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FIXED PROSTHODONTICS AND DENTAL MATERIALS

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EVALUATION OF STATIC AND DYNAMIC LOAD OF TWO METAL FREE IMPLANT SUPPORTED FIXED DENTAL PROSTHESES

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ABSTRACT

Purpose: to evaluate fracture resistance of implant supported superstructures fabricating of high translucent zirconia and PEEK restoration under static and dynamic load

Materials and methods: 32 epoxy resin blocks were fabricated. Two implant analogues were inserted centrally in epoxy resin block to replace the first premolar and first molar. The samples were divided according to material of superstructures into two groups, high translucent zirconia and high performance Polyether-ether-ketone PEEK (BioHPP). All copies were processed by CAD\CAM technology. PEEK samples were veneered by veneering composite. Half samples were exposed to fatigue procedures then all samples were loaded by universal testing machine until failure. All fracture samples were inspected. Data were statistically analyzed by SPSS Program.

Results: For static test, the mean fracture load value was 2319±139 N for PEEK(BioHPP) group and 1350±89 N for HTZ group. The results of dynamic loads showed that the mean fracture load value was 1850±136N for the PEEK (BioHPP) group and 716±79 N for the HTZ group. In HTZ group, framework fracture was detected. In PEEK, the samples showed veneer and framework fracture.

Conclusions: Restorative material of implant supported superstructure are affected the fracture resistance of dental restoration. PEEK (BioHPP) has higher fracture strength than HTZ in both static and dynamic tests.

KEYWORDS: zircona, peek, fracture strength

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INTRODUCTION

Interdisciplinary management with implant-supported prostheses in the therapy of partly dentate individuals has been shown to be a faithful strategy for improving oral health. Biomechanical factors have an essential role in the survival rate of oral implants. In order to prevent excessively unneeded strains on implant components and the bone, a well-planned and implemented prosthesis is crucial. The selection of superstructure materials are essential parameter to the transmitted force between the alveolar bone and implant. A porcelain fused to metal implant supported prostheses have a long history of outstanding clinical performance, yet they nevertheless have a number of shortcomings.(1)

Currently, the demand for non-metallic restorative alternative has increased. Virtually all ceramic materials used to restore single implant supported demonstrated high survival rates. (2) A ceramic material that has gained appeal in advanced dentistry is zirconium oxide. Numerous investigations have demonstrated this material's remarkable mechanical properties. The zirconia framework were fabricated by CAD\CAM Technology and veneered with translucent porcelain.(3-5) The latest consensus of the European Association for Osseointegration (EAO, 2018) has been recorded the high chipping rate of porcelain veneer for implant-supported (FDPs) that may be problematic for reconstructions utilizing this material.(6)

The advancement of zirconia ceramic has sustained. (7) By altering zirconia particle size and distribution, better optical characteristics have been achieved. (8,9) Monolithic zirconia are recently introduced as alternative to zirconia veneered ceramic. the whole prosthesis is fabricated by CAD/CAM that minimizes the possibility of veneer chipping. The monolithic zirconia are recommended for all fixed prostheses, including full arches and FPDs supported by implants. (8)

An innovative alternative restoration for implant-supported prostheses is Polyether-ether-ketone (PEEK) is a thermoplastic polymer with high mechanical properties. PEEK is a biocompatible biological inert material with high melting temperature.(10) Because of Low modulus of elasticity (4 Gpa) of PEEK, it considered a good substitutes for implant supported prostheses due to enhanced shock absorption criteria when compared to ceramic-based materials. (11, 12)

Various additive can be added to PEEK to enhance its criteria as ceramic fillers by 20% which distributed throughout PEEK polymer matrix (Bio-HPP). (13) Bio-HPP (high performance polymer) has outstanding mechanical properties due to the ceramic particles tiny grain volume, allowing it to be employed as a viable alternative to ceramic restorations. (13) it processed by CAD/CAM technology, but its veneering is critical due to its greyish color.(14) Since BioHPP is a novel material used in prosthetic dentistry, further research are required to compare this material to zirconia, especially concerning their use as FDPs. (15)

This study aimed to evaluate the fracture resistance of three-unit implant-supported FDPs fabricated of: 1) high translucent zirconia (HTZ) 2) PEEK (BioHPP) under static and dynamic load.

