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Research Article

Surface Roughness and Weight Loss of Heat Cure and Self-Cure Acrylic Resins Which Were Subjected to Tooth Brush and Tooth Paste Cleaning-an *In Vitro* Study

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Abstract

Objectives:

- To determine and compare the surface roughness of heat and chemically cured acrylic resins after subjecting them to mechanical polishing, chemical polishing and chemical polishing with microwaving.
- To find out the surface roughness and weight loss caused by tooth brushes and dentifrices on heat and chemically cured acrylic resins which were subjected to mechanical polishing, chemical polishing and chemical polishing with microwaving.

Materials and Methods: Rectangular specimens were prepared and they were subjected to mechanical polishing, chemical polishing and chemical polishing with microwaving. These specimens were then subjected to tooth brushing with tooth pastes. Surface roughness and weight of the specimens were measured before and after tooth brushing. Medium and hard tooth brushes and one regular tooth paste and one gel tooth paste were included. Brushing was done with a motor driven device and the brushing cycles were limited to 30,000. Data was statistically analyzed using ANOVA.

Conclusions

- Heat cure acrylic resin can resist surface roughness better than self cure resins. The roughness values observed in both the resins were within the clinically acceptable limits.
- Heat cure resin which is mechanically polished can resist surface roughness better than in chemically polished specimens.
- Tooth brushes and pastes included in the study will not cause surface roughness beyond the acceptable limit within a period of three years.
- Heat cure acrylic resin undergoes more weight loss than self cure resin when subjected to brushing with tooth pastes.
- Microwaving did not particularly improve the properties of the resins to resist surface roughness and weight loss.

Keywords: Polymethylmethacrylate; Chemical Polishing; Mechanical Polishing; Chemical Polishing and Microwaving; Brushing Simulator; Surface Roughness; Weight Loss

Introduction

The formation of acrylic acid was first reported 180 years ago. In 1937, poly methyl methacrylate (PMMA) was made available in the powder form to be used in the fabrication of denture bases. Auto polymerizing PMMA was commercially available in 1945. Within an year, acrylic has become a popular material for the making of dentures. The fifth decade of 20th century witnessed the diversified applications of PMMA; from dentures to different types of appliances and maxillofacial prostheses. Twenty first century witnessed the development of CAD/CAM dentures and the materials used for the fabrication [1-6].

Popularity of PMMA is mainly due to its aesthetics, favourable physical and mechanical properties, lack of proven non toxicity, limited water solubility and water sorption, repairability and processing technique which can be carried out in a clinic or a lab. Commonly used denture base resins are heat cure resins and self cure resins. Recent addition to this class of materials are CAD/CAM

resins which are usually milled and the resins used for three-dimensional (3D) printing [7,8].

Acrylic dentures and appliances should have a smooth surface to control bacterial and fungal colonisation on the surface which can lead to oral diseases viz. dental caries, periodontal diseases and denture stomatitis. The bio film accumulation may also lead to systemic diseases like aspiration pneumonia, pleural and gastro intestinal infections [9]. Direct intervention with peroxide containing denture cleansers can eliminate the microbial colonisation but they can cause hydrolysis and decomposition of acrylic resin eventually leading to surface roughness, discoloration and substance loss [10,11]. It is desirable to provide a highly polished surface to acrylic prosthesis to prevent microbial colonisation. Commonly used polishing methods are mechanical and chemical. The former utilises rag wheels, cones and wool buff along with pumice and precipitated chalk [12]. The latter makes use of a dip of prosthesis in monomer kept at 74-75^{0}C for a short spell of 60 seconds. This can polish prosthesis with very irregular morphology. Will this method of polishing negatively affect the properties of the resin is a matter to be investigated in detail [13,14]. Chemical polishing obtained with dip in warm monomer may not resist abrasion against cleaning with tooth brush and paste. Can the resin be strengthened with a session of microwaving is also a matter worth investigating. In this context the present study was designed with the following objectives

-todetermineandcomparethesurface roughness of heat and chemically cured acrylic resins after subjecting them to mechanical polishing, chemical polishing and chemical polishing with microwaving.

