Original Article

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Dentistry Section

A Comparative Evaluation of the Linear Dimensional Changes of Two Different Commercially Available Heat Cure Acrylic Resins during Three Different Cooling Regimens

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ABSTRACT

Introduction: Close mucosal adaptation of denture base to the underlying mucosa is of prime importance for denture stability. This however can be affected by various temperature changes which the denture base undergoes during processing and also to its material properties.

Aim: The aim of the present study was to compare linear dimensional change of heat cure acrylic resin with three different cooling regimens on two different commercially available acrylic denture base resins.

Materials and Methods: Six groups of acrylic specimens with 10 samples each were prepared using either PYRAX or DPI acrylic resin, with a standard processing technique. Three different cooling methods were used for both the commercially available heat cure acrylic denture base resins. Linear dimensional changes were measured between three pre-determined points on the specimens of all the groups using a travelling microscope after removing the sample from the flask. One way ANOVA and unpaired t-test was used for statistical analysis.

Results: Linear dimensional change was more in quenching followed by air and water bath method of cooling respectively. Amongst the materials, linear dimensional changes were more in PYRAX than in DPI acrylic.

Conclusion: Slow cooling by methods described should be advocated for better mucosal adaptation of the denture base.

Keywords: Complete denture, Denture base, Dental materials, Polymers

INTRODUCTION

Denture base materials have remained a challenge in dentistry from the beginning of the dental art. With the introduction of heat cure acrylic in 1937 by W. H. Wright [1] the discipline of dental prosthesis revolutionized, and today in spite of the development of various other denture base materials acrylic resin is still the most widely accepted material and is the principal choice when it comes to denture base.

Acrylic is used universally despite of not having all the ideal properties, the reason for which is its overall material properties which are suitable as a denture base rather than one single desirable property. Of all the properties the need for dimensional accuracy is a must for materials used in dentistry, especially with denture base a close contact between the denture base and mucosa is the most important requisite for the retention of acrylic denture base. However, dimensional changes due to polymerization shrinkage are inevitable in heat processed Polymethacrylate (PMMA) denture base, materials. In addition to polymerization shrinkage there is also thermal shrinkage as the processed denture cools in the flask [2]. These changes are compensated to some extent by water sorption. The final adaptation of the denture thus, is affected by several factors as: 1) Type of acrylic resin; 2) Flask cooling procedures and 3) Water uptake [3].

The shrinkage that the denture undergoes initially can be volumetric and linear, of which linear shrinkage occurs primarily due to thermal changes is responsible for significant effects upon the adaptation of denture base and cuspal inter-digitation [4].

Besides the curing cycle of the denture it's the cooling regimen followed which is of significance to determine the linear dimensional changes [5]. Since during the initial stages of cooling the resin remains relatively soft; therefore, the pressure maintained in the flask assembly causes the resin to contract at approximately the same rate as the surrounding dental stone [4]. However, as the cooling process proceeds resin approaches its glass transition temperature, which is a range where the resin reaches a glassy state from a rather soft, rubbery state. The shrinkage which occurs at this stage varies according to the composition of the resin [6].

Numerous studies have been conducted on the effects of long and short curing cycles and generally the longer cycles have produced the most dimensionally stable dentures [7-9].

However, comparatively little work has been done on the effect of different cooling regimens on the dimensional accuracy of heat cure PMMA dentures. Thus, this study was carried out to compare the linear dimensional change of heat cure acrylic resin with three different cooling regimens on two different commercially available acrylic denture base resins, with the study hypothesis that the slow cooling regimes should produce more dimensionally accurate dentures.

MATERIALS AND METHODS

This in-vitro study was conducted in the prosthodontic laboratory of Government Dental College and Hospital, Hyderabad, India, for preparation of acrylic samples; whereas, the measurements using travelling microscope were done in Osmania University, Hyderabad, India.

Six groups of specimens using two varieties of acrylic resin and having 10 samples each were prepared using the same processing technique as described below. Three different cooling methods were used for both the commercially available heat cure acrylic denture base resins used. Linear dimensional changes of all the groups were determined after removing the sample from the flask.

