



## **Comparison of marginal adaptation, internal fitness and microleakage of Zolid, Zirconia and Empress 2 all-ceramic crown materials (An in vitro study)**

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### **Abstract**

The purposes of this in vitro study were to compare the marginal adaptation, internal fitness and the microleakage of three CAD-CAM all ceramic crowns materials: Zolid, Zircon, and Empress 2. This study also evaluated the correlation of microleakage of these ceramic crowns materials to the marginal fitness.

Forty-five maxillary first premolar teeth were prepared with 2-mm occlusal reduction and 1-mm all around shoulder finish line, teeth were randomly divided into three main groups according to the type of ceramic material that was used (n=15). Group 1: received a CAD-CAM Ceramill Zolid® unlayered transparent zircon Group 2: received a CAD-CAM Ceramill ZI units (Zirconium oxide) Group 3: received a CAD-CAM Ceramill wax units that would subsequently invested and heat pressed to fabricate a hot-press ceramic crowns.

The results showed statistical significant difference in marginal fitness, internal fitness and microleakage between Zolid group and other groups ( $P > 0.0001$ ). There was highly significant correlation of the marginal and internal fitness, whilst there was no significant correlation marginal fitness and microleakage.

**Keywords** CAD-CAM, Empress 2, internal fitness, marginal gap, microleakage, zirconia, Zolid.

### **Introduction**

One of the most important properties of prosthetic restorations is their marginal adaptation <sup>(1)</sup>. Which mean the distance between the tooth's restoration line and its margin, or the degree of proximity and interlocking of tooth inner side to the wall of a tooth . <sup>(2)</sup>. Poor marginal adaptation or too large an opening negatively affects the restoration's strength, reduces its longevity and leads to a higher risk of recurrent

caries and periodontal illness<sup>(3)</sup>. It can also fracture the cement, allowing

the seepage of fluids, debris, and microorganisms along the interface between the restoration and the walls of the cavity preparation (microleakage). This causes marginal discoloration, pulpal irritation, secondary carious lesions and possible cement mechanical failure<sup>(4)</sup>.

Microleakage has been defined as the passage of bacteria, fluids, molecules or ions along the tooth-restoration interface <sup>(5)</sup>. This leakage may be clinically undetectable, but is a major factor influencing the longevity

of dental restorations as it causes many severe biological effects on the restored tooth including the recurrence of caries, pulp pathology, hypersensitivity and marginal breakdown<sup>(6)</sup>. The investigation of microleakage is, therefore, important in the assessment of restorative materials.

Although metal-ceramic crowns possess high strength, the increasing interest in more aesthetically pleasing restorations over the last few years has stimulated the development of all-ceramic crown restorations<sup>(7)</sup>.

All-ceramic crown systems may be fabricated using different techniques. One of these techniques is the heat-press, which is similar to the method of metal-ceramic crowns, as that also utilizes the lost-wax method<sup>(8)</sup>. The difference of the heat-press is that it involves the use of a special porcelain furnace with a pneumatic ram, which presses the ceramic material into the mold at high temperatures under vacuum. The system produces a high-strength core; consisting primarily of lithium-disilicate glass<sup>(9)</sup>.

Another technique is the computer-aided design and manufacturing (CAD/CAM) system, which focuses on precise and consistent manufacturing of ZrO<sub>2</sub> ceramics with high strength and toughness<sup>(10)</sup>.

The development of advanced dental ceramics has led to the application of partially stabilized zirconia in Restorative Dentistry, which can be produced from a computer-assisted design/computer aided manufacture (CAD/CAM) system. The use of zirconia – based ceramics for dental restorations has risen in popularity due to their superior fracture strength<sup>(11)</sup> and toughness compared with other dental ceramic systems<sup>(12)</sup>.

The aim of the present study was to compare the marginal, internal fitness and microleakage of Zolid, Zircon and

Empress 2 all-ceramic crowns materials, to evaluate the correlation of marginal adaptation and internal fitness of these crowns materials and to evaluate the correlation of microleakage of these crowns materials to the marginal adaptation.

