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Tensile Bond Strength of (PEEK) vs Lithium Disilicate Endocrown. (An Invitro study)

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Abstract

Aim

To assess the difference in tensile bond strength between (PEEK) and lithium disilicate endocrowns cemented to natural extracted teeth after thermocycling .

Methodology

22 recently extracted human maxillary first molar teeth from diabetic patients ranging from 20 to 50 years old were collected from the Oral and Maxillofacial Surgical Department of Faculty of Dentistry, Cairo University. All teeth were subjected to standard endodontic treatment and mounted into resin pattern. Cavity preparation with butt joint design was made with copious water cooling using CNC special milling machine . The specimens were divided into 2 equal groups (n=11). 11 endocrowns were allocated to be constructed from lithium disilicate and others were allocated to be constructed from PEEK. All endocrowns were cemented on their corresponding teeth using cementation loading device. All samples were subjected to thermal cycles(6000cycles,5-55c) . Tensile load was applied using universal testing machine .Retention was measured by Materials Testing Machine with a loadcell of 5 kN. Stereomicroscope was used to investigate the the mode of failure. Data was statistically analyzed used Kolmogorov-Smirnov and Shapiro-Wilk tests & Student's t tests ($\alpha = 0.05$) and failure mode (%) by the Fisher exact test & chi2 test ($p \leq 0.05$).

Results

The mean ± SD values of tensile bond strength were recorded for lithium disilicate group (2.683±0.56 MPa) meanwhile the mean ± SD value recorded with *PEEK* endocrown group(2.119±0.37 MPa) . It was found that lithium disilicate group recorded statistically significant higher tensile bond strength mean value than PEEK group.

Conclusions

It was found that lithium disilicate endocrown group recorded statistically significant higher tensile bond strength mean value than *PEEK* endocrown group after thermal loading .

Keywords

PEEK, Lithium disilicate , Endocrown , adhesion, tensile bond strength.

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Introduction

The restoration of endodontically treated teeth with an ideal treatment has always been an important and necessary step because they are more subjected to failure than vital teeth. The situation becomes more complicated when there is an extensive loss of tooth structure and it is not possible to provide sufficient criteria for post and core supported crown preparation. Adhesion concept allowed preservation of sound tooth structure and no more aggressive tooth structure removal and destructive preparation. Through the use of adhesive materials, adhesive systems as well as adhesive techniques, it became possible to retain the restoration in its place without the need of aggressive macroretentive methods.Endocrowns are single monolithic adhesive restorations that adhesively bond to tooth structure of endodontically treated teeth by resin cement . This type of restorations addresses applying the concept of "monoblock" which means that all components act as a single unit. **(Chang et al. , 2009)** . The materials from which endocrowns are made should be adhesive materials such as etchable ceramics containing glass (Feldspathic, Leucite or Lithium disilicate based), resin composite, reinforced glass ceramics with Zirconia or hybrid resin nanoceramics in order to adhesively bond to tooth structure. Inherited brittleness of all ceramics and high elastic modulus are claimed to be the major limitation of theses materials . **(André M et al., 2016)** . Poly Ether Ether Ketone (PEEK) was introduced in 1980 and launched to field of dentistry in the last decade is one of the high performance polymers . It was introduced to the dental field due to its wide range of potential application because of their appropriate stress distribution, high fracture resistance, and low abrasion to the antagonist enamel. BioHPP (High Performance Polymer) is based on polyether-ether-ketone (PEEK) polymer and was introduced as dental material for manufacturing the superstructure dentures on dental implants by the Bredent factory. Their strength is due to the special ceramic filler 20% (with the grain size of 0.3 to 0.5 µm), which optimized the mechanical properties. Due to this very small grain size, constant homogeneity can be produced. **(Bio Hpp brochure)** . The E-modulus of BioHPP lies in the range of 4000 MPa, which very strongly resembles the elasticity of human bone and dentin. The chewing forces are therefore cushioned through the material transferring less forces to tooth structure. The maximum fracture resistance of BioHPP is up to 1200 Newtons.Poly Ether Ether Ketone based materials bond strength can be achieved by surface treatment and some adhesive systems. However, most of the previous in vitro studies for bonding composite resin to high-performance polymer are limited to PEEK materials with few bonding materials. In addition, there are only few studies evaluating the bond strength of restorations manufactured from (PEEK) . **(Sang-Wan Shin et al.,2017)**

