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Role Of Polyetheretherketone (PEEK) And Polyamide As An Alternative Of Denture Base Material In Terms Of Surface Roughness

William Wijaya[1], Haslinda Z Tamin[2], Ricca Chairunnisa[3]
[1]*Postgraduate program in prosthodontics, Faculty of Dentistry, Universitas Sumatera Utara, Medan, Indonesia*
[2]*Professor, Department of Prosthodontics, Faculty of Dentistry, Universitas Sumatera Utara, Medan, Indonesia*
[3]*Lecturer, Department of Prosthodontics, Faculty of Dentistry, Universitas Sumatera Utara, Medan, Indonesia*

Abstract
Background: *Denture base acts as main foundation of denture and receives forces then distribute them to supporting structures. Polyamide's demands are high because of its esthetic, good color mimicking gingiva and can be used instead of metal clasp. The main problem of this material is high water sorption, surface roughness, bacterial contamination, color change, and difficulty in polishing. Surface roughness contributes in plaque accumulation, microorganism retention and potentially harm supporting structures of denture. Recently, a modified polyetheretherketone (PEEK) is reported to be used as framework instead of metal framework because of its low surface roughness. The purpose of this literature review is to know the role of PEEK as alternative denture base material in terms of surface roughness.*
Discussion: *PEEK is a polymer that can be modified with ceramic, carbon, or fiber. When it is modified with ceramic, ceramic fillers with grain size of 0.3 to 0.5 μm are used. Due to this small grain size, constant homogeneity can be achieved. The fine granularity of filler is the reason for the extremely good polishing properties. Deposit of plaque can be prevented because the surfaces are polished to a high shine so the surface roughness is low. Surface roughness of PEEK modified with ceramic can reach 0,05 μm. A clinically accepted threshold level of surface roughness is 0,2 μm.*
Conclusion: *PEEK modified with ceramic has low surface roughness results in low plaque accumulation, microorganism retention and maintain the health of supporting structures.*
Key word: *denture base, polyamide, PEEK modified with ceramic, surface roughness*

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I. Introduction

The denture base is the component of the denture that is in contact with the supporting tissues and where the denture elements are arranged. The role of the base is as the main foundation of the denture. The base also functions to receive pressure and distribute it to the supporting network underneath (1). Extension of the denture base to include the supporting area will improve denture retention and support denture base materials can be divided into two main categories, namely metal and non-metal. Based on thermal behavior, denture base materials are divided into two, namely thermoset and thermosens. Polymethylmethacrylate (PMMA) which is often used is part of a thermoset where the fabrication technique uses a compression molding technique (2). Meanwhile, thermoplastic is divided into groups of polyamide (nylon), thermoplastic acrylic, acetal, polycarbonate and polyetheretherketone (PEEK). The fabrication technique for this material uses injection molding techniques (2).

The main material of thermoplastic nylon is polyamide which is the product of the reaction between diamine and dibasic acid. Thermoplastic nylon is injected at temperatures between 274 and 293 °C (3). This material is mainly used to replace metal materials and has a gingival-like color. The main problem with the use of thermoplastic nylon materials is the material properties which include water absorption, surface roughness, bacterial contamination, discoloration and difficulties in the polishing process.

PEEK is a semi-crystalline and thermoplastic material with high temperature resistance and a high-performance plastic material with a melting point of up to 334 °C (4). PEEK is a polymer that can be modified by mixing particles such as ceramics, carbon or fiber to improve physical and mechanical properties (4,5).One of the particle mixing modifications used is ceramic, for example BioHPP. The addition of ceramic particles is intended to increase the ability to polish properly and increase the mechanical strength of PEEK materials (5). BioHPP (High Performance Polymer) is part of PEEK. BioHPP contains ceramic microparticles with a size of about 0.3-0.5 microns and makes up 20% of the total volume of BioHPP. BioHPP has excellent stability, good polishability and low plaque affinity (4,5).

Roughness is one of denture base material properties which show direct relationship between plaque accumulation and bond of Candida albicans. Studies showed that the surface roughness of thermoplastic nylon resin was three times more than polymethyl methacrylate acrylic resin. Chronic atrophic (erythematous) candidiasis, similarly known as denture sore mouth and denture stomatitis, is characterized by confined chronic erythema and oedema of the mucosa which contact the denture surface fittings. Its principal aetiology is the chance for the overgrowth of Candida in the zone between the palate and the surface of denture where natural salivary flow is limited. Consequently, inhibition of adhesion and growth of microorganisms is an effective way for suppression of the development and progress of denture plaque. The surface roughness of the denture base material has received special attention where existing studies have shown a relationship between surface roughness, plaque accumulation and Candida albicans adhesion (6). The clinically acceptable threshold for surface roughness is 0.2 microns (6,7). Because Therefore, it is hoped that this paper will be able to explain the role of polyamide and polyetheretherketone materials as denture bases in terms of surface roughness.

