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Comparison of the Marginal Adaptation of Zirconium Dioxide Crowns in Preparations with Two Different Finish Lines

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Keywords
CAD/CAM crowns; marginal fit.

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Abstract

Purpose: The purpose of this study was to evaluate the marginal adaptation of zirconium dioxide crowns in preparations with two different finish line configurations before and after porcelain firing cycles, after a glaze cycle, and after cementation.
Materials and Methods: Twenty human molar teeth were prepared to receive full crowns; ten were prepared with a 90° round shoulder and another ten with a 45° chamfer finish line. Zirconium dioxide copings were fabricated using CAD/CAM technology (Lava™ system). They were then veneered with a low-fusing glass-ceramic (IPS e.max® Ceram). Finally, they were glazed and cemented with a resin-composite cement (RelyX™ Unicem, Aplicap™). Measurements for marginal adaptation using stereomicroscopy (40×) were performed at four stages: copings (S1), after porcelain firing cycles (S2), after glazing (S3), and after cementation (S4). One-way ANOVA was used to assess the influence of the finish line design on the marginal adaptation in each stage. Two-way ANOVA with repeated measurements was performed to assess the influence on the marginal adaptation of the porcelain firing cycles, glaze firing cycle, and cementation.
Results: The measured marginal gap mean values for the shoulder group (μm) were: 50.13 (S1), 54.32 (S2), 55.12 (S3), and 59.83 (S4). The values for the chamfer group were: 63.56 (S1), 71.85 (S2), 74.12 (S3), and 76.97 (S4). When comparing marginal gaps between specimens with two different finish lines, differences were noticed at the four studied stages ($p = 0.0165$, $p = 0.0027$, $p = 0.0009$, and $p = 0.0009$, respectively). No differences were manifested in the marginal gap measurements of the shoulder group at the different stages of fabrication ($p = 0.4335$); however, in the chamfer group, differences were noticed between S1 and S3 ($p = 0.0042$).
Conclusions: Marginal adaptation was influenced by the finish line design. The firing cycles significantly affected the chamfer group; nevertheless, the marginal gap was within the range of clinical acceptability.

The success of a full crown restoration depends on several factors. One of the most important factors is the marginal adaptation,[1–6] which can be influenced by finish line design, repeated ceramic firing cycles, and cementation materials. These factors have been widely studied in metal ceramic and all-ceramic restorations.[2,7–11]

All types of ceramic restorations are becoming more popular every day. The use of zirconium dioxide-based ceramics (ZrO_2) in combination with CAD/CAM technology makes esthetic and resistant restorations with excellent marginal adaptations available to all clinicians.[7,12–14]

The Lava™ all-ceramic system (3M ESPE, Seefeld, Germany) comprises a CAD/CAM procedure for the fabrication of all-ceramic crowns and fixed partial dentures for anterior and posterior applications.[7,13,14] The system uses tetragonal polycrystalline zirconia partially stabilized with yttria (Y-TZP = yttria tetragonal zirconia polycrystals). Traditionally, coping fabrication is performed by scanning the model using the optical Lava™ Scan (3M ESPE), by designing the restoration with specific software (CAD), and by milling an enlarged form out of a presintered zirconia blank with the Lava™ Form (CAM; 3M ESPE). Seven different shades are available

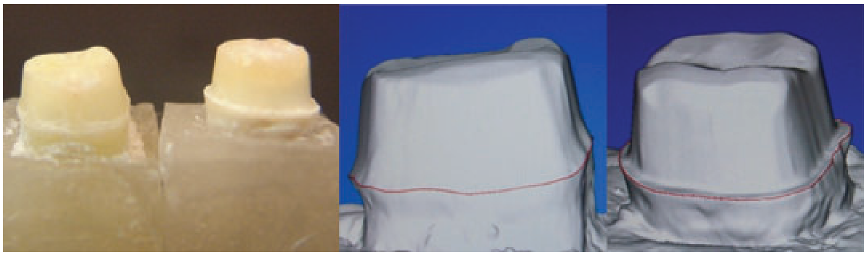

Figure 1 Representative chamfer (l) and shoulder (r) group. View of the scanned specimens.

