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A Comparative Evaluation of Effects of Denture Cleansers on Physical Properties of Denture base Resin: An in Vitro Study

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Abstract

The study aimed to evaluate and compare the effect of different denture cleansers on the physical properties of heat cure and cold cure denture base resins. A total of 150 specimens were prepared, seventy five from each denture base resin using a standard mold measuring 50 mm x 1.5 mm. For disinfection, specimens were immersed in denture cleansers (sodium hypochlorite and sodium perborate) for different time intervals (60 days, 90 days and 180 days). Surface roughness, hardness, color stability, sorption and solubility were measured for each specimen after the immersion procedure.

Results: Both denture base resins tested exhibited a change in physical properties to some degree in both the cleansers. Surface roughness, change in color and solubility increased with time in both denture base resins with both the cleansers. However, the maximum increase of surface roughness, change in color and solubility was seen in CC DBR with $NaBO_3n\ H_2O$ i.e. 2.20 µm, 2.3 ΔE and 2.9 µg/mm^3 respectively. Hardness decreased with time in both denture base resins with both the cleansers. However, the maximum decrease was seen in CC DBR with $NaBO_3nH_2O$ (13.20 VHN). Sorption increased with time in both DBR with both the cleansers. However, the maximum increase was seen in HC DBR with NaOCl (28.52 µg/ mm3).

Conclusion: Sodium hypochlorite showed the best results when compared with sodium perborate solution and HC DBR showed the best result when compared to CC DBR.

Keywords: Denture base resins; Denture cleansers; Sodium hypochlorite; Sodium perborate; Surface roughness; Hardness; Color stability; Solubility; Sorption.

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INTRODUCTION

Edentulism is the state of being edentulous or without any natural teeth. It is an irreversible and debilitating condition and is termed as the "final marker of disease burden" for oral health.[1]

Treatment options that are given to the patient of partial or complete edentulism may include removable partial dentures, complete dentures, fixed partial dentures or implant supported

prosthesis. Despite several advantages of the fixed and implant supported prosthesis, conventional complete dentures and removable partial dentures are still chosen as a treatment modality in many patients all over the world because of multiple factors such as cost, treatment time, patient unwillingness to undergo a surgical procedure, bone factors and systemic conditions.[2] To restore the normal functions of the oral cavity, dentures are the most accepted mode of treatment by the elderly, compromised edentulous patients.[3]

HC DBR is mostly accepted material for denture construction due to its superior physical properties such as high strength, better dimensional stability, low residual monomer content, reduced porosity and lesser water sorption rate.[4]

Fracture of denture is quite common and the fabrication of a new denture is time-consuming and costly for patients, denture repair is considered an alternative.[5] Repaired dentures should have adequate strength, dimensional stability and color match; moreover, the repair should be easily and quickly performed and must be affordable. Amongst various method proposed for repairing fractured denture bases, the use of CC DBR, which generally allows a simple and quick repair, is considered the most popular method.[6]

It is important to maintain the hygiene of the denture to prevent microbial colonization on dentures and to avoid bacterial & fungal infections in the oral cavity. Poor denture hygiene leads to undesirable effects such as bad breath, unpleasant staining and biofilm, calculus accumulation on the denture which can lead to denture stomatitis, angular cheilitis and poor oral health.[7] To prevent the infections that may originate from the acrylic dentures and for the longevity of the denture, maintenance of denture hygiene is extremely important.[8] Various methods are advocated for denture cleaning that include mechanical, chemical and a combination of both. Mechanical methods comprise brushing and ultrasonic treatments. Although brushing is the most widespread, simple, inexpensive and effective method but elderly patients with motor in-coordination find it difficult to perform and there is a possibility of acrylic resin wear and superficial damage to relining materials, therefore it is essential to use adequate brushes and auxiliary agents or use chemical methods.[9] The chemical method consists of immersion of denture in chemical solutions with solvents, detergents; antibacterial and antifungal actions and in combination method; such solutions can be employed in association with the mechanical method or ultrasonic method.[10]

Based on their physical forms, denture cleansers can be classified as Paste (mechanical) and Liquid (chemical). The basic constituents of denture cleansers in the paste are abrasives, humectants, detergents and flavouring agents. Abrasives are responsible for the formation of micro roughness over the surface of dentures. The density and size of abrasives are more in paste form when compared to liquid form. Therefore, cleansing by immersion in liquid is considered to be a better method as compared to paste.[11]

Daily use of denture cleansers is recommended to prevent microbial colonization, while daily use can also affect the physical properties of denture base material.[12] Properties that are mainly affected by denture cleansers are surface roughness, hardness, color stability, sorption and solubility and these are very important for the long term success of any prosthesis.[13]

The purpose of the present study is to evaluate and compare the effects of two different denture cleansers on the surface roughness, hardness, color stability, sorption and solubility of different denture base resins.

