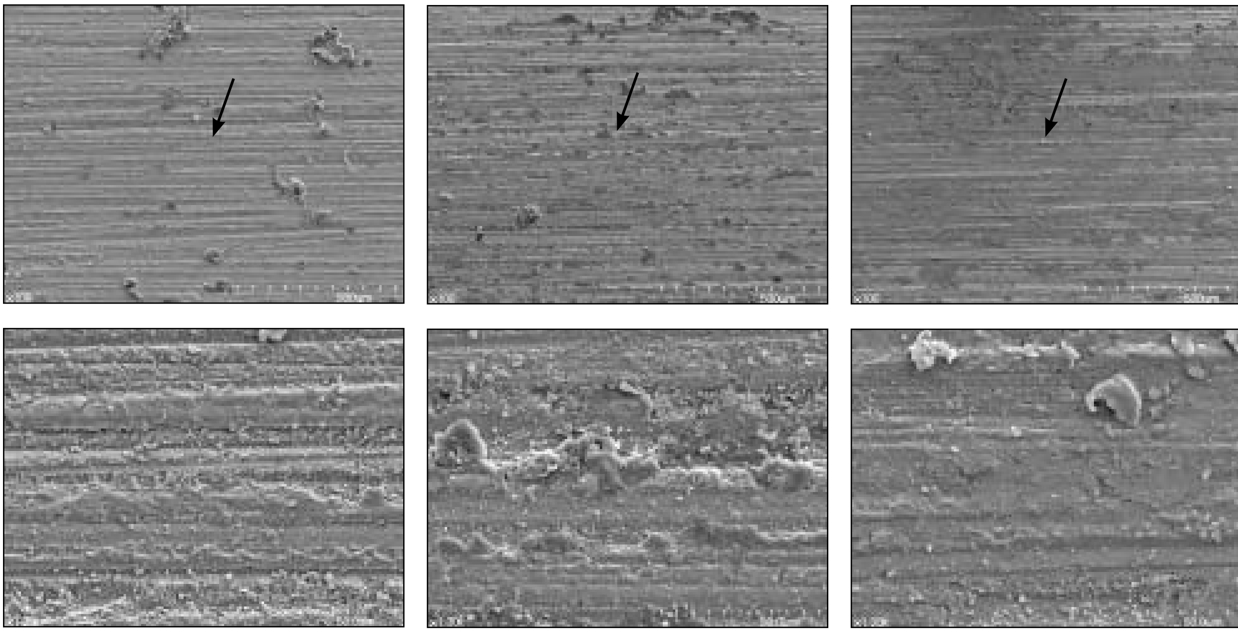

Fig 5 SEM images of group 4 (*left to right*: CM tip, CC tip, CA tip). *(Top row)* Magnification ×100. *(Bottom row)* Magnification ×1,000. Black arrows indicate the area that is magnified in the corresponding higher-magnification image.

