

Effect of Cement Space on the Marginal Adaptation of Monolithic Zirconia Crowns

ABSTRACT

Purpose: To evaluate effect of cement space on marginal fit of monolithic zirconia crowns after sintering, glazing, and cementation. *Materials and Methods:* Molar typodont teeth were prepared to receive crowns, and were scanned with a laboratory scanner to generate virtual dies. Crown design was planned with the CAD software with a simulated cement space of 60 μm or 80 μm . Zirconia crowns for the 60 μm and 80 μm groups were milled from zirconia discs. Milled crowns were sintered, glazed, and cemented. Marginal discrepancy was measured after sintering, glazing, and cementation. Measurements were carried out under 200X magnification, and data obtained were statistically analyzed. *Results:* Increasing cement space from 60 to 80 μm resulted in a non-significant decrease in marginal discrepancy. Marginal discrepancy was the lowest in the post sintered specimens, and increased significantly after glazing and cementation in both the groups. *Conclusions:* It was concluded that the glazing and cementation procedures significantly increased the marginal discrepancy. Increasing the cement space resulted in an insignificant decrease in the marginal discrepancy. *Clinical relevance:* The results of this study suggest that 60 μm of simulated cement space is recommended for achieving clinically acceptable marginal fit of the monolithic zirconia crowns.

INTRODUCTION

Yttria-stabilized tetragonal zirconia polycrystals (YTZP), often referred to as zirconia, has been used in dentistry to replace metal substructures because of its superior esthetics, acceptable strength and fracture toughness, chemical stability, biocompatibility, and ease of fabrication.¹ A common clinical problem observed with zirconia prosthesis has been chipping, delamination or fracture of the porcelain veneer component in the restoration.² The incidence of these complications and failures related to zirconia prostheses, reported in various clinical studies is found to be 25% in a 3 years, 26% after 31.2 months, 54% after 2 years, and 10-60% after 5 years.³⁻⁶ Full-contour zirconia or monolithic zirconia (MZ), that does not require the application of veneering porcelain, has been introduced to overcome this limitation of the veneered zirconia. MZ has decreased alumina content to improve the translucency, and increased sintering temperature to reduce the porosity and increase the grain size.⁷ MZ requires less tooth preparation, and is applicable in limited occlusal crown space, due to its higher fracture resistance compared to the veneered counterparts and other monolithic ceramics.^{7,8} The performance of MZ has been studied extensively to evaluate its surface roughness, fracture resistance, flexural strength, chipping resistance, compressive strength, elastic modulus, hardness, low temperature degradation, translucency, and color.⁹⁻¹⁹

Keywords

Marginal Adaptation
Monolithic Zirconia
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Cement Space

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Accurate marginal adaptation, esthetics, and fracture resistance are considered to be the most important qualities for the clinical success of ceramic crowns.²⁰ Inaccurate marginal fit is responsible for plaque retention, microleakage, cement breakdown and tooth sensitivity.²¹ Long term consequences of crowns with marginal gap include carious lesions, endodontic inflammation, and deterioration in optical properties, whereas overextended margins in crowns may result in gingival inflammation, periodontal disease, and bone loss.²² Holmes has defined the marginal discrepancy (MD) as the perpendicular measurement from the cervical margin of the restoration to the preparation margin.²³ The vertical marginal misfit measured parallel to the path of draw of the casting has been described as the vertical marginal discrepancy (VMD), while the horizontal marginal misfit measured perpendicular to the path of draw of the casting is known as the horizontal marginal discrepancy (HMD).²³ The absolute marginal discrepancy (AMD) is the angular combination of the VMD and the HMD, and is indicative of the underextension or overextension of the restoration margins relative to the margins of the preparation.²³

The marginal fit of the MZ crowns is affected by various factors like the proprietary materials used for fabrication, the differences between various CAD-CAM systems, the scanning device accuracy, software design, zirconia state at milling, milling machine accuracy, and manual adjustments of crowns by dental technicians.^{21,22} Besides, the cement spacer settings applied during the computer aided design procedure, aimed at creating a space between the die and the crown for the cement layer, and the cementation procedure significantly affect the marginal fit of the MZ crowns.²⁴ A small cement space could lead to premature contacts between the internal surface of the crown and the abutment tooth, and resultantly widen the marginal gap.²⁵⁻²⁹ Even though increasing the cement space can improve the marginal fit of crown restorations, an internal gap of more than 120 μm might decrease the fracture resistance of ceramic crowns without significantly improving marginal fit.^{30,31} Controversies exist in the recommended values of the cement space related to the MZ crowns, and the spacer setting most conducive to the appropriate marginal adaptation remains unknown.

