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INFLUENCE OF AXIAL WALL CONVERGENCE ON THE MARGINAL FIT OF ZIRCONIA AND LITHIUM DISILICATE COPINGS AFTER DIFFERENT SURFACE TREATMENT

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Aim: The aim of this research was to study the effect of tooth convergence and internal surface treatment on the marginal fit of Zirconia and Lithium disilicate all-ceramic copings.

Materials and Methods: Two stainless steel dies were fabricated simulating a prepared maxillary premolar. The first die had 12°and the second 20° axial wall occlusal convergence. For each material (Zirconia and Lithium disilicate), Thirty non anatomical all ceramic copings were fabricated using inlab MC XL unit (15 copings on each die). For each group of taper, specimens were subdivided according to the technique of the internal surface treatment into three subgroup (5 copings each); air abrasion, tribochemical coating and acid etching. Cervical marginal accuracy was tested before and after cementation using a stereomicroscope.

Results: Taper 12° recorded statistically significant higher mean value than taper 20°. Acid etching recorded statistically significant lowest marginal gap mean value. Regardless to ceramic material, taper or cement, the marginal gap after cementation was statistically significant higher than before cementation ($p<0.05$)

Conclusion: Increasing the degree of taper lead to better marginal fit regardless the type of ceramic material. The marginal gap of e.max copings is better than that of zirconia in both before and after cementation. Copings treated with acid etching surface treatment show better marginal adaptation than tribochemical coating and sandblasting surface treatments regardless the type of ceramic material and degree of taper of the preparation.

Keywords: Taper - Surface treatment – Zirconia - Lithium disilicate - Marginal fit

INTRODUCTION

Dental clinicians have remained suspicious about the structural longevity, potential abrasiveness and accuracy of fit of ceramic restorations. These concerns have directly influenced the development of new materials and laboratory processing systems. The recently introduced ceramic materials were claimed to possess high strength properties thus allowing the fabrication of anterior and posterior all ceramic copings.

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Marginal adaptation of restorations is of clinical importance because when the junction between the prepared tooth and a restoration is discontinuous, a niche is available for accumulation of plaque near the gingival margins. This plaque can initiate gingival inflammatory reactions and may lead to deterioration in soft tissue with periodontal disease.[1] Increased marginal discrepancy of a crown favors the rate of cement dissolution and microleakage that may lead to caries, pulpitis and periodontal disease. [2-4]

Measurements between the copings and the tooth can be made from points along the internal surface, at the margin, or on the external surface of the coping. The perpendicular measurement from the internal surface of the coping to axial wall of the preparation is called the internal gap, and the same measurement at the margin is called the marginal gap. The vertical marginal misfit measured parallel to the path of withdrawal of the coping is called the vertical marginal discrepancy. The horizontal marginal misfit measured perpendicular to the path of withdrawal of the coping is called the horizontal marginal discrepancy. [5]

The angular combination of the marginal gap and the extension error (over extension or under extension) is called the absolute marginal discrepancy and the horizontal marginal discrepancy also defines this same absolute marginal discrepancy. The absolute marginal discrepancy is the largest measurement of error at the margin and reflects the total misfit at the point. Any other measurement of fit may obscure part of the true marginal discrepancy that is actually present.[5]

The microscope has been the most frequently used device for quantitative assessment, because of its high-powered image magnification that allows more precise measurement. Two significant and precise methods analyze copings microscopically, internally and externally. However, internal cross-sectional measurement, although very accurate, result in the destruction of the crown.[6] Furthermore, only a limited number of parallel sections can be cut on each tooth and thus only few points of observation are possible for each specimen. Direct viewing with external measurements has the advantage of not being invasive, but it is difficult to repeat the measurements from an identical angle and to distinguish the actual marginal gap from its projection.[7]