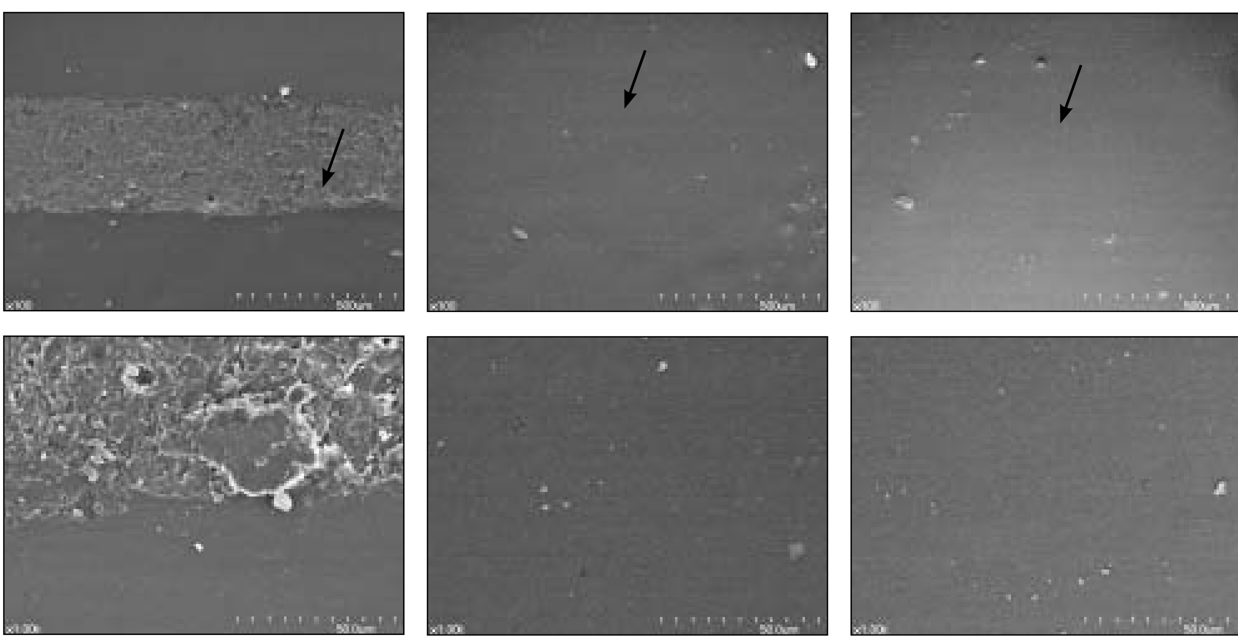

Fig 6 SEM images of group 5 (*left to right*: CM tip, CC tip, CA tip). *(Top row)* Magnification ×100. *(Bottom row)* Magnification ×1,000. Black arrows indicate the area that is magnified in the corresponding higher-magnification image.

by the CA tip were also observed, but the small changes in profile were unable to be measured (Fig 8). In group 3, surface alterations by the CM tip were observed. Surface alterations by the CA tip were also observed, but the small changes in profile were unable to be measured (Fig 9). In group 4, no surface alterations attributable to the CM, CC, or CA tips were observed (Fig 10). In group 5, surface alterations by the CM tip were observed. No surface alterations after use of the CC and CA tips were observed (Fig 11).

Based on the results acquired from the CLSM images, the scratch defects in each group were then measured.

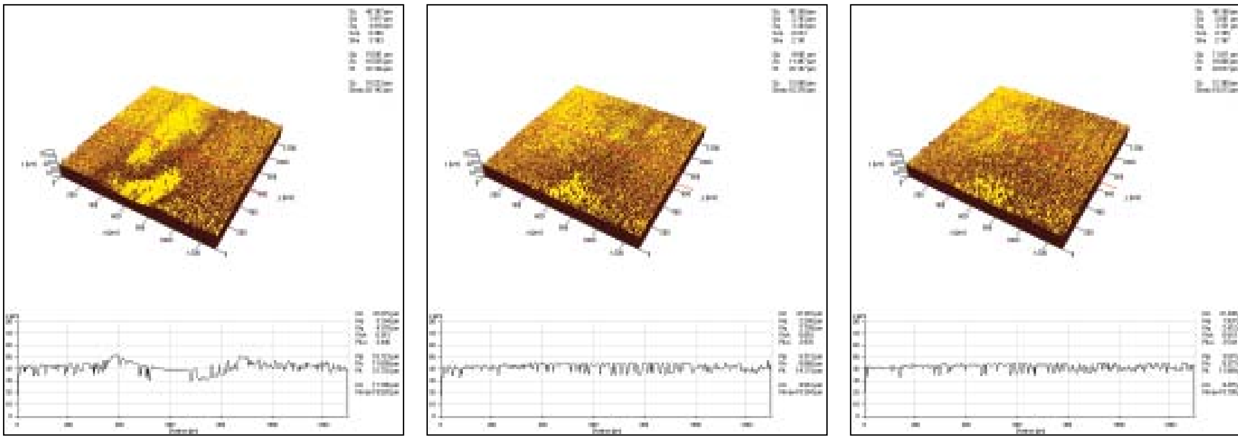

Fig 7 CLSM images of group 1. *(Left to right)* CM tip, CC tip, CA tip.

