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# Marginal and Internal Fit of Monolithic and Veneered Zirconia Crowns

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***ABSTRACT***

**Purpose:** The present study was conducted to evaluate the effect of veneering zirconia frameworks on the marginal and internal fit of zirconia based restorations. **Materials and methods:** Forty natural premolars were prepared to receive all-ceramic crowns. The forty premolars were divided into two groups according to the type of restoration. Group (I) consisted of ten samples restored using monolithic zirconia crowns. Group (II) consisted of thirty samples restored using veneered zirconia frameworks. Group II was subdivided into three equal subgroups according to veneering technique. Subgroup (IIA) veneered using manual layering technique, Subgroup (IIB) veneered using Press-on technique and Subgroup (IIC) veneered using CAD-on technique. All the finished crowns were cemented to their corresponding abutments then each tooth was vertically sectioned bucco-lingually into 2 sections. Marginal, axial and occlusal gaps were measured at seven defined points on each section using digital microscope. **Results:** The significance level was set at $P<0.05$. Regarding the marginal gap, statistical analysis revealed that there was a significant difference between groups and subgroups. The greatest mean value was recorded in subgroup IIA, veneered using manual layering technique. Whereas the lowest mean value was recorded in subgroup IIC, veneered using CAD-on technique. Regarding the internal gap statistical analysis revealed that there was a significant difference. The greatest mean value was recorded in group I (monolithic), whereas the lowest mean value was recorded in subgroup IIC, veneered using CAD-on technique. **Conclusion:** Veneering zirconia frameworks using the CAD-on technique produces superior marginal and internal adaptation of zirconia based restorations.

***KEYWORDS***

*CAD-on, monolithic, press-on, veneered, zirconia.*

## INTRODUCTION

The increased demand for aesthetic enhancement has led to the fast development of all-ceramic systems. Enhanced biocompatibility, strength, aesthetics and fit are essential for an all-ceramic restoration

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to be successful. However, the brittleness, low flexural strength and fracture toughness of conventional glass and alumina ceramics have always been an obstacle [1].

Zirconia is increasingly used as frameworks of all ceramic restorations due to its improved mechanical properties and aesthetics. Yttria-stabilized zirconia frameworks veneered using glass-ceramics represent an acceptable alternative for metal and metal ceramic restorations, due to both; the superior mechanical properties of zirconia and the enhanced aesthetics of glass-ceramics [2].

Hand layering technique of the veneering ceramic has some disadvantages such as lack of shade uniformity, formation of microbubbles and lack of consistent results as it depends mainly on the skill of the technician. Press-on and the CAD-on veneering techniques were recently developed to overcome these disadvantages[3].

Monolithic zirconia restorations without veneering porcelain have been recently introduced to eliminate the risk of chipping of the veneering porcelain. The thin monolithic zirconia crowns represent a much less invasive treatment [4].

Marginal adaptation is affected by many factors such as finish line design, method and materials used for fabrication of the restoration and number of firing cycles [5].

Poor fit of the crown can lead to dissolution of the luting cement which leads to tooth sensitivity, higher incidence of recurrent caries and inflammation of periodontal tissues. In addition, variations in adaptation could lead to stress concentration which may in turn reduce the strength of the restoration and consequently cause its fracture [5].

There is a debate regarding the effect of various veneering procedures on the fit of zirconia frameworks in comparison with monolithic restorations. Consequently, this study was undertaken to compare marginal and internal fit of monolithic zirconia crowns and zirconia frameworks veneered using different techniques.

The null hypothesis assumed that there will be no difference between internal and marginal adaptation of monolithic and veneered zirconia-based crowns. In addition, the various veneering techniques will not affect the internal and marginal adaptation of zirconia veneered restorations.

## MATERIALS AND METHODS

### Teeth selection and preparation

Approval for this study was obtained from the research ethics committee in the Faculty of Dental Medicine for Girls Al-Azhar University. Forty freshly extracted human maxillary first premolars due to periodontal or orthodontic reasons were used. The teeth were with completed roots, free of cracks, fractures and caries.

To standardize the size of the selected teeth, a digital caliper with accuracy 0.01mm was used to measure the bucco-lingual and mesio-distal dimensions of all premolars at the cemento–enamel junction (CEJ).

Each sample was individually mounted vertically in the epoxy resin block to a level of 2mm apical to the buccal cemento-enamel junction marked on the root surface simulating the natural biologic width.

