"Marginal Fit and Flexural Strength of 3D-Printed Crown and Bridge Resins: A Comparative In Vitro Study"

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ABSTRACT

Abstract

Background: Three-dimensional (3D) printed resins are now widely used for interim and definitive fixed dental prostheses (FDPs), yet comparative evidence on how well they adapt and how much load they tolerate remains limited.

Objective: To compare the marginal fit and flexural strength of 3-unit FDPs printed from two crown and bridge liquid resins.

Methods: Three-unit FDPs (abutments 15 and 17, pontic 16) were designed from an intraoral scan of a prepared typodont and printed in Prevest (Group 1, n = 25) or Prestocraft (Group 2, n = 25) crown and bridge resin. Marginal gap was measured under a stereomicroscope, and fracture load was recorded in a universal testing machine. Groups were compared with the unpaired t-test ($\alpha = 0.05$).

Results: Mean marginal gap was 99.6 ± 11.1 µm for Prevest and 103.3 ± 13.6 µm for Prestocraft ($p = 0.302$). Mean fracture load was 648.5 ± 61.3 N for Prevest and 586.2 ± 57.6 N for Prestocraft ($p < 0.001$).

Conclusion: Both resins produced marginal gaps within the clinically acceptable range and did not differ in fit, whereas Prevest withstood a significantly higher fracture load.

Keywords: 3D printing; crown and bridge resin; marginal fit; flexural strength; fixed dental prosthesis; digital dentistry

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INTRODUCTION

Interim and definitive fixed dental prostheses protect the pulp and periodontium, hold the occlusion steady, shape the emergence profile and let the clinician judge function and esthetics before the final result is committed. Over the last decade, additive manufacturing, particularly vat polymerisation using stereolithography (SLA) or digital light processing (DLP), has become a mainstream way of making these restorations. The appeal is easy to see: a fully digital workflow, short fabrication times and very little wasted material [1,2].

Two properties largely decide whether a printed prosthesis succeeds. The first is marginal fit. An open margin invites plaque retention, cement dissolution and secondary caries, and printed crowns have been shown to be sensitive to build direction and to the geometry of the preparation, with reverse-tapered axial walls proving especially unfavourable [3,4]. The second is flexural strength. In multi-unit prostheses, bending stresses gather in the connector region, which is usually the weakest zone, so strength matters far more in a bridge than in a single crown [5]. Printed resins generally record lower mechanical values than milled or conventionally

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processed materials, and their behaviour depends heavily on printer type, post-curing time and polymerisation parameters [6–8].

Most published work has examined single crowns or interim materials. Information on the newer permanent-grade crown and bridge resins, including those marketed in India, is scarce, and manufacturers rarely disclose composition or filler content. Clinicians therefore have little independent evidence to rely on when choosing between products [2,6].

This study set out to compare the marginal fit and flexural strength of 3D-printed 3-unit FDPs made from two crown and bridge liquid resins. The research hypothesis was that the two resins differ significantly in marginal fit and in flexural strength; the null hypothesis was that no difference exists.

MATERIALS AND METHODS:

Study design and setting

This was a laboratory-based comparative in vitro study carried out in the Department of Prosthodontics and Crown & Bridge, Saraswati Dental College and Hospital, and at the Central Institute of Petrochemicals Engineering & Technology (CIPET), Lucknow. The study involved no human participants or animals and was therefore exempt from ethical committee review. Reporting follows the Checklist for Reporting In-vitro Studies (CRIS).

Sample size:

Sample size was calculated in G*Power 3.1 for a two-group comparison with an effect size of 0.8, $\alpha = 0.05$ and a power of 0.80. The calculation indicated a minimum of 50 specimens, that is, 25 per group.

Master model and digital design:

Abutment preparations were made on teeth 15 and 17 of a typodont (Nissin, Japan) using an air rotor (NSK, Japan) and preparation burs (Mani, Japan), with a total occlusal convergence of 6°, 1.5 mm occlusal reduction, 1.2 mm axial reduction and a 1.0 mm chamfer finish line. The prepared arch was scanned with an intraoral scanner (FLNT R1, Upcera, China), and a master cast was printed from model resin (Prevest, India). A 3-unit FDP with tooth 16 as the pontic was designed in exocad with a cement space of 80 µm and a minimum connector height of 4 mm and exported as a standard tessellation language (STL) file. The same file was used for both groups.

