ORIGINAL RESEARCH

Assessment of Adaptability and Linear Dimensional Changes of Two Heat Cure Denture Base Resin with Different Cooling Techniques: An *In Vitro* Study

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ABSTRACT

Aim: The current study was designed to assess the linear dimensional changes and adaptability of two heat-cured denture base resins using various cooling methods.

Materials and methods: To prepare a total of 90 acrylic resin samples (45 acrylic resin samples for each material), four rectangular stainless-steel plates measuring 25 × 25 × 10 mm were fabricated. For both groups, the material was put into the mold at the dough stage. Group I – SR Triplex Hot Heat Cure acrylic; group II – DPI Heat Cure acrylic. Both groups used the same curing procedure. One of the following three techniques was used to cool the material (15 samples from each material) once the curing cycle was finished: (A) water bath, (b) quenching, and (C) air. A traveling microscope was used to measure the distance between the markings on the acrylic samples. The data was recorded and statistically analyzed.

Results: In SR Triplex Hot heat cure acrylic material, the maximum linear dimensional changes were found in the quenching technique (0.242 ± 0.05), followed by the air technique (0.168 ± 0.11) and the least was found in the water bath technique (0.146 ± 0.01). In DPI Heat Cure acrylic material, the maximum linear dimensional changes were found in the quenching technique (0.284 ± 0.09), followed by the air technique (0.172 ± 0.18) and the least was found in the water bath technique (0.158 ± 0.10). There was a statistically significant difference found between these three cooling techniques. On comparison of adaptability, the water bath technique, the marginal gap SR Triplex Hot was 0.012 ± 0.02 and DPI Heat Cure was 0.013 ± 0.02. In the quenching technique, the marginal gap SR Triplex Hot was 0.019 ± 0.04 and DPI Heat Cure was 0.016 ± 0.04. In the air technique, the marginal gap SR Triplex Hot was 0.017 ± 0.01 and DPI Heat Cure was 0.019 ± 0.01.

Conclusion: The present study concluded that among the different cooling methods, the water bath technique had the least linear dimensional change, followed by the air and quenching techniques. When comparing the materials, DPI Heat Cure acrylic resin showed a greater linear dimensional change than SR Triplex Hot heat cure acrylic resin.

Clinical significance: During polymerization, heat-cured acrylic resins experience dimensional changes. Shrinkage and expansion are dimensional changes that occur in heat-cured acrylic resins and have an impact on the occlusal relationship and denture fit. However, the denture base's material qualities and the different temperature variations it experiences during production may have an impact on this.

Keywords: Adaptability, Cooling techniques, Denture base materials, Dimensional change.

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INTRODUCTION

Dentistry has undergone a significant transformation with the invention and application of acrylic resin as a denture foundation material in 1937. Excellent color, chemical stability, and outstanding esthetic qualities characterize the resin. Acrylic resin has certain unsatisfactory qualities, yet it can be utilized to make dentures using a straightforward method. Hence, if relatively satisfying results are to be gained from the usage of the material, knowledge of chemistry, physical properties, attributes, features, and manipulative process is required. The denture's fit and the occlusal connection are impacted by the dimensional changes that shrinkage and expansion caused in heat-cured acrylic resins.[1]

Polymethylmethacrylate (PMMA) has been the material of choice because of its good esthetic qualities, sufficient strength, low water sorption, low solubility, absence of toxicity, and ease of molding and processing. Following is one of its main drawbacks has been acknowledged: The denture base's slight dimensional variation due to a lack of dimensional accuracy. The resin flasking technique, polymerization shrinkage, and time–temperature correlation during the polymerization process can all have an impact on this dimensional change in the denture base.[2]

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The denture conforms less to the tissue surface due to a variety of causes, including tension from stress release during deflasking, thermal contraction brought on by flask cooling, and shrinkage during polymerization.[3] Denture instabilities are most likely caused by later stress, water gain or loss, and inadequate denture polymerization, which all contribute to the dimensional alterations that take place after the denture is removed from the stone cast. It could be challenging to make up for dimensional changes that happen during polymerization after the resin base has been processed.[4] The goal of laboratory processing is to precisely duplicate the trial denture into the final prosthesis. Nonetheless, certain characteristics such as dimensional errors in the materials hinder the best achievement of this objective.[5]

