ORIGINAL RESEARCH

# Evaluation of Linear Dimensional Stability of Monomethacrylate-based Dental Polymer Containing a Novel Tricyclic Diacrylate Cross-linker Using a Novel Surface-level Index Technique

Ranganathan Ajay[1], Vikraman Rakshagan[2], Ramajayam Sasikala[3], Kandasamy Baburajan[4], Gnanasambandam Kalarani[5], Karthigeyan Suma[6]

*Received on:* 12 June 2022; *Accepted on:* 08 August 2022; *Published on:* 26 August 2022

## Abstract

**Aim and objectives:** To evaluate and compare the linear dimensional stability of denture base copolymer containing a cycloaliphatic comonomer by employing conventional engraving technique (ET) and a novel surface-level index technique (SLIT).

**Materials and methods:** Group I employed the SLIT and group II employed the ET. The subgroups were divided under both groups based on the: (1) Cycloaliphatic comonomer's concentrations (SG0, SG10, SG20, EG0, EG10, and EG20); (2) Corresponding mold spaces (SM0, SM10, SM20, EM0, EM10, and EM20). Rectangular mold spaces with four reference points were measured using the Euclidean norm. A total of 120 rectangular specimens ($n$ = 20 for each subgroup) were fabricated and the distances between the reference points in the specimens were measured. The differences between the Euclidean norms of the molds and the resultant specimens were recorded.

**Results:** A significant difference in the linear distortion between the techniques till 10% TCDDMDA comonomer concentration was observed beyond which there is no difference between the techniques. Within the techniques, a statistically significant difference in the linear distortion among and between the subgroups was evident.

**Conclusion:** Employing the SLIT showed an amplified linear distortion of the denture base specimens when compared to ET. The novel copolymer P(MMA-*Co*-TCDDMDA) with 20% TCDDMDA demonstrated negligible linear dimensional distortion with either technique.

**Clinical significance:** Employing P(MMA-*Co*-TCDDMDA) copolymer as denture base shall not only offset dimensional and occlusal inaccuracies but also improve the retention and stability of the denture base and eventually the life quality of the edentulous population.

**Keywords:** Copolymer, Cycloaliphatic, Denture base, Dimensional stability, Linear shrinkage.

*World Journal of Dentistry* (2022): 10.5005/jp-journals-10015-2106

## Introduction

Poly(methyl methacrylate) resin [P(MMA)] was introduced to dentistry in 1937. Thermo-polymerized (TP) denture base polymer is extensively employed in prosthetic dentistry. Dimensional change is the unsolved problem with the P(MMA) complete dentures. Processing shrinkage is a prime factor causing dimensional changes or inaccuracies. Several types of research have evaluated the dimensional changes by comparing different denture base materials, configurations of the palatal vault, packing methods, polymerization methods, and curing cycles. All these investigations elicited definite dimensional changes occurring in TP-P(MMA).[1] A fundamental integrant for determining the *in vivo* serviceability of denture materials was the *in vitro* research evaluating dimensional accuracy.[2] A denture can undergo both volumetric and linear polymerization shrinkages (PS). The linear PS predominantly due to thermal aberrations is accountable for consequential effects on the denture base adaptation, intercuspation, and occlusal vertical dimension.[3]

Previous studies used calipers, gauges, comparators, traveling microscopes, and radiographs for measuring the linear dimensional changes.[2] Linear shrinkage values ranging from 0.26 to 1.20% were reported. However, concerning TP-P(MMA), approximately 0.50% of linear shrinkage was reported.[4] A significant pitfall of this

[1]Department of Prosthodontics & Crown and Bridge, Vivekanandha Dental College for Women, Namakkal, Tamil Nadu, India

[2]Department of Prosthodontics and Implant Dentistry, Saveetha Dental College & Hospital, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India

[3]Department of Prosthodontics & Crown and Bridge, Vinayaka Mission's Sankarachariyar Dental College, Vinayaka Mission's Research Foundation, Salem, Tamil Nadu, India

[4]Department of Prosthodontics & Crown and Bridge, RVS Dental College and Hospital, Coimbatore, Tamil Nadu, India

[5,6]Department of Prosthodontics & Crown and Bridge, Government Dental College, Cuddalore, Tamil Nadu, India

**Corresponding Author:** Ranganathan Ajay, Department of Prosthodontics & Crown and Bridge, Vivekanandha Dental College for Women, Namakkal, Tamil Nadu, India, Phone: +91 8754120490, e-mail: jrangclassiq@gmail.com

**How to cite this article:** Ajay R, Rakshagan V, Sasikala R, *et al.* Evaluation of Linear Dimensional Stability of Monomethacrylate-based Dental Polymer Containing a Novel Tricyclic Diacrylate Cross-linker Using a Novel Surface-level Index Technique. World J Dent 2022;13(6):568–573.

