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In-vitro Comparison of Effect of Two Moulding and Polishing Methods on the Surface Roughness of Heat Polymerized Resin

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Abstract

Acrylic resin is the most common material used for the fabrication of bases for prostheses including overdentures. A smooth surface is ideal for the maintenance of dentures and the prevention of bacterial colonization. Polishing materials used and the method of moulding are the few factors that affect surface roughness. Hence the present in vitro study was done to compare the effect of polishing materials and moulding methods on the surface roughness of dentures. 120 specimens (50mm × 3mm) were divided into two equal groups and fabricated by compression and injection moulding techniques. Each group was subdivided into 3 groups based on the polishing method viz: control (pumice), pumice with universal polishing paste and pumice with rouge based on the polishing protocols advocated. Determination of surface roughness was done with a profilometer. Statistical analysis was done with one-way ANOVA and Tukey HSD. The surface roughness ranged between 0.372 ± 1.340 and 0.046 ± 0.027. In both the moulding methods control group with pumice exhibited the greatest surface roughness in comparison with the other two groups and universal polishing paste produced the least. On comparing the two moulding methods the injection moulding method exhibited the least surface roughness. (p=0.0001). From the results of the study, it can be inferred that irrespective of the moulding method polishing using pumice and universal polishing paste would produce a smooth surface with the least roughness and could be implemented by all clinicians to bacterial colonisation and plaque formation in dentures.

Keywords: *Compression Moulding, Injection Moulding, Pumice, Rouge, Surface Roughness, Universal Polishing Paste.*

Introduction

Acrylic resin has a very long history since its introduction in 1900 Rohn. However, it came into common use in the field of dentistry and medicine only after a patient was obtained by Kultzer in 1940. In a couple of years, most of the denture bases were manufactured with

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polymethylmethacrylate (PMMA) or its copolymers. Since then, several modifications of the material have been done and the current applications of acrylic resin in dentistry are widespread from denture bases to temporary prostheses, stents, removable orthodontic appliances, surgical guides and stents [1]. In recent years there has been an increased demand for dentures owing to the increase in the edentulous population. It is a well-known fact that these resin bases are used to replace the tissues that were lost during extraction and to transfer the forces during mastication from the prosthesis to the residual ridge [2-4]. Several factors determine the success rate of dentures such as physical properties, and mechanical properties that are determined by the processing method. [5,6,7]. In addition, denture bases ought to have a smooth and polished surface for aesthetics, patient comfort, and resistance to microbial colonization.

In other words, rough surface in dentures is associated with several ill effects including mucosal irritation followed by inflammation, bacterial colonisation and plaque formation, and ulcers of the mucosa. When the surface is rough due to microporosities there is an increase in surface energy which is associated with an increased chance of colonisation by microorganisms. A few studies have shown that the impact of surface roughness is more on microbial adhesion in comparison with surface energy. Since surface energy and surface roughness are interlined, a smooth finishing and polishing of denture bases are essential to ensure patient comfort and longevity of prosthesis [3, 8.9].

Studies have reported that surface roughness of Ra = 0.2 µm or below has minimum plaque accumulation. However, the surface roughness of denture bases polished using pumice, rubber polishers, prophylactic pastes, and abrasive stones, have shown to demonstrate surface roughness greater than Ra of 0.2 µm which is the standard threshold level. Polishing denture bases with aluminium oxide-based polishing paste or soap has shown lower levels of surface roughness [3,10,11]. This shows that there are no polishing materials to date that demonstrate an ideal surface roughness of 0.2 µm.

Conventional lathe polishing in a laboratory is the most common polishing technique [3]. Polishing is done sequentially commencing from removal of gross irregularities followed by final finishing and polishing [3,13]. Pumice and water are the most common polishing agents used in prosthetic laboratories. However, newer polishing materials such as rogue and universal polishing paste have been introduced recently.

Among the various factors affecting the surface roughness of the denture base, the role of the moulding technique cannot be underplayed. The first introduced method was compression moulding which is a conventional technique but has several disadvantages as high polymerisation shrinkage that has a detrimental effect on the outcome of the denture. To overcome these limitations, continuous injection was introduced in 1942 [2].

Considering the protocols to determine surface roughness currently, there are no specified protocols. In laboratories, the surface is assessed only with the naked eye and there is a lack of armamentarium for the same, Therefore, the smoothness of dental prosthesis and its ability to permit microbial plaque formation varies from one laboratory to the other [10,11,12]. This warrants the need for standardisation of polishing procedures and the use of novel polishing materials.

