

Effects of sonic scaling on the surface roughness of restorative materials

Peter Mourouzis¹⁾, Elisabeth A. Koulaouzidou¹⁾, Leonidas Vassiliadis²⁾
and Maria Helvatjoglu-Antoniades¹⁾

¹⁾Department of Operative Dentistry, Faculty of Dentistry, Aristotle University of Thessaloniki, Thessaloniki, Greece

²⁾Department of Endodontology, Faculty of Dentistry, Aristotle University of Thessaloniki, Thessaloniki, Greece

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Abstract: The surface roughness of dental restorative materials has a crucial effect on the health of dental and periodontal tissues as well as for the longevity of restorations. In this study we tested a glass ionomer restorative cement, two nanohybrid resin composites, a flowable resin composite and a silorane-based composite. Twenty cylindrical specimens of each material were prepared, cured, polished and instrumented with a sonic scaler (Alegra ST ZE-55 RM W&H, Austria). The mean surface roughness was recorded using a profilometer (SJ-201, Mitutoyo, Japan) at three stages: before scaling, after scaling and after re-polishing. Additional specimens were analyzed by scanning electron microscopy and back-scattered imaging. Data were examined statistically by analysis of variance (ANOVA) and post-hoc tests at a level of significance of $P < 0.05$. The profilometric measurements and the SEM evaluation showed that, in most of the materials tested, the surface roughness was significantly increased after sonic instrumentation. After re-polishing the specimens, the roughness values were decreased. Periodontal scaling should include polishing of restorations in order to overcome alterations in surface roughness. (J Oral Sci 51, 607-614, 2009)

Keywords: surface roughness; periodontal scaling; restorative materials.

Correspondence to Dr. Elisabeth A. Koulaouzidou, 1 Xenofontos Street, GR 55132, Kalamaria, Thessaloniki, Greece
Tel: +30-2310-482233
Fax: +30-2310-999616
E-mail: koulaouz@dent.auth.gr

Introduction

Periodontal therapy and prophylaxis involve the removal of plaque, calculus and endotoxin from teeth or exposed root surfaces with hand- or machine-driven instruments (1). Sonic and ultrasonic scaling have become the most widely used methods among dental surgeons and oral hygienists, due to the decreased time requirement and ease of application in comparison with hand instrumentation, and various studies have confirmed that the two techniques yield similar results (2). The effects of sonic and ultrasonic scalers on hard and soft tissues have been investigated and well documented (3,4). However, there is limited information regarding the effects of sonic and ultrasonic instrumentation on the esthetics of restorative materials (5,6). A large number of restorative materials have recently been marketed for esthetic restorations, and therefore practitioners have a variety of options when selecting materials and procedures for restoring teeth. The surface roughness of restorative materials is an important factor for the esthetic appearance and longevity of restorations. The presence of irregularities on the surface of the restorations may result in plaque and stain retention, gingival inflammation, and solubility of the organic matrix due to the formation of acids by plaque (7-9).

An additional issue is that the surface roughness of these restorative materials can promote biofilm formation (10). Increased surface roughness facilitates mechanical aggregation of the initial bacterial populations, which promotes the process of periodontal disease due to the retention of bacterial plaque. High substratum surface free energy and an increase in surface roughness facilitate

plaque accumulation (9) and increase the proportions of bacteria. If we consider that the gingival margins of Class II, IV and V restorations are often placed at or beneath the gingival margin, we can deduce that ultrasonic and sonic devices can directly or indirectly affect the health of periodontal tissues (10-13) through changes in the microbiological balance in the gingival sulcus conducive to bacteria associated with periodontal diseases.

This *in vitro* study investigated the effects of sonic scaling on the surface roughness of different types of commonly used dental restorative materials.

Materials and Methods

The materials tested were: Clearfil Majesty Esthetic (Kuraray Medical Inc., Tokyo, Japan), Clearfil Majesty Flow (Kuraray Medical Inc., Tokyo, Japan), Filtek Supreme

XT (3M/ESPE, St. Paul, MN, USA), Filtek Silorane (3M/ESPE, St. Paul, MN, USA) and Fuji IX (GC Corporation, Tokyo, Japan). The types, manufacturers and compositions of the tested materials are presented in Table 1.

