

RESEARCH PAPER

Evaluation of dimensional stability of three dimensionally printed resin model using three different photopolymer resin: An *in vitro* study

¹Priyanka K, ²Pawan Kumar Bhandari D, ³Syed Khalid Althaf, ⁴Nagalakshmi S, ⁵Monisha V and ⁶Varalakshmi KR

¹Post Graduate, Department of Orthodontics and Dentofacial Orthopaedics, Vivekanandha Dental College for Women, Tiruchengode, Tamil Nadu, India Email: priyanka11kandhasamy@gmail.com

²Professor, Department of Orthodontics and Dentofacial Orthopaedics, Vivekanandha Dental College for Women, Tiruchengode, Tamil Nadu, India Email: drdpawankumar@vdcw.ac.in

³Professor and Head, Department of Orthodontics and Dentofacial Orthopaedics, Vivekanandha Dental College for Women, Tiruchengode, Tamil Nadu, India Email: drsyedkhalidaltaf@vdcw.ac.in

⁴Principal and Professor, Department of Orthodontics and Dentofacial Orthopaedics, Vivekanandha Dental College for Women, Tiruchengode, Tamil Nadu, India Email: drsnagalakshmi@vdcw.ac.in

⁵Assistant Professor, Department of Orthodontics and Dentofacial Orthopaedics, Vivekanandha Dental College for Women, Tiruchengode, Tamil Nadu, India Email: monishask313@vdcw.ac.in

⁶Assistant Professor, Department of Orthodontics and Dentofacial Orthopaedics, Vivekanandha Dental College for Women, Tiruchengode, Tamil Nadu, India Email: drkrvaralakshmi@vdcw.ac.in

Corresponding Author: Pawan Kumar Bhandari D
Email: drdpawankumar@vdcw.ac.in

Abstract

This *in vitro* study evaluated the effect of storage on the dimensional stability of three-dimensionally printed resin models fabricated using three photopolymer resins. Ninety maxillary resin models were fabricated using Phrozen Aqua 4K (Group A), Anycubic Standard Resin (Group B), and Elegoo Standard Resin (Group C) (n=30 each) from a standardized STL reference obtained using a TRIOS 3 intraoral scanner. Models were scanned at baseline, 1st, 2nd, 3rd, 4th weeks, and 3rd month, and dimensional deviations were assessed by 3D superimposition using Geomagic Control X software. Dimensional deviation remained minimal up to 1 week in all groups. Significant intragroup increases were observed from the second week in Groups B and C and from the fourth week in Group A (p<0.05). Significant intergroup differences were evident from the second week through 3 months (p<0.001), with Group A consistently demonstrating the lowest dimensional deviation, followed by Groups B and C. Significant differences between all pairwise comparisons were confirmed by post-hoc analysis (p<0.001). Phrozen Aqua 4K resin models showed better dimensional stability with lower dimensional deviation and delay in their onset of significant dimensional changes than with Anycubic and Elegoo resins.

How to cite this article: K Priyanka, D Pawan Kumar Bhandari, Althaf SK, Nagalakshmi S, Monisha V, Varalakshmi KR. "Evaluation of dimensional stability of three dimensionally printed resin model using three different photopolymer resin: An *in vitro* study" Int J Drug Deliv Technol. 2026;16(84s): 2092-2096; DOI: 10.25258/ijddt.16.84s.212

Introduction

Digital technology has improved the precision and efficiency of healthcare, including dentistry. The advent of cone-beam computed tomography (CBCT), intraoral scanners, and three-dimensional (3D) printing has digitalized many dental procedures [1]. 3D printing, an additive manufacturing technique that transforms digital models into physical products through layer-by-layer production has gained widespread applications in orthodontics, prosthodontics, oral and maxillofacial surgery and implantology [2, 3]. Additionally, it is utilized for patient-clinician communication, customized surgical equipment manufacturing, and surgery planning [4].

In orthodontics, 3D printing is increasingly employed for

the fabrication of clear aligners, with advantages in terms of esthetics and oral hygiene compared with fixed appliances [5]. The workflow consists of intraoral scanning, conversion of treatment plan to STL file, 3D model printing and subsequent thermoforming and trimming [6]. Digital workflows reduce impression-related errors, processing time, storage requirements, fracture risk and laboratory dependence compared with conventional impressions and plaster models. Intraoral scanning also supports the storage of digital data, and 3D printed models can be created on demand, cutting down on labor and processing [7].