Specimen fabrication:

Specimens were printed on an Omni 9K printer (Prevest, India) in two groups: Group 1, Prevest crown and bridge permanent resin (n = 25), and Group 2, Prestocraft crown and bridge permanent resin (n = 25). All FDPs were printed at a layer thickness of 50 µm and a build angle of 45° with identical support design. After printing, specimens were washed in 95% isopropyl alcohol for 5 minutes and post-cured for 30 minutes according to each manufacturer's instructions. Supports were removed and the connection points were smoothed. Specimens with cracks, voids, printing artefacts or damage before testing, and any design other than a 3-unit FDP, were excluded and reprinted.

Marginal fit:

Each FDP was seated on its master cast under a constant finger pressure, and the marginal gap was measured under a stereomicroscope at 40× magnification at four points per abutment (mid-buccal, mid-lingual, mesial and distal). The mean of all readings for each specimen was used for analysis. All measurements were made by a single calibrated operator. The FDPs were then cemented onto the master cast with resin cement (Fusion Ultra, Prevest, India) under a static load of 50 N for 5 minutes.

Fracture load and flexural strength:

Each cemented FDP was mounted in a universal testing machine and loaded at the central fossa of the pontic with a 5 mm diameter stainless steel spherical indenter at a crosshead speed of 1 mm/min until fracture. The peak load at failure was recorded in newtons and taken as the measure of flexural resistance.

Statistical analysis:

Data were analysed in SPSS version 26 (IBM, Chicago, USA). Normality was checked with the Shapiro–Wilk test and homogeneity of variance with Levene's test. The two groups were compared with the unpaired Student t-test, and the level of significance was set at $p < 0.05$. Mean differences are reported with 95% confidence intervals, and effect size is expressed as Cohen's d.

RESULTS:

All 50 FDPs, 25 per group, were included in the analysis and no specimen was excluded. Data for both outcomes were normally distributed (Shapiro–Wilk $p > 0.05$) with equal variances (Levene $p > 0.05$), so the unpaired t-test was applied.

(1) Marginal fit

The mean marginal gap was 99.6 ± 11.1 µm for Prevest and 103.3 ± 13.6 µm for Prestocraft (Table 1). The difference of 3.7 µm (95% CI −10.7 to 3.4) was not statistically significant ($p = 0.302$; Cohen's $d = −0.30$). Both groups remained below the commonly accepted clinical limit of 120 µm (Figure 1).

Table 1. Marginal gap (µm) of the two groups.

Group	n	Mean ± SD	95% CI	Student 't' test Value	p value
Prevest	25	99.6 ± 11.1	95.1–104.2	−1.044	0.302(NS)
Prestocraft	25	103.3 ± 13.6	97.7–108.9		

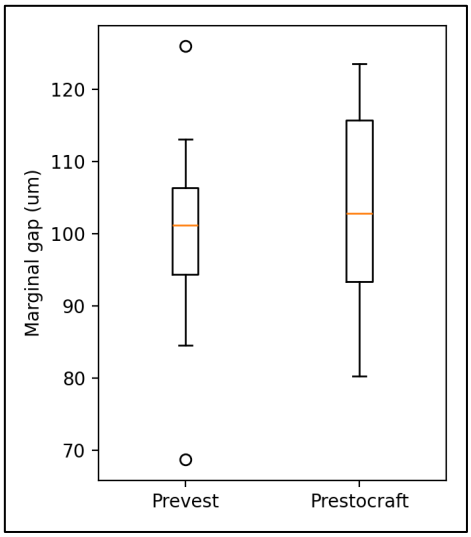


Figure 1. Box plot of marginal gap (µm) by group.

(2) Fracture load:
Mean fracture load was 648.5 ± 61.3 N for Prevest and 586.2 ± 57.6 N for Prestocraft (Table 2). Prevest withstood a higher load, with a mean difference of 62.3 N (95% CI 28.5 to 96.1) ($p < 0.001$; Cohen's d = 1.05), which is a large effect (Figure 2).

Table 2. Fracture load (N) of the two groups.