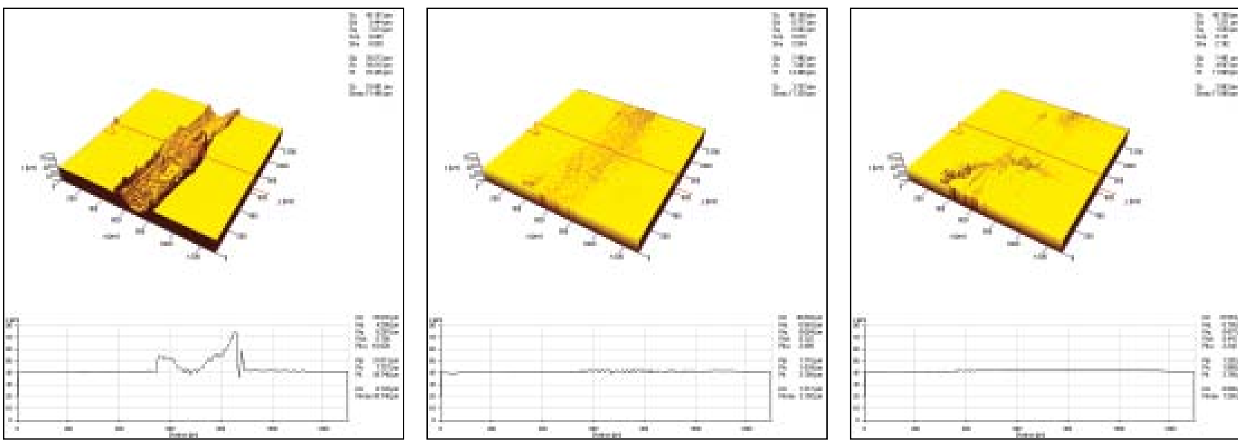

Fig 8 CLSM images of group 2. *(Left to right)* CM tip, CC tip, CA tip.

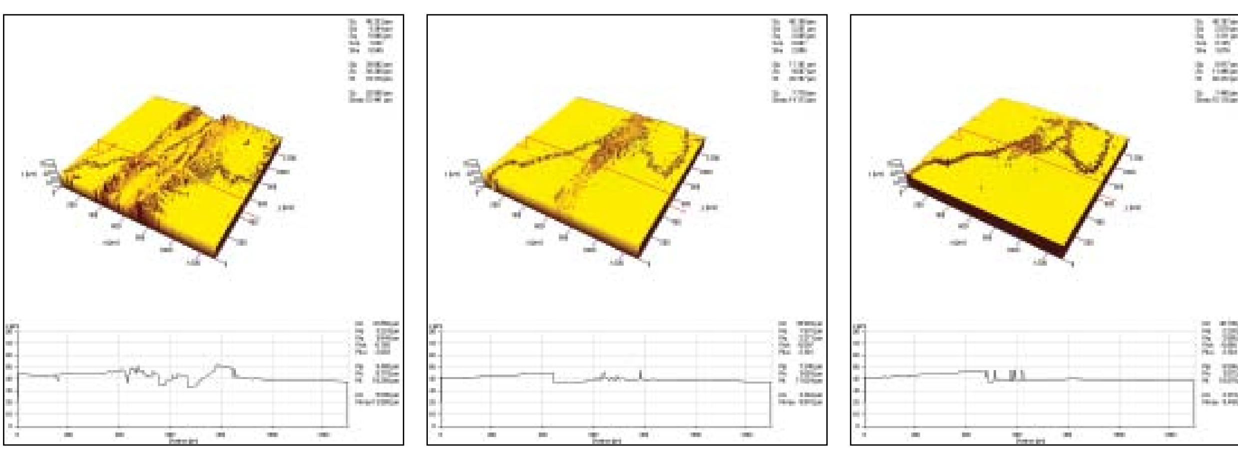

Fig 9 CLSM images of group 3. *(Left to right)* CM tip, CC tip, CA tip.

Surface Defect Measurement. As the surface of each material was modified by the ultrasonic scaler tips, peaks and valleys were generated. A line was drawn between two peaks, and the distance from the line to the deepest point was measured (Figs 12 to 15). The measurement values of the CM-induced scratch depths and widths in groups 1, 2, 3, and 4 are shown in Table 1 (Gaussian filter, low-pass, 24 μm). In group 4, the defect was unable to be measured. Group 5 scratches could not be measured using this same technique and were measured by an alternative method (see following section).

