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Influence of Manual and Ultrasonic Scaling on Surface Roughness of Four Different Base Materials Used to Elevate Proximal Dentin–Cementum Gingival Margins: An *In Vitro* Study

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Clinical Relevance

In terms of surface roughness, resin-based composite could be recommended for gingival margin elevation of subgingival proximal cavities rather than glass ionomer-based restorative materials. Whenever noninvasive periodontal treatment is required for such restored cavities, hand scaling may be preferable rather than the ultrasonic method.

SUMMARY

Aim: To evaluate and compare the effects of both manual and ultrasonic scaling on surface roughness of four different base materials, used for elevating dentin/cementum gingival margins of proximal cavities.

Methods and Materials: Eighty human upper molars with compound Class II mesial cavities, with gingival margins 1 mm below the cemento–enamel junction (CEJ), were divided into four different groups according to the type of the base material used; resin-modified glass ionomer (RMGI), glass hybrid (HV-GIC), flowable bulk-fill resin composite (Bulk Flow) and bioactive ionic resin (Activa). This was followed by completing the restorations with the same resin composite. All materials were used according to the manufacturers' instructions. All

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groups were further subdivided into two subgroups according to the scaling technique: manual (hand) or ultrasonic. All restorative and scaling procedures were performed after fixation of specimens with acrylic beside neighboring teeth to simulate natural contact. The mean surface roughness (Ra, μm) of all specimens was measured quantitatively and qualitatively by a three-dimensional (3D) surface analyzer system at two stages; (1) after thermal cycling for 5000 cycles without scaling and (2) after scaling. Data were statistically analyzed using analysis of variance (ANOVA), Tukey post hoc tests, and paired sample *t*-tests (at α=0.05).

Results: For baseline readings, the Bulk Flow group had the lowest R_a values, while HV-GIC group had the highest. RMGI and Activa groups had no statistical significant difference between their R_a values (p>0.05). For post scaling readings, hand scaling had significantly lower R_a values than ultrasonic scaling in all the material groups (p<0.05), except in the Bulk Flow group, where both scaling methods were not significantly different from each other (p>0.05)

Conclusion: Bulk Flow had the smoothest surfaces when cured against a matrix band compared with the other tested base materials. When hand and ultrasonic scaling methods were compared, the latter technique had more detrimental effect on the surface texture of the four tested base materials.

INTRODUCTION

Large posterior defects with proximal caries extending below the cemento–enamel junction (CEJ) and cavity margins located beneath the gingival tissues represent a very common clinical situation.[1] Beside the challenges encountered during restoration of such defects, deep cervical margins are critical areas that may cause gingival irritation and periodontal pockets,[1,2] especially if restorations are overhung or rough.[3]

The only structure that has a biological reaction after the invasion of the biological width is the connective tissue attachment, which is very selective about surfaces to be attached to; it needs cementum on one side and bone on the other. By contrast, epithelial attachment is not specific; it is capable of attaching to enamel, cementum, and restorative material, as long as the surface is hard, smooth, and clean.[4] *In vivo* studies showed a positive correlation between the surface roughness and the rate of supra and subgingival plaque accumulation that may lead to periodontal inflammation and an increased pathogenic bacterial colonization.[5,6] These previous findings highlighted the importance of smooth restorations placed below the gingiva.

The health of periodontal tissue should be maintained using the least invasive approaches.[7] Noninvasive periodontal treatment procedures, including scaling and root planning, are considered as the first line for management of the periodontal conditions.[8] Different methods of scaling and root planning can control the gingival inflammation and bleeding index.[9] In addition, a previous systematic review showed that subgingival mechanical debridement increased the mean attachment gain of gingival tissues.[10] These noninvasive periodontal procedures are of a particular importance in subgingival Class II and V cavities.[11] On the other hand, it was reported that all scaling methods have a negative effect on the surface smoothness of both the root and restorative materials.[12-14] Thus, although periodontal benefits are obtained after scaling procedures, there is still the risk of increasing the surface roughness after these procedures, affecting the long-term success of the treatment.[15]

Proximal cavities with cervical margins below the gingiva are usually restored using either an open-sandwich technique or cervical margin relocation concepts,[16,17] where direct restorations are used as a base for elevating the proximal cavity margin from an intracrevicular to a supragingival position and then completing the rest of the cavity with either direct or indirect options.[17] Different base restorative materials were investigated in the literature for gingival margin elevation in such situations, including different modifications of glass ionomers and resin composites.[18,19]

Deep proximal cervical restorative surfaces are inadvertently subjected to different scaling procedures. Thus, the influence of such procedures on surface roughness of these restorative surfaces should be of interest. There is ample data regarding the effect of different scaling techniques on soft tissues, root surfaces, and even on restorative materials placed in Class V cavities. However, there are insufficient studies reporting the effect of scaling techniques on deep proximal cervical restorative surfaces. Therefore, this study evaluated and compared the effect of both manual and ultrasonic scaling on surface roughness of four different base materials, three of them were glass ionomer-based and one was resin composite-based, used for elevating dentin–cementum gingival margins of the proximal cavities. The research hypotheses were: (1) there is no difference in surface roughness between different base materials; (2) there is no effect on roughness of the four base materials following either manual or ultrasonic scaling.

METHODS AND MATERIALS

Materials

Four commercially available restorative materials were tested in the current study. Resin-modified glass ionomer (Fuji II LC) (RMGI), glass hybrid (EQUIA Forte) (HV-GIC), flowable bulk-fill resin composite (Tetric N-Flow Bulk Fill) (Bulk flow), and bioactive ionic resin (ACTIVA BioACTIVE RESTORATIVE) (Activa). The detailed description of the materials is presented in Table 1.

Cavity Preparation

Eighty sound human upper molars recently extracted due to periodontal disease were included in this study; they had approximately similar dimensions, and were examined with stereomicroscopy to confirm that they were caries and crack free, then cleaned of soft tissue and calculus deposits with ultrasonic scaler, and stored in 0.1% thymol solution until used.

Compound Class II cavities with standardized dimensions were prepared on the mesial surfaces of all teeth using cylindrical, medium-grit diamond burs (K881 012, öko DENT, Germany) under copious water coolant with a high speed handpiece (W&H, RC-90RM, Austria). A pencil was used to mark the outline before preparation. The cavity dimensions were: occlusal: 3 mm buccolingual width, 3 mm depth; box: 1 mm below the CEJ, 1.5 mm mesiodistal dimension at the cervical floor, and 4 mm bucco-lingual width.[20] The margins were not beveled with slightly rounded line angels. A new bur was used after every five preparations. The dimensions were verified using a graduated periodontal probe.[20] After preparation, cavities were examined for any defects. Buccal and palatal walls of the proximal boxes of all teeth were marked with pencil 1.5 mm above the CEJ (to mark the level of the base material) (Figure 1A,B).

Tooth Fixation

Following cavity preparation, each tooth was fixed with mesial and distal acrylic neighboring teeth (Banna, Alexandria, Egypt) using condensation silicone impression material (Silaxil putty, Lascod, Italy). The teeth were fixed in a way to simulate natural contact and correct occluso-gingival level of the three teeth.