MATERIALS AND METHODOLOGY

Two commercially available denture base resins, conventional heat cure resin (Group A, DPI Ltd. India) and cold cure resin (Group B, DPI Ltd. India) and two commercially available denture cleansers, sodium hypochlorite (Labogens fine chem Industry) and sodium perborate (Labogens fine chem Industry) were used in this study.

A custom made stainless steel circular mold (1.5 mm x 50 mm) as per ADA specification No. 12 was prepared for making the study specimens (Fig. 1). Disc shape wax patterns (Fig. 2) were fabricated with the help of the mold, these wax patterns were invested in dental flasks using dental plaster and dewaxing was done (Fig. 3, 4).

Fig. 1: Stainless steel Die (1.5 mm x 50 mm)

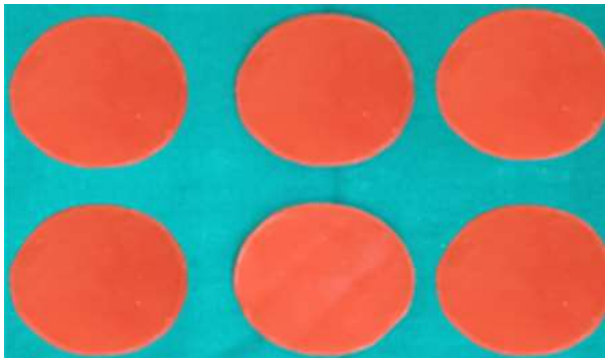


Fig. 2: Wax pattern

Fig. 3: Investment of wax pattern

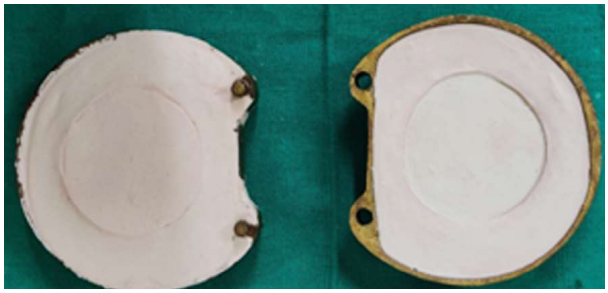


Fig. 4: Mold space after dewaxing

The mold space thus obtained was used for the preparation of the test specimens. For fabricating specimens of HC DBR (group-A), separating medium was applied onto the mold cavity, material was mixed in the polymer to monomer ratio of 3:1 by volume and was allowed to reach the dough like consistency. Then it was kneaded and placed into the mold cavity and final closure was done under bench press. The flask was maintained under pressure until bench curing was complete and then placed in acrylizer for long curing cycle in a water bath maintained at 74 degree Celsius for 8 hours and then increased the temperature to 100 degree Celsius for 1 hour. Following the completion of polymerization cycle, the flasks were allowed to cool down to room temperature. Then the specimens were retrieved from the mold cavity and finishing & polishing of specimen was done with acrylic burs, sand paper, rubber point to remove the scratches, pumice for final polishing of the specimens (Fig. 5). All specimens thus obtained were immersed in distilled water at 37±1°C for 24 hours for residual monomer elimination (Fig. 6).

For fabricating specimens of CC DBR (group-B), separating medium was applied onto the mold cavity and the appropriate amount of cold cure acrylic resin was mixed in the polymer to monomer ratio of 3:1 by volume. After attaining the dough stage, it will be kneaded and packed into the mold space and final closure was done under bench press. To ensure sufficient polymerization, the flask was held under pressure for a minimum of 3 hr. After the completion of the curing cycle, specimens was retrieved, finished and polished as described for heat cure specimens (Fig. 7).

