

A Comparative Evaluation of Internal Adaptation and Marginal Fitness of Two Zirconium Design Fabricated by CAD/CAM

Loura S. Marqus¹, Nabeel S. Martani²

Abstract

Objective: Full anatomic zirconia crowns had been launched to overcome the problems associated with veneering porcelain. The aim of this study was to evaluate the internal and marginal adaptation of CAD/CAM milled zirconia core to full anatomic zirconia crown.

Methods: The mandibular right first molar of a dentaform model was prepared for the full ceramic crown with deep shoulder finish line. The model was scanned using intra-oral scanner to produce ten full anatomic zirconia crowns and ten zirconia cores. The internal and marginal adaptations (that represents the cement analog) were evaluated using the replica technique with the aid of a stereomicroscope.

Results: There was no statistically significant difference between the internal and marginal adaptation of core and full anatomic zirconia crown, while a significant difference exists between them at the occlusal point that was greater in full anatomic crown. Both groups revealed the mean gap width of 146.7 ± 18 which is significant when compared to the standard value.

Conclusions: Both zirconia core and crown revealed comparable results of marginal and internal adaptation after sintering without any effect of bulk thickness. The obtained results were greater than the acceptable range.

Keywords: Zirconia bulk, Internal adaptation, Marginal gap, Replica technique.

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1. MSc student, College of Dentistry, Hawler Medical University, Erbil, Iraq.
 2. Department of Conservative Dentistry, College of Dentistry, Hawler Medical University, Erbil, Iraq.
- Corresponding author: lora_sh_89@hotmail.com.

Introduction

Zirconia had been launched to prosthetic dentistry for crown and bridge fabrication with the introduction of CAD/CAM system⁽¹⁾. It has mechanical properties that could withstand large masticatory forces and preferred optical properties due to its similarity to the tooth color, but it also has an opaque color that would be advantageous when trying to mask tooth discoloration^(2,3).

Zirconium oxide has three crystallographic phases: monoclinic, cubic, and tetragonal. The monoclinic phase is stable at room temperature and when heating up to 1170°C, with reduced mechanical performance. The cubic phase is stable above 2370°C and has moderate mechanical properties. While the tetragonal phase is stable between 1170°C and 2370°C and produces ceramic with improved mechanical properties^(1,3,4). Several different oxides (e.g. Yttrium oxide or Calcium oxide) added to zirconia to allow generation of multiphase material at room temperature, in this way a partially stabilized zirconia is obtained and named tetragonal zirconia polycrystal⁽⁴⁾.

Transformation is toughening which is the unique feature of zirconia produces favorable compressive stresses and inhibit crack propagation due to cooling phases transformation and tensile stress concentration at possible crack tip^(4,5).

Zirconia-based restorations are fabricated using CAD/CAM systems with two different machining techniques: soft machining of green state blanks which are fully sintered later and hard machining of fully sintered blanks that deals with already densely sintered zirconia blank⁽⁶⁾. Densely sintered zirconia is highly stable and tough; therefore, its machining is known to be time and material consuming and could lead to damage of the ceramic surface. Thus, processing of zirconia in the green state is recommended, in which sintering to final dimensions take place after machining⁽⁷⁾.

Regarding improvement in material properties of zirconia, both layered zirconias with coping and monolithic zirconia became available⁽⁸⁾. The strength and the esthetic required will demand the use of either design (full anatomic or core). The layered porcelain that adheres to the core represents the weakest point of restorations in the same time those layers could present best optical properties which could be advantageous over the monolithic crowns. Newer zirconia block with improved color and optical properties present to optimize the aesthetic outcome⁽⁹⁾.

Accurately fitted restorations decrease the prevalence of dental diseases and raise the restoration long-term survival rate⁽¹⁰⁾. As the internal gap is reduced, the mechanical features of restorations as strength and retention are enhanced⁽¹¹⁾.

The most common used milling variant in practice to prepare zirconia crown is soft machining in which the obtained framework is subjected to final sintering later, it usually results in higher shrinkage values. The aim of this article to evaluate the internal adaptation of CAD/CAM milled zirconia core to full anatomic zirconia crown by measuring the cement space using replica technique with a stereomicroscope.