Very few studies have compared the surface roughness with polishing agents. It is therefore important to determine the effect of different polishing agents and moulding methods on the surface roughness of denture base acrylic resins. With the available data, we intended to perform an invitro study that would aim to evaluate the effect of pumice, pumice with rogue and pumice with universal polishing paste on the surface roughness of heat cure denture base acrylic resins processed by compression and injection moulding techniques.

Materials and Methods

The present in-vitro study was conducted with 120 samples of uniform thickness based on similar studies [3.14,15]. The heat cure acrylic resin samples were equally divided into 2 groups of sixty each viz A and B respectively based on fabrication method compression and injection moulding technique. Each group were sub-grouped into groups I, II and III with 20 samples in each group based on the polishing method as follows:

Group I pumice alone

Group II conventional and universal polishing paste

Group III pumice and rogue.

The samples were randomly divided by coin toss method and the investigator was blinded.

Null Hypothesis

The null hypothesis was there would be no significant difference in the surface roughness produced by pumice, universal and rogue polishing methods in compression and injection moulding techniques. Also, there will be no significant difference in surface roughness processed by compression and injection moulding methods.

Inclusion Criteria

Specimens with accurate dimensions and surface finish were selected for the study.

Exclusion Criteria

Porous specimens, inaccurate dimensions, gross surface irregularities and visible crack lines were excluded from the study. Specimens that appeared porous on visual examination.

Preparation of Metal Die

A computer numerical control milling machine was used to prepare a stainless-steel disk-shaped die by Specification No. 12 of the American Dental Association (ADA). 120 heat-polymerized acrylic resin samples (50 mm in diameter and 3 mm in thickness) were fabricated to match the mean denture base thickness [16,17].

Sample Processing

Group A

Gypsum moulds for the construction of resin samples were made using the 2-pour method. Placement of the lower part of the flask was done on a vibrator to which a fresh mixture of dental stone at the water powder ratio of 3.3:10 was added and placement of metal die was done. Following the initial setting of the dental stone, a thin layer of petroleum jelly was added as a separating medium. Following this, the dental stone was added to the other portion of the flask and was gently placed on the lower portion of the flask and clamp pressure was applied. Once the setting was complete the flask was separated into two portions and metal was removed to create a mould space. Following this application of the separating medium (SR Separating Fluid, Ivoclar Vivadent AG) was done on the walls of the mould cavity and dried. Mixing of Heat cure polymer and monomer (SR Triplex hot polymer and SR triplex monomer –Ivoclar Vivadent) was done at a ratio (of 23.4 gm.: 10 ml) and the obtained acrylic dough was packed into the mould space. Placement of a polyethylene sheet was done on the packed acrylic dough and the flask was reassembled followed by incremental application of hydraulic pressure with Silfradent, hydraulic press. Following this, the polythene sheet and excess resin were removed. Bench curing was done for half an hour and heat curing was done. The flask was placed at room temperature in a water bath and heated steadily up to the boiling point of water and kept in boiling water for 45 minutes. Deflasking was done. A similar procedure was repeated to obtain sixty samples.

Group B

The samples were prepared by injection moulding technique according to the manufacturer's instructions using SR IVOCAP acrylic resin (Ivoclar Vivadent) and SR

IVOCAP heat cure injection system (Ivoclar Vivadent).

Type III dental stone was used as an investing material and was placed in the lower part of the flask followed by the placement of a metal die. After the removal of excess material and initial set placement of the injection funnel was done. After applying separating medium on the lower part of the flask using SR Separating Fluid, Ivoclar Vivadent AG, the upper part of the flask was placed and invested with type III stone and allowed to set for sixty minutes. Removal of metal die was done and separating medium was applied on mould space following which mixing of acrylic material was done according to manufacturer's instructions. Placement of the capsule was done on the capsule plunger and the contents were pressed upward with light rocking movements to allow air to escape through the capsule opening. The flask was placed in position and application of 3-ton pressure was applied to the clamping frame. Removal of the cover from the capsule was done and it was inserted into the flask. The pressure apparatus was connected to the compressed air supply (6 bar / 85 psi). Opening of the locking valve was done slowly to inject the material into the mould space and placement of the apparatus was done on a water bath at room temperature and slowly heated. Following the placement of the flask in a boiling water bath for 35 minutes, cooling was done by rinsing on cold water for 20 minutes. Then pressure apparatus was removed and further cooling was done for 10 minutes. Deflasking was done and pressure was applied again and divestment of the flask was done according to the manufacturer's instructions. The procedure was repeated to obtain sixty samples.

