Fracture Strength of Implant-Supported Ceramic Crowns with Customized Zirconia Abutments: Screw Retained vs. Cement Retained

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Abstract

Purpose: To compare the fracture resistance before and after cyclic fatigue assays of ceramic crowns with customized zirconia abutments when screw retained and cemented onto implants.

Materials and Methods: The sample of this study consisted of 40 ceramic crowns with zirconia infrastructure fixed onto external hexagonal implants. The crowns were distributed into two groups (n = 20): Screw-retained and cemented crowns. Half the crowns of each group (n = 10) underwent compression until fracture and the other half (n = 10) underwent cyclic fatigue and subsequent compression until fracture. The cyclic fatigue test was carried out using an electromechanical fatigue device (loads from 0 to 100 N, 2 Hz frequency, in distilled water, at 37°C for a period of 1 million cycles). The compression test was carried out using a universal testing machine with a 0.5 mm/min speed and 5 KN load cell. After fracture, the crowns were classified according to the type of fracture. Student’s t test (p < 0.05) was used for statistical analysis.

Results: The cyclic fatigue altered neither the mean fracture resistance of the screw-retained crowns (before = 1068.31 N, after = 891.49 N; p > 0.05) nor that of the cemented crowns (before = 2117.78 N; after = 2094.81 N; p > 0.05); however, the mean fracture resistance of the cemented crowns was higher than that of the screw-retained crowns both before (p < 0.001) and after (p < 0.001) the cyclic fatigue. Fractures occurred most frequently in the ceramic veneer, followed by fracture of some of the copings.

Conclusion: The ceramic crowns cemented onto the customized zirconia abutments offered greater fracture resistance than ceramic crowns with customized zirconia abutments screw retained onto implants. The cyclic fatigue did not seem to influence the fracture resistance of these crowns, whether cemented or screw retained onto implants. Fracture of the veneering ceramic was the predominant failure in this study.

Computer-aided design/computer-aided manufacturing (CAD/CAM) technology is used in dentistry to produce high-precision customized abutments on implants. These were initially made of titanium and alumina, and later of zirconium oxide.1 Alumina or zirconia abutments are recommended for esthetically important areas2 when the thickness of the marginal gingiva is less than 3 mm. They are also recommended when a metal-free crown is used, to enhance the translucency of the crown.1 Zirconium oxide blocks are machined into customized abutments for various implant systems.3 They are highly resistant to fracture,4 biocompatible,5 and have low quantitative and qualitative biofilm adherence, when compared with Ti abutments.6,7

Prostheses on implants can be fixed onto abutments using two mechanisms: (1) Screwing—the veneering ceramic is directly applied to the abutment, requiring a hole for the passage of the fixation screw into the implant; (2) Cementing—the veneering ceramic is applied onto a coping fabricated on the abutment and fixed with dental cement. The access hole for the screw increases the incidence of porcelain fracture.8-12 This does not occur in cemented prostheses.13,14
Osseointegrated implants do not have a periodontal ligament; therefore, during the impact of masticatory loads, fractures of the veneering ceramic and other components of the prosthesis often occur in this type of rehabilitation treatment. The most common complication associated with crowns with zirconia framework is fracture of the veneering ceramic. However, few studies have investigated the fracture strength of the ceramic coating on implant crowns with customized zirconia abutments. Therefore, the purpose of this study was to compare the fracture resistance, before and after cyclic fatigue assays, of ceramic crowns with customized zirconia abutments when screw retained or cemented onto implants. The null hypothesis of this study is that the cyclic fatigue does not alter the resistance to fracture of ceramic crowns with customized zirconia abutments, screw retained or cemented onto implants.

**Materials and methods**

**Construction of the standard implant model**

An external hexagon-type titanium implant replica (Neodent, Curitiba, Brazil) was coupled to an impression transfer using a parallelometer (B-2; Bio-Art, São Carlos, Brazil) for the inclusion of the implant in a container with self-cured colorless acrylic resin (Clássico; Artigos Odontológicos Ltda., São Paulo, Brazil). The resin was manipulated according to the ratio recommended by the manufacturer (two measures of powder to one measure of liquid). The implant platform was positioned 2 mm above the level of the resin. It was stored for 24 hours to completely cure the resin.

**Standardization of the crowns**

A plastic anti-rotational prosthetic cylinder with a cobalt chrome base, UCLA-type (Neodent) was screwed onto the implant, and a standardized maxillary premolar was created from wax. Afterwards, a Zetalabor® (Zhermack, Polesine, Italy) silicone matrix was manufactured on top of the wax-up, so that it could be used as reference model for the final shape of the crowns. These procedures of implant inclusion and waxing were repeated 40 times to obtain the replicas.