Materials and methods

The right mandibular first molar dentaform tooth (dental model, KSD, Zhejiang, China “Mainland”) was prepared for full coverage all-ceramic restoration. High-speed dental hand-piece was used for the preparation according to standard criteria. The circumferential tooth reduction of 1.5 mm was carried out with a diamond bur (no. 850014, DFS DiamonGmbH, Riedenburg, Germany) and the margins were finished with a diamond bur (no.839014, DFS DiamonGmbH, Riedenburg, Germany) to obtain deep shoulder finish line of 1 mm. The occlusal reduction was 1.5mm. Multi-planer occlusal reduction was performed, and the functional cusp was beveled. All point and line angles were rounded.

The involved quadrant was scanned with TRIOS scanner (3Shape TRIOS 3, Copenhagen, Denmark). The scanning process includes all the surfaces of the master die to ensure that all the details of the preparation, the occlusal, facial, proximal and lingual surfaces of the master die were captured and the margins were visible. Then all the datasets were exported into Standard Tessellation Language (STL) file format.

After evaluating the virtual models, the STL datasets were imported into the CAD/CAM software (Zirkonzahn Modellier software). Ten zirconia cores (group 1) and ten full anatomic crowns (group 2) were designed. The cement thickness was set at 60µm, 1mm above the margin for both groups. Before fabricating the restorations, the five-axis computerized numerically controlled milling machine (Zirkonzahn GmbH, Gais, Italy) was calibrated, and a new milling bur was inserted. The restorations were milled using green-state zirconia block (ICE zircon, zirkonzahn GmbH, Gais, Italy). All samples were fired in a furnace (Zirkonofen600; Zirkonzahn GmbH) at 1500°C for two hours.

The internal adaptation of the crowns and cores were measured using a replica technique^(12,13). A low viscosity polyvinyl siloxane impression material (R&S, Turboflex, light, fast set, CFPM, France) was used as the cement analog. The light body impression material was injected into the inner portion of the restorations and then was placed over the prepared tooth with maximum figure pressure. After the manufacture recommended setting time, the restorations were gently removed leaving fragile light body replica attached to the master die. A bite registration silicone of different color (R&S, Turbocclusion, fast set CFPM, France) was then placed over the fragile light body replica to achieve a steady structure with the aid of specially designed box, then an additional layer of the same material was applied to the internal surface of the light body film to make cutting off the replica easier without damage (Figure 1)⁽¹²⁾.

The replicas were then cut in occlusal-cervical direction and buccolingual path using a blade in two equal parts using the designed box as a cutting guide. All sections were examined under a stereomicroscope (MOTIC ST-39 C-N9GO, Hong Kong) at 20x magnification power and recorded using a digital camera (Canon, EOS 550D, Tokyo, Japan).

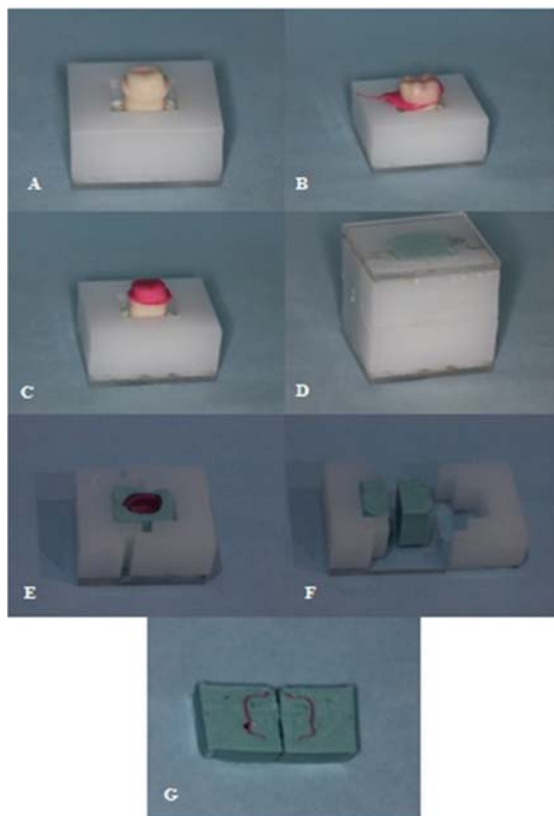


Figure 1: (A) The prepared master die. (B) The crown with the light body over the master die. (C) The light body representing cement analog attached to the master die. (D & E) the light body attached to the bite registration material. (F & G) Sectioning of the replica in buccolingual direction.

The cement analog thickness was measured using a computer program (imagej1.52a, national institution of health, USA) in nine regions in each of the replica halves then the mean is calculated for each point [Marginal gap (right and left), shoulder area (right and left), The middle of the axial wall (right and left), Axio-occlusal line angle (right and left) and Occlusal area (middle part)].

