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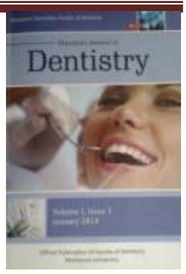
Fracture Strength of Two Zirconia All-ceramic Crown Systems: Influence of Intaglio Surface Conditioning



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Abstract:

Objectives: The purpose of this in-vitro study is to investigate the effect of intaglio surface conditioning on the fracture strength of veneered Zirconia crowns compared to full-contour Zirconia crowns.

Methods: Thirty two human maxillary premolars were prepared for two Zirconia all-ceramic crown Systems with the following preparation criteria: 6-degree axial taper, 1-mm shoulder finish line, 2-mm occlusal reduction and occluso-gingival height of 5 mm. All specimens were divided in to two groups (N=16) for each ceramic material. In the first group all prepared premolars restored by full contour zirconia crowns (MAD/MAM) while in second group all teeth restored by veneered zirconia crowns. The cores directly fabricated (VITA In-Ceram blocks) by (MAD/MAM) and build-up by ceramic. Each group subdivided into two subgroups (N=8). Crowns of first subgroup sandblasted with 50µm Al2O3while the second subgroups not treated by sandblast.All specimens were loaded in a universal testing machine with the compressive load (N) applied along axis of the specimen. Fracture load was recorded for each specimen. The kruskal-wallis test was used first and followed by Mann-whitney tests.

Results: The fracture resistance records high significance difference between VZ and FZ (P=0 for both tests) irrespective to the type of surface treatment. Contrary, both tests proved that the surface treatment has no significance effect on fracture resistance irrespective to the type of material (P=0.72 for Median test and P=0.27 for Mann-Whitney test).

Conclusions: Full-contour zirconia showed higher fracture resistance than veneered zirconia crowns. Surface treatment (sandblasting) has effect on fracture strength mean, but no significance difference statistically.

***Keywords**: Fracture Strength, zirconia all-ceramic crown, intaglio surface conditioning..*

Introduction

The increased popularity of all-ceramic materials as an alternative to metal-ceramic restorations is attributable to their excellent aesthetics where dental ceramics have the most natural appearing replacement material for missing tooth substance. They are available in a range of shades and translucencies to achieve life like appearance. Chemical stability and biocompatibility [1]. The surface of all-ceramic restorations does not release potentially harmful elements, and reduces the risk for surface roughening and an increased susceptibility to bacterial adhesion to insure excellent biocompatibility over time [2].

However, dental ceramics are inherently susceptible to fatigue and subsequent premature failure, especially when they are in moist environments, under high forces, and repetitive stresses during the chewing cycle. Clinically the fracture resistance of the ceramic may decrease and the restoration can fracture under normal loads. The performance of all ceramic systems remains less stable than that of metal-ceramic systems [3].

The use of a reinforced ceramic core combined with an esthetic veneer material was adopted to improve fracture resistance to of dental ceramics. Ceramic core materials intended for that purpose includes; alumina and zirconia-based materials [1].

Zirconia offers so far the best mechanical properties. The good results obtained from orthopedic procedures brought significant confidence to dentistry for the utilization of zirconia as a support material for esthetic restorations as well as for oral implants. However, controversies regarding to the proper interaction between the zirconia substrate and esthetic veneering porcelain arose, and in particular questions regarding veneered zirconia long-term performance for crowns and bridges [4]. So a newly developed full-contour zirconia crowns have become popular the last few years because of their high flexural strength (1,000+ MPa), tooth color, minimal wear on opposing teeth, conservative tooth preparation, and potential for long-term clinical durability [5].

To increase roughness of high-strength ceramic materials the airborne-particle abrasion with Al_2O_3 was the most appropriate method [6]. This may affect the ceramic surface by creating micro-cracks, which may reduce the fracture strength of a ceramic [7]. So, The aim of this study was to investigate the effect of air abrasion on the fracture strength of both veneered and full contour zirconia crowns.