**Source of support:** Nil

**Conflict of interest**: None

*© The Author(s). 2022 Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by-nc/4.0/), which permits unrestricted use, distribution, and non-commercial reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated.*

material is the manifestation of processing deformation when the polymerized dentures are removed from the cast irrespective of the polymerizing technique or acrylic material selected.[5] PS, thermal shrinkage due to coefficient of thermal expansion mismatch between the investment and resin polymer while cooling, and discharge of residual stress while deflasking are the combined factors causing compromised tissue adaptation by the denture base. The residual stress release, water sorption or desorption, and insufficient processing are facets accountable for the dimensional aberrations while the denture is removed from the model and causes denture instability.[6]

The addition of various materials such as synthetic fibers, metallic wires, polystyrene-rubber, and inorganic fillers in P(MMA) have been attempted to reduce the shrinkage.[3,7,8] However, these additions have their limitations and pitfalls making the modifications non-durable. Poor adhesion between the wire and resin is the crucial problem with the use of metal wire, leading to negligible enhancement of mechanical properties.[9–15] However, monomeric modification is not uncommon.[16] Nevertheless, literature concerning PS after monomeric modification is scarce. P(MMA) copolymerized with norbornyl- and phenyl-methacrylate comonomers evinced less PS.[17] Not long ago, CP of tricyclodecane dimethanol diacrylate (TCDDMDA) crosslinking comonomer with P(MMA) was established and the properties of the resultant copolymer P(MMA-*Co*-TCDDMDA) were good when compared to the conventional P(MMA).[18–23] However, the linear dimensional change of this copolymer has not been experimented with.

In the previous studies, the acrylic specimens were prepared by engraving holes (dimpling) in either the wax pattern[4,24,25] or the stone/metal molds.[26,27] For convenience, the above-mentioned techniques are collectively termed engraved-index techniques (ET). Engraving holes would lead to mechanical interlocking of either stone in the acrylic specimen or acrylic in the stone. This may directly affect the magnitude of the linear shrinkage of acrylic specimens. Therefore, marking or indexing at the level of acrylic or mold surface without dimpling or engraving may yield the actual linear shrinkage magnitude and this technique shall be termed as SLIT henceforth. Hence, the current research aimed to evaluate and compare the linear dimensional stability of the P(MMA-*Co*-TCDDMDA) copolymer by ET and the novel SLIT. The first null assumption is that the technique employed would not have any effect on the linear dimensions of the copolymer. The second null assumption is that the linear dimensions of the TP-P(MMA), assessed by either technique, would not be influenced by the TCDDMDA comonomer's substitution.

## Materials and Methods

Two main groups of the study were categorized based on the indexing technique. Group I employed the novel SLIT and group II employed the conventional ET. One hundred and twenty ($n$ = 60 for each group) rectangular specimens (75 × 25 × 3 $mm^3$)[26] were prepared out of plastic dies. Dies were invested using type IV die stone (Kalrock: Kalabhai Karson Private Limited, Mumbai, India) in the dental flask to obtain a mold space (water-powder ratio: 0.22) (Fig. 1). Another plastic pattern with a hole at each corner that fits the mold space was made (Fig. 2). For the novel SLIT, the pattern was oriented in the mold section and four distinct marks were made on the mold's surface through the holes by an indelible pencil (Fig. 3). Graphite pencil markers (2 mm diameter and 2 mm height) were positioned and affixed at the previously indexed mold surface markings. For the ET, a needle was inserted through the holes of the pattern to make a single, pointed mark on the mold's surface. Later, these marked points were prepared approximately 1.5–2.0 mm deep with straight round end diamond bur (SR-13; ISO 141/016; Mani