The materials were overfilled into customized Teflon molds. Twenty specimens of each material were prepared, cylindrical in shape (diameter 5 mm and height 1.5 mm) and covered with acetate strips (Polydentia SA, Mezzovico, Switzerland). A glass slide was placed over the acetate strips and pressure was applied to extrude excess material and to prevent oxygen inhibiting layer formation. The light-curing materials were polymerized according to the manufacturer's instructions, for 40 s, through the glass slide. The light-curing unit used was the PenCure Dental Curing Light VL-7-CE (J. Morita Mfg. Corp., Osaka, Japan).

Table 1 Restorative materials tested

Material	Type	Composition	Manufacturer
Fuji IX	Glass ionomer cement	Powder: Alumino silicate glass Polyacrylic acid powder Liquid: Polyacrylic acid Water	GC Corporation, Tokyo Japan
Clearfil Majesty Esthetic	Nanofilled composite	Silanated barium glass filler Pre-polymerized organic filler Hydrophobic aromatic dimethacrylate Bisphenol A diglycidylmethacrylate (Bis-GMA) dl-Camphorquinone Other additives	Kuraray Medical INC., Tokyo Japan
Clearfil Majesty Flow	Flowable composite	Silanated barium glass filler Silanated colloidal silica Hydrophobic aromatic dimethacrylate Trietheneglycol dimethacrylate (TEGDMA) dl-Camphorquinone Other additives	Kuraray Medical INC., Tokyo Japan
Filtek Supreme XT	Nanocomposite restorative	Silane treated ceramic Silane treated silica Bisphenol A polyethylene glycol diether dimethacrylate (BISEMA6) Diurethane dimethacrylate Bisphenol A diglycidyl ether methacrylate (Bis-GMA) Triethylene glycol dimethacrylate (TEGDMA) Water	3M/ESPE, St. Paul MN USA
Filtek Silorane	Low shrink silorane-based composite	Silane treated quartz 3,4-epoxycyclohexylcyclopolymethylsiloxane Yttrium trifluoride Bis-3,4-epoxycyclohexylethyl-phenyl-methylsilane Mixture of epoxyfunctional di- and oligo-siloxane by-products Mixture of alpha-substituted by-products Mixture of other by-products Mixture of epoxy-mono-silanole by-products Initiating system: camphorquinone, iodonium salt, electron donor Stabilizers Pigments	3M/ESPE, St. Paul MN USA

The irradiance of light-curing unit intensity was checked before the experiment, and was 800 mW/cm². For the self-curing material tested (Fuji IX), the specimens were left undisturbed for 10 min, according to the manufacturer's instructions, to allow self-curing.

All specimens were contoured, finished and wet-polished with abrasive discs (Flexi-Snap Kit 1295SO, Edenta AG, Switzerland) at low speed, and then subsequently rinsed in running tap water. The polishing procedure was performed by a single operator using abrasive discs for contouring and polishing over the whole surface of each specimen, at 10,000-12,000 r.p.m with 0.3-0.6 N pressure in accordance with the manufacturer's instructions. The polishing was performed sequentially with a complete series of abrasive discs (coarse medium, fine and ultra-fine). Average surface roughness (Ra, in μm) of the specimens was determined with a previously calibrated surface roughness tester (SJ-201, Mitutoyo, Kanagawa, Japan). Three measurements at different locations on each specimen were taken and the average of these three readings was recorded as the surface roughness value for each specimen. Then, the specimens were instrumented with a new sonic tip (Alegra ST ZE-55 RM, W&H, Austria) under standard operating conditions (medium power setting, 0° angulation and standard lateral force) for 15 s. To avoid operator variation, the same operator performed the sonication on all specimens, starting from the periphery to the center of

each specimen. After instrumentation, the specimens were rinsed in tap water and the mean surface roughness (Ra) was recorded. All specimens were re-polished using the polishing procedure described above, and then a third measurement of the surface roughness was recorded. Additional specimens (two for each material and treatment procedure) were prepared and analyzed by scanning electron microscopy (SEM, JEOL 840 A, Tokyo, Japan) at $\times 100$, $\times 500$ and $\times 1,000$ magnification at a voltage of 20kV. Back-scattered imaging (BSI) was also used for surface evaluation.

