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Original Research Article

Comparative evaluation of effectiveness of chemical, mechanical and chemico-mechanical methods of denture cleaning for removal of stains from heat polymerised acrylic resin denture base - An in- vitro study

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ABSTRACT

Introduction: An essential quality of acrylic resin denture bases is colour stability. Over time, acrylic resin bases have a tendency to attract stains, which causes the denture base's colour to alter. These modifications sometimes make the denture less aesthetically pleasing for the wearer, which leads to patient unhappiness and higher replacement costs.

The study's objective was to evaluate and compare the effectiveness of cleaning dentures using chemical, mechanical, and chemico-mechanical methods for removing stains from the heat polymerized acrylic resin denture base.

Materials and Methods: A total of 120 samples of heat polymerised acrylic resin were fabricated and stained using sambhar solution for 10 days under controlled conditions. The baseline optical density of the samples was determined. The samples were then subjected to stain removal procedure by either - chemical, mechanical or chemico-mechanical method. After which the optical density was again determined. The efficiency of the three methods used was determined by the difference in the optical density after staining and post cleaning and compared with the baseline optical density measured previously. The data was analysed using One-way ANOVA test. Post hoc comparison was made by Bonferroni t-test. $p<0.0.5$ was considered as statistically significant. Data analysis was done using the statistical software STATA version 13.0.

Results: The results suggested that the chemico-mechanical method was the best method for stain removal from the acrylic samples. However, the mechanical method of denture cleaning was found to be equally effective. The chemical method was least effective in removing stains from the surface of heat polymerised acrylic resin.

Conclusion : The chemico-mechanical method was 95.16% effective and the mechanical method used was 92.12% effective, proving that the chemico-mechanical was the most effective method for removing stains from the acrylic resin amongst the 3 techniques compared.

1. Introduction

An acceptable aesthetic effect in any dental restoration has been regarded as a contributory factor towards better prognosis of the treatment. A well-made prosthesis whether provisional or definitive will fail if it is deficient in this respect. The ability of a substance to retain its colour over time and in a particular setting makes colour the most significant aspect of aesthetics. Colour stability is a necessary property of denture base polymers that is mandated by numerous national and international standards, typically American Dental

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Association specification number 12, and may offer crucial information on the serviceability of prosthetic materials.[1]

In complete or partial removable denture prosthesis the denture teeth being aesthetically more important are noticed significantly, however, the denture base is equally important for aesthetics in all patients.[2] Colour stability of denture bases is an important factor in treatment acceptance by the patient. Any colour change of prosthetic materials may result in patient dissatisfaction and additional expense for replacement.[3]

The Indian diet is known to include a number of chromatogenic agents such as tea, coffee, turmeric powder, red chilli powder, spices etc. With high intake of such chromatogens, the colour stability of the heat cured acrylic resin denture bases becomes questionable.

Stains adhere to the biologic accretions which are similar to plaque and are also responsible for denture odour and generally poor aesthetic quality of the "dirty" denture.[4] There are a few methods for denture cleaning that are being practised currently, which include mechanically cleaning the dentures by brushing, or using ultrasonic cleaning units. Chemical cleansers which include alkaline peroxides, alkaline hypochlorite, acids, disinfectant and enzymes.[5] An ideal denture cleanser should fulfil multiple requirements, including the ability to remove both organic and inorganic deposits along with any associated stain. Soft debris that cling to dentures can be removed easily by light brushing followed by rinsing. Hard deposits such as stains are more difficult to remove.

There are several different kinds of denture cleaners on the market nowadays, and each of them makes a variety of promises about how effective it is at removing stains.

The present study was an effort towards determining the better method for removing stains from heat cured acrylic resin denture bases by comparing three techniques of denture cleaning - Chemical cleaning method by soaking the dentures in Clinsodent® denture cleaning powder, mechanically using the Ultrasonic cleaner and thirdly a combination of the two.

2. Materials and Methods

A total of 120 samples, each of the dimension 15mm x 30mm and thickness 3mm±0.1mm were fabricated using conventional heat polymerizing denture base material (DPI®) following manufacturers' recommendation.[6] The acrylic samples were fabricated using gypsum moulds that were made using metal dyes of the same dimensions.

