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The Effects of Scaling and Root Planing on the Marginal Gap and Microleakage of Indirect Composite Crowns Prepared With Different Finish Lines: An *In Vitro* Study

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Clinical Relevance Statement

Due to the surface alterations caused by mechanical periodontal maintenance, the 90° shoulder and the chamfer preparation proved to be a viable option for the fabrication of composite crowns, whereas the beveled 90° shoulder and the feather edge should not be recommended. The amorphous debris due to scaling and root planing could increase bacteria accumulation over time; consequently, hygienic maintenance should be stressed in the presence of composite restorations in order to reduce the need for root mechanical instrumentation.

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SUMMARY

The present *in vitro* study aimed to assess the effects of root surface mechanical instrumentation on the marginal integrity and adaptation of resin composite crowns. The following null hypotheses were tested: no differences exist between finish line and 1) marginal gap or 2) marginal microleakage before and after manual mechanical periodontal maintenance.

A total of 56 intact human mandibular molars were randomly distributed into four groups and subjected to standardized tooth prepara-

tions for indirect composite crowns with different marginal finish lines (90° shoulder, beveled 90° shoulder, feather edge, chamfer). One-half of the specimens was used as a control and remained untreated, and the remaining half was subjected to root surface procedures simulating five years of semestral mechanical supportive periodontal treatment. The marginal gap and microleakage were evaluated and statistically analyzed.

The specimens used as controls showed lower mean marginal gaps than those subjected to the simulated periodontal treatment, whereas the latter showed lower microleakage than the control crowns. Statistically significant differences were recorded for both the experimental variables.

The root surface procedures resulted in altered surfaces of the composite crowns. The marginal gap increased after the treatment, whereas the marginal microleakage was reduced. The 90° shoulder and the chamfer preparation could be considered a viable option to fabricate composite crowns, but the beveled 90° shoulder and the feather edge should not be recommended.

INTRODUCTION

Metal-ceramic prostheses still represent the gold standard in single crowns due to their optimal mechanical resistance, acceptable esthetics, and well-documented clinical longevity.[1–3] All-ceramic restorations were introduced in clinical practice to improve esthetic performances, eliminating the underlying grayish metal framework.[1–4] Polycrystalline ceramics, just like alumina and zirconia, combine tooth-like esthetic appearance with optimal mechanical properties[1–4] and require computer-aided design/computer-aided manufacturing (CAD-CAM) fabrication.[1–3] Conversely, resin composite full-coverage indirect restorations may reduce manufacturing costs up to 60%.[1] As a consequence, the interest toward composite crowns as a less expensive, promising interim alternative to metal and all-ceramic restorations has increased in the last years.[1,4,5–12]

Composite crowns can be considered as long-term temporary restorations, due to inferior esthetics and wear resistance compared with traditional ceramic prostheses.[1,12,14] Nevertheless, some authors have proposed them as permanent restorations thanks to the introduction of efficient dentinal adhesives, the development of resin composites with higher fracture toughness and wear resistance, and the possibility of CAD-CAM processing.[14–18] Indirect composite restorations are easy to use and less time-consuming compared with traditional procedures.[8,12] Moreover, they require less invasive preparations with minimal depth reductions, preserving more sound tooth structure: According to some authors, this could be paramount to increasing the survival probability of a restoration, particularly after endodontic treatment.[1,4,7,19,20] As a consequence of the absence of metal frameworks, prosthetic finish lines can be placed at the gingival margin, reducing gingival irritation.[21]

Quite scarce data are available regarding the clinical performances of composite crowns.[14] In an *in vitro* study,[22,23] adhesively luted posterior composite crowns showed failure loads higher than 1000 N. Acceptable fracture resistance[4,24–28] and promising results for clinical use after fatigue tests[29,30] were reported in laboratory investigations. Preliminary clinical studies[1,4] reported variable results depending on composite systems, occlusal thickness and type of cement. Probability survival rates of 96% and 88.5% were indicated after 3 and 5 years, respectively.[1,9] Success rates lower than those of all-ceramic restorations were reported after 3 years of function.[12] Estimated overall survival rates of 53% ± 14% at restoration level and 79% ± 11% at tooth level were reported in a controlled clinical trial.[8] As to complications, increased plaque accumulation was noticed, restricting the indication for permanent restorations.[1,5] With the introduction of modern composite materials, it is possible to reduce the above mentioned disadvantages;[4,18,31] nonetheless, further *in vivo* studies will be necessary to evaluate the stability and longevity of composite crowns in the oral environment.[1]

