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FLEXURAL STRENGTH OF MILLED PEEK BAR VERSUS PEKK BAR ON TOOTH SUPPORTED OVERDENTURES. IN VITRO STUDY

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ABSTRACT

Digital dentistry allowed for the introduction of high-performance polymers as an alternative for metals. The successful introduction of peek (Polyether ether ketone) in prosthodontics field has encouraged the researchers to try similar materials as Pekkton (polyether ketone ketone). This invitro study aimed to evaluate the flexure strength of the milled Pekkton tooth supported bar under an overdenture as an alternative for PEEK one.

Methodology a mandibular stone cast with two prepared canines was duplicated into an acrylic one, the cast was then scanned for digital designing of tooth supported bar to be milled in to either PEEK (group A) or PEKKTON bars (group B) respectively. Universal testing machine was used to measure the flexure strength of both materials under 4- point beam load resembling forces presented during functions.

Result: statistical analysis showed a significant difference between group A and group B, where group B showed better result and flexure resistance to bending over group A**.**

Conclusion: both materials showed an acceptable result to be used as bar attachment under tooth supported overdenture, more clinical trials are needed to allow for long term evaluation for both materials.

KEYWORDS: Overdenture, Ethers, Dental Prosthesis Design, supporting tooth, PEKK, PEAK, PEEK Materials Testing*,

INTRODUCTION

A retentive stable denture is a prime goal for every prosthodontist; however, this rendered difficult if the residual ridge resorption was gross. Some patients would willingly sacrifice their remaining few teeth for complete denture. Conservative Prosthodontics had offered these patients a better line of treatment by utilizing the remaining natural teeth to retain and support an overdenture.[1]

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According to the glossary of prosthodontics, Overdenture is defined as any removable dental prosthesis that covers and is partially supported by natural teeth, natural tooth roots, and/or dental implants. [2]

Different attachment systems have been used to retain an overdenture which could be mainly classified into studs and bars.[3]

Bar attachments retainers act as splints for roots present in the edentulous space. Since the bar is positioned close to the mandibular alveolar ridge, the forces applied through the bar would be less than the forces applied through the occlusal rest of a mandibular partial denture.[4]

Hader bar has a pear- shaped cross section which resulted in less torquing force, and better force distribution in the posterior edentulous area when compared to other tissue bar designs.[4]

Bars were commonly fabricated from metal alloys as cobalt chrome. After the spread of CAD/CAM technology different materials have been introduced as a substitute for metals in the field of prosthodontics.

Base metal alloys were commonly used in the fabrication of prosthetic frameworks. However, hypersensitivity and allergic reactions were reported by some patients in addition to unpleasant metal taste or display when the overlay prosthesis was removed. Zirconia ceramics have been suggested to act as an alternative for the fabrication of prosthetic frameworks too, but ceramics were 20 times harder. also, gold, titanium and other alloys were 10 times harder than bone. thus, their long-term use would cause wear and destruction of the opposing teeth and alveolar bone.[5]

When choosing a framework material it should have a close resemblance to the physical properties of bone, allowing less pressure transfer to the abutments and bone. Although ceramics are good materials to be used in allergic patients to base metal alloys, they were reported to transfer higher pressure to abutments which cause wear of the opposing teeth or damage in the opposing restoration. Also, their high fabrication cost, inability to be directly repair in the oral cavity have made them questionable to substitute the base metal alloys in the fabrication of frameworks and bars.[6]

Recently polymers have been used in many fields of science. Bio-high performance polymers have wide applications in both medical and dental fields.[7]

PEEK (polyether-ether ketone) has been known to be a high-performance polymer that could replace metal in dental prosthesis.[5] it has shown high strength properties which was attributed to the special ceramic filler of 0.3- 0.5 µm grain size, this optimized both the mechanical properties and the homogeneity of the material when used in dental application.[8]

PEEK was suggested to be used as frameworks when combined with acrylic resin denture teeth and heat-cured acrylic resin denture bases as an alternative to conventional Co-Cr frameworks.[9]

Studies suggested the use of an implant-supported overdenture with a milled PEEK bar polymerized into a zirconia framework for the rehabilitation of an edentulous patient. the results revealed high patient satisfaction regarding function and esthetics for a 6months period of time. [10]

The previous advantages of PEEK material as a substructure in different prosthesis, together with its ease of fabrication through the CAD CAM technology had turned PEEK into a successful replacement to metal alloys. [11] Moreover, it had encouraged the researchers to study the other members of the PEAK family[12].

