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## RESEARCH ARTICLE

# EVALUATION AND COMPARISON OF THE EFFECT OF THREE DIFFERENT FINISH LINE DESIGNS ON THE MARGINAL DISCREPANCY OF ZIRCONIA COPINGS - AN IN VITRO STUDY

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**ABSTRACT**

**Statement of problem:** This study was designed to compare the marginal discrepancy of zirconia copings (Ziecon) with heavy chamfer, shoulder and rounded shoulder finish line, pre and post-cementation to provide clinicians a guideline for tooth preparation and cementation.

**Material and method:** Stainless steel die was fabricated for each finish line design and duplicated with addition silicone impression material to obtain dies in Type IV die stone (n=60). The specimens were tested for marginal discrepancies before cementation, post-cementation and after sectioning. Marginal discrepancies were recorded in microns, statistically analyzed, and compared.

**Results:** Finish line designs significantly influenced the marginal fit of the zirconia copings ($p > 0.05$) and their mean marginal fit was acceptable for clinical application ($\leqslant$120 μm). Mean marginal discrepancies post-cementation were larger than respective pre-cementation values. Shoulder specimens exhibited least discrepancy. In sectioned specimens, marginal gaps were lowest and occlusal gaps were highest.



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## INTRODUCTION

Over the years, several ceramic systems have been developed and introduced, using various materials and techniques for crown fabrication (Baig, 2010). The use of zirconia as a metal substitute is a principal driving force behind the ever-increasing development and use of computerized dentistry. The two areas of concern have been fracture strength and marginal fit (Baig, 2010). The presence of marginal discrepancies in the restoration exposes the luting agent to the oral environment. Larger the marginal discrepancy and greater the subsequent exposure of the dental luting agent to oral fluids, the more rapidly cement dissolution will occur (Jacobs, 1991). The effect of various finish line designs on the marginal fit of newer materials like zirconia (Ziecon) is not entirely clear. Hence, the present study was designed to compare the effect of three different finish line designs on the marginal discrepancy of zirconia copings. Moreover, the effect of finish line designs on the fit of the crown during and after cementation should be understood which influences its mechanical stability and the fracture resistance of overlying ceramic. The null hypothesis to be tested is that no difference in marginal adaptation exists among the copings, pre and post cementation and with respect to the three different finish line designs.

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## MATERIALS AND METHODS

This study was carried out in the Department of Prosthodontics and was prior reviewed and approved by the ethical committee. Three stainless steel master dies representing three prepared teeth with different finish lines were fabricated (Fig.1). The dimensions of the master dies were as per Accredited Standard committee MD156 (Table 1). Finish lines were designed such that shoulder preparation had axio-gingival internal line angle of 90 degrees, rounded shoulder preparation with curvature radius (R) of axio-gingival internal line angle 0.5 mm and heavy chamfer preparation with curvature radius (R) of axio-gingival internal line angle 2.0 mm.

**Impression technique**

An elastomeric impression (double mix, double step) of the metal die was made using the custom made perforated stainless steel metal ring in addition silicone (Aquasil, Dentsply, Germany) (Fig.2). A thin layer of tray adhesive (Silfix, Dentsply, Germany) was coated on the impression surface of the cylindrical tray using a brush and allowed to air dry for 5 minutes as per the manufacturer's guideline. A pre-adapted polyethylene sheet of 0.5 mm thickness was used as a spacer while making the impression in putty to obtain uniform thickness of light body (Fig.2). The inner diameter of the tray was 20 mm while the diameter of the die was 10 mm, thus providing adequate space for the impression material. The die with the spacer was seated in the custom fabricated base designed such that it formed the base of the metal ring and positioned the die in its centre. A tube impression was made using soft putty followed by removal of spacer and a wash impression using light body addition silicone (Fig. 2). Vents were made in the putty impression to allow escape of the excess material. Moreover a unilateral marking was made on the base of the die and putty during the first step which was used as a guide during the second step of impression using light body to maintain orientation. After the material had set, the exposed portion of the master die that was seated into the base was held using a universal plier for retrieval. A unilateral marking was made on the base of the die and putty during the first step and was used as a guide to maintain same position of the die while using light body.