As the cooling process goes on, the resin gets closer to its glass transition temperature a range that separates it from a more rubbery, soft state and usable condition. Different techniques are practiced for cooling such as a water bath wherein the flask is submerged for a whole day resulting in more uniform cooling of the denture. While in air cooling, the flask is bench cooled for nearly 12 hours at room temperature and in the quench cooling technique the flask is quickly quenched for 30 minutes under running tap water.[6] There is currently very little information available comparing various cooling techniques to heat-cured denture base resin. Hence the present study was conducted to assess the linear dimensional changes and adaptability of two heat-cured denture base resins using three various cooling methods.

MATERIALS AND METHODS

Fabrication of Samples

The current *in vitro* study was conducted in the department of prosthodontics, Sri Rajiv Gandhi College of Dental Science and Hospital, Bengaluru, India during the year 2019. To prepare a total of 90 acrylic resin samples (45 acrylic resin samples for each material), four rectangular stainless steel plates measuring 25 × 25 × 10 mm were fabricated. The metal specimens had four 0.5-mm-deep holes as index marks. On stainless steel plates, two layers of wax (Cavex, The Netherlands) were applied, and the mixture was flasked. Dental stone (Herodent; Vigodent, Petropolis, RJ, Brazil) was used to embed the flasks, and it was mixed in accordance with the manufacturer's recommendations (mixing 30 mL of water with 100 gm of powder). For both groups, the material was put into the mold at the dough stage.

- Group I—SR Triplex Hot heat cure acrylic: A 2:1 weight ratio of preweighed polymer and monomer was used to prepare 45 samples of PMMA resin. Each flask held four samples, for which approximately 8 gm of polymer and 4 mL of monomer were measured and mixed in a clean porcelain jar under similar conditions of temperature. The material was put into the mold while it was still in the dough.
- Group II—DPI Heat Cure acrylic: A total of forty-five DPI Heat Cure acrylic resin samples were made. Pre-weighed monomer and polymer were combined in a weight-to-weight ratio of 2:1. Four samples were included in each flask. The mixture was put in the mold during the dough stage after the polymer and monomer were measured and combined in a cleaned porcelain jar.

Following two hydropress trial closures, the flask was clamped under pressure using a bench press set at 100 kg/cm^2. This pressure was held for half an hour to ensure that the monomer and polymer penetrated the flask properly. The curing unit's temperature was first raised to 73°C, held for 1.5 hours, and then elevated to 100°C and maintained for 30 minutes after the flask was placed in a water bath at room temperature. Every group used the same curing procedure.

Table 1: Mean linear dimensional changes of SR Triplex Hot heat cure acrylic after three different cooling techniques

Cooling techniques	*Mean ± SD*	*F-value*	*p-value*
Water bath	0.146 ± 0.01	18.164	0.001
Quenching	0.242 ± 0.05		
Air	0.168 ± 0.11		

SD, standard deviation

One of the following three techniques was used to cool the material once the curing cycle was finished (15 samples from each material for each technique):

- Water bath: The flask was submerged in water for a full day.
- Quenching: After being taken out of the water bath, the flask was quickly quenched for 30 minutes under running tap water.
- Air: After being taken out of the water bath, the flask was bench cooled for 12 hours at room temperature.

Measurement of Linear Dimensional Changes

After that, the acrylic samples were taken out, polished, and finished. Using a travelling microscope, the distances between the markings A–B, B–C, C–D, and D–A on the acrylic samples were measured. The samples were kept on the microscope's horizontal table while the measurement was taken. Main scale reading (MSD) was recorded as the reading to the left of the zero on the vernier scale and vernier scale reading (VSD) was found by locating the best-aligned lines between the two scales and the total reading (TR) was computed using the microscope's least count, which was 0.001 cm. All of the samples' grooves were the focus of the measurements. Every sample was measured. The collected data have been recorded and subjected to statistical analysis.