Hand and ultrasonic scaling and root planing of root surfaces are the most commonly used mechanical procedures for supportive periodontal care.[32–36] Such instrumentation may cause minor structural alterations of both root surface and restoration margins; the consequent roughening may result in unacceptable restorative margins associated with increased plaque accumulation and high risk of secondary caries.[21,33,35,36] Consequently, the side effects of mechanical periodontal care procedures should be limited so as not to interfere with marginal adaptation of restorations.[21,33,37] Plastic dental scalers were proposed to avoid scratching restorative materials so as not to affect their surface texture; nevertheless, some authors suggested that they could quickly become ineffective due to the greater hardness of restorative materials.[33] Sharp metal curettes are still the standard instruments for periodontal maintenance therapy.[38]

High-quality margins and smooth surfaces enhance biocompatibility of restorative materials because plaque retention is minimized and gingival inflammation prevented.[21,33,39] Several studies investigated the textural changes of restorations caused by mechanical periodontal maintenance.[21,33,37–41] Discordant results were reported for composite resin restorations: some authors reported significant altered composite surfaces after hand and ultrasonic scaling,[40] whereas other investigations demonstrated no damaging effects after scaling and jet-polishing procedures.[41] Such controversial results were probably due to the different characteristics of the periodontal treatment (eg, time, pressure, angulation, type of instruments) and techniques of investigation (eg, qualitative, quantitative, type of measurement).[21,32,37–41]

The present *in vitro* study aimed to assess the effects of root surface mechanical instrumentation on the marginal integrity and adaptation of resin composite crowns.

Two different null hypotheses were tested:

1. There is no difference between the finish line of indirect composite crowns and their marginal gap before and after manual mechanical periodontal maintenance.
2. There is no difference between the finish line of indirect composite crowns and their marginal microleakage before and after manual mechanical periodontal maintenance.

METHODS AND MATERIALS

A total of 56 intact human mandibular molars with no obvious pathology or restorations and extracted for periodontal reasons were selected. Dental plaque, calculus, and periodontal debris were removed by means of ultrasonic scaling. The teeth were disinfected by immersion in 5% sodium hypochlorite for five minutes and stored in 0.9% NaCl physiological solution at 37°C.

The teeth were randomly distributed into four groups, each containing 14 specimens. Silicone impressions of the teeth were made before tooth preparation in order to be used as templates to check the removal of dental tissues. Each group was subjected to standardized tooth preparations for

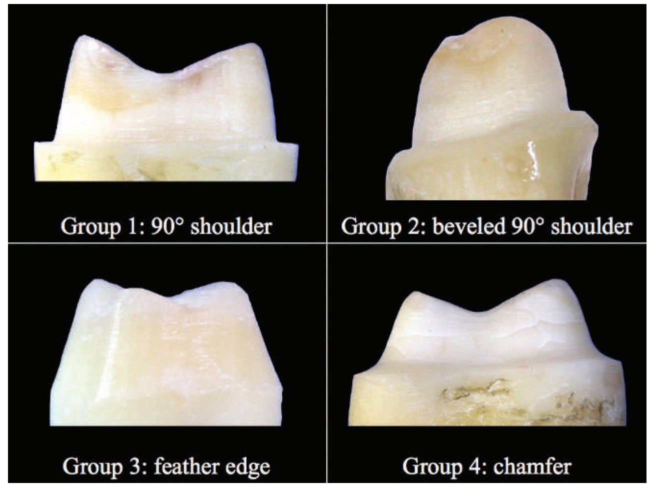

Figure 1. *Standardized tooth preparations and finish lines for indirect composite crowns: G1: 90° shoulder, G2: beveled 90° shoulder, G3: feather edge, G4: chamfer.*

indirect composite crowns with different marginal finish lines (Figure 1), as follows:

- Group 1 (G1): 90° shoulder
- Group 2 (G2): beveled 90° shoulder
- Group 3 (G3): feather edge
- Group 4 (G4): chamfer

The specimens were prepared by means of calibrated, diamond rotary cutting instruments (GS.341.ISO.013, GSD.18.ISO.015, 4035.ISO.014, GSD.4.ISO.015, Intensiv Dental Production, Grancia, Switzerland) mounted on a parallel milling machine under constant water irrigation. The preparations were standardized with 1.5-mm occlusal reduction, 1.0-mm axial reduction, and 0.5-mm margin preparation; preparation depth was checked using the aforementioned silicone templates. The marginal finish lines were placed 0.5 mm coronal to the cementoenamel junction. The finishing of the preparation margins was performed using Arkansas stones mounted on a low-speed handpiece under constant water irrigation. Tooth preparations were performed with 4× magnification loupes by the same experienced prosthodontist.

Precision impressions of the preparations were taken by means of calibrated custom trays and polyether impression materials (Permadyne Penta L, 3M ESPE, Seefeld, Germany). Master casts were obtained using type IV dental stone (Fuji Rock, GC Corporation, Tokyo, Japan). Each cast was coated with a surface conditioner to seal porosities (Kleen Lube, Kerr Corporation, Orange, CA, USA), and a thin layer of a die spacer was applied to simulate the luting agent (Quick Set Spacer, Kerr Corporation).

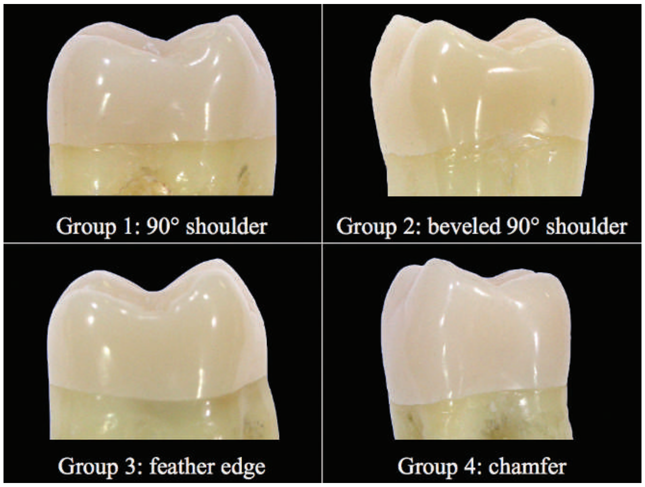

Figure 2. *Indirect composite crowns after cementation: G1: 90° shoulder, G2: beveled 90° shoulder, G3: feather edge, G4: chamfer.*

The buildup of crowns was performed by the same experienced dental technician with a microfilled hybrid resin composite (Gradia Direct, GC Corporation) using the incremental technique. Each increment was light cured for 10 seconds with a laboratory light-curing unit (Steplight, GC Corporation) for a whole polymerization time of five minutes per crown. The passive fit of the restorations was tried on the master casts and verified using a silicone disclosing agent (Fit Checker, GC Corporation). The composite crowns were polished with a hard, fine-grained polishing paste (Universal polishing paste, beige, Renfert GmbH, Hilzingen, Germany).

The adhesive cementation technique was used to lute the restorations onto the teeth. A gluing wax was used to protect the outer surfaces and margins of the crowns; then, the inner surface of each restoration was sandblasted with 50-100 μ of aluminum oxide particles. Afterward, the crowns were subjected to vaporization to clean any aluminum oxide remnant. The teeth were etched with 37% orthophosphoric acid for 15 seconds, rinsed with water for 15 seconds, and dried with cotton pellets. A thin layer of bonding (RelyX ARC Scotchbond 1 XT, 3M ESPE) was applied onto both the inner surfaces of the crowns and the preparations and light cured with 600 mW/cm^2 (Demetron Optilux 501, Kerr Corporation) for 10 seconds on each surface, as recommended by the manufacturer. The halogen light was tested for output before each cure (for consistency) in order to avoid halogen aging that could interfere with polymerization and cure. A dual-cure resin cement (RelyX ARC, 3M ESPE) was applied inside each restoration, and the crowns were carefully seated onto the preparations. Cement excess was removed with cotton pellets; then, the samples were carefully rinsed and dried to prevent fiber contamination. Each surface was light cured for 40 seconds, and the dual-cure cement was allowed to self-cure for two more minutes. Once the crowns were luted (Figure 2), the fit of restorations was visually checked with 4× magnification loupes.