MATERIAL AND METHODS

Thirty two epoxy resin (CMB. International, Egypt) solid bases were fabricated. (15) By special centralized device, two holes(4.00 mm diameter hole, 11 mm length) with 15mm separating distance were drilled in the base. (16) Two implant analogues(DTI implant Sistemeri SAN, Turkey) were locked in the corresponding holes to replace maxillary first premolar and first molar. Standard straight implant abutments (DTI implant Sistemeri SAN, Turkey) were screwed (occlusal diameter of 4.5 mm, height 5.5 mm, and a 1.00 mm shoulder margin of with a taper of 6°).

The samples were divided randomly into two groups (n = 16 each) according to the FDP processing materials and fracture test (n=8 for static tests and n=8 for fatigue tests): 1) **high translucent zirconia FDP (HTZ):** CAD/CAM milled full contour frameworks 2) **PEEK (BioHPP):** breCAM. BioHPP blank milled cutback framework with indirect composite resin veneer.

Framework fabrication and cementation

All models were scanned and FDPs were performed with the use of CAD software (Ceramill Mind software, Amann Girrbach). The connector dimensions were set to 3x3mm with 0.9 mm radius of the curvature. For high translucent zirconia group, the dies were scanned to design and mill 16 fully anatomical FDP from a high- translucency zirconia blank (Zolid HT, pre-shaded, Amann Girrbach), The FDP were sintered in a furnace at 1450° C to achieve their full strength.

For PEEK (BioHPP) group, 16 BioHPP FDP copies were constructed from pre CAM BioHPP blanks (Bredent, Germany) with the same system and procedures of zirconia frameworks figure (1). All copies were milled with a standardized 1 mm cutback for uniform veneer application. FDP frameworks were blasted with 110 μm and 2-3 bar pressure and conditioned (visiolink conditioner, Bredet, Germany) BioHPP frameworks were veneered by veneering composite (17) (visio.lign, Bredent, Germany). The veneer thickness was standardized by a silicone index.

All frameworks internal surfaces were air-abraded by alumina oxide particles (50μm, 0.25 MPa) for 15 sec. All FDP frameworks were bonded to their corresponding implant abutments with self-adhesive universal resin cement (Rely-X Unicem 2; 3M ESPE), and the FDPs were stabilized for 30 seconds under a static load of 20 kg, the excess cement removed and the margin light-cured. To prevent cement dehydration, all specimens were kept in a humidified environment similar to that of the oral cavity after cementation. The samples were thermal cycled for 5,000 cycles between 5 and 55 °C, (30 s dwell time for each temperature).

Static load test

The lower fixture of a universal testing machine (Zwick Z010/TN2S). 5 N load was applied by upper head at a crosshead speed of 2 mm/min on FDP pontic. The load was applied until fracture or plastic deformation which detected according to the subsequent criteria: (18) observable veneer cracks; veneer fracture with or without framework exposure; and both veneer and framework fracture. All failure load were registered in Newton(N).

The dynamic load test

The cyclic load was applied in waves of values of 20–200 N by mastication simulator (CS-4.2; SD Mechatronik GmbH) to simulate the average of human masticatory force in posterior region. The load

