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Original Research

Comparative Evaluation of Marginal Vertical Discrepancies of Full Zirconia Crowns, Layered Zirconia Crowns, and Metal Ceramic Crowns: An *In Vitro* Study

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Abstract:

Background: Strength, color stability, and precision of fit are requirements for all-ceramic restorations. Full zirconia has evolved to overcome the disadvantages of layered zirconia. However, marginal fit has not been evaluated so far. This original research compared the marginal vertical discrepancies of full zirconia, layered zirconia, and metal ceramic crowns and evaluated the effect of veneering on the marginal fit of zirconia copings as well as metal copings.

Materials and Methods: A total of 30 samples were used in this study. Three zirconia dies of the same dimensions were designed by computer aided designing/computer aided manufacturing (CAD/CAM) and were used to fabricate crowns in the following experimental groups: Group 1 (full zirconia); Group 2a (zirconia copings), Group 2b (layered zirconia crowns); Group 3a (metal ceramic copings) and Group 3b (metal ceramic crowns). Full crown restorations were prepared using CAD/CAM. The marginal gap was measured under a stereomicroscope. The measurement was done twice for Group 2 and Group 3 before and after veneering. The results were statistically analyzed using ANOVA test and *t*-test.

Results: All the three test groups showed statistically similar marginal gap, but there was a significant difference in the marginal gap between Group 3a and Group 3b.

Conclusion: The mean marginal gap of all the test groups was within the clinically acceptable level. There was no effect of veneering on the marginal fit of zirconia copings, but there was a significance of veneering on the marginal fit of metal ceramic restorations.

Key Words: Computer aided designing computer aided manufacturing, marginal fit, metal ceramic, monolithic zirconia, veneered zirconia

Introduction

Marginal adaptation is one of the most important criteria for determining the clinical success of the dental restoration. Various factors such as design of finish line, method of fabrication of restoration, veneering firing cycles and materials used for fabrication of restoration affect the marginal fit of full crown restoration. Poor fit of the crown can lead to deficient margins, and this could lead to tooth sensitivity in vital teeth and a higher plaque index and thereby causing caries and inflammation of periodontal tissues. In addition, stress concentrations may be created due to variations in the fit, and this may, in turn, reduce the strength of the restoration and consequently cause its fracture.[1]

In metal ceramic restorations, the metal provides strength to restoration, whereas the ceramic gives appropriate esthetics. However, the appearance is still inferior to all ceramic. Enhanced biocompatibility, strength, esthetics, and fit are requirements for all-ceramic restorations. However, the inherent brittleness, low flexural strength, and fracture toughness of conventional glass and alumina ceramics have been the main obstacles for extensive use posterior teeth. One of the most significant advances in restorative dentistry has been the introduction of zirconia based ceramic materials.[2]

The addition of yttrium oxide partly stabilizes the pure zirconia at a room temperature in the tetragonal phase, resulting the formation of a multiphase Yttrium-Tetragonal Zirconia Polycrystal (Y-TZP) ceramic. The ability of Y-TZP to transform from tetragonal to monoclinic structure, which helps to prevent crack propagation, is responsible for the strength and toughness of the ceramic.[3]

Fracture or chipping of the veneer has been reported as the major cause of failure of layered zirconia restorations in the posterior region.[4] To overcome the disadvantages of veneering on zirconia copings; full zirconia has been developed. It is a monolithic zirconia with no porcelain overlay.

To overcome the disadvantages of layered zirconia which is the most popular all-ceramic material, full zirconia is developed. Studies were undertaken to evaluate the changes in marginal fit during the porcelain veneering. Several studies showed the increased marginal discrepancy of all-ceramic restorations after veneering,[1,5,6] but few studies showed no significant differences in marginal fit of all-ceramic restorations before and after veneering process.[7]

As there were no studies comparing the marginal fit of full crowns made of full zirconia, layered zirconia, and milled metal ceramic full crowns, this study was undertaken.

The aims and objectives of this study:
1. To compare the marginal fit of full zirconia crowns (computer aided designing/computer aided manufacturing [CAD/CAM]) layered zirconia crowns (CAD/CAM) and metal ceramic crowns (CAD/CAM)
2. To investigate the effect of veneering on the marginal fit of zirconia copings and metal copings.

Materials and Methods

A total of 30 samples with 10 in each group were used in this study. The crown preparation was simulated by making one zirconia die in each group of the same dimension (Figure 1). Zirconia die was designed using CAD (Delcam DentCAD) (Figure 1) and milled (Roland DWX 30 dental milling system) (Figure 2). So, all the three dies had the same dimensions of height 5.5 mm, deep chamfer finish line width of 1.5 mm and 6° taper.