Removal of Surface Irregularities

Due to the smaller size of samples fabrication of a stainless-steel jig was done into fixation was done with cyanoacrylate. Further, they were mechanically finished and polished. The speed of abrasion was 3000 rpm, with a load of 400 grams for 90 seconds [18,19].

Finishing of samples was done with a lathe-mounted 30-fluted fine cross-cut tungsten carbide-bur so that a smooth surface could be obtained after the removal of irregularities and nodules on the surface. Sandpaper of grits varying from 320,400 and 600-grit was mounted with a lathe and the samples were subjected to further finishing at three thousand revolutions per minute for one and a half minutes. Then polishing was done by adhering to specification no: twelve of the American Dental Association (A.D.A.)

Polishing of Samples

Placement of specimens was done on a glass surface was done in such a way that the surface to be polished faced the glass. Then attachment of specimens was done on a stainless-steel jig with cyanoacrylate, where the entire specimen was in contact with the glass.

First, all the samples were subjected to a conventional polishing technique using water and pumice at equal volume for forty seconds at three thousand revolutions per minute. Following this, each subgroup was subjected to different polishing methods.

Control group (I): Polishing was done with pumice paste for twenty seconds at three thousand revolutions per minute.

Universal polishing paste (II) Polishing was done with universal polishing paste for twenty seconds.

Rogue (III): Polishing was done with rouge for twenty seconds at three thousand revolutions per minute.

The images are depicted in Figures 1 and 2

Figure 1. Image of Samples Finished by Compression Moulding Method

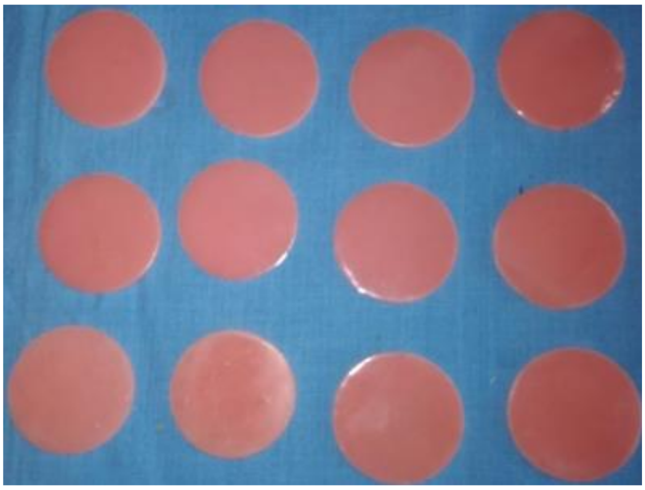

Figure 2. Image of Samples Processed with Injection Moulding Method

Outcome Analysis (Ra)

A contact profilometer (ISO-4287, Surtronic 128, Taylor Hobson, Romania) was used for the measurement of surface roughness. Calibration of the instrument was done with a cutoff filter of 0.08mm; evaluation length of 1.25 mm and a range of 100µm. Marking of 6 equidistant points on the stainless-steel cylinder surface was done a labelled in alphabetical order from A to F. Corresponding lines were drawn that connected A and D; B and E; C and F. Readings were taken at three different positions at 1.25mm. The experiment was done in triplicates by a single blinded examiner.

Statistical Analysis

Statistical Software SPSS Version 16 was used for statistical analysis. With Shapiro Wilk's Test and data to check if data could be asses by parametric test. One Way ANOVA and independent sample "t" test were used for intra and intergroup variation and a P Value of less than 0.05 was considered significant. A Post Hoc Turkey test was also done.

Results

Intragroup Comparison Group A

The samples in Group A demonstrated the lowest surface roughness value seen in subgroup-II with universal polishing paste (0.072 ± 0.018), followed by sub-group-III with Rogue (0.092 ± 0.032). The highest value is shown by subgroup-I with pumice (0.372 ±1.340). However, the results were not statistically significant (P=0.398). The results of ANOVA are depicted in Table 1 and the post hoc turkey test is depicted in Table 2 respectively.

Table 1. Comparison of Surface Roughness by Polishing with Different Materials Processed by Compression Moulding Method

S. No	Study groups	Mean	Standard deviation	P Value
1	Pumice paste	0.3723	1.34071	0.398
2	Universal polishing paste	0.0724	0.0187	0.398
3	Rogue	0.0927	0.0321	0.398

Table 2. Post Hoc Turkey Test Depicting Subgroup Analysis in Group A

S. No	Study groups	Pumice	Universal polishing paste	Rogue
1	Pumice paste	-	0.444	0.493
2	Universal polishing paste	0.444	-	0.996
3	Rogue	0.493	0.996	-

Intragroup Comparison Group B

In group B the roughness value was highest in subgroup 1 with pumice (0.113 ± 0.016) followed by subgroup III with Rogue (0.049 ± 0.031) and least in subgroup II with universal polishing paste (0.046 ± 0.027) The results were statistically significant. The results are depicted in Table 3 and Table 4.