## Materials and Methods

### Sample selection

Non-carious, unrestored Forty-five freshly extracted for orthodontic purposes, upper first human premolars with crown size (7 mm to 8 mm) according to their mesio-distal diameter teeth were selected<sup>(13)</sup>.

### Sample planning and arrangement

The apical part of roots apices were cut perpendicular to the long axis of the teeth using disk bur (stone bur, Neytech, USA), such that the length of each tooth was 16 mm from the highest cusp tip to the cut level, the samples placed on a 2mm thick sheet wax, then placed on the base of the special block; with the help of a analyzing rod of dental surveyor (Jelenko Dental surveyor, Dentarium, Germany) the wax give an easy routine for control a parallel long axes of the samples to each other as well as perpendicular level to the sheet wax fig (1).

Then a 2 mm layer of dental stone (Elite® Stone Thixotropic® type 4 die stone, Zhermack, Italy) was poured over the wax to secure the teeth subsequently another 2 mm layer of cold cure acrylic (Major Base 2, Major Prodotti Dentari S.p.A, Italy) were poured over the stone.

### Samples preparation

The teeth were prepared to receive metal free crowns, this is done by mounting the samples in special block unit to the base of a surveyor and a high-speed turbine (Alegra, W&H co., Austria) was mounted to the vertical

arm of the surveyor with a specially designed cross-like pipe holder.

Then a disk-shaped diamond bur (G 818, Neytech, USA) rotating at high speed with air-water coolant was used to prepare the occlusal surface such that all the tooth enamel was removed, a metal ruler was used to mark a 5-mm length from the occlusal level to the intended finish line, 90° radial shoulder of 1mm depth cervical finish line was prepared with a diamond flat end tapered fissure bur (G818, Neytech, USA) with 6° degree taper was used to prepare the axial wall, this insures a standard tapering to all samples. Finally, a flat end tapered Arkansas stone was used to round the line angles and to give the surface smooth finish.

### **Samples grouping and Crowns Fabrication**

The samples were divided into three groups of fifteen teeth for each according to the type of ceramic material that was used. The ceramic crowns had been fabricated in AmmannGirrbach lab. (ALMaghrib street-Baghdad).

**Group 1:** received a CAD-CAM Ceramill Zolid® unilayered transparent zircon (Ceramill Systems, AmannGirrbach, Germany).

**Group 2:** received a CAD-CAM Ceramill ZI units (Zirconium oxide) which is a typically two layer (core and veneer) crowns (Ceramill Systems, AmannGirrbach, Germany).

**Group 3:** received a CAD-CAM Ceramill WAX units that would subsequently invested and heatpressed to fabricate a hot-press ceramic crowns (Ivoclar, Vivadent).

The optical scanner scanned the die models with help of the Ceramill 3D InLab Software Three dimensional images were displayed on the computer monitor, so that all the

surfaces and the finish line were shown clearly (AmannGirrbach Ceramill CAD - CAM System).

### **Crowns Luting and curing**

A dual cure resin luting agent (RelyXTM U200 Self-Adhesive resin, 3M, Germany) was used to cement the ceramic crowns to each tooth, an equal length of the luting resin is dispensed with the special auto dispense property of the resin tube on the mixing pad, was done according to the manufacturer instructions, the mixed cement was painted on the internal surfaces of the crowns.

Crowns were initially seated on the prepared teeth with finger pressure then a stylus with a 5- mm diameter was placed on the tip of a surveyor arm and used to apply a constant 5-Kg load for 10 minutes. Buccal, lingual, mesial and distal tooth-crown margins photo polymerized (Dental light cure unit, LED type, SDI, Australia) at 1 mm distance for 40 seconds each with a light intensity of 400 mW/ cm<sup>2</sup>.<sup>(14)</sup>

After 24 hours of storage in distilled water at 37 °C, all teeth were subjected to 500 thermal cycles between 5 ° and 55 °C using a dwell time of 30 seconds<sup>(15, 16, 17)</sup>.