Table 1: *Materials Used in the Study*

Base Material	Type	Manufacturer	Composition	Filler Particle Size	Lot Number
Fuji II LC	Resin-modified glass ionomer	GC Corporation, Tokyo, Japan	Powder: 95% strontium fluoroalumino silicate glass Liquid: polyacrylic acid (20%-25%), 2-hydroxyl ethyl methacrylate bicarbonate (1%-5%), proprietary ingredient (5%-15%)	4.5 µm	1904231
EQUIA Forte	Conventional highly viscous glass ionomer	GC Corporation, Tokyo, Japan	Powder: 95% strontium fluoroalumino-silicate glass (including highly reactive small particles), polyacrylic acid powder Liquid: 5% polyacrylic acid, polycarboxylic acid, tartaric acid	25 µm + 4 µm	1808163
Tetric N flow bulk fill	Flowable bulk-fill resin composite	Ivoclar Vivadent, NY, USA	Bis-GMA, UDMA, TEGDMA, Ivocerin, Barium glass, ytterbium trifluoride, mixed oxide, silicon dioxide (filler loading: 68.2 wt%)	5 µm	Y35353
Activa Bioactive Restorative	Bioactive resin matrix and bioactive glass fillers	Pulpdent; Watertown, MA, USA	Powder: diurethane dimethacrylate, bis (2-(methacryloyloxy) ethyl) Phosphate, barium glass, ionomer glass, sodium fluoride, colorants Liquid: polyacrylic acid/maleic acid copolymer (filler loading: 56 wt%)	4 µm to submicron	190619

Abbreviations: Bis-GMA, Bisphenol A-glycidyl methacrylate; UDMA, Urethane dimethacrylate; TEGDMA, Triethylene glycol dimethacrylate.

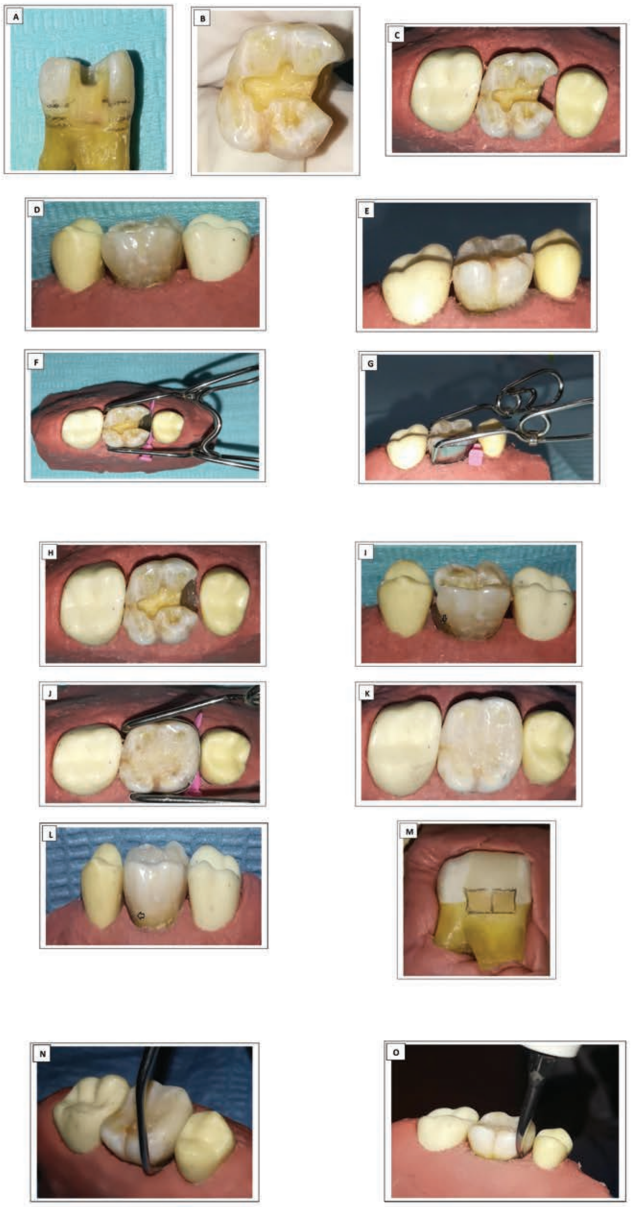

Figure 1. *Methodology steps for a representative specimen (Bulk Flow). A: Proximal cavity part outline and dimensions, the three lines mark 1.5 mm above CEJ, CEJ, 1 mm below CEJ. B: Occlusal cavity part outline and dimensions. C: Occlusal view for fixing the teeth in silicone impression material (putty consistency). D,E: Buccal and palatal views for fixation. F,G: Occlusal and buccal views for the Saddle matrix band and diamond wedge in place. H,I: Occlusal and buccal views after base placement, black arrow indicates the base material level (just below the contact). J,K: Occlusal views for the final restoration before and after finishing and polishing. L: Buccal view for the final restoration (black arrow indicates the level of base material/ junction between base material and overlying composite). M: Specimen in the 2nd silicone block for roughness evaluation, the margins of the base material were marked and divided into two halves—buccal and palatal. N: Gracey curette (no. 11/12) in place. O: Ultrasonic tip was placed at zero angulation while the end of the tip 1 mm below gingival simulation.*

The impression material was shaped using a dental wax carver (Lecron wax carver, Accurate Manufacturing, Pakistan) to simulate the correct contour and level of the gingiva around the teeth, especially parts simulating buccal and palatal gingival papilla. The impression material was kept at the level of buccal and palatal CEJ of the three teeth, then was left to set for 5 minutes before trimming of the excess using number #11 surgical blades (Tianda Medical Instruments Co, Huaian, China) (Figure 1C,D,E). Teeth were randomly assigned into four different groups, 20 molars each, according to the base material used. Each group's teeth were numbered from 1 to 20, with a specific color for each material group on the distal surface.

Restorative Procedures

After preparation and fixation procedures, cavities were washed with water and dried. For RMGI and HV-GIC groups, the gingival margins of the cavities were conditioned as recommended by the manufacturer with dentin conditioner (GC Co, Tokyo, Japan) for 20 seconds, followed by rinsing and drying. Occlusal and proximal enamel margins of all the cavities were selectively etched with 37% phosphoric acid (N-Etch, Ivoclar Vivadent, NY, USA) for 15 seconds, rinsed with water for the same time, excess water was blotted without desiccation. For Bulk Flow and Activa groups, a universal adhesive (Tetric N-Bond Universal, Ivoclar Vivadent, NY, USA) was applied before base placement on all cavity surfaces, air dried and light cured as recommended by the manufacturers' instructions with a LED curing light (Elipar Deep Cure, 3M Oral Care, St Paul, MN, USA) operating at 1000 mW/cm^2, and checked periodically after every 5 samples with a radiometer (Radiometer 100, Demetron Research Corp, Danbury, CT, USA).

Large-sized saddle contoured metal matrix bands with an enlarged subgingival ledge (N 1.313-0.035 mm, Tor VM, Moscow, Russia) with Small Spring clip (N 1.003 Tor VM, Moscow, Russia) were applied around each cavity while making sure that the end of the band was beyond the gingival margin of the cavity. Then, a suitable-sized plastic wedge (Diamond Wedges, Bioclear, Tacoma, WA, USA) was applied in the gingival embrasure between each tooth and neighboring premolar, ensuring intimate adaptation between the gingival margin of the cavity and internal surface of the band (Figure 1F,G). After that, each group was restored up to 1.5 mm above the CEJ using the group specific base material in a bulk technique (Figure 1H,I). All base materials were mixed, dispensed, and cured (RMGI, Activa and Bulk Flow groups) according to the manufacturers' instructions. For RMGI and HV-

GIC groups, the universal adhesive was applied after base placement with the same technique mentioned earlier. The remaining cavity was restored with a nanohybrid resin composite material (Tetric N-Ceram, Ivoclar Vivadent) that was inserted in the cavity in 2-mm horizontal increments using a plastic instrument until the cavity was completely filled.[21] Each increment was cured from the occlusal surface for 20 seconds. Additional curing for 40 seconds was performed from the proximal surface after removal of the wedge and matrix band (Figure 1J).