The two different resins used in this study were:

1) Heat cured PMMA denture base material (DPI- Dental Products of India)
2) Heat cured PMMA denture base material (PYRAX)

Stainless Steel Master Dies for Sample Preparation: Stainless steel master dies were prepared as per ADA specification no.12, with a 65mm length, 10mm width and 3mm thickness. [Table/Fig-1]. Each specimen had three V shaped grooves on the surface which were named as A, B and C. The distance between A-B and B-C was 20mm. Extreme care was taken to ensure that the dies had perfect edges with smooth surfaces without any irregularities.

Gypsum Mould Preparation for Obtaining Samples: Gypsum mould was prepared with stainless steel master dies for accuracy and convenience while processing the acrylic resin. A thin layer of petroleum jelly was applied to the die. Three dies were invested horizontally in denture curing metal flasks with dental stone. After the stone had set, sodium alginate separating medium was applied. The counter part of the flask was positioned over the base and filled with dental stone taking care not to incorporate any voids. The lid was then carefully positioned. After the dental stone had set, the flask was carefully opened and the dies were carefully teased out from the investing material. The mould cavities so obtained were then immersed in hot water and flushed with a suitable detergent to remove any traces of petroleum jelly and separating medium. The mould cavities so obtained were used for the preparation of acrylic specimens.

For preparation of PMMA resin specimens pre-weighed polymer and monomer was mixed in a ratio of 2:1 by weight. Each flask contained three specimens, for which approximately 6gms of polymer and 3ml of monomer was measured and mixed in a clean porcelain jar under similar conditions of temperature.

The material was placed in the mould in dough stage. After two trial closures using hydropress the flask was clamped under pressure by bench press of 100kg/cm^2 and this pressure was maintained for 30 minutes to allow proper penetration of monomer into polymer. For curing, the flask was placed in water bath at room temperature and the temperature of the curing unit was then raised to 73°C, held for one and a half hour and then raised to 100°C and maintained at half an hour. The same curing method was followed for all the groups.

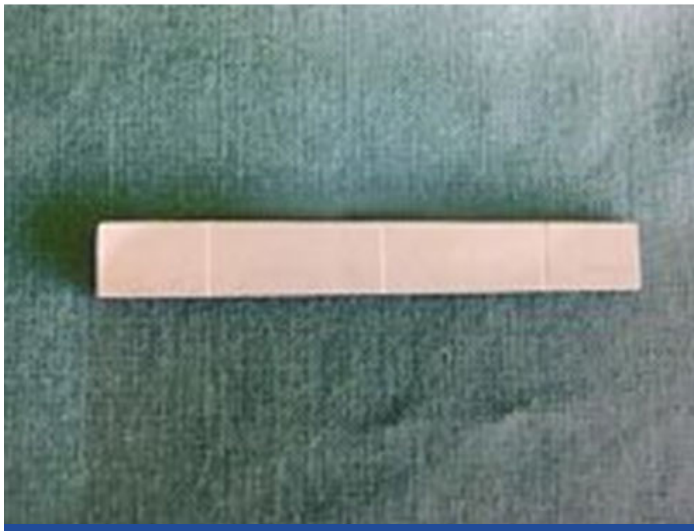
After the completion of the curing cycle cooling was done by one of the three methods:

1. Water Bath: The flask remained in water bath for 60 hours.
2. Air: The flask was removed from water bath and bench cooled for 12 hours at room temperature.
3. Quenching: The flask was removed from the water bath and quenched immediately under running tap water for half an hour.

The six groups of 10 samples each were prepared as tabulated [Table/Fig-2]. The acrylic specimens were then retrieved, finished and polished. The distances between the markings A-B, B-C, on the acrylic specimens were measured with the help of a travelling microscope (Manufacturer: Optiregion) upto the accuracy of 0.001mm [Table/Fig-3]. The measurement was made by keeping the specimen on the horizontal table of the microscope. It has two readings: Main Scale Reading (MSD) and Vernier Scale Reading (VSD) both were recorded and the Total Reading (TR) was calculated with the least count of microscope = 0.001cm. The measurements were made by focusing on all the grooves on the specimen. All the samples were measured. The obtained data was tabulated and statistically analyzed.

STATISTICAL ANALYSIS

One way analysis of variance test (ANOVA) was used for the inter-group comparison amongst various cooling methods used.



[Table/Fig-1]: Stainless steel master die (ORIGINAL).