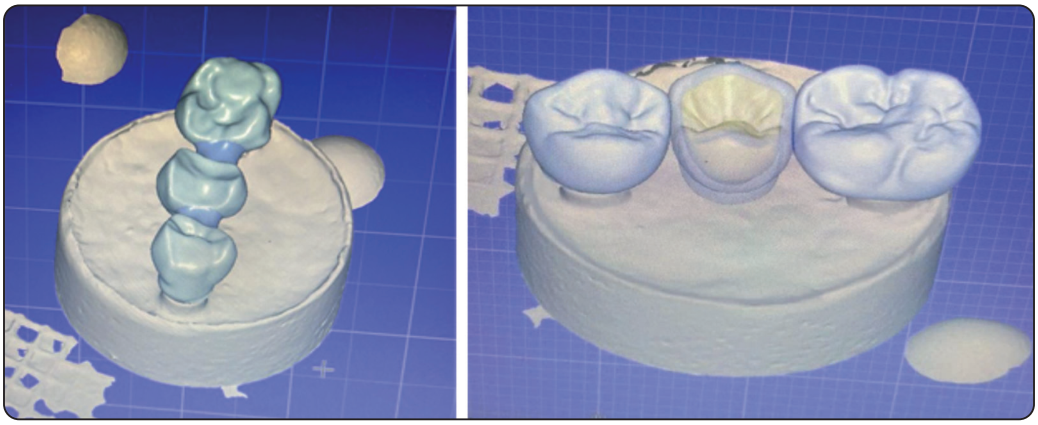

Fig. (1): PEEK Framework software designing.

was amplified incrementally by 20 N every 10,000 cycles to achieve the range of 20 to 200 N.(16) The loaded were applied by universal testing machine until failure or plastic deformation was detected figure (2).

All fractures samples were inspected and the fracture mode was ascertained under magnification.(19)

Fig. (2): Load application by universal testing machine

The failure load values were tabulated and statistically analysis by Kruskal-Wallis analysis of variance and Mann-Whitney test. (p-value less than 0.05 consider significant). ASSP statistical analysis program was used.

RESULTS

During the static and fatigue tests, the mean failure load data were statistically analyzed (table 1). The results of static test revealed that the mean fracture load value was 2319±139 N for PEEK (BioHPP) group and 1350±89 N for HTZ group. The results of dynamic loads revealed that the mean fracture load value was 1850±136N for the PEEK (BioHPP) group and 716 ±79 N for the HTZ group. The interaction between the tested materials and the dynamic loading on the fracture resistance was statistically significant (P=0.02). Dynamic load application significantly decrease the fracture strength for both testing materials. Statistics for groups showed statistical significant difference between all groups. Before and after dynamic loading, the PEEK (BioHPP) groups showed a statistically significant greater fracture load mean value than the HTZ groups (P0.01) figure (3).

TABLE (1) Characteristic fracture strength calculated from static and dynamic tests for HTZ and PEEK (BioHPP)

Groups		N	Mean	SD
Static test	PEEK(BioHPP)	8	2319	139
	HTZ	8	1350	89
Dynamic test	PEEK(BioHPP)	8	1850	136
	HTZ	8	716	79

All fracture samples were inspected. In HTZ group, During static test, framework fracture was detected of all samples deflecting to the connector area. During dynamic test, 75% of samples showed framework fracture and 25% of samples showed framework fracture with connector separation figure (4). In PEEK, for static test, all samples showed veneer fracture however, in dynamic test, 37.5% of samples showed veneer fracture however, the remaining samples had framework fracture figure (5).