Denture Base and Its Ideal Requirement

The denture base plays a role in supporting the denture elements and receiving functional stresses such as occlusion and transferring functional stresses to the existing oral cavity structures (1). The function of the denture base is very important in partially edentulous cases with free ends because it functions to gain stability and comfort because of its ability to distribute the applied pressure. In addition, the denture base also plays a role in stimulating the underlying ridge tissue. The denture base ideally fulfills the following requirements (1):

- Has good tissue adaptation accuracy (minimum volume changes)
- Has a solid and non-irritating surface and can be polished well
- Has good thermal conductivity
- Has a light weight
- Have good strength; resistant to fracture and distortion
- Easy to clean
- Has good aesthetics
- Ease of reline
- Low cost

Until now, there is no denture base material that fulfills all of these requirements, so further discoveries are still needed. The denture base has two surfaces, namely the intaglio surface and the cameo surface. The intaglio surface is the surface of the base of the denture that is in contact with the supporting tissue, while the cameo surface is the surface of the denture that extends occlusally from the margins of the denture covering the surface of the palate. The cameo surface is the part of the denture that is usually polished both on the buccal and lingual surfaces of the denture (1).

Thermoplastic Non-metal Denture Base Materials

Thermoplastic resins are used for fabrication of flexible dentures. Thermoplastic is a plastic material that can change shape when heated above a certain temperature and changes to a solid form after the temperature returns to room temperature (8) The advantage of thermoplastic resin materials is that they are aesthetically pleasing with tooth-colored and gingival materials and are comfortable to use (2). These materials are stable, has good fracture resistance, wear resistance, does not dissolve easily when in contact with liquids and has good impact strength (2,3,8). The thermoplastic resin materials that can be used include (9):

- Thermoplastic Nylon (Polyamide)
- Thermoplastic Acrylic
- Thermoplastic Acetal
- Thermoplastic Polycarbonate
- Polyethereketone (PEEK)

Thermoplastic Nylon (Polyamide)

Polyamide was first introduced as a denture base material in the 1950s (3). Nylon is the generic name for several types of thermoplastic polymers belonging to the polyamide group. Polyamide is produced from a condensation reaction between diamine NH_2-$(CH_2)6$-NH_2 and dibasic acid, CO_2H-$(CH_2)4$ COOH (3,8). Nylon is a semi-crystalline polymer. The advantages of this material are low liquid solubility, high temperature resistance, good strength, high elasticity, low polymerization shrinkage, and no residual monomer (no allergic reactions) (8).

The disadvantages of this material are high water absorption, surface roughness, bacterial contamination, discoloration problems and difficulty polishing. Nylon material as a denture base improves aesthetics and reduces rotational forces on abutment teeth due to its low elastic modulus value. The main drawbacks of this material are the inability to be relined and the lack of occlusal rest which can cause occlusal instability and vertical stress especially in class I and II Kennedy cases (1,8).

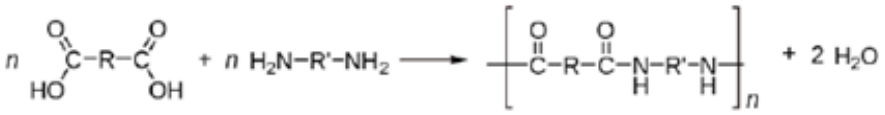

Figure 1: Polyamide's reaction between diamine and dibasic acid

Polyetheretherketone (PEEK)

PEEK is a thermoplastic polymer from the Polyaryleterketone (PAEK) group. At temperatures between 390 to 420 °C, PEEK can be processed by injection into the mold (9). After polymerization, at room temperature PEEK is chemically inert and insoluble in liquids except 98% sulfuric acid solution. The PEEK structure exhibits excellent chemical resistance due to the presence of aryl rings linked by ketones and ethers which are located at opposite ends of the ring. Its chemically stable structure leads to a higher delocalization of electron orbitals along the macromolecule making PEEK highly unreactive and resistant both chemically, thermally, and post-irradiation degradation. This property causes PEEK to have excellent biocompatibility (8).