Groups	Number of Samples	Type of Resin	Cooling Method Used
I	10	PYRAX Resin heat cured	Water bath
II	10	PYRAX Resin heat cured	Air
III	10	PYRAX Resin heat cured	Quenching
IV	10	DPI Resin heat cured	Water bath
V	10	DPI Resin heat cured	Air
VI	10	DPI Resin heat cured	Quenching

[Table/Fig-2]: Groups of acrylic samples used in the study.

[Table/Fig-3]: Travelling microscope (ORIGINAL).

Whereas, unpaired t-test was used to compare the difference between both the PYRAX and DPI materials with each cooling method used. Separate records were made for both the distances measuring from point A-B and point B-C.

RESULTS

The tests were carried out as described earlier and the linear dimensional changes were measured between all three points A-B and B-C, with the help of travelling microscope, for all the three cooling categories of both PYRAX and DPI resins and is tabulated and presented in [Table/Fig-4,5] respectively, while other comparative statements are presented in [Table/Fig-6-8].

The linear dimensional change was more in quenching followed by air and water bath respectively. There was statistically significant difference between the three cooling methods with both the materials. Very high statistically significant difference ($p<0.001$) was found in all measurements between the quenching and slow cooling in the water bath methods, with quenching resulting in more dimensional change. Similarly, there was a very high statistically significant difference

between the quenching method and the bench cooling method (p<0.001). However, no statistically significant difference was found between the bench cooling method and the slow cooling in water bath method (p>0.05) [Table/Fig-6]. Amongst the materials the linear dimensional change was more in PYRAX acrylic when compared to DPI acrylic and this difference was statistically significant. The results indicate that there is statistically highly significant difference between PYRAX and DPI materials when cooled in water bath for 60 hours or bench cooled for 12 hours (p<0.001), with DPI material showing less dimensional changes when compared to PYRAX material. There was no statistically significant difference between two materials with rapid cooling or quenching [Table/Fig-7,8].

DISCUSSION

The clinical implications of dimensional changes in denture base during processing may vary from case to case depending on clinical variables such as shape of the edentulous ridge, the amount to which the denture bearing mucosa can be displaced, effect of the impression on the displacement of the mucosa etc. However, the benefits of dimensional accuracy are self-evident [2]. Close contact with the mucosal surface is the most important in denture retention [2,3]. Besides the patient related factors, the stability of the denture base is also affected by the external factors that acrylic is subjected to while curing, amongst them the heating method used for denture curing has been widely studied, though besides this the method of denture base cooling after polymerization is of equal importance; hence, in this study the authors aimed at checking for the method of cooling after denture curing that causes the maximum distortion. Similar results as presented in the current study have been obtained by Kimoto S et al., in 2005 Kobayashi S et al., in 2004 and Rafael L et al., in 2006, to quote a few [5,10,11].

The dimensional changes of dentures have been examined by using a variety of shapes and methods. This is because the dimensional changes of specimens made with acrylic resins are affected by the shape of the specimen. In this study rectangular acrylic specimens were used because this method of determining the dimensional change has proved to be convenient and suitable [12,13]. Previously rectangular specimens for such studies have been used by other researchers [11-15].

The dentures processed by three different techniques, conventional heat compression, microwave and visible light activation have been found to have no significant difference in the overall dimensional accuracy [8,15-17]; thus, the conventional method of heat cure was used in this study for convenience. The temperature in this study was raised to 73°C, and was held for 1 and 1.5 hours, then raised to 100°C and maintained for one hour. The temperature dissipation in the denture actually depends upon the thickness and amount of surface area of the specimen. As long as the heat dissipation takes place a higher temperature can be used for processing in order to increase the efficiency of the polymerization of the resin [18].

Type	Water Cooled		Air Cooled		Quenched	
	A-B	B-C	A-B	B-C	A-B	B-C
PYRAX	0.149	0.149	0.129	0.141	0.281	0.286
	0.152	0.131	0.121	0.129	0.265	0.259
	0.178	0.168	0.177	0.178	0.298	0.276
	0.171	0.182	0.163	0.152	0.265	0.292
	0.143	0.67	0.168	0.167	0.286	0.273
	0.147	0.163	0.132	0.143	0.273	0.283
	0.108	0.156	0.145	0.136	0.293	0.289
	0.131	0.144	0.145	0.164	0.305	0.296
	0.109	0.105	0.156	0.145	0.267	0.261
	0.132	0.155	0.194	0.185	0.275	0.286

[Table/Fig-4]: Linear dimensional changes as measured with travelling microscope for all categories of PYRAX resin (in millimeters).

