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Surface roughness of acrylic denture base resins polished with different abrasive agents: an *in-vitro* study

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ABSTRACT

Background: Excessive surface roughness on the denture base can adversely impact the oral health of the patient. Therefore, it is necessary to polish the denture before they are delivered to the patient. The abrasive and polishing agents should provide a smoother surface without affecting the physical and mechanical properties of denture bases.

Aim: This study aims to examine and understand the potential of different polishing materials on surface roughness of acrylic denture base resins.

Materials and methods: A total of 60 Heat-cure acrylic specimens (acrylic bars) were made and grouped into six groups. Control (no abrasive), Pumice (Micro-white), Eggshell powder, Seashell powder, Black sand powder, White sand powder are used as abrasive materials for polishing these specimens. These polished specimens were subjected to profilometer surface roughness analysis.

Results: The acrylic specimens polished with eggshell powder on acrylic specimens showed the least surface roughness followed by black sand, white sand, pumice and seashell powders. Tukey HSD showed significant differences ($p=0.000$) between unpolished and polished specimens.

Conclusion: Eggshell powder effectively reduced the surface roughness of denture base resin material. However, the surface roughness demonstrated by all the abrasive materials used was within the threshold limit (2 µm). Therefore, all the materials can be used as abrasives.

1. Introduction

Acrylic resin is most commonly used for the fabrication of bases of removable partial dentures, complete dentures, the tooth-supported or implant-retained overdentures etc. [1]. PMMA (polymethyl methacrylate resin) material has desirable properties of excellent aesthetics, low water sorption and solubility, relative lack of toxicity, ability to repair, and simple processing techniques [1-3].

Surface roughness is an essential factor, which affects dentures by the accumulation of bacterial plaque and stains, leading to adverse impacts on oral health and makes the denture wearing patients to face difficulty for oral hygiene maintenance [1,4,5]. So, the removable complete or partial prosthesis must be highly polished before inserting into the patient's oral cavity. Biofilm is the slimy layer

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of colonies of microorganisms on any surface; the dental plaque is also an example of that biofilm only. Surface roughness is the finely spaced irregularities present on any surface, which can enhance the biofilm formation. If the denture surfaces are rough enough, they become a nidus for plaque accumulation as well as increase the adherence of microorganisms such as Candida albicans, Streptococcus oralis etc. [4,6]. So, the successful dentures should possess well finished and polished smooth surfaces intraorally [1]. It is one of the factors which can satisfy the patients also.

Pumice is one of the commonest fine dental abrasive used in dentistry, especially for prosthesis polishing [7]. It is used as a polishing agent on harder materials depending upon its particle size [8]. The pumice slurry is ideal to use as it reduces the generation of heat. The production of temperature may cause warpage to the non-metallic materials, and also wear away the brush. The wet pumice slurry keeps the work well covered with pumice and not allows the denture to slip off from the hand by the motion of the brush [9]. The only disadvantage of pumice is not readily available with processing. Unprocessed is not so useful for polishing purpose.

On the other hand, naturally available abrasives are widely used for polishing purpose in industries. The natural abrasives include eggshell powder, seashell powder, black sand and white sand [7]. Eggshell and seashells consist of calcium carbonate, which has superior abrasive properties [10]. Black and white sands consist of silicates (alumino-silicates), calcite, aluminium oxides and traces of other minerals like magnesium which help to enhance finishing properties of acrylic surfaces [11]. However, no substantial literature is available on the effects of these natural abrasives on the surface roughness of acrylic dentures. Hence, this study was designed to evaluate the effect of natural abrasives on the surface roughness of denture bases in comparison to pumice.

2. Materials and methods

Materials used in this study were Heat cure acrylic denture base materials resin (DPI Heat Cure, India), and abrasive materials including Pumice (Micro white, Asian Chemicals, India), Eggshell powder, Seashell powder, Black sand powder, White sand powder (Sheshrikisaan , India) are used as abrasive materials for polishing.