**Sample and study design**

The sample size for each subgroup was n = 10, making a total of 40 specimens. The sample size was based on other studies that used a similar methodology for cycling fatigue and compression tests. The crowns were constructed according to the following design: Screw-retained group (n = 20)–customized zirconia abutment with pressed ceramic veneer screw retained onto implant; Cemented group (n = 20)–zirconia coping with pressed ceramic veneer cemented onto zirconia customized abutment. Each group was divided into two, and half the crowns (n = 10) were subjected to compressive testing until fracture occurred, and the other half (n = 10) underwent cyclic fatigue and were subsequently subjected to compressive testing until fracture occurred.

**Customized zirconia abutments and copings**

The CAD/CAM Neoshape system (Neodent) was used to manufacture customized abutments from Z-CAD® (Metoxit AG, Thayngen, Switzerland) zirconium oxide blocks. To standardize the thickness of the ceramic veneering of the experimental groups, the thickness of the crown was measured for the Screwed group, scanning the standardized maxillary premolar made of wax. This value was used to calculate the thickness of the ceramic veneer. For the Cemented group, the thickness of the ceramic veneer and of the coping were calculated. Thus, both groups had ceramic veneer with the same thickness. The CAD/CAM Neoshape system was also used for the fabrication of the 0.5 mm thick zirconia copings, after scanning of the customized zirconia abutments.

**Application of the veneering ceramic**

IPS e-max Ceram® (Ivoclar Vivadent, Schaan, Liechtenstein) was used for the veneering ceramic. It is a nano-fluorapatite glass-ceramic with a low melting point, with optimal stability on zirconium oxide structures.

For the Screwed group, the veneering porcelain was applied directly onto the zirconia abutment (Fig 1A), and for the Cemented group, it was applied onto the zirconia coping.
Figure 2 Specimen showing: A. fracture of coping and veneering porcelain; B. fracture area in the veneering porcelain.

(Table 1)

<table>
<thead>
<tr>
<th></th>
<th>Screw-retained</th>
<th>Cemented</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>DP</td>
</tr>
<tr>
<td>Without fatigue</td>
<td>1068.31</td>
<td>267.56</td>
</tr>
<tr>
<td>With fatigue</td>
<td>891.49</td>
<td>155.26</td>
</tr>
</tbody>
</table>

Different letters in the same row mean significant difference by test t-student independent ($p < 0.05$). Different letters in the same column means significant difference by test t-student paired ($p < 0.05$).

Exerting a continuous vertical and perpendicular strength to the occlusal surface at a 0.5 mm/min speed and 5 KN load cell. The device was stopped when the fracture occurred, and the strength reading was obtained in Newtons (N). The fractured crowns were stored individually with their fragments and inspected with a magnifying glass for examination and classification of the fracture pattern into the following categories: (1) fracture of the veneering ceramic (Fig 2A); (2) fracture of the veneering ceramic and coping (Fig 2B); and (3) fracture of the abutment.

Statistical analysis

The processing and analysis of data were carried out using SPSS® for Windows software, v.18.0 (SPSS Inc., Chicago, IL). The Shapiro-Wilk test was used to test the normality of the variables. To compare means, the independent Student’s $t$ test was used. To compare the means before and after cyclic fatigue, the paired Student’s $t$ test was used. The differences were considered statistically significant when $p < 0.05$.

Results

Table 1 shows that the cyclic fatigue did not alter the mean fracture resistance of the screwed crowns ($p > 0.05$) or of the cemented crowns ($p > 0.05$); however, the mean fracture resistance of the cemented crowns was higher than that of the screw-retained crowns both before ($p < 0.001$) and after ($p < 0.001$) the cyclic fatigue. Table 2 shows the categories of fracture patterns. In the group of screw-retained crowns, fractures...
occurring exclusively in the porcelain veneer. In the group of cemented crowns, most fractures occurred in the porcelain veneer, but in some cases the copings also fractured. In both groups, there were no fractures in the customized zirconia abutment.

### Discussion

In this study, the CAD/CAM system enabled us to manufacture an accurate zirconia framework, which received ceramic veneering with the same thickness in both groups, to evaluate the fracture strength of ceramic veneering based solely on the cyclic fatigue and the type of fixation of the crown onto the implant. Therefore, the null hypothesis of this study, tested at a level of significance of 5% was accepted.

Implant-supported crowns can be fixed with a single screw or with systems using screwable intermediates with cemented crowns. According to several authors, the type of fixation not only affects the esthetics, occlusion, adjustment passivity, and cost-effectiveness, but also influences the ceramic veneer’s longevity.\(^{11,19,20}\) Thus, studies to assess these fixation systems are justifiable due to the development of new materials, such as ceramics applied onto customized machined abutments from zirconium oxide blocks.