-to find out the surface roughness and weight loss caused by tooth brushes and dentifrices on heat and chemically cured acrylic resins which were subjected to mechanical polishing, chemical polishing and chemical polishing with microwaving.

Methodology

Preparation of specimens

Hundred and forty-four acrylic resin specimens measuring 75 x 23 x 4 mm were fabricated of which 72 were made in heat activated (heat cure) acrylic resin and 72 were made in chemically activated (self cure) resin. Polymerisation was done according to the respective manufacturer's instructions. Specimens were trimmed using tungsten carbide trimmers and the surface was finished with silicon carbide paper of grit sizes 320(36µm), 400(23µm) and 600(16µm) successively. After this the specimens were stored in water kept at laboratory temperature (Figure 1).

Specimens were grouped as follows

- Heat cure acrylic-Mechanical polishing-24
- Heat cure acrylic-Chemical polishing-24
- Self cure acrylic-Mechanical polishing-24
- Self cure acrylic-Chemical polishing-24
- Heat cure acrylic-Chemical polishing + Microwave-24
- Self cure acrylic-Chemical polishing + Microwave-24

Figure 1: Acrylic specimens.

Mechanical polishing

Heat cure and self cure specimens were subjected to mechanical polishing. Dental lathe running at 1500 rpm was used for this purpose. The following was the sequence of polishing: soft cloth wheel with pumice slurry, polishing wheels with precipitated chalk powder mixed in water and dry polishing with wool buff.

Chemical polishing

A thermostatically controlled water bath which was set at temperature 75^{0}C was used for this purpose. Sufficient quantity of heat cure monomer was taken in a stainless steel vessel and kept in the water bath. When the monomer temperature reached 75 ± 1^{0}C, the specimens were dipped completely for a period of 10 seconds (Figure 2). After that the specimens were removed and allowed to dry in the air for 15 seconds. 24 heat cure, 24 cold cure specimens were subjected to chemical polishing. After polishing, the specimens were stored in water for a period of 24 hours for further evaluation.

Figure 2: Monomer kept in the water bath and the specimen dipped in it.

Microwaving

24 specimens of heat cure, 24 specimens of cold cure acrylic resin which were subjected to chemical polishing were micro waved for 3minutes /500 watts using a microwave oven (Figure 3).

Evaluation of surface roughness using contact profilometer

Specimens belonging to all the groups were subjected to surface roughness evaluation. The specimens were placed below the sty-

Figure 3: Microwave oven.

lus of a profilometer (P4 stylus). The diamond stylus was moved in two directions which were mutually perpendicular for a distance of 1.5mm with a contact force of 15gm. The change in position of the diamond stylus generated an analogue signal which was converted into a digital signal. After analysis the values were displayed in micrometers (Figure 4).

Figure 4: Contact profilometer.

Determination of weight of specimens

All the specimens were dried first with a tissue paper and then kept in a desiccator containing dry silica gel. The weight was determined after 24 hours, 48 hours and 72 hours to ascertain complete dryness of the specimen with an analytical balance of 0.001 gm precision.

Determination of abrasion resistance against tooth brush and tooth paste

For this purpose, a custom made brush simulating machine was used. It is powered by a reversible synchronous motor, having a torque of 20 kg/cm and speed of 60 rpm. Each specimen was subjected to 30,000 lenier strokes which is equivalent to 3 years of brushing (Figure 5). Tooth brushes of medium and hard varieties were used. Colgate regular and Close up gel were used in the form of a slurry. For that 5gm tooth paste was mixed with artificial saliva to obtain a working consistency. Half the number of specimens in each group were brushed with Colgate paste and the other half with Close up gel (Figure 6-9).