2.1 Preparation and finishing of acrylic resin specimens

A standard metal die (ISO standard 1567) with dimensions 10mm x 6mm x 3mm, was used for fabrication of acrylic resin specimens. Elastomeric putty impressions were made of the die and wax patterns were fabricated with the modelling wax with dimensions (10 × 6 × 3 mm). Moulds for acrylic resin specimens were prepared by flasking with dental stone according to conventional procedures. After dewaxing, packing was done with PMMA (Polymethyl methacrylate) heat cure acrylic material and cured by following long-curing cycle. A total of 60 specimens were fabricated. Finishing procedure of all test specimens was done by subjecting them to trimming with acrylic and tungsten carbide burs (Waldent, Premium, India). After that, they were hand-finished progressively using finer grades of silicon carbide paper with decreasing order of grit (emery paper numbers 80, 100, 120 and 220µm) and mandrel in unilateral direction and ten strokes for 10 seconds.

2.2 Preparation of abrasive powders

2.2.1 Preparation of Eggshell and sea shell powders

The seashells were collected from the sea coast. The collected Eggshells and seashells were washed, and then boiled at 100^0C, and vacuum dried in the microwave oven for 2min at 25^0C and crushed to powder using a blender (Prestige 730 Watts, India) for 40 minutes. After that powder was sieved for fineness with 25µm sieve.

2.2.2 Black sand and white sand powders:

Black sand and white sand were brought commercially from the aquarium shop. The sand was directly grounded in the mortar with pestle and then powdered twice using a blender for 40 minutes in two steps. After that powder was sieved for fineness with 25µm sieve.

2.3 Procedure of polishing with abrasive powders

A total of sixty samples were fabricated and divided into six groups, which comprises ten specimens (n=10) for each abrasive powders. Among the six groups, one is the control group, and the other five are for the individual abrasive powders such as pumice, eggshell, seashell, white sand, and black sand respectively.

The slurry with each abrasive powder was made by mixing the abrasive powders with 2 ml of distilled water.

A polishing felt cone was fixed on a dental lathe unit (Unident, India), and the abrasive pastes were applied. The acrylic specimens were polished by passing them across the felt cone, which was rotating at a speed of 1425 RPM. The acrylic specimens were polished for 2 minutes.

2.4 Evaluation of Surface Roughness

The polished specimens were tested for surface roughness using a profilometer (SRG 4000, I ndia) after polishing with each abrasive material. The specimen surface was fixed on a flat surface in a position to the horizontal base of the profilometer. The stylus (profilometer`s needle) was moved across the surface of each specimen two times in two different directions for a distance of 1.7 millimetres according to the apparatus design. The data was collected from the screen part of the profilometer.

The data were subjected to Oneway ANOVA and TukeyHSD tests for statistical analyses using SPSS for Windows, Version 21.0., SPSS Inc.

3. Results

The mean surface roughness of acrylic specimens polished with various abrasive agents was detailed in table 1. Statistical analysis showed that the surface roughness (Ra) was influenced by using polishing procedures compared to unpolished samples. Among the abrasive materials used, seashell powder on acrylic specimens showed more surface roughness (1.2760±.40484), and eggshell powder material on acrylic specimens showed less surface roughness (0.9510±0.51692) (Figure 1). One-way ANOVA showed significant differences (p=0.001) in the surface roughness among the materials tested (Table 1).

Posthoc analysis showed significant differences (p=0.000) between unpolished and polished specimens (Table 2). However, no significant differences were observed among the modified groups (Table 2). Though the polished acrylic specimens showed different mean surface roughness values, they were not statistically significant.

4. Discussion

Denture prostheses, which are widely used in dentistry, are made of heat-activated acrylic resin. Polishing involves removing rough surfaces incrementally. This may affect the physical and mechanical properties of acrylic resin, such as surface hardness [12-14]. Dental appliances can be polished through either mechanical or chemical polishing methods. For the fabrication of removable denture prosthesis, mostly polishing is done by mechanical polishing techniques [1,15,16]. In mechanical polishing, the surfaces are abraded by mechanical action and progressively reduce notches until a smooth polished surface is attained. In the chemical polishing method, the polishing agent penetrates through the surface of the denture prosthesis that results in breaking of the secondary bonds between the polymer chains, and finally promotes the

Table 1: Comparison of Surface roughness using One-way ANOVA

Groups	N	Mean	Standard Deviation	F value	Significance
Unpolished	10	2.2800	0.67728	9.846	0.001*
Pumice	10	1.2130	0.43405		
Egg Shell	10	0.9510	0.51692		
Sea Shell	10	1.2760	0.40484		
White Sand	10	1.0980	0.52115		
Black Sand	10	1.0730	0.29978		

* Significant differences were observed among the groups.