The cured specimens were carefully removed, finished and polished. Only one surface of the samples was finished and polished.[6] Specimens with defects were discarded. The finished and polished samples were stored in distilled water for 24 hours at 37^{o}C to remove any residual monomer present.[3,7]

The samples were stained using sambhar solution which was considered as a representative of a staple Indian meal liquid or curry with a conglomerate of spices found commonly in diet. The solution was prepared by adding two tablespoons of the sambhar powder (Everest® sambhar masala) to 400ml of boiling distilled water and then allowed to simmer for 5 minutes. The solution was then sieved through a muslin cloth and was then allowed to cool. The final staining solution was prepared by diluting the sambhar solution with artificial saliva in the ratio of 1:2 i.e., 500 ml of sambhar in 1000 ml of artificial saliva so as to mimic the oral conditions.

The absorption maximum (lmax) - i.e. the wavelength of light absorbed maximum by the staining media was determined using spectrophotometer. This was used for calculating the optical density of the stained samples and later even the treated samples.

In order to replicate in vivo circumstances, the heat-cured acrylic samples were suspended in the staining solution for 10 days at 37°C 1°C in an incubator.[2,8] Fresh staining solution was made every day, and the samples were placed in the freshly made solution.[9] After 10 days, the samples were removed from the staining media and rinsed with distilled water to remove any debris. At this point the stained samples were subjected to spectrophotometric analysis for optical density measurement using the **l** max.

The stained samples were randomly divided into 3 groups – Group A, Group B and Group C, and the mean optical density of each group was determined for future comparison.

The samples were divided into 3 groups, each of 40 samples (n=40) and were subjected to the stain removing process as follows:

In Group A**,** the samples were subjected to the chemical method of stain removal by soaking the samples in a cleansing solution made by dissolving one tablespoon of Clinsodent® denture cleaning powder in 250ml of distilled water (according to manufacturer instructions).[10,11] The samples were soaked in it for 20 minutes.[9]

In Group B, the samples (n=40) were subjected to a mechanical method of stain removal by treating them in an ultrasonic unit. The specimens were immersed in the ultrasonic unit containing 250ml of distilled water at 40^{0}C ± 2^{0}C (manufacturer's instructions) to achieve optimal cavitation and they were treated for 15 minutes.[11]

In the last group, Group C, the samples (n=40) were subjected to chemico-mechanical process of stain removal by treating them in an ultrasonic unit with 250ml of distilled water at 40^{0}C ± 2^{0}C and one tablespoon of Clinsodent® denture cleaning powder, and were treated for 15 minutes.[11]

In each group, 10 samples were treated at a time. And after the treatment they were air dried and subjected to spectrophotometric analysis to determine the optical density using the **l** max. The optical density was measured using a

double beam UV/Visible spectrophotometer. The samples were kept in the cuvete of the spectrophotometer with the polished surface facing the incident light.

A light of wavelength at the absorption maximum (**l** max) of the staining solution as previously calculated was incident upon the samples and the percentage transmittance (%T) was calculated. %T calculates the amount of light of a particular wavelength that was transmitted through the sample. Using the percentage transmittance, the optical density of each sample was calculated using the formula:

$$O.D = \frac{\log(\%\,transmittance)}{100}$$

The optical density of each sample was calculated after staining and after being treated by either of the three denture cleaning techniques, the difference in the optical density of the samples was used for evaluating and comparing the effectiveness of the three techniques used. By using the **l** max the authors could find and determine quantitatively the amount of stains that were removed from samples by comparing them to their baseline optical densities.

3. Results

The stain removing capacity of the three methods was determined by comparing the optical density of the stained and the treated samples. The absorption maximum for the staining solution (sambhar solution) was found to be 634 nm. The optical density of the samples was calculated by measuring the percentage transmittance (%T) through the samples using the formula previously mentioned.

For each group, the mean baseline optical density of the stained acrylic samples (before treatment) was estimated, and it was discovered that there was no statistically significant difference between the three groups. The mean optical density of stained samples in Group A was 0.2854 ± 0.0249, Group B was 0.2928±0.0256 and Group C was 0.2844±0.0216. (Table 2)

It was observed that after treating by the 3 techniques of denture cleaning the mean optical density of the acrylic resin samples was least in Group C (0.0124±0.0030), followed by Group B (0.023±0.0065) and was highest in the Group A (0.0364±0.009). (Tables 3, 4 and 5 and Figure 1)

The mean change in optical density i.e. the stain removing capacity was found to be highest for acrylic samples treated in Group C (95.61%) followed by Group B (92.12%) and least for Group A (87.22%). (Table 6 and Figure 2)

1. The optical density of the treated samples in Group C was found to be highly significant ($p<0.001$) as compared to samples in Group A. (Table 7)
2. The optical density of treated samples in Group B was highly significant ($p<0.003$) as compared to treated samples of Group A. (Tables 6 and 7)
3. The optical density of treated samples in Group C was not significant as compared to the treated samples Group B. (Table 7)

Optical density in each group was presented as Mean± SD. Baseline line values of optical density were compared between three groups by performing One-way ANOVA. Optical density was compared after staining and after treatment in each group by performing paired t-test for normalized data. Changes in optical density were compared between three groups by using One-way ANOVA test. Post hoc comparison was made by Bonferroni t-test. $p<0.05$ was considered as statistically significant. Statistical software STATA version 13.0 was used for data analysis.