All-ceramic preparations were prepared on the selected premolars using the Centroid milling machine. A standardized sample preparation was performed with the minimum thickness required for zirconia of 0.5mm. Sharp corners, edges and internal angles were avoided. The preparation was performed with 1.5mm axial walls reduction, 2mm occlusal surface reduction and a round shoulder of 1.2mm depth placed coronal to the cemento-enamel junction. The angle of convergence was 8°.

### Experimental design

All prepared premolars (n=40) were randomly divided into two main groups according to the type of restoration received. Group I (n=10): Premolars restored with monolithic zirconia crowns. Group II (n=30): Premolars restored with veneered zirconia frameworks.

Samples of group II were further subdivided into three subgroups (n=10 each) according to the veneering technique used. Subgroup IIA (n=10): Premolars restored with zirconia frameworks veneered by IPS e.max Ceram (Ivoclar Vivadent) using manual layering technique. Subgroup IIB (n=10): Premolars restored with zirconia frameworks veneered by IPS e.max ZirPress (Ivoclar Vivadent) using Press-on veneering technique. Subgroup IIC (n=10): Premolars restored with zirconia frameworks veneered by IPS e.max CAD (Ivoclar Vivadent) using CAD-on veneering technique.

Thicknesses of the monolithic crowns were designed to be 1.2mm at the margins, 1.5mm axial walls and 2mm occlusal surface thickness. While, as recommended by a study, thicknesses of the frameworks were designed to be 0.5mm uniform thickness while thickness of the veneering ceramic was 0.7mm at the margins, 1mm axial walls and 1.5mm occlusal surface thickness [(6)].

IPS e.max Ceram ZirLiner (Ivoclar Vivadent) was applied on zirconia frameworks of group II prior to the application of the veneer layer, in all subgroups as it was reported to provide a strong homogeneous bond with the zirconium oxide frameworks [(1)].

### Cementation

Sandblasting the fitting surfaces of the restorations was carried out in sandblasting device using 100$\mu$m aluminum oxide powder ($Al_2O_3$). Finished crowns were cemented to the corresponding teeth using totalcem self-adhesive resin cement (ITENA). The cement was applied directly into the fitting surfaces of the finished crowns. Cemented crowns were immediately subjected to a fixed load of 5kg for 10 minutes with a custom-made load applicator while curing the cement for 20 seconds per surface.

### Samples sectioning

Each tooth was vertically sectioned bucco-lingually using the IsoMet 4000 Linear precision saw (Buehler) cutting at 800 rpm speed using stainless steel saw under copious coolant. Sectioning was specified at a line drawn from the buccal to the palatal cusp tips on the occlusal surface of the crown.

Seven measuring points were defined on each section. P1**:** The buccal marginal discrepancy. P2: The buccal mid-axial discrepancy. P3: The junction of the buccal and occlusal walls. P4: The mid occlusal discrepancy on the occlusal plateau. P5: The junction of the palatal and occlusal walls. P6: The palatal mid-axial discrepancy. P7: The palatal marginal discrepancy.

### Measurements

The measurements were made at X150 magnification via a personal computer, connected to the Dino-Lite digital microscope (Dino-Lite).

## STATISTICAL ANALYSIS

Data obtained were collected and statistically evaluated; values were presented as means and standard deviations (SD). Kolmogorov-Smirnov test of normality was performed and indicated that most of the data were normally distributed (parametric data); therefore, one way analysis of variance (ANOVA) test was conducted. Pearson's correlation test was used to study correlation between marginal and internal fit. This was followed by Tukey's post hoc test which was used to compare between groups. The significance level was set at $p < 0.05$. Statistical analysis was performed with SPSS 18.0 for Windows.

## RESULTS

Regarding the marginal gap distances, the greatest mean value (98.65 ± 26.06$\mu$m) was recorded in subgroup IIA, veneered using manual layering technique, whereas the lowest mean value (68.85 ± 18.21$\mu$m) was recorded in subgroup IIC, veneered using CAD-on technique. Statistical analysis using

ANOVA test revealed that the difference between groups and subgroups was statistically significant (p=0.043). Tukey's post hoc test revealed no significant difference between group I (monolithic) and subgroup IIB, veneered using Press-on technique.

Regarding the axial gap distance, the greatest mean value (94.80 ± 21.63$\mu$m) was recorded in subgroup IIA, veneered using manual layering technique. Whereas the lowest mean value was recorded in subgroup IIC, veneered using CAD-on technique (63.35 ± 16.01$\mu$m) and group I (monolithic) (63.35 ± 15.57$\mu$m). Statistical analysis using ANOVA test revealed that the difference was statistically significant (p=0.013). Tukey's post hoc test revealed no significant difference between group I (monolithic), subgroup IIB (veneered using Press-on technique) and subgroup IIC (veneered using CAD-on technique).