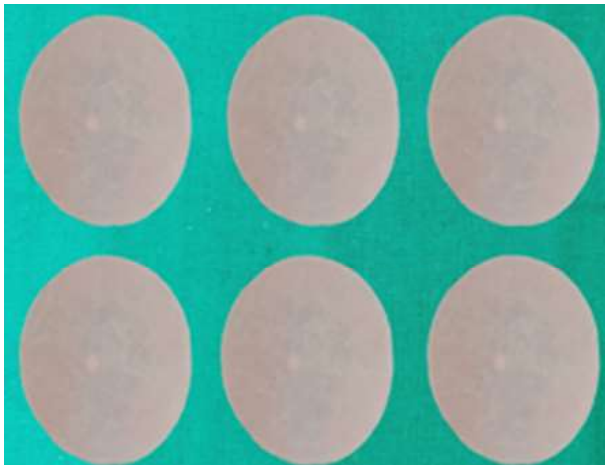


Fig. 5: Samples of heat cure

Fig. 6: Samples in distilled water

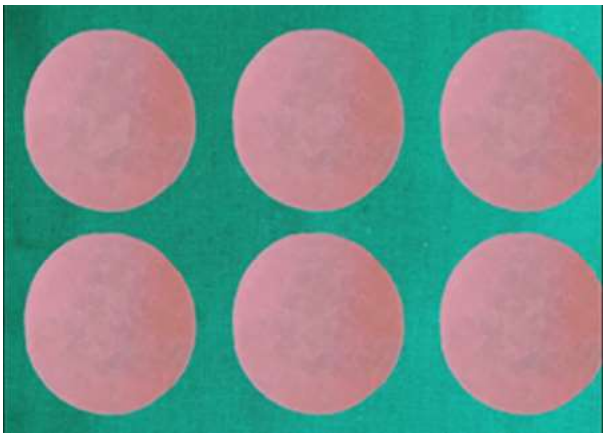


Fig. 7: Samples of cold cure

A total of 150 specimens were fabricated, seventy five each of HC and CC DBR. Further, specimens of each denture base material were randomly subdivided into three equal groups (n = 25) based on the different chemical cleansers (Control, NaOCl & NaBO3nH_2O) used in the study. All specimens in each group were subjected to daily cleansing for 10 minutes by immersion in 100 ml solution of respective denture chemical cleansers (0.5% sodium hypochlorite v/v and 3.8% sodium perborate w/v) then they were washed and stored in distilled water at room temperature to evaluate and compare the physical properties of DBR at different time intervals (60 days, 90 days, and 120 days) (Fig. 8, 9). For control group, specimens were immersed in distilled water at room temperature (Fig. 6).

Measurements for surface roughness, hardness, color stability, solubility and sorption were performed at different time intervals (60 days, 90 days, and 120 days). The surface roughness was analyzed with a profilometer (Fig. 10). The stylus of analyzer moved across the specimen surface and analyzer measured the stylus displacement through the inductance of the sensor inductor. Hardness was obtained with a Vickers hardness tester (Fig. 11). Diamond indenter point in the shape of a square based pyramid was used for measuring hardness. It was measured under a 20 gram load and 30 seconds penetration period. The color was measured with a spectrophotometer using Commission International de L'Eclairage L*a*b* system (Fig. 12). Sorption and solubility was measured by electronic balance (Fig. 13). It is the amount of increase or decrease in mass per unit volume (µg/mm3).

