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The flexural strength of temporary restorations made with various resins and 3D printing technology: A systematic review

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Abstract

Study Aim: The study aims to evaluate existing research on the flexural strength of temporary restorations fabricated using 3D printing technology with various resin materials. The study show the impact of material type, manufacturing method, and post-processing conditions on mechanical properties, flexural strength, surface roughness, microhardness, and bond strength.

Method: The study follows the PRISMA guidelines. A literature search was conducted in Web of Science, Scopus, PubMed, and Google Scholar, using keywords in relation to flexural strength, 3D printing, provisional restorations, polymer resins, and photopolymers. We include studies published from 2016 to 2025 were included. Experimental and in vitro studies comparing 3D-printed provisional restorations to conventional or CAD-CAM-milled alternatives were eligible for inclusion. Case reports, opinion papers, and narrative reviews were excluded. Two independent reviewers screened and extracted data, with a third reviewer resolving discrepancies.

Results: our study found that 3D-printed provisional restorations show superior surface hardness and elasticity, and CAD-CAM restorations show higher flexural strength. Some studies found a variability in adhesion strength depending on resin composition and post-processing methods.

Conclusion: 3D-printed dental restorations show a good mechanical properties, and CAD-CAM remains the gold standard for high-load applications. Advancements in resin formulations and post-processing can improve long-term durability and clinical performance, which make 3D-printed materials more competitive for provisional dental applications.

Keywords: Temporary restorations; Resins; 3D printing technology; CAD-CAM

1. Introduction

Due to the quick 3D printing capabilities, easy-to-use dental computer-aided design (CAD) software, and the widespread availability of intraoral scanning technologies, the usage of three-dimensional (3D)-printed temporary dental restorations is growing in clinical settings (1). In the realm of dentistry, it has received a lot of attention lately. Dental restorations, particularly temporary restorations, have been transformed by it (2,3). Due to cost-effectiveness, lower carbon emissions, and material and energy conservation, using technology in the fabrication of dental prostheses is preferable to more conventional approaches like the lost-wax process (4).

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Additionally, provisional restorations provide temporary support, protection, and aesthetics until the final restorations are completed (5), and they depend on elements like flexural strength to guarantee that abutment teeth stay stable throughout the interim time (6).

In order for dental restorations to endure stresses during mastication, flexural strength—the material's ability to bend without breaking—is essential (7). Using a variety of resins, each with unique compositions, curing processes, and physical properties, 3D printing technology makes it easier to create interim repairs. The flexural strength of temporary restorations may be impacted by these differences (8).

Dental practitioners can guarantee the life and durability of restorations by assessing the flexural strength (9). Materials and production methods are guided by this evaluation to ensure patient satisfaction and peak performance. Furthermore, by better understanding the variables influencing flexural strength, 3D-printed temporary restorations may be designed and produced with higher clinical success rates (10). Therefore, the goal of the current study was to critically evaluate and compile the body of research on the flexural strength of temporary restorations made with 3D printing and various resins.

2. Method

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) standards were followed in this systematic review and meta-analysis. Various search terms were used to search many databases, including Web of Sciences, Scopus, PubMed, and Google Scholar; Flexural strength, Strength, Flexural, Resistance, three dimensional, Printing, printing, 3D printing, Provisional restorations, CAD materials, Temporary restorations, Transitional restorations, Interim restorations, Substitute restorations, polymer resins, Resin materials, Photopolymers, Photopolymerizable resins, Methacrylate-based resins, Ionomer.

We include studied published in the period from 2016 to 2025. We include experimental studies, in vitro studies, that evaluate the mechanical properties of 3D-printed provisional dental restorations; Comparative studies that assess 3D-printed materials against conventional or CAD-CAM-milled materials; Studies that include quantitative analysis of material properties such as flexural strength, microhardness, surface roughness, bond strength, or wear resistance; Studies focusing on provisional dental restorations, including crowns, bridges, and fixed dental prostheses; we exclude case reports, opinion papers, narrative reviews, or editorials without experimental data. Abstracts, research titles, and original articles underwent independent evaluation.

A consensus was reached after two reviewers separately evaluated the full texts of the publications that satisfied the inclusion criteria. A third impartial reviewer arbitrated any disputes and reached a consensus. For the chosen studies that satisfied the inclusion requirements, information retrieval was done. Following the screening of the complete texts, abstracts, and titles of the publications, the retrieved data was entered into a data extraction form. Each demographic feature, 3D printing parameters, control, strength testing technique, post-processing or treatment used, conclusion, and limitations were separately documented by two reviewers for a systematic review.