Commonly used clinical evaluation techniques using an explorer and disclosing media may be inadequate for assessments of marginal accuracy. In order to better evaluate marginal adaptation of restorations, the routine use of a stereomicroscope in the laboratory is indicated and provides a superior quality control prior to examination of restorations intra orally. Clinical detection, with similar sensitivity and specifically as the stereomicroscope, occurs at greater than or equal to 124μm.[8]

Many researchers have investigated the factors that might affect marginal accuracy of all ceramic restorations. Some have found that dynamic loading decreased the marginal fit of the metal ceramic (54.1μm) and the zirconia resin bonded bridges (90μm).[2] Others have stated that the addition of porcelain to the copings of double layer all ceramic copings may cause a negative effect on the fit of the copings while the single layer CAD/CAM copings are not subjected to the porcelain firing cycle and thus have better fit.[9] On the other hand, comparisons between the Zirconia copings and copings demonstrated that ceramic firing did not significantly affect either the marginal or internal adaptation.[4,10]

In an evaluation of the marginal fit of different CAD/CAM (Procera and CEREC) fabricated zirconia frameworks and restorations, before and after cementation and after masticatory stimulation. The CEREC recorded significantly smaller marginal gap values than Procera after cementation. All mean marginal gap values were <100μm.[11-13] Others have concluded that the marginal fit of zirconia FDPs is significantly dependent on the CAD/CAM system used.[14-17]

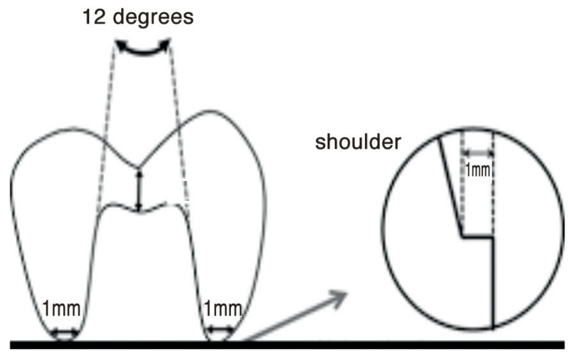
Regarding the preparation axial wall taper researchers have found that the internal space widths of zirconia ceramic copings may decrease with an increase in the convergence angles of the abutments. When the convergence angles of abutments were 12° and 20°, there were no significant influences, with three different cement spaces on the internal adaptation. While others reported that even when the occlusal convergence angle was set to 8 or even 4 degree, no large effect was observed on the marginal or internal gaps of the crown.[15] This is probably because the CEREC system had been improved so that images of preparation designs can be taken and ceramic blocks milled to a high degree of accuracy. Also, if the axial surface of the abutment is linear, milling is easy even when the occlusal convergence angle is small. It has been reported that in other system using the milling method, the more linear the axial surface of the abutment, the better the fit achieved.[18]

Researchers have investigated the effect of cement on marginal accuracy and some have concluded that adhesive cementation caused a significant increase of the marginal discrepancies for crown abutments.[19]

The aim of this research was to study the effect of degree of taper and internal surface treatment on the marginal fit of Zirconia and Lithium disilicate all-ceramic copings.

MATERIALS AND METHODS

Two stainless steel dies were fabricated simulating a prepared maxillary premolar using an industrial milling machine. The first die was prepared with non-anatomic flat occlusal table, 1mm thickness shoulder finish line, cervical diameter of 6 mm, occluso-cervical height of 7mm and 12° axial wall occlusal convergence. While the second die was similar in dimensions to the first die, but with 20° axial wall occlusal convergence. All sharp angles were rounded and an occlusal notch was prepared to facilitate accurate coping orientation on its die for measurements.



Design of First die

For each of the test materials (Zirconia and Lithium disilicate), 30 non anatomical copings were fabricated (15 copings on each die). The copings were then divided according to the degree of axial wall taper into two groups; **Group 1 (T12)** with a total occlusal convergence of 12 degrees and **Group 2 (T20)** with a total occlusal convergence of 20 degrees.

