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Influence of Connector Dimension on Stress Distribution in Fixed Partial Denture

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Abstract
Missing teeth which are not replaced by dentures will cause functional and aesthetic problems to the patient. Generally, patients who lose one or more teeth can be rehabilitated by fixed partial dentures (FPD). Increasing patient's need for aesthetics, biocompatibility in FPD manufacturing and weakness of metal has accelerated the development of alternatives from metal restoration materials to full ceramic materials. However, the strength of full ceramic remains a problem for long-term restoration; connector fractures is one of full ceramic materials' disadvantages. Other alternative material for FPD manufacture is Polyethereterketone (PEEK). The derivatives of this polymer showed biocompatibility, which has been demonstrated in in-vitro and in-vivo studies. The design of FPD is very important to reduce the stress on supporting teeth and surrounding bone structure. Structurally, connector area is the most influence area of failure. To prevent FPD failure, the connector must be high and wide enough. This paper aims to explain the role of connector dimensions for stress distribution on full ceramics and PEEK used for manufacture of FPD. The design of FPD is very important to reduce the stress generated over the teeth and surrounding bone structure. Connector area, specifically the gingival embrasure, requires special condition due to biological and aesthetic demands, which must be assessed properly. Rezeai M et al (2011) reported increasing the height of the connector dramatically reduce the stress level between the connectors and analyzed through Finite Element. Increasing the connector dimensions can inhibit failure when vertical or angled load is applied. An understanding on the role of these connector dimensions can contribute in design of dental restorations to reduce the risk of failure in FPD.

Keywords: *Fixed partial denture, Polietheretherketone, Stress distribution*

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I. Introduction

Fixed prosthetic treatment includes replacement and restoration of teeth with artificial substitutes that cannot be removed from the mouth. This treatment aims to restore function, aesthetics and comfort.(1) Loss of teeth can be replaced with dentures, and if tooth loss was not replaced, it will cause functional and aesthetic problems from patients.(2) Generally patients who lose one or more teeth will be rehabilitated by fixed partial denture (FPD) because it is more comfortable and cannot be removed. According to the Glossary of Prosthodontic, FPD is a denture that replaces teeth by cementing or attaching them mechanically to the original tooth, tooth root, or implant that has been prepared as a buffer that provides the main support for dentures.(3) Although some studies have found problems and complications that associated with FPD, it remains a very common treatment and high success in improving the function of losing one or more teeth. The commonly used FPD materials are full metal, porcelain, a combination of metal-porcelain, or metal-resin.(1)

Metal-free restoration materials have recently developed rapidly. (4) Increasing the patient's need has accelerated the development of this material in fabricating full-ceramic FPD.(5) However, the strength of ceramics remains a problem for long-term restoration, because the the material is brittle and weak when placed under tensile and torque stress and potential fracture of full ceramic material.(6) It has been reported that the high failure frequency of three full ceramic FPD units were found in the connector area, especially in thin connectors.(4)

The last decade has shown interest in Polietereterketon (PEEK) materials as an alternative to metal substitutes. Its mechanical and biological properties, also the xray translucency, provide interest in this material. The stable chemical structure of PEEK has been proven to be unreactive and resistant to chemical and thermal degradation. The derivatives of this polymer also show biocompatibility, which has been demonstrated in in vitro and in vivo studies. PEEK as a retainer gives a shock absorbent effect during mastication and has a high resistance to abrasion and caries.(7) The fracture load of 3 units of the FPD framework of PEEK material was

reported to be 1385 N, this value is 2.5 times greater than posterior bite strength.(8) According to Al Ashar et al (2017), PEEK has a low elastic modulus compared to full ceramic material, fracture is the main reason for failure of full ceramics, whereas in PEEK the main failure is plastic deformation.(9)

