



# Fracture Resistance of Aged Full-Coverage All-Ceramic Zirconia and Metal-Ceramic Restorations of Implant-Supported Fixed Partial Dentures

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## Abstract

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**BACKGROUND:** Metal-ceramics restorations were considered a preferable option for fabrication fixed partial dentures (FPDs) that have an acceptable durability, but they are not able to provide the same beauty as the entire ceramic material. Full-contour zirconia, such as Zolid, does not have problems with chipping of layered zirconia, along with translucency and staining capabilities.

**AIM:** This study aimed to assess the fatigue fracture strength of three-unit implant-supported full-contour zirconia and metal-ceramics posterior FPDs.

**MATERIALS AND METHODS:** In this *in vitro* study, 24 posterior three-unit implant-supported FPDs were fabricated of full-contour zirconia and metal-ceramics and were cemented on implant abutments. To simulate the oral environment, FPDs were subjected to 10,000 thermal cycles between 5 and 55°C for 30 s and were then transferred to a chewing simulator (100,000 cycles, 50 N, 0.5 Hz). Afterward, fatigue fracture strength was measured using a universal testing machine. Data were analyzed using an independent sample t-test.

**RESULTS:** The obtained results showed that the mean and standard deviation of fatigue fracture strength was higher for the metal-ceramics group (2567.8 ± 689.7 N) compared to those for the full-coverage zirconia group (2108.6 ± 455.2 N). However, the difference was not statistically significant ( $p > 0.05$ ).

**CONCLUSIONS:** Fracture resistance due to fatigue in the metal-ceramics group was not significantly different from full-coverage zirconia group. Full-coverage zirconia seems promising as a metal-ceramics material for the fabrication of posterior three-unit FPDs.

## Introduction

Several modalities are available for replacement of the lost teeth, such as removable partial dentures, fixed partial dentures (FPDs), and dental implants. Nowadays, dental implants are the most preferred treatment choice for the replacement of the lost teeth. Studies on all-ceramic FPDs are limited and there is a gap of information regarding the durability and clinical serviceability of all-ceramic implant-supported restorations.

Metal-ceramics (porcelain fused to metal [PFM]) FPDs are one of the most commonly used restorations due to their favorable long-term mechanical properties [1]. Despite numerous advantages, FPDs have inherent shortcomings such as corrosion, gingival discoloration adjacent to the crown margin, poor esthetics, and inability to mimic the transparency and translucency of the natural teeth [2].

All-ceramic dental restorations had reported better biocompatibility and higher esthetic properties than metal restorations [3]. Zirconia is increasingly used

for the fabrication of single crowns and FPDs. Zirconia cores are the strongest ceramic frameworks [4], [5] and are the most suitable ceramic material for use in the posterior regions [6], [7]. Development in computer-aided design/computer-aided manufacturing (CAD/CAM) technology had greatly increased the clinical application of dental zirconia [8]. They have superior mechanical properties and a clinical service comparable to that of metal-ceramics [7], [9], [10]. Therefore, zirconia ceramics are nowadays considered an excellent esthetic alternative to metal-ceramics. However, zirconia veneered FPDs do not reflect the aforementioned favorable mechanical properties, and they only have short-term optimal structural stability [11]. Porcelain chipping is the most critical defect of this type of restorations [11]. Monolithic zirconia restorations provide acceptable esthetics since they have a superficial glaze layer and are more cost-effective due to simpler fabrication process and requiring less workforce because they are fabricated with the CAD/CAM technology almost entirely [12], [13], [14]. Other advantages of monolithic zirconia include requiring less

tooth preparation [13], [14], [15] and higher resistance compared to other ceramic materials [12], [14], [16].

The study aimed to compare the fatigue fracture resistance of full-coverage zirconia to that metal-ceramics implant-supported FPDs. The aim of this study is comparing the fracture resistance of aged full-coverage all-ceramic zirconia and metal-ceramics restorations of implant-supported FPDs.

## Materials and Methods

In that *in vitro* study, the sample size was 12 in each of the two groups according to a previous study [17] considering the type I error of 5% and power of 80%. Thus, 24 three-unit implant-supported FPDs were fabricated to replace the missing mandibular first molars. Two groups (n=12) of full-contour zirconia and metal-ceramics FPDs were evaluated in this study.

### Preparation of matrix for the samples

Each sample was prepared from two threaded cylindrical implant fixtures (SICace, Schilli Implantology Circle, Germany) with 4 mm diameter and 11.5 mm length that were mounted in a polymethyl methacrylate (Orthodontic Resin, Dentsply Caulk, USA) resin block (30 mm × 50 mm × 30 mm) using a surveyor such that the center of the two implants had 19 mm distance from each other (corresponding to the size of a missing mandibular first molar) [17], [18]. The finishing line of implants was above the acrylic surface by 1 mm. Titanium abutments with 4.5 mm diameter, 8.5 mm height, and 1.5 mm gingival height were placed on implants and torqued to 20 NCm (Figure 1a). A resin jig (Pattern Resin, GC, Japan) was used for the purpose of standardization. The prepared resin blocks were randomly divided into two groups of 14, namely, full-coverage zirconia and metal-ceramic FPD restorations.