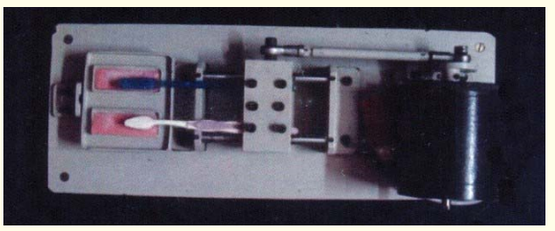

Figure 5: Custom made tooth brushing machine.

Figure 6: Colgate tooth paste.

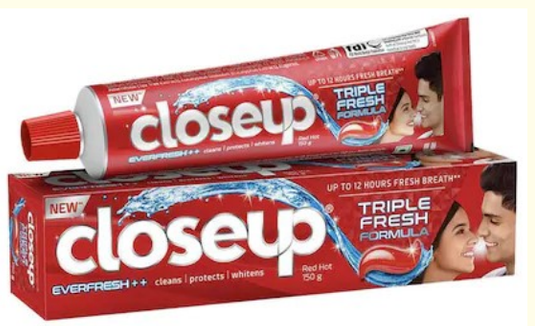

Figure 7: Close up gel tooth paste.

Figure 8: Colgate hard tooth brush

Figure 9: Oral B medium tooth brush.

Re-evaluation of surface roughness and abrasion resistance

After subjecting the specimens to brushing, surface roughness was evaluated using contact profilometer. The substance loss and thereby the abrasion resistance was calculated by determining the weight of the specimens. Results were tabulated and were subjected to statistical analysis-ANOVA (Figure 9a).

Results

Comparison of Surface Roughness

In this experiment, four factors were found to influence the causation of surface roughness which are given in table 1.

Table 1: Factors related to surface roughness.

Factors	Levels
Resins	Heat cure acrylic resin, Self cure acrylic resin
Brushes	Medium and Hard tooth brushes
Pastes	Colgate paste, Close-up Gel
Polishingtechnique	Mechanical, Chemical, Chemical+ Microwave

Null and alternate hypotheses were formulated. The p-values were compared with the level of significance. If P<0.05, the null hypothesis was rejected and accepted the alternate hypothesis. If P>0.05, the null hypothesis was accepted. If there was a significant difference, multiple comparisons (post hoc- test) using Bonferroni method were carried out to find out among which pair or groups there existed a significant difference. The statistical technique used was Factorial ANOVA. Mean surface roughness values obtained are given in table 2.

From the ANOVA table (Table 3) it was noticed that the type of resin, polishing technique and tooth pastes are significant factors that influence surface roughness. But brush was not a significant factor. The interaction (joint effect) of different factors have proved to have significant role on surface roughness. However, some interactions like Resin and Paste, Brush and Polishing technique, Paste and Polishing technique were not significant. Interaction of Resin, Paste and Polish as well as the interaction of Brush, Paste and Polishing technique together were not significant.

Table 2: Mean surface roughness recorded with different factors at their levels (µm).

Factor	Level	Mean	Std dev	Min	Median	Max
Resin	Heat Cure Acrylic	0.1023	0.0281	0.0220	0.1058	0.1726
	Self Cure Acrylic	0.1147	0.0667	0.0114	0.0879	0.2201
Brush	Hard	0.1059	0.0543	0.0114	0.1000	0.2170
	Medium	0.1111	0.0485	0.0432	0.1025	0.2201
Paste	Colgate	0.1121	0.0534	0.0114	0.1087	0.2201
	Close-up gel	0.1048	0.0494	0.0245	0.0966	0.2136
Polishing technique	Mechanical	0.0793	0.0255	0.0220	0.0841	0.1333
	Chemical	0.0919	0.0422	0.0114	0.0948	0.1726
	Chemical + Microwave	0.1543	0.0481	0.0726	0.1531	0.2201

Table 3: ANOVA Table on surface roughness.