The data obtained were distributed normally and were evaluated statistically by analysis of variance (ANOVA), followed by Tukey HSD test to define differences among the tested groups. The statistical analysis was carried out using the SPSS 10.0 for Windows software package (SPSS Inc., Chicago, IL, USA). Differences at $P < 0.05$ were considered statistically significant. The results of the statistical analysis are presented in Table 3.

Results

The mean surface roughness (Ra, in μm) values and standard deviations of each specimen measured before and after sonic instrumentation are presented in Table 2. Statistical analysis of the results showed that sonic instrumentation resulted in significant increases ($P < 0.05$) in surface roughness for all materials tested, except for

Table 2 Mean roughness (Ra, in μm) obtained before sonic instrumentation, after sonic instrumentation and after re-polishing

Material	Before sonic instrumentation	After sonic instrumentation	After re-polishing
Fuji IX	0.473 ^a (0.237)	1.238 ^b (0.656)	0.749 ^a (0.423)
Clearfil Majesty Esthetic	0.570 ^a (0.279)	1.190 ^b (0.440)	0.567 ^a (0.432)
Clearfil Majesty Flow	0.383 ^a (0.073)	0.484 ^b (0.115)	0.429 ^{ab} (0.119)
Filtek Supreme XT	0.351 ^a (0.169)	0.404 ^a (0.160)	0.340 ^a (0.212)
Filtek Silorane	0.250 ^a (0.145)	0.725 ^b (0.239)	0.382 ^a (0.232)

Values represent means of twenty samples ($n = 20$) and standard deviations in parentheses. Different letters as superscripts indicate statistical significant difference ($P < 0.05$).

Table 3 Results of the statistical analysis by Tukey HSD test

	Fuji IX		Clearfil Majesty Esthetic		Clearfil Majesty Flow		Filtek Supreme XT		Filtek Silorane	
	Mean difference	Sig.	Mean difference	Sig.	Mean difference	Sig.	Mean difference	Sig.	Mean difference	Sig.
Before sonication / After sonication	0.765	0.000	0.619	0.000	0.100	0.016	0.053	0.670	0.475	0.000
Before sonication / After re-polishing	0.276	0.232	0.003	1.000	0.045	0.401	0.011	0.983	0.132	0.391
After sonication / After re-polishing	0.489	0.014	0.622	0.000	0.055	0.267	0.064	0.558	0.343	0.006

Filtek Supreme. When the specimens of all materials were re-polished, their roughness values were decreased.

Fuji IX glass ionomer cement showed the highest roughness values (1.238 μm) after sonic instrumentation, while Clearfil Flow and Filtek Supreme showed the lowest values (0.484 μm and 0.404 μm , respectively). Clearfil Majesty Esthetic showed an initial surface roughness value of 0.570 μm that increased significantly to 1.190 μm after sonic scaling, and this difference was statistically significant ($P < 0.05$). Filtek Silorane revealed an initial Ra value of 0.250 μm , which increased significantly ($P < 0.05$) to 0.725 μm after sonic instrumentation, and then decreased to 0.382 μm after re-polishing. Finally, Filtek Supreme showed no statistically significant alterations in surface roughness either after sonic instrumentation or after re-polishing of the specimens ($P > 0.05$).

SEM examination of the specimens confirmed the roughness data. Typical SEM photomicrographs and back-scattered images of the specimens after sonication are shown in Figs 1-4. The sonic scaling generally created a surface rougher than the surface observed before sonic instrumentation or after re-polishing. The surface disruption was more evident in Fuji IX cement, where an irregular surface and cratered areas were observed after sonic instrumentation.

Discussion

One of the main etiological factors of periodontal disease is the formation and maturation of biofilm. The principal objective of prevention and/or treatment in periodontitis is the periodic removal of plaque and calcified deposits from teeth and restorations. This procedure is usually accomplished by sonic and ultrasonic scaling systems that may inadvertently affect not only dental tissues but also the restorative materials. In this study, we tested the effect of sonic instruments on materials used for esthetic teeth restorations *in vitro*. The prevalence of overhanging margins in restorations and their periodontal consequences have been well documented by many authors (13,14), but few studies have examined the consequences of maintenance therapy/dental scaling for dental filling materials. Restorative materials may differ in particle size, inorganic filler quantity, shape and volume, thus presenting different physical properties. It has been reported that the materials containing fillers tend to absorb energy, in order to avoid or lessen the formation and propagation of surface microcracks in the material (9).