Regarding the occlusal gap distance, the greatest mean value (208.57 ± 68.45$\mu$m) was recorded in group I (monolithic), whereas the lowest mean value (128.47 ± 27.90$\mu$m) was recorded in subgroup IIB, veneered using Press-on technique. Statistical analysis using ANOVA test revealed that the difference was statistically significant (p<0.0001). Tukey's post hoc test revealed no significant difference between subgroup IIB, veneered using Press-on technique and subgroup IIC, veneered using CAD-on technique.

Regarding the internal gap distance, the greatest mean value (150.48 ± 25.57$\mu$m) was recorded in group I (monolithic), whereas the lowest mean value (104.32 ± 15.87$\mu$m) was recorded in subgroup IIC, veneered using CAD-on technique. Statistical analysis using ANOVA test revealed that the difference was statistically significant (p=0.003). Tukey's post hoc test revealed no significant difference between subgroup IIB (veneered using Press-on technique) and subgroup IIC (veneered using CAD-on technique).

Values are presented numerically in table (1) and graphically in figure (1).

**Table (1):** *Mean values, standard deviation (SD) and statistical analysis of gap distances (µm) at different points and comparison between groups*

| Groups | | N | Mean | SD. | 95% Confidence Interval for Mean | | F | P value |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower limit | Upper limit | | |
| **Marginal** | Group I | 10 | 80.55$^{b}$ | 26.26 | 58.43 | 102.67 | 3.988 | 0.043$^{*}$ |
| | Subgroup IIA | 10 | 98.65$^{a}$ | 26.06 | 70.54 | 126.76 | | |
| | Subgroup IIB | 10 | 79.90$^{b}$ | 22.52 | 49.70 | 110.10 | | |
| | Subgroup IIC | 10 | 68.85$^{c}$ | 18.21 | 46.28 | 91.42 | | |
| **Axial** | Group I | 10 | 63.35$^{b}$ | 15.57 | 37.34 | 89.36 | 6.915 | 0.013$^{*}$ |
| | Subgroup IIA | 10 | 94.80$^{a}$ | 21.63 | 69.23 | 120.37 | | |
| | Subgroup IIB | 10 | 70.55$^{b}$ | 23.87 | 50.02 | 91.08 | | |
| | Subgroup IIC | 10 | 63.35$^{b}$ | 16.01 | 46.50 | 80.20 | | |
| **Occlusal** | Group I | 10 | 208.57$^{a}$ | 68.45 | 183.01 | 234.13 | 12.161 | <0.0001* |
| | Subgroup IIA | 10 | 146.57$^{b}$ | 35.60 | 125.81 | 167.33 | | |
| | Subgroup IIB | 10 | 128.47$^{c}$ | 27.90 | 114.32 | 142.62 | | |
| | Subgroup IIC | 10 | 131.63$^{c}$ | 16.47 | 106.44 | 156.83 | | |
| **Internal** | Group I | 10 | 150.48$^{a}$ | 25.57 | 123.32 | 177.64 | 4.834 | 0.003* |
| | Subgroup IIA | 10 | 125.86$^{b}$ | 20.36 | 108.71 | 143.01 | | |
| | Subgroup IIB | 10 | 105.30$^{c}$ | 19.17 | 91.33 | 119.27 | | |
| | Subgroup IIC | 10 | 104.32$^{c}$ | 15.87 | 85.60 | 123.04 | | |

**N** = *Number of samples,* **SD** = *Standard deviation,* **P value** = *Significance level, Significance level P<0.05, * significant.*

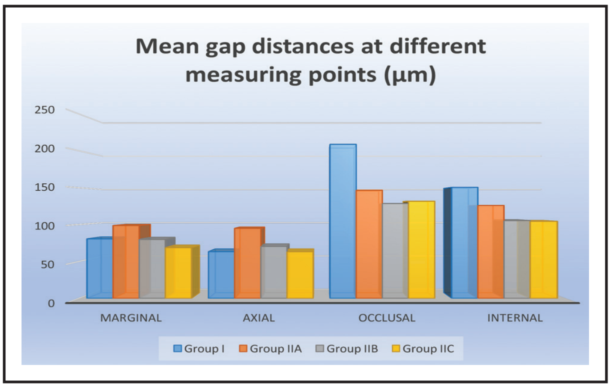


**Figure (1):** Bar chart showing mean values of marginal, axial, occlusal and internal gaps evaluation of group I and group II.