Kale *et al.* recommended a cement space greater than 30 μm to achieve improved marginal fit of the MZ crowns, whereas Hasanzade *et al.* reported that the cement space should not exceed 30 μm .^{32,33} Morsy *et al.* recommended a cement spacer setting of less than 50 μm for the zirconia fixed dental prostheses (FDP), while Rinke *et al.* suggested that the cement space should be no smaller than 60 μm .^{34,35} Iwai *et al.* reported improved internal and marginal adaptation of zirconia copings at 60 μm cement space, whereas Lee *et al.* observed similar results with 80 μm cement spacer setting.^{36,37} Taha *et al.* observed a decrease in the retention of the MZ crowns at 100 μm cement space, and cautioned against increasing the cement space beyond 80 μm .³⁸ Ibrahim *et al.* noted that most CAD-CAM technicians simply follow the default CAD software

program design parameters or manufacturer recommended values for the cement space, like 50 μm by Ceramill system, 35 μm by the Zirkozahn system, and 80 μm by Katana, and proposed that these parameters may not produce the best fit.³⁹ A clinician understanding the importance of modifying the CAD parameters can guide the technician regarding optimal cement spacer settings for improved marginal adaptation. The present study therefore aimed at evaluating the effects of two different spacer settings on the marginal fit of the CAD-CAM fabricated MZ crowns. The null hypothesis was that no difference would be found in the marginal fit of MZ crowns fabricated using the different cement space settings, evaluated at the end of sintering, glazing, and cementation of the crown.

MATERIAL AND METHODS

A total of 20 right mandibular first molar typodont teeth (ANA-4 ZP; Frasco) were prepared for a complete-coverage MZ crown with 2 mm occlusal reduction, 1.5 mm axial reduction and 360-degree 1 mm deep chamfer margin.⁴⁰ Tooth reduction was uniformly conducted with handpiece (NSK Pana Air; Nakanishi) attached to a jig mounted on a dental surveyor (Neytech; Dentsply), with total occlusal convergence angle of 12 degrees.³¹ The teeth were then randomly divided into two groups of ten teeth each, designated as CS60 for the cement space of 60 μm and CS80 for the cement space of 80 μm that would be incorporated during the design phase (*Figure 1*). Each prepared tooth was then scanned with a 3-dimensional (3D) laboratory scanner (MD-ID200; Medit) following the manufacturer's instructions to generate 10 individual virtual 3D dies per group in the standard tessellation language (STL) format. The crown design and finish line marking were planned with the software (DentalCAD; Exocad) and virtual anatomic contour crowns with a simulated cement space of 60 μm or 80 μm were designed for the ten prepared teeth in each group. The design was enlarged by 20% to offset the post sintering shrinkage. The designed crown data were used to mill 10 MZ crowns for the CS60 group, and 10 MZ crowns for the CS80 group ($n = 10$) from the pre-sintered zirconia discs (Zenostar T; Wieland Dental) with a CAM software (Mill box; CIM System)

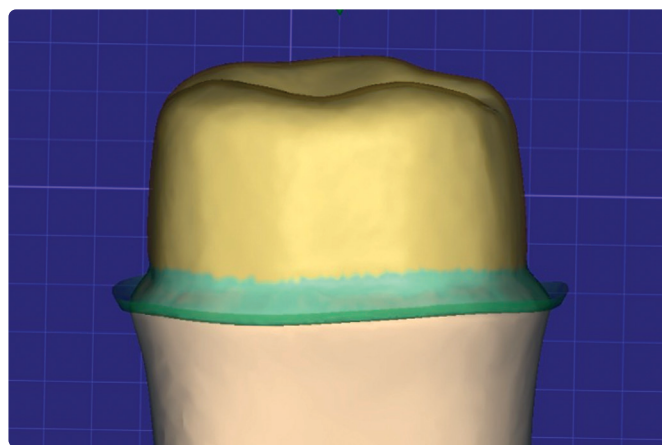


Figure 1: Cement space design on scanned typodont tooth.