Materials and methods

Thirty two caries and crack free human maxillary premolars were cleaned from both calculus deposits and soft tissues and then were stored in 0.1%thymol solution [8]. Roots were roughened by making transverse cutting grooves in the roots of the selected premolar using high speed contra angle hand piece to enhance their fixation in the self-cured acrylic resin. The selected premolars were embedded in upright position inside a plastic cylinder 20 in diameter and 25 in hight. Using self-cured acrylic resin (Acrostone, Dental Factory, Egypt) with their long axis perpendicular to horizontal plane of upper surface of cylinders. Prepared teeth for all-ceramic crown had the following criteria: 1mm shoulder finish line placed 0.5 mm occlusal to the CEJ, 2mm occlusal reduction and 5 mm occlusogingival height.

The prepared teeth were divided into two groups (N=16) for each ceramic material, then stored in distilled water to avoid dehydration and to provide as much as possible conditions closed to those found in the oral cavity, numbering of each ring was performed.

Sixteen prepared premolar were used for laboratory fabrication of veneered zirconia crowns. single stage impression technique with putty and light-body polyvinyl siloxane material (3M ESPE,6160J, Germany) was used for each prepared tooth, Type IV improved dental stone(Protechno,6873,Girona,SPAIN) was used for pouring impression, Stone dies were ready for composite build up. A separating medium was applied over the die using a small brush then air dried gently. Light curing composite resin was applied onto the prepared surfaces of the dies which will represent the copy of the core. The composite was cured using light curing unit until the composite coping was finally completed (copy). The copy was then lifted off, finished and polished with rotary instruments. The thickness of the walls of each copy was adjusted to be 0.5mmFig. Milling procedure by Zirkonzahn machine (zirkozahn manual milling system, Italy) was used for the MAD/MAM of VITA In-ceram blocks (Vita-In-Ceram, z-30660, Zahnfabrik, Germany). The milled zirconia cores were placed on firing tray and transferred to a special sintering furnace (Zirkonzahn, Italy). Veneering of zirconia cores by ceramic (VITA VM9) The dentin and enamel layers of porcelain were build up on zirconia cores by mixing its powder and liquid then they were placed on afiring tray which carried out in VitaVacumat (Vita-In-Ceram, Zahnfabrik, Germany.) The firing procedures were carried out according to the manufacturer recommendations; thickness of the veneered crown was adjusted to be 1.5mm in the occlusal surface. Entire surfaces were finished and crowns were coated with a layer of VITA Akzent GLAZE fluid. Glaze firing cycle was carried out in VITA VACUMAT. Completed crowns were then seated on their corresponding teeth.

Sixteen prepared premolar were used for laboratory fabrication of Full zirconia crowns. Single stage impression technique with putty and light-body polyvinyl siloxane material (3M ESPE, 6160J, Germany) was used for each prepared tooth, Type IV improved dental stone (Protechno,6873,Girona,SPAIN) was used for pouring impression. To obtain the same shape for occlusal surfaces of all crowns, a polyvinyl siloxane impression material was loaded into suitable plastic ring for taking an impression for occlusal surface of an extracted maxillary premolar natural tooth, light curing composite resin was loaded into the impression and then cured using light curing unit. The resulted part was finished at (1.5mm) thickness. The finished composite placed on the die and milling procedure by Zirkonzahn machine (zirkozahn manual milling system, Italy) was used for the MAD/MAM of (KATANA Zirconia Blocks, Kuraray Noritake Dental Inc, , Japan) the milled zirconia crowns were placed on firing tray and transferred to a special sintering furnace (Zirkonzahn, Italy).

The fitting surfaces of the specimens of two subgroups is sandblasted with 50µm Al_2O_3 at 1 bar for the same distance (10 mm) and time (40 seconds)for all crowns.

Self-adhesive resin cement (IvoclarVivadent AG FL-9494 Schaan/ Liechtenstein) was dispensed from the double-push syringe and the two pastes were mixed in a 1:1 ratio. The cement was applied soon after mixing to the internal surfaces of each crown, then immediately seated on its corresponding prepared tooth with finger pressure. Light-curing was then performed from four directions for 20sec along the cement interface using light curing unit. Excess cement at the margins was removed immediately with a scaler.

