



## Effect of Thermo-Mechanical Aging on The Marginal Fit of Two Types of Monolithic Zirconia Crowns With Two Finish Line Designs

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### ABSTRACT

**OBJECTIVES:** The purpose of this study was to compare the marginal fit of two CAD/CAM monolithic zirconia crowns with two finish line designs after thermo-mechanical aging. **MATERIALS AND METHODS:** A total of 20 zirconia crowns were divided into two groups Bruxzir and Prettau zirconia (n=10). Each type of zirconia crowns was divided into two groups according to the finish line design chisel (CH) and deep chamfer (DC) groups (n=5) After cementation of crowns to their corresponding dies, the vertical marginal gap was measured then the all crowns of both groups were subjected to thermo-mechanical aging then the vertical marginal gap was measured again. **RESULTS:** Statistical analysis showed that. The thermo-mechanical aging significantly increased the vertical marginal gap where DC non-aged Bruxzir recording the lowest mean value ( $31.41 \pm 5.9$ ) and the CH aged Bruxzir recorded the highest mean value ( $95.28 \pm 9.2$ ) as indicated by three-way ANOVA test ( $F= 23.0741$ ,  $p < 0.0001 < 0.05$ ). **CONCLUSIONS:** Thermo-mechanical aging significantly increased the vertical Marginal gap and the deep chamfer finish line preparation is preferred for construction of monolithic zirconia crowns.

### INTRODUCTION

The popularity of ceramic restorations stems from the properties of the ceramic materials itself such as translucency, esthetic, and biocompatibility.<sup>1,2</sup> The marginal fit is considered a very important criterion that should be carefully considered in the final restoration.<sup>3</sup> Inaccurate fit creates potential space between the internal margin of restoration and the prepared tooth. As this space increases, and since most of luting cements are soluble in oral fluid, bacterial plaque can be accumulated at this defective area with subsequent gingival inflammation, caries, and pulpal lesions.<sup>4-6</sup>

### KEYWORDS

*Thermo-Mechanical,  
Marginal Fit,  
Zirconia Crowns*

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Many CAD/CAM systems including inoffice and laboratory have been introduced for production of both coping for ceramic veneer application and anatomic fully-contoured restorations out of ceramic blocks.<sup>5,7-9</sup> One of the common misconceptions that the conventionally made restorations are more accurately fit than the CAD/CAM fabricated restorations.<sup>10</sup> in a study compared anterior CAD/CAM manufactured zirconia restoration to a metal-ceramic one with sufficient number of samples and sufficient measurements per specimen found that there are no significant differences between both types of restorations and that both of them are within the clinically accepted range.<sup>11</sup>

The white opaque color of zirconia framework requires veneering with more esthetic glassy porcelain to achieve natural appearance of final restoration.<sup>12</sup> However, cracking, chipping, and delamination of the porcelain veneer has been reported to be a major complication of these restorations.<sup>13-15</sup> Recently, fully contoured (monolithic) zirconia has been developed as an alternative and in order to overcome the failure of veneered zirconia restoration.<sup>12,16,17</sup>

Several investigators reported that the marginal fit of CAD/CAM manufactured ceramic restorations was dependent on different factors such as veneering process, preparation convergence, cement space, and type of finish line.<sup>18-20</sup> Monolithic zirconia enables the use of more conservative finish line designs. Some articles stated that some of the advantages of monolithic zirconia are reduction of breakage possibilities, avoiding chipping, high strength, minimal occlusal adjustment, and marginal accuracy.<sup>21-23</sup> Moreover, the assessment of thermo-mechanical aging may provide information about the long term stability of restoration.<sup>24</sup>

The purpose of the present study was to evaluate the effect of thermo-mechanical aging on the marginal fit of two types of monolithic zirconia crowns (Bruxzir and Prettau) with two finish line designs (1mm deep chamfer, and 0.3mm chisel). The null hypothesis was that the thermo-mechanical aging will have no effect on marginal fit of monolithic zirconia crowns.

## MATERIALS AND METHODS

Two different types of monolithic translucent zirconia materials were used in this study shown in (table 1).

Brand	Material type	Manufacturer	Lot #
Bruxzir	Translucent monolithic zirconia	Glidewell Laboratories, Irvine, USA	BZ0002762
Prettau	Translucent monolithic zirconia	Zirkonzahn, Taufers, Italy	ZB6088A

### Master dies fabrication

Two standard circular metal dies were milled by industrial lathe milling machine to simulate the preparation for mandibular first molar tooth. Each metal die prepared with flat occlusal surface and functional bevel, 5mm occluso-gingival height, and 12° degree axial taper, with two different finish line designs (one metal die with a circumferential 1mm deep chamfer, and the other with 0.3mm chisel finish line).