## Correlation between marginal and internal fit

Pearson's correlation test revealed a weak positive correlation between marginal and internal fit, table (2) and figure (2).

A positive correlation means a direct relation between marginal and internal fit. An increased marginal gap is accompanied by increased internal fit and vice versa.

**Table (2):** *Correlation between marginal and internal fit using Pearson's correlation test*

| R | $R^2$ | Interpretation | P value |
|---|---|---|---|
| 0. 3612 | 0.1305 | Weak positive | <0.0001* |

*Significance level P<0.05, * significant*

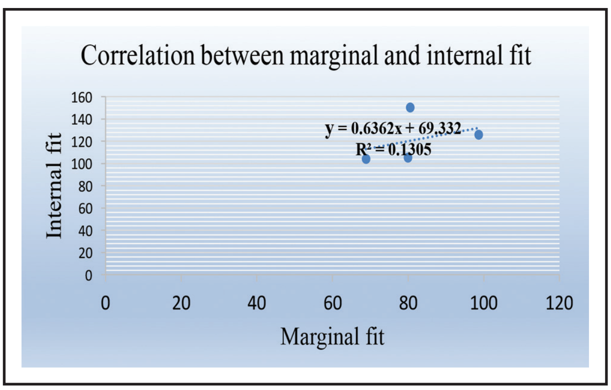


Figure (2) Scatter plot showing correlation between marginal and internal fit.

Digital microscopic images of measuring the marginal and internal gaps are presented in figures (3, 4).

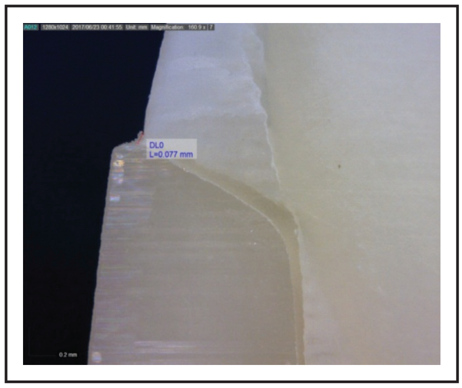


Figure (3): Digital microscopic image of measuring the marginal and internal gaps in one of the samples of group (I).

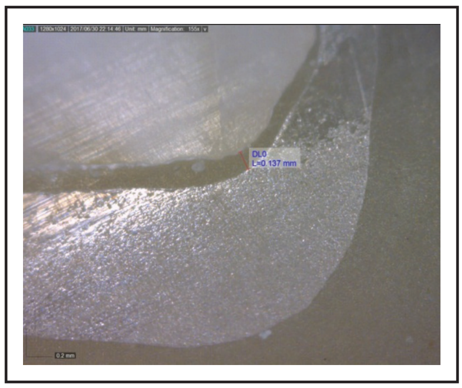


Figure (4): Digital microscopic image of measuring the marginal and internal gaps in one of the samples of group (II).

## DISCUSSION

As the longevity of fixed restoration is directly related to its marginal and internal accuracy; this study was directed towards comparing the differences in marginal and internal fit of double-layer type of CAD/CAM crowns (veneered crowns) and those of single-layer type system (monolithic crowns).

Human natural teeth were used as abutments in this study. Metal or acrylic resin dies have been used in several investigations (6-8), however, these abutments were found to give neither real information about the microstructure of hard tissues of teeth or about the micro and chemo-mechanical adaptation of the cement to dentin (9).

All frameworks in this study were fabricated with a die space of 50µm, starting 1mm above the margin as recommended by a study which stated the provision of internal relief that adds about 50µm space at the chamfer area, usually results in better seating at the margin (10).

In several studies (11-13), a large cement space was considered for CAD/CAM system. Though the larger the cement space the less is the marginal gap, it creates a critically large internal gap that adversely affects the mechanical properties of the cement(13,14). The decreased internal fit has been found to promote higher risks for veneer fracture (15).

Before cementation, fitting surfaces of all zirconia crowns and frameworks were sandblasted with 100µm aluminum oxide powder ($Al_2O_3$) under 1 bar pressure to promote mechanical interlocking by increasing the available surface area for bonding (16,17).

The cemented crowns were immediately subjected to a fixed load of 5kg for 10 minutes using a custom made load applicator. The fixed load ensures a uniform cement thickness as an uncontrolled pressure might produce a thicker cement layer in one axial wall than the opposite wall causing improper fit of the cemented crown (18).