The design of the FPD is very important to reduce the stress on abutment teeth and surrounding bone tissue.(10) Structurally, the connector area is the most influential area of failure. The failure rate is quite high on 3 full ceramic bridge units around sharp connectors. To prevent failure of the FPD, the connector must be of sufficient height and width, and the length of the pontic should not exceed a certain limit.(4) The shape of the bridge denture is not clinically similar, but is a complex combination of several curvature and concomitant geometric influences and alignment of the teeth. In Resin Bonded Fixed Partial Denture (RBFPD), the occlusal-gingival height in the interdental connector must be as large as possible (min 4 mm) In addition, the connector area usually narrows for biological or aesthetic reasons, which usually consider relative pressure to the average load level on other area. The recommended connector section is at least 12-16mm2. Previously, there was a hypothesis that the initial side of fracture in full ceramics could be controlled by changing the thickness of the ceramics. However, it is now more believed that the thickness of ceramics plays a second role in the onset of fracture, and critical defects in areas with reduced thickness are more important.(11) Because of the success of each dental prosthesis, it is strongly influenced by biomechanical factors, therefore, it is important to evaluate the pressure in the structure and which is transferred to the surrounding tissue. Finite Element Analysis has opened a new scene in the field of dental biomechanics and has been able to replicate most dental structures with various shapes and characteristics into three-dimensional (3D) shapes.(12) Several studies have analyzed load distribution in bridge dentures. One study examined distal cantilever in different cantilever morphology bridges made of two different materials, where the width of the connector between cantilever and the main support was 2.25 mm. The mean value of Von Misses Stress shows a high load value in occlusal embrasure from the connector between pontic and premolar abutments compared with cervical embrasure. In other studies, occlusal and gingival embrasure of the connector is the area with the highest stress.(11)

The purpose of this paper is to explain the influence of the connector dimensions for stress distribution on some metal-free materials used for the manufacture of fixed partial denture (FPD).

Fixed Partial Denture (FPD)

Based on the Term Glossary of Prosthodontics, FPD is any dental prosthesis that is attached, locked or mechanically connected or joined to the original tooth, tooth root, and / or dental implant / abutment that creates primary support to support the dental prosthesis and restores teeth in the partial edentulous, and cannot be remove by the patient.(3) FPD consists of a retainer that provides support for the supporting teeth, pontics that replace missing teeth, and connectors that connect the pontic to the retainer.(13)

Fixed Partial Denture (FPD)'s Failure

The factors that play a role in the failure of FPD are divided into 3 (three) types :(14)

1. Biological factors, including such as: caries, pulpa degeneration, gingival recession and periodontal damage, occlusal problems, tooth perforation, cementation failure.
2. Mechanical factors, including such as: loss of retention, pontic failure, connector failure, used of occlusal, tooth fracture, porcelain fracture.
3. Aesthetic factors. Aesthetic factors include such as inappropriate color selection, failure to achieve patient expectations, failure to communicate with laboratories in appropriate color selection, too thick opaque layers, thickness of metal margins in the incisal and cervical regions, failure to produce translucency, over / under contour of crown, exposed to metal edges in incisal connects or cervical margins, overglazing.

Fixed Partial Denture (FPD) Material

Full ceramics

Lately, full ceramic FPD has become popular for aesthetic reasons. Although its use is not recommended because of its lower strength compared to metal ceramics FPD, many material had been tried to improve success of all ceramic FPD. In the past, porcelain alumina was used by connecting alumina core with pure alumina stem with low success. Then ceramics reinforced with leucite but fail because of their lower strength. Later, Zirconia In-Ceram was introduced, lithium disilicate, heat-pressed ceramics and CAD / CAM (computer aid design and computer aid machine). All ceramic FPD must have 4 × 4 mm connector compared to a metal connector that requires a width of 2 × 3 mm. The disadvantage of the excess width of this connector is the difficulty in plaque control.(14)

Polyetheretherketone (PEEK)

Newer treatment modalities, materials and techniques not only extend the dental literature but also alternative prosthodontic treatments available to dentists and patients. Technology has brought some interesting

advances in dentistry. Progress in the field of dentistry and the increasing desire of patients to maintain their teeth has led to dental care that was once need to been removed.