Statistical Analysis

The statistical package for the social sciences, version 20 (IBM® SPSS® Corp.), was used to analyze all statistical data. To compare the groups that were assessed, an independent *t*-test was employed. When the analysis of variance (ANOVA) was significant, a *post hoc* test was performed for a pairwise comparison after one-way ANOVA was used to evaluate the various examined areas; $p < 0.05$ was used as the significance level.

RESULTS

Table 1 shows the mean linear dimensional changes of SR Triplex Hot heat cure acrylic after three different cooling techniques. The maximum linear dimensional changes were found in the quenching technique with a mean value of 0.242 ± 0.05, followed by the air technique with a mean value of 0.168 ± 0.11 and the least was found in water bath technique with a mean value of 0.146 ± 0.01. There was a statistically significant difference found between these three cooling techniques. As the ANOVA test was found significant, the *post hoc* test was used to explore the mean differences between pairs of groups and found a significant difference between water bath and quenching; air and quenching techniques ($p < 0.001$).

Table 2 depicts the mean linear dimensional changes of DPI Heat Cure acrylic after three different cooling techniques. The

Table 2: Mean linear dimensional changes of DPI heat cure acrylic after three different cooling techniques

Cooling techniques	*Mean ± SD*	*F-value*	*p-value*
Water bath	0.158 ± 0.10	19.439	0.001
Quenching	0.284 ± 0.09		
Air	0.172 ± 0.18		

SD, standard deviation

Table 3: Mean adaptability of two heat cure acrylic after three different cooling techniques

Cooling techniques	*SR triplex hot (Mean ± SD)*	*DPI heat cure (Mean ± SD)*	*t-value*	*p-value*
Water bath	0.012 ± 0.02	0.013 ± 0.02	4.362	0.677
Quenching	0.019 ± 0.04	0.016 ± 0.04	5.038	0.906
Air	0.017 ± 0.01	0.019 ± 0.01	4.496	0.854

SD, standard deviation

maximum linear dimensional changes were found in the quenching technique with a mean value of 0.284 ± 0.09 followed by the air technique with a mean value of 0.172 ± 0.18 and the least was found in the water bath technique with a mean value of 0.158 ± 0.10. There was a statistically significant difference found between these three cooling techniques. As the ANOVA test was found significant, the *post hoc* test was used to explore the mean differences between pairs of groups and found a significant difference between water bath and quenching; air and quenching techniques ($p < 0.001$).

The adaptability of two heat cure acrylic techniques after three different cooling techniques was assessed in Table 3. On comparison of the water bath technique, the marginal gap SR Triplex Hot was 0.012 ± 0.02 and DPI Heat Cure was 0.013 ± 0.02. In the quenching technique, the marginal gap SR Triplex Hot was 0.019 ± 0.04 and DPI Heat Cure was 0.016 ± 0.04. In the air technique, the marginal gap SR Triplex Hot was 0.017 ± 0.01 and DPI Heat Cure was 0.019 ± 0.01. There was no statistically significant difference found between these materials and in all three cooling techniques with respect to adaptability of the materials.

DISCUSSION

Acrylic resin has been a popular choice for denture bases because of its outstanding color stability, fine esthetic qualities, and ease of use in denture assembly. Acrylic resin dentures are generally acknowledged to have a number of drawbacks, despite their many benefits, including dimensional instability. When dentures are processed, some of the stress that the polymers undergo as they drop below this temperature is released when the dentures are taken out of the molds. The amount of shrinkage that happens is directly related to the range of cooling below the second-order transition temperature.[7]

To minimize denture delivery time for the targeted special needs population those with physical disabilities, chronic illnesses, or other social and economic challenges a more robust, more economical denture production method must be used. Good denture base adaptation that minimizes deformation and shrinkage is essential to the wearer's experience in all respects at the same time.[8]

