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EVALUATION OF THE SURFACE ROUGHNESS OF THREE ESTHETIC DENTURE BASE MATERIALS

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ABSTRACT

Aim: This study was conducted to compare the surface roughness of three denture base materials.

Materials and methods: Three materials were selected for the study; conventional heat cured polymethyl methacrylate resin (PMMA), Acetal resin and Polyetherether ketone (PEEK). Seven specimens of each material were constructed in the form of a disc 1cm in diameter and 1.5 thickness. Each disc had one finished surface and one polished surface. Surface roughness for both surfaces was measured for all specimens, then the discs were immersed in artificial saliva for 24 hours, one week and one month and surface roughness was measured at each interval. Two way ANOVA test was used for the statistical analysis.

Results: PMMA showed the highest mean surface roughness at the base line stage i.e. before insertion in saliva. Also PMMA showed the highest mean surface roughness compared to the other two materials through the follow up period however the increase was statistically insignificant. $p=0.814$.After insertion in saliva PMMA showed statistically significant increase in the mean surface roughness $p<0.0001$.

Conclusion: The study showed that Acetal resin base material and poly-ether-ether ketone showed significantlylower surface roughness than PMMA.

Keywords: Surface roughness, Denture base materials, Acetal resin, PEEK

INTRODUCTION

The use of biomaterials in the oral cavity will affect the oral ecology quantitatively and qualitatively.Biomaterials from which the prosthesis will be constructed differ from enamel with regard to surface roughness, surface energy, and chemical composition.[1,2]

Progress in the field of dental materials and the increasing expectations of both dentists and patients induced the manufacturers of stomatological materials to introduce more perfect and hygienic products to the market . The dental prosthesis should be constructed and fitted in such a way that it does not become an iatrogenic factor, but it

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fulfills therapeutic and preventive role.[3, 4] Many non -metallic materials are used as the conventional heat cured resin with its modifications and thermoplastic materials as: Valplast, polycarbonate, acetal resin and recently polyetheretherketone was introduced in the dental field. The recent advances in the denture base materials still conventional heat cure Polymethylmethacrylate (PMMA) is the most commonly used material.[5] It possess favourable functional, physical and mechanical properties, proper esthetical appearance and inexpensive equipment needed for its fabrication. It also slowly absorbs water with time, which is due to the polar nature of the resin molecules.[6,7] The small size of the components and hydrophilic nat ure leads to its ease of diffusion of oral fluids and so its irritational action hypersensitivity, or allergic reactions in some cases.[7]

Acetal resins are one of the esthetical resin materials. It is available in twenty different shades. It is twenty times stronger than acrylic resin, flexible, has high abrasion resistance and excellent tensile shock strength.[5]Acetal is cured through injection molding technique which shows better internal adaptation compared with conventional heat cured and microwave polymerized resins however there is no relevant improvement of porosity, transverse and impact strength.[8,9] Acetal resins have been used as an esthetic clasp material for more acceptable esthetics.[8,9] PEEK (Polyetherether ketone) is one of the recently introduced materials in the dental field. PEEK (Polyetheretherketone) can be used for fabrication of crowns and bridges. Also additives were used for the construction of definitive and removable dentures.[10] PEEK can be manufactured using several ways as Extrusion –Injection molding and by CAD/CAM milling technology from a pre-annealed block.[11] Using the digital design to manufacture PEEK matches the patient's individual anatomy, also eliminates the individual errors done by the dental technician.[11-13] The variations of temperature and pH caused by diet, decomposition of foods, cell debris, oral microflora, and their by-products are also important factors to be considered when evaluating the clinical behaviour of prostheses that remain in the oral cavity for years.[14] The relationship between bacterial adhesion and the surface roughness of dental materials has previously been demonstrated. Recurrent inflammation or erythema and burning sensation of denture bearing tissues are relatively common in denture wearers.[14,15] Initial attachment of bacteria on roughened surfaces is aided by surface irregularities, where bacteria are protected from salivary flow and masticatory function, and can attach to more points at the substratum.[16] Higher bacterial adherence on rougher surfaces occurs due to the presence of pits and grooves that reduce the influence of shear forces on the bacteria initially attaching to the surface.[17-19]

The required properties of denture base materials are the surface related as the surface tension, free surface energy wettability, hydrophobicity, hydrophilicity, electrostatic interactions, micro hardness and surface roughness. All these properties affect the plaque accumulation and staining. The roughness of a material affect plaque formation and accumulation and so the denture hygiene and its effect on the supporting tissues.[20-23]

The target of this research was to compare the surface roughness of three denture base materials.