Glass ionomer cements are generally indicated for root restorations, mainly because of their ability to release fluoride and therefore act in an anticariogenic manner (15,16). The Fuji IX cement tested in the present study

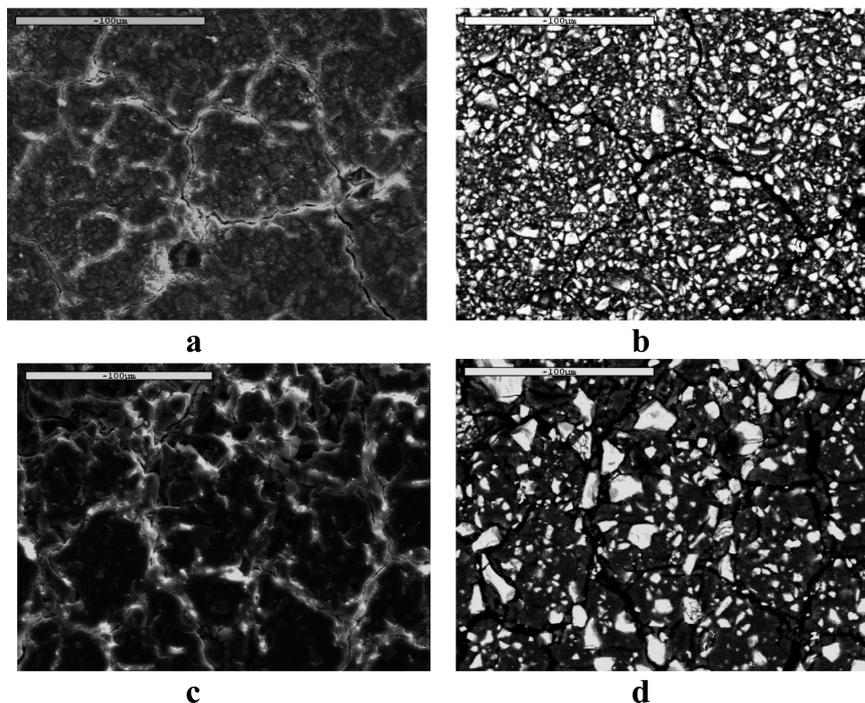


Fig. 1 Scanning electron micrograph (a) and back-scattered image (b) of the surface of Fuji IX before sonic scaling (magnification $\times 500$). Scanning electron micrograph (c) and back-scattered image (d) of the surface of Fuji IX after sonic scaling (magnification $\times 500$).

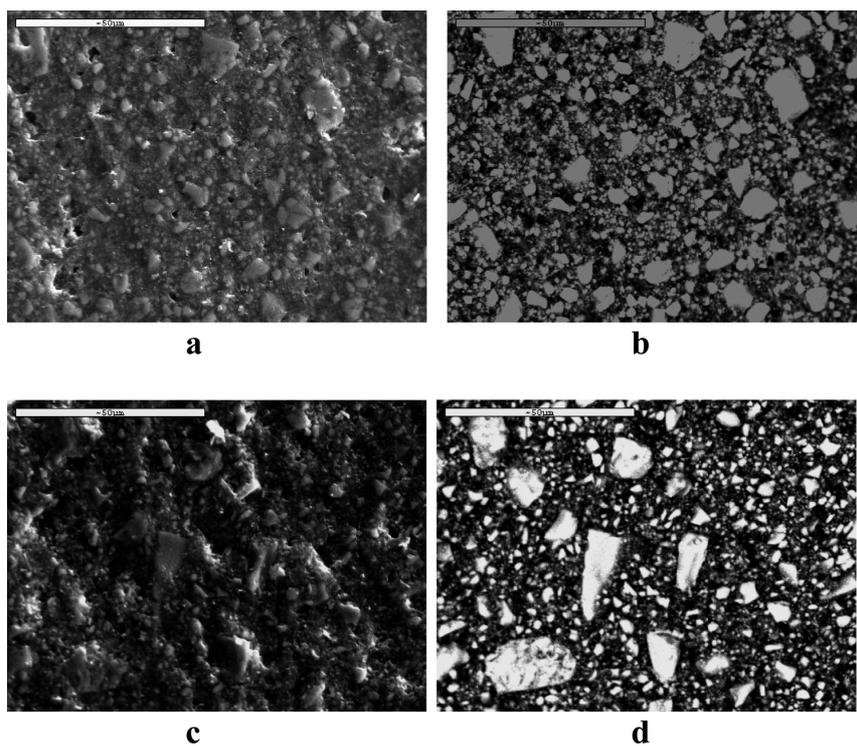


Fig. 2 Scanning electron micrograph (a) and back-scattered image (b) of the surface of Clearfil Majesty Flow before sonic scaling (magnification $\times 1,000$). Scanning electron micrograph (c) and back-scattered image (d) of the surface of Clearfil Majesty Flow after sonic scaling (magnification $\times 1,000$).