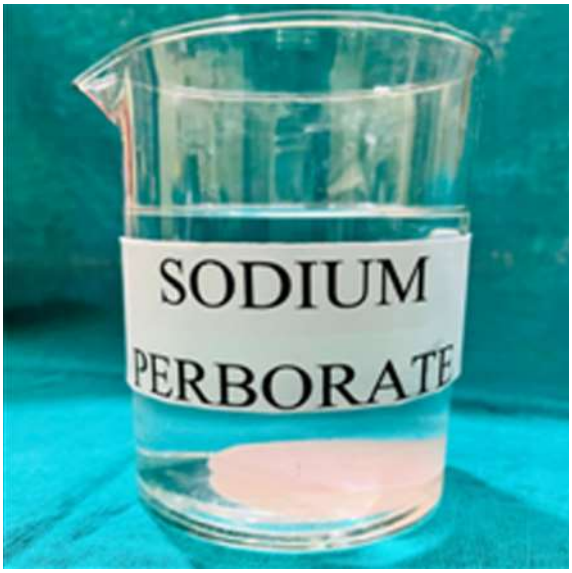


Fig. 8: Samples of in sodium perborate

Fig. 9: Samples of sodium hypochlorite

Fig. 10: Profilometer

Fig. 11: Vickers Hardness

Fig. 12: Spectrophotometer

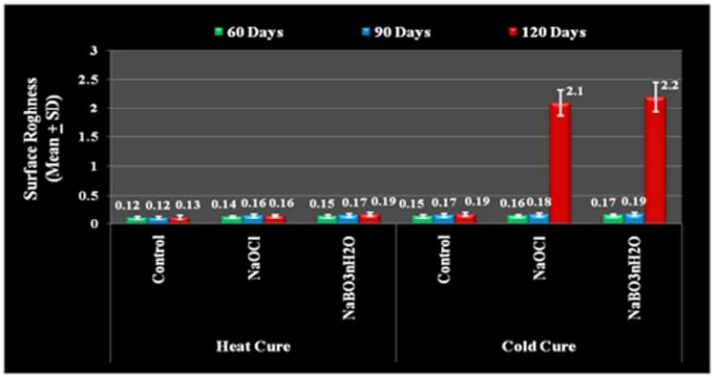
Fig. 13: Electronic balance

RESULTS

The results and statistical analysis of the study are summarized in tables 1–5 and graph 1-5. Tables and graphs shows mean value of physical properties of both the DBR specimens treated with different denture cleansers (0.5% sodium hypochlorite and 3.8% sodium perborate) at different time intervals (60 days, 90 days, 120 days). The results of the study revealed that all the specimens used in the study exhibited a change in physical properties with immersion in different denture cleansers.

Table 1: Surface roughness

Group	Sub Group	Surface Roughness					
		60 Days		90 Days		120 Days	
		Mean	SD	Mean	SD	Mean	SD
Heat Cure	Control	0.12	0.03	0.12	0.03	0.13	0.04
	NaOCl	0.14	0.02	0.16	0.03	0.16	0.02
	NaBO3nH2O	0.15	0.03	0.17	0.03	0.19	0.03
Cold Cure	Control	0.15	0.03	0.17	0.03	0.19	0.03
	NaOCl	0.16	0.02	0.18	0.03	2.10	0.23
	NaBO3nH2O	0.17	0.02	0.19	0.03	2.20	0.26
ANOVA (F)		**2.543**		**3.000**		**245.133**	
p – Value		**0.055 (NS)**		**0.030 (S)**		**< 0.001 (VHS)**	



Graph 1: Surface roughness

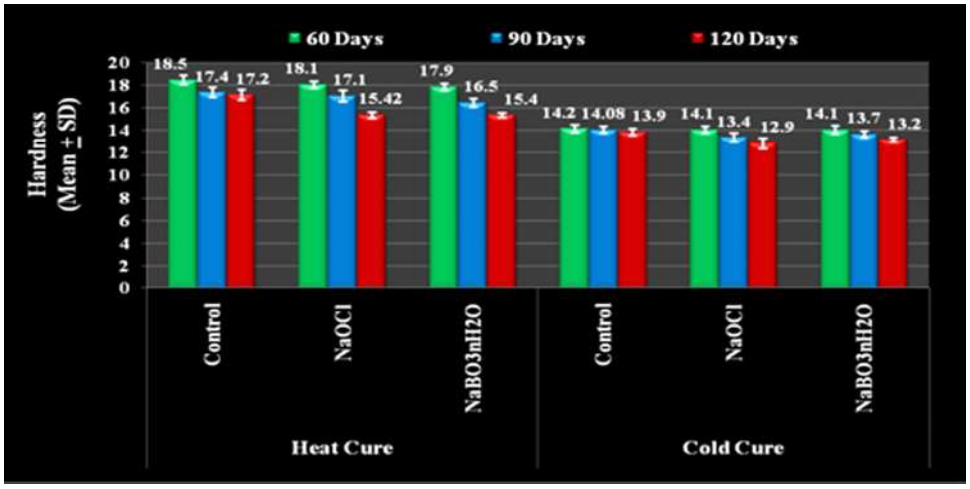
Surface roughness increased with time in both DBR with both denture cleansers. However, the maximum increase was seen in CC DBR with $NaBO_3nH_2O$. Increase in surface roughness was observed in the following order:

CC $NaBO_3nH_2O$ > CC NaOCl > CC Control = HC $NaBO_3nH_2O$ > HC N3aOCl > HC Control.

