Effect of Different Cement Spaces on the Vertical Marginal Gap of Full Anatomical Zirconia Bridges

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Abstract: The aim of this study was to evaluate the effect of three different cement spaces (20 µm, 30 µm and 50 µm) on the vertical marginal gap of full anatomical zirconia FPDs before and after glazing. **Material and Methods:** Thirty zirconia 3-unit fixed dental prostheses were constructed on the specially fabricated stainless-steel dies simulating prepared mandibular second premolar tooth and mandibular second molar tooth to ensure the standardization of specimen shape and dimensions. The samples were classified into 3 equal groups, 10 each (n=10), according to the cement space used. The vertical marginal fit was evaluated by using a scanning electron microscope at 150X magnification before and after glazing. Data were tabulated and statistically analyzed with three way ANOVA test followed by pair-wise Tukey's post-hoc tests. P values ≤0.05 are considered to be statistically significant in all tests. **Results:** The results showed that the cement space had a statistically significant effect on the mean marginal fit of zirconia FPDs. **Conclusions:** Better marginal fit values were exhibited by 50 µm cement space.
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1. Introduction

Apart from the mechanical properties and aesthetics, the long-term clinical success of all-ceramic prosthodontics can be influenced by marginal fit. (1)

Marginal fit is one of the most important criteria for the long-term success of all-ceramic crowns. Great marginal discrepancies expose the luting material to the oral environment, thus leading to a more aggressive rate of cement dissolution, caused by oral fluids and chemo-mechanical forces. The cement seal becomes weak and permits the percolation of bacteria. Consequently, the longevity of the tooth could be compromised by caries and periodontitis. (2)

For the dual purpose of meeting patient expectations for good esthetic results and circumventing allergy concerns arising from contact with metallic frameworks, all-ceramic restorations have become both a necessary alternative as well as a preferred choice.(3)

The idea of using CAD/CAM techniques for the fabrication of tooth restorations was originated by Dr. Duret in the 1970s. Ten years later Dr. Moermann developed the CEREC system first marketed by Siemens (now Sirona), which enabled the first chair side fabrication of restorations with this technology. Then, there has been a marked acceleration in the development of other CAD/CAM laboratory systems in recent years as a result of the greatly increased performance of personal computers (PCs) and software. (4)

The *Cerec* system (Sirona Dental Systems, Bensheim, Germany) is a computer-assisted design/computer-assisted manufacturing (CAD/CAM) system designed for the fabrication of indirect restorations. Since its development in 1984, the Cerec system has undergone several technical modifications. (5)

The first generation system, Cerec 1, was designed for chair-side fabrication of intra-coronal restorations such as inlays, onlays, and/or veneers, whereas the Cerec 2 was introduced in 1994 with redesigned software and hardware to fabricate complete crowns in addition to intra-coronal restorations. (6,7)

The Cerec 3 system was introduced to the dental profession in 2000 and has several improvements over the Cerec 2 system. These improvements include: an enhanced intraoral optical camera able to reproduce finer detail and depth of scale and improved software capable of recording the preparation much faster. (7,8) Additionally, the Cerec 3 system allows more flexible and more true-to-detail grinding than the Cerec 2, which in turn should lead to a better fitting crown with improved occlusal morphology and design. (5,6)

The novel Cerec inLab allowed an easy, reliable and rapid fabrication for all-ceramic dental restorations with high mechanical strength and good biocompatibility. CerecinLab was recently augmented by the new CEREC ML an inLab MC XL milling machines. Dentists and dental technicians who were on the threshold of introducing CAD (Computer Aided Dentistry) to their practice or laboratory could either obtain for a low-cost solution or for a system which offer an extended range of indications as well as enhanced reliability and ease of use. The Cerec in Lab milling machines were well-tried, accepted and proven, as they were not only faster and more precise, but also quieter and easier to use. [9]

The scan machine of the existing Cerec products forms the technical basis of the new CerecinLab instruments. Numerous modifications have been carried out. In addition the changes in the scan process have been modified, which allowed a higher resolution and the introduction of a new, very delicate milling bur. [10]

The software was designed to be very user-friendly; the design of caps and frames had been greatly simplified. Without basic changes to the clinical process used for metal-ceramic, the smooth transition to the full-ceramic restorations was possible for the dentist. The distinct separation of Cerec units for the dentist and CerecinLab as laboratory machine made sense simply because of the high proportion of dental-technical steps. The new instrument could be seen as a further step toward the integration of CAD/CAM technology in the field of dentistry, of equal benefit to dentists, dental technicians and patients. [10]