Precision impressions and master casts of the cemented restorations were made as previously described. Moreover, detailed digital pictures of each crown surface (ie, buccal, palatal, mesial, and distal) were taken (Nikon D100 reflex, Nikon Corporation, Tokyo, Japan).

The specimens were stored in physiological saline solution at 37°C for 24 hours. Then, the specimens were kept in artificial saliva and underwent thermal aging by 50,000 cycles from 5°C to 55°C for 30 seconds each (Willytec/SD Mechatronik, Feldkirchen-Westerham, Germany).

A total of 36 indirect composite restorations (ie, nine per group) were subjected to root surface procedures simulating five years of semestral mechanical supportive periodontal treatment.[39,43] Each crown surface was scaled and root planed with Gracey curettes 7/8 (Immunity, Hu-Friedy, Chicago, IL, USA) by the same experienced dental hygienist. Forty continuous overlapping strokes were used across the restoration margins with a movement of about 2 mm (ie, from 1 mm apical to 1 mm coronal to the margin) at 15 mm/sec with a force of 5 N. Twenty strokes were made with the tip held parallel, whereas another 20 strokes were made with the tip held diagonal to the longitudinal axis of the teeth; the direction of the strokes was standardized using a goniometer linked to the holder of the specimens. A digital dynamometer was linked to the curettes in order to standardize the force of the strokes; the holder of the dynamometer was linked to a metal ring that could slide around a horizontal metal bar in order to follow the curettes during the instrumentation (Figure 3).

Precision impressions, master casts, and detailed digital pictures of the scaled and root planed restorations were made as previously described.

The marginal gap (MG) of the composite crowns was evaluated on 16 teeth, four per group; in each group, one-half of the specimens were randomly used as controls and not subjected to any treatment (A), whereas the remaining half was subjected to the simulated periodontal treatment (B). A CAD digital software (AutoCAD, Autodesk Inc, San Rafael, CA, USA) was used for the analysis. Ten consecutive

Figure 3. *Dynamometric appliance used to standardized the force and the direction of the strokes.*

points were univocally identified and measured on each surface of the specimens (Figure 4); consequently, each specimen was characterized by 40 consecutive points. In each group, 160 measurements were assessed, for a whole of 640 measured

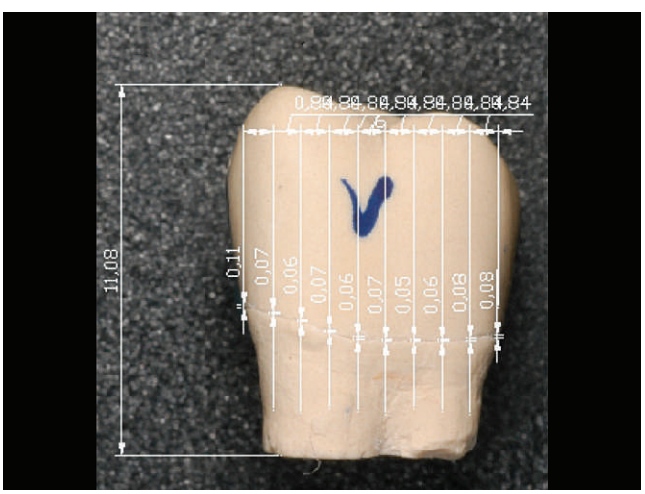

Figure 4. *Point-to-point measurements of the marginal gap by means of CAD digital software.*

Figure 5. *Specimens covering and margin exposure for microleakage test.*

points. Point-to-point measurements were performed before and after the simulated periodontal treatment.