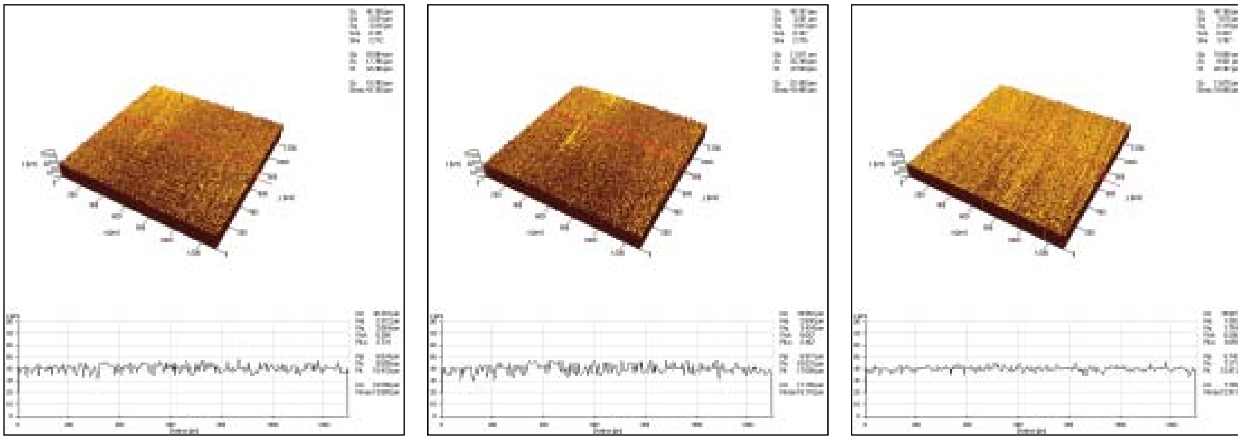

Fig 10 CLSM images of group 4. *(Left to right)* CM tip, CC tip, CA tip.

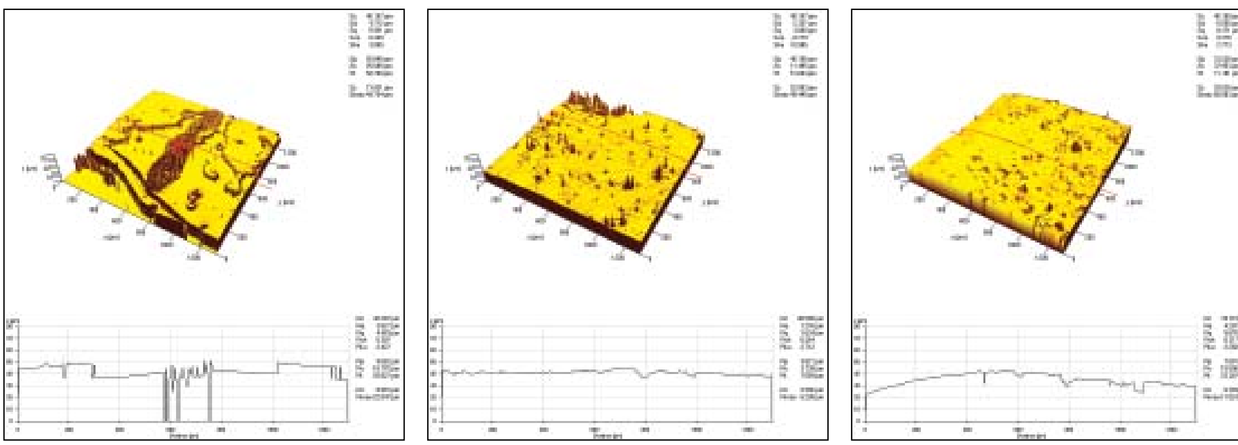

Fig 11 CLSM images of group 5. *(Left to right)* CM tip, CC tip, CA tip.

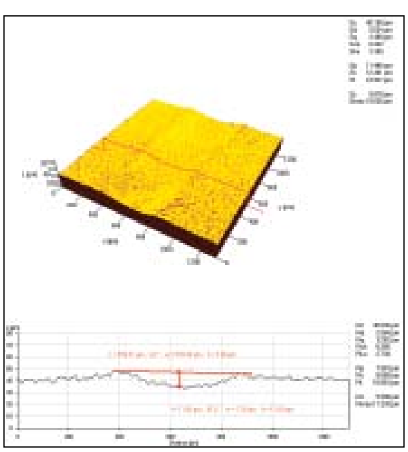

Fig 12 CLSM image of group 1 treated with a CM tip (low pass of 24 μm).