Table 3. Comparison of Surface Roughness by Polishing with Different Materials Processed by Injection Moulding Method

S. No	Study groups	Mean	Standard deviation	P Value
1	Pumice paste	0.1139	0.01642	0.0001
2	Universal polishing paste	0.0463	0.02788	0.0001
3	Rogue	0.0498	0.03110	0.0001

Table 4. Post Hoc Turkey Test Depicting Subgroup Analysis in Group B

S. No	Study group	Pumice	Universal polishing paste	Rogue
1	Pumice paste	-	0.001	0.0001
2	Universal polishing paste	0.001	-	0.906
3	Rogue	0.0001	0.906	-

Intergroup Comparison Group A and B

Pumice

The average surface roughness was lesser in the injection moulding technique group in comparison with the compression moulding technique group. However, the result was not found to be statistically significant i.e. $P > 0.05$ (0.394).

Universal Polishing Paste

The average surface roughness was greater in the compression moulding technique group in comparison with the injection moulding technique group. The variation was statistically significant i.e. $P < 0.05$ (0.0013).

Rouge

The average surface roughness was greater in Group A in comparison with Group B and was observed to be statistically significant $P < 0.05$ (0.0003).

Overall Comparison

The greatest surface roughness was produced by the control group (Pumice) irrespective of moulding techniques ie Group A and B. This was followed with rouge and universal polishing paste produced the least surface roughness. On comparing the two moulding methods the injection moulding method exhibited the least surface roughness. The results are depicted in Table 5 and Figure 3

Table 5. Comparative Surface Roughness of Acrylic Resin with Different Polishing and Moulding Methods

Fabrication technique	**Polishing Agent used**	**Mean Standard Deviation**	**P Value**
COMPRESSION MOULDING TECHNIQUE	Pumice paste	0.3723 ± 1.34	0.398
	Universal polishing paste	0.0724 ± 0.018	
	Rouge	0.0927 ± 0.032	
INJECTION MOULDING TECHNIQUE	Pumice paste	0.1139 ± 0.016	0.0001*
	Universal polishing paste	0.0463 ± 0.027	
	Rouge	0.0498 ± 0.031	

*Statistically significant

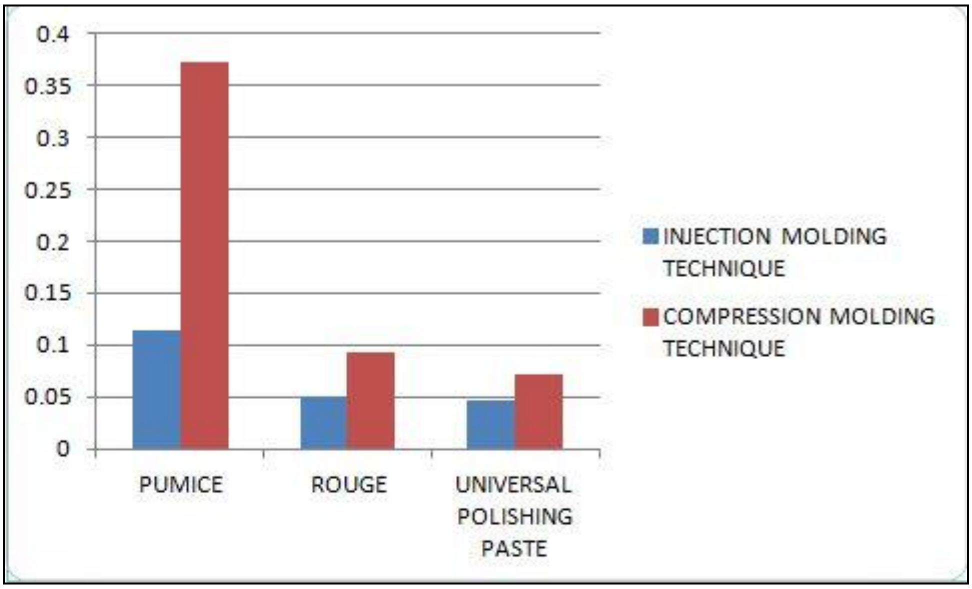

Figure 3. Comparative Surface Roughness of Acrylic Resin with Different Polishing and Moulding Methods

Inference

To infer, the injection moulding technique with pumice and the universal polishing method produced the least surface roughness.