and a CAM dental milling-device (X-Mill 300; XTCera). The milled crowns were sintered (Zubler S400; Zubler) at 1550°C for 8 hours. An experienced technician familiar with the CAD-CAM system fabricated the crowns, and manually adjusted them post sintering with a high-speed diamond rotary instrument (ZR6801; Komet) under water cooling. The premature contacts on the internal surface of the crown were recorded with disclosing material (SD-Fit control; Servo-Dental), and reduced with a small grit size diamond bur as recommended in previous studies.^{35,41} The crowns were then glazed (Vario 230ZR; Zubler) at 900°C for 10 minutes, and cemented with a self-adhesive resin cement (RelyX U-200; 3M ESPE), applying finger pressure for 3 minutes. The VMD was measured at three stages, on eight predetermined points, after sintering, glazing, and cementation using the following technique (Figure 2 and 3). Each zirconia crown was firmly seated over the abutment after the sintering and glazing, and mounted on a special cone shaped holding instrument, which allowed definite placement for the crowns. The VMD was measured with

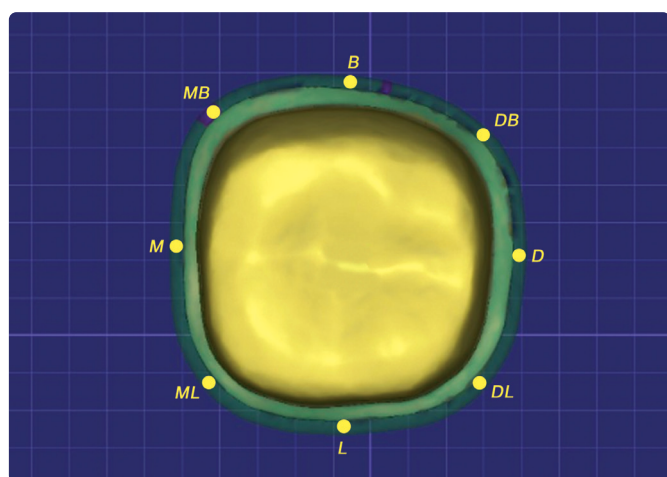


Figure 2: Diagrammatic representation of eight measurement locations for marginal discrepancy.



Figure 3: Vertical marginal discrepancy measurement at 200 X magnification.

a light microscope (Stemi 305; Zeiss) equipped with a digital camera (Axiocam 305 Color; Zeiss) under 200X magnification, and images were transferred to an image analysis program (Smartzone5v1.3; Ruckus). The average value of the eight measurement points was calculated for each specimen and considered as the circumferential VMD for that specimen. The data obtained were collected, tabulated with a spreadsheet (Excel 2021; Microsoft Corp), and analyzed with statistical software (SPSS Statistics v27.0; IBM Corp). The means and standard deviations were calculated for each group and statistically analyzed for significant differences with one-way ANOVA, Tukey honestly significant difference (HSD) test, and unpaired t test. The level of significance was set at 0.05.

