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Original article

Comparison of Fracture Strength Between Veneered and Full-Contour Zirconia Restorations (Without Surface Treatment) With PMF

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Abstract
The purpose of this in vitro study is to investigate the fracture of zirconia in the posterior region and to compare between fracture strength of zirconia crowns and porcelain fused to metal restorations. Twenty 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 into two groups (n=10) for each ceramic material. In the first group, all prepared premolars were restored by full contour zirconia crowns (mad/mam), while in the second group, all teeth were restored by veneered zirconia crowns. The cores were directly fabricated (Vita In-Ceram blocks) by MAD/MAM and built up with ceramic. All specimens were loaded in a universal testing machine with the compressive load (n) applied along the axis of the specimen. Fracture load was recorded for each specimen. The Kruskal-Wallis test was used first and followed by the Mann-Whitney test. The fracture strength records a highly significant difference between VZ and FZ (p=0 for both tests), irrespective of the type of surface treatment. Contrarily, both tests proved that the surface treatment has no significant effect on fracture resistance, irrespective of the type of material (p=0.72 for median test and p=0.27 for Mann-Whitney test). The fracture strength of zirconia is high in the posterior region, and full-contour zirconia showed higher fracture strength than veneered zirconia crowns and porcelain fused to metal restorations.
Keywords. Fracture Strength, Zirconia.

Introduction

Porcelain fused to metal restorations have been one of the most common restorations used in fixed prosthodontics because of the high strength properties of the metal and casting accuracy. Durability with added cosmetic appearance of porcelain [1]. Although porcelain or ceramic has been used extensively in dentistry, it has its limitations and disadvantages [1]. All-ceramic restorations are becoming increasingly popular as an alternative to metal-ceramic restorations because of their excellent aesthetics and the fact that dental ceramics are the most natural replacement material for missing tooth matter. They are available in a variety of shades and translucencies and offer a natural appearance. They are characterized by chemical stability and biocompatibility [2]. The surface of all-ceramic restorations does not release any potentially harmful elements. The risk of surface roughness and increased susceptibility to bacterial adhesion is reduced, ensuring excellent long-term biocompatibility [3]. 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 [4]. The use of reinforced ceramic cores in combination with aesthetic veneer materials to improve the fracture resistance of dental ceramics is described. Suitable ceramic core materials include alumina and zirconia-based materials [2].

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 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 [5]. So, newly developed full-contour zirconia crowns have become popular over 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 [6].

Zirconium (ZR) is a metal with the atomic number 40. It was first discovered in 1789 by the chemist Martin Klaproth. (7-9) The material has a density of 6.49 g/cm³, a melting point of 1852 °c, and a boiling point of 3580 °c. It has a hexagonal crystal structure and is grayish. ZR does not occur in nature in a pure state. It can be found in conjunction with silicate oxide, with the mineral name zircon, or as a free oxide (zro2) with the mineral name baddeleyite. These minerals cannot be used as primary materials in dentistry because of impurities of various metal elements that affect color and because of natural radionuclides like uranium and thorium, which make them radioactive [10]. Complex and time-consuming processes that result in an

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effective separation of these elements are necessary to produce pure zirconia powders. After purification, the material produced can be used as a ceramic biomaterial [11,12].
In recent years, all-ceramic restorations with stump veneers have become increasingly popular. The combination of the strength of the ceramic core and the aesthetics of the veneer ceramic and the use of layering techniques allows dental technicians to create personalized aesthetic restorations [13]. The mechanical integrity and adhesion of the veneer ceramic to the underlying structure are key factors in the success of dual-layer core/veneer restorations. The long-term success of veneered zirconia restorations appears to depend on the poor performance of the veneer ceramic and its limited bonding to the zirconia substrate. Exposure of the zirconia core ceramic and minor chipping of the veneer ceramic are considered to be the most common reasons for the failure of zirconia FPDs [14]. The following factors have been identified to decrease the core-veneer bond strength: (1) pre-stresses, due to differences in thermal expansion coefficients (tec) of the core and veneering materials, (2) poor wetting of the core by the veneering ceramic, (3) firing shrinkage of the veneering layer, (4) phase transformation of the zirconia crystals at the core-veneer interface due to thermal influences or loading stresses, and (5) inherent flaw formation during processing [15].
The development of fully anatomical monolithic zirconia (MZ) crowns has the potential to address the problem of aesthetic porcelain breakage in posterior crowns and bridges. The crowns can be prepared like traditional PFM crowns, with flat shoulders, bevels, or knife-edge veneers [16,17]. They can be fabricated with only a 0.5 mm occlusal reduction and, most importantly, can be cemented with the clinician's preferred conventional cement [18]. The early restorations were often rather boxy-looking, and although the color was close to the desired shade, the final restoration was usually too high in value. However, the shapes and contours of the new MZ crown are easily altered using a low-speed green stone [19]. Full-contour zirconia is very easy to shape, and it is equally easy to polish using conventional low-speed porcelain-polishing materials [20]. This study was conducted to investigates the fracture of zirconia in the posterior region and to compare between fracture strength of veneered zirconia crowns and full-contour zirconia and porcelain fused to metal restorations.