**Method of obtaining dies**

Dies were poured using type IV gypsum; (Ultrarock, Kalabhai Dental, India) using a vacuum mixer. A new impression was made to pour each die to avoid any dimensional changes in the subsequent dies during pouring and retrieval. They were allowed to set for 24 hours. 20 impressions were made of each master die. A total of 60 standardized dies were fabricated and divided into three groups (n=20 for each finish line), each of which were assigned a code for finish line and coping identification.

**Fabrication of zirconia copings**

The dies were scanned using a laser scanner (Dental Wings, Canada). The values for the die spacer (50μm) [3, 4, 5], 0.5 mm short of the margin, coping thickness (0.5mm) and design were set. Partially sintered zirconia blanks (Ziecon, Jyoti Ceramics, India) were milled using CAD/CAM technology (CAM 4-02) to obtain copings of desired thickness (0.5mm) and design, followed by subsequent sintering in the sintering furnace at 1400° C. The milled specimen is 25% enlarged by the manufacturer to compensate for shrinkage after the sintering process. Adjusting the intaglio surfaces was avoided to maintain standardization.

**Methods of evaluation of marginal fit**

The copings were seated on the die perfectly using the offset angle as a reference to evaluate marginal fit. The restorations were evaluated for marginal fit and the vertical marginal discrepancy was measured under the stereomicroscope using 0.8 x or 1.25 x magnification (Fig.3a, b, c). This consisted of a stereomicroscope (Olympus SZX7) attached to a CCD (charge-coupled device) camera, which captured and recorded live images obtained through the stereomicroscope and displayed them on a computer monitor using an Image Analysing Software (ProgRes).

**Cementation**

Before cementation, all copings were thoroughly cleaned for 15 minutes with distilled water in an ultrasound bath. They were cemented using Type I Glass Ionomer luting cement (GC Corporation, Tokyo, Japan) following manufacturer's instructions (Gonzalo *et al*., 2009; Kashinatha, 2011; Beuer, 2008; Komine, 2010 and Beuer, 2009). A thin, even layer of each of the mixed cements was applied to the fitting surface of the crown, the crown seated on its respective preparation by hand pressure and then subjected to a standard load of 10 N for 10 minutes (Gonzalo, 2009) using a custom spring-loaded device (Fig.4a) while the cement was setting. The excess cement removed from around the margins with a sharp explorer. Calibration of device was done after each measurement and zero reading was ensured before every measurement.

**Investment and sectioning procedure**

A custom stainless steel device was made with a slot corresponding to the diameter of the base of die for orientation. (Fig.4b) such that the coping cemented on the die lies at the centre of the device. Once the die was seated, type II gypsum (Kaldent, Kalabhai Dental, India).was poured around the die to obtain an investment block. It was then divided into 2 equal halves by sectioning in the centre using a die cutting machine.

**Image Analysis**

All measurements were performed thrice by the same investigator. Sites for evaluation around the circumference of the teeth were determined at 6 points (mesio-buccal, mid-buccal, disto-buccal, mesio-lingual, mid-lingual, disto-lingual). Four measurements were made at each site and the mean value was recorded in microns. Eight different points were evaluated on the cut section of each crown. A total of 60 crowns were measured. In an effort to avoid errors when choosing starting and ending points of the discrepancies, all measurements were performed by the same operator. All measured data for sectioned specimens, was averaged based on four locations: the marginal opening, margin angle, axial wall, and occlusal area (Fig.5a, b, c). The results were subjected to statistical analysis. The six groups were as follows: Group A1- Heavy chamfer pre-cementation; Group B1- Heavy chamfer post-cementation; Group C1- Shoulder pre-cementation; Group A2-Shoulder post-cementation; Group B2- Rounded shoulder pre-cementation; Group C2- Rounded shoulder post-cementation.

**Statistical Analysis**

The descriptive statistics was used to display univariate summary statistics for several variables in a single table and calculate the standard values i.e. mean, standard deviation, range etc.