### Crowns fabrication

A 10 Polyether impression (Impregum, 3M ESPE – Germany) was taken using custom made trays and 10 master resin dies were fabricated for each metal die.

All resin dies were sprayed by shera scan spray (Dentech Lab Supplies Ltd PO Box 87262 Meadow-bank, Auckland 1742) then, scanned via blue LED 3D dental scanner named Medit Identica Hybrid (Medit Company, 19 Inchon-ro 22-gil, Seongbuk-gu, Seoul, Korea 82-2-2193-9600). The crowns are designed by Exocad cad system (Exocad GmbH, Julius-Reiber-Str. 37, D-64293 Darmstadt, Germany). The data of the completed design is merged and saved in a file, a 5-axis dental milling machine Roland DWX-51D (ROLAND DGA CORP. | 15363 BARRANCA PARKWAY | IRVINE, CALIFORNIA) was used to mill 20 zirconia crowns out of zirconia blanks. (**Figure 1**)

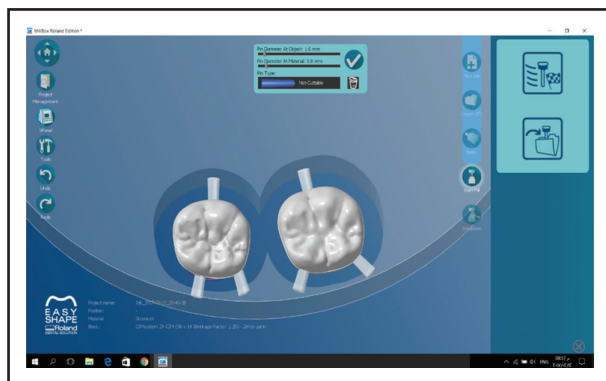


Fig. (1) Showing the type of material, blank size, its enlargement factor was inserted to the program and the selection of position of the restorations and their pins (nesting).

### Crowns assignment

Twenty monolithic zirconia crowns were fabricated for this study, 10 crowns of (Bruxzir monolithic zirconia), and 10 crowns of (Prettau monolithic zirconia). Each 10 crowns were divided into two groups of 5 crowns according to the finish line design. DC group (1mm deep chamfer) and CH group (0.3mm chisel).

All crowns were cemented to their corresponding dies using dual-curing self-adhesive resin cement (Theracem, BISCO, Inc. Schaumburg, IL60193 U.S.A) according to the manufacturer recommendation; half of each group was subjected to thermo-mechanical aging.

### Thermo-mechanical aging

Mechanical aging test was conducted using the newly developed four stations multi-modal ROBOTA chewing simulator\* integrated with thermo-cyclic protocol operated on servo-motor (Model ACH-09075DC-T, AD-Tech Technology CO., LTD., Germany). ROBOTA chewing simulator which has four chambers simulating the vertical and horizontal movements simultaneously in the thermodynamic condition. A weight of 5 kg which is comparable to 49 N of chewing force was exerted. The test was repeated 75000 times to clinically simulate the 6 months chewing condition.<sup>25</sup>

### Vertical Marginal Gap assessment before and after Thermo-mechanical aging

Each specimen was photographed using USB Digital microscope with a built-in camera (Scope Capture Digital Microscope, Guangdong, China) connected with an IBM compatible personal computer using a fixed magnification of 110X. A digital image analysis system (Image J 1.43U, National Institute of Health, USA) was used to measure and qualitatively evaluate the gap width. Within the Image J software, all limits, sizes, frames and measured parameters are expressed in pixels. Therefore, system calibration was done to convert the pixels into absolute real world units. Calibration was made by comparing an object of known size (a ruler in this study) with a scale generated by the Image J software. Samples were held in place over their corresponding dies using a specially designed and fabricated holding device. Shots of the margins were taken for each sample before and after thermo-mechanical aging. Then morphometric measurements were done for each shot [3 equidistant landmarks along the cervical circumference corresponding to each surface of the sample (Buccal, mesial, lingual, and distal). Measurement at each point was repeated five times.

Data analysis was performed in several steps. Initially, descriptive statistics for each group results. Three-way analysis of variance ANOVA test of significance was done for comparing variables (Zr ceramic, margin design and mechanical aging) affecting mean values. One-way ANOVA followed by pair-wise Tukey's post-hoc tests were performed if it showed significance between subgroups. Student t-test was performed to detect interaction between main groups with each margin and aging. Statistical analysis was performed using Asistat 7.6 statistics software for Windows (Campina Grande, Paraiba state, Brazil). P values  $\leq 0.05$  are considered to be statistically significant in all tests.