Statistical analysis

The mean and standard deviation of the margin and internal gap width between Zirconia core and full anatomic zirconia crown were calculated. All the measurements were subjected to statistical analysis using (IBM SPSS Statistics, version 22). The Kolmogorov-Smirnova test and the Shapiro-Wilk test were undertaken as the normality tests between different samples. To test the difference between the two groups, the independent sample t-test was used with a p-value of 0.05.

Results

The mean and standard deviation of the core and full anatomic crown groups shown in Table 1. The mean of the gap thickness at all the measurement points is referred to as mean gap thickness. The mean gap thicknesses of the core group and the full anatomic crown group are shown in Table 2 and 3. There was no statistically significant difference between the mean readings of the two groups ($P > .05$). There was no statistically significant difference between the two groups when the mean value was compared regarding the vertical marginal gap; the p-value was more than 0.05 as shown in Table 4.

The internal fitness evaluation was measured in buccal, lingual and occlusal surfaces. The analysis of the axial surfaces (buccal and lingual) showed no statistical differences in the cement space width ($P > 0.05$), but in the internal occlusal surface, a significantly greater cement thickness was obtained in the full anatomic crown group (p-value = 0.018) as shown in Table 5.

Table 1: Means and standard deviations (SDs) of the cement space at each measurement point in μm .

| Points | Type of zirconia | Mean | Std. Deviation | Std. Error Mean |
|---------------------|---------------------|----------|----------------|-----------------|
| Buccal margin | Zirconia core | 133.6000 | 60.84625 | 19.24128 |
| | Full anatomic crown | 119.7000 | 54.13984 | 17.12052 |
| Buccal finish line | Zirconia core | 206.0000 | 50.57887 | 15.99444 |
| | Full anatomic crown | 185.2000 | 50.66623 | 16.02207 |
| Mid-buccal | Zirconia core | 157.0000 | 27.90062 | 8.82295 |
| | Full anatomic crown | 136.1000 | 93.17182 | 29.46352 |
| Bucco-occlusal | Zirconia core | 181.8000 | 40.38372 | 12.77045 |
| | Full anatomic crown | 165.7000 | 82.77285 | 26.17507 |
| Mid-occlusal | Zirconia core | 168.7000 | 10.55199 | 3.33683 |
| | Full anatomic crown | 255.5000 | 94.58829 | 29.91144 |
| Occluso-lingual | Zirconia core | 126.2000 | 41.73674 | 13.19832 |
| | Full anatomic crown | 145.7000 | 74.99933 | 23.71687 |
| Mid-lingual | Zirconia core | 103.7000 | 35.66526 | 11.27835 |
| | Full anatomic crown | 105.5000 | 81.48926 | 25.76917 |
| Lingual finish line | Zirconia core | 128.3000 | 29.27285 | 9.25689 |
| | Full anatomic crown | 139.8000 | 33.80270 | 10.68935 |
| Lingual margin | Zirconia core | 90.1000 | 37.42979 | 11.83634 |
| | Full anatomic crown | 92.1000 | 27.00391 | 8.53939 |

Table 2: The mean gap thicknesses in μm .

| Groups | Mean | SD | 95% Confidence Interval for the Means | | Minimum | Maximum | P-value |
|---------------------|----------|----------|---------------------------------------|-------------|---------|---------|---------|
| | | | Lower Bound | Upper Bound | | | |
| Zirconia core | 143.9333 | 17.70736 | 131.2663 | 156.6004 | 118.89 | 169.56 | .506 |
| Full anatomic crown | 149.4778 | 18.80052 | 136.0287 | 162.9269 | 120.56 | 168.22 | .506 |

Table 3: Mean and standard deviation of the Mean gap thickness compared to the standard value of 120 μm .

| | mean | SD | p-value | Mean Difference | 95% Confidence Interval of the Difference | |
|--------------------|----------|----------|---------|-----------------|---|---------|
| | | | | | Lower | Upper |
| Mean gap thickness | 146.7056 | 18.00117 | .000 | 26.70556 | 18.2808 | 35.1304 |

Table 4: T-test for equality of means at the marginal area in buccolingual section.

| Marginal points | t | df | p-value | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
|---------------------|------|----|---------|-----------------|-----------------------|---|----------|
| | | | | | | Lower | Upper |
| Buccal margin | .540 | 18 | .596 | 13.90000 | 25.75537 | -40.21002 | 68.01002 |
| Buccal finish line | .919 | 18 | .370 | 20.80000 | 22.63910 | -26.76299 | 68.36299 |
| Lingual margin | .137 | 18 | .893 | -2.00000 | 14.59520 | -32.66339 | 28.66339 |
| Lingual finish line | .813 | 18 | .427 | -11.50000 | 14.14045 | -41.20798 | 18.20798 |