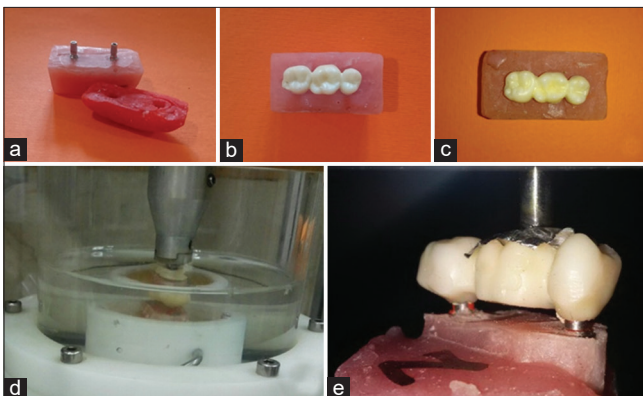


Figure 1: Study process: (a) Placement of implants in resin block; (b) three-unit fixed partial denture of monolithic zirconia; (c) three-unit fixed partial denture of metal-ceramic; (d) samples in chewing simulator; and (e) load application to samples until failure

### Fabrication of full-coverage zirconia FPDs

The bridges were fabricated using a CAD/CAM system. First, the resin block was scanned by a three dimensional (3D) scanner (D700 3D Scanner, 3Shape, Denmark), and the scan file was processed in 3D Designer software. A 3-unit bridge was fabricated with 4 mm × 4 mm connector dimensions and 12 mm pontic width. The iCAM-v4.6 software was used for proper alignment of the block, and the obtained file was transferred to Remote Dental 2.0 software. Afterward, full-coverage zirconia blocks (Ceramill Zolid, Amann Girrbach, Germany) were milled using a milling machine (imes-icore 250i, Germany). Sintering of the obtained full-coverage FPD zirconia restorations was performed at 1500°C for 4 h in a sintering furnace following the manufacturer's instructions.

### Fabrication of metal-ceramic FPDs

A silicon impression (Speedex Putty C-Silicone, Coltene, Switzerland) was made of the samples in the zirconia group as an index for veneering of the metal-ceramics restorations. That index was used for standardization of the dimensions of the finished metal-ceramic restoration and the all-ceramic zirconia FPD samples. Wax-up was performed by 1.2 mm cutback using the index.

Porcelain veneer (Kuraray Noritake Dental Inc.) was build up in layers using the prepared index as followed:

The opaque porcelain application step included a wash step at 950°C and application of opaque porcelain at 945°C under the vacuum, according to the manufacturer's instructions.

The body porcelain application step included the application of enamel followed by the first step of baking at 930°C under the vacuum followed by modifications in dentin porcelain and a second sintering step at 925°C under the vacuum and final glazing at 930°C in air atmosphere. The second layer was body porcelain (dentin layer) which baking at 930°C under the vacuum, followed by the third layer which was enamel layer backing at 920°C under the vacuum. Finally, the fourth layer (glaze layer) using mix external stain glaze with ES liquid applied in a thin coat and at 910°C in air atmosphere.

### Mechanical tests

All fabricated FPD restorations were cemented to its corresponding implant abutments with conventional chemical cured glass ionomer (Gold Lable 1, GC, Japan) [10], according to the manufacturer's instructions (Figure 1b and c). To simulate the oral conditions, the samples were thermocycled (TC/300, Vafaei Industrial Factory, Iran) between 5 and 55°C ( $\pm 2^\circ\text{C}$ ) for 10,000 cycles with a dwell time of 30 s and

then underwent dynamic cyclic loading in a chewing simulator (CS-4, Mechatronik, Germany) for 100,000 cycles with 50 N load and 0.5 Hz frequency (Figure 1d). The load was applied perpendicularly to the center of the occlusal surface of pontics [19]. That thermocyclic test was simulating the clinical serviceability of the FPD samples for 2–4 months [20], [21]. The vertical load was applied by a ball-shaped pointer to the center of pontic at a crosshead speed of 0.5 mm/min until fracture in a universal testing machine (Z050, Zwick/Roell, Germany) (Figure 1e).

### Statistical analysis

Data were analyzed using SPSS version 23. Quantitative data were reported as mean and standard deviation. For inferential data, the first normal distribution of data was evaluated using the Kolmogorov–Smirnov test. Since data were normally distributed, an independent sample t-test was used to compare the mean values between the two groups.  $p < 0.05$  was considered statically significant.

## Results

Table 1 shows the fatigue fracture resistance of the study groups. The results showed no statistically significant difference ( $p = 0.67$ ) between the mean fatigue fracture strength in the metal-ceramics group ( $2567.8 \pm 689.7$  N) and the full-coverage zirconia group ( $2108.6 \pm 455.2$  N).

