An *in vitro* study to evaluate and compare the surface roughness in heat-cured denture-based resin and injection-molded resin system as affected by two commercially available denture cleansers

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Abstract

Background: Denture hygiene is of utmost importance to maintain the dentures as well as the underlying tissues in appropriate health. Various denture cleansers as well as denture-based materials have evolved in the market; however, the effect of denture cleansers on different types of denture-based materials has not been very well documented.

Aim: The purpose of this *in vitro* study was to evaluate and compare the surface roughness in heat-cured denture-based resin and injection-molded resin system as affected by two commercially available denture cleansers for a period of 15, 30, and 45 days.

Methodology: A standardized metal die was fabricated to make 120 denture-based resin discs of uniform dimensions. The samples of heat-cured denture-based resin and injection-molded thermoplastic denture-based resin were immersed in the two denture cleansing solutions for a period of 15, 30, and 45 days, respectively. The surface roughness was evaluated by surface profilometer TR200. The data were subjected to statistical analysis and the comparison of quantitative data was done using unpaired *t*-test and repeated-measures ANOVA test.

Results: The surface roughness values (Ra) of heat cured denture base resin samples when immersed in two denture cleansers were 0.22 μm at 0 days, 0.27 and 0.29 μm at 15 days, 0.29 and 0.31 μm at 30 days, 0.30 and 0.31 μm at 45 days whereas for injection moulded samples surface roughness values were 1.31 & 1.27 μm at 0 days, 1.46 & 1.66 μm at 15 days, 1.50 & 1.69 μm at 30 days, and 1.50 & 1.69 μm at 45 days.

Conclusion : The surface roughness (Ra) increased significantly in injection-molded polyamide denture-based resin samples when immersed in both the denture cleansers. Whereas, heat-cured denture-based resin samples did not reveal any significant surface changes at the various time intervals. Hence, the use of denture cleansers is questionable in thermoplastic resins.

Keywords: Denture cleansers, flexible resin, surface roughness

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INTRODUCTION

Over the last three decades, developments in dentistry have largely been instigated as a result of scientific research. Of particular note, are developments in the field of dental materials and a drive toward the practice of evidence-based dentistry. Many aspects of prosthodontic treatment; be it clinical or laboratory based, have an impact on overall patient satisfaction and the clinical success of treatment.

Most removable prosthodontic appliances and dentures are made of a polymethylmethacrylate (PMMA) type of resin which were introduced in 1931.[1] It has numerous advantages such as superb esthetics, little water sorption and solubility, optimum strength, low toxicity, easy repair, and a simple molding processing technique. Nonetheless, it has some disadvantages such as polymerization shrinkage, weak flexural, lower impact strength, and low fatigue resistance.[2-4] In recent years, nylon polymer has attracted a lot of attention as a denture-based material as it overcomes the above-mentioned disadvantages of PMMA resins. Polyamide resin was proposed as a denture-based material in the 1950s.[5] Nylon is a generic name for certain types of thermoplastic polymers belonging to the class known as polyamides. Nylon is a crystalline polymer, whereas PMMA is amorphous. However, due to the low melting point of polyamides, operators have found it difficult to provide a satisfactory polish.

In human mouth, dentures act as an indwelling medical device, preparing an optimal environment for adhesion and multiplication of both pathogenic and nonpathogenic organisms.[6] The biofilm and food debris deposited on denture surfaces is commonly removed by mechanical methods.[7] Due to patient's lack of motor coordination, such methods may be ineffective, and thus demand alternative means such as chemical cleansing. The rate at which biofilm and deposits build up on dentures may vary between individuals and is most commonly affected by factors such as salivary composition, dietary intake, surface texture and porosity of the denture-based material, duration for which the dentures are worn, and the denture-cleansing regime adopted by the wearer.[8] Several disinfectants have been suggested for the disinfection of dentures. The disinfectants most commonly in use are sodium hypochlorite based or sodium perborate based.[9] The advantages of sodium hypochlorite are that it is not expensive, presents a broad spectrum of activity, and requires a short period of disinfection.[10]