Source	df	Sum of Squares(SS)	Mean SS	F	P-Value
Resin	1	0.00553	0.00553	12.31	0.001*
Brush	1	0.00097	0.00097	2.16	0.144
Paste	1	0.00190	0.00190	4.24	0.042*
Polishing technique	2	0.15458	0.07729	171.94	<0.001*
Resin x Brush	1	0.00465	0.00465	10.35	0.002*
Resin x Paste	1	0.00002	0.00002	0.05	0.826
Resin x Polishing technique	2	0.10962	0.05481	121.93	<0.001*
Brush x Paste	1	0.00677	0.00677	15.07	<0.001*
Brush x Polishing technique	2	0.00235	0.00118	2.62	0.077
Paste x Polishing technique	2	0.00244	0.00122	2.72	0.070
Resin x Brush x Paste	1	0.00549	0.00549	12.20	0.001*
Resin x Brush x Polishing technique	2	0.01377	0.00689	15.32	<0.001*
Resin x Paste x Polishing technique	2	0.00163	0.00081	1.81	0.168
Brush x Paste x Polishingtechnique	2	0.00221	0.00111	2.46	0.090
Resin x Brush x Paste x Polishing technique	2	0.01187	0.00594	13.20	<0.001*
Error	120	0.05394	0.00045	---	---
Total	143	0.37776	---	---	---

*denotes significance.