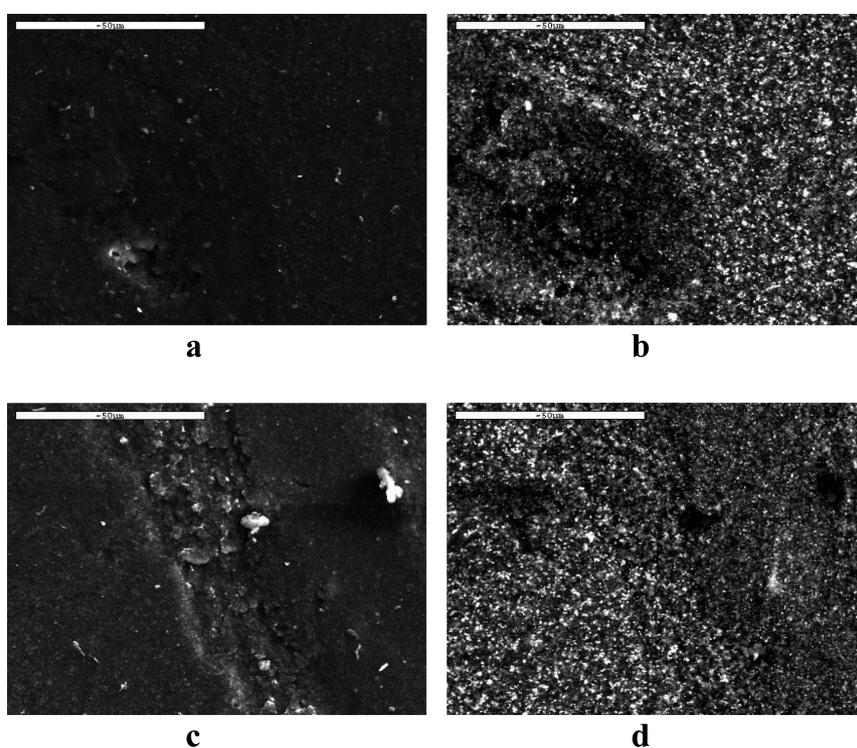


Fig. 3 Scanning electron micrograph (a) and back-scattered image (b) of the surface of Filtek Silorane before sonic scaling (magnification $\times 1,000$). Scanning electron micrograph (c) and back-scattered image (d) of the Filtek Silorane surface after sonic scaling (magnification $\times 1,000$).