The dimensional accuracy of 3D-printed models may be influenced by image acquisition, printer type, printing parameters, resin composition, and post-processing procedures [8, 9]. Resins derived from photopolymers used in

vat-polymerization technologies such as digital light processing (DLP), stereolithography (STL) and liquid crystal display (LCD) are commonly used due to their precision, rapid curing and ability to reproduce fine details [10]. There are different resin formulations for specific dental applications, with special consideration being given to the dimensional stability of 3D-printed models during storage when replacement aligners are needed for clear aligner therapy. Although 3D-printed models are durable and dimensional accurate over conventional stone models, printing-related errors may compromise aligner fit and treatment predictability [11, 12].

Printing orientation, wall thickness, layer thickness, surface characteristics, base design, and printer type have all been assessed in earlier research; however, there is still little data on how storage duration affects the dimensional stability of models made with various photopolymer resins [13, 14]. Therefore, this study aimed to evaluate the impact of storage on dimensional stability of three dimensionally printed resin models using three different photopolymer resins.

Materials and Methods

Fabrication of 3D-Printed Models

A patient with a well-aligned, complete maxillary dentition was selected as the reference. The maxillary arch was scanned using TRIOS 3 intraoral scanner (3Shape, Copenhagen, Denmark), and the obtained STL file was assigned as reference dataset. The STL file was prepared for 3D printing using standardized parameters, including wall thickness of 2.0 mm, layer thickness of 100 μ m, and model height of 2 mm. The standardized digital model was printed using DLP 3D printer (Phrozen Mighty 4K) with three different photopolymer resins: Group A, Phrozen Aqua 4K Resin (Grey); Group B, Anycubic Standard Resin (Grey); and Group C, Elegoo Standard Resin (Grey).

Post-Processing and Storage

Following printing, the resin models were cleaned in an ultrasonic bath and then immersed in isopropyl alcohol. Models were then dried with compressed air, checked for presence of cured up uncured resin, and allowed to rest for 30 minute. They were then post-cured in a light curing chamber of 280-580nm wavelength to cure any remaining uncured resin. The airtight containers were stored at room temperature and about 50% relative humidity protected from direct light exposure until evaluation.

Intraoral Scanning and Dimensional Stability Assessment

All models were scanned using TRIOS 3 intraoral scanner (3Shape, Copenhagen, Denmark) at baseline immediately after fabrication (T0), 1 week (T1), 2 weeks (T2), 3 weeks (T3), 4 weeks (T4), and 3 months (T5). All STL datasets received at every sampling time were compared with the reference STL dataset using 3D superimposition analysis to determine the dimensional stability of samples over time.

Dimensional Stability Analysis Using 3D Superimposition

The STL datasets generated from three resin groups and reference STL dataset were loaded into Geomagic Control X software (3D Systems, Rock Hill, SC, USA) for analysis. Each test model was set as floating model while the reference model was set as fixed model. Superimposition was performed using stable anatomical regions including palatal rugae, interdental regions and gingival attachment areas. After aligning the two sets of 3D comparison module was used to evaluate deviations between the reference and test models. A five-color deviation map was created, with the lowest and highest critical values of deviation set at -0.10 mm and +0.10 mm, respectively. The color map represented the magnitude and direction of dimensional deviations between the reference and test models. Green indicated minimal deviation, whereas red and blue represented positive and negative deviations, respectively.

Statistical Analysis

Data were analyzed using SPSS version 27.0. Results were expressed as mean $\pm$ SD. Repeated-measures ANOVA assessed within-group changes, and one-way ANOVA compared groups at each time point, with post-hoc tests for significant differences. A *p*-value <0.05 was considered statistically significant.