RESULTS

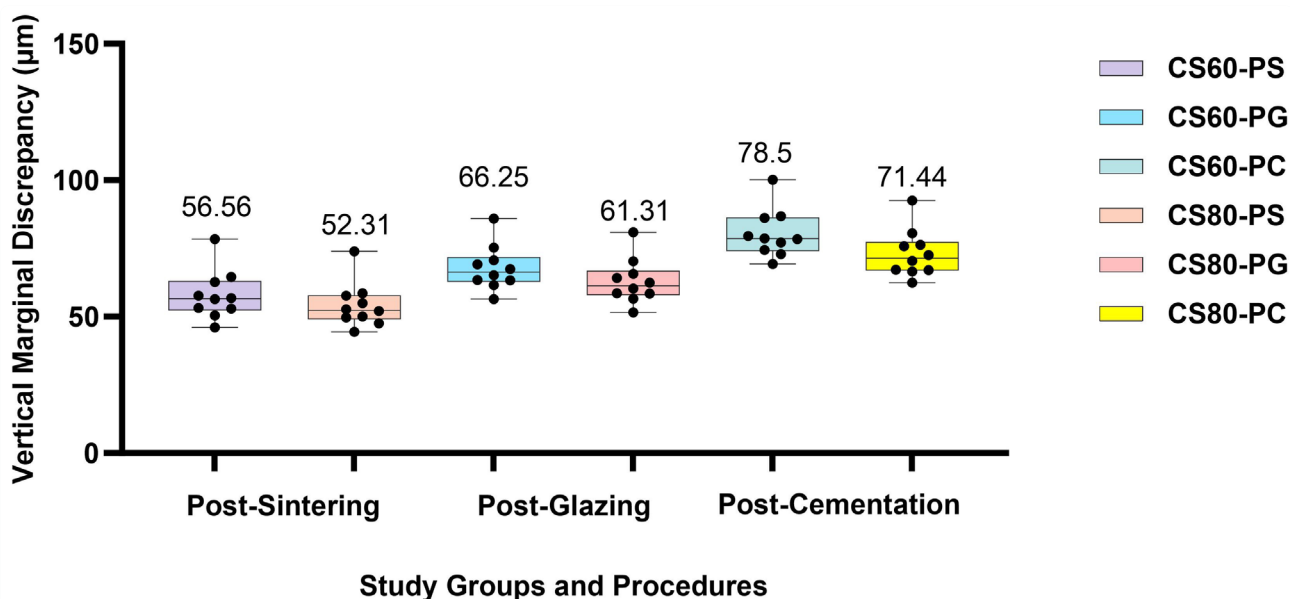
The results of the present *in vitro* study are expressed in Table 1 and Figure 4. The lowest value of the mean marginal discrepancy (52.31 ± 6.91) was recorded for the post-sintered specimens in the CS80 group, while the greatest discrepancy (78.50 ± 8.81) was observed at the post-cementation stage in the CS60 group. In both the CS60 and the CS80 groups, the recorded marginal discrepancy was the least in the post sintered specimens, and increased significantly after glazing and cementation. All the values of the mean marginal discrepancy recorded were below the clinically acceptable value of 120 μm for the marginal discrepancy. Increasing the cement space from 60 to 80 μm resulted in a non-significant decrease in marginal discrepancy recorded at the three stages.

DISCUSSION

The results supported acceptance of the null hypothesis for the VMD between the groups, since no statistically significant difference was observed in the marginal discrepancy with the increase in cement space from 60 μm to 80 μm . These results are in agreement with Eldamaty, who reported statistically non-significant difference in marginal gap when spacer thickness was increased from 20 to 50 μm , but contradictory to the results of Kale, who reported a significant decrease when the cement space was increased from 30 to 50 μm .^{32,46} This difference in the results could be attributed to the differences in the proprietary materials used during the fabrication and cementation of the crowns, and variation in the cement spacer settings. Glazing of the sintered crowns resulted in a significant increase in the marginal gap in both groups in the present study. This finding is in agreement with Toksoy *et al.*, but contradictory to Kale who found no significant difference in the marginal gap after glazing.^{24,47} Miura proposed that the marginal gap may increase after glazing due to the shrinkage of zirconia during the firing.⁴⁸ Hence, glaze application and firing might result in widening the marginal gap, as observed in the present study. Cementation of the crowns resulted in a significant increase in the marginal gap in both groups, which is in agreement with previously published studies.^{24,49} Evidence

Table 1. Mean (SD) marginal gap values (μm) for groups CS60 and CS80 at different stages of measurement. Same superscript letters indicate statistically insignificant difference.

Group	Stage of Measurement								
	Post Sintering			Post Glazing			Post Cementation		
	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max
CS60	56.56 \pm 9.04 ^a	46.01	78.38	66.25 \pm 8.23 ^b	56.38	93.00	78.50 \pm 8.81 ^c	69.25	100.10
CS80	52.31 \pm 6.91 ^a	44.38	68.88	61.31 \pm 8.2 ^b	51.5	80.88	71.44 \pm 8.74 ^c	62.38	92.50

**Figure 4:** Mean values and standard errors of vertical marginal discrepancy at different stages of crown fabrication for CS60 and CS80 groups.

indicates that an increase in VMD should be expected as the consequence of forming film of luting agent between the crown and abutment during cementation.^{24,49} A direct comparison of the results of the study could not be made as the authors could not locate a study evaluating the effect of different cement spaces on the marginal discrepancy of the MZ crowns evaluated after sintering, glazing and cementation.