The marginal microleakage (MM) of the composite crowns was evaluated on 40 teeth, 10 per group; in each group, one-half of the specimens were randomly used as controls and not subjected to any treatment (A), whereas the remaining half was subjected to the simulated periodontal treatment (B).

Wax and three layers of an isolating varnish were placed 1 mm coronal to the margin of the crowns; the root surfaces were fully covered with the same materials (Figure 5). Afterward, the specimens were immersed in a methylene blue supersaturated solution at room temperature for 10 minutes. The specimens were rinsed with water to remove the remnants of methylene blue, and the isolating materials were removed with a spatula.

A separating disk (Inline Wheel Slim, BM Dentale, Torino, Italy) was used to cut eight slices per specimen, for a whole of 80 sections per group. Detailed digital pictures of the slices were taken as

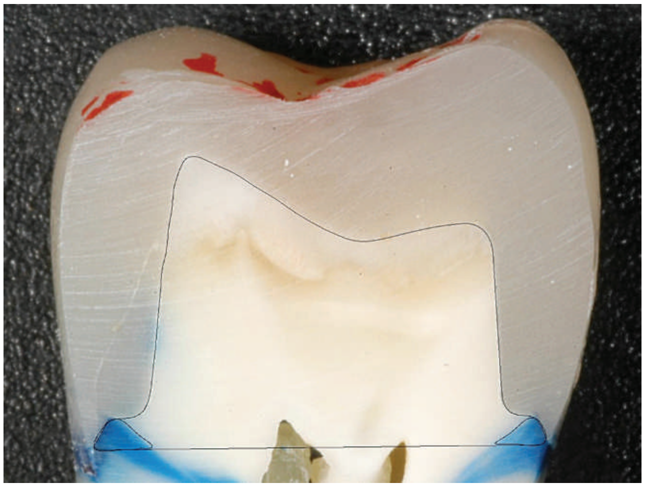

Figure 6. *Microleakage analysis by means of dedicated digital imaging and measurement software.*

previously described. Each section was analyzed for microleakage using dedicated digital imaging and measurement software (Image Pro Plus, Media Cybernetics, Bethesda, MD, USA) (Figure 6). The following parameters were recorded on each section:

- •length of the adhesive interface
- •linear marginal microleakage
- •percentage of linear marginal microleakage
- •margin-to-margin preparation area
- •preparation area microleakage
- •percentage of preparation area microleakage

Both the marginal gap and microleakage measurements were statistically analyzed by means of dedicated software (SPSS 11.0, SPSS Inc, Chicago, IL, USA); the analysis of variance (ANOVA), Scheffé test, and Student *t*-test were performed. In particular, the Scheffé test is a parametric, multi-comparison method applied to the set of estimates of all possible contrasts among the factor level means, so as to involve contrasts of more than two means at a time. A p-value < 0.05 was used in the rejection of the null hypotheses.

RESULTS

Marginal Gap

The mean values and standard deviations in millimeters of the marginal gap measurements are summarized in Table 1. The specimens used as controls (A) showed lower mean marginal gaps than those subjected to the simulated periodontal treatment (B); therefore, scaling and root planing procedures always increased the marginal gap of the composite crowns irrespective of the finish line

Table 1: *Mean Values and Standard Deviations of the Marginal Gap Measurements (mm)*

Group	Not Treated (A)	Treated (B)
G1	0.091 ± 0.065	0.258 ± 0.114
G2	0.133 ± 0.050	0.463 ± 1.875
G3	0.134 ± 0.051	0.409 ± 0.134
G4	0.101 ± 0.029	0.247 ± 0.064

design. The lowest mean value was recorded for the specimens prepared with the 90° shoulder, whereas the highest was recorded for the beveled 90° shoulder preparation.

The ANOVA revealed statistically significant differences in the control crowns (A, $p<0.0001$) but not in the periodontally treated specimens (B, $p>0.05$).

The Scheffé test performed on subgroups A showed statistically significant differences between G1-MG-A vs G2-MG-A ($p<0.0001$), G1-MG-A vs G3-MG-A ($p<0.0001$), and G2-MG-A vs G4-MG-A ($p<0.0001$).