For Group 1, (full zirconia) 10 crowns, with the thickness of 2 mm and for Group 2 (layered zirconia) 10 zirconia copings with the thickness of 0.5 mm were prepared by milling (Roland DWX 30 dental milling system). For Group 3 (metal ceramic) 10 metal copings (Kera Co-Cr disk, Germany) with thickness of 0.5 mm were prepared by milling (Dya Mach DT2, Italy) (Table 1).

Group 1 (full zirconia) and Group 2a (zirconia copings) were sintered in a sintering furnace (Nabertherm Sintering Furnace, Germany) at 1500°C temperature for 2 h.

To investigate the effect of porcelain veneering on the marginal gap of the crown, the marginal fit was measured in two different phases during the crown fabrication for Group 2 (layered zirconia) (Figures 3 and 4) and Group 3 (metal ceramic) (Figure 5). The first measurement was calibrated after copying and the second after veneering. There was only one measurement for the Group 1 (full zirconia crowns) as there was no veneering process.

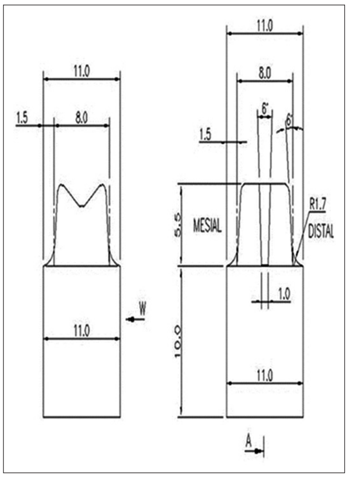


Figure 1: Schematic representation for computer aided designing design of zirconia die.

Figure 2: Zirconia die.

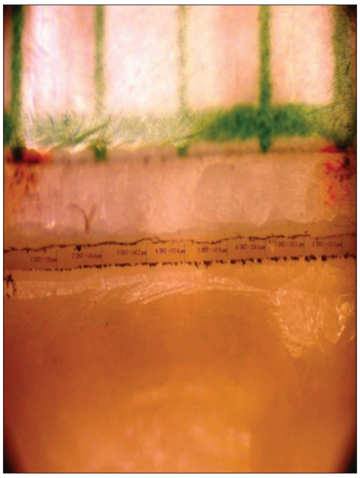


Figure 3: Stereomicroscopic photograph of a specimen of Group-2a (zirconia copings) while measuring the marginal gap.

The marginal fit was assessed by measuring the gap between the edges of the coping or crown and the die finish margin under the stereo microscope (Labomed CZM6, Labo America Inc, USA) at ×5 magnification. This was done by measuring the gap at 60 points (15 points per each surface) per sample, which were selected in a distance of approximately 700 μm. The marginal fit of one coping or crown was defined as a mean value of these 60 measurements. The marginal fit was measured without cementation on the zirconia die. ProgRes C14 plus microscope camera (Jenoptik, Germany) was used to capture the required points, and ProgRes Capture Pro software was used for image analysis.

ANOVA test was used to compare all the three groups. Intra group analysis was done using paired *t*-test. All tests were performed at 0.05 level of significance.

Results

Group 1 (full zirconia crowns), Group 2b (layered zirconia crowns), and Group 3b (metal ceramic crowns) showed similar marginal gaps (Graph 1).

Group 3a (METAL copings) showed less marginal gap before veneering as compared to Group 3b (metal ceramic crowns) after veneering. The mean and standard deviations of the marginal gap of all the test groups are given in Table 2.

Discussion

A good marginal fit is one of the most important requisites for the long term success of all-ceramic restoration. Deterioration of the initial fit of the metal copings has been reported after the porcelain firing cycle. Studies on marginal fit have revealed that a mismatch of porcelain–metal thermal contraction, alloy type, and margin design as contributing factors to the distortion.[8] To overcome the disadvantages of metal ceramic restorations, all ceramics have been evolved. An ideal all-ceramic restoration should possess enhanced biocompatibility, high strength, excellent fit, and very good esthetics. Low flexural strength, low fracture toughness, and inherent brittleness of conventional glass and alumina ceramics have been the main obstacles for extensive use. The introduction of zirconia based ceramic materials has been a major breakthrough in the field of restorative dentistry. To overcome the disadvantages of layered zirconia which is the most popular all-ceramic material, full zirconia is developed. However, evaluation of marginal fit of a zirconia crown has not been reported.

Table 1: Experimental groups.

