EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org
Vol. 68, 3559:3564, October, 2022
Print ISSN 0070-9484 • Online ISSN 2090-2360
EDJ EGYPTIAN DENTAL JOURNAL
Fixed Prosthodontics and Dental Materials
Submit Date : 14-06-2022 • Accept Date : 27-07-2022 • Available online: 01-10-2022 • DOI : 10.21608/edj.2022.139558.2114

# FRACTURE RESISTANCE OF DIFFERENT ZIRCONIUM DIOXIDE THREE-UNIT FIXED DENTAL PROSTHESES

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## *ABSTRACT*

This study was intended to evaluate the fracture strength and mode of three units fixed dental prostheses (FDP) fabricated of Porcelain-Veneered Zirconia (PVZ) and High-Translucency Zirconia (HTZ).

**Material and methods**: A total of 20 standardized three-unit zirconium dioxides FDP were made. These were divided into two groups 10 FDP in each group. One group of FDP frameworks made of porcelain veneered zirconia PVZ (control group), second group of FDP framework made of high translucent zirconia HTZ. All samples were loaded by universal-testing machine until fracture. The fracture mode was inspected with a stereomicroscope.

**Results:** Owing to the Independent t-test analysis, there was statistical significant differences between the values of both groups. The mean fracture load of HTZ group (mean= 1390 N) was higher than the mean fracture loads of PVZ group (mean = 950 N) (p-value < 0.001). The fracture concentrated at connector region of both group.

**Conclusion:** Both types of Zirconia persistent the pragmatic fracture load which may be considered clinically acceptable.


## INTRODUCTION

Patient perspectives for dental restorations have changed tremendously. There is great interest in recognizing the befits of cosmetic dentistry. All-ceramic restorations are routinely used in clinical dentistry owing to the expanded demand of dental clients for natural looking restorations. The most primitive all-ceramic materials provided high esthetic consequences but it lacks the strength that was required for multiunit restorations. zirconia has been introduced as a dental biomaterial that has superior mechanical properties that are stronger and tougher than a previous ceramic alternative. [1, 2]

Regardless of the favorable criteria of zirconia based ceramic, it has poor translucency, [3] so it was utilized as core material veneered with translucent

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porcelain. Superficial chipping of porcelain veneer has been considered the principle motive for clinical failure of veneered zirconia [2, 4, 5] leading to rough surface and sharp edge that have a worse effect on the esthetic and function. [6, 7]

Recently, translucent monolithic zirconia restorations have become widespread. These restorations were milled by CAD/CAM technology to full contour anatomy without porcelain veneer. [8] Monolithic zirconia has been recommended to overcome the clinical failure owing to the veneer shipping. [9] It has been counseled for use in clinical cases with restricted inter-occlusal space.[10]

The monolithic full contour restorations can be machined from a shaded blank. To enhance the tooth like appearance, the restoration can be individualized using a staining technique. [11] The unique Zirconia shading system provides laboratories with numerous choices for shading and characterization. [12]

One method of increasing zirconia translucency is decreasing the alumina content by 0.05% which didn't significantly influence the mechanical properties of the material; however, no important increase in translucency has been reported. [13] zirconia translucency can be also improved by reducing porosity size and quantity , [14-16] or by decreasing the grain sizes to sub-micron or Nano-scale level. [17, 18] However, extremely small grain sizes can affect the transformation toughening mechanism of zirconia.[19]

The most recent approach to enhance the translucency of zirconia is scattering a substantial cubic crystalline phase with the tetragonal phase to stabilize it that reduces the light scattering at grain boundaries. [20, 21] Depending on that, the cubic zirconia has improved translucency. However, transformation toughening or low-temperature degradation didn't occur.

High translucent zirconia is considered an advanced material and hasn't been broadly studied as It combines strength with improved esthetics. The distribution of force within FDPs is complex and its design is critical to achieve clinical success[22] However, few studies[23, 24] have evaluated the monolithic zirconia FDPs' fracture resistance. The aim of this study was to evaluate the fracture strength and subsequent mode of failure of both porcelain-veneered zirconia (PVZ) (control group) and high-translucency zirconia (HTZ) three units FDP frame work.

## MATERIALS AND METHODS

### Experimental design

All procedures were carried-out by the same operator and in accordance with the manufacturer's instructions. A total of 20 FDP die models were made. These were divided according to zirconium dioxide type into two groups10 FDP in each group. One group of FDP frameworks made of porcelain veneered zirconia PVZ (control group), second group of FDP framework made of high translucent zirconia HTZ.

### Abutment dies

Abutment preparations were made on the upper canine and second premolar hard thermo-setting plastic teeth. The preparation had 1 mm round chamfer finish line, 2 mm occlusal reduction and 8° convergence angle.[25] Abutment preparations were performed by dental surveyors. Abutment teeth have been digitalized. The prepared teeth were duplicated by a polyurethane die material (Alpha die MF ivory precision die material, Schütz Dental, Rosbach, Germany) to a twenty duplicated die.[26]

### Fabrication of the PVZ group

10 FDP was designed by CAD software (Ceramill Mind software, Amann Girrbach). The connector dimensions were planned as 3x3mm and 0.9 curvature radius with a 0.7 mm core thickness.