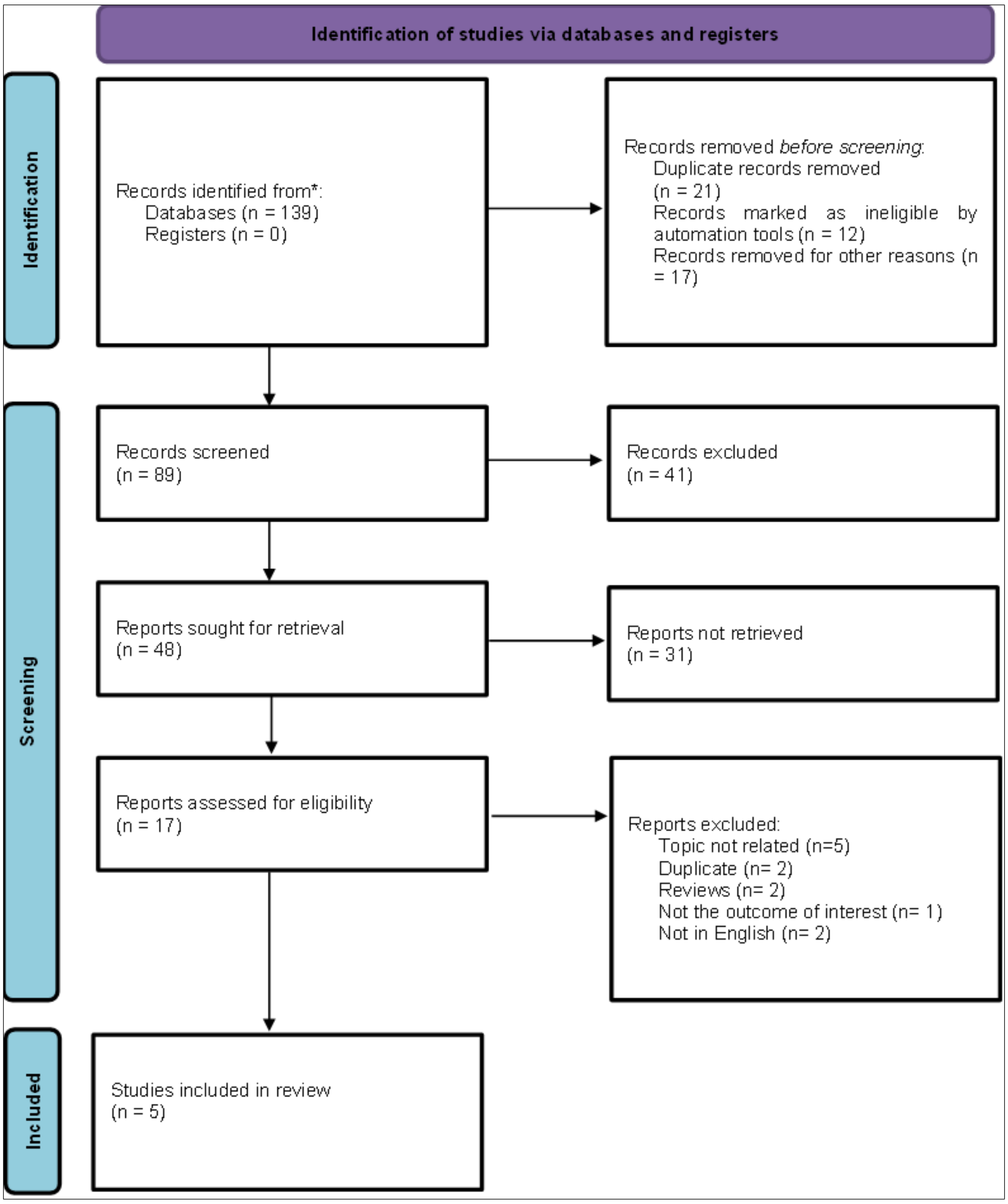

Figure 1 PRISMA consort chart of selection process

3. Result and discussion

The included studies provide evaluation of the mechanical and physical properties of 3D-printed provisional dental restorations in relation to conventional and CAD-CAM fabricated restorations, and the impact of material type, manufacturing method, and post-processing conditions on flexural strength, surface roughness, microhardness, and bond strength.