Irregularities, roughness, and porosities present on denture surfaces offer a favorable niche to retain stains and microbial plaque. The surface roughness is of particular clinical relevance since it can affect the biofilm formation or make its removal difficult. Microbial adherence capacity can further get enhanced by the increasing surface roughness of dentures. Although previous literature has focused on the prevention of the development of pathogenic biofilm on the dentures and the effects of denture cleansers on heat-cured denture-based resin, however, not much literature is available on the effect of the same denture cleansers on thermoplastic resins. Especially, as thermoplastic resins are becoming increasingly popular for rehabilitation of partially edentulous arches. Therefore, the present study was undertaken to evaluate and compare the surface roughness in injection-molded thermoplastic resin system as opposed to heat-cured denture-based resin as affected by two commercially available denture cleansers.

METHODOLOGY

Fabrication of metal die

A standardized metal die [Figure 1] was fabricated to make denture-based resin discs of uniform dimensions 2 cm in diameter and 2 mm in thickness. The internal diameter was 2 cm and the height of the stainless steel insert was kept 2 mm less than the height of stainless steel ring.

Fabrication of wax pattern discs and samples

The metal mold was coated with a thin film of petroleum jelly. Molten modeling wax was then poured into the window of the metal mold. The upper member was also coated with petroleum jelly which was then immediately placed on top of the metal mold. The molten wax was then allowed to solidify undisturbed. After complete hardening, the wax sample was removed from mold.

Figure 1: Metal die for fabrication of samples

Preparation of test specimens using conventional heat-cured denture-based resin material

The prepared wax models were invested in the flask following the manufacturer's instructions for water–powder ratio, mixing time, and setting time. One hour after the stone set, flasks were kept for dewaxing by immersing in boiling water for 5 min. A thin film of alginate separating media was applied on all surfaces of the stone except in the mold space. Travelon heat cure (Dentsply, India) was used as the conventional heat-cured denture-based resin. A combination of polymer and monomer, used in the ratio of 3:1 by volume was proportioned before mixing. Mixing was done in a porcelain jar and on achieving the dough consistency, it was packed into mold. After the flasks were clamped, closure was done under force of 20 KN and kept for 30 min. The flasks were then kept at room temperature for 1 h. The flasks were immersed in water in an acrylizer at room temperature, the curing was carried out as per the slow curing cycle, that is, at 700°C for 7 h followed by 100°C for 30 min to ensure complete polymerization. After curing of all the specimens, the flasks were brought down to room temperature and deflasked. A total of 60 test specimens were prepared by means of this procedure [Figure 2].

Preparation of test specimens using injection-molded thermoplastic denture-based resin material

For the fabrication of thermoplastic resin samples, injection molding technique was used which required a specially designed flask. The flask consisted of two accurately approximating parts. The wax models were placed into one-half of the flask with dental stone as investing material. Wax sprues were then attached to provide an inlet for resin mix. Following this, the other half of flask was approximated and filled with dental stone. The wax was boiled out after the stone had set and the flask was cleaned with a mild detergent solution to remove any remnants of wax. Lucitone FRS (Dentsply, India) in cartridge form was used as material for thermoplastic flexible denture-based samples. Lucitone FRS cartridge was placed in the furnace, which was preheated to a temperature of 302°C (575.6°F). The stone molds were also preheated under heat lamps for 17 min to a temperature of about 65°C–70°C. This was done to avoid any premature freezing of the molten nylon as it entered the mold cavity under pressure. The metal injector was placed in position and then the flask was assembled with brackets. Then, together with the cartridge containing melted nylon, they were placed into the injection unit. The injection molding pressure was maintained at a pressure of 5 bars for 1 min and immediately after that, the assembly was removed and disengaged. The dental flask was bench cooled for 5 min before deflasking. Once completion of the process, the specimens were retrieved from the flask, finished, and polished. A total of 60 test specimens were prepared by means of this procedure [Figure 3].