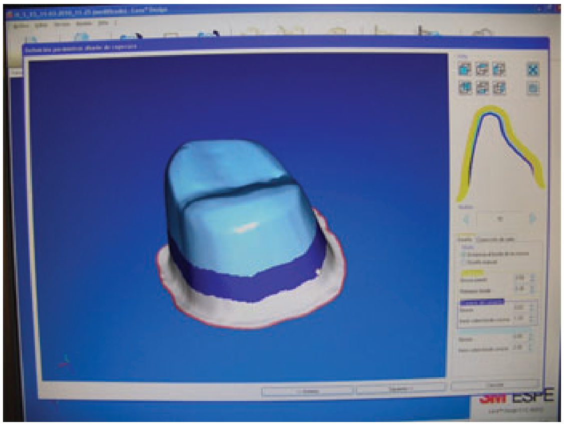

Figure 2 Restoration design with LAVA scan.

for coloring the coping, which is then sintered to its final density in the furnace. Finally, the coping is veneered and artistically finished.[15]

For metal-free restorations, the most popular finish line designs are round shoulder (RS) and chamfer.[2,13,16–18] However, there is not enough evidence to decide which design offers better marginal adaptation.

The field of dentistry remains without an agreement for the establishment of an acceptable marginal discrepancy. A marginal gap ranging from 10 to 500 μm, with mean values from 50 to 100 μm has been defined as acceptable.[6] Marginal openings ranging from 50 to 120 μm are considered clinically acceptable in terms of longevity.[17,19] For CAD/CAM restorations, the generally acceptable marginal gap discrepancies are between 50 and 100 μm.[3,7,8,16]