The Student *t*-test for independent samples was used to compare the marginal gap of the specimens prepared with the same prosthetic geometry but subjected or not to the simulated periodontal treatment: Statistically significant differences were shown in all groups (G1-MG-A vs B: $p<0.0001$, G2-MG-A vs B: $p<0.05$, G3-MG-A vs B: $p<0.0001$, G4-MG-A vs B: $p<0.0001$).

Microleakage

The mean values and standard deviations in percentage of the linear and area microleakage measurements are summarized in Table 2. The treated specimens (subgroups B) showed mean linear and area microleakage values lower than those noticed in the control crowns (subgroups A).

As to the linear measurements of the controls (A), the specimens prepared with the chamfer (G4) showed the lowest microleakage, whereas the teeth prepared with the beveled 90° shoulder (G2) were found to have the highest rate of infiltration. Differently, among the treated specimens (B), the crowns prepared with the 90° shoulder (G1) showed no linear microleakage, whereas the highest values

Table 2: *Mean Values and Standard Deviations in Percentage of the Linear and Area Microleakage Measurements*

Group	Not Treated (A)		Treated (B)	
	Linear	Area	Linear	Area
G1	1.551 ± 1.735	0.145 ± 0.342	0	0
G2	18.066 ± 16.655	13.947 ± 18.610	5.429 ± 2.025	2.060 ± 3.851
G3	1.933 ± 5.667	0.365 ± 1.156	0.359 ± 0.824	0.040 ± 0.099
G4	0.362 ± 0.570	0	0.235 ± 0.887	0

were recorded again for the beveled 90° shoulder finish line (G2).

As regards the area microleakage measurements of the controls (A), the crowns prepared with the chamfer (G4) showed no infiltration, whereas the highest percentage of microleakage was recorded for the beveled 90° shoulder finish line (G2). Among the treated specimens (B), no microleakage was noticed for both the crowns prepared with 90° shoulder (G1) and the chamfer (G4). Once more, the beveled 90° shoulder finish line (G2) showed the highest percentage of area infiltration.

The ANOVA revealed statistically significant differences for both linear and area microleakage among both the control crowns (A, $p<0.0001$) and the periodontally treated specimens (B, $p<0.0001$).

As to both the controls (A) and the treated crowns (B), the Scheffé test showed statistically significant differences for both the analyzed variables between G2-MM-A vs G1-MM-A ($p<0.0001$), G2-MM-A vs G3-MM-A ($p<0.0001$), G2-MM-A vs G4-MM-A ($p<0.0001$), G2-MM-B vs G1-MM-B ($p<0.0001$), G2-MM-B vs G3-MM-B ($p<0.0001$), and G2-MM-B vs G4-MM-B ($p<0.0001$).

The Student *t*-test for independent samples, used to compare both the marginal linear and area microleakage of the specimens prepared with the same prosthetic geometry but subjected or not to the simulated periodontal treatment, showed statistically significant differences in G1-MM-A vs B for both linear ($p<0.0001$) and area microleakage ($p<0.01$) and in G2-MM-A vs B for both linear ($p<0.0001$) and area microleakage ($p<0.005$).

According to these results, both the tested null hypotheses were rejected.

DISCUSSION

Although presenting significant differences, all the tested specimens showed a clinically acceptable marginal adaptation, irrespective of the finish line design.

According to the results of the present *in vitro* study and of other similar investigations,[38,41] the marginal gaps always increased after the simulated periodontal treatment. Conversely, scaling and root planing procedures reduced both the linear and area microleakage.

As regards the control specimens not treated with the simulated periodontal treatment (subgroups MG-A), the crowns prepared with 90° shoulder (G1) and chamfer (G4) showed mean marginal gaps ≤100 μ, within the range of clinical acceptability,[2,3] whereas the restorations prepared with beveled 90° shoulder (G2) and feather edge (G3) showed higher mean marginal gaps of about 130 μ. Similar to the control specimens, after simulated periodontal treatment (subgroups MG-B), the crowns prepared with 90° shoulder (G1) and chamfer (G4) showed mean marginal gaps of about 250 μ, lower than those recorded for the restorations prepared with beveled 90° shoulder (G2) and feather edge (G3) that reached mean marginal gaps of about 400–450 μ.