**Table 1. The dimensions of the master dies**

| Master dies | Height | Taper | Diameter | Shoulder | Offset angle for correct orientation of crowns |
|---|---|---|---|---|---|
| Master dies representing Prepared teeth. | 8mm | $6^0$ | 10mm | 1.5.mm | $30^0$ |

**Table 2a. Statistical analysis**

| Descriptive Statistics | | Heavy Chamfer Pre-cementation | Shoulder Pre-cementation | Rounded Shoulder Pre-cementation | Heavy Chamfer Post cementation | Shoulder Post-cementation | Rounded Shoulder Post-Cementation |
|---|---|---|---|---|---|---|---|
| N | Valid | 20 | 20 | 20 | 20 | 20 | 20 |
| | Missing | 0 | 0 | 0 | 0 | 0 | 0 |
| Mean (µm) | | 108.784 | 49.9660 | 83.7603 | 116.593 | 56.5062 | 94.1921 |
| Std. Deviation | | 16.5215 | 12.6912 | 18.6163 | 19.0766 | 16.4731 | 14.8505 |
| % C.V | | 15.19 | 25.39 | 22.22 | 16.36 | 29.15 | 15.76 |
| Minimum | | 84.40 | 28.99 | 54.25 | 85.18 | 29.52 | 74.13 |
| Maximum | | 140.02 | 68.20 | 117.82 | 152.90 | 84.10 | 132.82 |
| Range | | 55.62 | 39.21 | 63.57 | 67.72 | 54.58 | 58.68 |

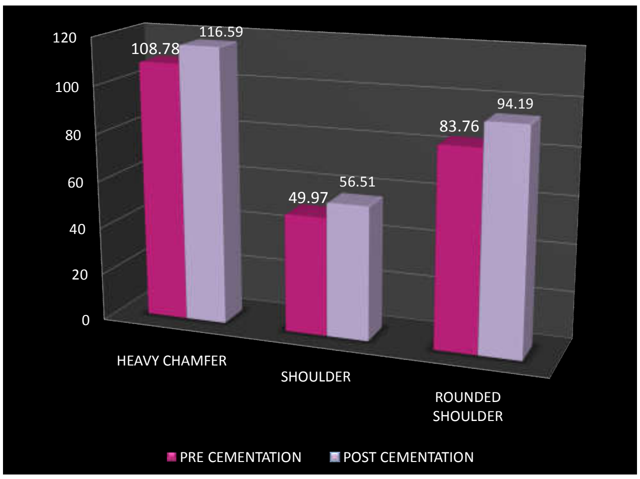
**Table 2b. Statistical analysis**

| Descriptive Statistics | | Heavy chamfer | | | | Radial shoulder | | | | Rounded shoulder | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Margin | Marginal angle | Axial wall | Occlusal area | Margin | Marginal angle | Axial wall | Occlusal area | Margin | Marginal angle | Axial wall | Occlusal area |
| N | Valid | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| | Missing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mean (µm) | | 120.53 | 126.78 | 160.55 | 262.15 | 55.77 | 62.10 | 79.54 | 173.31 | 99.57 | 105.79 | 151.16 | 274.45 |
| Std. Deviation | | 23.18 | 27.28 | 25.14 | 95.03 | 18.11 | 18.93 | 17.20 | 91.01 | 21.40 | 22.68 | 17.05 | 142.94 |
| % C.V | | 19.23 | 21.51 | 15.66 | 36.25 | 32.47 | 30.48 | 21.63 | 52.21 | 21.49 | 21.43 | 11.28 | 52.09 |
| Minimum | | 94.80 | 93.48 | 124.24 | 132.50 | 33.20 | 32.79 | 53.61 | 84.41 | 67.50 | 76.50 | 128.61 | 99.90 |
| Maximum | | 162.70 | 177.97 | 198.60 | 425.80 | 88.80 | 97.78 | 110.55 | 396.60 | 164.80 | 170.10 | 198.50 | 693.50 |
| Range | | 67.90 | 84.49 | 74.36 | 293.30 | 55.60 | 64.99 | 56.94 | 312.19 | 97.30 | 93.60 | 69.89 | 593.60 |

The entire data was entered in Microsoft Excel before it was statistically analyzed. A paired't' test was performed to determine whether there were differences between the before and after cementation marginal discrepancies within the same group. ANOVA was used to calculate the difference between the three groups and within the three groups. Further independent sample't'-test was used to calculate the statistical significance. All the results are shown in tabular as well as graphical format to visualize the statistically significant difference more clearly. The p-value less than 0.05 were considered statistically significant. All the hypotheses were formulated using two tailed alternatives against each null hypothesis. The entire data was analyzed using Statistical Package for Social Sciences (SPSS ver. 11.5) for MS Windows (Table 2a, b).