Alageel et al. (11) tested flexural strength, trueness, and surface characteristics of 3D-printed interim restorative materials fabricated with different printing systems. Flexural strength, microhardness, and surface roughness differ depending on the material, printing system, and orientation. Aging affected reliability and mechanical characteristics, with some materials show changes after simulated brushing and thermocycling. **Dos et al.** (12) studied the strength of the bond of 3D-printed provisional crowns with the use of three different provisional cements before and after thermal aging. Glass ionomer cement show the highest initial strength of the bond, and all cement types faced a decrease in adhesion force after aging. The findings explain the importance of appropriate provisional cements selection for long-term stability in 3D-printed restorations.

Madhav et al. (13) compared the flexural strength and microhardness of provisional restorations fabricated using rapid prototyping (3D printing), CAD-CAM milling, and conventional methods. The results showed that CAD-CAM fabricated restorations had the highest flexural strength, while 3D-printed restorations had the highest microhardness. This suggests that while 3D printing offers better surface hardness, CAD-CAM restorations may be more resilient under functional loads.

Pantea et al. (14) compared the compressive and flexural strength of 3D-printed and conventional interim prosthetic resins. The study found that 3D-printed materials had higher elastic moduli and bending strength than conventional resins, suggesting their superiority in terms of mechanical durability. This reinforces the growing adoption of 3D-printed materials in dentistry for long-term provisional restorations.

Park et al. (1) focused on the flexural strength of three-unit fixed dental prostheses fabricated using different 3D printing techniques, including digital light processing (DLP), stereolithography (SLA), and fused deposition modeling (FDM). DLP and SLA restorations demonstrated significantly higher flexural strength than conventional restorations, confirming their suitability for provisional prostheses.

Overall, the studies highlight that 3D-printed provisional restorations exhibit promising mechanical properties, particularly in terms of surface hardness and elasticity. However, CAD-CAM restorations still offer superior flexural strength, making them preferable for high-load applications. The findings underscore the need for careful material selection and post-processing to optimize the longevity and functionality of 3D-printed dental restorations.

The integration of 3D printing in dentistry has transformed the manufacturing process of provisional and permanent restorations. The included studies collectively highlight the advantages and challenges of 3D-printed provisional materials compared to conventional and CAD-CAM-milled alternatives.

Alageel et al. (11) and Alzahrani et al. (15) emphasize that 3D-printed resins exhibit superior hardness and wear resistance compared to conventional provisional materials. Studies like Park et al. and Madhav et al. confirm that digital light processing (DLP) and stereolithography (SLA) produce restorations with higher flexural strength than traditional counterparts. However, Pantea et al. and Dos et al. highlight variability in adhesion and bond strength, which may impact long-term clinical performance.

The role of digital workflows is evident in studies like Jiang et al. and Spagnuolo et al., (16) which discuss advancements in DLP technology that enhance precision and efficiency in fabricating dental prostheses. These studies suggest that improvements in adhesion and demolding techniques, such as porous build platforms, contribute to better manufacturing outcomes. Lakkala et al. (17) reinforce the idea that stereolithography (SLA) provides high precision, making it well-suited for customized dental applications, particularly in cases requiring detailed surface anatomy.

Comparing additive manufacturing (3D printing) with subtractive methods (milling), Spagnuolo et al. and Wang et al. (18) discuss the environmental and material efficiency benefits of 3D printing. Milling, despite its high precision, results in significant material waste, whereas 3D printing allows layer-by-layer fabrication, reducing excess material use. Nonetheless, Wang et al. point out that current DLP systems still struggle with limitations in speed and scalability, especially when high-volume production is needed.

While studies like Park et al. (1) suggest that 3D-printed restorations offer adequate mechanical properties for provisional applications, concerns regarding their long-term durability persist. Dos et al. (12) and Alzahrani et al. recommend further optimization of resin compositions to improve fracture resistance and bond stability under oral conditions. Future research should focus on hybrid resin formulations that combine the mechanical strength of milled restorations with the efficiency and adaptability of 3D-printed materials.