The methods of measuring the marginal discrepancy can be broadly divided into two-dimensional (2D) and three-dimensional (3D) measurement methods, each of which can be further subclassified as invasive and noninvasive.^{43,44} The 2D measurements evaluate the thickness of marginal discrepancy on the images of the specimens by image analysis, while 3D measurement methods consist of global thickness measurements at numerous points of the marginal and internal areas.⁴⁴ The invasive method is the one that involves sectioning of the specimen for measurement of the marginal discrepancy, whereas the specimen remains intact in the noninvasive method.⁴⁵ Commonly followed 2D methods include the photographic method, the cross sectional method, the silicone replica technique, optical coherence tomography, profile projection, and digimatic micrometre measurement. Some examples of the 3D method are

the triple scan method, micro-computed tomography, and optical coherence tomography.^{43,45} Photographic method captures external views of noncemented and cemented restorations to measure the distance between specific points on the marginal area under a microscope with image analysis software, and was used in the present study as it permitted a noninvasive quantification and multiple measurements.

Large variations exist regarding the acceptable marginal gap values of crowns in the literature. Christensen proposed that, a marginal gap value of 34 to 119 μm for subgingival margins, and 2 to 15 μm for the supragingival margins would be acceptable.²⁵ However, McLean and von Fraunhofer, after a clinical examination of more than 1000 crowns at 5-years, recommended 120 μm as the upper limit for the marginal gap value.²⁶ While many authors accept this criterion, authors of several studies recommended that the marginal gap value of no more than 100 μm would be acceptable.²⁶⁻²⁸ Marginal discrepancies in the range of 11 μm to 58 μm have been observed for CAD-CAM fabricated full zirconia crowns, while all the values of the mean marginal discrepancy recorded in the present study were below 100 μm .^{21,29}

Creating cement space for crowns facilitates proper adaptation of crown to the abutments, improves the outflow of excess cement, and reduces the force needed to adapt the crown on the abutment tooth during cementation.³¹ However, increasing the cement space to improve the marginal adaptation of ceramic crowns may result in compromised retention and decrease in fracture strength.³⁹ Moreover, the cement space determined during the CAD phase may not be reproduced exactly into the restorations, as observed in some previous studies.^{50,51} The present study incorporated 0 μm space at the margins, and a uniform 60 or 80 μm cement space starting 1 mm above the margin. Hammond *et al.* observed that increasing the cement space at marginal area to 25 μm reduces the marginal opening, owing to the increased chances of escapement of excess cement through the margin and decrease in the hydraulic pressure build-up during cementation.⁵² Ibrahim *et al.* observed that modifying the occlusal cement space significantly affects the fit of the MZ crowns, and reducing the occlusal cement space to 40 or 0 μm resulted in improved marginal adaptation of the crowns.³⁹ Further studies can be conducted with these variations in the cement space suggested by the researchers.

Some of the limitations identified in the present study were its *in vitro* nature with the typodont teeth used as abutments, the application of finger pressure to lute the crowns, the use of only one proprietary type of the MZ, software, and milling machine, and the two-dimensional nature of the measurements. The specimens were produced and examined under laboratory conditions which may not reflect the actual clinical situation including intraoral variables like saliva, occlusal forces, and temperature fluctuations. Hence, every effort was made to standardize the testing conditions and the results might provide valuable insights for the clinical applications. Future studies could include thermal cycling, mechanical loading, or other simulations to mimic intraoral conditions, along with other clinical parameters such as the crown retention, fracture resistance, and long-term wear.

CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

- Increasing the cement space from 60 to 80 μm resulted in a statistically non-significant decrease in the VMD of the CAD-CAM fabricated MZ crowns.
- The glazing and cementation procedures significantly increased the VMD of the MZ crowns.
- The mean VMD values were within the clinically acceptable limits for all the specimens tested at different stages of fabrication and cementation.

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