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Mechanical performance over time of printed resins through flexural strength tests

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Abstract
Introduction: 3D-printed resins have gained relevance in restorative dentistry due to their ability to produce highly precise, customized restorations. However, their mechanical behavior under thermal aging still requires further investigation. **Objective:** To evaluate the mechanical performance of 3D-printed light-cured dental resins using flexural strength tests and to determine the effect of simulated thermal aging via thermocycling.
Materials and methods: An *in vitro* experimental study was conducted using two light-cured resins (VoxelPrint Ceramic and Prizma BIO Crown Diamond). Forty specimens (25 × 2 × 2 mm) were fabricated and divided into four groups (n = 10): VCT, VST, PCT, and PST. Twenty samples were subjected to 10,000 thermocycling cycles (5–55 °C), and the remaining samples were stored in distilled water at 37 °C for 24 h. Flexural strength was assessed using a three-point bending test, and the data were analyzed with descriptive statistics, Shapiro-Wilk, 2×2 factorial ANOVA, and Welch's t-test (α = 0.05).
Results: The VCT group exhibited the highest flexural strength (89.08 ± 14.31 MPa), while PCT showed the lowest values (31.91 ± 11.14 MPa). Material type was the factor with the greatest influence on the results. Prizma Diamont showed a significant decrease after thermocycling, while VoxelPrint showed greater stability.
Conclusion: The flexural strength of printed resins is influenced by material type and thermal aging. VoxelPrint Ceramic showed better mechanical performance and greater stability after thermocycling than Prizma BIO Crown Diamont, although further studies are needed to evaluate its long-term behavior.

Keywords: 3D printing, dental resins, flexural strength, thermocycling, artificial aging, restorative materials

Introduction

Composite resins have acquired a fundamental role in modern restorative dentistry due to their ability to offer minimally invasive treatments with satisfactory aesthetic and functional results. In recent years, the development of additive manufacturing technologies has allowed the incorporation of light-cured resins for 3D printing into various dental treatments. These materials enable the fabrication of customized dental restorations with high dimensional accuracy, which optimizes clinical-digital workflows and reduces laboratory production times. In this context, the mechanical properties of these materials are crucial to ensuring their clinical performance and durability in the oral environment. (Di Fiore *et al*., 2024; Gad & Fouda, 2023; Saini *et al*., 2024) [13, 20].

Several studies have evaluated the behavior of 3D-printed resins used in restorative and prosthetic dentistry. It has been shown that factors such as the material's chemical composition, print orientation, layer thickness, and post-curing protocols significantly influence their mechanical properties. Recent research has reported that the flexural strength of printed resins can vary depending on the printing parameters and the subsequent polymerization process, which directly impacts the structural stability of restorations fabricated using this technology. (Al-Dulaijan *et al*., 2023; Bennett & Kohler, 2025; De Angelis *et al*., 2024) [2, 6, 9].

Flexural strength is one of the most widely used mechanical properties for evaluating the behavior of polymer-based restorative materials. This test determines a material's ability to withstand load without fracturing, simulating functional conditions similar to those found in the oral cavity. Recent studies have shown that impression resins can undergo changes in their mechanical properties when subjected to aging factors such as humidity, temperature variations, or prolonged exposure to the oral environment, which can lead to progressive degradation of the polymer matrix. (Baytur & Diken Turksayar, 2024, 2025; Choi *et al*., 2025; Temizci & Bozoğulları, 2024) [5, 16, 24].

Despite the increasing use of 3D-printed resins in dentistry, there is still limited evidence regarding their mechanical behavior over time under conditions that simulate the oral environment. Some studies have analyzed the influence of post-curing or impression orientation; however, further research is needed to evaluate the stability of these resins after accelerated aging processes, such as thermocycling, and their impact on flexural strength. Thermocycling is one of the most widely used methods for simulating the thermal aging of dental materials, as it reproduces the temperature changes present in the oral cavity. Understanding these effects is crucial for estimating the lifespan of 3D-printed restorations and their long-term clinical application. (Hasan, 2025; Mudhaffer *et al*., 2025; Tayeb *et al*., 2025) [14, 19].

In this context, the objective of this study was to evaluate the mechanical performance over time of printed resins using flexural strength tests. The null hypothesis stated that there would be no statistically significant differences in flexural strength between the resins evaluated or between the aging conditions applied.