Prosthodontic treatment must focus on masticatory, phonetic rehabilitation and the aesthetic function of the patient. There is a continuous increase in materials and techniques used in dentistry, especially in the prosthodontic area. One such material is polyether ether ketone (PEEK). This material is a high-temperature semi-crystalline thermoplastic polymer that belongs to the Polyaryletherketone (PAEK) group, which consists of a chain of aromatic molecules, which are interconnected by functional groups of ketones and ethers with a specific weight of 1.3-1.5 g / cm3 which shows good combination of high tensile strength, stiffness, toughness, good wear resistance, low friction coefficient, excellent chemical resistance, very low water absorption and high melting point (around 343 ° C), resistance to fatigue and dentistry is increasingly used because of its biocompatible properties as healing abutment, temporary crowns, permanent crowns and FPD also an alternative metal frames.(15)

PEEK has resistance to chemical and radiation damage and compatibility with many reinforcing materials (such as glass fiber and carbon) and greater strength (on a per mass basis than metal). PEEK has chemical stability for almost all organic and inorganic chemicals which makes it an attractive material in Prostodontic *Metal-free*. PEEK is an opaque material, generally white ash, but this material is the first material that is introduced that resembles the tooth colour. Because this material is not aesthetic, this material cannot be used as a monolithic prosthetic but it is necessary to add veneering.(8)

Fixed Partial Denture (FPD)'s Component

Abutment

Each restoration must be able to withstand the constant occlusal load it receives. This is especially important when designing and making FPD because the loads normally received by missing teeth are transmitted, through pontics, connectors, and retainer, to the teeth of the buffer. Therefore, the abutment teeth act to hold the load which is usually directed to the missing teeth. The supporting tissue around the supporting teeth must be healthy and free of inflammation before making the bridge denture. Abutment teeth should not show mobility because they will cause additional stress.

There are 3 factors of the abutment teeth that must be evaluated :(16)

1. Crown-root ratio
2. Root configuration
3. Periodontal ligament area

Retainer

The retainer is part of the denture bridge that unites the abutment with the rest of the restoration. There are two types of retainer that commonly used:

1. Intra coronal
2. Extra coronal

In intra-coronal retainer, retention is obtained between the inner wall of the prepared tooth. On the other hand, in an additional coronal retainer, retention is obtained between the outer wall of the tooth being prepared and the inner wall of the retainer.(17)

Pontic

Pontic is part of the bridge denture that replaces the missing original tooth, restores its function, and usually restores the space previously occupied by the clinical crown. Pontik comes from Latin pons, meaning bridge. The design of the pontic is determined by aesthetics, function, ease of cleaning, maintenance of healthy tissue in the edentulus and patient comfort.(16)

Connector

Connectors inside the FPD can be defined as part of FPD uniting the retainer with pontik. Connectors are generally divided into 2 (two), rigid connectors and non-rigid connectors. Rigid connectors are used when all loads on the pontic will be channeled directly to the buffer teeth. Non-rigid connectors are indicated in cases where a single tide direction cannot be obtained associated with non-parallel supporting teeth. This type of connector allows minimal movement between the retainer and the pontic.

The shape, size and position of the connector affect the success of a prosthesis. The connectors must be large enough to prevent distortion or fracture when functioning but not too large, due to the size of the backing connector with the effective control of plaque that can contribute to periodontal damage. If the connector is too large incisocervical, cleanliness can be disrupted, and over time, can cause periodontal damage. From the

aesthetic side, a large connector or shape that is not in accordance with the patient's condition will result in exposure to metal connectors that will interfere with the appearance of the patient.(13)

Finite element analysis

Finite element analysis (FEA) is a numerical method for analyzing structural loads and deformations for the needs of solving complex structural problems. In dentistry, FEA has been used to simulate bone remodeling processes, to study internal loads in teeth and some dental materials, and to optimize the forms of various restorations. Due to the wide variety of biological and anatomical properties, mechanical tests involving biomaterials usually require large sample sizes, with FEA the need for a large number of samples can be avoided, and using mathematical models also eliminates the need for large numbers of experimental teeth. FEA has been used to describe simulations of the mechanical properties of teeth when receiving detailed occlusal loads. (18)

Most failures of dental materials used in dental restorations are caused by tensile stress. Precision of occlusal adjustment of the occlusal surface must be created to prevent this occurrence. The difference between the elastic modulus of the tooth and the restorative material can be the source of the load on the tooth structure. If the load exceeds the yield strength of the material, a fracture from restorative or dental material can occurFEA helps to improve preparation design, indicates suitable materials or combinations of materials used in various loads and pressures in terms of reducing material / tooth failure in clinical practice.(18)