All specimens were stored in distilled water at 37°C for 24 hours in an incubator (BTC, Model: BT1020, Egypt) prior to the finishing and polishing procedures.[22] Finishing and polishing of the occlusal surfaces was performed with Al_2O_3 discs (Tor VM, Moscow, Russia) using a low-speed handpiece (Strong 204, Daegu, South Korea) under water cooling; proximal surfaces were kept without finishing and polishing to simulate clinical situations (Figure 1K,L). All procedures were performed by a single operator using magnification (4× loupes, Amtech, Wenzhou, China).

Thermocycling

After restoration, each specimen was removed from the rubber base block. All specimens (n=80) were thermocycled for a total number of 5000 cycles (SD Mechatronik thermocycler, Germany), which represents approximately 6 months of clinical service before scaling.[23] The specimens were alternated between 5°C and 55°C ± 2°C, according to ISO 11405 (International Standards Organization) recommendations, continuously checking for water temperature, with a dwell time of 15 seconds and a transfer time of 5 seconds.[24] Afterwards, all the specimens were carefully evaluated under an optical microscope to check for cracks. Finally, each specimen was fixed in a second rubber base block where the mesial surface to be evaluated was facing upwards to facilitate roughness evaluation (Figure 1M).

Pre-instrumentation Roughness Reading

The area of the base material (2.5 mm × 4 mm) was marked with pencil, and then divided into buccal and palatal haves. Each half was assessed quantitatively and qualitatively for surface roughness using a 3D surface analyzer system. Each half was photographed using a USB digital microscope with a built-in camera (U500× Capture Digital Microscope, Guangdong, China) connected with an IBM compatible personal computer using a fixed magnification of 120× and a resolution of 1280×1024 pixels per image. The digital microscope images were cropped to 350×400 pixels using Microsoft Office picture manager to specify and standardize the area of roughness measurement. The cropped images were analyzed using WSxM software (Ver 5 develop 4.1, Nanotec, Electronica, SL, Spain) where a 3D image of the surface profile was created.[25,26] Three 3D images with an area of 10 μm × 10 μm were collected at different sites for each half; then the average of the three readings were recorded as the surface roughness (R_a, μm) value for either buccal side or palatal side to serve as the prescaling baseline controls.[12]

Scaling

After initial roughness evaluation, each group was further subdivided into 2 subgroups (n=10) according to the scaling technique; (1) hand scaling subgroup, or (2) ultrasonic scaling subgroup, and returned back to the rubber base mold with the same proximal and occlusal relation with the two neighboring teeth used for restoration.

For hand scaling subgroups, a Gracey curette (no 11/12; Goldman Products Inc, Wauconda, IL, USA) was used. Each buccal/palatal side received 10 apical to coronal consecutive strokes parallel to the long axis of the tooth using medium force,[12,27] each side of the curette was used with either buccal or lingual side scaling, and when the interproximal side was changed, the side of the curette was replaced. Curettes were sharpened using a ceramic sharpening stone (SST-C3, Osung, Seoul, South Korea) after every tooth. A sharp, new curette was used for each group (Figure 1N).

For ultrasonic scaling subgroups, a piezoelectric ultrasonic scaling device (Intelligence PS-25, Rolence Enterprise Inc., Taoyuan, Taiwan) with one type of subgingival fine-diameter ultrasonic tip was used (P1, Woodpecker, Guangxi, China).[28] The machine was operated according to the manufacturer's instructions under profuse water irrigation for cooling of the scaler tip at medium power settings, standard lateral force, and a frequency of 29 kHz for all specimens.[13,14] The side of the scaler tips were placed in the mesial interproximal areas from both buccal and palatal sides (between each specimen and premolar) 1-mm below the gingival simulation with zero angulation in relation to the base material.[11,29] Each side received 10 apical to coronal consecutive strokes.[29] A new scaler tip was used for each group (Figure 1O).

One experienced periodontist instrumented all the specimens who was blind to the restoration step. Following instrumentation, all the specimens were removed from the rubber base mold, thoroughly rinsed with water for 10 seconds, and then cleaned in an ultrasonic cleaner for 3 minutes. Finally, specimens were placed back in the second rubber base block for roughness evaluation.

Postinstrumentation Roughness Evaluations

The same areas of base materials were evaluated for the second time, as previously described in the preinstrumentation roughness evaluation.

Statistical Analysis

Sample Size Calculation—The sample size for this study was calculated before conducting any work using G*Power program (G*Power Ver. 3.0.10, Kiel, Germany).[13] The total sample size of 64 teeth achieved 80% power (equal to type II error); type I error (α) was 0.05. Due to the new methodology proposed by our study, two more teeth were included in each subgroup to have a total sample size of 80 teeth.

Statistical Methods—The R_a values for buccal and palatal sides for both control and scaling subgroups of all base material groups were compared using independent sample *t*-tests; when there was no significant difference, the R_a value of each tooth with each scaling technique tested was calculated by obtaining the mean R_a value of the six readings combined, three from the buccal side and three from the palatal. All data were statistically analyzed using SPSS (SPSS version 20, IBM, Chicago, IL, USA). R_a values proved to be normally distributed after they were subjected to the Shapiro–Wilk test, and the homogeneity of variances was tested using Levene's test; so parametric tests were used to compare the study groups. One-way analysis of variance (ANOVA) was used to compare the control groups of the four materials; when significant differences were detected, a pairwise comparison was performed using Tukey post hoc tests (at α=0.05). The effect of scaling technique per each material group was evaluated using paired sample *t*-tests. Two-way ANOVA was used to determine the effect of study variables (base material type and scaling technique), and their interaction on surface roughness followed by Tukey post hoc test (at α=0.05).

RESULTS

One-way ANOVA revealed that baseline R_a readings for all the groups were statistically significant ($p<0.05$). The mean R_a values and standard deviations for baseline readings are presented in Table 2. Pairwise comparisons revealed that Bulk Flow had the lowest R_a values followed by RMGI and Activa, respectively; the latter two had no statistically significant difference between their R_a values. The highest R_a values were shown by HV-GIC.

Table 2: *Mean ± Standard Deviation (µm) of Ra Values of Baseline Readings of All Base Materials Evaluated*[a]

Base Material	Control
RMGI	0.162 ± 0.005 b
HV-GIC	0.194 ± 0.010 c
Bulk Flow	0.131 ± 0.010 a
Activa	0.165 ± 0.005 b

Abbreviations: RMGI, Resin modified glass ionomer; HV-GIC; Highly viscous glass ionomer cement; Bulk Flow, Flowable bulk fill resin composite; Activa, ACTIVA BioACTIVE Restorative.

[a] *Groups identified with the same lowercase letters are not significantly different (Tukey HSD;* p*<0.05).*

Paired sample *t*-test results (Table 3) revealed that, regardless of the base material used, both scaling methods adversely affected the surface smoothness in a significant way ($p<0.05$).

