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Comparative Evaluation of Fractural Strength of Zirconia and Biohpp Crown- An in Vitro Study

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KEYWORDS
BioHPP, Zirconia, Fracture Strength, CAD-CAM, Universal Testing Machine (UTM)

ABSTRACT:

Background: The in vitro investigation aimed to comparatively assess the fracture resistance of CAD/CAM Zirconia and BioHPP materials utilizing a universal testing machine.

Materials and Methods: A customized metal die was fabricated, and a silicone mould was created from this die, followed by pouring of a cast, this cast was then sent to lab for indirect scanning from which a total of 30 samples were fabricated, 15 Zirconia crowns and 15 BioHPP crowns, these crowns were placed on the customized metal die with an attachment for a Universal Testing Machine (UTM) and subjected to loading under the UTM to evaluate fracture strength.

Results: The results indicated that the BioHPP crown had mean fracture strength of 1626.50 N, which was higher than the zirconia crowns of 1166.78 N, and that the difference was statistically significant (p-0.000).

Conclusion: Based on the results of this study, BioHPP appears to be a promising alternative material for the restoration of the posterior tooth region. However, clinical studies with long-term follow-up are necessary to evaluate its clinical performance.

Introduction

In routine dentistry, the replacement of a missing tooth is a common and challenging issue. This challenge arises due to the need to meet various requirements related to soft and hard tissue, aesthetics, phonetics, functionality, and occlusion, whether in the anterior or posterior regions. Prosthetic alternatives for replacing missing teeth or tooth include resin-bonded fixed partial dentures, conventional fixed partial dentures (FPDs), removable partial dentures, and implant-supported fixed prostheses, each of which addresses different parameters essential for successful tooth replacement.[1,2,3]Metal-ceramic and all-ceramic materials are the most commonly used for permanent tooth replacement. However, metal-ceramics can cause "greying" of the gingival margin and may induce allergic or toxic reactions in the soft or hard tissues.[4] These drawbacks have prompted the development of all ceramic alternatives. CAD/CAM, the revolution in dentistry has enabled the precise and accurate milling of newer materials such as titanium, zirconium, high-performance ceramics, and polymers. Crown and bridge fabrication with CAD/CAM is becoming increasingly popular. Zirconia is a crystalline dioxide of zirconium. It has almost the same mechanical properties as metals, while its color is that of the tooth being almost half of the dentine.[5] Based on the results of tests carried out in 1975, Garvie proposed a model to explain the good mechanical properties of zirconia. It was named

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"ceramic steel".[6]It is a fact that the use of zirconia materials in dentistry is not something of the past two or three decades. It has been discovered that zirconia layered with ceramic is very hard and therefore does not absorb the occlusal loads; as a result, sometimes, prosthesis is fractured. Failures of zirconia-veneered restorations happen because masticatory forces exerted onto the very weak porcelain material.[6,7] A new class of dental materials, the high-performance polymer BioHPP, may also be a feasible option with wear qualities equivalent to ceramics. BioHPP is a German substance, and it is made of polyether-ether-ketone polymer. BioHPP was first produced as dental material for manufacturing fixed prosthesis.[8] The strength of BioHPP is ceramic fillers which are made with the same grain size which is 0.3 to 0.5 and optimises mechanical properties. As a result of the very small grain size constant homogeneity can be produced. The clinical application of BioHPP crown is another viable option in prosthetic treatment on dental abutment. The inside coping is made of BioHPP, and the outside coating is made of composite material.[8,9] Based on the excellent physical and biological properties of this material, it appears to be suitable for superstructures in dentistry, such as provisional abutments, dental impingements, and dental implants.[10,11] The goal of this study is to compare the fractural strength of zirconia and BioHPP crown materials.

Material and Methods

This study employed an in vitro comparative design, encompassing the following steps:

1. Fabrication of metal die
2. Designing and milling of the crown
3. Measuring fracture strength using UTM machine
4. Statistical Analysis

Metal die fabrication

Stainless steel die was designed using the full functionality of a three-dimensional (3D) computer-aided design programme. A stainless-steel definitive die with 0.8mm wide light chamfer margin was developed and subsequently, it was machined using a computer numerical control milling machine.It had a total convergence angle of 12 degrees and an axial surface height of 5.5 mm with a 6-degree taper. The abutment had round occlusal and cervical line angles measuring 6.0 mm and 7.0 mm in diameter, respectively.The abutment was fabricated on the metal base that is cylindrical and serves as a master die for the BioHPP and Zirconia crowns production.