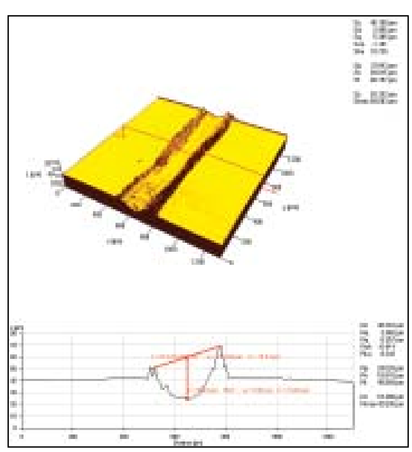

Fig 13 CLSM image of group 2 treated with a CM tip (low pass of 24 μm).

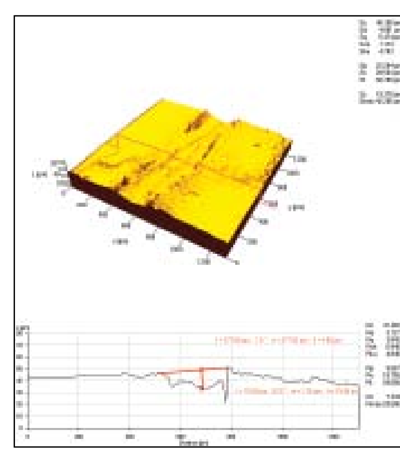

Fig 14 CLSM image of group 3 treated with a CM tip (low pass of 24 μm).

The mean depth of group 2 was 3.9 times greater than those of groups 1 and 3, and the mean width of group 1 was 1.7 times higher than those of groups 2 and 3 (Figs 16 and 17).

Surface Roughness. In group 5, the depths and widths of the scratches were not able to be measured using the method of Sánchez-Brea et al, so an alternative method of surface alteration was used. R_a measurement values (1,300 × 1,300 μm^2) are shown in Fig 18 (Gaussian filtering, high-pass, 8 μm). The R_a value of the scratches caused by the CM tip was about 1.8 times higher than those caused by the CC and CA tips (Fig 19).

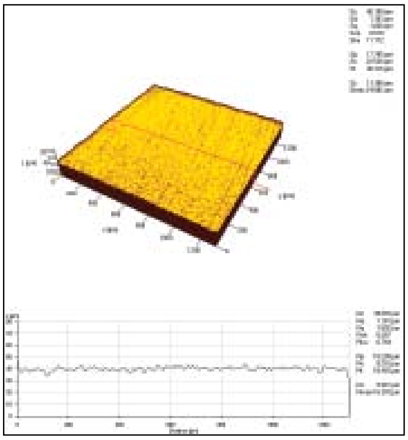

Fig 15 CLSM image of group 4 treated with a CM tip (low pass of 24 μm).

Table 1 Depths and Widths (Means ± SD, in μm) of the Scratches Caused by the CM Tip

Group	n	Depth	Width
Group 1	25	7.340 ± 2.433	476.440 ± 120.282
Group 2	25	27.857 ± 5.393	255.285 ± 24.260
Group 3	25	6.953 ± 2.895	292.574 ± 69.841
Group 4	25	*	*

*The surface defect was unable to be measured.
SD = standard deviation.

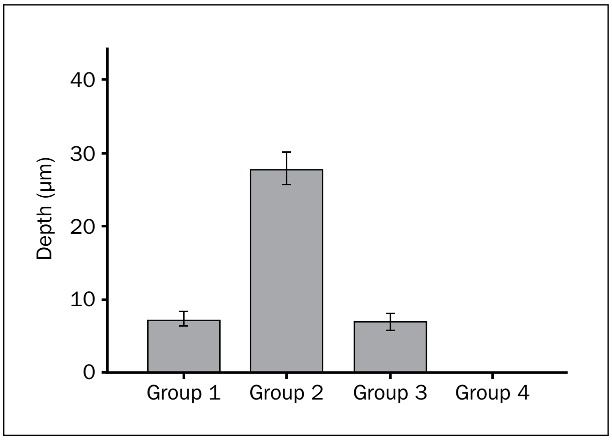

Fig 16 Depths of the scratches (μm).