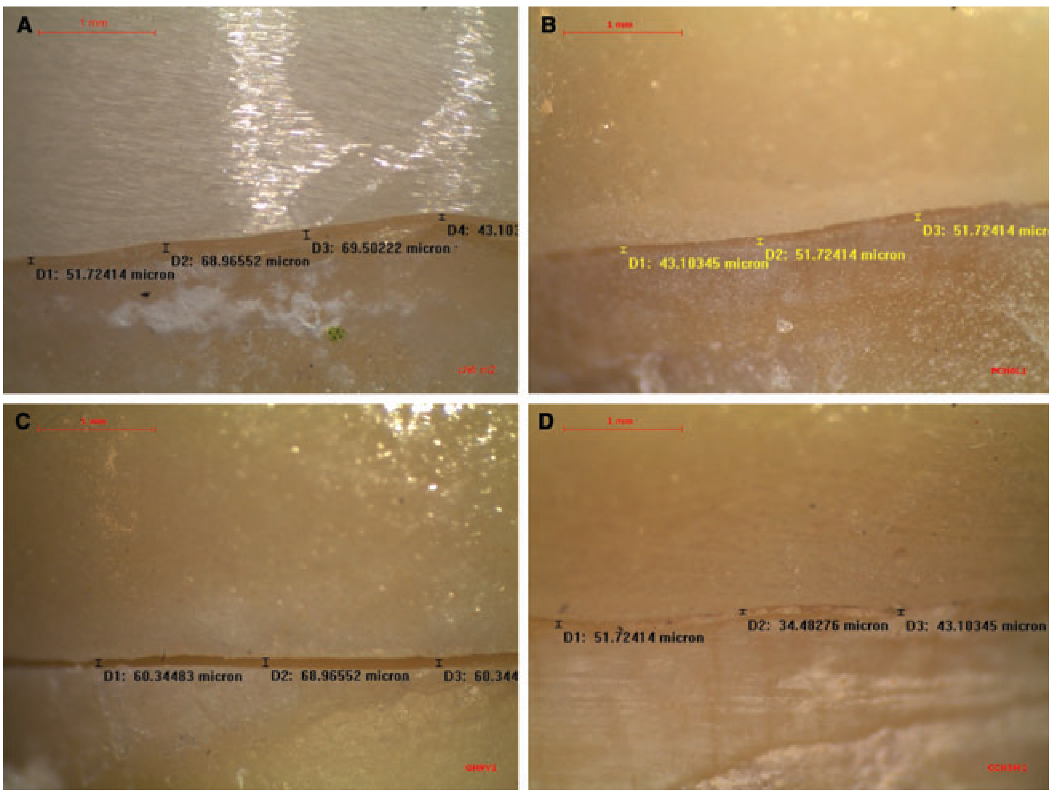

Figure 3 A. Measurements of the zirconium copings taken in Image-Pro® Plus. B. Measurements after porcelain firing cycles (IPS e.max® Ceram, Ivoclar Vivadent®) C. Measurements after glaze firing cycle, using IPS e.max® Ceram Gaze (Ivoclar Vivadent®). D. Measurements after cementation with Rely X™ Unicem Aplicap™ (3M ESPE)

The ceramic firing cycles and glaze firing cycles have shown effects on the marginal adaptation of all-ceramic restorations. Balkaya et al examined the effects of porcelain and glaze cycles on the fit of three types of all-ceramic crowns (conventional In-Ceram, copy-milled In-Ceram, copy-milled feldspathic crowns) and concluded that porcelain firing cycles affect the marginal fit of all-ceramic crowns.[20] Komine et al[8] found that firing cycles did not affect the marginal adaptation of zirconium crowns in preparations with different finish line designs (shoulder, RS, and chamfer); these results are consistent with those found by Vigolo and Fonzi.[7] However, there are not enough studies to support the effect of the firing cycles on zirconium-based restorations.

Properties of luting agents and cementation procedures are important to the success of a fixed restoration because marginal discrepancies and leakage can lead to failure.[21] Several studies show that the use of adhesive resin composite cement promotes a good marginal fit and minimizes microleakage.[13,21-24]

The aim of this investigation was to evaluate the marginal adaptation of ZrO_2 crowns in preparations with two different finish line designs (90° RS, 45° chamfer) before (stage S1) and after porcelain firing cycles (stage S2), after glaze cycles (stage S3), and after cementation (stage S4). The hypotheses to be tested were as follows: (1) the finish line design significantly affects the marginal adaptation of CAD/CAM zirconium crowns (2) the porcelain firing cycles and glaze cycles do not affect the marginal adaptation of CAD/CAM zirconium crowns, and (3) the cementation procedure with resin composite cement does not affect the marginal adaptation of CAD/CAM zirconium crowns.

Materials and methods

Twenty extracted human molar teeth with no caries or anatomical defects were used in this study. Teeth were obtained following the guidelines of the local human research ethics committee. All teeth were relatively comparable in size, and were cleaned and stored in 10% formaldehyde solution until they were used for the study. The teeth were randomly divided into two groups of ten each. They were then mounted in a block of autopolymerizing resin (Nic Tone mdc dental® Zapopan, Jalisco, Mexico). Both groups were prepared to receive all-ceramic crowns by the same prosthodontist.

In both groups, preparations were performed with the following characteristics in common: anatomic oclusal reduction of 2 mm, 6° axial convergence, axial reduction of 1.0 to 1.5 mm, and a finish line located 0.5 mm above the cementoenamel junction (CEJ; Fig 1). The finish line for teeth in group A was a 1-mm wide 90° RS. Flat-end tapered diamond burs (Axis® modified shoulder No. 847KR, Axis Dental, Kerr Corporation, Copell, TX) were used. In group B, the finish line was 1-mm wide, and 45° chamfer and torpedo-shaped diamond burs were used (Axis® No. 879K, Axis Dental, Kerr Corporation). All preparations were approved by an experienced prosthodontist.

Impressions of each tooth were made with a polyether impression material (Impregum™ Penta™ medium and Impregum™ soft, 3M ESPE). A light-body impression material was injected around the tooth preparations and then inserted in custom-made trays of regular body material. After the impression, the prepared teeth were stored in a fresh 10% formaldehyde solution. Master dies were fabricated with type IV dental stone (Elite® Rock Fast, Zhermack, Badia Polesine, Rovigo, Italy) prepared by an automatic vacuum mixer following the proportions indicated by the manufacturer.