The Monolithic Zirconia and Biohpp Crowns' design

The Monolithic Zirconia and Biohpp crowns were fabricated using the over-impression technique. A vinyl polysiloxane impression material (flexseed, GC dental products crops, Japan) was mixed and placed over the abutment surface of the metal die. After setting, the impressionwas removed and controlled for any damage to the contour. The impression was poured into Type IV dental stone, this stone model was then sent to the laboratory.The working die was sprayed (Easyscan; Alphadent) with scan spray and scanned using a trios 3 shape lab scanner(3Shape, Copenhagen, Denmark, Software Version 1.4.7.5). Using a standard protocol, the copings in the Cercon® were designed. The parameters were as follows: 0.8 mm for the occlusal and axial wall thickness, 30 mm for the virtual cement layer, and 90% spacer coverage, which corresponds to about 0.8 mm off the finish line. Once the design phase was completed, Cercon Brain proceeded with milling of selected cercon zirconia blank, the enlargement factor compensating for sintering shrinkage (-18% linear) was calculated. The framework was cut off from the blank using a fissure bur mounted on a low-speed handpiece. The framework was placed on a silicon heat furnace tray and sintered at 1350 C for 6 hrs. The veneering porcelain underwent two dentin firing cycles at 830 C and 820 C respectively under vacuum, building it up gradually to restore the crown's final anatomical shape. At last, the glaze was put on and fired at 810 C with the vacuum turned off. The silicon indexes were employed to verify the ultimate thickness of the crown.Once the design phase was completed, the CerconBrainproceeded with milling the selected Cercon zirconia blank into the final Zirconia Crown. Based on the margins of the restorations that were connected to the designs for the emerging profile, 15 zirconia crowns (Figure 1) were created for the control group and 15 BioHPP crowns (Figure 2) were created for the testing group.

Test measuring Fracture Strength

Each zirconia and BioHPP crown was seated on itsmetal die without cementation. A universal testing

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machine was used to apply a compressive axial load vertically from the zirconia crown's occlusal surface along the tooth's long axis. This machine used a round-end (10 mm diameter) hard steel punch at a crosshead speed of 0.2 mm/min to create the circumferential hoop stress at the crown margin, as shown in fracture load and durable time that induced the ultimate cracks in each groupwas investigatedat an optimal rate of 50 frames per second (s) until it reached its ultimate crack. Latter data was then viewed with the load-displacement curve recorded by the UTM. Two mirrors (6 × 6 inches) were placed in an oblique position to visually maximize the observation of the crack around the zirconia crown and BioHPP crowns (Figure 3).

Statistical Analysis

The data was entered into the excel sheet. The data was analyzed using SPSS (Statistical Package for Social Sciences) 26.0 version, IBM, Chicago. The data was analyzed for probability distribution using Kolmogorov-Smirnov test. Mean values and Standard Deviation was calculated. The unpaired t- test was performed. p value<0.05 was considered statistically significant. Confidence interval was set at 95%.

Results

The present in-vitro study was conducted to comparatively evaluate the fracture strength of CAD/CAM Zirconia crowns and BioHPP crowns . All the samples in Group A (Zirconia) and Group B (BioHPP) were subjected to compressive axial loading with a 10mm diameter spherical head mounted in a computer-controlled universal testing machine at a crosshead speed of 0.2 mm/min and the force at which the material fracture were noted with the load displacement curve with 5 samples of each group (Zirconia &BioHPP) demonstrated in 2 graphs .A load displacement graph was plotted,capturing the behaviour of Zirconia and BioHPP, respectively during testing . As the materials deformed under applied loads,the point on the graph exhibited a slight decline. However a distinct point was observed when the crown failed, marked by a sharp drop in the graph.This load displacement curve offers insights in to the mechanical responses of the material, revealing their stiffness, strength and ductility characteristics. The present study compared the fracture strengths of zirconia and BioHPP crowns made using CAD/CAM processing. The results indicated that the BioHPP crown had mean fracture strength of 1626.50 N, which was higher than the zirconia crown's of 1166.78 N, and that the difference was statistically significant (p-0.000). (Table 1, Figure 4)

Table 1- Comparison of mean fracture strength of Zirconia and BioHPP crown (n=30)

Groups	n	Fracture strength (N)	95% Confidence Interval of the Difference		t-value	p-value
		Mean+ SD	Lower	Upper		
Group A (Zirconia crown)	15	1156.78+87.93	-526.18	-413.25	-17.041	0.000* (HS)
Group B (BioHPP crown)	15	1626.50+60.52				
SD- Standard Deviation, n-number of samples,*HS- Statistically highly significant						

Discussion

Fixed prosthodontic treatment entails the permanent restoration or replacement of teeth within the oral cavity. Fixed Partial Dentures (FPDs) serve as prostheses securely attached to natural teeth, dental implants, or tooth roots, providing primary support.[12,13]