A variety of techniques have been employed to investigate the dimensional accuracy of denture base materials. These techniques include using an optical comparator to measure the distance between two reference points on the denture base, a measuring microscope, postdam discrepancies, measuring vertical dimensions or incisor pin movement, weighing silicone material to quantify the space between the denture and master cast, and, more recently, superimposing scanned data using specialized software.[9,10]

When using the standard method for flasking acrylic resin, the flask is positioned in typical clamps following the last pressing in a hydraulic press. In the event that this state persists, the acrylic resin dough may release any remaining internal strains prior to polymerization. Reduced tissue adaption of the denture may result from the release of residual internal stress together with polymerization shrinkage, thermal contraction during flask cooling, and strain concurrent with stress release during deflasking.[11]

In the present investigation, the temperature was first raised to 73°C and remained there for one and a half hours. It was then elevated to 100°C and stayed there for an additional hour. In actuality, the specimen's thickness and surface area determine how much heat dissipates in the denture. A greater processing temperature can be utilized to improve the resin's polymerization efficiency as long as heat dissipation occurs.[12]

In the present study, the least linear dimensional changes were found in the water bath technique compared to the air and Quenching technique. Similarly, according to Shinsuke S et al.[13] and Yeung KC et al.,[14] denture bases may be produced with less distortion as compared to quench cooling due to the reduction in residual stress achieved by gently cooling the denture resins by water bath cooling. While the stress resulting from polymerization contraction releases more gradually, the stress resulting from thermal contraction releases the denture quickly once it is taken out of the mold. Similarly, according to Robert KF et al.[15] This is because in quench cooling stress from polymerization affects molecules by involving polymer chains, whereas thermal contraction is of an immediate mechanical origin.

Similar to the present study, Bhanodya M et al.[16] and Ganzarolli G et al.[17] state that the primary factor contributing to the stress release that happens when the denture separates from the cast is thought to be the difference in thermal contraction between the acrylic resin and the mold during cooling. This difference is also thought to be the cause of any residual stress in the processed denture. Denture dimensional changes are influenced by the flask's rate of cooling following processing; the quenching process, for example, causes uneven thermal contraction in different places, increasing tension and consequent warpage. The present study results were similar to Savirmath A and Mishra V[6] study, stating that a denture cooled slowly in a water bath should cool more uniformly and see less dimensional change. Although it could be anticipated that the bench cooling approach would permit cooling without undue stress accumulation, it might be vulnerable to slight temperature variations.

In the present study, the adaptability of the SR Triplex Hot material was slightly superior to DPI Heat Cure material in all the cooling techniques. Fast cooling during the quenching process may have caused an uneven thermal contraction, which may have partially relieved the resulting tension during deflasking, resulting in increased warpage among the cooling techniques utilized for the acrylic specimens. Similarly, Chen JC et al.[18] stated that there could be some influence on distortion from the increased volumetric shrinkage that happens during the dentures' polymerization. The denture sample and cast specimen in the quenched group separated by a greater amount, suggesting that the flask's rate of cooling has a significant impact on the denture shrinkage that has been observed.

The limitation of the present study includes, that it only examined the cooling method; other heating methods and a wider range of factors were not taken into account. It was unable to control the mix's homogeneity, the existence of internal porosity, or the release of stresses during finishing operations. It might be suggested in the future to include additional types of acrylic resins with various heating techniques to compile all the comparisons into a single study.

CONCLUSION

The present study concluded that among the different cooling methods, the water bath technique had the least linear dimensional change, followed by the air and quenching techniques. When comparing the materials, DPI Heat Cure acrylic resin showed a greater linear dimensional change than SR Triplex Hot heat cure acrylic resin.