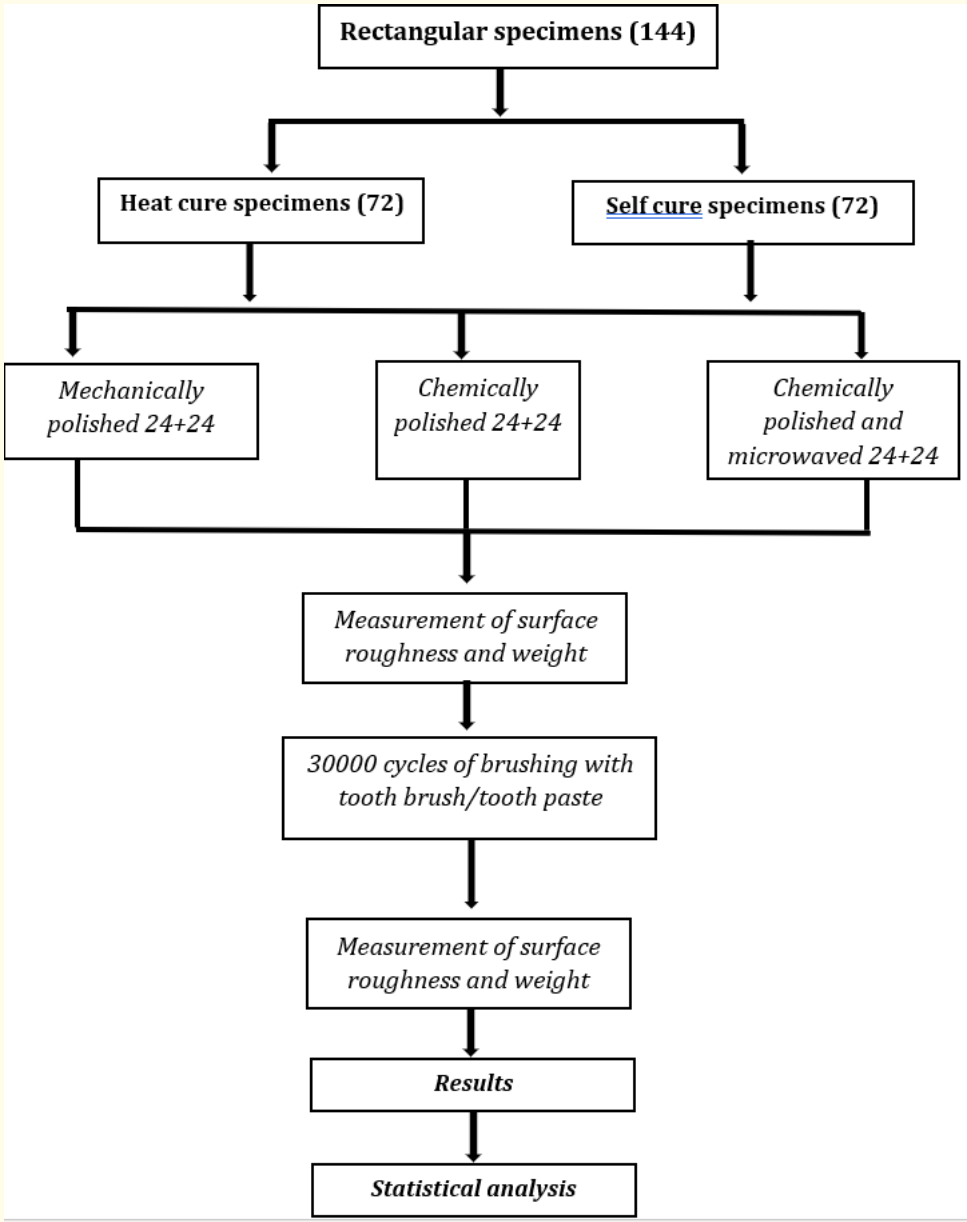

Figure 9a: Flow chart on methodology

From the multiple comparisons (Table 4) it was observed that there was a significant difference in mean surface roughness of specimens which were mechanically polished, chemically polished as well as chemically polished with microwave curing. When subjected to the brushing experiment, selfcure acrylic specimens received significantly higher surface roughness than the heatcure specimens ($P < 0.001$). The roughness causing potential of medium and hard tooth brushes were almost similar ($P > 0.05$). Though not significant, the potential of medium brush was higher than the hard brush in causing surface roughness. Higher roughness was caused by Colgate tooth paste than Close up gel and the difference was statistically significant ($P < 0.05$). Among the different polishing methods deployed, higher mean surface roughness was recorded in Chemical + Microwave polishing followed by chemical polishing and by mechanical polishing respectively. The difference in mean surface roughness recorded in specimens polished with different methods was found to be statistically significant ($P < 0.001$) (Figure 10).

Main effects plot:

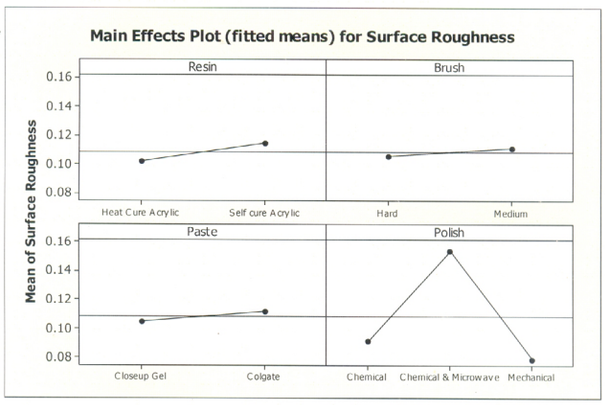

Figure 10: Main effects plot for surface roughness.

Both heat cure and self-cure specimens received almost similar surface roughness when hard brush was used but with medium brush, self-cure specimens received a higher surface roughness in comparison to heat cure specimens. With both the toothpastes, heat cure specimens received lower surface roughness than self cure acrylic specimens. Self-cure specimens which received chemical polishing and microwaving had high surface roughness. But when chemical and mechanical polishing was employed individually, heat cure specimens had higher mean surface roughness than self-cure acrylic specimens. Hard brush makes slightly higher mean surface roughness when compared to medium brush when used with close-up gel. But with colgate paste, medium brush made a higher mean surface roughness value when compared to hard brush (Figure 11).

Interaction plot:

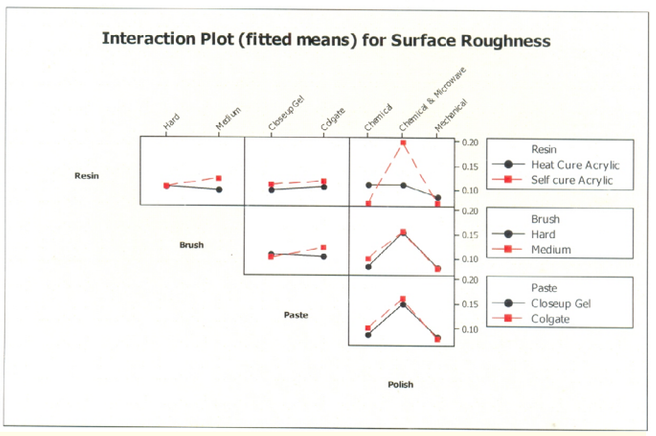

Figure 11: Interaction plot for surface roughness.