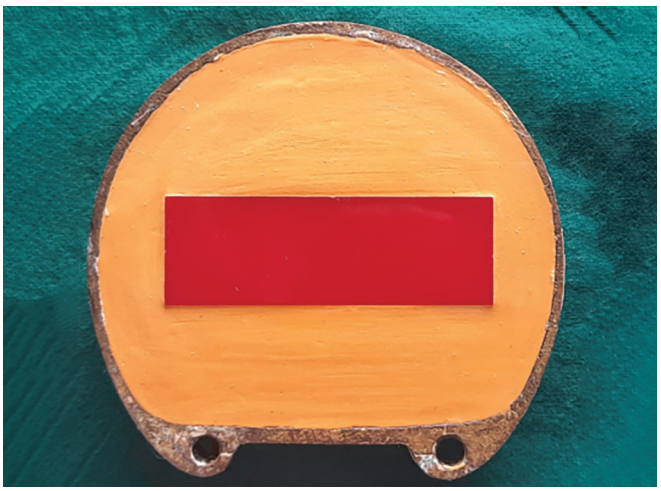


**Fig. 1:** Red acrylic die invested in type IV dental stone

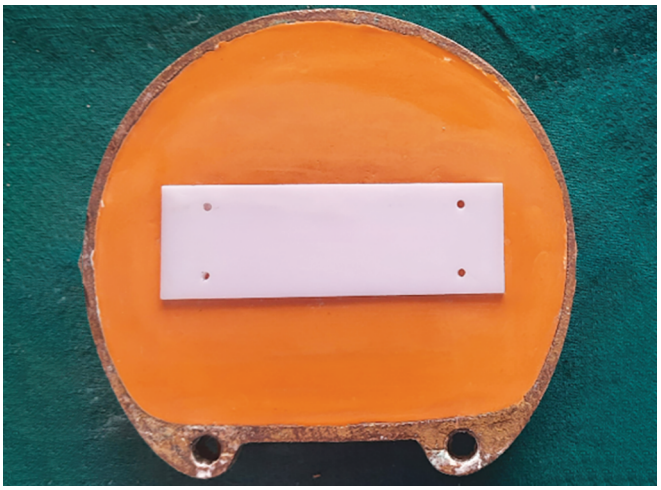


**Fig. 2:** White acrylic template with holes at the four corners placed in the mold space

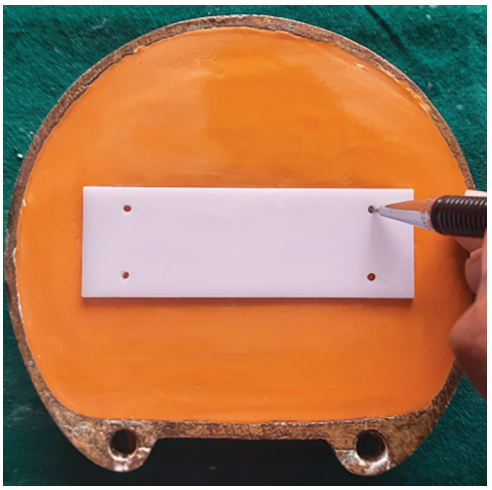


**Fig. 3:** Marking the indexing sites through the hole

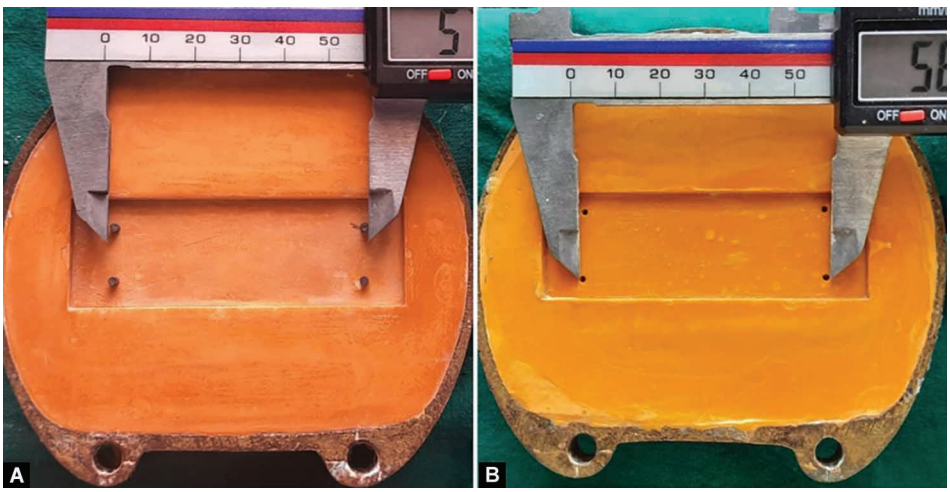
Inc. Tochigi, Japan). The pits engraved in the mold would generate positive juts on the polymerized specimens for mensuration. The reference points in the molds of both SLIT and ET were assigned alphabets for reference videlicet A, B, C, and D.