Exciting as the new developments in zirconia milling technology are, little attention has been paid to the optical behavior of the various zirconia core systems relative to core design to optimize esthetics. [11]

Zirconia can be aesthetically improved using nano-sized powders, high sintering temperature, dispersants, and suitable additives. These techniques allow the fabrication of zirconia with enhanced sintered density and few pores, thus improving its translucency to match the natural appearance of human teeth. So, zirconia becomes suitable for ceramic dental restoration when all of the desired properties (natural appearance, superior mechanical properties, and bio-inertness) for dental crown application are fulfilled. [12]

By internal and external stain techniques, full-contour zirconia restorations can now be used. However, the clinical indication of full zirconia restorations is limited to posterior regions with little esthetic demand and excess wear of the opposing teeth has become a concern because of the high strength and hardness of zirconia. Nevertheless, with proper polishing protocol, opposing enamel attrition can be avoided. [13, 14]

Sirona Dental Systems has expanded its material line by introducing inCoris TZI full-contour, translucent zirconia blocks. These blocks are indicated for full-contour crowns, bridges, and screw-retained implant crowns. Made of solid zirconia with no porcelain overlay, they are virtually chip-proof. [15]

The new zirconia restorations have a flexural strength of 950 MPa (+/- 50) and because the material is made with a monolithic composition, the absence of layered materials makes the new zirconia blocks extremely strong and durable. [15]

The precision of the zirconia-based restorations is dependent on various factors, like differences in manufacturing systems, individual characteristics of the prosthesis (e.g. span length, framework configuration), effect of veneering and influence of aging. As to soft-machined zirconia restorations, the precise numerical compensation required by such a system for the enlargement ratio of the model is a paramount factor, strictly dependent also on the composition and homogeneity of pre-sintered zirconia blanks that should be consistent and precise. [16]

The cement space or internal adaptation is considered to be a uniform space that facilitates seating without compromising retention and resistance forms. This is of paramount importance because all-ceramic restorations are more fragile compared to metal ceramics, as ceramic is a brittle material and sensitive against tension. [17]

Also there is evidence demonstrating the influence of excessive cement space on veneering porcelain failures. [18] As thick cement layer complicates the challenge to minimize stress concentrations on the tensile surface of the restoration caused by the viscoplastic deformation of the adhesive material under cyclic loading. The increased stress propagates damage and may cause failure of the veneering porcelain. [19]

A method for determining the marginal fit is to measure the marginal gap, i.e. the distance between the restoration margin and preparation margin. The methods and measurement units to determine the marginal gap of restorations are not validated. [20] Furthermore, the definition of marginal fit scatters widely.

Generally, the evaluation of the marginal discrepancy of crowns depends on several factors:

- Measurements of cemented or not-cemented crowns.
- Storage time and treatment (such as ageing procedures) after cementation.
- Kind of abutment used for measurements.
- Kind of microscope and enlargement factor used for measurements.
- Location and quantity of single measurements. [21]

The null hypothesis of the current study postulated that there will be an influence of the cement space on the vertical marginal fit of zirconia FPDs.

The aim of this study was to investigate the effect of three different cement spaces (20 µm, 30 µm and 50 µm) on the vertical marginal gap of full anatomical zirconia fixed partial denture.

2. Material and Methods

Specially fabricated stainless-steel dies simulating a prepared mandibular second premolar tooth and mandibular second molar tooth were with flat occlusal table, 1 mm thickness shoulder finish line, rounded internal line angle, degree of convergence 8° occlusally, preparation height 5 mm and cervical diameter of 8 mm for the premolar and 10 mm for the molar. Prepared dies were then fixed on a metal plate to prepare the master model for a three-unit bridge. [22] with mesiodistal width of the pontic of 11 mm. [23] (Figure 1)

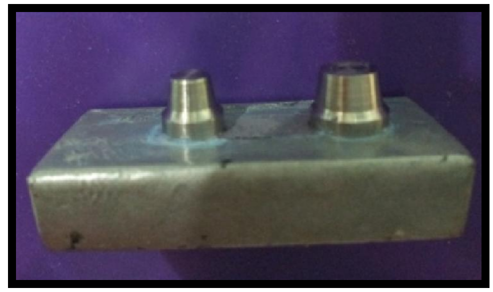
Thirty full anatomical zirconia 3-unit fixed dental prostheses were constructed on the master model. These were divided into 3 equal groups, 10 each (n=10), according to the cement space used. Group I for 20 µm, group II for 30 µm and group III for 50 µm cement space.