Comparison of weight loss

Weight of the specimens were found out before and after subjecting them to brushing (Table 5). Weight loss indicated the abrasion resistance of the material; more the weight loss, the abrasion resistance is less. The influencing factors of weight loss were four viz. Resin, Brush, Paste and the Polishing technique similar to those identified with the experiments of surface roughness evaluation (Table 1,2). From the ANOVA table it was observed that the type of resin has a significant role in causing weight loss. Other than that, all other factors like tooth brush, tooth paste and the technique used for polishing the specimens had no significant role in causing weight loss. The interactions of factors also were not significant in causing weight loss of the specimens (Table 6).

Table 5: Mean weight loss recorded in different factors at their levels (gm).

Factor	Level	Mean	Std dev	Min	Median	Max
Resin	Heat Cure Acrylic	0.0327	0.0239	0.0136	0.0299	0.1658
	Self Cure Acrylic	0.0235	0.0066	0.0042	0.0236	0.0355
Brush	Hard	0.0282	0.0179	0.0042	0.0274	0.1658
	Medium	0.0280	0.0183	0.0084	0.0262	0.1586
Paste	Colgate	0.0305	0.0245	0.0042	0.0267	0.1658
	Close-up gel	0.0257	0.0067	0.0084	0.0271	0.0389
Polishing technique	Mechanical	0.0293	0.0288	0.0102	0.0234	0.1658
	Chemical	0.0283	0.0110	0.0042	0.0286	0.0866
	Chemical + Microwave	0.0267	0.0060	0.0132	0.0273	0.0398

Table 6: ANOVA Table for weight loss of specimens.

Source	Df	Sum of Squares (SS)	MeanSS	F	P-Value
Resin	1	0.00301	0.00301	9.54	0.002*
Brush	1	0.00000	0.00000	0.00	0.958
Paste	1	0.00084	0.00084	2.66	0.105
Polish	2	0.00016	0.00008	0.26	0.770
Resin x Brush	1	0.00000	0.00000	0.00	0.966
Resin x Paste	1	0.00082	0.00082	2.60	0.110
Resin x Polishing technique	2	0.00068	0.00034	1.09	0.341
Brush x Paste	1	0.00000	0.00000	0.01	0.940
Brush x Polishing technique	2	0.00008	0.00004	0.13	0.882
Paste x Polishing technique	2	0.00129	0.00064	2.04	0.135
Resin x Brush x Paste	1	0.00000	0.00000	0.00	0.980
Resin x Brush x Polishing technique	2	0.00012	0.00006	0.18	0.832
Resin x Paste x Polishing technique	2	0.00148	0.00074	2.34	0.101
Brush x Paste x Polishing technique	2	0.00012	0.00006	0.19	0.830
Resin x Brush x Paste x Polishing technique	2	0.00010	0.00005	0.16	0.849
Error	120	0.03785	0.00032	---	---
Total	143	0.04655	---	---	---

*denotes significance.

It was observed that self cure acrylic specimens had lower weight loss when compared to that of heat cure acrylic specimens and the difference in mean weight loss was found to be statistically significant (P < 0.01). Lower mean weight loss was recorded with medium brush when compared to that of hard brush though the difference was not statistically significant (P > 0.05). Colgate paste recorded a higher mean weight loss compared to Close-up gel but the difference was not significant (P > 0.05). When the effect of polishing methods on weight loss was considered, specimens which were polished chemically and subsequently microwaved showed the lowest value followed by chemical polishing and mechanical polishing (P > 0.05) (Figure 12).