Conclusión

Based on the results obtained, the null hypothesis was rejected, as statistically significant differences in flexural strength were identified among the resins evaluated and among the aging conditions applied. The results demonstrated that both the type of material and the thermocycling process influenced the mechanical behavior of the printed resins, and a significant interaction between these two factors was also evident.

The behavior under thermal aging was not uniform. Prizma BIO Crown Diamont showed a significant decrease in flexural strength after thermocycling, while VoxelPrint Ceramic showed no statistically significant changes, demonstrating greater mechanical stability under the evaluated conditions. Comparatively, VoxelPrint Ceramic exhibited higher flexural strength values under all experimental conditions, suggesting better mechanical performance compared to Prizma BIO Crown Diamont.

From a clinical perspective, these findings indicate that the performance of printed resins depends on their formulation and their response to aging. However, clinical extrapolation of these results should be approached with caution due to the inherent limitations of *in vitro* studies.

It is recommended that future research include a greater number of materials, evaluate multiple mechanical properties, and consider additional variables such as impression orientation, post-curing protocols, and more complex accelerated aging methods. Furthermore, it is essential to develop *in vivo* studies to validate these findings under real clinical conditions and evaluate the long-term durability of resins printed in digital restorative dentistry.

References

1. Abad-Coronel C, Durán Urdiales D, Benalcázar Arias MV, Córdova AK, Medina MS, Bravo Torres W. Flexural Strength, Fatigue Behavior, and Microhardness of Three-Dimensional (3D)-Printed Resin Material for Indirect Restorations: A Systematic Review. Materials (Basel, Switzerland), 2025, 18(3). https://doi.org/10.3390/ma18030556
2. Al-Dulaijan YA, Alsulaimi L, Alotaibi R, Alboainain A, Akhtar S, Khan SQ, *et al*. Effect of Printing Orientation and Postcuring Time on the Flexural Strength of 3D-Printed Resins. Journal of Prosthodontics,2023:32(1):45-52. https://doi.org/10.1111/jopr.13572
3. Alshamrani A, Alhotan A, Kelly E, Ellakwa A. Mechanical and Biocompatibility Properties of 3D-Printed Dental Resin Reinforced with Glass Silica and Zirconia Nanoparticles: *In vitro* Study. Polymers,2023:15(11):2523. https://doi.org/https://pmc.ncbi.nlm.nih.gov/articles/PMC10255304/
4. Anusavice KJ, SC. Phillips' Science of Dental Materials. (12th ed.). St. Louis: Elsevier; Retrieved March 16, 2026, from https://biomedisca.com/wp-content/uploads/2025/02/Phillips-Science-of-Dental-Materials-12th-Edition.pdf
5. Baytur S, Diken Turksayar AA. Effects of post-polymerization conditions on color properties, surface roughness, and flexural strength of 3D-printed permanent resin material after thermal aging. Journal of Prosthodontics: Official Journal of the American College of Prosthodontists,2025:34(3):298–307. https://doi.org/10.1111/jopr.13818
6. Bennett GW, Kohler A. Analysis of Flexural Strength and Brittleness of a Polyjet 3D-Printed Denture Base Polymer. Clinical and Experimental Dental Research,2025:11(5):70228. https://doi.org/10.1002/cre2.70228
7. Borella PS, Alvares LAS, Ribeiro MTH, Moura GF, Soares CJ, Zancopé K, *et al*. Physical and mechanical properties of four 3D-printed resins at two different thick layers: An *in vitro* comparative study. Dental Materials,2023:39(8):686-692. https://doi.org/10.1016/j.dental.2023.06.002
8. Choi HE, Kim S, Kim GY, Li J, Pieralli S, Oh KC. Mechanical and esthetic properties of denture base resins in relation to thermocycling. Scientific Reports,2025:15(1):40789. https://doi.org/10.1038/s41598-025-24596-2
9. De Angelis F, D'Amario M, Jahjah A, Frascaria M, Vadini M, Sorrentino E, *et al*. Flexural Properties of Three Novel 3D-Printed Dental Resins Compared to Other Resin-Based Restorative Materials. Prosthesis,2024:6(3):619–630. https://doi.org/10.3390/prosthesis6030043
10. Di Fiore A, Stellini E, Alageel O, Alhotan A. Comparison of mechanical and surface properties of two 3D printed composite resins for definitive restoration. Journal of Prosthetic Dentistry,2024:132(4):839:e1-839.e7. https://doi.org/10.1016/j.prosdent.2024.07.003
11. ElMalah NS, Hanafy SA, Osman EM, Aboulgheit SA, Baz AS. Effect of nanomodified 3D printed photopolymerizable resin on flexural strength, color, and antimicrobial efficacy: An *in vitro* study. Journal of Prosthetic Dentistry,2024:132(1):2681-2688. https://doi.org/10.1016/j.prosdent.2024.03.036
12. Fouda S, Ji W, Gad MM, AlGhamdi MA, Rohr N. Flexural Strength and Surface Properties of 3D-Printed Denture Base Resins—Effect of Build Angle, Layer Thickness and Aging. Materials,2025:18(4):913. https://doi.org/10.3390/ma18040913
13. Gad MM, Fouda SM. Factors affecting flexural strength of 3D-printed resins: A systematic review. Journal of Prosthodontics,2023:32(1):96–110. https://doi.org/10.1111/JOPR.13640
14. Hasan NH. The Impact of Thermocycling on the Physico-mechanical Properties of SLA and DLP 3D-Printed Dental Ceramics: A Comparative Study. Dentistry, 2025, 13(1). https://doi.org/10.5195/d3000.2025.866
15. ISO 4049:2019 - Dentistry — Polymer-based restorative materials. (n.d.). Retrieved, 2025, from https://www.iso.org/standard/67596.html
16. Korkmaz YN, Buyuk SK, Simsek H, Abay F. Comparison of the Flexural Strength of Three Different Aged and Nonaged 3D-Printed Permanent Crown Resins. The International Journal of Prosthodontics,2024:37(7):203–207. https://doi.org/10.11607/ijp.8987
17. Li R, Albaghli A, Orgev A, Marrano J, Sadid-Zadeh R. Effect of thermal cycling on the flexure strength of CAD-CAM denture base materials: An *in vitro* study. The Journal of Prosthetic Dentistry,2024:132(3):6451-6457. https://doi.org/10.1016/j.prosdent.2024.07.005
18. Lozada MIT, Rondón AKA, Cordeiro IB, Borella PS, Junqueira PC, Mendonça G, *et al*. Physicomechanical properties of 3D printed resins for producing definitive dental crowns. Journal of Prosthetic Dentistry, 2025. https://doi.org/10.1016/j.prosdent.2025.07.017
19. Mudhaffer S, Haider J, Satterthwaite J, Silikas N. Effects of print orientation and artificial aging on the flexural strength and flexural modulus of 3D printed