Table 2: Hardness

Group	Sub Group	Hardness					
		60 Days		90 Days		120 Days	
		Mean	SD	Mean	SD	Mean	SD
Heat Cure	Control	18.50	0.41	17.40	0.44	17.20	0.47
	NaOCl	18.10	0.29	17.10	0.48	15.42	0.26
	$NaBO_3nH_2O$	17.90	0.29	16.50	0.34	15.40	0.22
Cold Cure	Control	14.20	0.33	14.08	0.30	13.90	0.29
	NaOCl	14.10	0.31	13.40	0.38	12.90	0.46
	$NaBO_3nH_2O$	14.10	0.35	13.70	0.27	13.20	0.22
ANOVA (F)		**221.910**		**117.777**		**116.882**	
p – Value		**< 0.001 (VHS)**		**< 0.001 (VHS)**		**< 0.001 (VHS)**	

SD – Standard Deviation, VHS – Very Highly Significant



Graph 2: Hardness

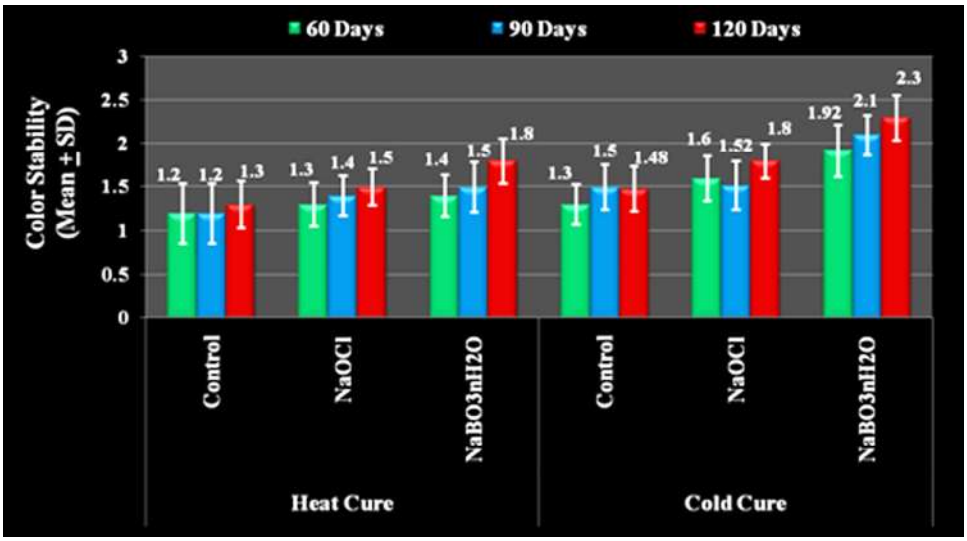
Hardness decreased with time in both DBR with both denture cleansers. However, maximum decreased was seen in CC DBR with $NaBO_3nH_2O$.

Decrease in hardness was observed in the following order:

HC Control > HC NaOCl > HC NaBO3nH2O > CC Control > CC NaOCl > CC NaBO3nH2O.

Table 3: Color Stability

Group	Sub Group	Color Stability					
		60 Days		90 Days		120 Days	
		Mean	SD	Mean	SD	Mean	SD
Heat Cure	Control	1.20	0.34	1.20	0.34	1.30	0.27
	NaOCl	1.30	0.25	1.40	0.23	1.50	0.21
	NaBO3nH2O	1.40	0.24	1.50	0.29	1.80	0.26
Cold Cure	Control	1.30	0.23	1.50	0.26	1.48	0.26
	NaOCl	1.60	0.26	1.52	0.28	1.80	0.20
	NaBO3nH2O	1.92	0.30	2.10	0.23	2.30	0.26
ANOVA (F)		**4.639**		**5.939**		**10.272**	
p – Value		**0.004 (HS)**		**0.001 (HS)**		**< 0.001 (VHS)**	



Graph 3: Color stability

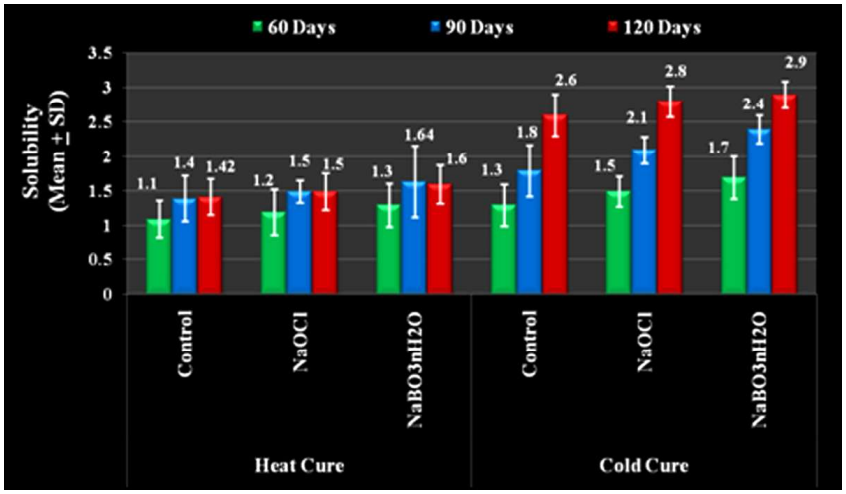
Change in color increased with time in both DBR with both denture cleansers. However, maximum increased was seen in CC DBR with NaBO3nH2O.