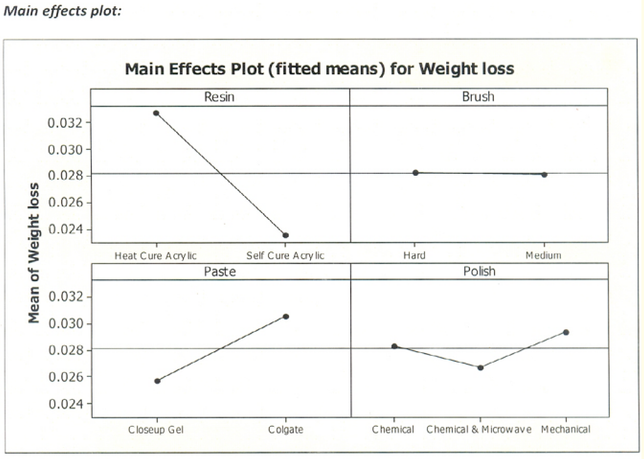

Figure 12: Main effects plot for weight loss.

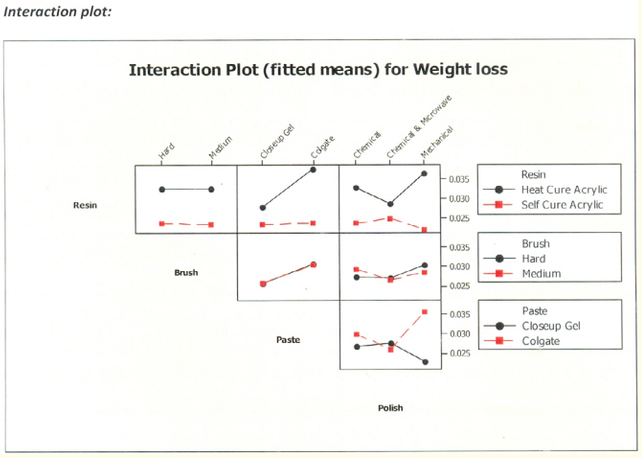

Figure 13: Interaction plot of weight loss.

Heat cure acrylic resin specimens had undergone higher mean weight loss when compared to self-cure acrylic specimens irrespective of the type of tooth brush or tooth paste. Same pattern was followed with all the polishing techniques viz. mechanical, chemical and chemical with micro waving.

Mean weight loss recorded with hard brush as well as medium brush was almost equal. When close up gel and Colgate paste were used, heat cure specimens showed higher weight loss. On chemically polished specimens, medium brush induced slightly higher mean weight loss when compared to hard brush. In chemically polished and microwaved specimens, the weight loss caused by both

the brushes was found to be almost equal whereas in mechanically polished specimens, hard brush induced a higher mean weight loss when compared to medium brush. The mean weight loss recorded with close-up gel was less when compared to Colgate paste on mechanically and chemically polished specimens. This pattern was reversed with chemically polished and microwaved specimens ie. Colgate caused less weight loss than close up gel. The mean weight loss was found to be higher in close-up gel compared to Colgate paste when used with chemical polishing and microwave curing (Figure 13).

Discussion

Denture wearing individuals very often prefer to use tooth brushes and tooth pastes to maintain hygiene of the dentures but by convention dentists discourage that practice for fear of the effect of abrasion and eventually the material loss. There is not much evidence to forbid the practice of tooth pastes because, the much recommended effervescent denture cleansers and baking soda also can cause surface roughness [15,16]. The present study evaluated the roughness causing potential of two types of brushes and two different brands of tooth pastes on heat cure and self cure acrylic resins which were subjected to mechanical polishing, chemical polishing and chemical polishing with subsequent microwaving. Employing the same parameters, the weight loss of the specimens was also evaluated which would indicate the abrasion resistance of the resin. To conduct the brushing experiment, a simulator was fabricated which could make 30000 strokes which is equivalent to 3 years of brushing. The brush applied a pressure of approximately 2N [17-19].