The samples obtained were divided into three groups as follows [Table 1];

- Group 1 (control group) consisted of 40 samples and it was further divided into 1A and 1B consisting of 20 samples each made of conventional heat-cured acrylic resin and flexible denture-based resin that were immersed in artificial saliva
- Group 2 consisted of 40 samples and it was further divided into two subgroups, 2A and 2B consisting of 20 samples each that were made up of heat-cured denture-based material and were immersed in the two denture cleansers, that is, Fittydent and Clinsodent, respectively. Group 2A and 2B were further subdivided into Group 2Ai, 2Aii, 2Aiii, and Group 2Bi, 2Bii, 2Biii according to the time period of immersion, that is, 15, 30, and 45 days, respectively
- Group 3 consisted of 40 samples made of thermoplastic resin and it was subsequently divided into two subgroups, 3A and 3B consisting of 20 samples each, and immersed in the two denture cleansers, that is, Fittydent and Clinsodent, respectively. Group 3A and 3B were further

Figure 2: Heat-cured denture-based resin samples

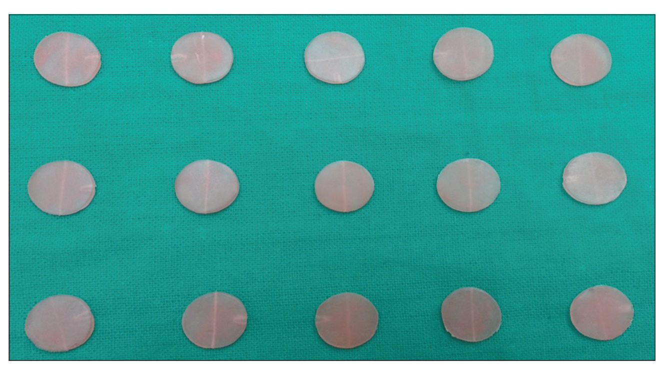

Figure 3: Flexible denture-based resin samples

subdivided into Group 3Ai, 3Aii, 3Aiii and Group 3Bi, 3Bii, 3Biii according to the time period of immersion, that is, 15, 30, and 45 days, respectively.

Sample evaluation

Each sample discs of conventional heat-cured and injection-molded flexible denture-based material had a small depression drilled on one side using a round bur [Figure 4]. The depression was used to indicate the side from which the measurements were to be taken. Each sample disc was kept in Petri dish and numbering on Petri dish was done for sample identification [Figure 5].

Initial surface roughness measurements of the sample discs of conventional heat-cured and injection-molded thermoplastic denture-based material were made using profilometer after being placed in the artificial salivary sample (containing sodium carboxymethyl cellulose 0.5% and glycerin in a pleasantly flavored base with a pH of 6.8) for 8 h and then in distilled water for 24 h. 40 specimens of conventional heat-cured resin and 40 specimens of injection-molded flexible denture-based material were immersed at the same time in the separate Petri dish for 8 h everyday for 15 days with the surface to be measured facing upward [Figure 6]. The cleansers were prepared according to the manufacturer's directions, by adding one tablet to 200 ml of warm tap water (40°). At the end of 15 days, the samples were washed and stored in distilled water for 24 h and were evaluated for surface roughness using a profilometer. The samples were again immersed in the two denture cleansers for 30 days for 8 h daily and the surface roughness was evaluated after washing and storing in distilled water for 24 h. Finally, the samples were immersed in the two denture cleansers for 45 days for 8 h daily and at the end of 45 days, the samples were washed and placed in distilled water and surface roughness was evaluated again. The changes in the surface roughness of the heat-cured sample and flexible denture samples before and after placement in the denture cleansers for 15, 30, and 45 days was assessed and compared.

