Evaluation of internal adaptation of full contour zirconia crowns versus veneered zirconia crowns: In vitro study

Abdulsattar Hasan Al-Baadani¹²

¹Department of Fixed Prosthodontic, Faculty of Dentistry, Thamar University, Yemen, ²Department of Fixed Prosthodontic, Faculty of Oral and Dental Medicine, Cairo University, Egypt.

Abstract

Background: The fit of zirconia crowns varies with the variation in the finish line design. In this study, we evaluate the internal adaptation of full contour zirconia crowns to veneered zirconia with two different finish line designs.

Materials and Methods: 24 dies were received 12 full contour zirconia crowns (Prettau) and 12 veneered zirconia crowns (ICE Zirconia). Each group will be subdivided into two equally subgroups: (Subgroup 1, n = 6) with shoulder finish (SH) line and (Subgroup 2, n = 6) with deep chamfer finish (CH) line. Measurements of internal fitness were recorded.

Results: The lowest overall mean value of internal adaptation was recorded with ICE Zirconia crowns with deep CH line design (74.6 μm ± 19.14), then with SH line design (93.40 μm ± 9.99), followed by Prettau zirconia crowns with deep CH line design (157 μm ± 27.25) and finally Prettau zirconia crowns with SH line design (181 μm ± 24.86).

Conclusions: The overall mean values of the internal adaptation were within the clinical acceptance range. The ICE Zirconia crowns recorded better overall internal adaptation values than Prettau crowns with both finish line designs.

Keywords
Fit, full contour, internal adaptation, zirconia

Introduction

All-ceramic crowns are popular for the restoration of single teeth due to their excellent esthetic appearance and metal-free structure. There was an introduction of various materials and techniques for metal free all ceramic restorations. Zirconia was known for its superior mechanical properties. Its strength (900-1150 mpa) and fracture toughness (6.2-7.4 mpa x m⁻⁰.⁵) which place it as an excellent choice as high-strength ceramic core material.

Zirconia first used as orthopedic implants in the nineties then was introduced to the market for use as a framework in prosthodontics about 10 years ago. Concurrently to the generalization of computer-aided-design (CAD) and computer-aided-manufacturing (CAM) processes, zirconium dioxide-based partial fixed dental prostheses (FDP) have been suggested as an alternative treatment to traditional metal ceramic FDPs. However, clinical studies evaluating their longevity and related complications are limited. The clinical long-term behavior of veneered zirconia-based core restorations was not only limited by the strength of the framework itself. Clinical trials have shown that the long-term success is greatly affected by the veneering process, as cracking of the veneer material is reported to be the most prevalent cause of failure while zirconia framework fractures are generally uncommon. The prevalence of interfacial failures led to the clinical application of monolithic zirconia. However, some properties of monolithic zirconia need to be improved such as relative opacity, monochromatic appearance, and marginal adaptation after polishing and glazing. The fit of zirconia veneered copings or full contour zirconia varies with the variation in the finish line design and preparation angles.

Full contour (monolithic) zirconia crowns have become popular the last few years because of their flexural strength, tooth color, minimal wear on opposing teeth, conservative tooth preparation, and the potential for excellent long-term clinical success. Without a layering porcelain, the clinical performance has been excellent, as long as tooth preparation is adequate and the dental laboratory and clinical materials are handled in the correct manner. With monolithic zirconia, a preparation can be done with reduction very similar to that of full-gold restorations. An occlusal clearance of 1.0-1.5 mm is recommended. Feather-edge
margins are acceptable depending on laboratory team’s skill.\[5\]

There are a lot of researches and studies that have been done with different types of finish lines. Some studies fabricated zirconia fixed partial dentures (FPDs) restorations with shoulder finish (SH) line.\[6,8\] Other studied fabricated it with chamfer finish (CH) line\[9,15\] or both of them (shoulder and CH lines).\[16,20\]

Shoulderless or knife edge finish line was also evaluated with zirconia restorations.\[7,10,15,21,22\] Therefore, this study will assess internal fit adaptation of full contour zirconia restoration relative to zirconia coping with porcelain veneer with two different finish line designs. The null hypotheses tested will be there are no differences in internal fit regardless both the type of finish line (shoulder and chamfer) and the type of restoration (full contour zirconia or Veneered Zirconia \{yttrium stabilized-tetragonal zirconia polycrystals \{Y-TZP\}\}).