Two-way ANOVA showed that both study variables significantly affected the R_a values ($p<0.05$); the interaction between them were also significant ($p<0.05$). The mean R_a values and standard deviations for subgroups of all the base materials are presented in Table 4. Tukey honestly significant difference (HSD) multiple comparisons revealed that manual scaling had significantly lower R_a values than ultrasonic scaling in all groups ($p<0.05$), except in the bulk flow group, where the scaling methods were not significantly different ($p>0.05$). RMGI, Bulk Flow, and Activa hand scaling subgroups had the lowest R_a values; on the other hand, HV-GIC ultrasonic subgroup had the roughest surfaces. Representative 3D and histogram images for the four base materials are shown in Figure 2.

DISCUSSION

Previous clinical and histological studies have linked the presence of subgingival cervical margins and the increase in bacterial plaque, gingival indices, and probing depth.[1,11] Smooth subgingival restorations are required to prevent jeopardizing the periodontal health in these critical areas.[30] Therefore, this study evaluated and compared the surface roughness of different restorative materials placed below the CEJ in clinically simulated subgingival restorations, in order to determine the smoothest base material to be used in restoring such defects.

The main objective of prevention and/or treatment of periodontitis includes periodic removal of plaque and calcified deposits from the teeth and restorations.[8] This procedure is usually accomplished by different scaling techniques that may accidently not only affect the dental tissues but also the restorative surfaces creating

Table 3: *Results of Comparing R_a Values of each Base Material Evaluated Before and After Each Scaling Method*

	Paired Differences					*t*	*df*	Sig. (2-Tailed)
	Mean	Std Deviation	Std Error Mean Lower	95% Confidence Interval of the Difference				
				Lower	Upper			
RMGI control 1 – RMGI hand	0.016	0.007	0.002	0.022	0.011	6.926	9	p<0.001
RMGI control 2 – RMGI ultrasonic	0.049	0.011	0.003	0.057	0.041	14.215	9	p<0.001
HV-GIC control 1 – HV-GIC hand	0.033	0.009	0.002	0.039	0.026	11.587	9	p<0.001
HV-GIC control 2 – HV-GIC ultrasonic	0.058	0.007	0.002	0.063	0.053	26.371	9	p<0.001
Bulk Flow control 1 – Bulk Flow hand	0.056	0.008	0.002	0.062	0.049	20.452	9	p<0.001
Bulk Flow control 2 – Bulk Flow ultrasonic	0.041	0.008	0.001	0.048	0.035	15.233	9	p<0.001
Activa control 1 – Activa hand	0.017	0.005	0.001	0.021	0.013	9.173	9	p<0.001
Activa control 2 – Activa ultrasonic	0.028	0.008	0.002	0.034	0.023	11.271	9	p<0.001

Abbreviations: RMGI, Resin-modified glass ionomer; HV-GIC; Highly viscous glass ionomer cement; Bulk Flow, Flowable bulk-fill resin composite; Activa, Activa Bioactive Restorative.

roughness that may lead to unfavorable periodontal consequences.[11] Thus, this study also evaluated the effect of scaling techniques on roughness of restorations placed below the CEJ, to determine the most suitable scaling technique in proximal subgingival restored areas.

The selection of the four tested base materials was based on both open-sandwich technique and cervical margin relocation concepts.[16,17] The open-sandwich technique includes using conventional glass ionomer cement (GIC) for elevation of the gingival margin. High clinical failure rates have been reported with this material.[31] Thus, modifications using RMGI and HV-GIC have been introduced to be used with this technique with acceptable long-term outcomes.[18,32] Recent studies argue that glass ionomer with its hydrophilic nature, flexibility, and chemical bonding could be a more suitable option for bonding to deep, moist dentin–cementum margins.[33,34] That is why RMGI and HV-GIC were included in this study as base materials.

Table 4: *Mean ± Standard Deviation of R_a Values (µm) of All Base Materials Evaluated with Different Scaling Methods*[a]

Scaling Method Material	Hand	Ultrasonic
RMGI	0.177 ± 0.006 a	0.214 ± 0.007 c
HV-GIC	0.227 ± 0.007 d	0.253 ± 0.007 e
Bulk Flow	0.179 ± 0.004 a	0.180 ± 0.002 a
Activa	0.184 ± 0.006 a	0.194 ± 0.005 b

Abbreviations: RMGI, Resin-modified glass ionomer; HV-GIC; Highly viscous glass ionomer cement; Bulk Flow, Flowable bulk-fill resin composite; Activa, Activa Bioactive Restorative.

[a] *Groups identified with the same lowercase letters are not significantly different (Tukey HSD;* p<0.05*).*

On the other hand, cervical margin relocation includes using a flowable resin composite base to lift the proximal gingival margin. Kielbassa and others[31] reported how promising this technique is in their systematic review. Bulk-fill resin composites have been developed with different chemical compositions to reduce polymerization shrinkage stress. In addition, they can be placed in layers up to 4 mm in thickness and cured in one single step.[19] Thus, they can be quickly applied and save chair time, especially when used for deep and large cavities.[35] Previous studies found higher bond strength for flowable bulk fill compared

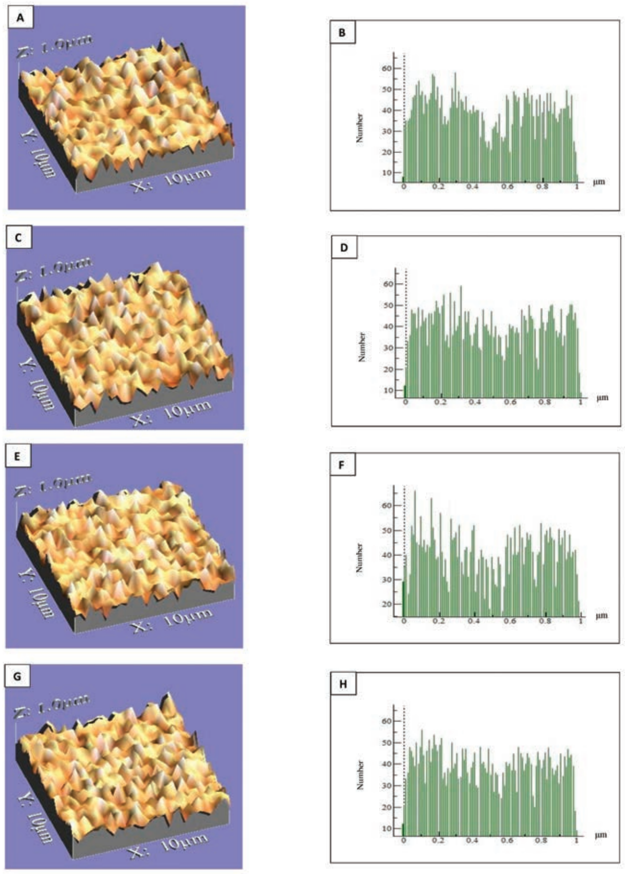

Figure 2: *Representative 3D and histogram images for the four base materials. For 3D images, spikes at the borders are artifacts. For histogram images, the Y axis represents the number of repetitions for each reading (μm), the Ra value was recorded as the mean of the five readings with the highest repetitions. A,B: Representative 3D and histogram images for hand scaling subgroup in RMGI group. C,D: Ultrasonic in HV-GIC. E,F: Control in Bulk Flow. G,H: Hand in Activa.*

to nanofilled layered composites when bonded to proximal dentin–cementum margins;[20,36] moreover, others reported promising marginal adaptation of flowable bulk fill with such margins.[37] That is why a flowable bulk-fill material was tested in this study.