Under each group, subgroups ($n = 20$) were divided based on the TCDDMDA comonomer concentration. In group I, subgroup SG0 comprised of P(MMA) specimens made of 100% methyl methacrylate (MMA). Subgroups SG10 and SG20 comprised of P(MMA-*Co*-TCDDMDA) specimens containing 10 and 20% comonomer, respectively. As mentioned above, group II was also divided into EG0, EG10, and EG20 subgroups. With a digital Vernier caliper (Mitutoyo 500-197-20, Mitutoyo South Asia Pvt. Ltd., Bengaluru, India), six mensuration (AB, CD, CB, DA, CA, and DB) were measured for each mold under individual subgroups (SM0, SM10, SM20, EM0, EM10, and EM20). The six-dimensional ($n = 6$) measurements in the molds were determined by the Euclidean norm: $\|x\|_e = \sqrt{\sum_{i=1}^{n} x_i^2}$ (Fig. 4). This norm is a definite manifestation of the comprehensive dimensions of four measuring points on each mold.[2,24,26] Compression molding technique for specimen fabrication, thermopolymerization regimen, and steps concerning finishing of specimens were described in the previous research.[20] The Euclidean norm determination of the polymerized specimens was as same as the molds (Fig. 5). Differences in the magnitude of Euclidean norms between molds and corresponding resultant subgroup specimens [linear distortion: mold minus (–) subgroup] were calculated.

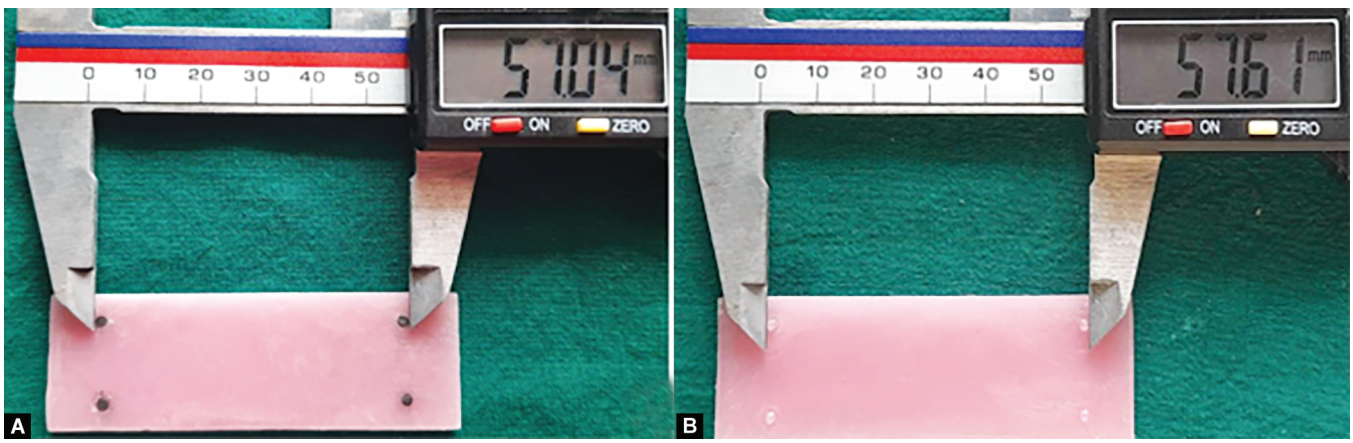
The data analyses were performed by a statistical software program (SPSS Inc., Chicago, IL, USA, version 20.0). The normal distribution of the data was ascertained by Shapiro-Wilk's test ($p > 0.05$). An independent *t*-test was employed to determine the level of significance between the groups. The level of significance within the groups and between the subgroups was tested with one-way ANOVA followed by *post hoc* Tukey's HSD multiple comparison test. A statistically significant difference was claimed when the *p*-value is less than 0.05.