**Materials and Methods**

**Ceramic blocks**

1. Full contour zirconia (Prettau): Partially sintered Y-TZPs blocks (98 mm × 14 mm) were used for the production of full contour anatomical crowns. The standard chemical composition of the Prettau blocks is shown in Table 1

2. Veneered zirconia (ICE Zirconia): Partially sintered Y-TZP blocks (98 mm × 10 mm) were used for the production of veneered zirconia crowns. The standard chemical composition of the ICE Zirconia blocks is shown in Table 1.

**Master dies construction**

Two master stainless steel dies (a) and (b) were machined representing the all-ceramic crown preparation for the maxillary first premolar tooth. The two specially designed stainless steel dies with Teflon cylindrical base were machined in a standardized manner using an engineering lathe machine (Automatic feedback lathe - BV20B-L, Bengu Dome Sitimashim tool, China). Each die was made to provide 15° total occlusal convergence angle and axial occluso-gingival height of 6 mm [Figure 1]. A 90° SH line of 1 mm thickness was prepared in die [Figure 2a] and CH of 1 mm thickness was prepared in die [Figure 2b]. A U-shaped groove, 3 mm length and 0.5 mm depth, was made parallel to the long axis on both dies for repeatable seating of samples and to prevent their rotation. This procedure was carried out using high-speed handpiece (W&H Dental Work Burmoos, Austria) under water coolant using a round-end cylindrical diamond bur (Suzhou Syndent Tools Co., Ltd.) [Figure 2a and b].

Table 1: Prettau and ICE Zirconia chemical compositions

<table>
<thead>
<tr>
<th>Materials Description</th>
<th>Composition</th>
<th>Manufactures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Contour Zirconia (Prettau)</td>
<td>ZrO₂ + HfO₂ + Y₂O₃ &gt; 99.6 wt%</td>
<td>Prettau, Zirkonzahn, Pustertal, Italy</td>
</tr>
<tr>
<td>Block ZRAB8001 (98 mm×14 mm)</td>
<td>Y₂O₃: 5.2 wt%</td>
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<tr>
<td>Al₂O₃: 0.2-0.5 wt%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SiO₂: Max. 0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fe₂: Max. 0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na₂O: Max. 0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other oxide: &lt;0.2 wt%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veneered ICE Zirconia</td>
<td>ZrO₂ + HfO₂ + Y₂O₃ + Al₂O₃ &gt; 99.9 wt%</td>
<td>ICE Zirconia, Zirkonzahn, Pustertal, Italy</td>
</tr>
<tr>
<td>Block ZRAD8021 (98 mm×10 mm)</td>
<td>Y₂O₃: 5.15±0.20 wt%</td>
<td></td>
</tr>
<tr>
<td>Al₂O₃: 0.25±0.01 wt%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SiO₂: Max. 0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fe₂: Max. 0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na₂O: Max. 0.04</td>
<td></td>
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</tbody>
</table>
Working dies fabrication

To obtain an exact replica to the stainless steel dies, a cylindrical copper perforated tray having an internal diameter of 22 mm, and 26 mm height was constructed [Figure 3]. Impressions for the prepared stainless steel dies were made using medium viscosity additional silicone impression material (Elite HD+, ZERC100730 - Zhermack, Italy). A Teflon cylindrical base was fabricated having a central hole of 10 mm diameter and 15 mm depth to secure the stainless steel die in place during impression [Figure 4].

24 impressions were made; giving a total number of 12 impressions for each master dies. The impressions were then poured into Type IV improved dental stone (Super - Hard Dental Stone (Type IV), ZOGEAR-TM025, Shanghai, China). Die materials were manipulated following the manufacturer instructions.