A profilometer (TR200 Times Group India G) was used for evaluation of surface roughness (Ra, μm) of the specimens before and after immersion procedures. A diamond stylus (tip radius, 5 μm) was moved across the surface under a constant load of 0.75 μN with a range of 350 μm and speed of 0.5 mm/s to measure the roughness profile value in micrometers. The instrument was calibrated using a standard precision reference specimen. For each specimen, three traces were recorded at three different locations in different positions (parallel, perpendicular, and oblique) giving nine tracings per specimen. The average of nine mean surface roughness measurements was accepted as the score for each specimen. Initial roughness values were subtracted from the roughness values after immersion to obtain the Ra values, which were then entered into a spreadsheet for calculating descriptive

Figure 4: Small depression drilled on one side in sample disc

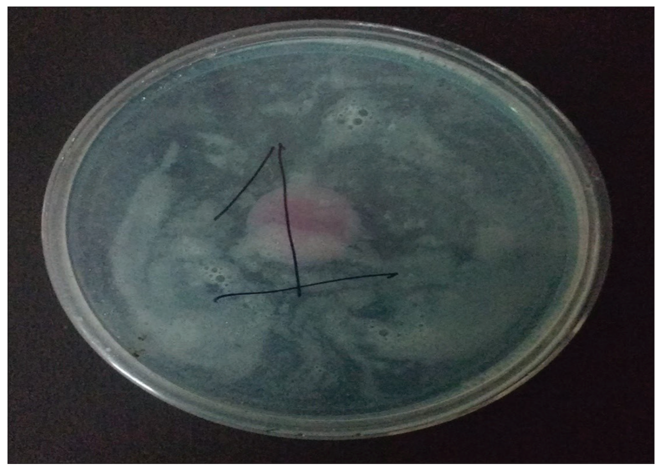

Figure 5: Numbering on Petri dish

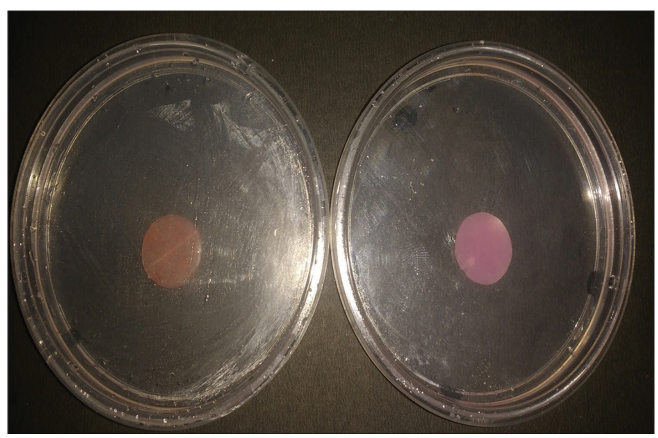

Figure 6: Sample disc immersed in denture cleanser solution

statistics. For surface characterization, one representative specimen from each group with Ra values close to the mean values were selected.

Statistical analysis

Data obtained by evaluating the surface roughness of injection-molded denture-based material and conventional heat-cured denture-based material before and after their immersion in the two denture cleansers data were represented as mean ± standard deviation. SPSS 16 software package (IBM company, New York, US) and Epi Info version 3.0 (CDC, Atlanta, Georgia, USA) were used for the present study. The comparison of quantitative data was done using unpaired *t*-test and repeated measures ANOVA test wherever applicable.

RESULTS

Table 2 depicts that among heat-cured denture-based resin samples immersed in Fittydent denture cleanser, the mean surface roughness was compared at 0, 15, 30, and 45 days using the repeated-measures ANOVA test. There was no significant change in mean surface roughness at different time intervals.

Table 3 depicts that among heat-cured denture-based resin samples immersed in Clinsodent, there was no significant change in mean surface roughness at different time intervals.

Table 4 depicts that among injection-molded polyamide denture-based resin samples immersed in Fittydent, the mean surface roughness was compared at 0, 15, 30, and 45 days using the repeated-measures ANOVA test. There was a significant change in mean surface roughness from 0 to 15 days as compared to 30 and 45 days.

Table 5 depicts that among injection-molded thermoplastic denture-based resin samples immersed in Clinsodent, the mean surface roughness was compared at 0, 15, 30, and 45 days using the repeated-measures ANOVA test. There was a significant change in mean surface roughness from 0 to 15 days as compared to 30 and 45 days.