Sixty epoxy resin dies were fabricated by introducing the polymerizing resin into a polyvinylsiloxane duplicate mould of the master dies. After complete polymerization, the epoxy resin dies were removed and checked for complete filling, presence of air bubbles, and accurate margin reproduction using a magnifying lens. Defective dies were excluded from the samples.

Non-anatomical copings (8-mm diameter, 9 mm height, 2-mm occlusal thickness and margin thickness 1-mm) of both materials were fabricated according to the manufacturer's instructions for each material using an inLab MC XL milling unit (Sirona, Bensheim, Germany), IPS e.max CAD C14 block (Ivoclar) and Zirconia InCoris mono L block (Sirona). The copings were checked for fit on the corresponding die samples.

For each group, specimens were subdivided according to the technique of the internal surface treatment into three subgroup (5 samples each); **Subgroup A:** The copings were sandblasted and **Subgroup B:** The copings were surface treated with tribochemical coating and **Subgroup C:** The copings were acid etched before being cemented to their respective die under a constant static load (3 Kg).

Air Abrasion: The fitting surface of the copings were sandblasted with 150μm AL_2O_3 (Korox, Bego) at a maximum pressure of 4 bar for 30 seconds at an approximate distance of 20 mm.

Tribochemical coating: The Cojet blaster (3M ESPE, USA) with 30μm silicatized sand particles was directed perpendicular to the internal surface of the copings from a distance of 10 mm at maximum pressure of 2 bars for 15 seconds. The fitting surface of the copings was not touched after that until cementation to avoid contamination with impurities.

Acid Etching: VITA Ceramic Etching (VITA Zahnfabrik, Germany) acid gel, hydrofluoric acid 9 % concentration for 20 seconds was used. Any acid remaining on the etched surfaces was completely removed by means of intensive water spray and then dried with oil free air spray for 30 seconds.

Adhesive resin RelyX ARC (3M Dental products, USA) cement system was used to cement the copings on their resin dies. A thin layer of cement was applied and evenly distributed over the bonding surfaces of the restorations. The restorations were seated slowly with gentle finger pressure for 1 minute. Excess luting material was removed with sponge pellets immediately. As soon as they were completely seated, the copings were placed for 10 minutes under a constant static 3 Kg load to ensure an effective flow of the cement and maximal adaptation to the abutment and each cement surface/ margin was light cured for 40 seconds.

Cervical marginal accuracy was tested before and after cementation using a stereomicroscope (Carl Zeiss stereomicroscope, Germany). Shots of the margins were taken for each crown using digital camera (Olympus Camedia C-5060 digital camera, Japan) fitted on the stereomicroscope using a fixed magnification of 40X. The software (Image Tool for Windows version 3) was used for image analysis. The vertical gap distance was measured for each shot [6 equidistant landmarks along the cervical circumference for each crown (mesio-buccal, mid-buccal, disto-buccal, mesio-lingual, mid-lingual and disto-lingual line angles)]. Measurement at each point was repeated five times. Then the data obtained were collected, tabulated and then subjected to statistical analysis.

Statistical Analysis

Data analysis was performed in several steps. Initially, descriptive statistics for each subgroup result. One way analysis of variance ANOVA followed by Newman Keuls post hoc-tests were used to detect significance between surface treatment. Student t-test was performed to detect significance between tapers. Three-factor analysis of variance ANOVA test of significance comparing variables (Ceramic, taper and surface treatment) affecting mean values. 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.

RESULTS

Marginal gap results (Mean ± SD) measured in μm for both groups as function of taper and surface treatment before/after cementation are summarized in table (1) and graphically drawn in figure (1)

Before cementation

Effect of Ceramic Material; Regardless to taper or surface treatment it was found that zirconia (**31.81**μm) recorded statistically non-significant higher mean value than e.max (**28.65** μm) ($p>0.05$).