Fabrication of full contour zirconia crowns

The Roland Milling Unit (Roland Milling Machine, DWX-50, Japan) was used to mill the Prettau Blocks to produce the CAD/CAM milled full contour crowns. Each stone die was scanned with Zirkonzahn scanner. On the computer software, the finish line was marked, and the spacer parameter was adjusted as indicated by the manufacturer (50 μm). The full anatomical crown was designed, 1.5 mm in thickness and each crown was given a number in the software that corresponds to its scanned stone working die. The Prettau block (Y-TZP) was plugged into the 5 axis/auto tool changer milling machine, and milling procedure was started with 2 L bur to mill the outer and internal form of the crowns. The final finishing was achieved using 1 L bur. The final shape of the milled crown was 20% larger than the actual crown size to compensate the shrinkage of the zirconia during sintering. The crowns were carefully placed on the tray of the sintering furnace and a preinstalled sintering program for the Prettau (Y-TZP) crowns was selected. The fabrication of ICE Zirconia copings was similar as mentioned previously to the construction of full contour zirconia except the dimension of the Ice blocks was (98 mm × 10 mm) rather than (98 × 14) in Prettau blocks. To standardize the veneering thickness Silicon Index (Zetaplus Putty, ZERC100730 - Zhermack, Italy) of a previously milled full anatomical Prettau crown was made and was used to guide the veneer contour and anatomy in thickness and external dimensions.[23] Veneering of the cores was done using the layering technique by one specialist technician as follows: The specimens were cleaned with 70% ethyl alcohol for 10 min in a digital ultrasonic cleaner (Model cd-4820, China) and air dried. ICE Zirconia copings were veneered with wash dentin material using a brush to create an even layer to be fired at 920°C for 17 min. This ensures controlled shrinkage of the veneering material and homogenous bond to the zirconia coping. Copings were then; layered by sintering of the veneering material in which ceramic dentin powder and an appropriate amount of the indicated liquid were mixed in vacuum to form slurry. The material was applied with a brush to the zirconium coping and properly vibrated with speculation for 30 s; excess liquid was absorbed and sucked off with a paper tissue then the samples were positioned on the firing tray. The specimens were pre-heated in porcelain furnace (Programat, P300, Ivoclar Vivadent), to dry at 400°C for 6 min before the temperature was increased at 55°C/min to 820°C under vacuum for 17 min. After sintering, the space left by shrinkage was filled with a second layer of veneering material applied and condensed for another 30 s. Each specimen was placed in the mold to ensure correct dimensions of the crown shape and then subjected to a second dentin firing cycle. The occlusal surface of the crown shapes was flattened and adjusted to the same height. Finally, the crowns were manually finished and polished before the glaze firing.

Measurement of internal adaptation

A specially designed loading device was constructed to assure constant pressure to the zirconia crowns on their corresponding metal dies during replica technique steps. The loading device consist of two flat rectangular plates parallel to each other and connected together with two metal tubes, a circular base with a metal hole on the lower plate for holding the die during the test. The upper plate engages a central tube that carrying a circular loading plate that holds a 4 kg load. A light-body silicon rubber impression paste was used for the purpose of recording the cement space and the metal die. A light-
body material was injected into the fitting surface of the crown and positioned in the corresponding metal die with the constant defined load of 40 N for 3 min using the loading device. After setting of the light silicon rubber, the crown was removed from the metal die. The film of the light-body impression material adhered to the fitting surface of the crown in all instances. The crowns were boxed with pink wax and to support the thin light silicon impression film; heavy body silicon was injected onto the light body at the fitting surface of the crown so as to adhere to the light-body film and form one piece with it creating the silicon die replica. After setting of the supporting heavy-body material, each silicon die replica was removed from the crown and carefully segmented with a surgical blade No. 11 in mesio-distal direction. The measured internal adaptation was defined as the perpendicular distance from the internal surface of the crown to the die at five different points on the replica. The following are the five points that were defined for internal adaptation [Figure 1]: P1 - left axial cervical thirds; P2 - left axial occlusal third; P3 - middle occlusal; P4 - right axial occlusal third; and P5 - right axial cervical third [Figure 1]. Measurements were recorded by viewing the specimens at \( \times 12.5 \) magnification under a stereomicroscope. Data of internal adaptation (in microns) for both Prettau zirconia and ICE Zirconia crowns of both deep chamfer and SH line preparation designs were collected and tabulated for evaluation and statistical analysis. Statistical analysis was carried out using SAS program (SAS, 1988). Student’s t-test (Procedure t-test of SAS) was used for testing significant differences in finish line design (deep chamfer and SH line designs) on the internal adaptation results between the Prettau and ICE Zirconia crowns.

**Results**

**Comparison of overall mean values of internal adaptation recorded for finish line design within each restorative system [Table 2]**

From the results of overall mean when comparing both finish line designs within the Prettau crowns, it was found that the lowest overall mean of internal adaptation values was recorded for Prettau zirconia crowns with a deep CH line (157 \( \pm \) 27.25 \( \mu \)m). Prettau zirconia crowns with SH line design recorded higher values (181 \( \pm \) 24.86 \( \mu \)m). However, the differences were statistically insignificant \( (P > 0.05) \) between the two finish line designs. For the Ice Zirconia crowns, it was found that the lowest overall mean of internal adaptation values was recorded with the deep CH line (74.6 \( \pm \) 19.14 \( \mu \)m) while with SH line design recorded higher values (93.40 \( \pm \) 9.99 \( \mu \)m). However, the difference was statistically insignificant \( (P > 0.005) \) between the two finish line designs.