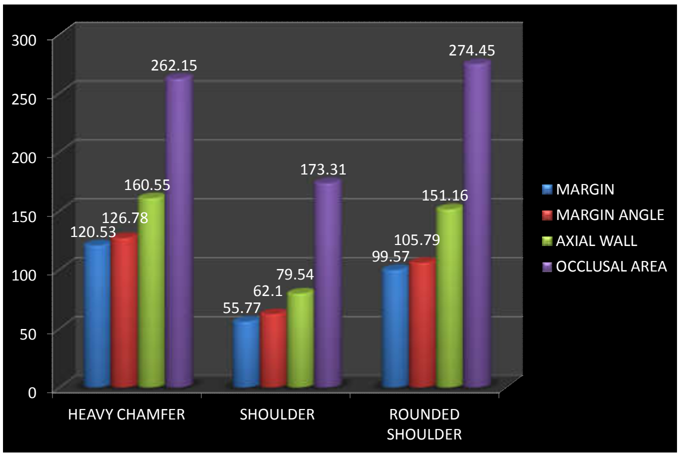
## RESULTS

- The mean marginal discrepancies pre-cementation with the heavy chamfer, shoulder and rounded shoulder finish line designs are 108.78µm, 49.97µm and 83.76µm respectively. (Table 2a)
- The mean marginal discrepancies post-cementation for heavy chamfer, shoulder and rounded shoulder finish lines are 116.59µm, 56.51µm and 94.19µm respectively. (Table 2a)
- The mean marginal discrepancies post-cementation were larger than the pre-cementation values for all the three finish lines.(Graph 1)
- The smallest and largest pre-cementation marginal discrepancies for heavy chamfer, radial shoulder and rounded shoulder finish lines are 84.40/140.02µm, 28.99/68.20µm and 54.25/117.82µm respectively. (Table 2a)
- The smallest and largest post-cementation marginal discrepancies for heavy chamfer, radial shoulder and rounded shoulder finish lines are 85.18/152.90µm, 29.52/84.10µm and 74.13/132.82µm respectively. (Table 2a)




**Graph 1. Bar graph for comparison of mean marginal discrepancy of heavy chamfer, shoulder and rounded shoulder finish lines pre and post-cementation in microns (µm)**

- The largest marginal discrepancies were seen with heavy chamfer margin and lowest with shoulder finish line. (Table 2a)
- The marginal discrepancy with respect to all the three margins was reported to be within the clinically accepted range. (Table 2a)
- In all the sectioned specimens tested, mean marginal gaps were the lowest and occlusal gaps were the highest. (Graph 2)




**Graph 2. Bar graph showing mean difference in the fit of the zirconia coping at 4 levels of the sectioned specimens with each of the finish lines**