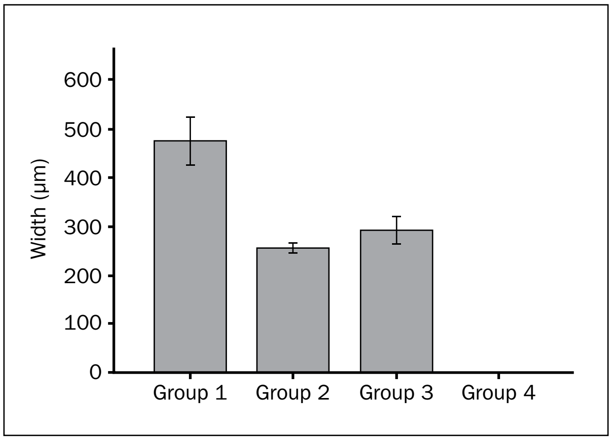

Fig 17 Widths of the scratches (μm).

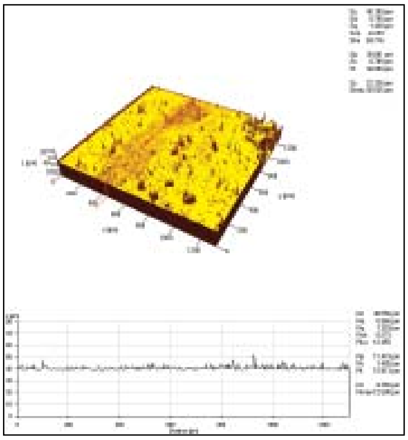

Fig 18 CLSM image of group 5 following treatment with the CM tip (high pass of 8 μm).

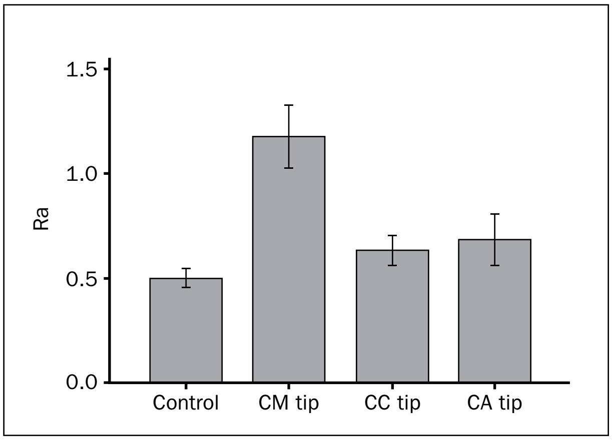

Fig 19 Surface roughnesses (R_a, μm) in group 5.

One-way analysis of variance revealed significant differences among the groups ($P < .001$; Table 2). Table 3 shows the significant differences between the control and CM tips ($P < .001$) and between the control and CA tips ($P = .024$). However, the Scheffé post hoc test indicated that there was no significant difference between the control and CC tips ($P = .163$). Likewise, no significant difference was observed between the CC and CA tips ($P = .903$).

Table 2 One-Way Analysis of Variance for Group 5

R_a	*df*	Sum of squares	Mean square	F	*P*
Between groups	3	4.679	1.560	46.480	< .001
Within groups	71	2.382	0.034		
Total	74	7.061			

df = degrees of freedom.

Table 3 Scheffé Multiple-Comparison Test of Group 5 (R_a, in μm)

Tip	n	Mean	SD
Control[a]	30	0.498	0.117
CC tip[a,b]	15	0.630	0.131
CA tip[b]	15	0.681	0.222
CM tip[c]	15	1.174	0.275

Different superscript letters indicate significant differences between groups.
SD = standard deviation.

DISCUSSION

The purpose of the present study was to investigate the surface alterations of several dental materials following treatment with three different ultrasonic scaler tips, including a novel model made of CA. Peri-implantitis is associated with the presence of plaque and soft tissue inflammation.[19] Berglundh et al[20] suggested that the progression of peri-implantitis is more pronounced at implants with a moderately rough surface than at those with a polished surface. Accordingly, surface alterations of five dental materials by representative ultrasonic scaler tips were evaluated in the present study.