REFERENCES

1. Arora S, Khindaria SK, Garg S, et al. Comparative evaluation of linear dimensional changes of four commercially available heat cure acrylic resins. Contemp Clin Dent 2011;2(3):182–187. DOI: 10.4103/0976-237X.86452.
2. Wieckiewicz M, Opitz V, Richter G, et al. Physical properties of polyamide-12 versus PMMA denture base material. Biomed Res Int 2014;2014:150298. DOI: 10.1155/2014/150298.
3. Consani RLX, Domitti SS, Mesquita MF, et al. Effects of packing types on the dimensional accuracy of denture base cured by the conventional cycle in relation to the post pressing times. Braz Dent J 2004;15(1):63–67. DOI: 10.1590/s0103-64402004000100012.
4. Consani RLX, Domitti SS, Mesquita MF, et al. Dimensional stability of maxillary denture bases flasked with the RS tension system. Braz J Oral Sci 2003;2(4):152–155. DOI: 10.20396/bjos.v2i4.8641666.
5. Dixon DL, Breeding LC, Ekstrand KG. Linear dimensional variability of three denture base resins after processing and in water storage. J Prosthet Dent 1992;68(1):196–200. DOI: 10.1016/0022-3913(92)90304-s.
6. Savirmath A, Mishra V. A comparative evaluation of the linear dimensional changes of two different commercially available heat cure acrylic resins during three different cooling regimens. J Clin Diagn Res 2016;10(11):ZC50–ZC54. DOI: 10.7860/JCDR/2016/22066.8903.
7. Komiyama O, Kawara M. Stress relaxation of heat-activated acrylic denture base resin in the mold after processing. J Prosthet Dent 1998;79(2):175–181. DOI: 10.1016/s0022-3913(98)70213-6.
8. Jadhav SS, Mahajan N, Sethuraman R. Comparative evaluation of the amount of the residual monomer in conventional and deep-frozen heat cure polymethylmethacrylate acrylic resin: An in vitro study. J Indian Prosthodont Soc 2018;18(2):147–153. DOI: 10.4103/jips.jips_206_17.
9. Hsu CY, Yang TC, Wang TM, et al. Effects of fabrication techniques on denture base adaptation: An in vitro study. J Prosthet Dent 2020;124(6):740–747. DOI: 10.1016/j.prosdent.2020.02.012.
10. Hwang HJ, Lee SJ, Park EJ, et al. Assessment of the trueness and tissue surface adaptation of CAD-CAM maxillary denture bases manufactured using digital light processing. J Prosthet Dent 2019;121(1):110–117. DOI: 10.1016/j.prosdent.2018.02.018.
11. Consani RL, Domitti SS, Consani S. Effect of a new tension system, used in acrylic resin flasking, on the dimensional stability of denture bases. J Prosthet Dent 2002;88(3):285–289. DOI: 10.1067/mpr.2002.128447.
12. Yau WF, Cheng RK, Clark TW. Pressure and temperature changes in heat cured acrylic resins during processing. Dent Materials 2002;18(8):622–229. DOI: 10.1016/s0109-5641(01)00092-6.
13. Shinsuke S, Triyandani G, Taizo H, et al. Influence of thickness and location on the residual monomer content of denture base cured by the three processing methods. J Prosthet Dent 1994;72(1):19–22. DOI: 10.1016/0022-3913(94)90210-0.
14. Yeung KC, Chow TW, Clark P. Temperature and dimensional changes in the two stages processing technique to cure complete denture. J Dent 1995;23(4):245–253. DOI: 10.1016/0300-5712(95)91190-x.
15. Robert KF, Clark Y, Cheng Y, et al. Events in the mould during heat processing of the polymethyl methacrylate. J Prosthodont. 2001;11(1):29–31. PMID: 12705036.
16. Bhanodya M, Andrzej SJ, David R, et al. Dimensional change of heat cured acrylic resin dentures with three different cooling regimens following a standard curing cycle. J Dent 2005;13(4):159–163. PMID: 16411572.
17. Ganzarolli G, Rached RN, Garcia RCMR, et al. Effect of cooling procedure on final denture base adaptation. J Oral Rehabil 2002;29(8):787–790. DOI: 10.1046/j.1365-2842.2002.00886.x.
18. Chen JC, Lacefield WR, Castleberry DJ. Effect of denture thickness and curing cycle on the dimensional stability of acrylic resin denture bases. Dent Materials 1988;4(1):20–24. DOI: 10.1016/s0109-5641(88)80083-6.