Each specimen was mounted on the lower fixed compartment of a universal testing machine (Model LRX-Plus, Lloyd Instruments, Fareham, UK.) with a load cell of 5 KN then secured by tightening screws. Data were recorded using computer software (Nexygen-MT-4.6; Lloyd Instruments). A steel rod with round tip with a diameter of 2.5 mm was attached to the upper jaw of the machine and placed at the center of the occlusal surface of crowns. A tin foil sheet was placed between the load applicator and the specimen to ensure even stress distribution. The specimens were subjected to a slowly increasing compressive load (1mm/min) until chipped veneer or fracture occurred. Load was recorded in Newton. Sample from each pattern of fractured surface was evaluated by using Scanning electron microscope to examine these patterns accurately. Because the data were found not to be normally distributed, nonparametric methods, kruskal-wallis test and mann-whitney U test were used for statistical analysis.

Results

The date were found to be not normally distributed, Therefore non parametric procedures were used for statistical analysis, Kruskal-Wallis test and followed by Mann-Whitney test was used for comparison between each two groups.

Table 1 demonstrates necessary descriptive statistics for the experiment. Mann-Whitney test and Median test proved that the fracture resistance records high significance difference between VZ and FZ (P=0 for both tests) irrespective to the type of surface treatment. Contrary, both tests proved that the surface treatment has no significance effect on fracture resistance irrespective to the type of material (P=0.72 for Median test and P=0.27 for Mann-Whitney test). Therefore, the material type becomes the main determinant of the fracture resistance.

Omnibus Kruskal-Wallis test and Median test shows that the difference between groups for fracture resistance is highly significant (P=0 for both test). Table 2 showned Mann-Whitney pairwise comparisons. Notice that although there is no significance difference between the means of FZ-Sandblast and FZ-as Milled, FZ-Sandblast is preferred because of it has lower variation (SD=773.807). The overall decision of this experiment should be "Full Zirconia with sandblast surface treatment is preferred over other selections".

Discussion

In this study natural teeth (maxillary premolars) were used as a core material to be as similar as possible to the clinical condition. Natural teeth were prepared according to clinically established preparation criteria for all-ceramic crowns [9,10].

In the present study two types of all-ceramics was used: Core veneered zirconia widely used in the last few years, combining the strength of zirconia cores (transformation toughening mechanism, white appearance, chemical and structure stability) and the esthetics of veneering porcelains to achieve optimal esthetics [11].

Full-contour zirconia crowns have become popular in the last few years because of their flexural strength (1,000+ MPa), these values exceed the maximal occlusal loads during normal chewing. Materials might also exhibit a fracture resistance of more than 2,000 N [12]. Tooth color, minimal wear on opposing teeth, conservative tooth preparation, and potential for excellent long-term clinical success. Monolithic yttria-stabilized tetragonal polycrystalline zirconia has become very widely used in the last few years because of its durability, excellent fit, and improved aesthetics. Without 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 [13,14].

The results of this study showed that the fracture strength of full-contour zirconia was higher than that of veneered zirconia. This result is in agreement with Beuer et al. [15] who reported that the zirconia restorations showed high resistance to failures and fracture, full-contour zirconiademonstrated higher fracture strength than that of veneered zirconia.

These results coincide with the findings of several studies; Pries et al. [16] and Johansson et al. [17] reported that fracture strength of monolithic high translucent crowns is considerably higher than that of porcelain-veneered crown cores, porcelain-veneered high translucent Y-TZP crown cores and monolithic lithium disilicate crowns.

Resistance to fracture of full-contour zirconia showed the tendency for a crack to spread in zirconia is reduced as the stress created in its leading edge causes a transformation in configuration from tetragonal into a monoclinic phase that is 3 to 5% more volumous. The monoclinic crystal places the region in compression and prevents the crack from spreading ("transformation toughening) [18,19].