**Figure 1.**

**Figure 2.**

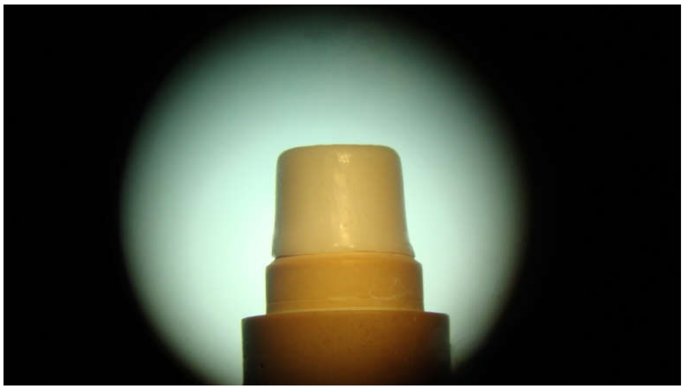


**Figure 3a.**

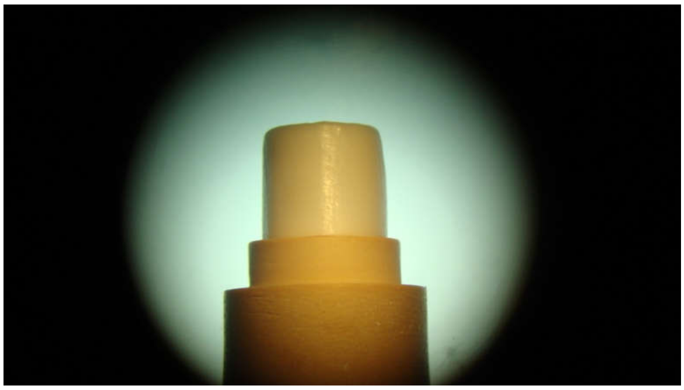


**Figure 3b.**

**Figure 3c.**

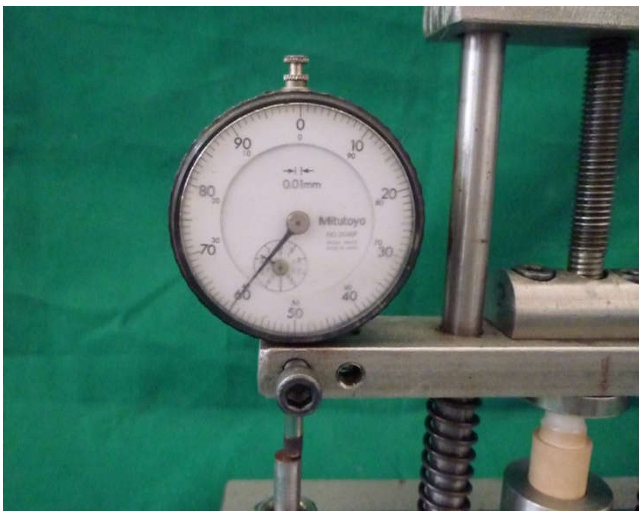



**Figure 4a.**

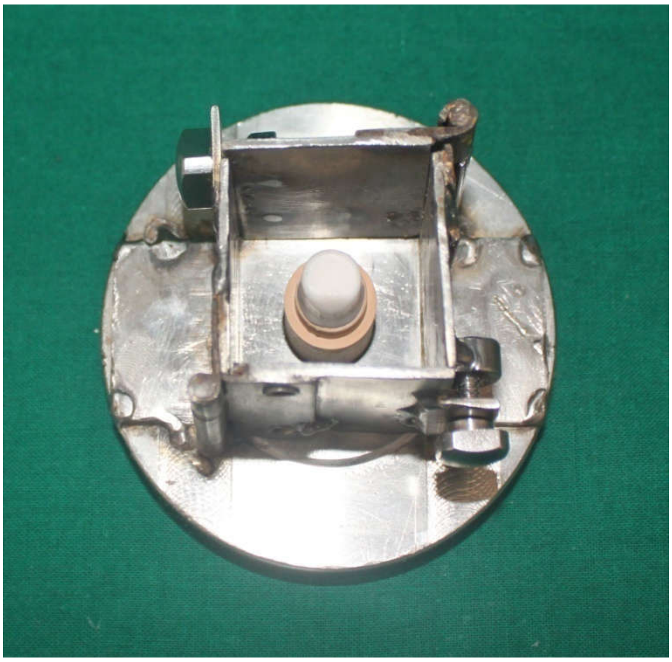


**Figure 4b.**

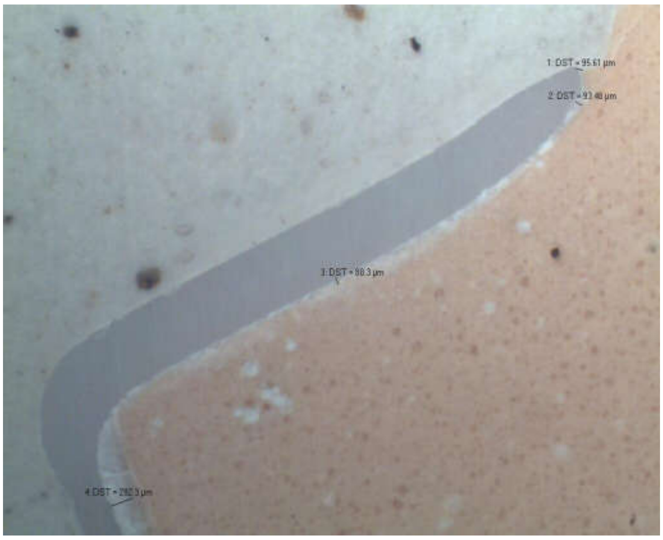


**Figure 5a.**

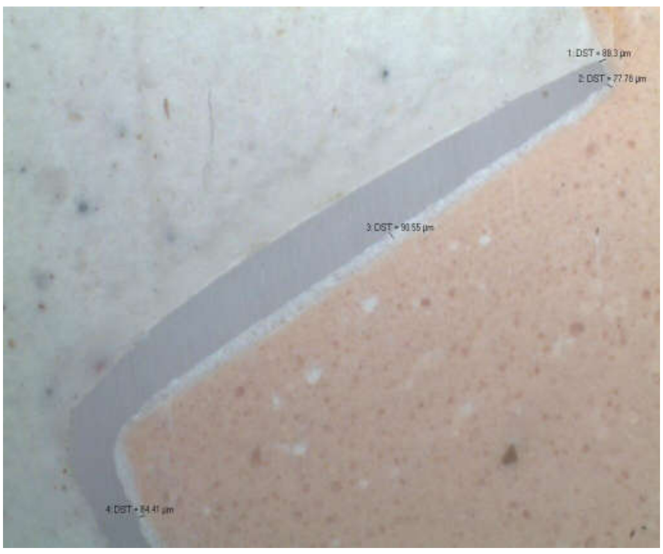


**Figure 5b.**

**Figure 5c.**

## DISCUSSION

The ever increasing use of new all ceramic materials makes it important for clinicians to have guidelines for tooth preparation for these materials. This study is aimed at providing the same. The use of a metal die as a standard allowed the investigator to accurately control the variables of preparation dimensions, degree of axial wall taper and the finish line dimensions, similar to Komine, Iwai, Quintas *et al* ((Quintas, 2004; Kashinatha, 2011; Gavelis, 2004; Komine, 2007 and Subasi, 2012). The mean marginal fit discrepancies at all measurement locations reflect the overall magnitude of the marginal fit discrepancy of the entire crown (Subasi, 2012). A large gap may cause cement solubility and result in plaque accumulation, marginal leakage, secondary caries, and eventually crown failure. The clinically acceptable marginal gap, within 120 µm, was reported by McLean and von Fraunhofer (Kashinatha, 2011), Thus the marginal discrepancy with respect to all the three margins is reported to be within the clinically accepted range. The differences in the marginal fit of the zirconia copings for heavy chamfer, shoulder and radial shoulder finish lines were statistically significant ($p > 0.05$). Thus, the data supports rejection of the null hypothesis for this variable. In the present study large marginal discrepancies of specimens with heavy chamfer could be attributed to the accuracy of laser scanning for the finish line angle. An additional plausible explanation could be the curvature radius of the axio-gingival internal line angle that may affect the scanned results of the axial wall of the abutments.[11] In the present study, no negative influences of radial shoulder finish line were noted. Shearer *et al*. reported no significant differences in the internal fit of chamfer and shoulder finish line designs with InCeram crowns manufactured using the slip casting technique. This result agreed with our present findings, the difference in range of values could be explained by the different materials or fabrication procedures used in the two studies (Shearer, 1996). Most importantly, the internal space values of $ZrO_2$ copings and crowns were well within the 50 to 100 µm range shown by Molin *et al*. (1996).