MATERIALS AND METHODS

Seven samples of each material; Conventional heat cured acrylic resin, Acetal resin and PEEK were constructed in the form of discs 1cm in diameter and 1.5mm in thickness; this sample configuration was selected because it was approximately the minimum thickness that would be present in a complete or removable partial denture, and it fits the experimental system by allowing the medium to completely cover the specimens with artificial saliva. **Heat cured acrylic resin specimens' construction:** The heat cured acrylic resin specimens (Pala, Kulzer, Germany) were fabricated by investing wax patterns in stone moulds within a dental flask as done in actual denture processing. Packing and processing were carried out in accordance with the manufacturer's instructions (100^0C, 60 min), 1:3 monomer to polymer ratio by weight. The polymerization of the resin was performed by immersion in boiling water for 60 min. The specimens were cooled at room temperature for 30 min. The acrylic specimens were finished and polished as is done with an actual acrylic resin denture base. **PEEK specimens construction:** Wax patterns of 7 discs 1cm in diameter with thickness of 1.5 mm were constructed and sprues were attached. The assembly was attached to the investment ring then invested using special investment material Brevest for 2 press (Bredent-Senden-Germany), after material setting the mould was then heated to 630^0C then temperature was gradually increased by rate of 8^0C/min until it reached 850^0C in a preheated oven (IBEX-dental oven-USA) for wax burnout for 60 minutes before starting the melting process. Granular PEEK-BioHPP thermoplastic (BioHPP (granulate) 20g-Bredent-Senden-Germany) material was placed in the melting channel. Then the ring was placed back into the preheated oven for 20 minutes at temperature 400^0C to get a creamy molten material with uniform appearance indicating that the material was ready for pressing. By the end of the process the mould was allowed to cool for 35 minutes. The mould was then placed in water bath for 10 minutes then devesting was done first with scissors to remove the mould then using pneumatic devesting chisel. The fine blasting device was used to get the discs. **Acetal specimens construction:** The acetal resin (Thermoflex Acetal Resin Densply UK) specimens were prepared in accordance with manufacturer's instructions. The pattern of the disc was made in wax and flasked using special Aluminum flask (Thermopress flask, bredent GmbH, Senden/Witzighausen, Germany) mouldwith Class IV type plaster (Marble Stone, PressingDental San Marino, Italy). Heated softened acetal resin was injected into the mold then curing was done at $215C^0$ for 25 minutes. After curing the specimens were deflasked, finished and polished using thermal resin finishing burs (Abraso-Star K 50, bredent GmbH, Senden/Witzighausen. Germany) and pumice at low speed then finally buffed with swansdown mop for fine luster.

For all specimens one surface was polished and the other one was only finished without polishing to resemble both the fitting and polished surface.

Surface roughness measurements: The surface roughness (Ra) of specimens was measured using a contact profile meter. The method used was to scan a diamond stylus across the surface under a constant load and compute the numeric value representing the surface roughness(Ra) which was measured in µm. The surface roughness of the discs was measured after finishing and before polishing to resemble the fitting surface of the denture base, and then all specimens were immersed in artificial saliva(saliva naturamund spray; Parnell pharmaceuticals, Ltd. Dublin 2, Ireland) and incubated in an incubator (Barnstead Imperial III Standard Incubators., Lab-Line Instruments Inc in Melrose Pk, IL, USA) at 37^0C for 24 hours after which roughness was again measured for both sides then after 1 week and finally after 1 months immersion and incubation in artificial saliva were the saliva was changed on daily bases to ensure a clean sterile medium.

Two way ANOVA test was used for the statistical analysis and Post hoc Tukey test for pairwise comparison.

RESULTS

Evaluation of the surface roughness before and after immersion for the finished surface:As shown in table 1

Regarding the surface roughness before immersion: Although no significant difference, PMMA showed the highest mean surface roughness at the base line stage i.e. before insertion in saliva.

Regarding the type of material: Also PMMA showed the highest mean surface roughness compared to the other two materials through the follow up period however the increase was statistically insignificant.

Regarding the effect of saliva by time on the finished surfaces: The three materials showed statistically insignificant increase in the mean surface roughness through the follow up period.

Evaluation of the surface roughness before and after immersion for the polished surface: As shown in table 2

Regarding the surface roughness before immersion: PMMA resin was higher than acetal resin and PEEK at baseline.

Regarding the type of material: PMMA resin was higher than acetal resin and PEEK starting from baseline through the whole follow up period and this increase was statistically significant.

Regarding the effect of saliva by time on the polished surfaces: The results of PEEK, showed increase in the mean surface roughness through the follow up period but this increase was statistically insignificant. The results of Acetal resin, showed increase in the mean surface roughness through the whole period although this increase was statistically insignificant. For PMMA the increase in the mean surface roughness was statistically significant. The mean surface roughness for PMMA was higher than both Acetal and PEEK and the difference was statistically significant.