For all groups, a full anatomical FPD was milled by Cerec inLab (Cere cinLab, Sirona, Dental Systems Gmbh FabrikstraBe, Bensheim) using Sirona inCoris TZI blocks. For group I (20 µm), the cement space was adjusted to be -80 µm, For group II (30 µm), the cement space was adjusted to be -70 µm and for group III (50 µm), the cement space was adjusted to be -50 µm. Glaze firing of all groups was conducted with IPS e.max Ceram Glaze Spray which was applied in an evenly covering layer on the FPDs in the usual manner. (Figure 2-4)

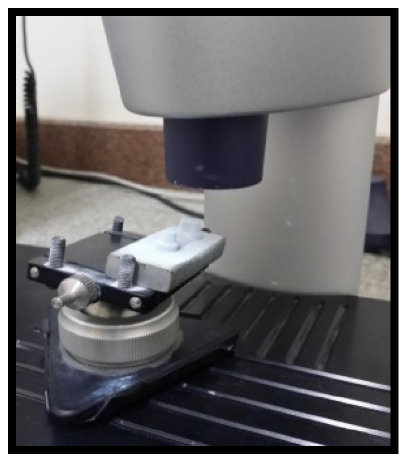
All tested FPDs were individually seated on the stainless steel master model and were held in place using a specially designed and fabricated holding device (Figure 5)and were examined for vertical marginal fit by scanning electron microscope [24, 25] (JEOL, JXA-840 AElectron Probe Microanalyzer, Japan) at magnification 150 X. Digital images were captured at six measuring locations along the cervical circumference for each retainer [26, 27] mesiobuccul, midbuccal, distobuccal, mesiolingual midlingual and distolingual.

The measurements were done on an IBM compatible personal computer (PC). After that the software, which was used for image analysis was calibrated and the vertical gap distance was measured for each shot. A measurement at each point was repeated five times. Then the data obtained were collected, tabulated and subjected to statistical analysis. (Figure 6)

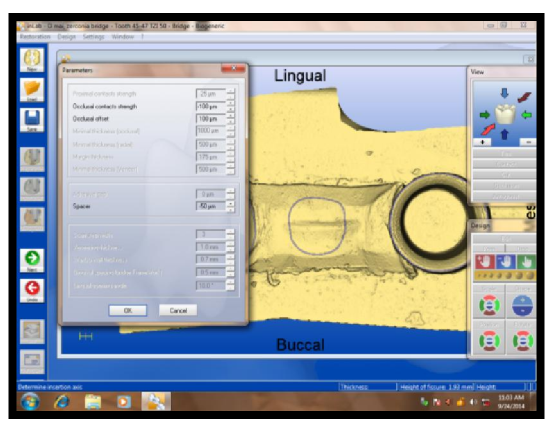
The vertical marginal fit was measured two times; before and after glazing. Data analysis was performed using three factorial analysis of variance ANOVA test followed by pair-wise Tukey's post-hoc tests. Statistical analysis was performed using Aasistat 7.6 statistics software for Windows. P values ≤0.05 are considered to be statistically significant in all tests.



(Figure 1):The master model



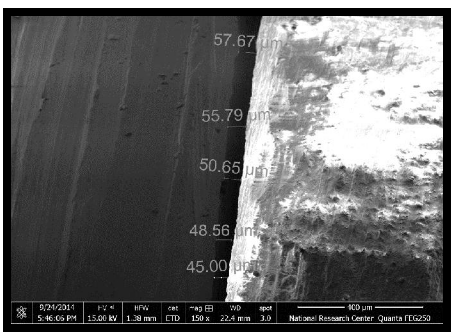
(Figure 2): The model is secured in the inEos specific tray.



(Firgure 3): Adjusting the cement space.

(Figure 4): The full anatomical bridge

(Figure 5): A sample secured on the specially fabricated holding device.



(Figure 6): Measuring of vertical marginal fit using the scanning electron microscope.

3. Results

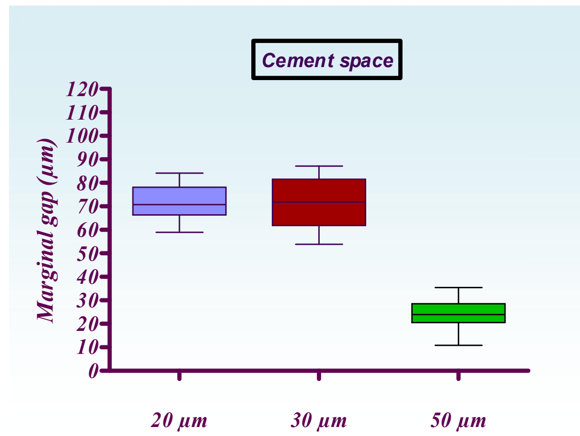
For simplicity and convenient of statistical comparisons, the mean recorded from the molar and the premolar were averaged to get one single value which was used in the statistical analysis. [22,28,29]