All the samples were painted with nail varnish under 1mm from the finish line to prevent dye penetration from the root surface , then all the sample were placed in a flat container in upside down position and 2% methylene blue dye (Sparks, USA ) were poured such that the finish line of all samples are covered. All samples were immersed for 12 hours<sup>(13)</sup>. All the samples were kept in the incubator at 37°C temperature.

### **Blocking and Sectioning**

The teeth were separated from each other using the Diamond cut off saw and prepared for blocking with cold cure methyl methacrylate; this was done by fabrication of a special mold

using a Biostar® (Scheu Dental, China) to dimension of 1×1×1.5 cm. Each tooth-crown unit that already blocked with acrylic was longitudinally cut into four pieces using microtome (MT-4 Diamond cut-off saw, USA) with a disk thickness of 0.01mm cutting at high speed with water coolant. The first cut dissect the tooth mesiodistally, the second cut divides the sample buccolingually. The two cuts were made perpendicular to the long axis of the sample; this was done by marking the long axis of the sample using the analyzing rod of the surveyor with a marker pen<sup>(15)</sup>.

### Measurements

**Marginal gap:** Values were recorded under a digital microscope camera at × 160 magnifications (Micros®). Margin gap had been considered as the perpendicular measurement from the margin of the crown to the margin of the preparation<sup>(17)</sup>. Hyper extended and hypo extended margins were excluded and the micrometer was used a unit of length.

**Internal gap:** Values had been measured as a mean of point of lowest measurement and highest measurement of each one of the four pieces derived from cutting between the inner surface of the crown and the tooth apposing tooth surface measured at a perpendicular line to the internal tooth surface<sup>(17)</sup>.

**Micro-leakage:** The presence of microleakage was confirmed by the visualization of a blue colored reaction at the tooth-cement interface. Microleakage patterns are fully registered on the buccal and lingual margins as well as mesial and distal margins with the stereomicroscope (Hamilton, USA) 45X magnification.<sup>(15)</sup>

Microleakage is scored using Tjan's et al. method<sup>(18)</sup>. Fig. (2):

**0**=no microleakage

**1**=microleakage to one-third of axial wall

**2**=microleakage to two thirds of axial wall

**3**=microleakage along the full length of axial wall

**4**=microleakage over the occlusal surface.

### Statistical Analysis

The SPSS software package was used to perform the statistical analysis. Descriptive statistics were computed for marginal fitness, internal fitness and microleakage. Statistical methods were used in order to analyze and assess the results which include:

**A- Descriptive statistics:** Statistical tables, Standard deviation "SD", Standard error, "SE," Maximum mean value, Minimum mean value, Arithmetic mean.

**B-Inferential statistics:**

1- One-way ANOVA (analysis of variance) test was carried out to see if there were any significant differences among the means of groups for marginal fitness.

2- One-way ANOVA (analysis of variance) test was carried out to see if there were any significant differences among the means of groups for internal fitness.

3- Chi-Square test was carried out to see if there were any significant differences among the means of groups for microleakage.

4- Correlation test between marginal and internal fitness.

5- Correlation test between Marginal fitness and microleakage.

Statistical significance according to probability value (P) was determined to be as:

1- Non-significant at  $P \geq 0.05$ .

2- Significant at  $P < 0.05$ .

3- Highly significant at  $P \leq 0.001$ .

## Results

The mean, standard deviation, standard error minimum and maximum mean values for marginal gap internal fitness and microleakage for the three groups are shown in tables 1, 2.

ANOVA test for both marginal gap and internal fitness is shown in table 3. Chi-square test for microleakage is shown in table 4.

Correlation test between marginal gap and internal fitness is shown in table 5, while the correlation test between marginal gap and microleakage is shown in table 6.

## Discussion

In this study Zolid materials group showed the lowest mean of marginal fitness values ( $61.39 \pm 4.16 \mu\text{m}$ ) whereas zircon materials group and Empress 2 materials group showed mean marginal values of ( $70 \pm 2.46 \mu\text{m}$ ) and ( $72.16 \pm 3.55 \mu\text{m}$ ) respectively.