Table 1 Characteristics of the included studies

Study	Study Type	Method	Participants Characteristics	Outcome
Alageel et al.	Experimental in vitro study	Experimental study testing physical and mechanical properties of 3D-printed interim restorations using three-point bending, surface	Six groups of 3D-printed interim restorative specimens (N=96), printed at 0Â° and 90Â° angles, subjected to	Trueness, flexural strength, and surface roughness varied based on material, system, and printing angle. Some

		roughness, and microhardness tests.	thermocycling and simulated brushing.	materials showed significant changes after aging.
Dos et al.	Experimental in vitro study	In vitro study testing immediate and long-term bond strength of 3D-printed crowns using three different provisional cement agents, with tensile strength tests and finite element analysis.	36 provisional crowns printed and divided into three groups (n=12 per cement type), tested before and after 2000 thermal cycles.	Glass ionomer cement had the highest immediate bond strength, but all cements experienced reduced bond strength after thermal aging.
Madhav et al.	Comparative experimental study	Comparative experimental study measuring flexural strength and microhardness of provisional materials fabricated using 3D printing, CAD-CAM milling, and conventional methods.	20 specimens per group fabricated using 3D printing, CAD-CAM milling, and conventional methods, following ADA-ANSI specifications.	CAD-CAM fabricated restorations had the highest flexural strength, while 3D-printed restorations had the highest microhardness.
Pantea et al.	Experimental in vitro study	In vitro mechanical testing study evaluating compressive and flexural strength of 3D-printed and conventional resins using a universal testing machine.	40 resin samples (two 3D-printed resins and two conventional resins) prepared for compressive and flexural strength testing.	3D-printed resins exhibited higher elastic moduli and bending strength than conventional resins, suggesting better mechanical properties for dental use.
Park et al.	Comparative experimental study	Comparative experimental study assessing flexural strength of three-unit fixed dental prostheses fabricated using DLP, SLA, and FDM 3D printing, compared to milled and conventional restorations.	Three-unit fixed dental prostheses fabricated using DLP, SLA, and FDM 3D printing, with flexural strength measured using a universal testing machine.	DLP and SLA 3D-printed restorations had significantly higher flexural strength than conventional restorations, indicating their suitability for provisional prostheses.

Table 2 Study aim and main findings of included studies

Study	Study Aim	Intervention	Main Findings
Alageel et al.	Evaluate physical and mechanical properties of 3D printed resins for interim dental restorations after accelerated aging.	Three 3D printing systems (NextDent, Asiga, Nova3D) with two printing angles (0Â° and 90Â°) were used to fabricate interim restorations and subjected to accelerated aging (thermocycling and brushing).	Flexural strength, microhardness, and surface roughness varied by material, system, and printing angle. Some systems showed significant changes after aging.
Dos et al.	Assess the immediate and long-term bond strength of 3D-printed provisional crowns using different provisional cement agents.	36 provisional crowns were printed and divided into three groups cemented with Relyx Temp, Provicol, and Meron. Half were subjected to 2000 thermal cycles before tensile strength testing.	Glass ionomer cement showed the highest immediate bond strength, but all cements suffered bond strength reduction after thermal aging.
Madhav et al.	Compare flexural strength and microhardness of	20 specimens were fabricated using rapid prototyping (3D	CAD-CAM fabricated restorations had the highest flexural strength, while 3D-printed

	provisional crown and bridge materials fabricated using rapid prototyping, CAD-CAM, and conventional methods.	printing), CAD-CAM milling, and conventional heat-activated polymerization. Flexural strength and microhardness were measured.	restorations had the highest microhardness.
Pantea et al.	Compare the compressive and flexural strength of 3D-printed and conventional resins used in interim fixed dental prostheses.	40 resin samples (two 3D-printed resins and two conventional resins) were tested for compressive and flexural strength using a universal testing machine.	3D-printed resins had higher elastic moduli and bending strength than conventional resins, indicating better mechanical properties for dental applications.
Park et al.	Evaluate the flexural strength of 3D-printed provisional fixed dental prostheses compared to conventional and milled restorations.	Three-unit fixed dental prostheses were fabricated using DLP, SLA, and FDM 3D printing and compared to milled and conventionally fabricated restorations for flexural strength.	DLP and SLA 3D-printed restorations had significantly higher flexural strength than conventional restorations, suggesting their suitability for provisional dental prostheses.

4. Conclusion

The studies collectively affirm that 3D printing is a viable alternative to conventional and CAD-CAM-milled methods for dental prostheses. While it offers superior customization, reduced material waste, and improved mechanical properties in certain aspects, there are still challenges regarding long-term durability and adhesion. Ongoing advancements in resin development and DLP printing technologies will likely bridge the existing gaps, making 3D-printed dental restorations even more competitive in the clinical setting.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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