Methods

Twenty caries and crack-free human maxillary premolars were cleaned from both calculus deposits and soft tissues and then stored in 0.1% thymol solution. Roots were roughened by making transverse cutting grooves in the roots of the selected premolar using a high-speed contra-angle handpiece to enhance their fixation in the self-cured acrylic resin. The selected premolars were embedded in an upright position inside a plastic cylinder 20 in diameter and 25 in height. Using self-cured acrylic resin (Acrostone, dental factory, Egypt) with its long axis perpendicular to the horizontal plane of the upper surface of the 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=10) for each ceramic material, then stored in distilled water to avoid dehydration and to provide as many conditions as possible close to those found in the oral cavity. The numbering of each ring was performed. Twenty prepared premolars 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 the impression, and 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 a 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 0.5 mm. Milling procedure by Zirkonzahn machine (Zirkonzahn 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 a 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 built up on zirconia cores by mixing their powder and liquid, then they were placed on a firing tray, which was carried out in vitavacumat (Vita-In-Ceram, Zahnfabrik, Germany). The firing procedures were carried out according to the manufacturer's recommendations; the 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. The glaze firing cycle was carried out in Vita Vacumat. Completed crowns were then seated on their corresponding teeth.
Ten prepared premolars 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 a suitable plastic ring for taking an impression for the occlusal surface of an extracted maxillary premolar natural tooth, light-curing composite resin was loaded into the impression,

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and then cured using a light-curing unit. The resulting part was finished at (1.5mm) thickness. The finished composite was placed on the die and milling procedure by the zirkonzahn machine (Zirkonzahn 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).
Self-adhesive resin cement (Vivadent 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 20 seconds along the cement interface using a 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 a 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 the 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. The load was recorded in Newton. A sample from each pattern of fractured surface was evaluated by using a scanning electron microscope to examine these patterns accurately. Because the data were found not to be normally distributed, nonparametric methods, the Kruskal-Wallis test and the Mann-Whitney U test were used for statistical analysis.

Result

Descriptive statistics of fracture strength results measured in Newton (N) for two zirconia all-ceramic crowns are shown in Table 1. It was found that the highest mean value of fracture strength was for full contour zirconia (2492.7 N), while the lowest value was for veneered zirconia (1322.0 N).
Regarding the two zirconia all-ceramic crown systems Kruskal-Wallis test showed that the fracture strength of full contour zirconia had higher statistical significance than veneered zirconia ($p=0.000$).

Table 1. Descriptive statistics of fracture strength

Tested group	N	Min	Max	Mean	Median	S.D
Vzm	8	1095.8	1534.1	1322.0	1290	159.4
Fzm	8	972.5	4338.5	2492.7	2253	1037.4

Vz: Veneered Zirconia. Fz: Full Contour Zirconia.

Discussion

Failures in porcelain are fairly common and have been reported in the range of 2.3%– 8% and are said to be the second greatest cause of failure after caries [21][22]. These failures may be classified as: Simple (involving only porcelain body), Mixed (associated with exposure to metal and porcelain), and complex (with substantial metal exposure) [23]. In recent years, zirconia veneer crowns have become widely used, combining the strength of the zirconia core (transformation hardening mechanism, white appearance, chemical and structural stability) with the aesthetic properties of veneer ceramics to achieve the best aesthetic results. [24].
Since their flexural strength (1,000 MPa) surpasses the maximum occlusal loads during typical chewing, full-contour zirconia crowns have gained popularity in recent years. Additionally, materials may have a fracture resistance of over 2,000 N [25]. The materials may also have the potential for outstanding long-term clinical success, little wear on opposing teeth, conservative tooth preparation, and tooth color. The endurance, superior fit, and enhanced aesthetics of monolithic yttria-stabilized tetragonal polycrystalline zirconia have led to its increased use in recent years. As long as teeth are adequately prepared and dental laboratory and clinical materials are treated correctly, clinical performance has been outstanding without stacking porcelain [26,27].
In-vitro evaluation of fracture resistance of dentin-bonded all-ceramic crowns under compressive load gives an idea about the clinical durability of these restorations. In other studies, many factors influence the results, such as preparation design, crown thickness, direction and location of the applied load, radius of the loading stylus, and the ceramic material used [28]. These factors must be standardized and as close as possible to the clinical condition.
In this study, the following criteria of teeth preparation were used: a circumferential shoulder finish line 1 mm, a preparation design with a 6-degree axial taper was used, length of preparation of 5 mm. In-vivo and in-vitro studies showed that the following preparation is usually used for all-ceramic crowns, different axial tapering angles were used for all-ceramic preparation, ranging from 4-12 degrees. However, a 6-degree tapered angle was the most commonly used [29-31]. Clinically occlusal forces are divided into two components, one vertical and the other horizontal. In the premolar area, the triangular ridges of both buccal and palatal cusps of maxillary premolars share the vertical component of the occlusal force. (32) inter cuspal

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distance from buccal to palatal cusp tips of maxillary premolars ranges from 3-6 mm [33]. In this study, the upper plate of the machine included a steel rod with a round tip with a diameter of 2.5 mm placed at the center of the occlusal surface of crowns in a vertical direction parallel to the long axis of the tooth, also it was positioned in the midline fissure of the crown. So, the triangular ridges of buccal and palatal cusps are similar to the clinical condition [34].
The result 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. (2012) [35] who reported that the zirconia restorations showed high resistance to failures and fracture. Full contour zirconia demonstrated higher fracture strength than that of veneered zirconia.
Also, Pries et al. (2012) [31] and Johansson et al. (2013) [36] reported that the 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.

Conclusion

Zirconia systems have the potential to withstand physiological occlusal forces applied in the posterior region. Veneered zirconia crowns can be interesting alternatives to replace PFM restorations.

Conflict of interest. Nil

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