Group	N	Mean ± SD	95% CI	Student 't' test Value	p value
Prevest	25	648.5 ± 61.3	623.2–673.8	3.703	<0.001(HS)
Prestocraft	25	586.2 ± 57.6	562.4–610.0		

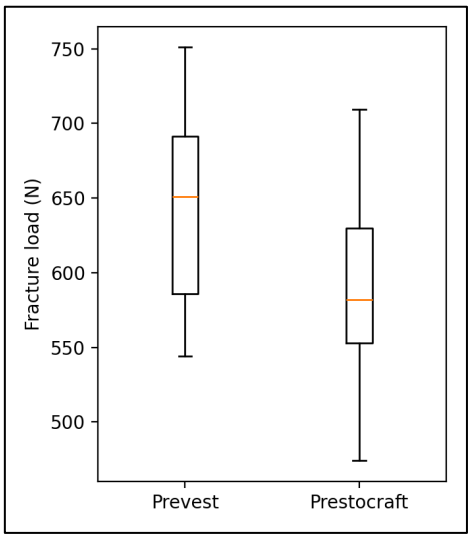


Figure 2. Box plot of fracture load (N) by group.

DISCUSSION

This study compared two crown and bridge resins printed from the same design file on the same printer. The resins showed comparable marginal adaptation but a clear difference in fracture resistance. The null hypothesis was therefore retained for marginal fit and rejected for fracture load.

Both materials produced marginal gaps within the range generally regarded as clinically acceptable, which agrees with earlier reports on printed provisional restorations [3,4,9]. The same conclusion has been reached in recent synthesis work: a 2026 systematic review of 13 in vitro studies reported marginal gaps of printed fixed prostheses generally between 40 and 120 µm, and identified print layer thickness and build orientation as the main controllable influences, with 50 µm layers and orientations of 45° to 60° giving the best adaptation [12]. Our protocol used exactly these settings (50 µm layers, 45° build angle), which probably explains why both resins fitted well. It is also worth noting that our mean gaps of about 100 µm, although acceptable, lie in the upper part of that reported range. This may reflect the 80 µm cement space set in the design software, the 40× two-dimensional stereomicroscopic measurement, and the fact that a multi-unit prosthesis must seat on two abutments at once, which is less forgiving than a single crown.

Because design, printer, preparation and printing parameters were identical, the absence of a difference suggests that resin choice had little effect on adaptation in this model. Most of the variation in printed fit appears to come from the process rather than the material. In a 2026 study of three-unit permanent composite prostheses, build orientation significantly changed marginal and internal misfit, with the 45° group the most consistent, even though the same resin was used throughout [13]. Likewise, a 2025 trueness study of printed restorations found that external accuracy of four-unit prostheses was clearly poorer than that of single crowns and veneers, with large deviations from the design and notable variability between printed specimens, and the authors concluded that some chairside adjustment may be needed [14]. Long-span and multi-unit prostheses are therefore the situation in which printing error is most likely to show, and our finding of comparable, acceptable fit for a three-unit span is reassuring but should not be extended to longer bridges. Build direction and preparation taper, which previous investigators identified as the main drivers of fit, were held constant and could not be assessed here.

Prevest withstood a higher load than Prestocraft, in line with reports that printed resins vary considerably in mechanical performance [6–8]. Recent work reinforces this point. A 2025 comparison of printed and milled resin composites indicated for definitive crowns examined flexural strength and hardness of printed versus milled materials as a basis for judging their suitability for definitive crowns [6], and a 2025 systematic review of printed indirect restoration resins evaluated flexural strength together with fatigue behaviour and microhardness, outcomes that matter for long-term service but that our single static test cannot capture [7]. In a 2026 study of printed permanent crown resins, biaxial flexural strength of the printed materials was about 136 to 145 MPa against 212 MPa for a conventional composite, and the Weibull modulus of the printed groups was lower, meaning less predictable strength [15]. Our result, in which two commercially available resins processed identically differed by about 62 N (roughly 10%) in fracture load, fits this picture: product-specific formulation matters even when the printer and protocol are the same.