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Over the past three decades, crown-based tooth rehabilitation has significantly increased. Materials such as all-metal, porcelain fused to metal, or all-ceramic are commonly used for crown fabrication. However, all restorations carry a risk of malfunction. Metal-ceramic restorations have been the standard in prosthodontics since the 1960s, despite the emergence of stronger ceramic systems, but they are susceptible to mechanical fracture, especially porcelain veneer fracture . Metal-ceramic restorations exhibited a 97% survival rate after ten years of clinical service.[14] However, the most common issue with metal-ceramic prostheses is veneering porcelain fracture, as noted in a systematic review by Goodacre et al.[15] Advancements in Zirconia core technology have shown that all-ceramic crowns possess mechanical properties comparable to metal-ceramic crowns. Despite its high mechanical strength, Zirconia frameworks can still fail due to thermal coefficient mismatches, processing defects, and inherent material defects, necessitating the exploration of alternative materials with reduced fracture load in fixed prosthesis.[16] BioHPP (Bredent, UK) is a partially crystalline polyether ether ketone (PEEK) reinforced with ceramic fillers, enhancing its strength and abrasion resistance.[17] This unique composition provides BioHPP with a balanced combination of elasticity and rigidity, making it suitable for CAD-CAM and heat-press techniques. BioHPP blocks, pellets, and granules are available for various prosthetic applications, with restorations made from these materials known for their excellent marginal adaptation.[18] Despite its opaque and radiolucent nature, BioHPP can achieve aesthetic results when veneered with specially developed laboratory composite resins. Notably, BioHPP has demonstrated compatibility with adjacent teeth, exhibiting no abrasive effects despite its ceramic content. Additional advantages include improved stress modulation, color stability, and excellent polishing properties, positioning BioHPP as a viable alternative to zirconia. Furthermore, BioHPP prostheses have been associated with reduced maximum masticatory forces, making them suitable for individuals with parafunctional habits.[19,20] BioHPP® exhibits mechanical and physical qualities comparable to zirconium oxide or veneering composites, including a balanced combination of stiffness and elasticity (4200–4400 MPa), weight and breaking strength (700-1600 N), physiologic integration, and resistance to plaque.[21]Ceramic-reinforced PEEK abutments with titanium bases have shown promising fracture types and strengths.[22]However, Ardakani et al. suggest that BioHPP may not be suitable for enhancing the fracture strength of PMMA denture base material.[23] Despite this, BioHPP's wear behavior makes it well-suited for clinical use in dentistry. Its low elastic modulus, comparable to bone, and low hardness prevent abrasion of opposing teeth, making it appropriate for various prosthetic applications, including removable partial denture frameworks, removable dentures, obturators, crowns, fixed partial dentures, endo-crowns, post-core restorations.[24] In this in vitro experimental study, we evaluated the fracture strength of zirconia and BioHPPCAD/CAM crowns in group A and group B with 15 samples each . Fracture strength was evaluated using a Universal testing machine (UTM) . Our study observed that BioHPP(Group B) exceeded the fracture strength than that of Zirconia (Group A), demonstrating statistical significance at the 1% level ($p < 0.01$). This discrepancy can be attributed to inherent structural disparities, such as BioHPP's lower modulus of elasticity compared to zirconia, indicating greater flexibility and resistance to deformation leading to higher fracture thresholds as mentioned in the previous studies on BioHPP. Additionally, BioHPP exhibited greater stiffness in contrast to zirconia and higher breaking strength relative to zirconia. These findings suggestsBioHPP as a viable alternative to zirconia for posterior fixed restorations. While numerous in vitro studies have elucidated the mechanical properties of BioHPP, comprehensive reviews amalgamating these findings and assessing its clinical applicability remain scarce. Given the promising outcomes of this investigation and evidence from existing literature, further research endeavors are warranted to explore the potential of BioHPP in dental applications.

Conclusion

Based on the results obtained in this in-vitro study, a comparison of the fracture strength between Zirconia and BioHPP crowns was conducted. The mean fracture strength of CAD/CAM Zirconia Crowns was 1156.78 ± 87.93, whereas for BioHPP (Group B), it was 1626.50 ± 60.52. These findings indicate that BioHPP exhibits superior fracture strength compared to Zirconia, suggesting its potential as an alternative material for posterior restorations in clinical practice. In summary, both Zirconia and BioHPP demonstrate suitability for posterior tooth replacement. However, BioHPP emerges as an intriguing alternative due to its higher fracture strength. Further clinical studies with long-term follow-up are warranted to comprehensively evaluate the clinical performance of BioHPP in posterior tooth restorations.

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