## RESULTS

### Vertical Marginal Gap

#### *For Bruxzir zirconia crowns;*

It was found that the highest vertical marginal gap mean $\pm$ SD values were recorded with **aged CH** group (95.28 $\pm$ 9.2), while the lowest vertical marginal gap mean $\pm$ SD values were for **non-aged DC** group (31.41 $\pm$ 5.9). The difference between margin design groups was statistically **significant** as indicated by one-way ANOVA test (F=133.19,  $p < 0.0001 < 0.05$ ).

#### *For Prettau zirconia crowns;*

It was found that the highest vertical marginal gap mean $\pm$ SD values were recorded with **aged DC** group; lowest vertical marginal gap mean $\pm$ SD values were for **non-aged DC** group. The difference between margin design groups was statistically (F=36.15,  $p < 0.0001 < 0.05$ ). Tukey's post-hoc test showed no-significant ( $p > 0.05$ ) difference between aged groups - table (2) and figure (2)

#### **Bruxzir vs. Prettau**

**With non-aged DC margin;** it was found that Prettau group recorded statistically significant higher vertical marginal gap mean values than Bruxzir group as indicated by t-test (t=17.6,  $p < 0.0001 < 0.05$ )

#### **With aged DC margin;**

It was found that Prettau group recorded statistically significant higher vertical marginal gap mean values than Bruxzir group as indicated by t-test (t=12.47,  $p < 0.0001 < 0.05$ )

#### **With non-aged CH margin;**

It was found that Prettau recorded statistically significant higher vertical marginal gap mean values than Bruxzir as indicated by t-test (t=2.26,  $p = 0.0297 < 0.05$ )

#### **With aged chesil margin;**

It was found that Bruxzir recorded statistically non-significant higher vertical marginal gap mean values than Prettau as indicated by t-test (t=0.3143,  $p = 0.7551 > 0.05$ )

*Totally, irrespective of margin design or aging, it was found that **Prettau** recorded statistically significant higher vertical marginal gap mean values than **Bruxzir** as indicated by three-way ANOVA test (F= 23.0741,  $p < 0.0001 < 0.05$ ).*

*Totally, regardless to type of zirconia or aging, it was found that **CH** margin design group recorded statistically significant higher vertical marginal gap mean values than **DC** margin design group as indicated by three-way ANOVA test (F= 174.52,  $p < 0.0001 < 0.05$ ).*

Table (2) Vertical marginal gap results (Mean values  $\pm$ SD) for both Zirconia ceramics as function of margin design and aging

Variable	Margin design				
	DC		CH		
	Non-aged	Aged	Non-aged	Aged	
Zr ceramic	Bruxzir	31.41 <sup>d</sup> $\pm$ 5.9	62.35 <sup>b</sup> $\pm$ 6.9	52.78 <sup>c</sup> $\pm$ 10.5	95.28 <sup>a</sup> $\pm$ 9.2
	Prettau	80.48 <sup>b</sup> $\pm$ 7.9	95.05 <sup>a</sup> $\pm$ 6.4	62.27 <sup>c</sup> $\pm$ 12.3	94.07 <sup>a</sup> $\pm$ 8.9
t-test	P value	<0.0001*	<0.0001*	0.0297*	0.7551 ns

Different letters in same row indicating significant ( $p < 0.05$ )  
smd for columns = 3.45172 \*; significant ( $p > 0.05$ )

Significant minimum difference (smd) for rows = 3.45951  
ns; non-significant ( $p > 0.05$ )

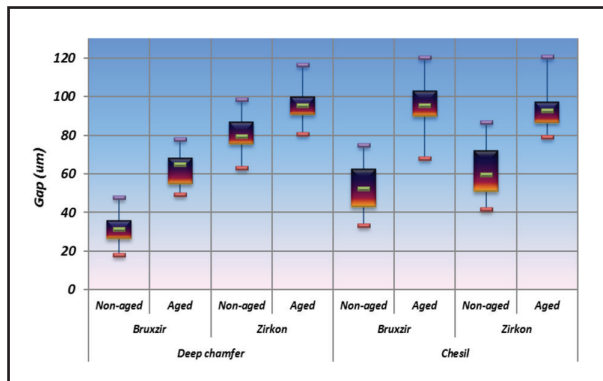


Fig. (2) Box plot showing vertical marginal gap mean values for both Zirconia ceramics as function of margin design and aging

*Totally, irrespective of the type of zirconia or margin design, it was found that aged group recorded statistically significant higher vertical marginal gap mean values than non-aged group as indicated by three-way ANOVA test ( $F= 371.7359$ ,  $p<0.0001<0.05$ ).*