It was found that 20 µm cement space group recorded marginal gap mean value (71.69 ± 5.9 µm) higher than that of 30 µm cement space group (71.36 ± 8.5 µm). Yet it was statistically non- significant ($p>0.05$). While 50 µm cement space group recorded statistically significant lowest marginal gap mean value (23.58 ±4.8 µm) as indicated Pair-wise Tukey's post-hoc tests. It was found that after glazing the marginal gap mean value (57.64 ± 4.9 µm) was higher than before glazing (53.44 ± 6.7µm). Yet it was statistically non-significant ($p>0.05$). (Figure 7) (Table 1).

(Table 1): Comparison between marginal gap results (Mean values± SDs) as function of cement space.

Cement space	*Mean± SD*	*Tukey's rank*	*Statistics (p value)*
20 µm	71.69± 5.9	A	<0.0001*
30 µm	71.36± 8.5	A	
50 µm	23.58±4.8	B	

Different letter in the same column indicating statistically significant difference ($p < 0.05$
*; significant ($p < 0.05$)
ns; non-significant ($p>0.05$)



(Figure 7): Box plot chart of marginal gap mean values as function of cement space

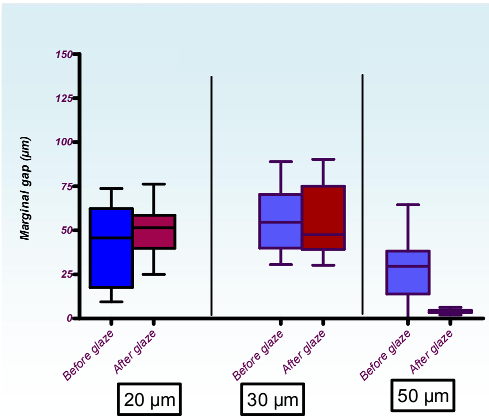
(Table 2): Marginal gap results (Mean values± SDs) for Full anatomical technique as function of cement space and glazing.

Stage	*Before glaze*	*After glaze*	*t-test*
Group	Mean ± SDs	Mean ± SDs	P value
20 µm (I)	40.59 ± 21.2	50.01 ±10.6	0.0389*
30 µm (II)	56.31 ± 15.1	53.76 ± 15.1	0.5035ns
50 µm (III)	27.74 ±12.2	3.910 ± 0.8	<0.0001 *

*; significant ($p < 0.05$)
ns; non-significant ($p>0.05$)

Interaction between Cement Space and Glazing: With 20 µm cement space; it was found that after glazing the marginal gap mean value (50.01 ±10.6µm) was statistically significant ($p<0.05$) higher than before glazing (40.59 ± 21.2 µm) as indicated by t-test. With 30 µm cement space; it was found that after glazing the marginal gap mean value (53.76 ± 151µm) was lower than before glazing (56.31 ± 15.1µm) as indicated by t-test. Yet it was statistically non-significant ($p>0.05$). With 50 µm cement space; it was found that after glazing the marginal gap mean value

(3.910 ± 0.8µm) was statistically significant ($p<0.05$) lower than before glazing (27.74 ±12.2µm) as indicated by t-test. (Figure 8) (Table 2).



(Figure 8): Box plot of marginal gap mean values for Full anatomical technique as function of glazing and the cement space.

4. Discussion:

The present research was directed towards the evaluation of the vertical marginal fit of full anatomical zirconia 3-unit posterior bridges fabricated using different cement spaces, 20 µm, 30 µm and 50 µm.

In this study, machined stainless-steel dies were used in substitution to natural teeth. **Beschnidt & Strub** [(21)] report that natural teeth present great variation considering the age, individual structures and time of storage, making the standardization of the pillars difficult. Therefore, several authors have employed metallic models or resin ones for measurement of the marginal fidelity **[(30-36)]**. The advantages of the metal die include the easy reproduction achieving, the few present variables, standardized preparation and lack of wear during the manufacturing process and measurement.

A total occlusal convergence angle of the dies was range between 4° to 6°. [(37)] An optical scanner requires a minimum of a 4° occlusal convergence angle to adequately read the margin of the master die. [(38,39)] Parallel walls "confuse" most scanners and should be avoided.