TABLE (1) Showing the mean surface roughness of the finished surfaces values for the three materials through the follow up periods:

	PEEK		**ACETAL**		**PMMA**		
	Mean	SD	Mean	SD	Mean	SD	**p- value**
BL	0.125	0.032	0.148	0.149	0.172	0.131	0.6495
24h	0.129	0.076	0.151	0.122	0.184	0.177	0.6248
1w	0.132	0.048	0.164	0.137	0.189	0.163	0.2808
1m	0.138	0.051	0.167	0.148	0.192	0.169	0.2178
p -value	0.972		0.973		0.814		

TABLE (2) Showing the mean surface roughness of the polished surface values for the three materials through the follow up periods:

	PEEK		**ACETAL**		**PMMA**		
	Mean	SD	Mean	SD	Mean	SD	**p- value**
BL	0.021	0.003	0.043	0.017	0.103*	0.027	0.0073
24h	0.023	0.001	0.048	0.023	0.116*	0.038	<0.0001
1w	0.026	0.007	0.071	0.015	0.138*	0.041	<0.0001
1m	0.025	0.004	0.084	0.027	0.143*	0.028	<0.0001
p -value	0.133		0.571		0.273		

DISCUSSION

Surface roughness is directly related to the biological behaviour of materials used intraorally which in turn affects the rate of microbial colonization and biofilm formation. The higher the surface roughness of the material the more harbouring areas will be provided. These areas are considered shelters for bacterial accumulation and colonization. The materials selected for this study were the conventional PMMA as it is the most commonly used material for denture construction. Acetal resin was selected as it has been used as a clasp material for dentures due to its inherent flexibility. While PEEK has been widely used in the last few years as a replacement for many intraoral materials for construction of crowns, dentures and implant abutments. So it is important to study its surface roughness which will reflect its behaviour intraorally when used in different forms. Concerning the surface roughness before and after polishing: First, it should be known that surface roughness of Ra 0.2μm is considered the maximally accepted for intra oral use to minimize bacterial accumulation and plaque formation.[24]And since all the materials surface roughness falls under this value so they are all accepted for intra oral use. The results of this study showed that PEEK BioHPP had the least surface roughness before & after polishing followed by acetal resin while PMMA showed the highest mean surface roughness. These results may be due to a number of factors. First the powder mean particle size of components of PEEK BioHPP is 80µm which is considered very fine, followed by Acetal resin with the particle size ranged from 110-150 µm[25], while for PMMA the particle size was 600 µm. Second; the manufacturing technique of the each material, there are three manufacturing techniques and the conditions by which the material was adapted in its mould will probably affect the density of the final product regarding the density, porosity and henceroughness.[26] The materials with lowest surface roughness (PEEK BioHPP was made by *2 press vacuum press device* while Acetal was made by injection moulding technique both techniques the material is pressed under pressure into its mould with absence of manual manipulation while PMMA was made by conventional manual packing in the flask which may have increased the risk of imperfection due to human factor.

The effect of saliva was concerned: There is a direct relation between the water diffusion coefficient of the material and time required for the water to get into it and its saturation.[26] It is believed to be directly related to the solubility characteristics of each material including the leaching of some ingredients: For PMMA although heat cured resin yet had minimal amount of residual monomer there is still a minute amount leached in saliva. This allowed the saliva to penetrate in between the polymer chains. Consequently the secondary chemical bonding forces (van der Waals forces) between the polymer chains decline and results in weight and volume increase to cause an expansionso increase in the surface roughness.[27] For Acetal resin the semi-crystalline and monomer free nature of the material gave it a harder surface. The higher the crystallinity in a plastic, the harder it will be and so the smoother will be its surface.[28]During the copolymerization of acetal the -CH2-CH2- are randomly distributed in the polymer chain, this raw polymer is then heated and treated resulting in a polymer that is resistant to degradation by various environmental conditions.[29] For PEEK it is a high-performance semi-crystalline polymer. BioHPP is a PEEK variant its basematerial is PEEK and it contains about 20% ceramic filler. This ceramic filler has a grain size of 0.3 to 0.5 μm. The fine granularity of the filler is the basis for the extremely good polishing properties. BioHPP water solubility < 0.3 μg/mm^3. Also its surface Hardness (HV) is 110 this ensures high surface qualities and resistance to penetration by different solutions.[29]

CONCLUSION

Within the limits of this in vitro study it was concluded that:

- PMMA showed the highest surface roughness yet within the minimally accepted value for intraoral use.
- Both Acetal resin and PEEK Bio HPP showed lower surface roughness than PMMA which allowed them to be used intra orally.
- Although PMMA showed the highest surface roughness yet its construction procedure is much cheaper than the other two materials which makes it still the material of choice in many cases due to financial aspects.

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