Samples of the current study were sectioned bucco-lingually into two halves as recommended in a study (19). The cross-sectioning method allows for direct measurement of the cement layer minimizing any errors that might occur due to software or repositioning errors (20).

In the present study; monolithic restorations in group I recorded statistically significant higher marginal gap distances compared to CAD-on veneered samples, subgroup IIC. In addition; group I recorded the statistically significant highest internal gaps compared to all the veneered crowns in group II, indicating that monolithic restorations do not always ensure superior adaptation.

During sintering of the pre-sintered zirconia restorations, the shrinkage of the material makes the crown denser and stronger. This shrinkage has to be compensated through increasing the dimensions of the crown by the CAD/CAM system (21). Some studies investigated the effect of the dimensions of the crown on the fit (22-24). They stated that larger crowns lead to higher amounts of sintering shrinkage that result in decreased crown adaptation (22).

As the monolithic crowns in the present study were designed to have anatomic non-uniform thicknesses of 1.2mm at the margins, 1.5mm axial walls and 2mm occlusal thickness while the ZirCAD frameworks were designed to have 0.5mm uniform thickness, it was expected that the amount of shrinkage in the monolithic crowns of group I would be higher than that of the frameworks in groupII.

Also, due to the uneven thickness of monolithic crowns, uneven shrinkage was also expected. This different amount of shrinkage yielded inconsistent ranking of group I samples in occlusal, axial and marginal gap values when they were compared to subgroups (IIA, B and C). The lower linear sintering shrinkage of the material resulted in better accuracy improving marginal and internal adaptation. Thus, monolithic crowns in group I recorded the statistically significant highest occlusal gap distance values (occlusal thickness of the crowns was 2mm) among tested groups.

Among the three different veneering techniques investigated in the current study, manual layering resulted in the highest mean marginal and internal gaps followed by Press-on technique and CAD-on technique.

This result is in accordance with a study which evaluated the effect of manual layering, Press-on and CAD-on veneering techniques on the marginal fit of zirconia frameworks and found out that the vertical marginal gap of the three groups increased after porcelain veneering and that the highest mean marginal gap value was recorded in the manual layering group [6].

Alterations of the marginal fit during the veneering process could be caused by multiple factors. One of the possible reasons might be the shrinkage of the veneering ceramic during sintering process causing it to be lifted from the margin of the die [25].

Another reason might be the thermal incompatibility between the framework and the veneering porcelain [26].

Also the number of firing cycles needed in each veneering technique might be the reason for significant differences in marginal and internal adaptation recorded among the different techniques. Manual layering technique needs more firing cycles than Press-on and CAD-on veneering techniques.

Regarding the internal gap values obtained**;** the statistically significant highest mean value was recorded in group I (monolithic zirconia crowns, whereas the statistically significant lowest mean value was recorded in subgroup IIC (CAD-on technique).

This result agrees with a study which compared the internal adaptation of full contour zirconia crowns versus manual layering veneered zirconia crowns in an in vitro study with two different finish line designs. In that study the veneered zirconia crowns recorded better overall internal adaptation values compared to the monolithic crowns with both finish line designs. The lower adaptation values recorded for monolithic crowns were attributed to the sintering shrinkage of zirconia in relation to the thickness of the structure, which had led to inferior marginal adaptation of the monolithic group described earlier in the present study[2].

Pearson's correlation test revealed a highly significant positive correlation (r= 0.1305), between marginal and internal fit. An increased marginal gap is accompanied by increased internal gap. This result is in accordance with a study which found a positive correlation between marginal and internal gaps of full contour CAD/CAM crowns made of zirconia, lithium disilicate, zirconia-reinforced lithium silicate and hybrid dental ceramic [19]. It stated that this might be due to the equal thicknesses of the crown restorations which permit uniform and constant changes during the successive fabrication procedures resulting in merely even alteration in their dimensions and shapes.

## CONCLUSIONS

Within the limitation of the current study, the following could be concluded:

1. Veneering zirconia frameworks using IPS e.max CAD blocks through the CAD-on technique produces superior marginal and internal adaptation of zirconia based restorations.
2. Veneering zirconia frameworks using glass based ceramics through manual layering technique compromises marginal and internal accuracy of zirconia based restorations.
3. Marginal and internal adaptation of zirconia based restorations are positively correlated to each other.
4. A compromised occlusal adaptation is usually associated with CAD/CAM monolithic and veneered zirconia based restorations.

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