## Results

The mean linear distortions and standard deviations (SD) of SM0–SG0, EM0, EG0. SM10–SG10, EM10–EG10, SM20–SG20, and EM20–EG20 were 1.8549 ± 0.1015, 0.9012 ± 0.0400, 0.9968 ± 0.0980, 0.0311 ± 0.0243, 0.0001 ± 0.0006, and 0.00005 ± 0.00051, respectively (Table 1). The independent *t*-test revealed a significant difference ($p = 0.000$) in the linear distortion between the techniques till 10% TCDDMDA comonomer concentration in the P(MMA-*Co*-TCDDMDA) copolymer. At 20% TCDDMDA concentration, there is no significant difference ($p = 0.599$) between the techniques. Within the techniques, one-way ANOVA (Table 2) and *post hoc* Tukey HSD




**Figs 4A and B:** Linear measurements of mold in (A) SLIT; (B) ET




**Figs 5A and B:** Linear measurements in specimens obtained from (A) SLIT; (B) ET

multiple comparison tests (Table 3) declared significant differences in the linear distortion among and between the subgroups ($p$ = 0.000), respectively. Hence, by employing SLIT, the actual linear distortion can be deduced and the incorporation of TCDDMDA cross-linker reduced the linear distortion with either of the techniques.

## Discussion

The linear distortion of the polymerized specimens was investigated by ET and the novel SLIT. The specimens of subgroups SG0 and SG10 exhibited an amplified magnitude of linear distortion than their corresponding counterparts EG0 and EG10 subgroups. Hence, the first null hypothesis was rejected. This can be attributed to the fact that the resin anchored in the engraved indentations of the mold would restrict the shrinking phenomenon. This factual concept has been largely proven and accepted in previous research. Drilling anchoring holes into the cast along the posterior palatal area was a successful strategy in eradicating the shrinkage of the denture base with negligible warpage.[28] Instead of allowing the denture base to distort toward the investing matrix, the resin trapped in the anchoring holes held the denture base adapted to the cast during polymerization. Other studies found that anchoring with mechanical retention holes not only diminished the denture distortion but also reduced occlusal discrepancies due to tooth movement and diminished incisal pin raise from the incisal table.[29–31] Therefore, from the above studies, it is obvious that utilizing ET for evaluating the linear distortion would yield false, restricted, and diminished values. Hence, in the present study, the novel SLIT was employed which yielded factual, unrestricted, and amplified linear distortion values of acrylic specimens.

While comparing the linear distortions of SG20 and EG20 subgroups, there is no significant difference between them. Within the subgroups in either technique, there was a significant difference in the linear distortion. Subgroups SG0 and EG0 suffered the greatest distortion whilst the dimensions of subgroups SG20 and EG20 were almost similar to their corresponding molds (SM20 and EM20, respectively) which ultimately means the linear distortion is negligible. Hence, the second null hypothesis was also rejected. This can be attributed to the addition of 20% TCDDMDA in the proprietary comonomer. This comonomer possesses high reactive double carbon-carbon (C = C) bonds. The tricyclic-ringed structure at the center of the TCDDMDA structure protects the monomer's alignment and thus bypasses PS.[18] Before reaching the point of solidification, the tricyclic ring sterically decelerates the polymerization pace and promotes adjoining polymer chains to slither aiding in the relaxation of residual stress.[18] Another plausible explanation for negligible linear shrinkage/distortion in SG20 and EG20 subgroups could be accredited to the cross-linking property of the TCDDMDA comonomer. The addition of cross-linking agents caused low molecular weight polymers to gain dimensional stability similar to that of the high molecular weight polymers.[32]