Group 1	Full zirconia crowns		
Group 2	Layered zirconia	Group 2a	Zirconia copings
		Group 2b	Layered zirconia crowns
Group 3	Metal ceramic	Group 3a	Metal copings
		Group 3b	Metal ceramic crowns

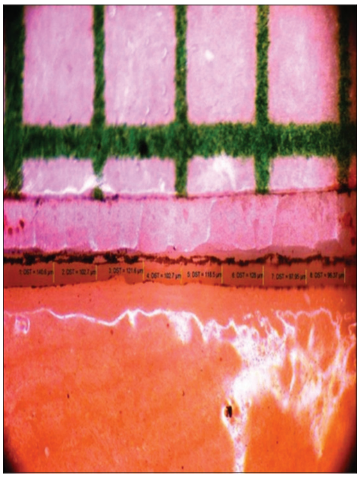


Figure 4: Stereomicroscopic photograph of a specimen of Group-2b (layered zirconia crowns) while measuring the marginal gap.

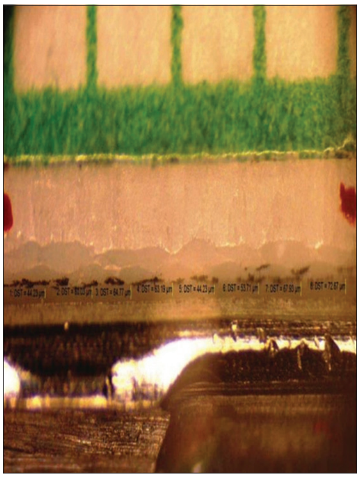
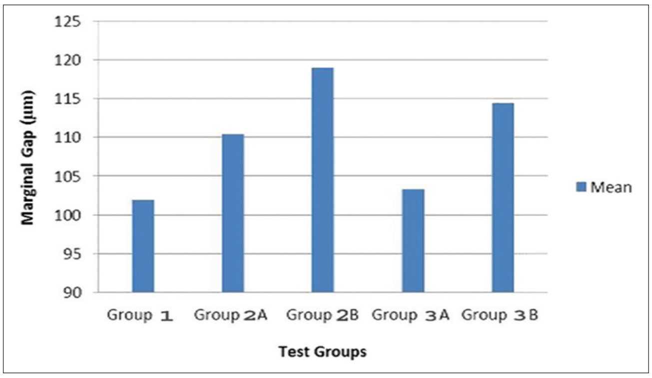


Figure 5: Stereomicroscopic photograph of a specimen of Group-3a (metal copings) while measuring the marginal gap.



Graph 1: Mean marginal gap values of all test groups.

Table 2: Mean and standard deviations of marginal gap of all the test groups.

Group	Group 1 (Full zirconia crowns)	Group 2a (Zirconia copings)	Group 2b (Layered Zirconia crowns)	Group 3a (Metal copings)	Group 3b (Metal ceramic crowns)
Mean (μm)	101.90	110.41	118.97	103.35	114.43
Standard deviation	49.14	22.61	39.97	22.92	23.26

The advancements in the translucency of zirconia materials have shown the way to the application of monolithic crowns in the posterior region. The elimination of chipping is the main advantage of monolithic zirconia restorations, and it is economical as these restorations can be produced with CAD/CAM at reasonable prices. With regard to clinical aspects, a reduced thickness of the crown of 0.5-0.7 mm, and thus a reduced preparation depth are important in comparison with veneered restorations.[9]

The most common method to fabricate a zirconia substructure is by CAD/CAM milling from a solid block.[10] In metal ceramic restorations, the most common method to fabricate a metal coping is lost wax technique. In lost wax technique, errors may occur in any stage as it involves many steps. A common problem encountered with the use of the base metal alloys is the casting shrinkage which will lead to poor marginal fit.[11] To overcome the casting errors, CAD/CAM was introduced for making cobalt-chromium copings. The advantages of CAD/CAM technique are simplicity, reduced manufacturing time, and fatigue of operator.[12] It uses a computerized mechanical mill to fabricate copings on the basis of data recorded directly from the die surface and does not require wax patterns and casting. With the CAD/CAM system uniform thickness of the coping can be maintained.[13] Hence, metal milling using CAD/CAM was done to fabricate the coping in Group 3.

Various die materials such as Type IV, Type V die stone,[14] Epoxy resin,[2] and metal[15] have been used for evaluation of the marginal fit. The ideal die should be accurate, dimensionally stable over time, hard enough to withstand the fabrication process.[16] In the present study for the first time, zirconia was used for the fabrication of die because of the various advantages. The Vickers hardness of zirconia die is 1200 Hv[17] which is very high when compared with other die materials such as Type V die stone - 47 Hv and Epoxy resin - 27 Hv[18] thereby more abrasive resistant. Moreover, the zirconia die facilitates direct viewing of marginal gaps under the microscope as it does not reflect the light and it is dimensionally stable unlike epoxy resins and gypsum products.