**Table 1: Fatigue fracture resistance of the two groups**

Groups	Number	Mean resistance	Standard deviation	t-statistic	p-value
Full-contour zirconia	12	2108.6	455.2	-1.925	0.067
Metal-ceramic	12	2567.8	689.7		

## Discussion

According to this study, the mean fracture resistance values in the metal-ceramics group and the full-coverage zirconia group were 2567.8 N and 2108.6 N, respectively. The current results showed that the fracture resistance of metal-ceramic implant-supported FPDs was higher than that of full-coverage zirconia implant-supported FPDs; however, this difference was not statistically significant.

Full-coverage zirconia crowns are increasingly used recently due to their optimal strength, flexural resistance, favorable color, minimum wear of the opposing teeth, conservation of tooth reduction, and acceptable long-term clinical serviceability [22], [23].

Beuer *et al.* [12] demonstrated that full-coverage zirconia had higher fracture resistance than the veneered zirconia; therefore, full-coverage zirconia was used in the study.

The ready-made zirconia blocks were fabricated from semi or fully-sintered ceramic blocks [1]. Preparation of fully-sintered zirconia blocks might alter the zirconia microstructure [24]. Moreover, it required an expensive equipment and it was time-consuming. Thus, semi-sintered zirconia blocks were used in the study.

Bonfante *et al.* concluded that metal-ceramics restorations were still considered the gold standard for posterior restorations due to their relatively higher fracture resistance compared to that of zirconia [18] that finding was in contrast to the obtained results as no significant difference in fracture resistance values between full-coverage zirconia and metal-ceramics restorations was found.

Vafae *et al.* [25] evaluated the fatigue fracture resistance of implant-supported FPDs made of full-coverage zirconia and Sintron. They concluded that the fracture resistance of both materials was significantly higher than the mean masticatory loads; thus, both materials can be used for the fabrication of 3-unit posterior restorations, depending on the esthetic requirements of patients. In their study, the fatigue fracture resistance of the Sintron group was significantly higher than that of full-coverage zirconia.

Eroglu *et al.* [19] evaluated the fatigue behavior of zirconia, galvano-ceramic, and PFM FPDs. They reported that the mean fracture resistance was higher in the zirconia group and a significant difference existed among the groups in terms of fracture resistance. The significant difference reported in their study may be due to the difference in sample size since the present study evaluated 28 FPDs while they assessed 60 restorations. This is due to a large number of groups tested in Eroglu study and might have no clinical significance. Regarding the zirconia group, the values reported in their study for the zirconia group were almost similar to the range in the present study. In general, the difference in the results of the two studies may be due to the fact that the implant-supported bridge was fabricated to replace a missing first molar with 10 mm pontic size. However, Eroglu *et al.* [19] fabricated a bridge to replace a missing first premolar with 5 mm pontic width supported by a metal die. In addition, different types of zirconia blocks were used in the two studies. The mean value obtained in the metal-ceramics group by Eroglu *et al.* [19] was lower than that obtained in the study. The reason might be the type of alloy used since Eroglu *et al.* [19] used nickel-chromium, while the study used cobalt-chromium. Piloto *et al.* [26] evaluated the fracture resistance of metal-ceramics FPDs and stated that the formation of propagating cracks was the most important factor responsible for the reduction in fracture resistance. On

the other hand, this study showed that the design of restoration might play a role in the initiation of cracks. The magnitude of load applied was higher in sharp geometries, which increases the risk of cracks and fracture. Tinschert *et al.* [27] demonstrated that the fracture resistance of zirconia FPDs was high, which explained the favorable mechanical properties of zirconia ceramics.

Another effective factor that must be considered when comparing the fracture resistance of FPDs was the difference in the type of abutments. Kheradmandan *et al.* [28] showed that the mobility of the abutment is an important factor adversely affecting the fatigue fracture resistance. Accordingly, it might be concluded that controversy in the results of studies regarding the fatigue fracture resistance of FPDs might be due to the difference in the type of implant abutments.

Evidently, the metal coping alloy used for the construction of the metal-ceramics FPDs might affect the fracture resistance values of those restorations. Yoon *et al.* measured the fracture resistance of 15 FPDs using different types of metal collarless coping. They found that collarless metal-ceramics FPD groups had lower fracture strength than the metal collared control group ( $p < 0.05$ ), and however, the tested groups were not significantly different in terms of fracture resistance, the fracture resistance was generally higher than maximum incisive biting force in the study groups. Thus, it might be stated that by changing the type of coping in the process of fabrication of metal-ceramics FPDs, high-strength restorations can be fabricated [29].

The results revealed that the fatigue fracture resistance values of metal-ceramics and full-coverage zirconia FPDs were not significantly different. Therefore, the *in vitro* study proved that 3-units full-coverage zirconia FPDs might be used as an alternative to metal-ceramics FPDs. However, further clinical studies are required to assess the fatigue fracture resistance of these two types of restorations considering the differences in the abutment type and other variables affecting the fracture resistance.

## Conclusions

The current results revealed that the fatigue fracture resistance of metal-ceramics and full-coverage zirconia FPDs was not significantly different. Thus, this *in vitro* study showed that 3-units full-coverage zirconia FPDs can be used as an alternative to metal-ceramics FPDs. However, further clinical studies are required to assess the fatigue fracture resistance of these two types

of restorations by taking into account the differences in the abutment type and other variables affecting the fracture resistance.

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