Material and methods

Teeth selection:

22 recently extracted human maxillary first molar teeth from diabetic patients ranging from 20 to 50 years old were collected from the Oral and Maxillofacial Surgical Department of Faculty of Dentistry, Cairo University. An approval from the Research Ethics Committee of Cairo University was received. The teeth were intact, free from caries or any fillings, without cracks, fractures or wear. The selected molars had similar dimensions as much as possible . Teeth were measured using a caliper buccolingually and mesiodistally at the CEJ(Figure 1) . All teeth were subjected to standard endodontic treatment. Access cavity was done using a high speed handpiece under copious irrigation.

Teeth mounting:

All teeth were ultrasonically cleaned from remnants of calculus and debris . Indentations were made on the roots of the teeth for retention with resin using diamond stone . Each tooth was vertically mounted using a holding device (Figure 2) to ensure their placement with the long axis perpendicular to the horizontal plane in circular plastic mould with 2 cm diameter and 1.5 cm height then autopolymerizing epoxy resin was applied 2mm below the cementoenamel junction (CEJ) .

Figure (1): measuring with caliper

Figure (2): teeth mounting.

Endocrowns preparation design:

Butt joint design was selected for this research. Gutta percha was removed till the canal orifice with no drilling inside root canals. Cavity preparation was made with copious water cooling using CNC special milling machine holding a high speed handpiece with a flat end diamond tapered stone having 10° taper to ensure a standardized 10° coronal divergence.

Randomization:

All samples were numbered from 1 till 22 then were divided by web site (www.Random.org) into 2 equal groups.

Teeth grouping:

Teeth were then stored in distilled water at room temperature. Samples were given numbers and divided into 2 groups according to material of construction:

Group (A):11 endocrowns were allocated to be constructed from lithium disilicate .

Group (B): 11 endocrowns were allocated to be constructed from (PEEK) .

Endocrowns construction:

Wax patterns of all endocrowns in this study were constructed using Sirona CAD/CAM system then IPS-Emax press was used for construction of lithium disilicate ,and (Bio HPP granules) was used for construction of (PEEK) endocrowns using heat pressing machine .

Cementation procedures:

A-Surface treatment of lithium disilicate endocrowns:

Surface treatment was done according to the manufacturer recommendations. The inner surface of the restorations was etched for 20s with 10% HF CONDAC, washed with air water spray for 30 s then dried with air spray . Silane monobond N was applied with a microbrush for 60 seconds then air thinned and left to dry

B-Surface treatment of (PEEK) endocrowns:

The fitting surfaces of the endocrowns were airborne-particle abraded with 110 mm aluminum oxide at 4 bar and 1 cm standardized distance from plasting nozzle for 10 seconds then the bonding agent (visio.link bredent) was applied with a microbrush .

Surface treatment of prepared natural teeth was done according to the manufacturer recommendations. Etching the surface was conducted with 37% phosphoric acid gel* for 30 seconds on the enamel and for 10–15 seconds on the dentin (selective etching technique) , followed by rinsing with water air spray for at least 30 seconds.

Seating of the restorations with average finger pressure onto the prepared teeth was done, then a cementation device with constant load of 3 kg for 5 minutes was applied for cementation standardization.