Core veneer interface is one of the weakest aspect of these restorations so that ceramic chipping or cracking are possible .Different factors may influence veneer cracking as differences in thermal expansion coefficients between core and ceramic, firing shrinkage of ceramic, flaws on veneering and poor wetting by veneering core [20,21].

In a veneered zirconia system, the stiff zirconia core provides stress shielding of the veneer layer and the underlying tooth structure. The exceptionally high strength of the zirconia core prevents flexure induced cementation surface radial fracture. The high modulus of the zirconia core (compared to porcelain) minimizes flexure of the porcelain veneer and propagation of partial core cracks. Therefore, with the support of a stiff and strong zirconia core, flexure of the veneer layer is suppressed, resulting in a steady pace propagation of partial or cores throughout the entire veneer layer. However, joining porcelain veneer with zirconia core at elevated temperatures poses another problem. Due to the difference in coefficient of thermal expansion and thermal conductivity between the porcelain veneer and zirconia core, residual stresses forms inevitable in the system upon cooling. These residual stresses can superimpose on the mechanical stresses induced from fatigue loading, resulting in premature. Fracture or chipping of the porcelain veneers [22].

In the present study was used air abrasion with aluminum oxide particles. Air abrasion was routinely performed to remove layers of contaminants, thus increasing micromechanical retention between the resin cement and the restoration [23,24]. Usually, air abrasion units use aluminum oxide particles with sizes ranging from 25 µm to 250 µm [25].

The result of this study showed that the surface treatment with alumina oxide particles (sandblasting) increased the mean fracture values. These finding are in agreement with the results of Curtis et al. [26], Papanagiotou et al. [27], Kosmac et al. [28].

Sandblasting in zirconia will induce a spontaneous t-m phase transformation by the impact of particles [29,30]. The strength increases after sandblasting, and attributed this increase to the transformation from tetragonal to monoclinic which in turn generate compressive stresses on the surface. Additionally, the biaxial flexure strengths increased with increase in monoclinic ZrO_2 content [31].

On the other hand, Zhanget al. [32] showed that sandblasting before the cementation of Y-TZP restorations mechanically assists the growth of pre-existing flaws, reducing the strength and lifetime of the restoration.

Conclusion

Within the limitations of this in vitro study, the following conclusions can be drawn:

1. Both types of zirconia system have the potential to withstand physiological occlusal forces applied in the posterior region and can be interesting alternatives to replace PFM restorations.
2. There was high significance difference between full-contour zirconia and veneered zirconia crowns.
3. Full-contour zirconia showed higher fracture loads than veneered zirconia crowns.
4. Surface treatment (sandblast) has an effect on the mean value of fracture strength, but it was unsignificant statistically.

Table 1: showing: Descriptive statistics Mean Values of fracture resistance and S.D of veneered zirconia and full zirconia crowns.

Variable	N	Min	Max	Mean	S.D
Veneered Zirconia (as Milled)	8	1095.8	1534.1	1322.0	159.4
Veneered Zirconia (sandblast)	8	1013.3	2334.9	1673.6	375.1
Full Zirconia (as Milled)	8	972.5	4338.5	2492.7	1037.4
Full Zirconia (sandblast)	8	768.7	3235.2	2502.7	773.8
Veneered Zirconia	16	1013.3	2334.9	1497.9	332.8
Full Zirconia	16	768.7	4338.5	2497.7	884.2
as Milled	16	972.5	4338.5	1907.4	937.8
Sandblast	16	768.7	3235.2	2088.2	727.1

Table 2: showing: Statistically significant difference between fractured groups.

Tested groups	*P value <0.05*
Veneered zirconia (sandblast) - Veneered zirconia(as milled)	0.021
Veneered zirconia (sandblast) - Full zirconia (sandblast)	0.015
Veneered zirconia (sandblast) - Full zirconia (as milled)	0.046
Veneered zirconia (as milled) - Full zirconia (sandblast)	0.012
Veneered zirconia (as milled) - Full zirconia (as milled)	0.012
Full zirconia (sandblast)-Full zirconia (as milled)	0.798

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