3.1. Table : Materials used in the study

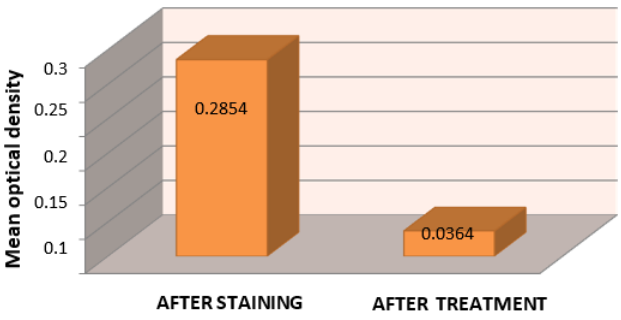

Figure 1: Mean optical density in Group A- Before and after treatment.

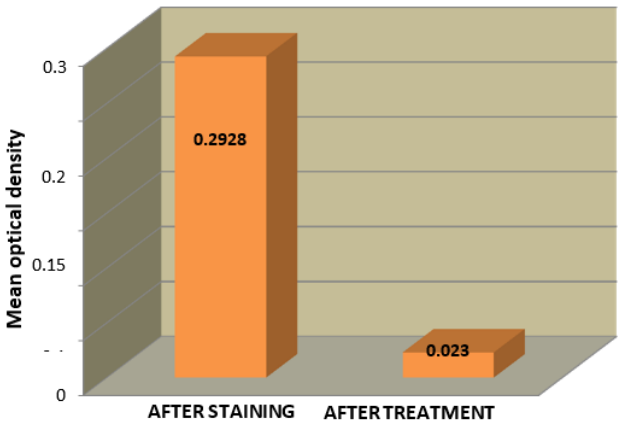

Figure 2: Mean optical density in Group B- Before and after treatment.

4. Discussion

The importance of aesthetics is crucial in contemporary prosthodontics. Today's prostheses and restorations are expertly crafted to precisely fit the adjacent oral anatomy. As one of the most desirable characteristics of an aesthetic

Table 1: Materials used in the study

a. Materials for fabrication of the heat cure acrylic samples: (Plate I)			
Product	**Material type**	**Manufacturer**	**Batch No.**
DPI Heat Cure ™	Heat polymerized acrylic resin	Dental products of India Ltd.	3148
b. Materials used for preparation of staining solutions: (Plate I)			
Product	**Material type**	**Manufacturer**	**Batch number**
Everest	Sambhar masala	E.S. Narendrakumar & Co, Mumbai.	(E) SM 1404
Artificial Saliva	Artificial saliva	MP Sai Enterprise, Mumbai.	-
Material used for removing stains: (Plate I)			
Product	**Material type**	**Manufacturer**	**Batch number**
Clinsodent ®	Alkaline Peroxide Denture cleansing powder.	ICPA Health Products Ltd. Ankleshwar.	P40017
Miscellaneous materials:			
Product	**Material type**	**Manufacturer**	**Batch number**
Pyrax Cold Mould Seal (PlateII)	Separating medium	Pyrax Polymers Roorkee	-
Vaseline	Petroleum jelly	HUL, Mumbai.	B.302,09/09
Kalrock die stone (Plate I)	Die stone	Neelkanth healthcare (P) LTD, Jodhpur	359
Pumice Powder(Plate III)	Pumice	Vishal Dentocare Ahmedabad	-

Table 2: Baseline values of optical density in 3 groups.

	Group-A	**Group-B**	**Group-C**
Mean	0.2854	0.2928	0.2844
SD	0.0249	0.0256	0.0216
Range	(0.2415- 0.3405)	(0.2354-0.3274)	(0.2434-0.3284)
F-statistics		1.42	
p-value		0.2447, Not significant	

Table 3: Mean optical density of group-A: Before and after treatment.

	After staining		**After treatment**
Mean	0.2854		0.0364
SD	0.0249		0.009
% change		87.22%	
t-value		54.1133	
p-value		<0.0001,Highly Significant	

Table 4: Mean optical density of group-B: Before and after treatment.