Increase in the change in color was observed in the following order:

CC NaBO3nH2O > CC NaOCl = HC NaBO3nH2O > HC NaOCl > CC Contol > HC Control.

Table 4: Solubility

Group	Sub Group	Solubility					
		60 Days		90 Days		120 Days	
		Mean	SD	Mean	SD	Mean	SD
Heat Cure	Control	1.10	0.27	1.40	0.33	1.42	0.26
	NaOCl	1.20	0.33	1.50	0.16	1.50	0.27
	NaBO3nH2O	1.30	0.31	1.64	0.52	1.60	0.28
Cold Cure	Control	1.30	0.30	1.80	0.37	2.60	0.30
	NaOCl	1.50	0.22	2.10	0.19	2.80	0.22
	NaBO3nH2O	1.70	0.31	2.40	0.20	2.90	0.19
ANOVA (F)		**2.738**		**7.042**		**36.942**	
p – Value		**0.052 (NS)**		**< 0.001 (VHS)**		**< 0.001 (VHS)**	



Graph 4: Solubility

Solubility increased with time in both DBR with both denture cleansers. However, maximum increased was seen in CC DBR with NaBO3nH2O.

Increase in solubility was observed in the following order:

CC NaBO3nH2O > CC NaOCl > CC Control > HC NaBO3nH2O > HC NaOCl > HC Control.

Sorption increased with time in both DBR with both denture cleansers. However, maximum increased was seen in HC DBR with NaOCl.

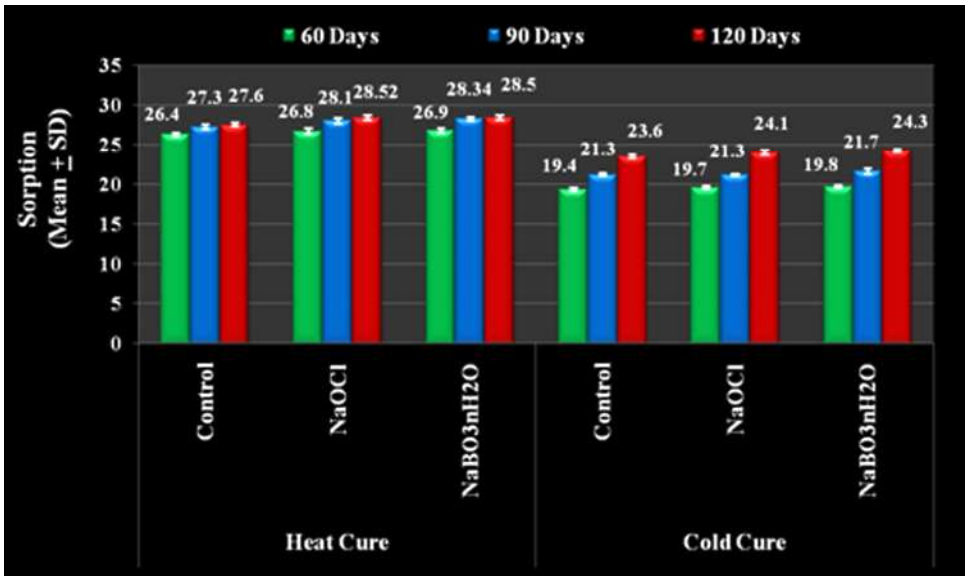
Increase in solubility was observed in the following order:

HC NaOCl > HC NaBO3nH2O > HC Control > CC NaBO3nH2O > CC NaOCl > CC Control.