**Comparison between the overall mean values of internal adaptation of restoratives system within each finish line design [Table 3]**

Prettau crowns with deep CH line design (157 \( \pm \) 27.25 \( \mu \)m) showed a higher internal adaptation value when compared to the ICE Zirconia crowns with deep CH line design (74.6 \( \pm \) 19.14 \( \mu \)m).

<table>
<thead>
<tr>
<th>Zirconia</th>
<th>Finish line design</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deep CH line</td>
<td>SH line</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Prettau zirconia</td>
<td>157</td>
<td>27.25</td>
</tr>
<tr>
<td>Ice zirconia</td>
<td>74.6</td>
<td>19.14</td>
</tr>
</tbody>
</table>

\(^{*}P<0.05\) (significant), NS: Non-significant, SD: Standard deviation, SH: Shoulder finish, CH: Chamfer finish

**Table 2: Overall mean values of internal adaptation of Prettau crowns and Ice zirconia crowns with different finish line design**

<table>
<thead>
<tr>
<th>Finish line design</th>
<th>Prettau zirconia</th>
<th>Ice zirconia</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep CH line</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>157</td>
<td>27.25</td>
<td>74.6</td>
</tr>
<tr>
<td>SH line</td>
<td>181</td>
<td>24.86</td>
<td>93.40</td>
</tr>
</tbody>
</table>

\(^{*}P<0.05\) (significant), NS: Non-significant, SD: Standard deviation, SH: Shoulder finish, CH: Chamfer finish

A statistically significant difference \( (P \leq 0.001) \) was observed between the two restorative systems with the deep CH line design Table 2. Whereas with the SH line design, Prettau crowns (181 \( \pm \) 24.86 \( \mu \)m) showed a higher internal adaptation value when compared to ICE Zirconia crowns (93.40 \( \pm \) 9.99 \( \mu \)m) with SH line, indicating better internal adaptation for the ICE Zirconia crowns. There was statistically significant difference \( (P \leq 0.001) \) between the two restorative systems with the SH line design.