Denture thickness and processing technique affect the dimensional accuracy. Wolfaardt et al.[33] demonstrated nonuniform dimensional changes in the flask during TP-P(MMA) resin processing. It was suggested that the dimensional aberrations would vary depending on the thickness of the resin undergoing polymerization and the location within the flask.[33] For injection molding, the linear shrinkage was in the 3.5 > 1.5 > 2.5 mm specimen thickness order whilst for compression molding, it was 1.5 > 2.5 > 3.5 mm order.[34] Hence, the mold selected was 3 mm thick utilized for compression molding in the present study. The present study did not consider the water sorption factor. Attention was primarily focused to compare the SLIT with ET and the effect of TCDDMDA comonomer addition on the linear dimensional stability of the novel denture base copolymer P(MMA-*Co*-TCDDMDA). Goodkind and Schulte[35] concluded that water immersion does not alter the denture base mensuration. Ninety days of water storage did not affect the linear dimension of denture bases considering the deflasking period as a variable.[36] Water immersion resulted in sizable dimensional inaccuracies and denture base adaptation issues after 180 days.[37] Substantial acrylic expansion is evident due to water sorption, where the absorbed water molecules exert thrust on the polymeric macromolecules to move apart and eventually improves the denture's tissue adaptation by compensating the PS.[37,38]

**Table 1:** Independent *t*-test between the groups

| *Linear distortion* | *Mean ± SD* | *p-value* |
|---|---|---|
| SM0–SG0 | 1.8549 ± 0.1015 | 0.000 |
| EM0–EG0 | 0.9012 ± 0.0400 | |
| SM10–SG10 | 0.9968 ± 0.0980 | 0.000 |
| EM10–EG10 | 0.0311 ± 0.0243 | |
| SM20–SG20 | 0.0001 ± 0.0006 | 0.599 |
| EM20–EG20 | 0.00005 ± 0.00051 | |

**Table 3:** *Post hoc* Tukey's HSD multiple comparisons

| *Linear distortion* | *Compared linear distortion* | *Mean difference* | *Sig.* |
|---|---|---|---|
| 1. Group I | | | |
| SM0–SG0 | SM10–SG10 | 0.858150* | 0.000 |
| | SM20–SG20 | 1.854800* | 0.000 |
| SM10–SG10 | SM20–SG20 | 0.996650* | 0.000 |
| 2. Group II | | | |
| EM0–EG0 | EM10–EG10 | 0.870100* | 0.000 |
| | EM20–EG20 | 0.901100* | 0.000 |
| EM10–EG10 | EM20–EG20 | 0.031000* | 0.002 |

*, the mean difference is significant at the 0.05 level

**Table 2:** One-way ANOVA within the groups

| *Linear distortion* | *Mean ± SD* | *f-value* | *p-value* |
|---|---|---|---|
| 1. Group I | | | |
| SM0–SG0 | 1.8549 ± 0.1015 | | |
| SM10–SG10 | 0.9968 ± 0.0980 | 2595.686 | 0.000 |
| SM20–SG20 | 0.0001 ± 0.0006 | | |
| 2. Group II | | | |
| EM0–EG0 | 0.9012 ± 0.0400 | | |
| EM10–EG10 | 0.0311 ± 0.0243 | 7142.511 | 0.000 |
| EM20–EG20 | 0.00005 ± 0. 00051 | | |

Effect of water storage for different time intervals on linear or volumetric shrinkage and assessment of denture base adaptation on the cast may be considered for future investigations.

## Conclusion

Within the research constraints, it is concluded that employing SLIT in measuring the linear distortion provided a factual and unrestricted shrinkage of the copolymer when compared to ET. The novel copolymer P(MMA-*Co*-TCDDMDA) containing 20% TCDDMDA in MMA demonstrated negligible linear dimensional distortion with either technique.