TABLE (1): Marginal gap results (Mean ± SD) for both groups as function of taper and surface treatment before/after cementation

Variables		Air abrasion		Tribochemical coat		Acid etch	
		Before	After	Before	After	Before	After
e.max	Taper20	31.01±1.2	40.25±6.78	26.10±2.762	37.9±7	21.1±2.8	29.4±9.4
	Taper12	35.3±1.95	43.9±3.4	29.53±1.864	41.3±10.7	28.88±1.39	37.5 ±4.3
Zirconia	Taper20	35.33±2.88	47.4±3.1	27.84±2.139	37.8±3.8	24.75±2.06	32.9 ± 3.2
	Taper12	38.18±1.87	48.1±3.91	33.71±2.958	42.1±6.7	31.05 ±1.7	39.75±3.5

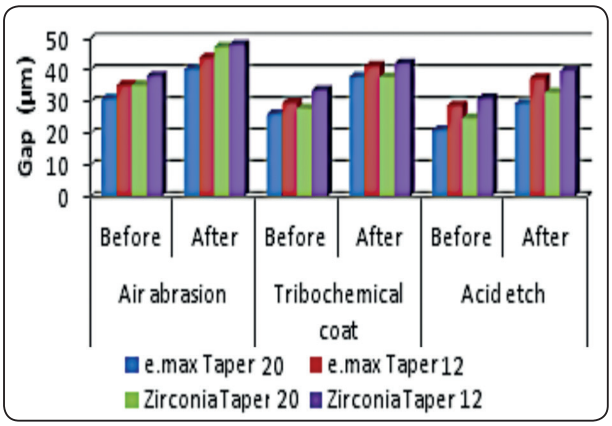


Fig. (1) Histogram of marginal gap mean values for both groups as function of taper and surface treatment before/after cementation.

Effect of Taper; Regardless to ceramic material or surface treatment it was found that taper 12 (**32.78** µm) recorded statistically significant higher mean value than taper 20° (**27.69** µm) ($p < 0.05$)

Effect of Surface Treatment; Regardless to ceramic material or taper, it was found that air abrasion surface treatment (**34.96** µm) recorded statistically significant highest marginal gap mean value followed by tribochemical coating (**29.3** µm) while acid etching (**26.45** µm) recorded statistically significant lowest marginal gap mean value ($p<0.05$)

The ***interaction*** between factors was statistically significant ($p<0.5$)

TABLE (2): Three way analysis of variance ANOVA test of significance comparing variables affecting marginal gap results before cementation

Source of Variation	Df	SS	MS	P value
Ceramic Material	1	346.62656	346.62656	0.0557 ns
Effect of taper	1	90.56	90.56	0.005*
Surface treatment	2	187.6	93.82	0.0032*
Interaction	2	107.5	26.88	0.0002*

SS; sum of squares. df; degree of freedom. MS; mean squares *; significant (p<0.05) ns; non-significant (p>0.05)

After cementation

Effect of Ceramic Material; Regardless to taper or surface treatment it was found that zirconia (**38.38** µm) recorded statistically significant higher mean value than e.max (**41.34** µm) ($p<0.05$)

Effect of Taper; Regardless to ceramic material or surface treatment, taper 12 (**42.11** µm) recorded statistically significant higher mean value than taper20 (**37.61** µm) ($p < 0.05$)

Effect of Surface Treatment; Regardless to ceramic material or taper, it was found that air abrasion surface treatment (**44.9** µm) recorded statistically significant highest marginal gap mean value followed by tribochemical coat (**39.8** µm) while acid etch (**34.9** µm) recorded statistically significant lowest marginal gap mean value ($p<0.05$)

The ***interaction*** between factors was statistically non-significant (p>0.5)

TABLE (3): Three way analysis of variance ANOVA test of significance comparing variables affecting marginal gap results after cementation

Source of Variation	Df	SS	MS	P value
Ceramic Material	1	132.01667	132.01667	0.0384*
Effect of taper	1	303.75000	303.75000	0.0087*
Surface treatment	2	1005.21458	502.60729	0.0127*
Interaction	2	9.30625	4.65313	0.2443 ns

SS; sum of squares. df; degree of freedom. MS; mean squares *; significant (p<0.05) ns; non-significant (p>0.05)