Surface roughness

Self cure specimens exhibited significantly higher roughness (0.1147μm) than the heat cure specimens (0.1023 μm) (Table 2). While comparing the polishing techniques, mechanical polishing, chemical polishing and chemical with microwaving showed roughness in an ascending order (0.0793, 0.0919, 0.1543 μm) (Figure 10,11). Heat cure specimens which were mechanically polished showed superior resistance to surface roughness possibly because of the better physical properties of the heat cure resins which was maintained during the polishing process. Colgate paste caused more roughness (0.1121μm) than Close up gel (0.1048μm). The difference might be possibly due the size variation of the particles contained in the pastes. Both hard and medium brushes caused similar surface roughness. Surface roughness of 0.2 μm is the threshold for bacterial adhesion [20]. It can be observed that both heat cure and self cure acrylic resins included in the study had surface roughness but not to the level of harboring plaque. None of the polishing systems had a negative effect on the resin. There was a significant difference in surface roughness between the mechanically polished specimens and chemically polished ones. Methyl methacrylate molecules contained in the polishing liquid penetrate the polymeric chains and break the bond causing more roughness [20]. However, microwaving did not improve the properties of the resins as expected. Tooth brushes and tooth pastes can be used for cleaning the dentures and it can be recommended safely. This practice will improve the self esteem of the senior citizens because they feel that they are on par with the dentulous individuals in the matter of tooth cleaning (Figure 10,11).

Weight loss

The only significant factor that could be related to weight loss was the type of resin viz. heat cure or self cure. Other factors like tooth brush, tooth paste and the polishing techniques, though had effect in causing weight loss, were not significant. Unlike in the case of surface roughness, self cure specimens (0.0235gm) had lower weight loss than heat cure specimens (0.327gm) (Table 5). Chemically polished and microwaved specimens resisted weight loss better than chemically polished and mechanically polished specimens (Figure 12). On the contrary, chemically polished and microwaved specimens received maximum surface roughness. This can be explained as follows: surface roughness on the microwaved specimens were due to a plastic deformation and not due to material loss. In mechanically polished specimens surface roughness was less but weight loss was high. As in the case of surface roughness, there is no acceptable optimum value of weight loss of acrylic resin [21,22]. Data on weight loss cannot be compared with other studies because of the variation of specimen dimensions (Figure 12,13).

Tooth brushes and tooth pastes did not differ considerably in causing surface roughness and weight loss. Bristle texture-hard or medium-does not particularly challenge the integrity of the acrylic resins. Ability of the bristles to eliminate the debris from denture surface should be the primary; for that purpose, standard tooth brushes and pastes will serve good for a reasonable period of 5-6 years. Many of the authors have divided opinion on this matter [22]. In the present study, a brushing simulator was fabricated which could make 30000 lenier strokes which is equivalent to a period of three years. It may be considered as a limitation of the study. More studies can be done in future utilizing advanced simulators and for longer durations making use of standard tooth brushes and pastes available in the market.

Conclusions

- Heat cure acrylic resin can resist formation of roughness better than self cure resins. The roughness values observed in both the resins were within the clinically acceptable limits.
- Heat cure resin which is mechanically polished can resist surface roughness better than in chemically polished specimens.
- Tooth brushes and pastes included in the study will not cause surface roughness beyond the acceptable limit within a period of three years.

- Heat cure acrylic resin undergoes more weight loss than self cure resin when subjected to brushing with tooth pastes.
- Microwaving did not particularly improve the properties of the resins to resist surface roughness and weight loss.

Author Contributions

Conceptualization-K. Chandrasekharan Nair, Himanbindu Krishnamurti, Jaykar Shetty; *Lab experiments*-Himabindu Krishnamurti, *Review of articles*-Himabindu Krishnamurti, Jaykar Shetty; *Initial draft preparation*-Himabindu Krishnamurti; *Review and editing*-K. Chandrasekharan Nair, Jaykar Shetty; *Supervision* -K. Chandrasekharan Nair.

All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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