Type	Water Cooled		Air Cooled		Quenched	
	A-B	B-C	A-B	B-C	A-B	B-C
DPI	0.086	0.083	0.086	0.106	0.265	0.259
	0.073	0.076	0.118	0.116	0.247	0.286
	0.095	0.093	0.096	0.096	0.245	0.257
	0.098	0.104	0.126	0.119	0.286	0.249
	0.096	0.108	0.095	0.086	0.278	0.239
	0.076	0.073	0.086	0.093	0.248	0.276
	0.101	0.096	0.116	0.135	0.234	0.283
	0.076	0.084	0.096	0.086	0.294	0.284
	0.095	0.079	0.135	0.124	0.276	0.246
	0.096	0.063	0.127	0.119	0.279	0.296

[Table/Fig-5]: Linear dimensional changes as measured with travelling microscope for all categories of DPI resin (in millimeters).

Cooling Method	Mean	Standard Deviation	Mean Difference	p-value
Water bath	0.11	0.04	-0.013	0.101
Air	0.13	0.04		
Water bath	0.11	0.04	-0.157	<0.001*
Quenching	0.27	0.02		
Air	0.13	0.04	-0.144	<0.001*
Quenching	0.27	0.02		

[Table/Fig-6]: Comparison of three cooling methods used for significance (ORIGINAL).
One way ANOVA test used * p<0.05

Cooling Method	Material	Mean	Standard Deviation	Standard Error of Mean	Mean Difference	T-Value	p-value
Water bath	PYRAX	0.142	0.023	0.0072	0.528	6.59	<0.001*
	DPI	0.089	0.010	0.0033			
Air cooling	PYRAX	0.153	0.023	0.007	0.044	4.834	<0.001*
	DPI	0.108	0.018	0.005			
Quenching	PYRAX	0.280	0.014	0.0045	0.015	1.980	<0.0631
	DPI	0.265	0.020	0.0064			

[Table/Fig-7]: Comparison of two materials with three cooling methods from A-B (ORIGINAL).
Unpaired t-test used * p<0.05

Cooling Method	Material	Mean	Standard Deviation	Standard Error of Mean	Mean Difference	T-Value	p-value
Water bath	PYRAX	0.152	0.021	0.0068	0.066	8.050	<0.001*
	DPI	0.085	0.014	0.0044			
Air cooling	PYRAX	0.154	0.018	0.005	0.046	5.749	<0.001*
	DPI	0.108	0.017	0.005			
Quenching	PYRAX	0.280	0.012	0.0039	0.012	1.696	<0.107
	DPI	0.267	0.019	0.0062			

[Table/Fig-8]: Comparison of two materials with three cooling methods from B-C (ORIGINAL).
Unpaired t-test used * p<0.05

Amongst the cooling methods used for the acrylic specimens, fast cooling in the quenching process may have induced an uneven thermal contraction, leading to some resultant stress which may have been relieved partly during deflasking thereby inducing greater warpage. Fast cooled dentures which had greater processing shrinkage, showed larger expansion than did slow cooled dentures. The greater volumetric shrinkage which occurs during the polymerization of the thicker dentures may have some effect on distortion of the posterior palatal area than the anterior region. A wider gap occurred between the denture and cast in the posterior palatal region in water quenched group which indicates that the rate of cooling of the flask has a definite effect upon the observed shrinkage of dentures [17,19]. During water quenching a sudden change in temperature caused by quenching in water causes unequal thermal contraction in various areas inducing a greater amount of warpage [2-4,10].

In this study it was found that with the reduction in residual stress by cooling the denture resins slowly by water bath or bench cooling the denture base could be fabricated with less deformation when compared to quench cooling [14,20]. The stress caused by the thermal contraction is relieved shortly after the denture is removed from the mould whereas the stress caused by polymerization contraction is relieved more gradually [21,22]. This is because thermal contraction is of an instantaneous mechanical nature, whereas the stress caused by polymerization is on a molecular level, involving polymer chains. This study used heat activated acrylic base resin so that the polymerization of specimen was not involved. Therefore, in this study, the stress caused by thermal contraction in the heat activated acrylic denture base resin was relaxed by molecular reorientation of the polymer chains, despite the temperature being less than that needed for glass transition [4,14].