Before vs. after cementation

Regardless to ceramic material, taper or cement, the marginal gap after cementation was statistically significant higher than before cementation (p<0.05)

TABLE (4): Comparison between marginal gap results (Mean ± SD) before and after cementation

Variables		Mean ± SD	Statistics
Cementation	Before	30.23 ± 3.03	P value
	After	39.86 ± 3.3	0.0001 *

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

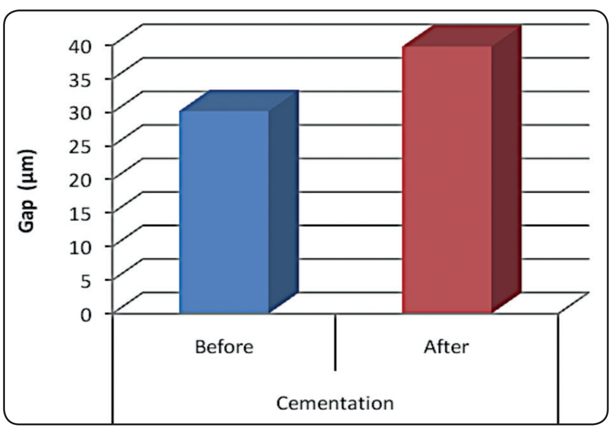


Fig. (2): Bar chart of marginal gap mean values before and after cementation

DISCUSSION

The ideal and final success of any restorative procedure in dentistry is intimately linked to the precision of adaptation and durability of the substitute material to the tooth. It seemed to be important to investigate newly developed fabrication technologies and materials; The IPS e.max CAD based on a lithium disilicate glass-ceramic system ($Li_2O.2SiO_2$), and Zirconium ceramic, Y-TZP (Yttrium stabilized zirconia polycrystals). The main interest of the present research was directed towards the evaluation of the cervical marginal accuracy of these two ceramic crown materials.

Natural teeth have not been used in this study, because they are difficult in standardization as they show a large variation depending on age, and anatomy. Several studies used steel or resin dies for the fracture testing of copings as they include standardized preparation and identical physical quality of materials used. Thus, because of the variability of the dentin surface structure and if manually prepared, the variability of abutment dimensions, together with the shortage of extracted teeth, the use of human teeth as the abutment material was discarded to avoid the increased chance for the variability of the cervical marginal accuracy. Therefore, machined stainless steel dies simulating maxillary premolar preparation for an all-ceramic crown were particularly designed and fabricated with standard dimensions in order to allow accurate control on the variables of the preparation dimensions, degree of axial wall taper and the finish line dimensions.[20]

In the present study the height of the preparation was 7.0 mm, 6.0 mm diameter after creating a shoulder finish line of 1.0 mm as the most accepted occluso-cervical dimension for prepared premolars to receive an all-ceramic crown.[21]

The shoulder finish line was used in this study, because it is the most recommended in the literature to be used with metal free copings. This was due to their horizontal configurations, as bevel finish line was contraindicated in this restoration type, because thin margins tend to fracture with easiness in ceramic restorations.[22]

Measurements of the cervical marginal accuracy were performed on the ceramic copings without being veneered, since it was proven from previous studies that veneering or glazing did not affect significantly the cervical marginal accuracy of different all-ceramic systems.[23-24-25]

Marginal and internal accuracy of fit is valued as one of the most important criteria for the clinical quality and success of all-ceramic copings. Increased marginal discrepancy of a crown favors the rate of cement dissolution and of microleakage that may cause inflammation of the vital pulp. Poor marginal adaptation of copings increases plaque retention and changes the composition of the subgingival microflora indicating the onset of periodontal disease.[26,27] The vertical cervical marginal gap measurement was selected as the most frequently used to quantify the accuracy of fit of a restoration.[28,29]