The 10 copings were milled from pre-sintered Y-TZP materials (Zircostar®, Kerox Dental, Sóskút, Hungary) using a milling machine (Ceramill Motion 2, Amann Girrbach).The copies sinter using a sintering furnace.

The porcelain veneer layer dimensions were set as 0.3 mm axially and 1.3 mm occlusally. The veneer layer was shaped by millable wax. The wax veneer was sprued and invested completely with the pressable glass-ceramic ingots [27] (IPS e.max ZirPress Ingots, Ivoclar Vivadent AG, Schaan, Liechtenstein).

### Fabrication of HTZ

One (PVZ) FDP model was scanned by software to set up the dimensions of full contour (HTZ) FDP.[27] 10 HTZ FDP were milled from a high-translucency zirconia blank (Zolid HT, pre-shaded, Amann Girrbach) then sintered at 1450° C.

### Cementation

The die internal surfaces were cleaned in an ultrasonic water bath after being sandblasted with 50 m aluminium oxide particles. Each FDP was cemented to the corresponding die by a self-adhesive resin cement (RelyX Unicem 2 Automix, 3M ESPE, Seefeld, Germany). FDP were fixed under a standardized 20 N static load for 30 s. The load applied to occlusal surfaces. The excess cement was removed and light-cured for 20 s. To avoid cement dehydration, all specimens were stored in sealed water container to create a humid environment that simulate the oral condition.

### Thermal aging

The specimens were thermo-cycled for 5,000 cycles between 5°C and 55°C in distilled water (dwell time: 30 s, pause time: 13 s)

### Fracture testing

By universal-testing machine (Zwick Z010/ TN2S), all samples were loaded by a perpendicular load at a crosshead speed of 2 mm/min (Figure 1). The load was applied to occlusal surface of the first premolar until the point of fracture. The fracture load of the samples were recorded.

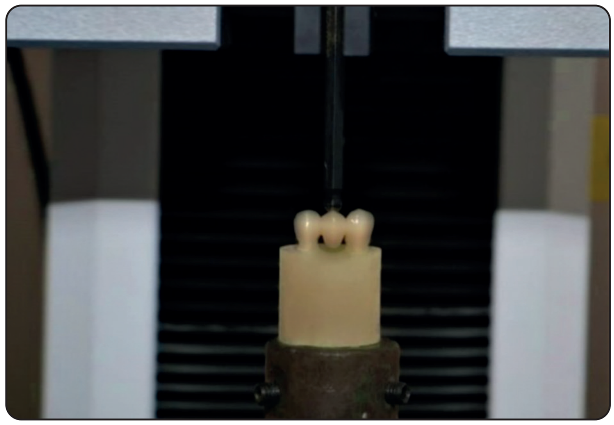

Fig. (1): Fracture load by universal testing machine.

### Failure mode analysis

The fractured FDPs were examined by a stereomicroscope (Leica EZ4, Leica, Wetzlar, Germany) with 30× magnification.

### Statistical Analysis:

The SPSS software was used for statistical analysis. The independent t-test was used to statistically analysis the mean fracture loads of both groups. A p-value below 0.05 was considered statistically significant.

## RESULT

### Fracture load

The measured fracture loads' mean, maximum and minimum values and standard deviations (SDs) were represented in table (1). The statistical analysis showed that there was significant differences in fracture loads in both groups. In comparison to the PVZ group (mean = 950 N), the HTZ group had higher fracture loads (mean= 1390 N) (p-value 0.001). Figure (2) shows the overall mean fracture resistance loads in each specimen of both groups.

Table (1): Means, Maximum and Minimum Values, and Standard Deviations (SDs) of the Measured Fracture Loads

| Group | Mean | Maximum | SDS | P-value |
|---|---|---|---|---|
| HTZ | 1390 | 1450 | 55.6 | < 0.001 |
| PVZ | 950 | 1100 | 30.09 | |

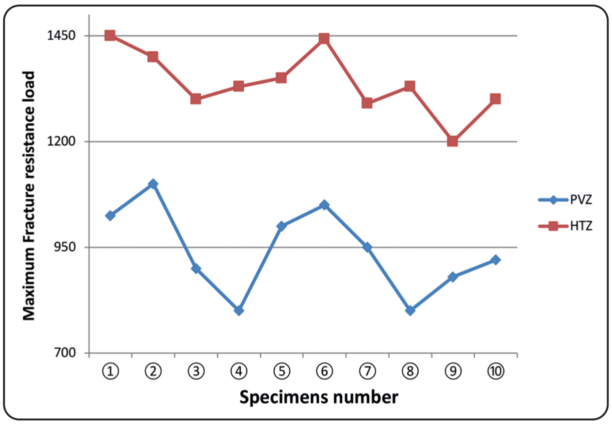


Fig. (2): Fracture resistance load of PVZ and HTZ groups

### Fracture mode

In PVZ, veneer fracture was detected underneath the loading indenter and extended obliquely to the connector area. Fracture In HTZ group, Copies fracture were observed at axial wall and deflected to the connector area. (Figure 3)