The FEM method uses adequate software such as ANSYS. This software makes it possible to analyze voltage and voltage conditions based on discrete principles and model analysis using FEM. To analyze the pressure distribution, the equivalent voltage von Mises (σecv) is used and the ANSYS program calculates it as the average square of the normal voltage at the base, middle or above of finite element. For real simulations, the bite force simulated in FEM with Ansys software is 400 N / teeth following the results of the Waltimo study, where the value of 847 N in the molar region is evenly distributed. (19)

II. Discussion

The design of the fixed partial denture (FPD) is very important to reduce the stress generated on the teeth / implants and the surrounding bone structure. The area of the connector, specifically the gingival embrasure, requires special conditions due to biological and aesthetic demands, and must be assessed properly especially in the posterior region where the load received is much higher and the clinical crown is shorter.(10)

Special considerations about the design of this fixed partial denture can be properly assessed by a combination of engineering techniques, such as Finite Element Analysis, Finite Element Analysis (FEA), which is a suitable instrument for determining pressure and strain in a given structure. FEA was first used in dentistry in the 1970s. FEA is a numerical technique for analyzing stresses and deformations in any geometric structure. The number, type, and arrangement of finite elements and their vertices form a net. The accuracy of the results can be close to the results in the actual conditions if the selection of mesh, load, and surrounding conditions is adequate. The FEA method has often been used and widely used in structural, thermal or other types of analysis in dental restorat(10)ions, such as inlays, crowns, implants, and FPD.(10,20)

Stress distribution is an important factor that shows the fairness of a structure. Fixed partial denture (FPD) will fracture if the tensile stress received exceeds the tensile strength of the material. Stress distribution in FPD depends on material properties and geometric configuration. (20)

Some studies of FPD connector morphology are mainly based on Finite analysis elements. To increase the longetivity of the FPD restoration, it was realized to make the cross-sectional area of the GTJ connector as large as possible, regardless of the material used. Clinically, however, the very large cross-sectional area of the FPD connector is not desirable from a morphological and aesthetic standpoint. When FPD ceramics are emphasized in aesthetic features, adequate space is needed at the connector to allow the formation of porcelain-based veneers. Therefore, it is important to determine the minimum cross-sectional area that can be received from the connector in the ceramic frame. In the use of full ceramic molar regions designed using lithium disilicate or alumina glass infiltration materials, connectors require a height of 5 mm and a 4 mm bucolic dimension if glass ceramics are used, or 4-5 mm height and 3-4 mm bucolic dimensions when using zirconia glass infiltration. When using FPD in the molar region with Y-TZP material, it is recommended that the cross-sectional area of the connector frame must be more than 9mm2. To reach a 9mm2 cross section with a circular shape (a form that can reduce the concentration of the load), the diameter must exceed 3-4mm.(21)

Mohammad Rezaei et al. Conducted a study on the effect of connector thickness on load distribution of posterior bridge denture with Leucite material. From this research, it can be concluded that increasing the width of the connector can reduce the probability of failure when vertical and tilted loads are given. (11)

Lakshmi DR et al. Conducted a study of the role of connector dimensions on load distribution on inlay bridge dentures with disilicate zirconia and lithium monolithic materials. The study compared the comparison of the load distribution from different connector dimensions (9mm2 and 16mm2) to the load distribution of each

material. Lakshmi et al was concluded that the increasing dimensions of connectors can reduce fracture load, the tensile stress concentrated on the gingival aspects of the connector and is the main reason for failure of treatment that starts at that point. (22)

Bogna Stawarczyk et al. Conducted a study of fracture loads from three units FPD using PEEK framework. From this research the results of the PEEK framework were obtained with connector dimensions with a cross-sectional area of 7.36mm2 which obtained a fracture load of 1385 N, which corresponded to about 2.5 times the average bite load in the posterior region. From the study, the researchers concluded that PEEK material is suitable for use as a material for making bridge dentures and requires further research on these materials. (23)

III. Conclusion

The connector is the smallest part and is also a component that needs to be designed very carefully in fabricating fixed partial denture because the connector design determines the success of a prosthesis. Increasing the width of the connector can reduce the possibility of failure when vertical or tilted loads are applied. An understanding of the role of the width of these connectors can help in the design of dental restorations so as to reduce the risk of failure of fixed partial denture, thus this review expected to be an input in future research.

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