Studies have stated that pre-sintered blocks machined with the aid of CAD/CAM system, are pre-shaped into a size 25 to 30% larger than desired to compensate for the sintering shrinkage (Comlekoglu, 2009). In the present study, marginal adaptation was evaluated using a direct view of the non-cemented specimen on a die. This non-destructive method thus measured distortion arising strictly from the manufacturing process. In this study, cross sectional measurement technique was employed to study the internal adaptation and thus the error due to the difference in flow between the luting agent and silicone paste which could affect the adaptation of restorations as in replica technique was eliminated (Komine, 2007). Similar studies were carried out by Gavelis, Comlekoglu, Mitsuyoshi Tsumita *et al* wherein the specimens were sectioned (Gavelis, 2004; Comlekoglu, 2009; Kokubo, 2011). Depending on the height and convergence angle of the abutment and the marginal configuration, there will always be the possibility of inaccurate crown placement when seated with finger pressure. Thus a standardised cementation device has been used in the study to ensure uniform cementation pressure throughout. An offset has been incorporated in the die and respective coping to ensure correct orientation and accurate coping placement. Definite number of rotations was given during cementation, to have a uniform seating pressure confirmed with the pressure gauge. The mean marginal discrepancies post-cementation were larger than the pre-cementation values for all the three finish lines. Thus, the data supports rejection of the null hypothesis for this variable. The question is how the finish line affects cementation. When the crown is cemented the axial wall of the preparation approaches the axial wall of the internal crown surface. The escape path for the cement decreases, causing the hydrostatic pressure within the crown to increase until it matches the patients biting pressure. At this point, the crown fails to seat further. It is thought that less hydrostatic pressure results in greater seating of the restorations (Gavelis, 2004). The cement space or internal adaptation is of paramount importance because all-ceramic restorations are more fragile compared to metal-ceramics, as ceramic is a brittle material and sensitive to tension. Thin cement layers (80 µm) at measurement location occlusal area have been reported to be more favourable for the mechanical stability of zirconia based restorations. There is also evidence that a lack of precision in internal fit can promote higher risks for veneering fracture. Despite this aspect, the result of the present study indicates that gaps were similar or better than those of metal ceramic restorations (Beuer, 2009). Also, the internal fit measurement was included in the study design, since this may provide better understanding of what had happened after coping cementation. In all the specimens tested, marginal gaps were the lowest and occlusal gaps were the highest. These results were the same as another report that used the Procera system. Thus, these results might be typical to such CAD/CAM systems (Beuer, 2007 and Boening, 2000). In this study, slight increase in marginal discrepancy after cementation in all of the groups may be explained by the fact that the predetermined internal space of 50 µm for the luting agent seems to be enough to obtain an adequate space for the cement and results in no significant increase in the vertical marginal fit of the restorations (Quintas, 2004; Beuer, 2007 and Gonzalo, 2009). In the present study, the adaptation of copings was assessed without porcelain veneering because the copings principally define the overall adaptation of veneered crowns (Subasi, 2012).

**Clinical Implication**

These results confirm that all-ceramic crowns fabricated using Ziecon zirconia banks, show promising clinical results and will have good marginal fit within clinically accepted parameters. A prospective evaluation in a clinical situation should be compared with these crowns after 5 years of function. The results of this study address the need of obtaining minimum marginal discrepancies, favouring a radial shoulder finish line preparation rather than a chamfer and rounded shoulder in this system which will provide a good guideline to the clinicians. Adequate cement layers have been reported to be more favourable for the mechanical stability of zirconia based restorations.

**Limitations of the Study**

The specimens in this study were not subjected to an artificial aging process like thermal cycling and mechanical loading used to simulate oral conditions. Some studies have demonstrated a negative effect of thermal cycling on marginal fit of crowns, whereas Beschnidt *et al*. (1999) demonstrated otherwise. Marginal gaps were not measured post ceramic veneering which causes shrinkage of zirconia coping and influences the marginal discrepancy.

**Compliance with ethical standards**

**Conflict of Interest:** All authors declare that he/she has no conflict of interest.

**Ethical approval:** This article does not contain any studies with human participants or animals performed by any of the authors.

**Conclusion**

The differences in the marginal fit of the zirconia copings for heavy chamfer, shoulder and radial shoulder finish lines were statistically significant ($p > 0.05$). The marginal discrepancies with respect to all the three margins were reported to be within the clinically accepted range, the shoulder finish line exhibiting the least discrepancy. The mean marginal discrepancies post-cementation were larger than the pre-cementation values. In all the sectioned specimens tested, mean marginal gaps were the lowest and occlusal gaps were the highest.

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