Polyether ketone ketone (PEKKTON) is a high-performance polymeric material. It was first introduced by Bonner in 1962 for military and industrial purposes, Recently, many improvements have been done to the properties of this material to become suitable for dental and medical applications.[13]

The evolution in digital dentistry and Computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies have increased the accuracy and facilitated the way of fabrication for these modern restorative and prosthetic materials [14.]

PEKK as a material can be used in dentistry due to their mechanical properties in terms of flexure, tensile, and compressive strength. Modifications and improving the material properties could result in wider applications in clinical dentistry. Long term evaluations are needed as PEKK is recently applied in dentistry with limited studies. [14]

As there is an increase in the demand for high quality, reliable and long- lasting materials, flexural tests have become a very important and essential testing method for both the manufacturing process and research development to define a material's ability to resist deformation under load .thus facilitating the decision of the clinician when choosing among different materials for a certain type of prosthesis.[15]

The Universal testing machine is used to measure flexure strength by employing a transverse bending test. This measures the maximum force that a material withstands before it breaks or yields. Yield is when you have pushed a material beyond its recoverable deformation, and it will no longer go back to their shape again.[16]

Measuring can be done using either 3 points or 4 points bending test. The main difference between both bending tests is the area in which the maximum bend stress occurs. Where in the 3 points bending tests, it is under the loading nose in the middle, while for 4 points bend tests it is distributed in a wider area between the loading points. There are no shear forces in the four-point bending flexural test in the area between the two loading pins. [17]

This invitro study was made to assess the flexure strength of milled PEKK Hader Bar when compared to milled PEEK Bar. The flexure strength of the bar underneath an overdenture was very important where it is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. This reflected how much force was required to break the material used, so as this value was exceeded, the material broke. The higher the value, the more impacting forces the material could withstand.

MATERIALS AND METHODS

7 samples were made for each group, Group A PEEK bar and Group B PEKK bar.

Model Preparation

An edentulous mandibular stone model with only two canines remaining was used. Canines were preferably selected in clinical practice as they ensure greater stabilization and retention arising from their root morphology, large root surface, and wide junctional epithelium when compared to the other teeth . also, they possess large canal space making them very wishful for endo treatment.[18]

The two canines were prepared into a dome shaped with no undercuts and vertical height of 3 mm above gingival margin. Light chamfer finish line was produced to ensure a proper seating for the coping.

The cast was duplicated using hooper duplicator and silicone duplicating material (Ecosil, duplicating silicone, DENTAURUM, Germany), to produce an identical duplicated acrylic cast to avoid any damage in the abutments when subjected to load.

Scanning of the cast

The acrylic cast was sprayed with an anti-reflection spray (Renfert-Scanspray,200m 6.80 fl.oz., 17310000, Germany), for better scanning. The sprayed cast was then scanned using (AMMAN GIRRBACH ceramill 200+) producing the 3D virtual model used in this study.

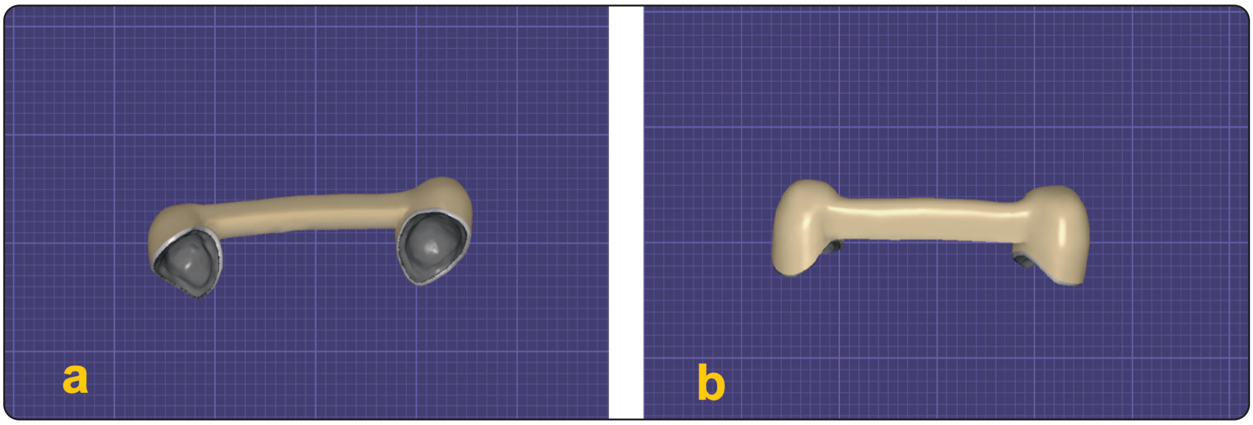

Fig. (1a&b): Digital designing for the bar on virtual model.

CAD design for the Bar.