Table 5: Sorption

Group	Sub Group	Sorption					
		60 Days		90 Days		120 Days	
		Mean	SD	Mean	SD	Mean	SD
Heat Cure	Control	26.40	0.24	27.30	0.29	27.60	0.24
	NaOCl	26.80	0.33	28.10	0.31	28.52	0.29
	NaBO3nH2O	26.90	0.29	28.34	0.18	28.50	0.29
Cold Cure	Control	19.40	0.24	21.30	0.20	23.60	0.20
	NaOCl	19.70	0.20	21.30	0.12	24.10	0.31
	NaBO3nH2O	19.80	0.12	21.70	0.32	24.30	0.19
ANOVA (F)		**1218.378**		**1038.348**		**408.303**	
p – Value		**< 0.001 (VHS)**		**< 0.001 (VHS)**		**< 0.001 (VHS)**	

SD – Standard Deviation, VHS – Very Highly Significant



Graph 5: Sorption

DISCUSSION

Denture hygiene is of utmost importance because dentures are used by the patients throughout the day and are in constant touch with the oral environment including various microorganisms.[14] Therefore, denture cleaning should be carried out on a daily basis to reduce the incidence of plaque accumulation, staining, halitosis, calculus formation, and bacterial & fungal infection of the oral mucosa and gingivae.[15]

In the present study HC DBR and CC DBR were used as HC DBR is the material of choice for denture base fabrication because of its favorable working characteristics, processing ease, accurate fit, stability in the oral environment, low solubility and cost effectiveness.[16,17] CC DBR is used for repairing the fractured denture and they generally allows a simple and quick repair and is considered as the most popular method.[18,19]

Denture cleaning can be accomplished by mechanical or chemical methods. In this study, chemical methods were selected over mechanical methods because mechanical cleaning is insufficient and should be accompanied by chemical cleaning, especially for elderly and disabled patients who have limited manual dexterity and low motor capacity.[15,20] Another disadvantage is that the abrasive action could result in the wear of the denture base and relining materials.[21]

Chemical methods for cleaning dentures mainly include soaking in a household or commercial solution.[10] Many authors studied the effect of various chemical solutions on the physical properties of PMMA. In these studies, the author used various disinfectant solutions with different concentrations.[22] However in the present study, 0.5% NaOCl and 3.8% $NaBO_3nH_2O$ were used for the immersion procedure to evaluate their effect on the physical properties of denture base material at a different time intervals.

At 0.5% NaOCl solution is an effective method for killing adherent microorganisms and 3.8% $NaBO_3nH_2O$ acts as an appropriate denture cleanser for protecting prosthesis from microbial colonization and maintaining oral and denture health.[10,12]

In high concentration these chemicals may damage the physical properties of denture materials.[23] Therefore 0.5% NaOCl and 3.8% $NaBO_3nH_2O$ were used in this study.

The first parameter included in the study was surface roughness. It influences biofilm formation by providing retentive areas for food debris and microorganisms.[24] Therefore, it is imperative to have a smooth surface to prevent the colonisation of microorganisms.[25,26] The second parameter was hardness. It indirectly predicts how easily the material will respond to abrasive and indenting forces, and provides an indication of physical properties.[27,28] The third parameter was color stability. It is a sign of material ageing or damage and may refer to the degree of serviceability (longevity) and durability of the material.[29] Fourth and fifth parameter were solubility and sorption. PMMA is relatively stable in oral fluids as it has a low rate of water absorption.[30] Polymers can be degraded by the physico chemical process after absorbing a high amount of water, starting with swelling which causes flexibility, reduces hardness, dimensional distortion, discoloration or staining and may dissolve water soluble ingredients.[31,32] Soluble ingredients leach into the oral cavity, reducing the volume of the material and leaving spaces in the denture which later occupied by water or colonized by microorganisms.

The results in the current study showed that the specimens of both the DBR when immersed in 0.5% NaOCl and 3.8% $NaBO_3nH_2O$ solution showed an increase in surface roughness with time when compared to the control group.

After the simulation of 60 days, 90 days and 120 days HC DBR showed the least change in surface roughness with time when compared with CC DBR. This can be attributed to the high cross linking structure present in HC DBR causing fewer surface changes in it as compared to CC DBR.[33] Between the denture cleansers, the increase was more in $NaBO_3nH_2O$. $NaBO_3nH_2O$ have an effervescent component, which when dissolved in water form an alkaline peroxide solution that decomposes to produce oxygen that loosens the food debris via mechanical means.[34] Therefore, its use results in hydrolysis and decomposition of the polymerized acrylic resin itself. Similar results have been seen in previous studies where surface roughness have been increased, more in CC DBR when compare to HC DBR after immersion in $NaBO_3nH_2O$.[35]