	After staining		**After treatment**
Mean	0.2928		0.023
SD	0.0256		0.0065
% change		92.12%	
t-value		57.2389	
p-value		<0.0001, Highly Significant	

Table 5: Mean optical density of group-C: Before and after treatment.

	After staining		**After treatment**
Mean	0.2844		0.0124
SD	0.021		0.0030
% change		95.61%	
t-value		77.6783	
p-value		<0.0001 , Highly significant	

Table 6: Mean change and Percentage change in optical density after treatment in 3 groups

	Group-A	Group-B	Group-C
Mean change	0.2489	0.2697	0.2720
SD	0.029	0.0298	0.0221
% change	87.22%	92.12%	95.61%

Table 7: Multiple Comparison of mean change in optical density between 3 groups

	F-statistics	p-value	Multiple comparison(Bonferroni test)		
			A vs. B	A vs C	B vs C
Oneway ANOVA test	8.69	0.0003 (Highly Significant)	0.020(0.003)* Highly Significant	0.023(0.001) Highly Significant	0.0022(1.00) Not Significant

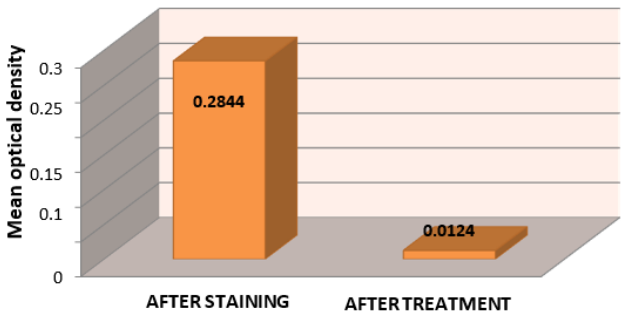

Figure 3: Mean optical density in Group C- Before and after treatment.

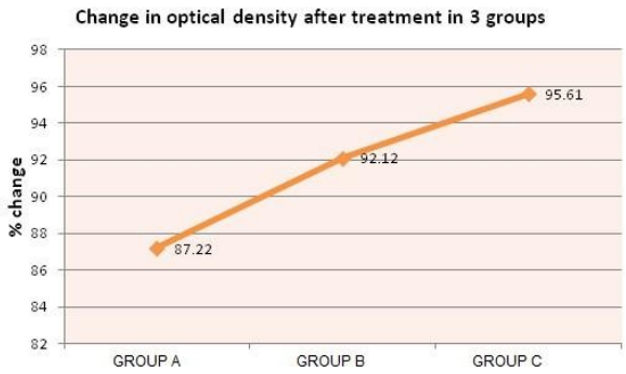

Figure 4: Percentage change in optical density after treatment in the 3 groups.

restorative material is colour, how well the material is maintained during its full-service life will also influence its success or failure. One of the major concern of the denture wearers is the stains which accumulate on their dentures during the service period, which in turn may lead to poor aesthetic appearing prosthesis and even denture stomatitis.[9,12] This study was undertaken to address this concern, by employing a standardised scientific approach in analysing the stain removing ability of three different methods of denture cleaning.

In the present study Polymethyl methacrylate (PMMA) which is the most commonly used material for denture fabrication was chosen to fabricate the samples which represented the denture surfaces. Singh et al.[2] and Gupta et al.[13] suggested that strong chromatogenic spices like turmeric powder, red chilli powder are amongst the main causative agents for the staining of the denture base resins. An average daily Indian diet invariably consists of these spices. The sambhar solution which contains these spices along with other additional spices was considered as the representative liquid of Indian food (e.g. Curries, vegetables etc). The stains on the acrylic resin samples in the study relate to the stains seen commonly with the clinical use of the dentures by the patients.

The stains causing the discoloration of the denture surfaces can be evaluated visually and by instrumental techniques (spectrophotometer and colorimeter). However, Okubo et al.[14] in their study, suggested that colour evaluation by visual comparison is an unreliable method as it can result in inconsistencies in colour perception specifications among observers. Hence in our study the degree of stain produced was determined using spectrophotometer which has some advantages; in particular, a quantitative measurement of staining could be obtained. This method is far more accurate than the subjective assessment of colour and shade.[14,15] Gupta et al.[13] have proven that Spectrophotometers are more accurate in measuring the colour change than colorimeters as they contain monochromators and photodiodes that measure the reflectance curve of a product's colour every 10 nm or less.