The stereomicroscope with a fixed magnification of 40X was the adopted method in measuring the cervical marginal accuracy, as it allowed long-term study and without sacrificing the samples, such as the cross-section method. The measurement was performed at six equidistant landmarks along the cervical circumference before and after cementation for each ceramic coping (Mesio-buccal, mid-buccal, disto-buccal, Mesio-lingual, mid- lingual, and disto-lingual line angles).[30,31]

The results obtained in the current study showed that there were statistically significant differences in the marginal gap between all groups ($p<0.05$) as evidenced by Three-factor analysis of variance ANOVA test**.** This indicated that different ceramic materials, taper, and surface treatment had influenced significantly the vertical cervical marginal accuracy. Marginal gap results of all tested groups were within a clinically acceptable level. That range from 19μm up to 120μm, while others considered up to 70μm marginal fit values to be clinically acceptable.[32,33]

Regarding the effect of ceramic materials before and after cementation on the vertical cervical marginal accuracy; **Before cementation:** A non-significant differences were found**,** between e.max and zirconia, but with better marginal adaptation in case of e.max, this may due to sintering shrinkage of zirconia. **Bindl** and **Mormann** [34] suggested that the CEREC InLab system provided greater balance between the enlarged machining of the presintered ceramic block and the shrinkage occurring during the sintering process compared with the other CAD/CAM systems, thus creating frameworks with an overall improved internal and marginal fit. **After cementation:** Zirconia recorded statistically significant higher mean value than e.max and this may be due to the difference in spacer between zirconia and e.max copings due to difference in shrinkage between the two materials.

Regarding the effect of taper on the vertical cervical marginal accuracy before and after cementation; Statistical significant differences were found. The use of taper 12° increased the mean vertical cervical marginal gap distances in both before and after cementation than those with taper 20° copings. This could be explained by better seating of the crown when the taper of the preparation increased. Reviewing the literature, there are two main factors that may affect the seating of copings; the existence of hydraulic pressure resisting seating and escape of excess cement. Hydraulic pressure that is developed during cementation process is supposed to be higher if the taper of the preparation is lower. In addition, excess cement escapes better if the taper is increased.(40) So with increased preparation taper, space for cement between side walls of the preparation and restoration increased, reducing stress areas created during cementation, and resulting in better fit of final restoration. These findings coincide with the conclusions of **Broderson** [35] who proposed that increasing the degree of tapers of total occlusal convergence between 10 and 20 degrees allows greater seating of restorations. The smaller the taper, the greater the frictional resistance between the restoration and preparation and the more difficult for the cement to escape as excess cement can escape only through the space at cervical margin as the crown approaches its final position.

Regarding CAD/CAM, the scanning accuracy of abutments could have been enhanced with larger convergence angles of abutment, since the increase in convergence angles allow more data to be obtained from the axial wall. This could result in a higher quality of data for milling process, and better internal fit. This finding is in agreement with that of **Iwai et al** [15] who found that the internal space widths of zirconia ceramic copings may decrease with an increase in the convergence angle of abutments. In contrast to the present study **Nakamura et al** [18] reported that even when occlusal convergence angle was 8 or even 4 degrees no large effect was observed on internal adaptation of the crown.

Regarding the effect of surface treatment on the vertical cervical marginal accuracy before and after cementation; Statistical significant differences were found and the use of air abrasion surface treatment recorded the highest marginal gap mean value in both before and after cementation followed by tribochemical coat then acid etch. This may be due to; acid etching as a surface treatment has no effect on Zirconia copings while it has a selective etching on the e.max copings and no damaging effect on the margins. On the other hand, tribochemical coating added a thin layer of silica that decreased the spacer thickness thus affecting the adaptation.

CONCLUSIONS

Within the limitation of this study the following conclusions could be obtained;

Increasing the degree of taper lead to better marginal fit regardless the type of ceramic material.

The marginal gap of e.max copings is smaller than that of zirconia in both before and after cementation.

Copings treated with acid etching surface treatment show better marginal adaptation than tribochemical coating and sandblasting surface treatments regardless the type of ceramic material and degree of taper of the preparation.

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