Results & Discussion

Dimensional Stability of 3D-Printed Resin Models During Storage

Table 1: Dimensional deviation of study groups at different time intervals

Time Point	Group A	Group B	Group C
Baseline	0.24 $\pm$ 0.01	0.26 $\pm$ 0.03	0.28 $\pm$ 0.01
1st week	0.24 $\pm$ 0.02	0.26 $\pm$ 0.03	0.29 $\pm$ 0.03
2nd week	0.25 $\pm$ 0.02	0.39 $\pm$ 0.03	0.49 $\pm$ 0.03
3rd week	0.25 $\pm$ 0.01	0.39 $\pm$ 0.05	0.49 $\pm$ 0.03
4th week	0.33 $\pm$ 0.13	0.39 $\pm$ 0.10	0.49 $\pm$ 0.10
3rd month	0.33 $\pm$ 0.13	0.39 $\pm$ 0.10	0.50 $\pm$ 0.04

Dimensional stability was assessed using RMS deviation at baseline, 1st, 2nd, 3rd, 4th weeks, and 3rd months (Table 1). RMS values showed minimal change at 1 week but increased thereafter. At 3 months, RMS values were 0.33 $\pm$ 0.13mm (Group A), 0.39 $\pm$ 0.10mm (Group B), and 0.50 $\pm$ 0.04 mm (Group C), with Group A showing the greatest and Group C the lowest dimensional stability. The progressive increase in RMS deviation suggests storage-related dimensional changes, potentially related to continued polymerization and residual stress relaxation.

Intragroup Changes During Storage

Table 2: Intragroup comparison of dimensional deviation

Time point	Group A	Group B	Group C
Baseline	0.24 $\pm$ 0.01	0.26 $\pm$ 0.03	0.28 $\pm$ 0.01
1st week	0.24 $\pm$ 0.02	0.26 $\pm$ 0.03	0.29 $\pm$ 0.03
2nd week	0.25 $\pm$ 0.02	0.39 $\pm$ 0.03*	0.49 $\pm$ 0.03*
3rd week	0.25 $\pm$ 0.01	0.39 $\pm$ 0.03*	0.49 $\pm$ 0.05*
4th week	0.33 $\pm$ 0.13*	0.39 $\pm$ 0.10*	0.49 $\pm$ 0.10*

3rd month	$0.33 \pm 0.13^*$	$0.39 \pm 0.10^*$	$0.50 \pm 0.04^*$
-----------	-------------------	-------------------	-------------------

*p-value<0.05-statistically significant

The intragroup comparison is presented in Table 2. No significant change in RMS deviation was observed between baseline and 1 week in any group. Groups B and C showed a significant increase from the 2nd week onward ($p < 0.05$),

Intergroup Changes During Storage

Table 3: Intergroup comparison of dimensional deviation

Time point	Group A	Group B	Group C	p-value
Baseline	0.24 ± 0.01	0.26 ± 0.03	0.28 ± 0.01	0.96
1st week	0.24 ± 0.02	0.26 ± 0.03	0.29 ± 0.03	0.95
2nd week	0.25 ± 0.02	0.39 ± 0.03	0.49 ± 0.03	<0.001*
3rd week	0.25 ± 0.01	0.39 ± 0.03	0.49 ± 0.05	<0.001*
4th week	0.33 ± 0.13	0.39 ± 0.10	0.49 ± 0.10	<0.001*
3rd month	0.33 ± 0.13	0.39 ± 0.10	0.50 ± 0.04	<0.001*

*p-value<0.05-statistically significant

No significant differences at baseline and 1 week ($p > 0.05$). There were significant differences between all groups ($p < 0.001$) between the 2nd week and 3 months with Group A having the least and Group C having the most RMS deviation.(Table 3) At 3 months, RMS values were $0.33 \pm$

whereas Group A showed a significant increase only from the 4th week ($p < 0.05$). Therefore, Group A revealed increased dimensional stability during the storage period. Differences of resin formulation, polymerization, filler content and post-curing response may be responsible for delayed changes in dimensions in Group A.

0.13 , 0.39 ± 0.10 , and 0.50 ± 0.04 mm for Groups A, B, and C, respectively. Therefore, the resin type proved to be an important variable for the dimensional stability during storage with the Group A being the most stable.