restorative resin materials. The Journal of Prosthetic Dentistry,2025:133(5):1345–1357. https://doi.org/10.1016/j.prosdent.2024.08.008
20. Saini RS, Gurumurthy V, Quadri SA, Bavabeedu SS, Abdelaziz KM, Okshah A, *et al*. The flexural strength of 3D-printed provisional restorations fabricated with different resins: a systematic review and meta-analysis. BMC Oral Health,2024:24(1):66-. https://doi.org/10.1186/s12903-023-03826-x
21. Salonen R, Garoushi S, Vallittu P, Lassila L. Characterization of temporary and permanent 3D-printed crown and bridge resins. Biomaterial Investigations in Dentistry,2025:12:43584. https://doi.org/10.2340/biid.v12.43584
22. Tavuz KA, Al-Haj Husain N, Mätzener KJ, Ateş MM, Eyüboğlu TF, Özcan M. Evaluation of flexural strength of additively manufactured resin materials compared to auto-polymerized provisional resin with and without hydrothermal aging. Journal of the Mechanical Behavior of Biomedical Materials,2025:161(5):106817. https://doi.org/10.1016/j.jmbbm.2024.106817
23. Tayeb HK, Silikas N, Alhaddad AJ, Satterthwaite J. Flexural Strength and Hardness Analysis of 3D-Printed vs. Milled Resin Composites Indicated for Definitive Crowns. Journal of Functional Biomaterials, 2025, 16(12). https://doi.org/10.3390/jfb16120468
24. Temizci T, Bozoğulları HN. Effect of thermal cycling on the flexural strength of 3-D printed, CAD/CAM milled and heat-polymerized denture base materials. BMC Oral Health,2024:24(1):357. https://doi.org/10.1186/s12903-024-04122-y
25. Yıldırım Ö, Yeşil Z, Hatipoğlu Ö. Effect of different 3D-printing systems on the flexural strength of provisional fixed dental prostheses: a systematic review and network meta-analysis of *in vitro* studies. BMC Oral Health, 2025, 25(1). https://doi.org/10.1186/s12903-025-05470-z