Bioactive restorative materials are a relatively new category that react to pH changes in the mouth by providing calcium, phosphate, and fluoride ions to maintain the chemical integrity of the tooth structure. ACTIVA BioACTIVE restorative is one in this category.[38] Benetti and others[39] stated that this material has a promising mechanical behavior, as it showed comparable flexural strength and fracture toughness to flowable and bulk-fill resin composites.[40,41] On the other hand, the material's compromised hardness suggests the importance of using an abrasive-resistant resin composite as coverage.[42] That is why it was used in this study as a base material.

This study included two different scaling methods: hand and ultrasonic. Scaling and root planning by curettes (hand) are the most frequently used procedures for removing of subgingival calculus and treatment of periodontal diseases, due to their low cost and effectiveness in reducing the clinical signs of inflammation and the levels of pathogens.[43] Despite different developments in scaling techniques, hand instrumentation is still considered the gold standard.[44] Ultrasonic scaling is considered to be less strenuous for the operator and more comfortable for patients than hand scaling, and can be performed in considerably less time.[44] Thus, it has become increasingly popular for subgingival debridement.[28]

Upper molars were used in this study, as their buccal surface is the second most predominant site for supragingival calculus deposition after the lingual surface of the six lower anterior teeth.[45] Supragingival calculus creates an environment more conducive to subgingival plaque accumulation,[46] thus, a significant association between supra- and subgingival calculus was found,[46] indicating the importance of subgingival scaling and root planning in upper molars area.

After cavity preparation, the teeth were fixed with neighboring teeth using condensation silicone impression material (putty consistency). This material was selected based on several fixation trials with other materials like wax, stone, and impression compound. These trials failed due to both distortion and brittleness that prevented good fixation of teeth or due to excess stiffness that prevented placement of matrix bands and wedges for restoration.

Contoured sectional bands and wedges were used during restoration to create correct clinically simulated contact areas, gingival embrasures, and proximal surface contour.[47] The cavities were filled with base materials up to 1.5 mm above the CEJ that nearly corresponded to the level just below the proximal contact, which was then built with overlying resin composite with the rest of the cavity. Interproximal wear usually affects the proximal contact tightness, and consequently the contact should be built with hard and strong restorative materials,[48] like the overlying resin composite used in this study. Five thousand cycles of thermocycling was performed to simulate 6-months of clinical service before scaling procedures.[23] This was chosen based on the frequent 6-month scaling and prophylactic polishing interval performed by most of the dentists.[49]

In this study, evaluation of surface roughness was performed both quantitatively and qualitatively in a nondestructive method, to allow detailed visualization for the surface without contact.[50] This would accurately allow further recording of roughness values for the same specimens after scaling.

All scaling procedures were carried out by one periodontist to eliminate interoperator variability and minimize variations in stroke length, force, and pressure applied during instrumentation. A piezoelectric ultrasonic unit was chosen in this study, as its oscillation pattern produces movement that is primarily linear in direction, in contrast to magnetostrictive devices with their circular motion.[28] This linear motion provides more efficient calculus removal with less damage to the surface being scaled.[51] A number of *in vitro* studies demonstrated that working parameters such as power settings and tip angulation can determine the amount of damage for the root or restoration surface.[28,51] The device was operated at medium power settings as a previous review mentioned that increasing the power settings from medium to high can lead to high surface roughness and alterations.[52] Narrow probe-shaped tips were used in this study, as it was reported that they are less aggressive to root dentin than wide probe-shaped tips.[28] In piezoelectric units, tip angulation has the most important effect on surface alteration depth of the scaled surfaces.[52] The least surface damage was obtained when the tip was used at zero angulation,[52] as was used in the current study.

Although there was no significant difference between R_a values for buccal and palatal sides for either control or subgroups of all material groups, it is worth mentioning that roughness values from the palatal side were higher than the buccal side in most of the specimens. This could be explained by the wider gingival embrasure on the palatal side than buccal embrasure,[53] making either curette or ultrasonic tip touch a wider surface palatally, thus creating more roughness.

The results of this study showed that R_a baseline readings differed among the four base materials; Bulk Flow had the smoothest surfaces, while HV-GIC had the roughest, therefore, the first null hypothesis was rejected. The literature has already shown that curing of resin-based materials against a matrix band can produce a relatively smooth surface compared with any finishing and polishing procedures.[54,55] This smooth surface is related to the resin-rich layer that is accumulated against the band.[55] A previous study explained that the compression applied through the matrix band on the surface of the resin-based materials can probably cause the filler particles to slide in the organic matrix, so that smaller particles, with lower density, appeared more and closer to the top in relation to the larger ones.[56] This may indicate that filler particle shape and size can have a minor role in affecting the surface roughness when curing the resin-based materials against the matrix band. HV-GIC has no resin methacrylate content; its composition is mainly formed of 90%-95% strontium fluoroalumino silicate glass (FAS) (25 μm),[57] which mostly protruded on the surface when the material was left to set against the matrix band, thus having the highest roughness values among the base materials. The amount of resin in the RMGI used in this study was 1%-5% [2-hydroxyethyl methacrylate (HEMA)], most of its composition also contains FAS;[57] this heterogeneous and biphasic chemical composition can explain why it has higher roughness values than Bulk Flow.

Activa contains 42 wt% organic resin, while Bulk Flow contains 28 wt%. The organic resin of Activa is called an “ionic resin,” which has a more hydrophilic nature compared to Bulk Flow and contains a small amount of water. This aqueous ionic resin may cause the material to be more susceptible to matrix degradation after thermal cycling, as was previously reported.[58] Yilmaz and others[59] showed that following thermal cycling, the hydrophilicity of the material allowed water to penetrate more easily, leading to matrix degradation, exposing the underlying filler particles and increasing its roughness.

The results of the current study showed that regardless of the scaling technique used, the roughness values increased significantly compared with baseline readings, which means the second null hypothesis was rejected. This is in accordance with previous studies that examined the scaled surfaces under scanning electron microscope (SEM) and found valleys, cracking at the filler–matrix interface, filler dislodgment, and even removal of a whole layer of the root surface or restoration,[11,29,60] and reported that this surface alteration is an unavoidable complication of the scaling procedures.

The hand scaling technique had smoother surfaces than the ultrasonic technique for all the base materials in this study, except for Bulk Flow where both the scaling methods created comparable roughness values. This could be explained by the finding of a previous study showing that hand scaling instruments usually made greater contact area with the surface than ultrasonic tips;[29] a greater contact area could result in masking the roughness created by the instrument resulting in smooth surface. Mishra and others[61] noticed that hand scaling resulted in more surface flattening than ultrasonic scaling, and attributed the smooth surface they found after hand scaling to this surface loss. Moreover, hand scaling was reported to facilitate better tactile proprioception and controlled movement to the operator, resulting in a smoother surface.[62] A possible explanation for the increased R_a values for ultrasonic subgroups is the vibration effect of the ultrasonic scaling that could potentially create more cracks and greater filler dislodgement.[13] Conversely to the current results, previous studies found that ultrasonic scaling produced smoother surfaces when compared to hand scaling.[63,64] The difference in results could be attributed to different experimental designs, including surfaces to be scaled, in the current study restorative materials and in the former studies root dentin, methods of roughness evaluation, in addition to different characteristics of the instruments like shape, size and material of the tips used, and different force and pressure of application due to operator variability.