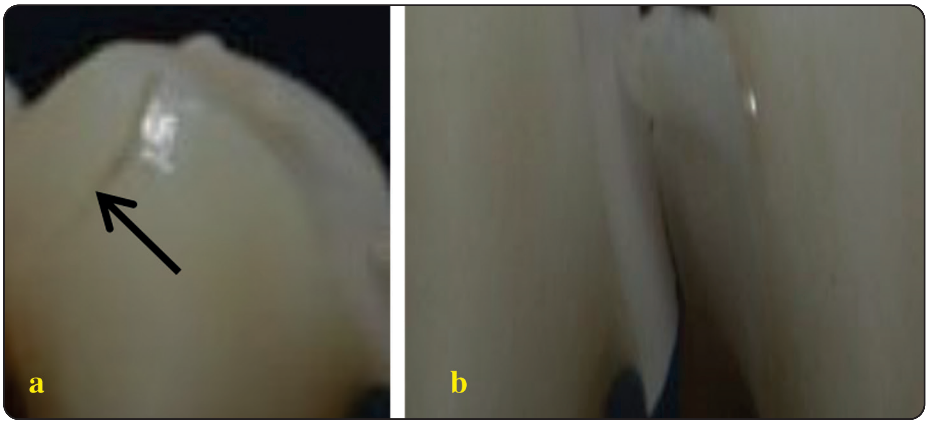

Fig. (4) : a. Framework fracture b. Connector separation of HTZ sample

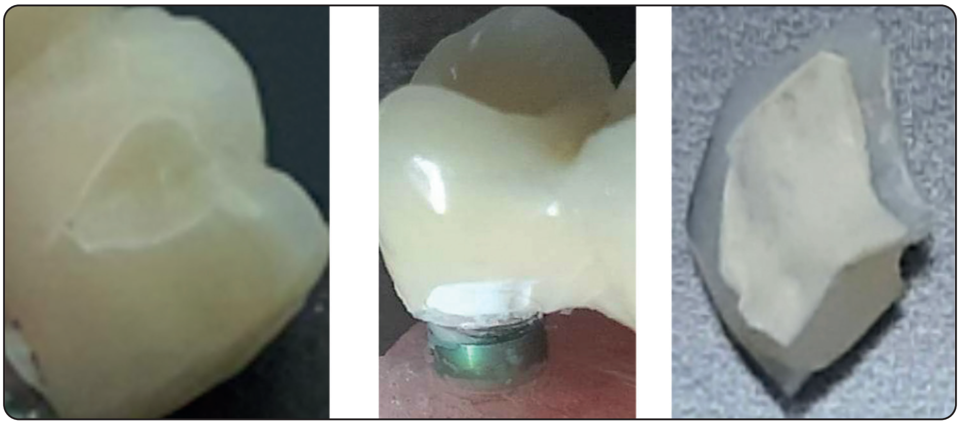
(a) (b1) (b2)

Fig. (5): a. PEEK veneer fracture b1. PEEK veneer and frame-work fracture b2: Fracture veneer segment showed framework fracture

DISCUSSION

Fracture properties are governed by FDP material qualities and the geometric configuration of the restorations. The elastic modulus of a material is an important factor to consider when evaluating a prosthetic restoration. A restorative material with an elastic modulus comparable to the tooth structure had better a more equal stress distribution. For traditional FDPs, all-ceramic restorative systems have worse survival rates than metal ceramics (FDPs). (20) In implant-supported prostheses, numerous factors are considered during treatment plan as no existing of periodontal ligament resiliency, implant–abutment connection geometry, abutment configuration and screwed or cemented prosthesis. (21) The distribution of stresses was significantly influenced by the superstructure's restorative material characteristics. (22)

Implant-supported fixed dental prostheses (FDPs) are commonly utilized in partial edentulous patient to rehabilitate the function and aesthetics. These achieve numerous clinical benefits in terms of FDP function and stability. Because of increased the patient aesthetic demands and the advances in esthetic dentistry, zirconia FPDs are frequently employed, despite the fact that metal ceramic (MC) FDPs have been still suggested for implant-superstructures. (23)

several studies have proven that Zirconia-based ceramics are considered an appropriate substructure to resist the great tensile loads generated by multi-units FDPs. Using Metal Ceramic (FDP), the metal framework have sufficient strength to withstand the applied forces. (24-28)

Other desirable attributes of zirconia include outstanding mechanical properties, chemical stability and excellent biocompatibility. Several applied clinical studies showed that zirconia FPD survival rates were satisfactory and comparable to those of MC FPDs. However, the most common technical issue of zirconia FPDs has been chipping fracturing of the layered porcelain, (29, 30) which required critical laboratory processing restrictions as a slow cooling protocol during the final glaze cycle. (31) Monolithic full contour zirconia have been recently revolved to over comes veneer zirconia drawbacks.(7)