Table 6 depicts that the mean surface roughness when compared between heat-cured denture-based resin samples and injection-molded thermoplastic denture-based resin samples after immersion in Fittydent at 0, 15, 30, and 45 days using the unpaired *t*-test. The mean surface roughness was significantly more among injection-molded flexible denture-based resin samples at 0, 15, 30, and 45 days.

Table 1: Grouping of samples

Groups	Number of samples	Group details
Group 1 (control)	40	Samples immersed in artificial saliva
Group 1A and 1B	20	20 samples made of conventional heat-cured acrylic resin and 20 flexible denture-based resin samples immersed in artificial saliva
Group 2	40	Heat-cured denture-based resin immersed in denture cleanser
Group 2Ai, 2Aii, 2Aiii	20	Immersion of heat-cured denture-based resin in Fittydent for 8 h for a period of 15, 30, and 45 days, respectively
Group 2Bi, 2Bii, 2Biii	20	Immersion of heat-cured denture-based resin in Clinsodent for a period of 15, 30, and 45 days, respectively
Group 3	40	Injection-molded polyamide denture-based resin sample immersed in artificial saliva
Group 3Ai, 3Aii, 3Aiii	20	Immersion of injection-molded flexible denture-based resin in Fittydent for 8 h for a period of 15, 30, and 45 days, respectively
Group 3Bi, 3Bii, 3Biii	20	Immersion of injection-molded flexible denture-based resin in Fittydent for 8 h for a period of 15, 30, and 45 days, respectively

Table 2: Evaluation of the surface roughness (μm) in heat-cured denture-based resin samples when immersed in Fittydent for a period of 15, 30, and 45 days for 8 h

	Heat-cured denture-based resin, Fittydent (μm)		
	Mean±SD	*F*	*P*
Group 2 (0 day)	0.22±0.03	1325.022	>0.001#
Group 2Ai (15 days)	0.27±0.03		
Group 2Aii (30 days)	0.29±0.03		
Group 2Aiii (45 days)	0.30±0.03		

Repeated-measures ANOVA test. #No significant difference. SD: Standard deviation

Table 3: Evaluation of the surface roughness (μm) in heat-cured denture-based resin samples when immersed in Clinsodent for a period of 15, 30, and 45 days for 8 h

	Heat-cured denture-based resin, Clinsodent (μm)		
	Mean±SD	*F*	*P*
Group 2B (0 day)	0.21±0.02	1354.32	>0.001#
Group 2Bi (15 days)	0.29±0.02		
Group 2Bii (30 days)	0.31±0.03		
Group 2Biii (45 days)	0.31±0.03		

Repeated-measures ANOVA test. #No significant difference. SD: Standard deviation

Table 7 depicts the comparison of mean surface roughness between heat-cured denture-based resin samples and injection-molded thermoplastic denture-based resin samples in Clinsodent at 0, 15, 30, and 45 days using the unpaired *t*-test. The mean surface roughness was significantly more among injection-molded thermoplastic denture-based resin samples at 0, 15, 30, and 45 days.

DISCUSSION

The longevity of any dental prosthesis is mainly dependent on the maintenance/cleanliness of the prosthesis, which in turn relies on the proper home care procedures carried out by the patient. Inadequate cleaning of the denture leads to accumulation of food debris, which in turn harbors bacteria and salivary mucin resulting in malodor. On long term, it may lead to degradation of mechanical properties of the denture material and affect the oral mucosal health of the patient.[11-14] The most routinely followed method for cleaning the dentures is overnight soaking in any commercially available denture cleansing solutions. Most proprietary immersion cleansers can be divided into alkaline peroxides (percarbonate or perborate) and alkaline hypochlorites besides they may also contain dilute organic or inorganic acids and enzymes.[13,14]

Denture cleaning by immersion in chemical solution should ideally not involve any physical, mechanical, or chemical change in the acrylic resin. However, it has been observed that the decontamination process may result in alterations of the surface morphology. The effervescent tablets are efficient in removing biofilm and stains, but the alkaline peroxide solution may alter the resin properties. In addition, the rough surface of the dentures may protect the bacteria from natural removal forces and even those of oral hygiene methods.[15]

In 2012, Kumar *et al.*[16] reported that the commercial denture cleansers (Fittydent and Clinsodent) were more effective than household denture cleansers (vinegar and diluted vinegar) in removing *Candida albicans* from the acrylic specimen after immersion for 8 h.