The marginal gap values recorded in the present study in the absence of periodontal instrumentation (subgroups MG-A) were comparable to those obtained in other similar investigations.[20,38,41,43] After the simulated periodontal treatment (subgroups MG-B), the resulting marginal gap measurements were higher than those recorded for the controls, reaching doubled or tripled values. Such increases were proportional to the gap evidenced in the absence of the periodontal treatment.

As regards the feather-edge preparation, significant marginal gap values were recorded, but they were not proportional to the microleakage. It could be speculated that this was probably due to the combination of two phenomena: the tapering of the preparation, which favors an even distribution of the luting agent, and the orthogonal or slightly oblique cut of the dentinal tubules, which could enhance the creation of the adhesive hybrid layer. Nonetheless, in the presence of the feather-edge preparation, the marginal gap could worsen over time.

According to the results of the present investigation, composite crowns prepared with beveled 90° shoulder and feather edge could fracture during function and periodic periodontal treatments more easily than restorations prepared with other finish lines due to their thin margins. As a consequence, beveled shoulders and feather edges should not be considered a first choice for the fabrication of composite crowns.

As to the marginal microleakage, a direct proportionality between linear and area infiltration was noticed in both control (A) and treated (B) crowns. The 90° shoulder (G1), the feather-edge (G3), and the chamfer (G4) finish lines showed lower marginal microleakage than the beveled 90° shoulder (G2); as regards the specimens not subjected to any instrumentation, the latter showed massive marginal microleakage and the rate of microleakage seemed scarcely related to the dimensions of the marginal gap. This was probably due to the fact that, in the presence of the same marginal gap, the beveled preparation exposed a greater number of dentinal tubules than other finish geometries. Another possible explanation for such a massive microleakage with the beveled 90° shoulder is the higher cement thickness due to a more difficult flow of the luting agent during cementation;[38,41] subsequently, the crown margin was probably impacted by a more critical polymerization shrinkage. The latter hypothesis is just a speculation and should be verified experimentally.

According to the results of the present *in vitro* study, no correlation between the marginal gap and microleakage was noticed. The root surface instrumentation significantly reduced the marginal microleakage; these data seem in contrast to the recorded increased marginal gap after the periodontal treatment. This was probably due to the debris compacted at the level of the margin by the curettes moving in an apical-coronal direction, increasing the resistance to microleakage; such a speculation should be verified by further experimental investigations.

The amorphous debris could increase bacteria accumulation over time; as a consequence, both professional and domiciliary hygiene maintenance should be stressed in the presence of composite restorations in order to reduce the need of scaling and root planing procedures. As regards the domiciliary oral hygiene procedures, the use of spongy dental flosses and interproximal brushes should be recommended to the patients. Furthermore, if scaling and root planing are needed, dentists should polish the margins of composite crowns by means of rotary bristles and interproximal finishing strips.

Moreover, the reduction of microleakage in the treated specimens could also be explained considering that the instrumentation removed areas of infiltrated margins; nevertheless, the fractures that occurred at the level of some margins, particularly in the specimens prepared with the chamfer finish line (G4), did not influence significantly the reduction of microleakage after the periodontal treatment.

CONCLUSION

Within the limitations of the present *in vitro* study, the following conclusions can be drawn:

- The manual mechanical periodontal instrumentation altered the surface of composite crowns and the marginal gap increased proportionally after such treatment.
- The 90° shoulder and the chamfer finish lines revealed lower marginal gaps both before and after periodontal treatment and showed a stable marginal integrity.
- The beveled 90° shoulder and the feather edge presented with a higher risk of damage due to scaling with curettes.
- The 90° shoulder, the feather-edge, and the chamfer preparations showed lower marginal microleakage both before and after periodontal treatment.
- The mechanical root surface instrumentation reduced the marginal microleakage.

According to the results of the present *in vitro* study, the 90° shoulder and the chamfer preparation proved to be a viable option for the fabrication of composite crowns, whereas the beveled 90° shoulder and the feather edge should not be recommended.

Conflict of Interest

The authors of this manuscript 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.

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