## References


1. Ranganath LM, Shet RGK, AG Rajesh, et al. The effect of fiber reinforcement on the dimensional changes of poly methyl methacrylate resin after processing and after immersion in water: an *in vitro* study. J Contemp Dent Pract 2011;12(4):305–317. DOI: 10.5005/jp-journals-10024-1051
2. Baydas S, Bayindir F, Akyil MS. Effect of processing variables (different compression packing processes and investment material types) and time on the dimensional accuracy of polymethyl methacrylate denture bases. Dent Mater J 2003;22(2):206–213. DOI: 10.4012/dmj.22.206
3. Naik P, Mathur S. An in vitro study evaluating the effect of addition of carbon nanotubes on linear dimensional change of heat - polymerized denture base resin. Natl J Integr Res Med 2017;8(2): 65–68. http://nicpd.ac.in/ojs-/index.php/njirm/article/view/1205.
4. Duymus ZY, Yanikoglu ND. Influence of a thickness and processing method on the linear dimensional change and water sorption of denture base resin. Dent Mater J 2004;23(1):8–13. PMID: 15164918.
5. Chen JC, Lacefield WR, Castleberry DJ. Effect of denture thickness and curing cycle on the dimensional stability of acrylic resin denture bases. Dent Mater 1988:4(1):20–24. DOI: 10.1016/s0 109-5641(88)80083-6
6. Grunewald AH, Paffenbarger GC, Dickson G. The effect of molding processes on some properties of denture resins. J Am Dent Assoc 1952;44(3):269–284. DOI: 10.1016/s0002-8177(52)43004-4
7. Begum SS, Ajay R, Devaki V, et al. Impact strength and dimensional accuracy of heat-cure denture base resin reinforced with $ZrO_2$ nanoparticles: an *in vitro* study. J Pharm Bioallied Sci 2019;11(Suppl 2):S365–S370. DOI: 10.4103/JPBS.JPBS_36_19
8. Aljafery AMA, Basima MAH. Effect of addition $ZrO_2$-$Al_2O_3$ nanoparticles mixture on some properties and denture base adaptation of heat-cured acrylic resin denture base material. J Bagh Coll Dentistry 2015;27(3):15–21. DOI: 10.12816/0015028
9. Carroll CE, Von Fraunhofer JA. Wire reinforcement of acrylic resin prostheses. J Prosthet Dent 1984;52(5):639–641. DOI: 10.1016/0022-3913(84)90132-x
10. Ruffino AR. Effect of steel strengtheners on fracture resistance of the acrylic resin complete denture base. J Prosthet Dent 1985;54(1):75–78. DOI: 10.1016/s0022-3913(85)80074-3
11. Vallittu PK, Lassila VP. Effect of metal strengthener's surface roughness on fracture resistance of acrylic denture base material. J Oral Rehabil 1992;19(4):385–391. DOI: 10.1111/j.1365-2842.1992.tb01580.x
12. Jagger DC, Harrison A, Jandt KD. The reinforcement of dentures. J Oral Rehabil 1999;26(3):185–194. DOI: 10.1046/j.1365-2842.1999.00375.x
13. Sehajpal SB, Sood VK. Effect of metal fillers on some physical properties of acrylic resin. J Prosthet Dent 1989;61(6):746–751. DOI: 10.1016/s0022-3913(89)80055-1
14. Ellakwa AE, Morsy MA, El-Sheikh AM. Effect of aluminum oxide addition on the flexural strength and thermal diffusivity of heat-polymerized acrylic resin. J Prosthodont 2008;17(6):439–444. DOI: 10.1111/j.1532-849X.2008.00318.x
15. DeBoer J, Vermilyea SG, Brady RE. The effect of carbon fiber orientation on the fatigue resistance and bending properties of two denture resins. J Prosthet Dent 1984;51(1):119–121. DOI: 10.1016/s0022-3913(84)80117-1
16. Ajay R, Suma K, Ali SA. Monomer modifications of denture base acrylic resin: a systematic review and meta-analysis. J Pharm Bioallied Sci 2019;11(Suppl 2):S112–S125. DOI: 10.4103/JPBS.JPBS_34_19
17. Umemoto K, Kurata S. Basic study of a new denture base resin applying hydrophobic methacrylate monomer. Dent Mater J 1997;16(1):21–30. DOI: 10.4012/dmj.16.21
18. Ajay R, Suma K, Jayakrishnakumar S, et al. Chemical characterization of denture base resin with a novel cycloaliphatic monomer. J Contemp Dent Pract 2019;20(8):940–946. PMID: 31797851. DOI: 10.5005/jp-journals-10024-2634
19. Ajay R, Suma K, Sasikala R, et al. Chemical structure and physical properties of heat-cured poly(methyl methacrylate) resin processed with cycloaliphatic comonomer: an *in vitro* study. J Contemp Dent Pract 2020;21(3):285–290. PMID: 32434976. DOI: 10.5005/jp-journals-10024-2769
20. Ajay R, Suma K, Rahila C, et al. Effect of novel cycloaliphatic comonomer on the flexural and impact strength of heat-cure denture base resin. J Oral Sci 2021;63(1):14–17. DOI: 10.2334/josnusd.19-0493
21. Ajay R, Suma K, Rakshagan V, et al. Effect of novel cycloaliphatic comonomer on surface roughness and surface hardness of heat-cure denture base resin. J Pharm Bioallied Sci 2020;12(Suppl 1):S67–S72. DOI: 10.4103/jpbs.JPBS_20_20
22. Ajay R, Suma K, SreeVarun M, et al. Evaluation of *In vitro* cytotoxicity of heat-cure denture base resin processed with a dual-reactive cycloaliphatic monomer. J Contemp Dent Pract 2019;20(11):1279–1285. PMID: 31892679. DOI: 10.5005/jp-journals-10024-2688
23. Ajay R, Suma K, Arulkumar S, et al. Histocompatibility of novel cycloaliphatic comonomer in heat-cured denture base acrylic resin: histomorphometric analysis in rats. J Pharm Bioallied Sci 2020;12(Suppl 1):S453–S461. DOI: 10.4103/jpbs.JPBS_139_20
24. Salim S, Sadamori S, Hamada T. The dimensional accuracy of rectangular acrylic resin specimens cured by three denture base processing methods. J Prosthet Dent 1992;67(6):879–881. DOI: 10.1016/0022-3913(92)90606-b
25. 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
26. O'Toole TJ, Furnish GM, von Fraunhofer JA. Linear distortion of acrylic resin. J Prosthet Dent 1985;53(1):53–55. DOI: 10.1016/0022-3913(85)90065-4
27. Gharechahi J, Asadzadeh N, Shahabian F, et al. Dimensional changes of acrylic resin denture bases: conventional versus injection-molding technique. J Dent (Tehran) 2014;11(4):398–405. PMID: 25584050.
28. RistauB. Shrinkage and warpage of denture base materials using the Ristau Platform and the Ristau Post Dam. Quintessence Dent Technol 1981;5(7):671–674. PMID: 7029670.
29. Polyzois GL. Improving the adaptation of denture bases by anchorage to the casts: a comparative study. Quintessence Int 1990;21(3):185–190. PMID: 2197666.
30. Jow J. Mechanical undercuts as a means of decreasing shrinkage in the postpalatal seal region of the maxillary denture. J Prosthet Dent 1989;62(1):110–115. DOI: 10.1016/0022-3913(89)90054-1
31. Laughlin GA, Eick JD, Glaros AG, et al. A comparison of palatal adaptation in acrylic resin denture bases using conventional and anchored polymerization techniques. J Prosthodont 2001;10(4): 204–211. DOI: 10.1111/j.1532-849x.2001.00204.x
32. Gowman DJ, Cornelljpowers CM. Effect of composition on dimensional stability of denture bases. J Am Dent Assoc 1965;70:1200–1203. DOI: 10.14219/jada.archive.1965.0207
33. Wolfaardt J, Cleanton-Jones P, Fatti P. The influence of processing variables on dimensional changes of heat-cured poly(methyl methacrylates). J Prosthet Dent 1986;55(4):518–525. DOI: 10.1016/0022-3913(86)90191-5