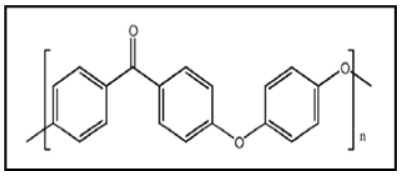

Figure 2. PEEK's chemical structure

PEEK can be modified with fillers such as ceramics to improve mechanical properties and polishability (BioHPP; Bredent GmBH, Senden, Germany). BioHPP (High Performance Polymer) is a PEEK-based thermoplastic polymer. This material was developed to optimize its use in dentistry. BioHPP contains ceramic microparticles for better polishing results. The size of the ceramic filler is between 0.3-0.5 microns and the volume is 20% of the total volume of BioHPP. Due to its micro size, macro polymer structure has good homogeneity. In addition, its ability to be polished properly results in low plaque retention and good color stability (4). Other advantages as a denture base are its light weight, bone-like elasticity, shock-absorbing effect, metal-free restorations, good biocompatibility. , no corrosion, no viscoplastic fracture and low fatigue value (4). There are several properties of polyetheretherketone (PEEK) materials, namely (10):

- Resistant to hydrolysis
- It has good mechanical properties and is resistant to high temperatures
- Non toxic, mutagenic, carcinogenic or immunogenic
- Material is inert (low reaction to other materials)
- Has a melting point >280°C
- Has high resistance to chemicals
- Has a low modulus of elasticity close to bone
- It has light weight with low density (1.32g/cm3)
- Has low water absorption and solubility
- Stable color change

Surface Roughness

The surface roughness of a material is very important to know before the process of determining the material, fabrication and use of prostheses in the oral cavity. A rougher surface can cause discoloration, a source of patient discomfort, and also contributes to microbial colonization and biofilm formation. Bacterial and fungal species have a tendency to adhere to the rough surface of the denture base. The threshold for surface roughness of dental materials used in the oral cavity is 0.2 microns where there is no significant reduction in plaque accumulation below 0.2 microns.

The rough surface acts as a reservoir with irregular surfaces such as voids and microcracks, thus providing gaps for the retention of microorganisms, candida attachment and protection against shear forces. Patient comfort and denture durability are affected by the smoothness and excellent polishability of the denture surface (6,7).

Polyamide specimens have higher surface roughness compared to PMMA materials both before and after the polishing process. The unpolished polyamide surface can be affected by the disintegration of the mold surface where the polyamide will be heated to a higher temperature than PMMA and also the effect of pressure during the injection molding process. Polyamide is difficult to polish because of its low melting point temperature, so a more thorough wax up procedure is sought to minimize the finishing and polishing processes (7,9).

II. DISCUSSION

A rougher surface can cause patient discomfort as well as discoloration of the prosthesis. Surface roughness also plays a role in the formation of microbial colonization and biofilm formation. A study conducted by Abuzar, et al (2010) evaluated the surface roughness of polyamide denture base materials (Flexi-plast) compared to PMMA materials (Vertex RS). The results showed that the polyamide specimens had higher surface roughness than PMMA materials, both before and after the polishing process. A study conducted by Kawara, et al (2014) evaluated the surface roughness of four thermoplastic materials (Polyamide : Valplast, Lucitone FRS, Polyethylene terephthalate and Polyester : EstheShot Bright) and two conventional acrylic materials (heat-polymerized PMMA : Urban and auto-polymerized PMMA : Pro- Cast DSP) with the scratch test method. The results showed that the surface of the thermoplastic denture base was more easily damaged than PMMA material (6).

A clinical trial study conducted by Bechir, et al (2016) evaluated the BioHPP polymer framework as a superstructure in 35 patients after 1 year of use showing no allergic reactions, no discoloration, no fractures, low plaque accumulation and easy integration by patients. The clinical trial study conducted by Mekawy and Gad (2016) evaluated the surface roughness of removable framework from conventional Co-Cr materials with CAD/CAM system PEEK materials. From the research results, the surface roughness value was 0.863 microns. Meanwhile, from the values obtained from other in vitro studies, BioHPP can be polished until the value reaches 0.018 microns. This difference in results may be due to differences in the manufacturing system where one uses a lost wax technique with injection molding while in this study the CAD/CAM system was used (7,11). The results of several in vitro studies show that if a denture base material with a surface roughness exceeding 0.2 µm can increase the level of attachment of bacterial colonization. The threshold for surface roughness of dental materials used in the oral cavity is 0.2 microns where there is no significant reduction in plaque accumulation below 0.2 microns (12).

III. CONCLUSION

Surface roughness has a role in plaque accumulation, retention of microorganisms, and has the potential to threaten the health of the denture supporting tissues. A surface roughness value of 0.2 micron is considered an acceptable threshold value for preventing plaque retention. Surface roughness is considered to have a direct or indirect role in wear resistance, patient comfort, periodontal tissue health, and discoloration. Polyamide has a higher surface roughness compared to other resin materials which causes bacterial and fungal colonization. Modified PEEK materials with ceramic fillers such as BioHPP have excellent polishability resulting in low plaque retention and good color stability. Therefore, the selection of thermoplastic resin materials must be carried out as best as possible according to the properties, advantages and disadvantages of each material.

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