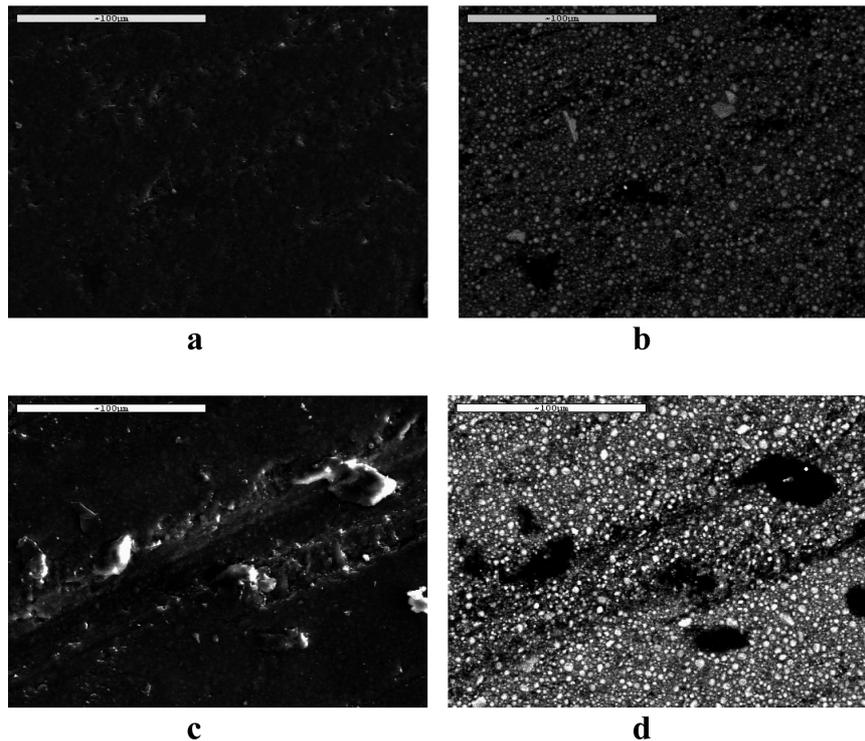


Fig. 4 Scanning electron micrograph (a) and back-scattered image (b) of the surface of Filtek Supreme before sonic scaling (magnification $\times 500$). Scanning electron micrograph (c) and back-scattered image (d) of the surface of Filtek Supreme after sonic scaling (magnification $\times 500$).

showed an initial roughness value of $0.473 \mu\text{m}$. After scaling, the roughness was significantly altered and reached $1.238 \mu\text{m}$. This may be attributed to the heterogeneous and biphasic nature of glass ionomer materials (6). The weak matrix phase may be easily removed, leaving unreacted harder glass particles protruding from the surface (6). Although SEM analysis has limitations for observing surface defects or scratches (17), in the present study the SEM results were correlated well with the Ra measurements.

Recently marketed flowable resin composites have an increased filler content and superior physical and mechanical properties as compared with those marketed previously. In Clearfil Majesty Flow, the filler content reaches 62% vol. and 81% wt., percentages that are similar to the filler content of non-flowable resin composites (18,19). This may be related to their low wear resistance and susceptibility to degradation by sonic instrumentation.

Nanohybrid composites have a smaller average particle size than conventional composites, reaching the order of 0.02 to $2 \mu\text{m}$. This explains the superiority of their physical properties in comparison with conventional composites, as well as their very smooth surface after contouring and finishing of the restoration (20).

In our study, relatively high values of surface roughness after sonic scaling were observed for Clearfil Majesty Esthetic. The presence of pre-polymerized organic fillers in Clearfil Majesty Esthetic may be related to alterations in surface roughness after sonic instrumentation.

Sonic instrumentation altered significantly ($P < 0.05$) the surface of the silorane-based composite we tested. The network of siloranes is generated by cationic ring opening polymerization of the cycloaliphatic oxirane moieties, which is related to their low shrinkage and low polymerization stress (21). The most important difference is that methacrylates are cured by radical intermediates while oxiranes polymerize via cationic intermediates. With regard to filler content, silorane composites contain fine particulate quartz fillers below $0.5 \mu\text{m}$ in size, and this is related to the composite's esthetic properties and mechanical stability.

In a similar *in vitro* study, Lai et al. (6) reported that, after ultrasonic scaling, glass ionomer cement (Fuji II) showed significantly higher surface roughness than did resin composites Z100 and Tetric Flow, while Bjornson et al. (5) reported that ultrasonic and sonic scaling altered the composite resin surfaces, allowing the particles and matrix

to be visible by SEM. Ultrasonic and sonic scalers produced similar changes in weight and surface profile, but the majority of the composite surface that was instrumented by the sonic scaler was unaltered (5).

The profilometric results after sonic scaling, in combination with the results obtained by SEM and BSI, suggest that scalers cause chips, scratches and sometimes loss of the material. These surface alterations may cause plaque and stain accumulation, increasing the risk of both caries and periodontal inflammation. Therefore, upon initial use of the scaler, the power must be adjusted to the appropriate level, so that the plaque will be removed quickly. During maintenance therapy, when biofilms have been recently created, the power of the scaler must be decreased so that the restoration materials and dental tissues will not be damaged (5).

The present data, although not directly applicable to clinical conditions, suggest that the use of sonic scalers might affect the surfaces of restorative materials, especially those of glass ionomer cements. In terms of surface roughness, it is recommended that routine periodontal scaling should be carried out very carefully, and that polishing of the scaled surfaces may overcome the alterations in roughness, thus preventing secondary caries, surface staining, plaque accumulation and subsequent periodontal inflammation.

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