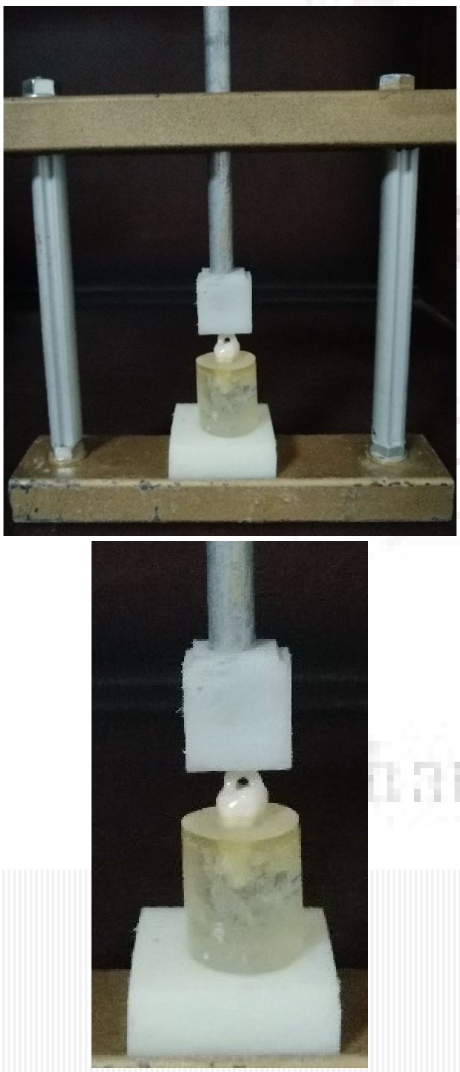

Figure (3): cementation of endocrown using the cementation device.

Laboratory tests:

Thermo cycling:
The cemented specimens were first introduced in the thermocycling machine for 6000 thermal cycles in a water bath between 5 and 55 degrees.

Retention test
Tensile load was applied using universal testing machine .Retention was measured by Materials Testing Machine with a loadcell of 5 kN. Data were recorded using computer software (Bluehill Lite; Instron Instruments). STL data of the scanned prepared teeth was installed into meshmixer to calculate the average bonded surface area of specimens (total bonded surface area / number of specimens) . The load recorded was divided by the obtained average surface area 106.3 mm2 to obtain tensile bond strength in (MPa) (newton per square mm). **Tensile bond strength (MPa) = Load (N) / Surface area (mm^2)**

Data were recorded and collected then statistically analyzed.

Results

It was found that ***E.max*** endocrown group recorded statistically ***significant*** higher bond strength mean value (2.683±0.56 MPa) than ***PEEK*** endocrown group(2.119±0.37 MPa) as indicated by t-test (t=2.8, P=0.012<0.05),and as shown in in **table (1)** and **figure (4).**

Table (1): Comparison of tensile bond strength results (Mean±SD) between both material groups in MPa

Variables		*Mean*	*SD*	*95% CI*		*Range*	
				Lower	*Upper*	*Mini.*	*Maxi.*
Material type	*E.max*	2.683	0.56	2.35	3.011	1.848	3.210
	PEEK	2.119	0.37	1.903	2.335	1.753	2.485
t-test	*t-value*	2.8					
	P value	0.012*					

*; significant ($p < 0.05$)   ns; non-significant ($p>0.05$)

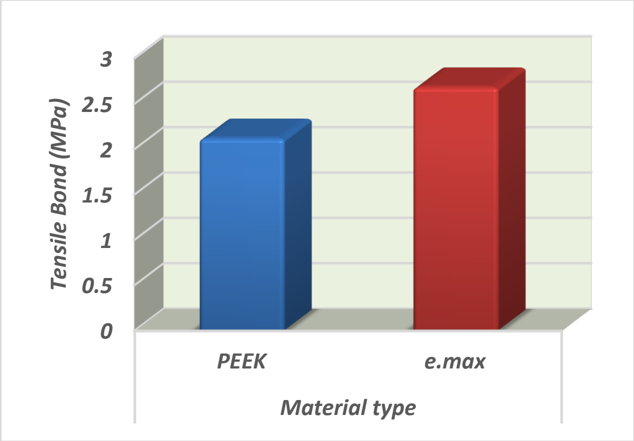

Figure (4): Column chart showing the mean values of tensile bond strength for both material groups

Discussion

In this study, natural teeth were used because they are the most representative of the clinical situation in terms of morphology, architecture, size and bonding properties supporting adhesive restorations. **(Bhowmick et al. ,2007)**

Upper molar teeth with average similar dimensions were used due to the very limited supply of many acceptable natural molar teeth of nearly the same dimensions without a single defect and with the exact criteria. So there was a necessity to discard many teeth for selection standardization.