Discussion

In recent days there has been an increase in the population of edentulous individuals due to poor oral care in developing countries and increased life expectancy in developed countries. Hence research on improving the properties of denture base materials is warranted. Several factors affect the success rate of a denture base material including the processing method, the hardness, biocompatibility, and physical and mechanical properties [5,6,7].

Among the various factors affecting the success of dentures the most vital one is the highly polished smooth surface as it renders aesthetics, gives comfort to the patients and prevents plaque-retention [1]. Surface roughness and surface-free energy play a key role in bacterial adhesion and colonization. It is a well-known fact that bacteria adhere to irregular surfaces of prosthesis, and restorations, in four phases namely transportation, initial adhesion with a reversible and irreversible stage, attachment by specific interactions and colonization [11,20]. Thus, a reduction in surface roughness will retard the process of plaque formation and maturation. A decrease in surface-free energy led to a slower plaque growth rate and retention. Although both parameters are interconnected, the influence of surface roughness is more important. Thus, a smooth surface with a low surface free energy is required to prevent plaque formation and associated inflammation [9].

Polishing is crucial to produce a smooth and glossy surface that prevents microbial growth. The various modalities of polishing currently used are conventional lathe polishing, chair side polishing and chemical polishing. Among these conventional lathe polishing with pumice in a laboratory is the most cost-effective polishing technique [3]. The chair side polishing is less effective than conventional lathe polishing as demonstrated by Kuhar et al; O'Donnell et al; and Rahal et al [12.21]. The newer polishing materials are the universal polishing paste and rogue. Hence, the present study compared pumice, universal polishing paste and tongue.

Compression and injection moulding methods are the two common processing methods of denture bases that could affect surface roughness. Ivoclar Vivadent (Liechtenstein) was chosen to fabricate denture bases as both compression and injection moulding materials were available with the same manufacturer and are the most common brands used by dental professionals. Surface roughness was calculated with a profilometer as it is better than other methods such as non-contact profilometer, confocal microscope scanning electron microscope and visual method [22.23]. Similar studies have used the same instrument to determine surface roughness [4,23,24].

The results of the present study have shown that the ideal threshold level of 0.2 µm is achievable with are concurrent with that of Bollen et al and Quirynen et al [10,23]. In the present study, the conventional polishing technique produced a surface roughness below the accepted threshold (Ra = 0.2 µm). The results are concurrent with several studies that have reported values ranging between 0.008 µm and 0.152 µm. Lamfon, et al., Abuzar et al., Srividya et al., Vitalariu, et al., Ahmad. Et al., [25,26,27,28,29].

The mean surface roughness polished with pumice alone was greater than the other two groups irrespective of the moulding method. This is concurrent with the results reported by Srividya et al. According to their study pumice produced a significantly less smooth surface than metallic polishing liquid and polishing paste [27]. This could be attributed to the fact that the particle size of the pumice is quite large and the presence of loose abrasives in the pumice slurry. Rogue and universal polishing paste have abrasive substances that are in a bound state as they are dissolved in solvent. This could be the probable reason for the decreased surface roughness demonstrated by subgroups II and III in the present study.

It was observed that universal polishing paste produces the least surface roughness in our study. This could be because of the presence of aluminium oxide in universal polishing paste that has a higher Mohr's hardness of 9 in compassion with pumice which has a value of 6 to 7. The compression moulding techniques demonstrated greater mean Ra values than the injection moulding technique irrespective of the polishing method. The results are concurrent with similar studies reported by Moslehifard et al., and Porwal et al. [30,31].

The limitations of the study include that the study had an in vitro design and the wear and tear of patient use and long-term follow-up were not done. The samples were very smooth had a definite shape and did not mimic denture bases fabricated from impressions obtained from patients hence the smoothness and final finish may vary. Also, plaque retentive capacity was not assessed. Further randomised control clinical trials with long-term follow-up on surface roughness and plaque formation have to be conducted.

Conclusion

The compression moulding technique has been shown to provide the highest mean surface roughness in comparison with injection moulding. In both compression and injection moulding, traditional polishing with pumice and universal polishing paste produced the smoothest surface. We recommend clinicians commence the procedure by selecting a high-quality heat-cure denture base acrylic resin and select injection moulding method. Finishing has to be done with a lathe-mounted 30-fluted fine cross-cut tungsten carbide bur, to effectively remove gross irregularities and surface nodules. Polishing could be done with pumice followed by universal polishing paste**.**

Conflict of Interest

The authors declare that there is no conflict of interest.

Acknowledgements

Nil.

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