Differences in filler content, monomer chemistry or degree of conversion could explain the difference between the resins, but none were measured, and since manufacturers do not disclose composition the explanation remains speculative. Post-curing is a further plausible contributor. The 2026 study of two post-curing units found that the unit used did not change the flexural strength of either printed resin but did change surface hardness and indentation modulus of one of them [15], suggesting that the effect of post-processing is resin specific. Both groups here were washed and post-cured according to each manufacturer's instructions, as is usual in practice, so any difference in the adequacy of these protocols would be part of the product comparison, but this could not be separated from the effect of composition in the present design.

Printed prostheses may also perform below milled alternatives under load [5,6], so these values should not be extended to other materials. This is supported by a 2026 comparison of aged three-unit interim prostheses, in which a printed photopolymer fractured at a mean of 163 N compared with about 1130 N for milled PMMA, although the authors cautioned that the printed resin had been used in an open material mode and was not validated for the printer [16]. The much higher loads recorded here (586 to 649 N) therefore do not contradict that report; they show how strongly results depend on the resin, the printer-resin validation and the post-curing combination, which is why a result for one product cannot be generalised to printed resins as a class. By contrast, a 2026 study of permanent composite three-unit prostheses found no significant difference in fracture load between build orientations, and the

printed composite tended to fail through connector deformation rather than catastrophic fracture [13]. That pattern, a connector-related and less brittle failure, is clinically favourable and is consistent with our choice of the connector as the critical region.

Studies from Indian centres, which use materials and printers closer to those available in local practice, point the same way. In a 2025 comparison of provisional materials, 3D-printed resin gave a mean marginal gap of about 108 µm, smaller than that of chairside tooth-moulding acrylic and bis-acryl composite (about 193 and 178 µm) [17]. In a study of three-unit interim prostheses subjected to 5,000 thermocycles, however, the printed group showed a mean marginal gap of about 110 µm, significantly larger than that of the milled group (about 67 µm), and the printed prostheses also had the lowest flexural strength of the three methods tested [18]. Similarly, a 2025 study of temporary crown materials reported that milled PMMA (about 115 MPa) was stronger than two printed resins (about 91 and 80 MPa), and that the two printed resins differed significantly from each other [19]. These findings agree with ours in two respects: printed marginal gaps cluster around 100 µm, close to but below the 120 µm limit, and different printed products differ significantly in strength. Most of the available Indian studies, however, tested interim rather than permanent-grade resins, which underlines the gap that the present study addresses.

Comparison with other studies is further limited by differences in specimen geometry; for example, disc-based biaxial testing of printed resins has reported characteristic strengths of roughly 150 to 250 MPa [8], which cannot be compared directly with the fracture load of a complete 3-unit prosthesis. Whole-prosthesis loading, as used here, includes the effects of connector design, cement layer and abutment support, and is closer to clinical conditions, whereas disc testing isolates the material. The two approaches are complementary, and future studies would benefit from reporting both.

Clinically, both resins appear suitable on marginal criteria, while the stronger resin may be preferable where connector stress is high, for example in posterior bridges with heavy occlusal load or long pontic spans. The wider literature on printing in dentistry, including early reviews of polymer printing and its technical challenges [10,11], has long stressed that outcomes depend on the whole workflow and not only the material, and the recent studies above confirm that view. Clinicians choosing a printed permanent resin should therefore look for products validated for their printer and post-curing unit, and should not rely on marginal fit data alone.

This study has limitations. It was an in vitro investigation using one printer, one design and one preparation geometry. It did not reproduce saliva, thermocycling, cyclic occlusal loading or patient variability, and static loading to fracture does not represent fatigue failure in the mouth. Recent investigations show that chewing simulation significantly increases marginal and internal discrepancy of printed prostheses [13] and that artificial ageing can change the fracture behaviour of interim materials [16], so our values may overestimate performance after clinical function. Marginal gap was measured in two dimensions at a limited number of points, and three-dimensional methods such as micro-computed tomography would give a fuller picture of internal fit. Resin composition was unknown, and the failure mode of the fractured specimens was not classified. Future work should include aging protocols, different build orientations, longer-span prostheses, fatigue testing, analysis of failure modes and clinical follow-up.

CONCLUSION

Within the limitations of this in vitro study, both 3D-printed crown and bridge resins showed marginal fit within clinically acceptable limits with no significant difference between them, while Prevest resin showed significantly higher fracture load than Prestocraft resin.

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