34. Shah RJ, Lagdive SB, Machchhar AH, et al. Comparison of dimensional changes of compression molded vs Injection-molded heat-cured resin with different thicknesses. Int J Dent Sci Innov Res 2020;3(1):170–177. https://www.ijdsir.com/asset/images/uploads/1580056871931.pdf
35. Goodkind RJ, Schulte RC. Dimensional accuracy of pour acrylic resin and conventional processing of cold-curing acrylic resin bases. J Prosthet Dent 1970;24(6):662–668. DOI: 10.1016/0022-3913(70)90103-4
36. Consani RL, Domitti SS, Rizzatti Barbosa CM, et al. Effect of commercial acrylic resins on the dimensional accuracy of the maxillary denture base. Braz Dent J 2002;13(1):57–60. PMID: 11870965.
37. Miéssi AC, Goiato MC, dos Santos DM, et al. Influence of storage period and effect of different brands of acrylic resin on the dimensional accuracy of the maxillary denture base. Braz Dent J 19(3):204–208. DOI: 10.1590/s0103-64402008000300005
38. Duymuş ZY, Yanikoğlu ND. The investigation of solubility values, water sorption, and bond strength of auto-polymerizing and heat polymerizing acrylic resin materials. Eur J Prosthodont Restor Dent 2006;14(3):116–120. PMID: 170249.