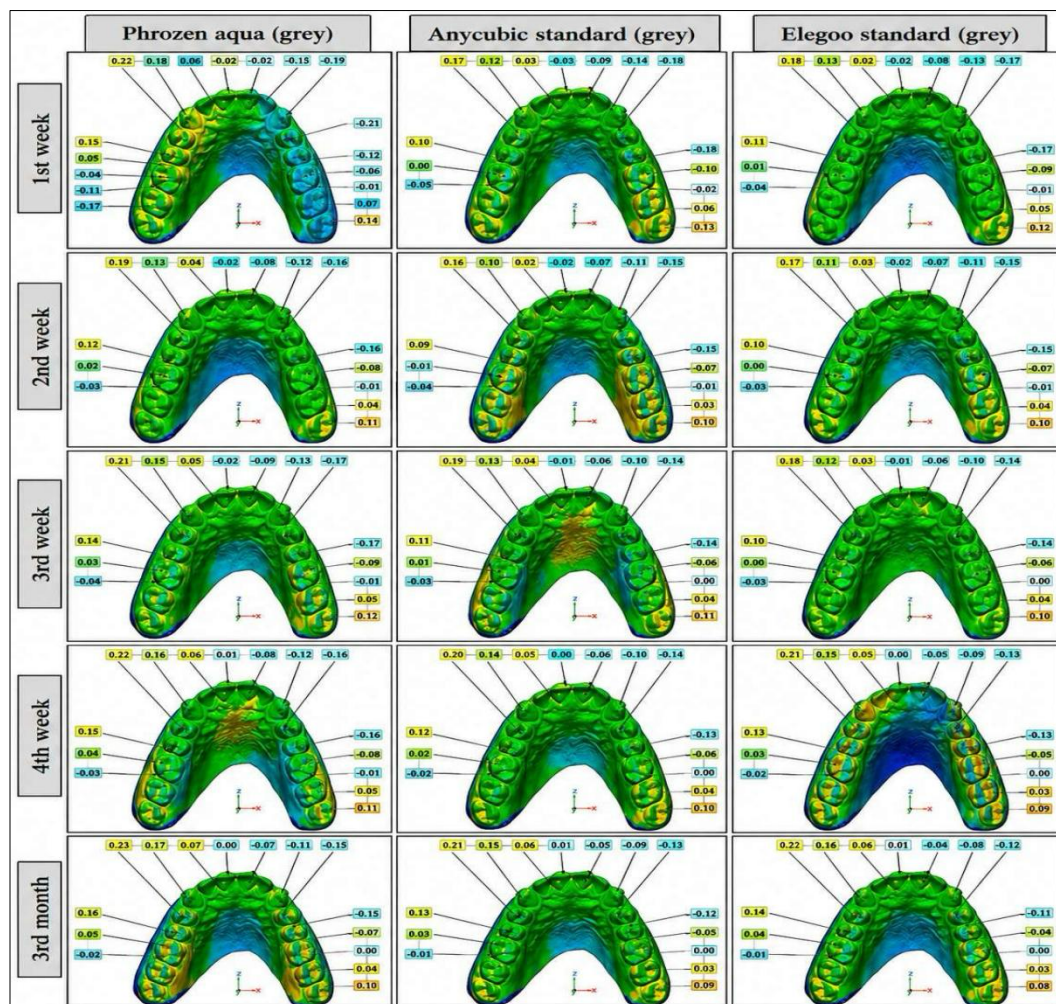


Fig 1: Superimposition of three resin model using geomagic control x software

Post-hoc Comparison Between Resin Groups

Table 4: Post-hoc analysis of dimensional deviation at different time intervals

Time point	Group A vs Group B	Group A vs Group C	Group B vs Group C
2nd week	<0.001*	<0.001*	<0.001*
3rd week	<0.001*	<0.001*	<0.001*
4th week	<0.001*	<0.001*	<0.001*
3rd month	<0.001*	<0.001*	<0.001*

*p-value<0.05-statistically significant

The overall intergroup differences were similar among resin pairs, as confirmed by post-hoc analysis, which revealed significant differences in all pairwise comparisons from 2nd week through 3 months (Table 4), including Groups A–B, A–C, and B–C ($p < 0.001$), confirming that the overall intergroup differences were consistent across resin pairs. Group A demonstrated superior dimensional stability, which may be advantageous for applications requiring prolonged model storage, whereas Group C showed greater susceptibility to storage-related changes.