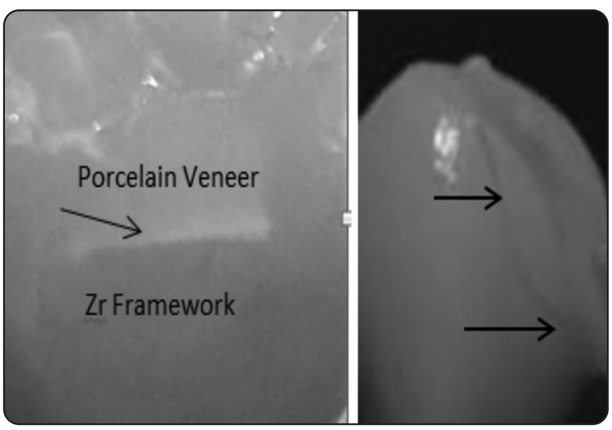


Fig. (3): (a ) Fracture of porcelain veneer of PVZ. (b) Fracture of HTZ framework

## DISCUSSION

When fabricating FDPs, it's important to pay great attention to the mechanical behavior of used materials and oral cavity force during function. The maximum occlusal force increases greatly in the posterior region. Forces exerted during normal function are less than the occlusal biting forces. Consequently, FDPs should be designed to persist with all applied force during function. Consequently, It's important when testing a material for dental use to evaluate linically shaped restorations under simulating oral conditions. [28]

In the current research, the samples were designed as three-unit FDPs extending from upper canine to second premolar. Both HTZ and PVZ were constructed according to manufactures' instructions that were appropriate for clinical application. A deep chamfer margins was used for both groups as it is recommended to improve the biomechanical performance of zirconia restorations.[25] A modulus of elasticity of polyurethane die material that used in this study are comparable to that of natural tooth to simulate the required strength criteria of oral condition. [27]

A similar design and dimension was used for both groups to facilitate the comparison. The porcelain veneer layer of PVZ group was designed by CAD/CAM software technique to standardize the thickness. [26] Also, one PVZ FDP was scanned and used as a bio-copy to plan HTZ group to standardize the dimension of each group. [26]

Tooth load distribution helps dentists to understand a distinctive type of dentition and provides reference data for studies on the biomechanics of prosthetic restoration. The literature introduced numerous proposals for the fracture strength that was required for dental restorations.[28, 29]

The human maximum bite force is an objective and quantitative measure for evaluating masticatory performance, which is verified effectively between patients and in the same individual over time.[29] Moreover, it differs between different areas in the same mouth, increasing from ~ 90–340 N in anterior to 400–900 N in the molar area. [30] According to the results of this study, all tested materials in the current study have values exceeding the maximum average loads with a satisfactory safety margin.

The results of this study indicated that, there is significant difference between the mean values of fracture strength of translucent and conventional zirconia. The fracture strength of HTZ FDP was significantly higher than PVZ FDP. In HTZ group, full contour zirconia copings have increasing shielding capacity due to even thickness of the copies, so higher loads are required to convey adequate stress to propagate internal fracture. [31] The failure mode supports this justification as HTZ specimens revealed a core fracture of axial wall and the fracture of PVZ initiated at veneer ceramic. As well as heat treatment and veneering process affect the fracture strength of zirconia, this effect depends on the zirconia type. It's significant to conclude that the statistically significant differences in fracture strength values of both types of zirconia are related to the difference in material composition. This suggests that HTZ is recommended for PVZ, especially in areas where there is a significant biting force in the molar region. The use of HTZ is favored over PVZ, especially in the area subjected to an eminent biting force (such as the first molar). [23]

However, the noted difference between two groups, all FDP frameworks withstand the function load. The results of this study were in agreement with result of previous studies that concluded that the tested zirconia indirect restoration have acceptable fracture load values for clinical demands. [23, 24, 26] Also the results of this study in accordance with Ezzat Y et al[27], they proved that the monolithic HTZ exhibited higher fracture load compared to PVZ.

In the current study, all fractures were concentrated around the connector area. This was in covenant with the assumption that the most mechanical failures of zirconia FDPs concentrated in connector area,[23, 24] that subject to excess load during mastication. [33]

## CONCLUSION

The monolithic HTZ FDPs are predictable to have better clinical application in comparison to PVZ. That may be considered sufficient for function application as single tooth restoration or 3-unit FDPs. However, the noted difference between the two groups, all zirconia FDP, persistent in the pragmatic fracture load.

This study assessed a restricted number of samples, so as to create additional clinical recommendations for dental practitioners. Further researches should be conducted to compare various types of translucent zirconia.

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