The residual internal stress in heat activated acrylic denture base resin at the region of shrinkage restriction was relaxed in the stone mould with the lapse of time after completion of cooling, so that dimensional change at deflasking was reduced. The shrinkage strain at deflasking was two thirds for 1-day restriction, and one half for 3-5 day restriction, compared with the quenching, in which the dentures were removed from the stone mould immediately. Gradual cooling for 12 hours or more after processing a heat-activated acrylic denture base is preferred since the deformation of the prosthesis is lesser when such a procedure is used [4,21,22].

Dymus Z et al., and Mandava RB et al., have used travelling microscope to determine dimensional changes in various kinds of acrylic denture base specimens in their respective studies [23,24]. The same was used in the present study as well; the precision of the travelling microscope used was 0.001mm. The distances between the three points in the specimens were measured in the same plane to represent the dimensional changes.

The difference in the thermal contraction between the mould and the acrylic resin during cooling is believed to be the cause of residual stress in the processed denture and is also considered to be the main contributor to the stress release that occurs when the denture is separated from the cast. The rate of cooling of the flask after processing has a definite effect on the dimensional changes of dentures, with the quenching method causing an unequal thermal contraction in various areas and thus inducing a greater amount of stress that results in greater warpage [2,3]. Slow cooling in water bath can be expected to result in more uniform cooling of the denture resulting in a less dimensional change. The bench cooling method might also be expected to allow cooling without excessive stress build up, but may be susceptible to minor temperature difference [2,21].

The absence of a statistically significant difference between cooling overnight in the water bath and bench cooling can be explained by the probability that there is very little difference between the two methods and as a result many more samples would be required to identify if any statistically significant difference can be found [5,10]. This study has shown that slow cooling, either in the water bath or on the bench results in less dimensional change than quenching [Table/Fig-4]. Cooling by quenching in cold water should be discouraged as it has been shown to result in greater dimensional change. In the present study cooling by quenching was achieved by plunging the hot flask straight into a sink full of cold water at 20°C. To achieve quicker cooling the flask was left in the sink with tap running so that the heat was carried away by the water and the dentures were not deflasked until the next day. However, in a busy laboratory, using the quenching method, it might be expected that the denture would be devested at the first possible opportunity, possibly before the flask was completely cooled. This might be the source of more dimensional change.

Linear dimensional changes observed in the bench cooled denture bases and in those cooled slowly inside the water bath were almost similar. Dimensional changes by water sorption cause expansion due to the entry of water between molecules of PMMA, which results in a plasticizing effect when absorbed during polymerization or immersion in water. Since, the content in the wet heat processed denture is great the subsequent water saturation level by water shortage is decreased.

Since, most of the studies for dimensional changes in the denture base are done by comparing the denture curing by various heating methods; thus, this study adds to our knowledge about the way cooling cycles can affect the denture base. This study clearly has implications for laboratory practice which can affect the clinical outcomes. Processing cycles, which allow slow cooling, are preferable and technical laboratory protocols to allow for this should be developed. Very few commercially available heat cure acrylic resins give instructions regarding cooling after processing. The processing instructions of modern heat cured acrylic resins generally advocate heating for approximately four hours. With such a short heating cycle, overnight cooling should be feasible. A protocol which allowed an extra day would also have an advantage.

LIMITATION

In this study only the cooling method was considered without applying a more wide combination of factors, including the other acrylic resin types, and other heating methods. In future inclusion of more varieties of acrylic resins with different heating protocols can be advocated in order to have all the comparisons in a single study.

CONCLUSION

Within the limitations of this study, it can be concluded that amongst the different cooling methods, linear dimensional change is more in quenching method followed by air and water bath methods respectively, though amongst the air and water bath methods there is no such significant difference. Amongst the materials, linear dimensional change is more in PYRAX acrylic when compared to the DPI resin. Though this dimensional change amongst the material is seen only when it is cooled by air or water bath method, in quenching no significant difference is observed between the two materials.

It can be concluded from this study that the dentures should be cooled either by bench cooling method or water bath cooling in order to reduce the linear dimensional changes so that there will be close contact between the denture base and the mucosa which is an important factor in retention of the acrylic denture base.

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