Epoxy resin was used as an embedding material around the roots due to its modulus of elasticity which is near to that of human bone.**(Burstein et al. ,1994)**

Some researchers supported the use of a material that imitates the periodontal ligament (as wax, polyether, polysiloxane, polyurethane elastomeric material) claiming that rigid acrylic resin reinforces the tooth structure thus; increasing the fracture resistance. Yet , no periodontal ligament simulation was made in this study due to its insignificance in tensile bond strength tests.**(Soares et al., 2005)**

Teeth preparation was conducted according to the clinically followed criteria for all ceramic endocrowns and crowns using a special milling machine to ensure preparations standardization. **(Samran A et al. ,2015)**

Lithium disilicate Emax ingots were used because of their excellent mechanical and esthetic properties, bonding capabilities and clinical acceptability.**(Samran et al., 2015)**

Bio Hpp granules was used in an attempt to make use of a new material having suitable resiliency, strength and low abrasion to the antagonist enamel with reasonable cost. PEEK exhibits a modulus of elasticity of 4 GPa, which could dampen force transmission, thereby preventing the tooth and subsequently the root from overloading and breakage as stated by **(Shin et al., 2017)**.

Butt joint preparation design was selected due to the the fact that it allows preservation of the peripheral enamel layer around all margins ,which is effective in eliminating microleakage at restoration tooth interface ,thus counteracting shear sresses. Moreover, the butt joint preparation design was able to remove the prismatic and the inter-prismatic mineral crystals that improves enamel etching and enhance tooth restoration bonding . **(Rocca et al., 2013)**

Bonding protocol was strictly followed to all samples according to the manufacturer recommendations. Total etch bonding technique was chosen as it is the gold standard technique to ensure optimum bonding . **(Meharry et al. ,2013)**

The present study used air-abrasion technique for the surface treatment on PEEK

following **Shin et al. ,2017** who reported that when bonding resin composite to PEKK materials, the combination of air-abrasion surface treatment with MDP or MMA-containing bond materials are recommended and acid surface treatment of PEKK is not required. Moreover ,On the basis of the SEM images and their result of Ra and contact angle measurement they reported that bond strength was higher in air-abrasion treatment groups.

They added that the combination of air-abrasion surface treatment techniques and not only methacrylate containing adhesive systems but also MDP containing universal bond materials results in suitable bond strengths. This may be attributed to the fact that MDP has similar effect to MMA-containing bond materials on roughened PEKK surface. As having a hydrophobic methacrylate terminal end and a hydrophilic phosphate terminal end, copolymerizing resin monomers and chemically binds to oxides, respectively, MDP has a bifunctional adhesive monomer that can bind to zirconia or metal.

Dental clinicians and researchers have always tried to imitate the oral cavity environment with a laboratory in-vitro testing due to the difficulties faced trying to get significant clinical results for a new medical treatment. These restrictions could be the high investments, low significant outcomes due to small number of subjects or high variability of results as well as the ethical problem .

It was very important to conduct the thermal loading before fracture retention test as they significantly reduce the restoration bond strength . Restorative materials have a different coefficient of thermal expansion than the dental structure which generates stresses at the adhesive interface during thermomechanical cycling. These stresses may result in microcracks that propagate along the bonded interface, causing a gap to form. **(Brum et al., 2011)**

Based on the results of this study ,the null hypothesis was rejected ,since the results showed that lithium disilicate endocrowns recorded statistically *significant* higher tensile bond strength mean value than ***PEEK*** endocrown. This might be attributed to the ultimate bond strength between lithium silicate ceramics and resin as stated by many authors . **(Brentel et al., 2007) (Tian, et al .,2014) (Yao, et al., 2018)** and confirmed by which showed mixed mode of failure where about more than 40% of cement attached to E-max fitting surface .The retention values of PEEK endocrowns might be due to the combination of air-abrasion surface treatment and MDP containing universal adhesive application as recommended by manufacturer and **(Shin et al. ,2017)** having a hydrophobic methacrylate terminal end and a hydrophilic phosphate terminal end, copolymerizing resin monomers and chemically binds to oxides of Bio Hpp ceramic fillers .However , PEEK endocrowns showed adhesive mode of failure where the cement was almost detached from endocrowns and remained attached to the teeth

Conclusion:

Within the limitation of this study , the following conclusions were drawn :

1. lithium disilicate endocrowns provide superior retention and tensile bond strength than PEEK endocrowns .
2. Both lithium disilicate and (PEEK) endocrowns survived thermocycling without any failure .
3. Both lithium disilicate and (PEEK) endocrowns could be considered as clinically reliable restorations ,based on their bond strength values .

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