Using EXOCADE software (Exocad GmbH CAD/CAM software) the Hader bar was designed with width of 3mm, length of 2mm, 0.6 mm for the copings as a minimum thickness and with vertical height of 2mm from the bottom of the bar to the cast which present the distance between the bottom of the bar and the soft tissue covering the ridge.

The STL file produced was saved and sent to the cam software to form the PEEK bar from milling a PEEK blank of 20 mm thickness. (BioHPP, high performance polymer, Bredent GmbH&Co.KG, WeiBenhorner Str.2,89250 Senden,Germany) and PEKK bars using PEKK blank of 20 mm thickness (Pekkton [R] ivory, high performance polymer,Cendres+Metaux SA Biel/ Bienne,Switherland) with IMES milling machine (imes-icore GmbHIm Leibolzgraben 1636132 Eiterfeld) both materials were milled dry and at low pressure with medium speed producing 5 samples for each material.

The bar was then trimmed out of the blank, finished by cross toothed mill bur with low pressure on the bar, Then the finished bar was returned to the selected cast in order to be checked for proper seating and good adaptation. Each finished bar was cemented to the acrylic cast using resin cement (Nova resin cement) as shown in Figure 2a, b.

Flexure strength of bar in both groups; group A; the PEEK bar and group B; PEKK bar was measured using the universal testing machine 4-point loading bending test. (nstron model 3345 universal testing machine.)

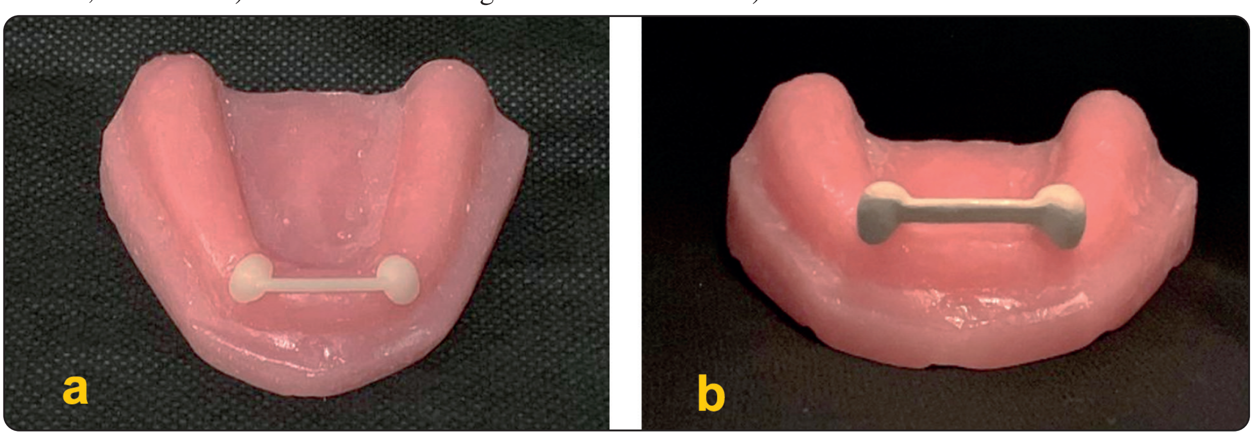

Fig. 2 a) PEEK bar on the cast b) PEKK bar on the cast

Each bar fabricated in both groups was returned to the same acrylic cast after removal of the tested bar for standardization. One cast was used in the study to avoid the risk of any change that could happen when duplicating the stone cast. Mold produced from the original stone cast was preserved until samples were finished to act as a backup if any damage happened to the acrylic cast during the study.

To calculate the flexural strength when one load or force was applied at one-third the way between the supports at the two copings of the bars and the second is applied two-thirds of the way between them. So that the middle third of the bar would have forces applied at either side of it. In this study the bar length was 2mm length, the determination of the span length was made as explained to be 0.6 mm. The first load beam was 0.6mm from the first support; and the second loading beam was 1.2 mm from the first support, where supports here in our study are the coping on the two canine abutments. As shown in fig 3.

Fig. (3): Sample of bar under testing load

The load was applied uniformly and gradually increased up to specimen failure. Cross head speed with rate 1mm/ min. Data calculated and recorded using computer software (BlueHill universal Instron England). Load at maximum flexure was calculated to be the flexure strength value through this formula; $\sigma = FL / wd^2$ where **F** means the maximum force applied, **L** is the length of the sample, **w** is the width of the sample and **d** is the depth of the sample.

RESULTS

The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests, data showed parametric (normal) distribution. Independent sample t-test was used to compare between two groups in non-related samples. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

When the Flexural strength was assessed; there was a statistically significant difference between (Group A PEEK) and (Group B PEKK) where (p=0.004). In which the highest mean value was found in (Group B PEKK) representing a higher flexural strength, while the lowest mean value was found in (Group A PEEK) representing a lower flexural strength.as shown in table (1) and Fig (4).