These results could be due to Zolid is a single-layered computer-aided design / computer - aided manufacturing material that is subjected to a less firing cycles than that for zircon which is double layered computer-aided design/computer-aided manufacturing material or that for Empress 2 which is a heat-pressed ceramic material. Additionally, these results could be due to that Zolid material required less amount of heat for sintering compared to that for zircon and Empress 2, and this could be due to the unique composition of Zolid material.

Other possible causes is that zircon and Empress 2 usually require more laboratory steps for fabrication and processing which might increase the possibility for errors and distortion. Zolid requires fewer steps for fabrication and processing which in turn reduces chances for errors.

When all-ceramic crowns are fabricated conventionally, the ceramic is cast from ceramic ingots or shaped from firing porcelain powder. Therefore, distortions that occur during the manufacturing process will adversely affect crown fitting. These distortions include Influence of firing cycles and the effect of the veneering layer(s). This is a conspicuous disadvantage of the double-layer type of CAD/CAM crowns materials (zircon and Empress 2). Conversely, the single layer type of CAD/CAM crowns materials (Zolid) does not require conventional laboratory works (Bindl and Mormann 2006) <sup>(20)</sup>.

It has been reported that the internal gap of conventional all-ceramic crowns was within the range of 49 to 136  $\mu\text{m}$ . <sup>(19,20)</sup> In this study, internal gaps smaller than that of conventional all-ceramic crowns were produced, especially with the Zolid group materials ( $99.24 \pm 2.86 \mu\text{m}$ ) whereas zircon group materials and Empress 2 group materials showed ( $113 \pm 1.99 \mu\text{m}$ ) and ( $122 \pm 6.21 \mu\text{m}$ ) respectively.

For the Zolid single layer system fabricated directly from the milling block, relatively small internal gaps existed. This is because of the good marginal adaptation that was shown by Zolid group material.

One of the major objectives of tooth restoration is the protection of exposed dentine against bacteria and their toxins <sup>(21)</sup>. The interface between the restoration and dental hard tissue is an area of clinical concern as insufficient sealing can result in marginal discoloration, secondary caries, and pulpitis <sup>(22)</sup>. For that reason, adequate sealing is essential for optimal clinical performance <sup>(23)</sup>.

In this study microleakage was measured as scores, in which Zolid group materials showed the lowest mean of ( $0.55 \pm 0.42$ ) whereas zircon

group materials and Empress 2 group materials showed a means of  $(1.38 \pm 0.69)$  and  $(2.15 \pm 0.51)$  respectively. There was significant relation between groups and this may be due to the effect of the dual cure resin cement.

In this study, correlation test between marginal and internal fitness showed highly significant correlation of the marginal and internal fitness ( $P < 0.01$ ). This might be due the equal thickness of the crown restoration permits uniform and constant changes during the successive fabrication procedures which result in merely even alteration in their dimensions and shapes.

Microleakage can be related to margin misfit, although no strong correlation between margin fit and microleakage scores in complete crowns has been demonstrated.<sup>(19, 22, 24, 25, 26)</sup> Marginal opening did not directly correlate with marginal microleakage.<sup>24</sup> Also, the authors stated that a complex interaction between variables related to dental restoration, luting agent, and tooth structure probably influenced microleakage.

These results could be due to luting agents, Adhesive luting agents have been shown to be less soluble, biocompatible, and bacteriostatic. To explain this, Fick's first law of diffusion states that "the rate of material dissolution is independent of the exposed area (amount of luting agent)"<sup>(15)</sup>. Correlation values between misfit and microleakage were low because the gap formation at the tooth-cement interface partially accounts for the microleakage values observed.