Table 5: T-test for equality of means at internal areas in buccolingual direction.

| Internal points | t | df | p-value | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
|-----------------|--------|-------|---------|-----------------|-----------------------|---|-----------|
| | | | | | | Lower | Upper |
| Mid-buccal | .680 | 18 | .505 | 20.90000 | 30.75619 | -43.71636 | 85.51636 |
| Bucco-occlusal | .553 | 18 | .587 | 16.10000 | 29.12420 | -45.08767 | 77.28767 |
| Mid-occlusal | -2.884 | 9.224 | .018 | -86.80000 | 30.09699 | -154.63295 | -18.96705 |
| Lingo-occlusal | -.718 | 18 | .482 | -19.50000 | 27.14195 | -76.52313 | 37.52313 |
| Mid-lingual | -.064 | 18 | .950 | -1.80000 | 28.12919 | -60.89723 | 57.29723 |

Discussion

Replica technique is the method of measuring cement gap thickness that was dependent in this study; it is used as an accurate and reliable method to reproduce the cement space⁽¹⁴⁾. This method had various advantages that enhance its uses, is easy and efficient to carry out, permit accurate marginal adaptation measurements before cementation and it is quite inexpensive, non-invasive and non-destructive^(15,16). Finger pressure was used as crown seating force to mimic the clinical situation. As it was reported by Weaver et al⁽¹⁷⁾ that seating forces do not affect the marginal adaptation.

The fit of any restoration is defined by its marginal and internal adaptation⁽¹⁸⁾. The marginal fit is one of the important factors that are closely related to the structural durability of the restoration, and it is determined in the vertical and horizontal direction^(19,20).

Meanwhile, the internal gap had been defined as the vertical distance between the crown and the prepared tooth. For internal adaptation improvement, a proper and even cement space is mandatory⁽²¹⁾.

Impression making phases and ceramic construction both change the dimensions and fitness of the final restoration. A minimum marginal gap prohibits plaque accumulation, decrease cement dissolution and reduce the possibility of secondary caries development⁽²⁰⁾.

Variation exists in determining the clinical acceptable, marginal misfit. Several studies measured the marginal misfit that is not seen by the naked eye or felt by the tip of the explorer. An in vivo study conducted by McLean and Von Fraunhofer⁽²²⁾ stated that the maximum clinically accepted marginal gap is 120 μ m based on the result of a 5-year study period of 1000 restorations.

Similarly, Balkaya et al.⁽²³⁾ compared the marginal fit of all-ceramic systems: conventional In-Ceram, copy-milled In Ceram and copy-milled feldspathic crowns. They reported that the marginal gap of 120 μ m is the maximum clinically acceptable range. Other studies repeated this maximum accepted range⁽²⁴⁻²⁶⁾. Furthermore, a previous study conducted by Rinke et al.⁽²⁷⁾ suggested that for CAD/CAM-fabricated zirconia

prosthesis the cement space should not be set at a smaller value than 60 μ m to enhance its seating on the abutment and to decrease the necessity of manual adaptation.

When evaluating the outcome of the study measurements concerning clinical acceptance, it was 146.7 μ m which is in disagreement with previous findings. Differences in this measurement values given between different studies may be due to different material used, different measurement technique followed and different CAD/CAM machine and intraoral scanner used.

Regarding the effect of different thickness of zirconia core on the marginal adaptation, Jalalian et al.⁽²⁸⁾ concluded that by increasing the zirconia core thickness, the marginal gap would decrease. The result of this study was in disagreement with the results of the previous finding that showed no difference in marginal gap thicknesses reading between different zirconia prosthesis. Both full anatomic zirconia, and core present same precision of fit excluding the effect of material thickness on the marginal and internal adaptation with full anatomic zirconia being easier to fabricate with no weak points regarding the aesthetic layering. Furthermore, the development of a new zirconia block with improved optical characteristic favorite use in the aesthetic zone when strength and aesthetic required.

Conclusions

Findings of this study showed that an adaptation of zirconia (marginal and internal) is not affected by its thickness as there was no significant difference in the marginal and internal adaptation between the two groups. On comparing it to the acceptable range, both groups showed slightly greater gap thickness.

Conflicts of interest: The authors report no conflicts of interest.

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