## DISCUSSION

In the present study two standardized metal dies with two margin designs were used and duplicated with epoxy resin as a substitution to natural teeth to allow for fabrication of identical crowns, which is important for a reliable comparison of different groups.<sup>26</sup>

The metal dies were machine-milled to simulate a preparation of mandibular first molar for full coverage all-ceramic crown with 5 mm occluso-gingival height, 8 mm cervical diameter according to other studies.<sup>24, 27</sup> A functional bevel is made to simulate clinical conditions and to achieve the exact positioning of the crowns on their corresponding dies. The total occlusal convergence angle was made 12° as it was recommended that the proper convergence angle should be in a range of 10° to 20°.<sup>28</sup> In addition, it was found that preparation angle of 12° achieved the best overall precision of zirconia-based single crowns in range of 36.6 and 45.5µm.<sup>29</sup>

The vertical marginal gap measurement was selected as it is one of the most frequently used methods to quantify the accuracy of fit of a restoration. The marginal fit was evaluated by direct viewing with external measurements using a digital microscope at fixed magnification of x100 this measurement technique has the advantage of being non-invasive and is, therefore, useful to determine the precision of fit of the whole restoration margin.<sup>5</sup> all measurements were made by the same operator to avoid errors as much as possible.

Even though the results of this study support the rejection of the null hypothesis that the thermo-mechanical aging will have no effect on marginal fit of monolithic zirconia crowns the marginal discrepancies of the tested groups were within the threshold of clinical acceptability, the 120 µm proposed by (McLean and Fraunhofer 1971).<sup>30</sup>

The thermo-mechanical aging performed in this study was found to significantly increase the vertical marginal gap. Although the critical aging temperature of zirconia suggested to be above 100°C<sup>31</sup> which is far from the applied temperature in the present test (5-55°C), it was found that artificial Aging significantly increased the vertical marginal discrepancy through thermo-mechanical loading.<sup>32</sup> Also another study found that conducting 10 h of artificial aging for veneered specimens of (IPS e-max ZirCAD, Ivoclar) resulted in 55% T/M phase transformation.<sup>33</sup> Another explanation for the increased marginal gap with thermo-mechanical aging is related to the wash out of some of the luting cement at the margin as result of fluctuation of temperature during aging process.<sup>24</sup>

When we use the same scanning device, CAD-software, and milling machine it seem to have no influence on the restorations marginal fit,<sup>34</sup> however, the Prettau zirconia crowns recorded statistically significant higher marginal gap mean value than Bruxzir crowns, the reasons of this significant difference in the marginal fit are the difference in their chemical structure, the way of the manufacture of



the zirconia material and consequently their different enlargement factors. The Glidewell Laboratories used the Colloidal technology in the manufacture of Bruxzir zirconia unlike the way of manufacture used by ZirKonzahn Company to manufacture the Prettau zirconia. These findings supported by study stated that the reason of the large contrast in internal fit between Lava and IPS ZirCAD crowns is the differences in material properties, sintering shrinkage, and dimensional stability between the two-zirconia systems.<sup>35</sup> also another study revealed that the differences in marginal fit between each system result from zirconia blocks with various shrinkage rates depending on manufacturing company, scanning process, size of milling bur used, and the number of milling axis.<sup>36</sup> in addition to the type of zirconia material itself might also affect the marginal fit.<sup>37</sup>

In the present study; regardless to zirconia type, the CH group recorded statistically significant higher marginal gap mean value than DC group. Although, the knife-edge finish line resulted in lower marginal opening values in another study they recommended shoulder and mini-chamfer in clinical application from biological and technical standpoint, as it triggers the wedging effect at the margin and may provide additional marginal bulk.<sup>38</sup>

However, these recommendations to avoid knife-edge margins are not supported by clinical study as they found that knife-edge margins allow clinical performance similar to that reported by other margin designs but with less invasive preparations.<sup>39</sup> However, others do not support this, as the histological evidence was showing no difference in periodontal health among different patterns of margin designs.<sup>40, 41</sup> Moreover, knife-edge margins showed no more influence over gingival conditions than natural teeth in a sample of periodontal patients.<sup>42</sup>

The limitation of this study include the use of resin dies for measuring the marginal gap which doesn't represent the patient's mouth however, it is good for standardization. Also the vertical marginal gap was measured. The horizontal relationship was not quantified

## CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

- 1- The vertical marginal gap values of the tested groups were all within the clinically acceptable threshold (120  $\mu$ m).
- 2- Thermo-mechanical aging significantly increased the vertical marginal gap.
- 3- Deep chamfer finish line preparation is preferred with monolithic zirconia crowns.

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