After fabrication, all models were sent to an authorized LAVA center for production of the zirconium copings. All copings were designed to the following manufacturer's instructions: 0.5 mm wall thickness, a 0.35 mm reinforcement of the restoration edge, and a 0.02 mm space for cement initiated at a distance of 1.2 mm from the coping of the margin and increased to 0.05 mm at a distance of 2.3 mm from the margin of the coping (Fig 2).

Evaluation of marginal adaptation

Copings and crowns were placed on their teeth, and the margins of each coping and crown were evaluated using a dental explorer (EXD 11/12, Hu-Friedy Chicago, IL) and magnification loupes with a power of 2.5× (Task Vision, Cherry Hill, NJ) to perform an initial clinical evaluation. The marginal adaptation was then evaluated for all specimens with a stereomicroscope (Leica® EZ4D, Bensheim, Germany) and a coupled digital camera. Finally, marginal discrepancy was measured with image analysis software (Image-Pro® Plus version 6.0.0.260 Copyright© 1993–2006 Media Cybernetics, Inc. Bethesda, MD).

Measurements

To measure the marginal adaptation, we used the criterion proposed by Holmes et al,[25] defining absolute marginal discrepancy as the distance from the edge of the crown to the edge of the finish line. Measurements of marginal discrepancies were made at five equidistant points on each of the four axial walls for a total of twenty marginal adaptation evaluation sites for each coping (S1; Fig 3). After all measurements were made, all copings were returned to the dental laboratory to veneer them with a low-fusing nano-fluorapatite glass-ceramic (IPS e.max® Ceram, Ivoclar Vivadent®, Schaan, Liechtenstein). After veneering, all measurements were taken again (S2; Fig 3). The crowns were then glazed using IPS e.max® Ceram Glaze (Ivoclar Vivadent®) and marginal discrepancy was determined again (Fig 3). During these measurements each tooth with the restoration fully seated was maintained in place with a C-clamp (Truper®, Col Granada, D.F., Mexico). Finally, crowns were cemented on the prepared teeth using resin composite cement (RelyX™ Unicem, Aplicap™, 3M ESPE). Finger pressure was initially applied for 2 minutes, excess cement was removed, and pressure was applied again for an additional 5 minutes. The marginal interface was finally finished with Jiffy composite polishing brushes and diamond paste (Ultradent®, South Jordan, UT). After the cementation process, all marginal discrepancy measurements were repeated (Fig 3).

Statistical analysis

The normality and variance homogeneities of all sample measurements were initially confirmed by the Kolmogorv-Smirnof test and Levene test, respectively. Therefore, parametric statistics were used (Statgraphics Centurion XV, Warrenton, VA) at a 95% confidence level. One-way ANOVA was used at each stage to determine any difference in the marginal adaptation of the two groups dictated by the type of finish line design.

A multifactor ANOVA with repeated measurements was used in each of the two groups to study the effects of the ceramic firing cycles, the glaze firing cycles, and the cementation process on the marginal discrepancy. When significant differences were present, a multiple comparison test was performed using Scheffe's method.

Results

The measured misfit mean (μm), standard deviation (μm), and misfit statistical comparison between RS and chamfer restorations (C) before porcelain firing cycles (S1), after porcelain firing cycles (S2), after glaze cycles (S3), and after cementation (S4) are shown in Table 1. In the RS group, porcelain firing cycles, glaze cycles, and cementation had no effect on the amount of marginal discrepancy. There were statistically significant differences in the chamfer group. Scheffe's test revealed that these differences occurred between S1 and S3.

Discussion

This in vitro study evaluated the marginal adaptation of zirconium crowns fabricated by CAD/CAM with the Lava™ System in preparations with two different finish line designs: modified 90° shoulder and 45° chamfer. In addition, we noted the effect of the porcelain firing cycles, glaze cycles, and cementation on the marginal misfit of crowns in both groups.

The results of this study show that the marginal misfit measured in zirconium crowns with an RS finish line is significantly lower than the measured misfit in chamfer finish line restorations, so our alternative hypothesis is accepted. These results are consistent with those found by Ferreira et al[2] and Cho et al.[10] However, they differ from those found by Komine et al,[8] who also found lower values of marginal discrepancy in shoulder preparations but did not find a statistically significant difference. Suárez et al[17] also did not find any significant differences; however, the specimens used in these studies were not natural teeth prepared under clinical criteria. They were mechanized specimens, which allow less variability in the sample but do not accurately reflect clinical circumstances.