Romeed et al. (32) stated that to avoid dental material failure, In all materials, the highest primary stress value should be lower than the corresponding critical value. According to some implant researchers, the elastic deformation characteristic of a more resilient superstructure material could lower tensions around the implant. (33)

The need for alternatives ceramic materials has been the concern of some researches. BioHPP was introduced as a dental CAD / CAM processed material to achieve high mechanical durability such as fatigue, bending and tension.(34) BioHPP has a low modulus of elasticity comparable to that of bone, resulting in uniform load distribution and overcoming stress concentration on bone. (35)

The goal of this study was to assess the fracture resistance of two different prosthetic materials for three-unit implant-supported FDPs: high translucent monolithic zirconia (control group) and polyet hyletherketon(experimental group) under static and fatigue force.

In the present study methodology, the selected implants analogues were fixed in epoxy resin blocks as its young's modulus is close to that of jaw bone. (15, 36) The implant analogues were fixed with special centralized device to ensure that all the specimens were placed concentrically with a standardized embedment depth. Furthermore, to standardize the frameworks thickness, the frameworks were processed by CAD/CAM technology.(37)

The fracture resistance test is crucial in predicting clinical service and failure of tested materials. Cyclic fatigue loading test investigate the mechanical longevity of dental prostheses. Fatigue is one of the most effective causes of prostheses failure during clinical use. Great attention should be paid to cyclic loading as it considered a more clinically reliable than the static loading as it duplicate the force that affect dental restorations.(38) in the current study, half samples were subjected to dynamic loading, as materials would experience subcritical cracks when chewing, in order to assess sample behavior under clinically relevant settings.(24, 39)

In the current study, the characteristic extreme fracture strength were calculated from the fracture load during static and dynamic test. The results of both tests revealed significant statistical differences with highest values for PEEK (BioHPP) followed by HTZ. The is expected to be due to zirconia's low-temperature degradation, which restricts its durability. The zirconia is a brittle material that cannot withstand tension. (40)

The dynamic test showed lower fracture strength values than static test for both groups. Fatigue loading hasn't sufficient strength to cause failure, however the samples which exposed to chewing simulation were subjected to a slow crack propagation. These cracks gradually progress until getting critical extent that cause failure.(41)

The results of this study are in accordance with Montaser A (15) concluded that the PEEK (BioHPP) has superior fracture strength than zirconia ceramic under dynamic loading test. Jayesh et al (40) and other (42) reported that PEEK consider a promising restorative material as it showed higher fracture resistance than zirconia under static loading test.

These study's outcomes are in contrast with earlier studies [43-45] that reported that zirconia restoration to be superior fracture strength than PEEK (BioHPP) that is interrelated to material characters of used materials.

By inspection of fracture samples, the two different failure patterns were detected in the PEEK (BioHPP) were either composite veneer fracture or framework fracture. These may be explained by bonding mechanism of veneer composite and PEEK framework that may weakened during fracture test especially after fatigue application. PEEK Veneer fracture should be taken in consideration during clinical application as clinical repaire is required. Zirconia framework fracture involved all samples and cause connector separation of a substantial number of samples. These results were in accordance with previous studies.(15, 16)

In conclusion, the use of PEEK(BioHPP) as superstructure for implant supported prostheses should be considered when possible. Veneer fracture of PEEK (BioHPP) group can be repaired clinically by chair-side composite application for continuous use. Fracture load values for both HTZ and PEAK groups under static and dynamic loads are acceptable to be applied in clinical use. This vitro study was performed under controlled laboratory parameters with limited number of samples. It is important to approve these results in well-performed clinical trials.

CONCLUSIONS

Within limitation of this study, the following conclusion can be estimated:

1. The choice of used material has a significant impact on the restoration fracture resistance.
2. PEEK (BioHPP) copings outperformed zirconia copings in terms of fracture resistance.
3. The dynamic test, which duplicate the oral condition, PEEK (BioHPP) was shown to have a better chance of survival.
4. Framework fracture occurred in both groups, however veneer fracture were restricted to PEEK (BioHPP) group.

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