Hardness decreased with time in both the DBR after immersion of specimens in both the denture cleansers (0.5% NaOCl and 3.8% $NaBO_3nH_2O$) when compared to the control group. On comparing between the cleansers, $NaBO_3nH_2O$ showed a greater decrease in hardness than NaOCl because of active oxygen released by hydrogen peroxide and oxygen liberating solution.[36] A similar study was conducted by Machado et al, he found that hardness of denture base was decreased significantly after seven days of immersion in $NaBO_3H_2O$ as compared to the control group which was distilled water.[13]

The change was greater in CC DBR as compared to HC DBR because of the amount of free monomer, which is higher with CC DBR. The free monomer may impede water absorption before complete leaching into the water.[37] In general, absorbing water has an adverse effect on the hardness of PMMA based material due to being a plasticizer. The polymerization cycle mainly influences hardness due to the relation between the processing cycle and degree of conversion, namely residual monomer, and in turn hardness. Similar results have been seen in previous studies also.[38]

Increase in the change in color stability with time after immersion of specimens of both the DBR in 0.5% NaOCl solution and 3.8% $NaBO_3nH_2O$ solution when compared to control group.

CC DBR showed an increase in color change as compared with HC DBR because CC DBR has fewer cross linked agents and also due to leaching out of the coloring agents & soluble components from the resins, oxidation of amines, increasing roughness, and tendency to absorb stains. High ΔE may also be due to material degradation, which can be triggered by exposure to cleansers, in particular cleansers containing many oxidising agents.[35]

On comparing both the cleansers to each other, $NaBO_3nH_2O$ showed a greater change in color than NaOCl. It was stated that the reason for damage to denture resin when immersed in peroxide-containing denture cleanser was increased peroxide content and the accelerated level of oxygenation in highly alkaline solution. Similar results have been seen in previous studies also.[39]

Increase in solubility with time after immersion of specimens of DBR in 0.5% NaOCl and 3.8% $NaBO_3nH_2O$ solution when compared to the control group. When compare between the DBR, CC DBR show more solubility than HC DBR. The principal difference between HC DBR and CC DBR is that more residual monomer is present in the CC DBR. In addition, with a high monomer to polymer ratio, residual monomer content in the polymerized acrylic resin would be large.[40] Fletcher et al. found that cold cure resins exhibited higher residual monomer levels than did heat cures resins. These higher residual monomer contents could be related to the higher solubility levels of CC DBR reported.[41]

When compared between the cleansers, $NaBO_3nH_2O$ showed more solubility in both the DBR because of the high ionic concentration which causes higher dissolution of soluble component. Similar results have been seen in previous studies where solubility have been increased in CC DBR when compared with HC DBR after immersion in different denture cleansers at different time intervals.[41]

In the present study, CC DBR showed lower water sorption than HC DBR, which was in agreement with the findings in another study.[32] Chemical nature of the polymer versus that of the water molecule directly affected the water sorption of resin. Highly polymerized resin specimens absorb more water than other specimens. To reduce the amount of residual monomer in acrylic resins and pass it into the water, prolonged boiling during processing and keeping in water for long period is essential. The water molecules fill the space created in the structure of acrylic resin by diffusion. Therefore, more water sorption in heat cured acrylic resins was observed compared to cold cured resins in different time intervals and solutions. When compared between the cleansers both the cleansers showed sorption in both the DBR because they fill the space created in the structure of acrylic resin by diffusion.[40,41] Similar results have been seen in previous studies where sorption increased in HC DBR after immersion in different denture cleansers at different time intervals.[41]

Clinically, both the denture cleansers (NaOCl and $NaBO_3nH_2O$) caused alteration in the physical properties of both heat cure and cold cure DBR. In general, NaOCl showed the best results when compared with $NaBO_3nH_2O$ solution at different time intervals.

CONCLUSION

From the results of this study, it could be concluded that both DBR used in this study exhibited the change in physical properties to some degree with use of both denture cleansers (sodium hypochlorite (0.5% v/v) and sodium perborate (3.8% w/v). DBR results in increase in surface roughness, color stability, solubility and sorption, while the maximum increase in surface roughness, color stability and solubility was in CC DBR when treated with sodium perborate solution and increase in sorption was seen in HC DBR with sodium hypochlorite. Hardness decreased with time in both DBR with both denture cleansers. However, maximum decreased was seen in CC DBR with $NaBO_3nH_2O$.

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