This study found a statistically significant difference \((p < 0.001)\) between the mean fracture strength of screwed crowns \((979.81 \text{ N})\) when compared with cemented crowns \((2106.30 \text{ N})\). Studies that used a similar method, but evaluating the fracture strength of metal ceramic crowns, proved that cemented crowns are more resistant to fracture than screwed crowns.\(^{11,14,21}\) The presence of the access hole for the screw of screw-retained crowns significantly decreases the fracture strength of porcelain, regardless of its location on the occlusal surface.\(^{11}\) The access hole for the passage of the screw of a metal ceramic crown’s implant is a fragile site in the ceramic layer, and fractures may occur more frequently during dynamic loading than in cemented crowns.\(^{21}\)

Given the evidence found in the literature\(^{11,14,21}\) and the results of this study, we can suggest that, similar to implant-supported metal ceramic crowns, the access hole for the passage of the screw can also influence the fracture strength of crowns with zirconia abutments screwed onto implants.

Aspects such as esthetics, recoverability, retention, passivity, occlusion, and accessibility should be discussed when comparing screwed crowns with cemented crowns. In some cases, the access hole for the screw may be in an esthetically important region of the mouth, which would be a limiting factor for the use of a screwed crown. Regarding recoverability, screw-retained crowns can be removed without damage, which facilitates cleaning. Certain properties may affect retention in cemented crowns, such as the angle, height, and surface area, which is not the case in screw-retained crowns. As for passivity and occlusion, the axial loads are distributed more evenly in cemented crowns. Finally, the use of screws and tools is more difficult in restorations of posterior areas, which can make them less accessible.\(^{22}\)

In this experiment, there was no statistical difference between the fracture strength of the specimens after cyclic fatigue when compared with those that underwent compression only, for either type of fixation: screw retained \((p = 0.102)\) and cemented \((p = 0.912)\). Studies using similar methods have reported that cyclic fatigue did not affect the fracture strength of ceramic coatings of implant-supported metal ceramic crowns.\(^{14,21}\)

A study that evaluated the influence of cyclic fatigue on the shear strength of IPS and e.max ZirCAD applied on a Y-TZP zirconia structure did not result in lower bond strength with ceramics. This demonstrated the stability of the zirconia/ceramic interface.\(^{23}\) In this study, it seems that the zirconia/ceramic interface was not affected.

In clinical studies of posterior fixed partial prostheses with zirconia infrastructure, with 3-\(^{4}\) and 4-year\(^{24}\) follow-ups, ceramic-zirconium prostheses had survival rates similar to those of fused-to-metal prostheses. Even when the survival rates of ceramic frameworks were slightly lower than those of metal structures, no significant difference was found in the probability of success during this period.\(^{15}\) Another study reported a survival rate of 92% after 5 years, suggesting that zirconia has sufficient mechanical strength for use in posterior teeth, and the highest rate of fracture of the ceramic veneer was due to the inadequate design of structures or bruxism.\(^{25}\)

In this experiment, the fracture strength of crowns with zirconia infrastructure, when cemented on zirconia abutments screw retained onto implants \((2106.30 \text{ N})\), was higher than those found in a study of crowns with zirconia framework cemented onto teeth \((1773.92 \text{ N})\) using the same ceramic veneer (Ceram and IPS e.max).\(^{26}\) A similar result was found when we evaluated the fracture strength of implant-supported ceramic crowns with a zirconia abutment, which shows that artificial aging (cyclic fatigue) had no significant influence on the fracture loads of premolar pillars, and all of the crowns tested could also withstand physiological chewing forces.\(^{12}\)

For the crowns with zirconia abutment that were screw retained onto implants, all the fractures were in the porcelain

### Table 2: Type of fracture observed in implant-supported crowns according to the type of fixation: cemented or screw-retained

<table>
<thead>
<tr>
<th>Crowns</th>
<th>Screw-retained Without fatigue</th>
<th>Screw-retained With fatigue</th>
<th>Cemented Without fatigue</th>
<th>Cemented With fatigue</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porcelain</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>4</td>
<td>60%</td>
</tr>
<tr>
<td>Porcelain + coping</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>40%</td>
</tr>
<tr>
<td>Customized abutment</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>
veneer. In the cemented crowns, 60% of the fractures occurred in the porcelain veneer and 40% in the coping and porcelain veneer. Similar results were found for cemented crowns: the majority of the fractures occurred in the porcelain veneer, with a lower proportion of coping and pillar tooth fractures. The most common technical failure in the coating of CAD/CAM zirconia crowns is fracture of the porcelain veneer, not of the zirconia/ceramic interface.

**Conclusion**

Ceramic crowns cemented onto the customized zirconia abutments provided greater fracture resistance than the ceramic crowns with customized zirconia abutments screw retained onto implants. The cyclic fatigue did not seem to influence the fracture resistance of these crowns, whether cemented or screw retained onto implants. Fracture of the veneering ceramic was the predominant failure in this study.

**References**