TABLE (1) The mean, standard deviation (SD) values of Flexural strength of different groups.

Variables	Flexural strength	
	Mean	SD
Group A PEEK	163.44 b	10.60
Group B PEKK	200.76 a	9.06
p-value	0.004*	

Means with different letters in the same column indicate significant difference. *; significant (p<0.05)

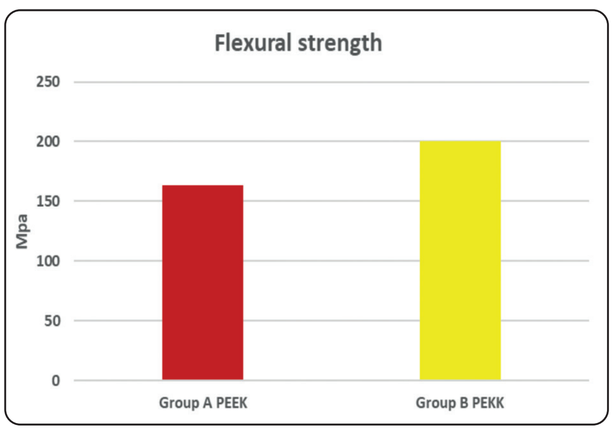

Fig. (4) Bar chart representing Flexural strength for different group.

DISCUSSION

Recently, polyetheretherketone (PEEK) has become the Material of choice when high performance polymers were needed, however it might not be the best choice for dental applications where aesthetic and long-term structural properties are of primary importance, due to its crystalline structure which limits its performance [19].

Polyetherketoneketone (PEKK) was used in this study due to its carbon fiber reinforced with extra ketone group, which gives an excellent physical properties, as high thermal stability, low moisture absorption, low specific weight, shock-absorbing ability as well as high mechanical properties, high toughness, and tensile modulus. There are only a few studies that have been previously performed on PEKK [14,19, 20].

PEKK, unlike PEEK, has crystalline as well as amorphous structure giving a wide range of products, where PEKK was specially produced for dental applications [14].

The crystalline variants of Pekkton are employed when goods with superior mechanical characteristics, stiffness, or both are required. Due to the material's perfect viscosity and wide operating temperature range, there is significantly less shrinkage during the cooling process, which increases precision. Additionally, PEKK crystallizes slowly, allowing for the achievement of tight tolerances without the need for post-treatments. This provides the ideal way to build profitable goods with excellent structural qualities because it never needs to be post-treated. [21].

It should be noted that a variety of variables, such as the manufacturing process, could have an impact on a variety of its qualities, including flexural strength. Evidence suggests that FPDs created of PEEK using the CAD/CAM system have higher fracture strength than those formed using the pressed approach. [22]

PEEK has shown flexibility with high mechanical resistance wear as well as high tensile, fatigue and flexural strength and due to limited studies discussing the PEKK as a bar material this invitro study was made to evaluate the flexure strength of PEKK Bar compared to that of PEEK bar.

In this study when testing PEEK and PEKK as dental bar for a tooth supported overdenture the results revealed a significant difference where PEKK showed higher flexure strength under the applied load, which may be as a result of their high compressive strength and the PEKK's superior shock absorption behavior, which together led to a reduced stress and, clinically, a lower fracture risk as investigated by Villefort and Regina Furbino in their finite element analysis study.. [23]

As a result of replacing one of the flexible ether linkages in the PEKK structure with a ketone group, which is more rigid, the glass transition temperature of the material increased by about 15°C compared to PEEK. By adjusting the proportion of straight and kinked portions, it is feasible to control the melting temperature and crystallization rate of this extra ketone group, which is selectively straightened or connected. Particularly in terms of shock absorption capability and shear compression, these variations have an impact on the mechanical response. [24]

The impediments of this study considered incorporate the assurance of flexural quality for temporary rebuilding materials in conditions that didn't mimic the intraoral environment or incorporate thermocycling. More consideration with a greater test measure is required to compare the flexural quality of different CAD CAM materials is needed. Flexural strength was the mechanical property considered because it partially and indirectly the tensile and compressive strength as well as the elastic modulus of a material.

CONCLUSION

Both PEEK and PEKK are suitable for bar attachment on a tooth supported overdenture, while PEKK showed a significantly higher flexure strength than PEEK. Which can be considered in situations of high occlusal forces.

RECOMMENDATION

Clinical studies with larger sample size are needed to evaluate the nature of complex forces inside patient's mouth and their effect on the flexure strength of both materials.

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