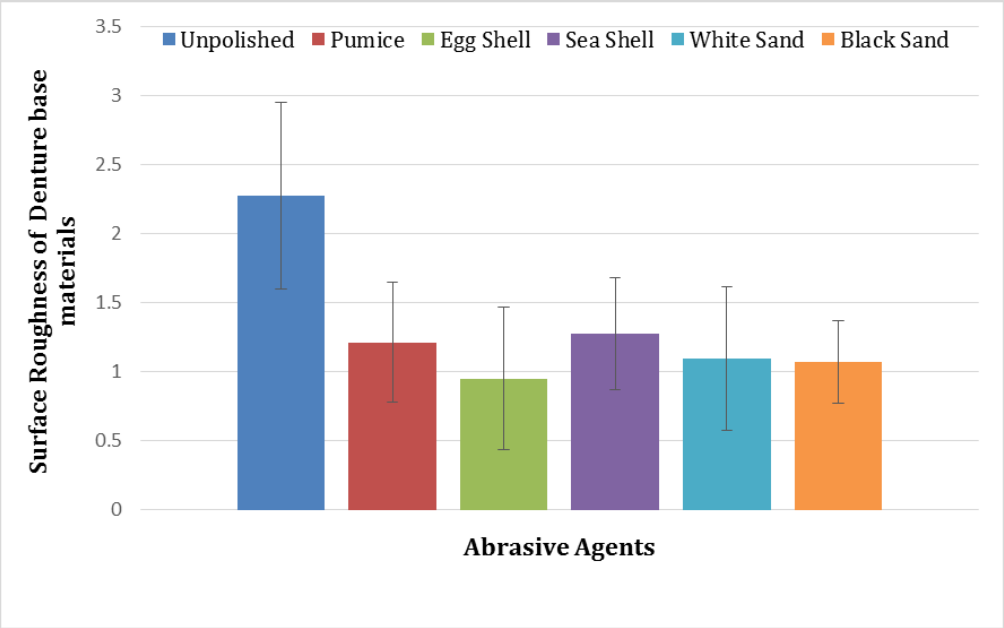

Figure 1: Surface roughness of denture base material polished with different abrasive agents.

Table 2: Pair-wise comparison of surface roughness using Posthoc analysis

Groups		Mean Difference ± Standard Error	Significance
Unpolished	Pumice	1.06700±0.21906	0.000*
	Egg Shell	1.32900±0.21906	0.000*
	Sea Shell	1.00400±0.21906	0.000*
	White Sand	1.18200±0.21906	0.000*
	Black Sand	1.20700±0.21906	0.000*
Pumice	Egg Shell	0.26200±0.21906	0.837
	Sea Shell	0.06300±0.21906	1.000
	White Sand	0.11500±0.21906	0.995
	Black Sand	0.14000±0.21906	0.987
Egg Shell	Sea Shell	0.32500±0.21906	0.676
	White Sand	0.14700±0.21906	0.984
	Black Sand	0.12200±0.21906	0.993
Sea Shell	White Sand	0.17800±0.21906	0.964
	Black Sand	0.20300±0.21906	0.938
White Sand	Black Sand	0.02500±0.21906	1.000

* Significant differences were observed between the groups.

plasticizing effect of the acrylic resin surface [17]. So, mechanical polishing was considered to be a better method, and it was the reason for choosing the mechanical polishing procedure in this study. Various studies also suggested that mechanical polishing produces significantly smoother surfaces on acrylic dentures compared to chemical polishing [17].