A shoulder finish line with rounded internal line angle of 1 mm thickness was used. [(38)] A 90° internal angle is contraindicated. The exit angle of the gingival margin should be a butt joint and lack any beveled edges. Knife-edge or feather margins are not acceptable because they do not allow for adequate areas for porcelain build-up. Undercuts and sharp line angles should be avoided, also. Sharp line angles should be rounded to avoid over milling by the diamond-cutting bur.

The vertical marginal gap measurement was selected as the most frequently used to quantify the accuracy of fit of a restoration **[(34, 40)]**, as this discrepancy, if undetected prior to crown cementation, will result in a vertical crown/tooth interface with wider zones of exposed luting agent. While horizontal discrepancies result in a crown or tooth structure step defect that may affect cleansability and plaque retention. In addition, the investigation did not assess the internal fit of the copings; however, this assessment would require cross-sectioning the crowns, which would limit the marginal gap measurement to only a certain number of sites.

Testing procedure of the vertical marginal adaptation was performed without cementation. This is another point of relevance that concerns to the cementing of the bridges. Some authors measure the marginal fit with cementation [(41, 42)], because they believe that the most important inadaptability is the one that occurs in vivo, when the crowns are already cemented. In our study, as well as in many other studies **[(30, 32, 34-36)]**, this was not accomplished.

Tinschertet al **[(30)]** affirmed that when we cement the crowns, we lose the precision of the primary adaptation, allowing the influence of the cement type, viscosity and cementation techniques to be a variable in the outcome results. Some authors approved that on comparing crowns construction techniques and modifications that will influence in the precision of primary adaptation as the type of finish lines; the cementation should not be used. [(32,34-36)]

Also, when measuring the marginal gap after cementation, the same number of teeth or steel dies as that of restoration sample is needed because of the control of variables. On the other hand, only one tooth or steel die is needed if the measurement is done without a luting agent. [(43)]

A specially fabricated holding device was used to hold the bridges on the master model during measurement. **Wanserski et al** **[(44)]** fabricated a specimen positioning device to allow fixation of the specimen in consistent, reproducible manner. This was used by some investigators with some modifications [(32,36,45-47)], while others remained using finger pressure. [(21,28,30, 48-52)]

Scanning Electron Microscope using a fixed magnification of 150X was used in this study to measure the marginal adaptation. It was ascertained by earlier studies that SEM is the most reliable and realistic method to quantitatively measure the marginal fit of indirect restorations.[(24,25)] However, there have been earlier investigations, which employed digital microscopes [(32,36)], stereomicroscopes [(33)] to analyze the marginal fit of CAD/CAM fabricated crowns.

It was reported that the restorations are successful when they had marginal discrepancies less than 120 µm. However, gaps lesser than 80 µm were proven to be very difficult to detect clinically.[53]

Regarding the effect of cement space on the vertical marginal adaptation, it was found that 20 µm cement space group recorded statistically significant highest marginal gap mean value (71.69 ± 5.9 µm) followed by 30 µm cement space group (71.36 ± 8.5 µm) while 50 µm cement space group recorded statistically significant lowest marginal gap mean value (23.58 ±4.8 µm).

The results of this study are in agreement with **Adriana et al [54] and Hunter AJ and Hunter AR [55]** who reported that adequate die spacing is a more important factor than margin configuration for the accuracy of crown margins.

Also our results are in agreement with **Soriani N.C et al [56]** who reported that less marginal discrepancy was recorded with two die spacer layers than one die spacer.

The differences between the results of the present study and those of some other studies may be related to the different methods of measurements, different types of microscope and magnification, different location [57] and number of measurements, and the use of different luting agents.[21] Also sample size and the degree of accuracy in its fulfillment was another major factor.

Further investigations are needed to measure both the marginal and internal fits and to evaluate the influence of the aging process on the margin distortion. [46] Also further studies are needed to evaluate the influence of the scanning process and the milling process on the accuracy of a CAD/CAM restoration as well as the influence of cementation technique on the marginal and internal fits of zirconia restorations. [58]

From previous results and discussion, the null hypothesis of this study was accepted regarding that the cement space had an influence on the vertical marginal fit of zirconia FPDs.

5. Conclusions

Under the limitations of this study, several conclusions could be detected:

1. The three tested groups had clinically acceptable vertical marginal fit which is within the recorded levels of the suggested acceptability for vertical marginal fit, which leads to clinical success.
2. Cement space of 50 µm exihibited superior vertical marginal fit for both tested fabrication techniques.
3. Inferior vertical marginal fit was exhibited after glazing than before glazing but it was non-significant.

Recommendations

Regarding to minimum marginal discrepancy, using of 50 µm cement space is recommended.

Further investigations are needed to measure both the marginal and internal fit of zirconia FPDs.

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