**Discussion**

The substantial increase in esthetic consciousness and patient demand for natural appearance dental restoration has led to rapid development in the art and science of ceramic dental materials. Superior esthetic requirements are no longer a luxury. It is the everyday basic need that has pushed dental materials to the edge of its limitations. Contemporary all-ceramic systems combine high-strength properties with improved esthetics and translucent the dental restorations. Y-TZP restorations are gaining popularity due to their good mechanical properties, esthetics, and biocompatibility. Nowadays, Y-TZP is used as a framework material for crowns and FPDs, both in the anterior and posterior region. However, the clinical success of the zirconia-based restorations has been questioned with the reports of veneering porcelain chipping. Therefore, highly sintered monolithic or full anatomic zirconia crowns were developed to reduce these failures by eliminating the veneering porcelain layer and improving their clinical success and reliability. Due to the white-opaque color of zirconia, full contour zirconia has gained popularity in restoring posterior and anterior teeth. The continuous enhancements in its color and translucency gave a rising hope to full contour zirconia to become acceptable anterior restorations.\(^{[4]}\) An in vitro study is supposed to offer standardized conditions with respect to the preparation design.
leading to assessment that may be closer to reality. Beschnidt and Struβ\textsuperscript{[35]} stated that the in vitro study allows standardization in comparison to in vivo ones which is complex. Nevertheless, it is worthy to mention that in contrast to the in vivo studies, and the in vitro results should be viewed cautiously because of the testing limitations as reported by Fahmy and Salah\textsuperscript{[26]} which cannot reflect exactly the clinical situations. However, it might be beneficial to provide valuable clues and guidelines for the clinical applications. Taking this into consideration thus in the present investigation, every effort was taken to simulate the clinical situation. During the late two decades, CAD/CAM technology has expanded the application of advanced dental ceramics and allowed the development of new treatment alternatives. Thus, CAD/CAM construction technique was selected in this study; based on the benefit of elimination of the human manufacturing steps that might add a variable. According to Quintas et al.,\textsuperscript{[27]} the manufacturing technique represents the most important factor for evaluation the definitive vertical marginal discrepancy of all ceramic copings. For standardization, a stainless steel die was used as an abutment to measure the marginal accuracy during the whole procedure. The advantages of using metal dies include easy reproduction, standardized preparation, and lack of wear during the manufacturing process and measurements. The geometry of tooth preparation has been the subject of many debates where clear evidence of only one type of tooth preparation or method of fabrication that provides consistently a superior marginal fit was not found.\textsuperscript{[28,29]} The present research aimed to evaluate the internal adaptation of full contour highly translucent zirconia crowns to veneered zirconia with two different all-ceramic restorations. Contrary to their findings, Sulaiman et al.\textsuperscript{[36]} stated that veneering porcelain a non-anatomical occlusal surface was carried out for the purpose of standardization to ensure an even thickness of copings and to eliminate the variation obtained with the anatomical occlusal surface. This was documented by Martínez-Rus et al.,\textsuperscript{[30]} who stated that copings with flat occlusal reduction had a better internal and marginal fit compared with copings with anatomic occlusal reduction. In this study, zirconia copings were veneered by layering technique as the veneering process represent one of the most important factors that may affect the internal adaptation with the repeated ceramic firing cycles.\textsuperscript{[17]} Measurements of the internal accuracy were performed on veneered zirconia crowns after the veneer and glazing firing. Balkaya et al.\textsuperscript{[31]} and Abduo et al.\textsuperscript{[38]} reported that the firing of veneering porcelain affects the accuracy of different all-ceramic restorations. Contrary to their findings, Sulaiman et al.\textsuperscript{[36]} stated that veneering and glazing did not affect significantly the accuracy of different all-ceramic systems. Full zirconia crowns showed higher strength, easier laboratory procedures compared to the layering technique\textsuperscript{[36-38]} and could save the time to deliver restorations or adjust occlusal relationship. Full contour crowns fabricated without layering porcelain, showed excellent clinical performance, as long as tooth preparation is adequate and the dental laboratory and clinical materials are handled in the correct manner.\textsuperscript{[5]} To simulate finger pressure applied during crown placement, a load of 40 N was applied on the occlusal surface of the crown for 3 min using the specially designated loading device during setting of the light-body impression for the replica technique during internal adaption measurements. Additional silicon impression was used to fabricate impression die replicas of the master dies for internal adaptation measurements according to Tsitrou et al.\textsuperscript{[36]} Different techniques had been proposed for internal adaptation measurements which include an optical microscope, micro-computed tomography, stereomicroscope, and replica technique with a magnification microscope. In this study, the cement space was measured using replica technique and stereomicroscope with fixed ×12.5 magnification after had been sectioned mesiodistally at five points: P1 - Left axial cervical thirds; P2 - Left axial occlusal third; P3 - Middle occlusal; P4 - Right axial occlusal third, and P5 - Right axial cervical third. Regarding the effect of the finish line design on the internal adaptation of both restorative systems, results in this study reviled that the overall mean value of the internal adaptation recorded for Prettau zirconia crowns with the deep CH line design were lower than Prettau zirconia crowns with SH line design. When comparing the internal adaptation of the two crown materials within each different finish line designs, Prettau zirconia crowns with both deep chamfer and SH line designs recorded higher overall mean internal adaptation values when compared to ICE Zirconia crowns with both deep chamfer and SH line designs. Collectively our results indicated that crowns with deep CH line design showed the lower overall mean value of internal adaptation than crowns with SH line design. Our results indicated that the lowest overall mean value of internal adaptation was recorded with ICE Zirconia crowns with deep CH line design (74.6 μm), then ICE Zirconia crowns with SH line design (93.40 μm), followed by Prettau zirconia crowns with deep CH line design (157 μm) and finally Prettau zirconia crowns with SH line design (181 μm).

Conclusions

Within the limitations of this study, the following conclusions can be drawn:
1. Finish line design and crown fabrication technique affect measurements of internal adaptation of the zirconia crowns
2. The overall mean values of the internal adaptation of the two restorative systems were within the clinical acceptance range
3. The ICE Zirconia crowns recorded better overall internal adaptation values when compared to Prettau crowns with both finish line designs
4. Crowns with deep CH line design fabricated from both Prettau and ICE Zirconia recorded better internal adaptation overall mean values than those with SH line design.

Recommendations

Further studies are required to elaborate the effect of different types of the luting agent on the vertical marginal discrepancies. Further investigation with a larger sample size and clinical trials is necessary to reinforce the results.
References