This in vitro study showed that there was no strong correlation between margin fit parameters and microleakage in this technique ( $P > 0.05$ ). This observation comes in agreement with the findings of White,

et al.<sup>(24)</sup> and a study conducted by Piwowarczyk et al in 2005.<sup>(26)</sup>

## Conclusions

Within the limit of this in vitro study, it was concluded that Zolid material show the best for marginal adaptation, internal fitness and less microleakage compared to the two groups. There was highly significant correlation between marginal and internal fitness for the three groups. There was nonsignificant correlation between microleakage and marginal fitness. Also CAD-CAM ceramic is better than heat-pressed ceramic.

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Table (1): descriptive statistics of analysis of marginal fitness and internal Fitness (in  $\mu\text{m}$ ) for experimental groups

|                         |                  | N  | Mean (in $\mu\text{m}$ ) | SD   | SE   | Min. (in $\mu\text{m}$ ) | Max. (in $\mu\text{m}$ ) |
|-------------------------|------------------|----|--------------------------|------|------|--------------------------|--------------------------|
| <b>Marginal Fitness</b> | <b>Zolid</b>     | 15 | 61.39                    | 4.16 | 1.07 | 54.167                   | 67.734                   |
|                         | <b>Zircon</b>    | 15 | 70.28                    | 2.46 | 0.64 | 66.770                   | 74.036                   |
|                         | <b>Empress 2</b> | 15 | 72.16                    | 3.55 | 0.92 | 65.157                   | 78.453                   |
| <b>Internal Fitness</b> | <b>Zolid</b>     | 15 | 99.24                    | 2.86 | 0.74 | 93.584                   | 100.278                  |
|                         | <b>Zircon</b>    | 15 | 113.73                   | 7.69 | 1.99 | 101.848                  | 122.204                  |
|                         | <b>Empress 2</b> | 15 | 122.20                   | 6.21 | 1.60 | 111.383                  | 131.499                  |

Table (2): Microleakage descriptive statistics of analysis of experimental groups (in scores)

|                         |                  | N  | Mean (in $\mu\text{m}$ ) | SD   | SE   | Min. (in $\mu\text{m}$ ) | Max. (in $\mu\text{m}$ ) |
|-------------------------|------------------|----|--------------------------|------|------|--------------------------|--------------------------|
| <b>Internal Fitness</b> | <b>Zolid</b>     | 15 | 0.55                     | 0.42 | 0.11 | 0.00                     | 1.50                     |
|                         | <b>Zircon</b>    | 15 | 1.38                     | 0.69 | 0.18 | 0.25                     | 2.50                     |
|                         | <b>Empress 2</b> | 15 | 2.15                     | 0.51 | 0.13 | 1.25                     | 3.00                     |

Table (3): ANOVA test among groups for marginal fitness and internal Fitness analysis

|                         | Source                  | SS        | df | MS      | F     | P      | Sig. |
|-------------------------|-------------------------|-----------|----|---------|-------|--------|------|
| <b>Marginal Fitness</b> | <b>(between groups)</b> | 993.2669  | 2  | 496.63  | 41.43 | <0.001 | HS   |
|                         | <b>Error</b>            | 503.5167  | 42 | 11.99   |       |        |      |
|                         | <b>Total</b>            | 1496.7836 | 44 |         |       |        |      |
| <b>Internal Fitness</b> | <b>(between groups)</b> | 4046.3726 | 2  | 2023.19 | 57.3  | <0.001 | HS   |
|                         | <b>Error</b>            | 1482.9076 | 42 | 35.31   |       |        |      |
|                         | <b>Total</b>            | 5529.2802 | 44 |         |       |        |      |

Table (4): Chi-Square test for microleakage

| Taste Statistics <sup>(a,b)</sup> | Dye Penetration Score |
|-----------------------------------|-----------------------|
| <b>Chi-Square</b>                 | <b>25.91</b>          |
| <b>Df</b>                         | <b>2</b>              |
| <b>Asymp Sig</b>                  | <b>&lt;0.0001</b>     |