Although the tested HV-GIC used in this study was reported to have promising wear resistance and microhardness results compared with other types of glass ionomers,[65,66] its roughness values increased significantly after both scaling techniques, especially after ultrasonic scaling. During scaling procedures, the weak polysalt matrix phases in HV-GIC, which usually press against the matrix band, were easily removed while the harder unreacted FAS glass particles protruded from the surface;[60] this may explain why this material had the highest R_a values among the other scaled base materials. In addition, Buldur and others[65] observed deep cracks, pits, and fissures after aging on the same material surface under SEM, even if the surfaces were varnished; so maybe ultrasonic scaling increased these already existing cracks and resulted in the highest roughness values.

For resin-based materials, the resin-rich layer that forms the smooth surface resulting from adaptation of the material against the matrix band during restoration is usually removed after any surface alteration,[67] like scaling procedures in this study. Consequently, inorganic fillers have an effect on surface roughness. The surface roughness values increased with the increase of the filler particle size.[11,13,14] RMGI, Activa, and Bulk Flow have nearly the same filler particle size (5 μm); this may explain the comparable R_a results after hand scaling. On the other hand, after ultrasonic scaling, both RMGI and Activa R_a values differed significantly. This may be explained by the results of previous studies showing significantly higher wear resistance with Activa compared to the RMGI used in this study;[66,68] the authors partially attributed the cause to the resilient resin matrix with energy-absorbing elastomeric components of Activa.[68] This higher wear resistance may lead to less degradation by ultrasonic scaling and subsequent lower inorganic filler exposure and roughness values.[11] Another possible reason was suggested by Garoushi and others,[68] as they found that the RMGI used in this study had a greater initial burst of fluoride release than Activa. Leaching of ions from filler particles of regular fluoride-releasing materials was attributed previously to filler–matrix debonding, because of a weakened filler. This leads to microcracks and higher degradation of the material[69]; these cracks may be aggravated by ultrasonic scaling.

Bulk Flow was the only material that showed no significant difference between scaling methods. The smooth surfaces of this material could be related to filler shape. The Bulk Flow used in this study has homogenous, rounded-shaped fillers compared with the irregular, heterogeneous-shaped fillers in other base materials. Marghalani and others[67] concluded that spherical-shaped fillers may allow more flow and stress relaxation of the material resulting in smooth surface compared to irregular ones that may develop stress concentration around them. Another possible reason is the form in which Bulk Flow is supplied. Bulk Flow is a single component material, whereas in the case of glass ionomers and Activa, powder has to be mixed with liquid or two pastes have to be mixed, respectively, therefore risking more air bubble incorporation and increased porosity.[66] These porosities may get enhanced after ultrasonic instrumentation leading to greater surface roughness. The Bulk Flow used in this study is not like conventional flowable composite with their lower filler amount; instead, the filler content reaches 68.2 wt%, leading to high wear resistance and less susceptibility to degradation by ultrasonic devices.[11]

The literature suggests that the critical threshold of roughness for patients was nearly 0.3 μm, and the threshold for biofilm accumulation was 0.2 μm[70]; so it could be inferred that, in the current study, none of the materials' roughness with either scaling technique would be perceptible by the patient, and that HV-GIC with both scaling techniques and RMGI when ultrasonically scaled would be at a risk for biofilm accumulation. Considering that their R_a values were just above the biofilm threshold, it is worth mentioning that Quirynen and others[71] found that variations around biofilm threshold had only a negligible impact on bacterial adhesion. In addition, a recent study showed that surface roughness had a minor role in the retention of a fully grown biofilm.[72]

It should be recognized that the present *in vitro* study has limitations; the scaling techniques were performed by one operator; consequently, the manual pressure exerted, even after specific training, cannot be considered replicable or standardized. In addition, only two scaling techniques were assessed among different other promising scaling methods. The methodology performed in the current study is new and intended to simulate the clinical situation, so further *in vitro* studies, including microbiological adhesion assessment and even histological evaluation for the attachment of gingival epithelial cells to the tested base materials' surfaces, are needed. In addition, clinical studies are required to assess periodontal healing in critical dental areas, like below the proximal CEJ, after different scaling methods for debridement of microbial deposits on restorative materials placed in such areas.

CONCLUSIONS

Within the limitations of the present study, the following may be concluded:

1. In terms of surface roughness, the evaluated resin-based composite may be recommended to restore subgingival proximal margins rather than the tested glass ionomer-based restorative materials, especially when curing and setting of these base materials are done against a matrix band.
2. Both hand and ultrasonic scaling methods had a negative effect on the surface quality of the four tested base materials, so they should be performed with caution when used on restored subgingival proximal areas.
3. Considering changes in surface texture following the use of each scaling technique, the present study showed that hand scaling may be preferable to ultrasonic scaling for the tested base materials, especially for glass ionomer-based restorative materials.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the human subjects' oversight committee guidelines and policies of Faculty of Dentistry, Mansoura University Ethics Committee. The approval code issued for this study is A05121120.

Conflicts of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article. The authors alone are responsible for the content and writing of this paper. Dr. Garcia-Godoy is a consultant for Pulpdent, manufacturer of Activa. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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REFERENCES

1. Veneziani M (2010) Adhesive restorations in the posterior area with subgingival cervical margins: new classification and differentiated treatment approach *European Journal of Esthetic Dentistry* **5(1)** 50-76.
2. Shenoy A, Shenoy N, & Babannavar R (2012) Periodontal considerations determining the design and location of margins in restorative dentistry *Journal of Interdisciplinary Dentistry* **2(1)** 3.
3. McConnell MD, Liu Y, Nowak AP, Pilch S, Masters JG, & Composto RJ (2010) Bacterial plaque retention on oral hard materials: Effect of surface roughness, surface composition, and physisorbed polycarboxylate *Journal of Biomedical Materials Research Part A* **92(4)** 1518-1527.
4. Frese C, Wolff D, & Staehle H (2014) Proximal box elevation with resin composite and the dogma of biological width: Clinical R2-technique and critical review *Operative Dentistry* **39(1)** 22-31.
5. Quirynen M, van der Mei HC, Bollen CM, Schotte A, Marechal M, Doornbusch GI, Naert I, Busscher HJ, & van Steenberghe D (1993) An *in vivo* study of the influence of the surface roughness of implants on the microbiology of supra- and subgingival plaque *Journal of Dental Research* **72(9)** 1304-1309.
6. Leknes KN, Lie T, Wikesjö UM, Bogle GC, & Selvig KA (1994) Influence of tooth instrumentation roughness on subgingival microbial colonization *Journal of Periodontology* **65(4)** 303-308.
7. American Academy of Periodontology (2011) Comprehensive periodontal therapy: A statement by the American Academy of Periodontology *Journal of Periodontology* **82(7)** 943-949.
8. Deas DE, Moritz AJ, Sagun RS, Jr., Gruwell SF, & Powell CA (2016) Scaling and root planing vs. conservative surgery in the treatment of chronic periodontitis *Periodontology 2000* **71(1)** 128-139.
9. Greenstein G (2000) Nonsurgical periodontal therapy in 2000: A literature review *Journal of the American Dental Association* **131(11)** 1580-1592.
10. An der Weijden GA & Timmerman MF (2002) A systematic review on the clinical efficacy of subgingival debridement in the treatment of chronic periodontitis *Journal of Clinical Periodontology* **29(Supplement 3)** 55-71; discussion 90-51.
11. Mourouzis P, Koulaouzidou EA, Vassiliadis L, & Helvatjoglu-Antoniades M (2009) Effects of sonic scaling on the surface roughness of restorative materials *Journal of Oral Science* **51(4)** 607-614.
12. Ribeiro FV, Casarin RC, Nociti Júnior FH, Sallum EA, Sallum AW, & Casati MZ (2006) Comparative *in vitro* study of root roughness after instrumentation with ultrasonic and diamond tip sonic scaler *Journal of Applied Oral Science* **14(2)** 124-129.
13. Lai YL, Lin YC, Chang CS, & Lee SY (2007) Effects of sonic and ultrasonic scaling on the surface roughness of tooth-colored restorative materials for cervical lesions *Operative Dentistry* **32(3)** 273-278.
14. Hossam AE, Rafi AT, Ahmed AS, & Sumanth PC (2013) Surface topography of composite restorative materials following ultrasonic