This present study evaluated the efficacy of different abrasive materials in comparison with pumice. Those abrasive materials are eggshell powder, seashell powder, black sand powder and white sand powder. These abrasive materials are used in the present study has their composition is almost similar and has properties same as pumice. The eggshell powder is composed of approximately 98.2, 0.9, 0.9% Calcium carbonate, Magnesium and Phosphorous (phosphate) respectively. Eggshell powder abrasive material consists of calcite, graphite tracers and thenardite [18,19]. They increase the abrasion rate and smoothness of dentures. The seashell powder contains calcium carbonate, silicon dioxide, aluminium oxide, which helps in an abrasive activity [9]. White and black sand consists of silicon dioxide, Aluminium oxide, ferrous oxide and Tracers of minerals which has abrasion properties [11].

Quirynen *et al.* [18] reported significant bacterial accumulation and their colonization would occur if the surface roughness is more than 2µm. Based on this study, the surface roughness of dental prostheses should not exceed 2µm. The plaque accumulation may result if the surface roughness is exceeded this threshold limit [20]. So, this threshold limit is considered as a basis to use an abrasive material to finish and polish the dentures.

In the present study, the eggshell material caused the least surface roughness compared to other abrasive materials. Whereas the specimens polished with seashell powders exhibited more surface roughness. However, the surface roughness of all the polished specimens with different abrasive powders was within the threshold limit (2 µm). Posthoc analysis showed significant differences between unpolished and polished specimens with different abrasive powder. However, no significant differences were observed between the polished specimens. This phenomenon indicates that all the five abrasive materials used in the study may be considered for polishing the acrylic denture prosthesis,

The results of this study were in agreement with Stanley *et al.*, who suggested that eggshell abrasive powder provides better smoother surfaces on the denture base acrylic resin than pumice [4]. The reason for this can be attributed to the hydrophilic nature of calcite ($CaCO_3$) and sodium sulphate coating present on the egg shells that aids to become instant slurry with water to enhance abrasive property [4,21].

Ahmed SA *et al.* [7] concluded that acrylic specimens polished with black sand exhibited higher surface roughness than white sand and pumice . Black sand possesses better mechanical and physical properties compared to white sand and pumice that made the black sand as a better abrasive material. Numerous SEM studies described the morphology of black sand powders that they contained fine and ultra-fine particles with an average particle size of 50 to 500 nm. This variation in their particle sizes made this material a better abrasive agent [22]. In contrast, black sand demonstrated less surface roughness compared to white sand in the present study.

Song E *et al*. [23] studied the effect of surface modification of $CaCO_3$, which is constituent in eggshell powder, by Laureth sulfonic acid surfactants on its wettability. They concluded that increase in surfactant concentration after the formation of a monolayer saturated with surfactant molecules produce a reverse change from hydrophobic to hydrophilic due to bilayer formation of surfactant molecules on the $CaCO_3$ surface [23,24]. The hydrophilic property of $CaCO_3$ makes it easy to become slurry with water to enhance dental polishability [25,26].

Al-Kheraif [27] reported a mean surface roughness (Ra) value of 0.10 mm on PMMA specimens polished with pumice; however, they used an automatic polishing machine, which is different from the conventional hand polishing method applied in the present study.

The eggshell powder showed less surface roughness than seashell powder, as the harder and finer the particles more will be the abrasive nature and properties of the polishing materials. Eggshell is most effective because of its composition and inclusion of LAS (Laureth sulfonic acid surfactants) coating, which increase the abrasion rate and causes smoothness of the dentures [20, 25].

5. Conclusion

From this study, the following conclusions were drawn;

- Unpolished group of acrylic specimens showed the highest surface roughness compared to polished acrylic specimen groups; so, it necessitates polishing the acrylic denture prosthesis before they delivered to the patient.

- Eggshell powder effectively reduced the surface roughness of denture base resin among all polishing materials used followed by black sand, white sand. However, the surface roughness demonstrated by all the abrasive materials was within the threshold limit (2 μm). Therefore, all the materials can be used as effective polishing agents in dentistry.

- Eggshells are available readily in every source, even domestically. So, its powder can be made abundantly at free of cost, unlike pumice powder, which is expensive and not readily available.

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