Table 1 Statistical Comparison of the restorations with round shoulder and chamfer finish line at all fabrication satges. S1 (zirconium coping before porcelain firing cycles), S2 (after porcelain firing cycles), S3 (after glaze cycle), and S4 (after cementation). Mean (μm), standard deviation (μm). Asterisk indicate statistically differences between S1 and S3 in chamfer group

Round shoulder group	Means	Standard deviation	Chamfer group	Means	Standard deviation	p-value
S1	50.13	13.82	S1	63.56*	8.17	0.0165
S2	54.32	14.06	S2	71.85	7.59	0.0027
S3	55.12	12.62	S3	74.12*	8.50	0.0009
S4	59.83	11.28	S4	76.97	7.55	0.0009
	$p = 0.4335$			$p = 0.0042$		

During specimen preparation, it was believed that the adjustment of the zirconium copings in the master die might be a critical step that could explain the different amount of marginal misfit measured for both types of studied restorations. During zirconium coping design, the manufacturer thickens the margin to prevent defects in this area during milling.[15] This reinforcement is then partially retrieved with 30 μm particle-sized diamond burs at the master cast die during the adjustment process at the dental laboratory. It was believed that this retrieval might be easier to perform when the finish line was a 90° round shoulder. Therefore, we strongly recommend the use of a laboratory microscope during removal of the margin reinforcement.

Although the modified shoulder group showed lower marginal discrepancies than the chamfer group, both groups always demonstrated misfit measurements within the range of clinical acceptance (<120 μm).[1,3,17,26] Marginal fit comparisons after porcelain firing cycles and glaze cycles showed no differences in the RS group, as described by Komine et al.[8] However, porcelain firing cycles and glaze cycles had a significant increasing effect on the chamfer group due to the small amount of porcelain applied at the edge area that was easily altered during porcelain firing cycles and glaze firing cycles. Komine et al[8] and Vigolo and Fonzi[7] did not find any differences during the fabrication stages in restorations with chamfer finish lines. These authors used a deeper chamfer of 1.2 to 1.5 mm that gave more stability to zirconium copings during porcelain firing cycles. Another recent study[27] found no dimensional changes during firing procedures with zirconia core ceramic in bars of $1.2 \times 4 \times 20$ mm^3; however, the dimensions of these specimens were much larger than the copings used in this study. Therefore, the second alternative hypothesis is accepted for the RS group, but is rejected for the chamfer group.

Cementation procedures had no influence on the marginal gap in both groups, so we accept the third alternative hypothesis presented in this study and recommend the use of resin cements to zirconia restorations. These results are consistent with those reported by other authors.[3,22,23,28] As noted earlier, finger pressure was used for cementation in an attempt to simulate the clinical procedure, and although the standard deviation of the results suggests that this variable had no effect in this study, we recommend the use of a device to standardize the cementing force for future studies.

The results of this *in vitro* study showed that marginal gap of Lava® crowns are within the clinically acceptable range for both finish line designs, although we found statistically significant differences between groups; therefore, our recommendations for clinicians is the use of an RS finish line, which had smaller marginal discrepancies and remained without significant changes in the marginal adaptation after firing cycles. Further investigation with a larger sample size and clinical trials is necessary to corroborate the results.

Conclusions

Within the limitations of this study, the following conclusions can be drawn:

1. The marginal adaptation of zirconia crowns (Lava™) made by a CAD/CAM system was influenced by the finish line

design. Preparations with a 90° RS finish line showed a better marginal seal than did preparations with a 45° chamfer finish line in all fabrication stages; however, both preparations showed marginal gap measurements within acceptable clinical standards, less than 120 μm.
2. Marginal adaptation after porcelain firing cycles and glaze firing cycles was not significantly affected in the RS group; however, after porcelain firing cycles and glaze firing cycles, marginal adaptation increased significantly in the chamfer group.
3. The use of resin cement (Rely X ™ Unicem Aplicap) had no significant effect on the marginal gap in all-ceramic crowns with zirconia cores (Lava™) in both groups studied.

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