Conclusion

The type of resin and the length of storage have an impact on the dimensional stability of 3D-printed resin models. Phrozen Aqua 4K resin demonstrated significantly greater dimensional stability, lower dimensional deviations and delayed onset of significant dimensional changes than Anycubic Standard Resin and Elegoo Standard Resin. Further, Phrozen Aqua 4K exhibited the least dimensional deviation, whereas Elegoo Standard Resin showed the greatest deviation suggesting that resin selection is an important consideration when 3D-printed orthodontic models are intended for prolonged storage and subsequent clinical or laboratory applications.

References

1. Sousa MV, Vasconcelos EC, Janson G, Garib D, Pinzan A. Accuracy and reproducibility of 3-dimensional digital model measurements. *Am J Orthod Dentofacial Orthop.* 2012;142(2):269-273.
2. Osman RB, Alharbi N, Wismeijer D. Build angle: does it influence the accuracy of 3D-printed dental restorations using digital light-processing technology? *Int J Prosthodont.* 2017;30(2):182-188.
3. Favero CS, English JD, Cozad BE, Wirthlin JO, Short MM, Kasper FK. Effect of print layer height and printer type on the accuracy of 3-dimensional printed orthodontic models. *Am J Orthod Dentofacial Orthop.* 2017;152(4):557-565.
4. Lin HH, Lonic D, Lo LJ. 3D printing in orthognathic surgery: a literature review. *J Formos Med Assoc.* 2018;117(7):547-558.
5. Jeong M, Radomski K, Lopez D, Liu JT, Lee JD, Lee SJ. Materials and applications of 3D printing technology in dentistry: an overview. *Dent J (Basel).* 2024;12(1):1.
6. Anacleto MA, Souki BQ. Superimposition of 3D maxillary digital models using open-source software. *Dental Press J Orthod.* 2019;24(2):81-91.
7. Sousa PMP, Lustosa KO, Luz DMR, Barros IDCA, da Silva EF, Simplício AHM, *et al.* Dimensional stability of 3D-printed models for orthodontic aligners: a six-month storage evaluation. *Dental Press J Orthod.* 2026;31(1):e2625115.
8. Zhang ZC, Li PL, Chu FT, Shen G. Influence of the three-dimensional printing technique and printing layer thickness on model accuracy. *J Orofac Orthop.* 2019;80(4):194-204.
9. Choi JW, Ahn JJ, Son K, Huh JB. Three-dimensional evaluation on accuracy of conventional and milled gypsum models and 3D printed photopolymer models. *Materials (Basel).* 2019;12(21):3499.
10. Tsolakis IA, Gizani S, Panayi N, Antonopoulos G, Tsolakis AI. Three-dimensional printing technology in orthodontics for dental models: a systematic review. *Children (Basel).* 2022;9(8):1106.
11. Rungrojwittayakul O, Kan JY, Shiozaki K, Swamidass RS, Goodacre BJ, Goodacre CJ, *et al.* Accuracy of 3D printed models created by two technologies of printers with different designs of model base. *J Prosthodont.* 2020;29(2):124-128.
12. Bor S, Oğuz F. Effect of different printing designs and resin types on the accuracy of orthodontic model. *Polymers (Basel).* 2025;17(20):2724.
13. ElShebiny T, Matthaïos S, Menezes LM, Tsolakis IA, Palomo JM. Effect of printing technology, layer height, and orientation on assessment of 3D-printed models. *J World Fed Orthod.* 2024;13(4):169-174.
14. Tongkitcharoen N, Manopattanakul S, Boonpratham S, Santiwong P, Viwattanatipa N. Comparison of dimensional accuracy of 3D printing model for clear aligner among various orientation types and hollow types. *Clin Investig Orthod.* 2023;82(4):177-193.
15. Bennett GW, DiGiovanni T. Effect of wall thickness of 3D-printed models on resisting deformation from thermal forming in-office aligners. *Clin Exp Dent Res.* 2024;10(1):e827.
16. Neoh SP, Khantachawana A, Santiwong P, Chintavalakorn R, Sriksirin T. Effect of post-processing on the surface, optical, mechanical, and dimensional properties of 3D-printed orthodontic clear retainers. *Clin Oral Investig.* 2025;29(1):48.
17. Alshaibani RM, Fan Y, Giordano R. Effect of different storage conditions on dimensional accuracy of 3D-printed dental models. *J Prosthodont.* 2025;34(6):617-625.