Previous studies reported that CC or plastic ultrasonic scaler tips induced minimal alterations on a titanium surface and that a CM ultrasonic scaler tip caused considerable surface alterations.[4,9–15] Most studies have investigated and focused on surface alterations of titanium. However, the present study focused not only on the surface alterations of titanium but also on those of gold, Co-Cr alloy, zirconia, and porcelain, which are frequently used for implant prostheses.

Earlier studies adopted different scaling times, reciprocation rates, and force of the ultrasonic scaler device.[4,10,13–15] In the present study, each sample was instrumented with each ultrasonic scaler tip under standardized conditions, and the scaler tip was set perpendicular to the surface of samples to simulate severe conditions to emphasize the surface alterations. Accordingly, the characteristics of each scaler tip were recognized easily. However, the degree of surface alterations may not correlate with clinical situations, since the ultrasonic scaler is not used for the same duration of time and small area as were used in this study. Therefore, further study of the clinical relevance of the scaler tip is necessary.

Surface scratches were evaluated quantitatively by CLSM profilometric analysis and viewed under SEM. For the zirconia samples, the CLSM profiles and SEM images showed no significant surface changes following use of the CM, CC, and CA scaler tips.

Following use of the CM tip, scratches were detected in the SEM images of the surfaces of titanium, type II gold, Co-Cr alloy, and porcelain. They were analyzed by CLSM and profiles of the surface. To measure the size of scratches, CLSM profile data were processed by Gaussian filtering to remove very small peaks and unrepresentative noise. Defects on the titanium consisted of shallow but wide scratches, and the scratches on type II gold were narrower but deeper. Surface irregularities, where bacteria can be sheltered against shear forces, accumulate plaque more easily than smooth surfaces.[21] The scratches on the gold surface induced by the CM tip might provide a relatively better niche for bacterial accumulation than those on the titanium surface. Therefore, careful instrumentation during implant maintenance therapy is recommended.

Restorative dental materials, including porcelain and composite resin, instrumented with power-driven scalers may experience chips, scratches, or loss of material. Current evidence suggests that operation of ultrasonic scalers at medium rather than high power may cause less damage to surfaces.[22] Therefore, low to medium power for ultrasonic scalers is recommended for maintenance care.

In group 5, because the glazed surface of porcelain was disrupted with a CM tip, the change in surface integrity was analyzed via the changes in surface roughness. The glazed surface of porcelain showed a wavelike appearance following laboratory preparation. Therefore, the CLSM profile data were processed by cutting off the wavelength that exceeded 8 μm to eliminate the longer wavelength. Surface roughness of the porcelain caused by the CM tip was greater than that induced by the CC and CA tips, both of which caused minimal surface alterations.

In this study, the effects of the CA tip on surface alterations were compared to the effects induced by the CC tip, and the CA and CC tips were found to have similar effects. Despite the severe condition of instrumentation, the surface alterations could not be recognized easily following use of the CC or CA tips.

Therefore, the CC tip might be replaced by the CA tip to compensate for the fragility of the CC tip, and the CA tip may be safely used in maintenance procedures. Further research is necessary to investigate the clinical significance of the CA tip regarding surface alteration and roughness.

CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn. Surface alterations of titanium, type II gold, and cobalt-chromium alloy induced by conventional metal ultrasonic tips were much greater than those made by carbon composite and copper alloy tips. Alterations were not found on a zirconia surface following treatment with conventional metal, carbon composite, and copper alloy tips. On a porcelain surface, surface roughness (R_a) induced by the conventional metal tip was greater than the roughness induced by the carbon composite and copper alloy tips. The surface alterations caused by the carbon composite and copper alloy tips were similar. Copper alloy tips may be recommended for the maintenance of implant prostheses.