The samples were stained for 10 days in an incubator to mimic the in-vivo conditions. In the previous studies carried out to determine the color stability of acrylic resin samples, Chan et al.[16] found that the greatest degree of staining with all samples occurred during the first week of the study time. After 10 days of immersion staining differs significantly with succeeding time interval.[2]

Budtz-Jorgensen[5] classified the denture cleaning techniques as - chemical methods and mechanical methods of denture cleansing. Different chemical agents that

can be used for denture cleaning include- hypochlorite, peroxides, enzymes, acids, mouth washes etc. In this study Clinsodent® denture cleaning powder – a peroxide type of denture cleanser containing sodium perborate and sodium carbonate was used since hypochlorites have been found to have a bleaching action on the acrylic resins and rest have not been found to be as effective. The peroxide cleansers act by releasing oxygen bubbles which helps in detaching the biofilm from the denture surface. The oxidant agents help to remove stains and have some antibacterial action as well. [5]

The mechanical methods comprise of brushing, sonic vibrators and ultrasonic.Dyer et al. [17] found that brushing tends to wear off and even cause superficial damage to the denture surface. Jagger et al. [18] found in their survey that although brushing is the most widely used methods of denture hygiene, with increasing age of the patients the motor co-ordination is limited and patients find it difficult to perform the daily hygiene routine effectively. In order to overcome this difficulty for the geriatric denture patients, the authors compared the ultrasonic cleanser's stain removing capacity. In the Ultrasonic devices the cleaning action occurs by vibration of the liquid and the second, by cavitation. This action prevented any physical damage caused to the denture surface as compared to the convention cleaning method of brushing.

In accordance with the limitations of the study by de Andrade [19] and Cruz et al. [20] which suggested the use of different chemicals such as surfactants or antimicrobial agents within the ultrasound device, the third method of denture cleaning was a combination of chemical and mechanical techniques which incorporated the denture cleaning powder into the ultrasonic unit.

After the treatment of the samples, it was found that the stain removing capacity was the most effective in group C (the chemico-mechanical method, Table 5). The least stain removal capacity was seen in the (chemical) group A (Table 3), and the stain removing capacity of group B (Table 4) was better than Group A, but not Group C. However, the difference between group B and C was found to be statistically insignificant (Table 7).

The maximum stain removal in Group C was attributed to the combined effect of the vibration of conducting fluid and ultrasonic cavitation and alkaline peroxide which by releasing nascent oxygen aided in detaching the biofilm from the denture surface and hence helped in removal of stains. The combined action of the two methods proved it to be the most effective method of denture cleaning amongst the three techniques.

When the entire spectrum of this study is analysed, it becomes evident that the stains accumulated on the denture surface due to the use of various chromatogens can be effectively removed by the use of any of the three methods of denture cleaning. The chemical method (soaking of dentures) can be very easily used by the patients as the routine 'at home' denture hygiene maintenance method. While the mechanical and chemico-mechanical method of denture cleaning which mainly depends on the availability of the ultrasonic unit can be used by the patients at home and even in dental offices or institutes during the recall appointments as it requires very less time and are economical too.

The amount of stain reduction following the use of a chemical agent along with a mechanical aid of ultrasonic unit or using the ultrasonic unit alone offers the patients a more rapid and a highly effective method of denture hygiene maintenance without any damage to the dentures within a short span of time, thus increasing the serviceability of the prosthesis and ensuring a successful prognosis of the treatment. Consequently, such a faster and economical method of denture hygiene will help in spreading awareness among the Indian patient population about denture hygiene and shall lead to better compliance towards regular follow up and denture hygiene maintenance amongst them.

5. Limitations of the Study

1. The staining media used in the study does not contain all the substances to which the denture base may be exposed in the oral cavity.
2. Although all the samples were visually checked for porosities before testing, micro porosities present in the samples could have had an effect on the absorption of stains by the samples.

6. Conclusion

Three techniques were evaluated for their stain removal capacity from denture base resins, Within the limitations of this study following conclusions were drawn:

1. All techniques used in the study were capable of reducing the amount of stain from the heat cure acrylic resin denture base samples. Using ultrasonic cleaner with Clinsodent® in the conducting fluid was found to be most effective method.
2. The use of ultrasonic cleaning alone was also effective in removing the stains from the samples. But the chemical method of soaking dentures in Clinsodent® removed the least amount of stains and therefore is the least effective method for cleaning dentures.
3. The study proves that the ultrasonic cleaning method with Clinsodent® in the conducting fluid is the best and the fastest technique for stain removal from the denture base surfaces.
4. Ultrasonic cleaner routinely used in dental offices can be used easily for the denture cleaning processing less time and effectively. No additional instruments are required.

7. Source of Funding

None.

8. Conflict of Interest

None.

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