In this study, the marginal gap was measured without cementation of the crowns. The reason for not cementing was to eliminate the variability in the cementation procedure for each crown in terms of viscosity of the mix and force applied.[7] Many investigators found a significant increase in the marginal discrepancy due to cementation.[19] These results, however, varied according to the luting agent used.[1]

Direct viewing is a non-destructive and a relatively simple method.[7] Direct viewing to measure the marginal gap can be done by the use of stereomicroscope with image analysis software,[20] optical microscope with image analyzing software.[7] The other non-destructive methods reported in the literature are profile projector[21,22] and laser videography.[23] In this study, direct viewing of the specimens was performed under a stereomicroscope which allowed examination of the same sample at various stages. The image analyzing software greatly improved the quality of the data obtained.

Groten *et al.*[24] suggested that ideally 50 or at least 20-25 measurements are required for each specimen on all sides to obtain clinically relevant information about the gap size, regardless of whether the measurement sites are selected in a systematic or random manner. In this study, 60 points (15 points on each surface) were selected with the distance of approximately 700 μm between two measuring points.

McLean and Von Fraunhofer[25] proposed that a restoration would be successful if marginal gaps and cement thickness of <120 μm could be achieved. It has been reported in the literature that the all-ceramic crowns showed a mean marginal discrepancy that ranged from 19 μm to 160 μm.[5,26]

In the present study, the mean marginal gap of Group 1 (full zirconia crowns) was 101.90 μm, Group 2a (zirconia copings) was 110.41 μm, and the Group 2b (layered zirconia crowns) was 118.97 μm. There was no statistically significant difference of marginal gap between the Group 1 (Full Zirconia) and Group 2b (layered zirconia crowns) and between the Group 2a (zirconia copings before veneering) and Group 2b (layered zirconia crowns after veneering). This could be attributed to the dimensional stability of zirconia coping, sintered at 1500°C temperature which has been later veneered with porcelain at a temperature of 930°C. This might also be due to the strength of ZrO_2 copings preventing them from being affected by porcelain firing shrinkage.[27] These results were in comparison with the study done by Komine *et al.*[27] who evaluated the marginal fit of ZrO_2 copings and crowns and concluded that there was no significant difference before and after veneering. They attributed this to the strength of zirconia.

In the present study, the results showed the mean marginal gap of 103.35 μm in Group 3a (metal copings before veneering) and 114.43 μm in Group 3b (metal ceramic crowns after veneering). These results are in agreement with the results of Shokry *et al.*[28] who postulated the reason for the increased marginal gap after veneering due to the difference in thermal contraction between the metal coping and the layering porcelain during cooling of the prosthesis from the firing temperature.

In the present study, the following reasons could be attributed to the increased gap after porcelain veneering on metal copings. (1) When the porcelain veneering procedure is carried out, particles of porcelain melt and gather and fill the voids. The resulting contraction of the porcelain mass at this stage causes a compressive force on the coping. The deformation of the coping under the stress of contracting porcelain is spread all along the circumference of the margin.[1] The highest discrepancy might have occurred during the opaque firing.[28] (2) It can also be attributed to the increased thickness of the oxide layer formation due to repeated porcelain firing.[29]

There was no statistically significant difference between the Group 1 (Full zirconia crowns) and Group 3b (metal ceramic crowns) and between the Group 2b (layered zirconia crowns) and Group 3b (metal ceramic crowns). This could be attributed to the avoidance of the casting procedure in our study for the making of metal copings, thereby eliminating the numerous errors[8] in Group 3b (metal copings).

Summary and Conclusion

Under the conditions of this *in vitro* study, there was no statistically significant difference among the marginal fit of full zirconia crowns, layered zirconia crowns, and metal ceramic crowns. However, there was a significant difference in the marginal gap after layering of metal ceramic crowns which indicate the distortion of metal coping during the firing process of ceramic.

Full zirconia monolithic crowns meet the requirements of good strength, good wear resistance, and good esthetics thereby meeting the functional demands in posterior teeth. The main advantage being very minimal tooth reduction of 0.5 mm as compared to layered zirconia and metal ceramic crown of 1.5-2 mm. Moreover, layered restorations tend to fail at the bonding interface. By considering these advantages including the comparable marginal fit with layered zirconia and metal ceramic crowns, full zirconia monolithic crowns could be suggested as a suitable alternative to layered zirconia crowns and metal ceramic crowns in posterior teeth. Promising research is underway in improving the esthetics of zirconia as a suitable material for anterior teeth.

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