The surface irregularities on denture-based materials may act as a reservoir of infection and increase the possibility of hosting microorganisms even after the cleaning of dentures. Increase in surface roughness due to denture cleanser would further aggravate the collection of bacterial and fungal cells on the denture-based resins. Ideally, a surface with the lowest possible roughness is required to

Table 4: Evaluation of the surface roughness (μm) in injection-molded thermoplastic denture-based resin samples when immersed in Fittydent for a period of 15, 30, and 45 days for 8 h

	Flexible denture-based resin, Fittydent (μm)		
	Mean±SD	*F*	*P*
Group 3A (0 day) control	1.31±0.06	67123.273	<0.001*
Group 3Ai (15 days)	1.46±0.07		
Group 3Aii (30 days)	1.50±0.01		
Group 3Aiii (45 days)	1.50±0.01		

Repeated-measures ANOVA test. *Significant difference. SD: Standard deviation

Table 5: Evaluation of the surface roughness (μm) in injection-molded thermoplastic denture-based resin samples when immersed in Clinsodent for a period of 15, 30, and 45 days for 8 h

	Flexible denture-based resin, Clinsodent (μm)		
	Mean±SD	*F*	*P*
Group 3B control (0 day)	1.27±0.05	95283.604	<0.001*
Group 3Bi (15 days)	1.66±0.03		
Group 3Bii (30 days)	1.69±0.02		
Group 3Biii (45 days)	1.69±0.02		

Repeated-measures ANOVA test. *Significant difference. SD: Standard deviation

Table 6: Comparison of mean surface roughness (μm) in heat-cured denture-based resin samples and injection-molded flexible denture-based resin samples as effected by immersion in Fittydent at different time intervals

Fittydent	Mean±SD		Mean difference	t-test value	*P*
	Heat-cured denture-based resin (μm)	Flexible denture-based resin (μm)			
Group 2A and Group 3A	0.22±0.03	1.31±0.06	−1.09	−75.758	<0.001*
Group 2Ai and Group 3Ai	0.27±0.03	1.46±0.07	−1.18	−68.518	<0.001*
30 days	0.29±0.03	1.50±0.01	−1.20	−148.042	<0.001*
45 days	0.30±0.03	1.50±0.01	−1.21	−148.485	<0.001*

Unpaired *t*-test. *Significant difference. SD: Standard deviation

Table 7: Comparison of mean surface roughness (μm) in heat-cured denture-based resin samples and injection-molded flexible denture-based resin samples as effected by immersion in Clinsodent at different time intervals

Clinsodent	Mean±SD		Mean difference	t-test value	*P*
	Heat-cured denture-based resin (μm)	Flexible denture-based resin (μm)			
Group 2B and 3B	0.21±0.02	1.27±0.05	−1.05	−87.783	<0.001*
Group 2Bi and 3Bi	0.29±0.02	1.66±0.03	−1.37	−172.416	<0.001*
Group 2Bii and 3Bii	0.31±0.03	1.69±0.02	−1.38	−173.793	<0.001*
Group 2Biii and 3Biii	0.31±0.03	1.69±0.02	−1.38	−175.294	<0.001*

Unpaired *t*-test. *Significant difference. SD: Standard deviation hamper microorganism retention, ward off local infections and untimely denture deterioration. Bollen *et al*.[17] 1997 reported that the threshold Ra for plaque retention of intraoral materials is 0.2 μm. Below this value, minimal plaque accumulation may be expected. Above this value, a proportional increase in plaque accumulation may occur.