scaling and its Impact on bacterial plaque accumulation. An in-vitro SEM study *Journal of International Oral Health* **5(3)** 13-19.

15. Ota-Tsuzuki C, Martins FL, Giorgetti AP, de Freitas PM, & Duarte PM (2009) *In vitro* adhesion of Streptococcus sanguinis to dentine root surface after treatment with Er:YAG laser, ultrasonic system, or manual curette *Photomedicine and Laser Surgery* **27(5)** 735-741.

16. Welbury RR & Murray JJ (1990) A clinical trial of the glass-ionomer cement-composite resin "sandwich" technique in Class II cavities in permanent premolar and molar teeth *Quintessence International* **21(6)** 507-512.

17. Dietschi D & Spreafico R (1998) Current clinical concepts for adhesive cementation of tooth-colored posterior restorations *Practical Periodontics and Aesthetic Dentistry* **10(1)** 47-54; quiz 56.

18. Francois P, Vennat E, Le Goff S, Ruscassier N, Attal JP, & Dursun E (2019) Shear bond strength and interface analysis between a resin composite and a recent high-viscous glass ionomer cement bonded with various adhesive systems *Clinical Oral Investigations* **23(6)** 2599-2608.

19. Czasch P & Ilie N (2013) *In vitro* comparison of mechanical properties and degree of cure of bulk fill composites *Clinical Oral Investigations* **17(1)** 227-235.

20. Al-Harbi F, Kaisarly D, Michna A, ArRejaie A, Bader D, & El Gezawi M (2015) Cervical interfacial bonding effectiveness of class II bulk versus incremental fill resin composite restorations *Operative Dentistry* **40(6)** 622-635.

21. Nikolaenko SA, Lohbauer U, Roggendorf M, Petschelt A, Dasch W, & Frankenberger R (2004) Influence of c-factor and layering technique on microtensile bond strength to dentin *Dental Materials* **20(6)** 579-585.

22. Irie M, Suzuki K, & Watts DC (2009) Delayed polishing technique on glass–ionomer restorations *Japanese Dental Science Review* **45(1)** 14-22.

23. Ernst CP, Canbek K, Euler T, & Willershausen B (2004) *In vivo* validation of the historical *in vitro* thermocycling temperature range for dental materials testing *Clinical Oral Investigations* **8(3)** 130-138.

24. Morresi AL, D'Amario M, Capogreco M, Gatto R, Marzo G, D'Arcangelo C, & Monaco A (2014) Thermal cycling for restorative materials: Does a standardized protocol exist in laboratory testing? A literature review *Journal of the Mechanical Behavior of Biomedical Materials* **29** 295-308.

25. Shivanna D, Kiran M, & Kavitha S (2014) Evaluation of 3D surface roughness parameters of EDM components using vision system *Procedia Materials Science* **5** 2132-2141.

26. Hamza GE, Salem HN, & Samman MA (2019) Evaluation of two-body wear rate and roughness of polyetheretherketone and zirconia opposing enamel structure: An in-vitro study *Journal of The Arab Society for Medical Research* **14(2)** 73.

27. Busslinger A, Lampe K, Beuchat M, & Lehmann B (2001) A comparative *in vitro* study of a magnetostrictive and a piezoelectric ultrasonic scaling instrument *Journal of Clinical Periodontology* **28(7)** 642-649.

28. Jepsen S, Ayna M, Hedderich J, & Eberhard J (2004) Significant influence of scaler tip design on root substance loss resulting from ultrasonic scaling: A laserprofilometric *in vitro* study *Journal of Clinical Periodontology* **31(11)** 1003-1006.

29. Casarin RCV, Ribeiro FV, Sallum AW, Sallum EA, Nociti-Jr FH, & Casati MZ (2009) Root surface defect produced by hand instruments and ultrasonic scaler with different power settings: An *in vitro* study *Brazilian Dental Journal* **20(1)** 58-63.

30. Folwaczny M, Merkel U, Mehl A, & Hickel R (2004) Influence of parameters on root surface roughness following treatment with a magnetostrictive ultrasonic scaler: An *in vitro* study *Journal of Periodontology* **75(9)** 1221-1226.

31. Kielbassa AM & Philipp F (2015) Restoring proximal cavities of molars using the proximal box elevation technique: Systematic review and report of a case *Quintessence International* **46(9)** 751-764.

32. Andersson-Wenckert IE, van Dijken JW, & Kieri C (2004) Durability of extensive Class II open-sandwich restorations with a resin-modified glass ionomer cement after 6 years *American Journal of Dentistry* **17(1)** 43-50.

33. Vertolli TJ, Martinsen BD, Hanson CM, Howard RS, Kooistra S, & Ye L (2020) Effect of deep margin elevation on CAD/CAM-fabricated ceramic inlays *Operative Dentistry* **45(6)** 608-617.

34. Sarfati A & Tirlet G (2018) Deep margin elevation versus crown lengthening: Biologic width revisited *International Journal of Esthetic Dentistry* **13(3)** 334-356.

35. Roggendorf MJ, Krämer N, Appelt A, Naumann M, & Frankenberger R (2011) Marginal quality of flowable 4-mm base vs. conventionally layered resin composite *Journal of Dentistry* **39(10)** 643-647.

36. Kumagai RY, Zeidan LC, Rodrigues JA, Reis AF, & Roulet JF (2015) Bond strength of a flowable bulk-fill resin composite in class II MOD cavities *Journal of Adhesive Dentistry* **17(5)** 427-432.

37. Campos EA, Ardu S, Lefever D, Jassé FF, Bortolotto T, & Krejci I (2014) Marginal adaptation of class II cavities restored with bulk-fill composites *Journal of Dentistry* **42(5)** 575-581.

38. Kaushik M & Yadav M (2017) Marginal microleakage properties of Activa bioactive restorative and nanohybrid composite resin using two different adhesives in noncarious cervical lesions-an *in vitro* study *Journal of the West African College of Surgeons* **7(2)** 1-14.

39. Benetti AR & Michou S (2019) Adhesion and marginal adaptation of a claimed bioactive, restorative material *Biomaterial Investigations in Dentistry* **6(1)** 90-98.