<sup>(a)</sup> Kruskal – Wallis test<sup>(b)</sup> Variable: Material

Table (5) Correlation between Marginal and Internal Fitness for each group

|                  |                         | Mean   | S.D  | t – test | P – value | Sig.      |
|------------------|-------------------------|--------|------|----------|-----------|-----------|
| <b>Zolid</b>     | <b>Marginal Fitness</b> | 61.39  | 4.16 | 29.05    | 0.000     | <b>HS</b> |
|                  | <b>Internal Fitness</b> | 99.24  | 2.86 |          |           |           |
| <b>Zircon</b>    | <b>Marginal Fitness</b> | 70.28  | 2.46 | 20.83    | 0.000     | <b>HS</b> |
|                  | <b>Internal Fitness</b> | 113.73 | 7.69 |          |           |           |
| <b>Empress 2</b> | <b>Marginal Fitness</b> | 72.16  | 3.55 | 27.10    | 0.000     | <b>HS</b> |
|                  | <b>Internal Fitness</b> | 122.20 | 6.21 |          |           |           |

Table (6) Correlation between Marginal fitness and Microleakage for each group

|                  |                         | Mean   | S.D  | t – test | P – value | Sig.      |
|------------------|-------------------------|--------|------|----------|-----------|-----------|
| <b>Zolid</b>     | <b>Marginal Fitness</b> | 61.39  | 4.16 | 29.05    | 0.000     | <b>HS</b> |
|                  | <b>Microleakage</b>     | 99.24  | 2.86 |          |           |           |
| <b>Zircon</b>    | <b>Marginal Fitness</b> | 70.28  | 2.46 | 20.83    | 0.000     | <b>HS</b> |
|                  | <b>Microleakage</b>     | 113.73 | 7.69 |          |           |           |
| <b>Empress 2</b> | <b>Marginal Fitness</b> | 72.16  | 3.55 | 27.10    | 0.000     | <b>HS</b> |
|                  | <b>Microleakage</b>     | 122.20 | 6.21 |          |           |           |



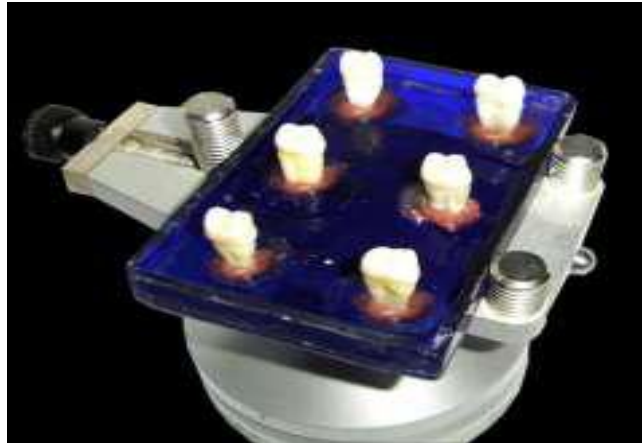


Figure (1): Teeth in place with the aid of the analyzing rod of the dental surveyor and the dental wax, 2cm space between each tooth.

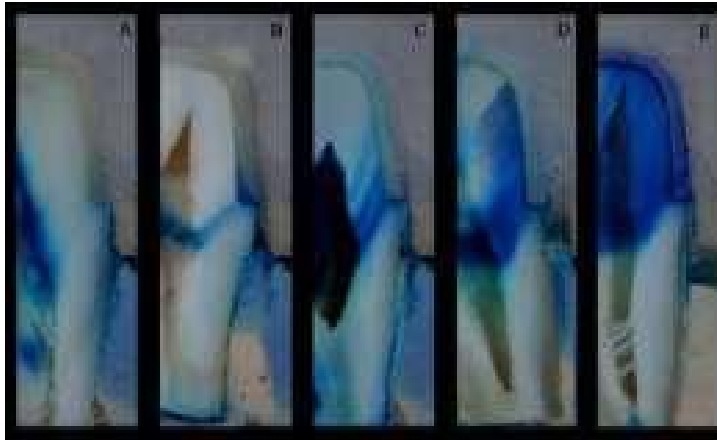


Figure (2): Microleakage score measurements: (A), 0 score; (B), 1; (C), 2; (D), 3; (E), 4