The surface roughness of heat-cured denture-based resin samples when immersed in Fittydent for a period of 0, 15, 30, and 45 days for 8 h was 0.22 μm, 0.27 μm, 0.29 μm, and 0.30 μm, respectively. Fittydent containing sodium hypochlorite did not significantly increase the surface roughness of heat-cured denture-based resin at the various time intervals. These results are in harmony with the studies done by Paranhos Hde *et al*.[18] in 2013. They found no increase in surface roughness of heat-cured denture-based resin with sodium hypochlorite. Their study employed 1½ year of simulated periods of use. However, the results of this study were in contradiction to a study conducted by Garcia *et al*.[19] in 2003. She reported the roughness of acrylic resin was significantly changed by the hypochlorite solution. Their study employed similar immersion periods of 1, 15, and 30 days. Many other studies have shown that sodium hypochlorite did not cause changes on surface roughness of heat-cured denture-based resin.[20,21]

The surface roughness of heat-cured denture-based resin samples when immersed in Clinsodent for a period of 0, 15, 30, and 45 days for 8 h was 0.22 μm, 0.29 μm, 0.31 μm, and 0.31 μm, respectively. Clinsodent containing alkaline peroxides did not significantly increase surface roughness of heat-cured denture-based resin at different time intervals. These results are again contradictory with the studies done by Peracini *et al*. in 2010.[22] and Garcia *et al*. in 2004.[23] They reported that alkaline peroxides increase the surface roughness of heat-cured denture-based resin during stimulated period.

The surface roughness of injection-molded polyamide denture-based resin samples when immersed in Fittydent for a period of 0, 15, 30, and 45 days was 1.31 μm, 1.46 μm, 1.50 μm, and 1.50 μm, respectively. There was significant change in mean surface roughness from 0 to 15 days, that is, 0.15 μm as compared to 30 days and 45 days. The reason for increase in roughness of injection-molded denture-based resin samples could be due to the bleaching action of sodium hypochlorite. These results were in harmony with the studies done by de Freitas Fernandes *et al*.[24] in 2011 who reported that the surface roughness of polyamide resin was increased due to bleaching action of sodium hypochlorite.

Similarly, the surface roughness of injection-molded polyamide denture-based resin samples when immersed in Clinsodent for a period of 0, 15, 30, and 45 days for 8 h was 1.27 μm, 1.66 μm, 1.69 μm, and 1.69 μm, respectively. There was a significant increase in surface roughness observed in thermoplastic resin when treated with Clinsodent. Therefore, all the samples indicated the possibility for dramatic increase in bacterial adhesion and colonization as well. The probable reason for increase in roughness of injection-molded polyamide denture-based material could be attributed to the higher peroxide content and level of oxygenation that can cause hydrolysis and decomposition, which can be damaging to the denture-based materials.[25] These results are in harmony with the studies done by Polychronakis *et al*.[26] in 2010. They reported that the surface roughness of polyamide resin was increased due to action of sodium perborate during stimulated periods of 30 days. Durkan *et al*.[27] in 2013 also reported that the surface roughness of polyamide resin was increased due to action of sodium perborate during stimulated periods of 20 days.

Among heat-cured denture-based resin samples and injection-molded thermoplastic denture-based resin samples immersed in Fittydent and Clinsodent, the surface roughness (Ra) increased significantly in the latter, that is, 1.09 μm and 1.06 μm at 0 day, 1.19 μm and 1.38 μm at 15 days, 1.21 μm and 1.38 μm at 30 days, and 1.20 μm and1.38 μm at 45 days. The probable reason may be that the thermoplastics are difficult to finish and polish due to their low melting temperature consequently they produced rough surface. Moreover, the rate of cooling of processed polyamide affects the surface properties and it has been mentioned that very slow cooling produces a strong and relatively stiff material but also produced rough surface which may be another reason for the rough surface of polyamides.

CONCLUSION

Among heat-cured denture-based resin samples and injection-molded thermoplastic denture-based resin samples immersed in Fittydent or Clinsodent, the surface roughness (Ra) increased significantly in injection-molded thermoplastic denture-based resin samples as compared to heat-cured denture-based resins. Therefore, within the limitations of this study, it may be concluded that use of denture cleansers should not be recommended for thermoplastic resins; however, further studies focusing on the *in vivo* and clinical applications of the same are desired.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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