40. Pameijer CH, Garcia-Godoy F, Morrow BR, & Jefferies SR (2015) Flexural strength and flexural fatigue properties of resin-modified glass ionomers *Journal of Clinical Dentistry* **26(1)** 23-27.

41. Garoushi S, Vallittu PK, & Lassila L (2018) Characterization of fluoride-releasing restorative dental materials *Dental Materials Journal* **37(2)** 293-300.

42. Alrahlah A (2018) Diametral tensile strength, flexural strength, and surface microhardness of bioactive bulk fill restorative *Journal of Contemporary Dental Practice* **19(1)** 13-19.

43. Haffajee AD, Patel M, & Socransky SS (2008) Microbiological changes associated with four different periodontal therapies for the treatment of chronic periodontitis *Oral Microbiology and Immunology* **23(2)** 148-157.

44. Tunkel J, Heinecke A, & Flemmig TF (2002) A systematic review of efficacy of machine-driven and manual subgingival debridement in the treatment of chronic periodontitis *Journal of Clinical Periodontology* **29** 72-81.

45. Balaji VR, Niazi TM, & Dhanasekaran M (2019) An unusual presentation of dental calculus *Journal of Indian Society of Periodontology* **23(5)** 484-486.

46. Corbett TL & Dawes C (1998) A comparison of the site-specificity of supragingival and subgingival calculus deposition *Journal of Periodontology* **69(1)** 1-8.

47. Wirsching E, Loomans BA, Klaiber B, & Dörfer CE (2011) Influence of matrix systems on proximal contact tightness of 2- and 3-surface posterior composite restorations *in vivo Journal of Dentistry* **39(5)** 386-390.

48. Loomans BA, Opdam NJ, Roeters FJ, Bronkhorst EM, & Plasschaert AJ (2007) The long-term effect of a composite resin restoration on proximal contact tightness *Journal of Dentistry* **35(2)** 104-108.

49. Lamont T, Worthington HV, Clarkson JE, & Beirne PV (2018) Routine scale and polish for periodontal health in adults *Cochrane Database of Systematic Reviews* **12(12)** Cd004625.

50. Rigo LC, Bordin D, Fardin VP, Coelho PG, Bromage TG, Reis A, & Hirata R (2018) Influence of polishing system on the surface roughness of flowable and regular-viscosity bulk-fill composites *International Journal of Periodontics & Restorative Dentistry* **38(4)** e79–e86.

51. Flemmig TF, Petersilka GJ, Mehl A, Hickel R, & Klaiber B (1998) The effect of working parameters on root substance removal using a piezoelectric ultrasonic sealer *in vitro Journal of Clinical Periodontology* **25(2)** 158-163.

52. Arabaci T, Ciçek Y, & Canakçi CF (2007) Sonic and ultrasonic scalers in periodontal treatment: A review *International Journal of Dental Hygiene* **5(1)** 2-12.

53. Nelson SJ (2009) The Permanent Maxillary Molars *Wheeler's Dental Anatomy, Physiology, and Occlusion* Elsevier Saunders St. Louis, Missouri 171-184.

54. Bayrak GD, Sandalli N, Selvi–Kuvvetli S, Topcuoglu N, & Kulekci G (2017) Effect of two different polishing systems on fluoride release, surface roughness and bacterial adhesion of newly developed restorative materials *Journal of Esthetic and Restorative Dentistry* **29(6)** 424-434.

55. Cazzaniga G, Ottobelli M, Ionescu AC, Paolone G, Gherlone E, Ferracane JL, & Brambilla E (2017) *In vitro* biofilm formation on resin-based composites after different finishing and polishing procedures *Journal of Dentistry* **67** 43-52.

56. Costa GdFAd, Fernandes ACBdCJ, Carvalho LAdO, de Andrade AC, de Assunção IV, & Borges BCD (2018) Effect of additional polishing methods on the physical surface properties of different nanocomposites: SEM and AFM study *Microscopy Research and Technique* **81(12)** 1467-1473.

57. Ruengrungsom C, Burrow MF, Parashos P, & Palamara JEA (2020) Evaluation of F, Ca, and P release and microhardness of eleven ion-leaching restorative materials and the recharge efficacy using a new Ca/P containing fluoride varnish *Journal of Dentistry* **102** 103474.

58. Rinastiti M, Özcan M, Siswomihardjo W, & Busscher HJ (2011) Effects of surface conditioning on repair bond strengths of non-aged and aged microhybrid, nanohybrid, and nanofilled composite resins *Clinical Oral Investigations* **15(5)** 625-633.

59. Yilmaz EC & Sadeler R (2016) Effect of thermal cycling and microhardness on roughness of composite restorative materials *Journal of Restorative Dentistry* **4(3)** 93.

60. Abdel-Hamid DM & El-Nahass H (2018) Effect of routine scaling and prophylactic polishing on the surface roughness of nano-filled restorative materials: *In vitro* study *Future Dental Journal* **4(1)** 64-71.

61. Mishra MK & Prakash S (2013) A comparative scanning electron microscopy study between hand instrument, ultrasonic scaling and erbium doped: Yttirum aluminum garnet laser on root surface: A morphological and thermal analysis *Contemporary Clinical Dentistry* **4(2)** 198.

62. Zafar MS (2016) Comparing the effects of manual and ultrasonic instrumentation on root surface mechanical properties *European Journal of Dentistry* **10(4)** 517-521.

63. Graetz C, Plaumann A, Wittich R, Springer C, Kahl M, Dörfer CE, & El-Sayed KF (2017) Removal of simulated biofilm: An evaluation of the effect on root surfaces roughness after scaling *Clinical Oral Investigations* **21(4)** 1021-1028.

64. Maritato M, Orazi L, Laurito D, Formisano G, Serra E, Lollobrigida M, Molinari A, & De Biase A (2018) Root surface alterations following manual and mechanical scaling: A comparative study *International Journal of Dental Hygiene* **16(4)** 553-558.

65. Buldur M & Karaarslan ES (2019) Microhardness of glass carbomer and high-viscous glass Ionomer cement in different thickness and thermo-light curing durations after thermocycling aging *BMC Oral Health* **19(1)** 273.

66. Latta MA, Tsujimoto A, Takamizawa T, & Barkmeier WW (2020) *In vitro* wear resistance of self-adhesive restorative materials *Journal of Adhesive Dentistry* **22** 59-64.

67. Marghalani HY (2010) Effect of filler particles on surface roughness of experimental composite series *Journal of Applied Oral Science* **18(1)** 59-67.

68. Garoushi S, Vallittu PK, & Lassila L (2018) Characterization of fluoride-releasing restorative dental materials *Dental Materials Journal* **37(2)** 293-300.

69. Ilie N & Stawarczyk B (2016) Evaluation of modern bioactive restoratives for bulk-fill placement *Journal of Dentistry* **49** 46-53.

70. Ruivo MA, Pacheco RR, & Sebold M (2019) Surface roughness and filler particles characterization of resin-based composites *Microscopy Research and Technique* **82(10)** 1756-1767.

71. Quirynen M & Bollen CM (1995) The influence of surface roughness and surface-free energy on supra- and subgingival plaque formation in man. A review of the literature *Journal of Clinical Periodontology* **22(1)** 1-14.

72. Cazzaniga G, Ottobelli M, Ionescu AC, Paolone G, Gherlone E, Ferracane JL, & Brambilla E (2017) *In vitro* biofilm formation on resin-based composites after different finishing and polishing procedures *Journal of Dentistry* **67** 43-52.