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REFERENCES

1. Lindh T, Gunne J, Tillberg A, Molin M. A meta-analysis of implants in partial edentulism. Clin Oral Implants Res 1998;9:80–90.
2. Esposito M, Hirsch J-M, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (I). Success criteria and epidemiology. Eur J Oral Sci 1998;106:527–551.
3. Tonetti MS, Schmid J. Pathogenesis of implant failures. Periodontology 2000 1994;4:127–138.
4. Ruhling A, Kocher T, Kreusch J, Plagmann HC. Treatment of subgingival implant surfaces with Teflon-coated sonic and ultrasonic scaler tips and various implant curettes. An in vitro study. Clin Oral Implants Res 1994;5:19–29.
5. Drisko CL, Cochran DL, Blieden T, et al. Position paper: Sonic and ultrasonic scalers in periodontics. J Periodontol 2000;71:1792–1801.
6. Tunkel J, Heinecke A, Flemmig TF. A systematic review of efficacy of machine-driven and manual subgingival debridement in the treatment of chronic periodontitis. J Clin Periodontol 2002;29:72–81.
7. Walmsley AD, Lea SC, Landini G, Moses AJ. Advances in power driven pocket/root instrumentation. J Clin Periodontol 2008;35:22–28.
8. Thomson-Neal D, Evans G, Meffert R. Effects of various prophylactic treatments on titanium, sapphire, and hydroxyapatite-coated implants: An SEM study. Int J Periodontics Restorative Dent 1989;9:300–311.
9. Rapley JW, Swan RH, Hallmon WW, Mills MP. The surface characteristics produced by various oral hygiene instruments and materials on titanium implant abutments. Int J Oral Maxillofac Implants 1990;5:47–52.
10. Matarasso S, Quaremba G, Coraggio F, Vaia E, Cafiero C, Lang NP. Maintenance of implants: An in vitro study of titanium implant surface modifications subsequent to the application of different prophylaxis procedures. Clin Oral Implants Res 1996;7:64–72.
11. Kawashima H, Sato S, Kishida M, Yagi H, Matsumoto K, Ito K. Treatment of titanium dental implants with three piezoelectric ultrasonic scalers: An in vivo study. J Periodontol 2007;78:1689–1694.
12. Hallmon WW, Waldrop TC, Meffert RM, Wade BW. A comparative study of the effects of metallic, nonmetallic, and sonic instrumentation on titanium abutment surfaces. Int J Oral Maxillofac Implants 1996;11:96–100.
13. Mengel R, Buns CE, Mengel C, Flores-de-Jacoby L. An in vitro study of the treatment of implant surfaces with different instruments. Int J Oral Maxillofac Implants 1998;13:91–96.
14. Sato S, Kishida M, Ito K. The comparative effect of ultrasonic scalers on titanium surfaces: An in vitro study. J Periodontol 2004;75:1269–1273.
15. Ramaglia L, di Lauro AE, Morgese F, Squillace A. Profilometric and standard error of the mean analysis of rough implant surfaces treated with different instrumentations. Implant Dent 2006;15:77–82.
16. Baek SH, Shon WJ, Bae KS, Kum KY, Lee WC. Evaluation of the safety and efficiency of novel metallic ultrasonic scaler tip on titanium surfaces. Clin Oral Implants Res 2011 Sep 30 [epub ahead of print].
17. Buchheit O, Arnoult C, Eddoumy F, Del Frari D, Di J. Combining WLI and SEM techniques to obtain a 4D surface image of a ppHDMSO/AlCeO3 nanocomposite. Image Anal Stereol 2010;29:27–34.
18. Sánchez-Brea LM, Gómez-Pedrero JA, Bernabeu E. Measurement of surface defects on thin steel wires by atomic force microscopy. Appl Surf Sci 1999;150:125–130.
19. Baron M, Haas R, Dortbudak O, Watzek G. Experimentally induced peri-implantitis: A review of different treatment methods described in the literature. Int J Oral Maxillofac Implants 2000;15:533–544.
20. Berglundh T, Gotfredsen K, Zitzmann NU, Lang NP, Lindhe J. Spontaneous progression of ligature induced peri-implantitis at implants with different surface roughness: An experimental study in dogs. Clin Oral Implants Res 2007;18:655–661.
21. Quirynen M, De Soete M, van Steenberghe D. Infectious risks for oral implants: A review of the literature. Clin Oral Implants Res 2002;13:1–19.
22. Chapple IL, Walmsley AD, Saxby MS, Moscrop H. Effect of instrument power setting during ultrasonic scaling upon treatment outcome. J Periodontol 1995;66:756–760.