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Repair bond strength of composite resin to additively manufactured permanent resin materials: a comparative evaluation of light-cure, self-cure, and dual-cure universal adhesives

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Abstract

Background This study aimed to evaluate the repair bond strength of composite resin to two 3D-printed permanent resin materials using different universal adhesive systems—light-cure, self-cure, and dual-cure—following a standardized air abrasion.

Methods Seventy-two disc-shaped specimens ($n=12$ per group) were fabricated using two different commercial 3D-printed materials: Saremco Crowntec and Bego VarseoSmile Crown Plus. After post-processing, all specimens were thermocycled for 5,000 cycles to simulate aging. The bonding surfaces were then subjected to air abrasion, followed by the application of one of three universal adhesive systems: light-cure (G-Premio Bond), self-cure (Tokuyama Universal Bond II), or dual-cure (Futurabond U). A composite resin (Filtek Z250) cylinder was then bonded and light-cured. Shear bond strength (SBS) was measured, and fracture modes were examined under a stereomicroscope. Data were analyzed using two-way analysis of variance (ANOVA) and Tukey HSD tests ($p<0.05$).

Results Self-cure universal adhesives exhibited the highest SBS values, especially in the Bego material group (19.20 ± 2.11 MPa), while the lowest bond strength was observed in the Saremco + light-cure group (14.28 ± 1.23 MPa). Both the adhesive system ($p<0.001$) and material type ($p=0.002$) significantly affected SBS. Failure mode analysis revealed predominantly adhesive failures in the light-cure groups, and more mixed/cohesive failures in the self-cure and dual-cure groups.

Conclusions Bond strength of repaired 3D-printed permanent resins is significantly influenced by the adhesive systems and material type. Self-cure universal adhesives provided the most effective bonding performance, particularly when combined with Bego VarseoSmile Crown Plus.

Keywords 3D-printed resin, Composite repair, Universal adhesive systems, Shear bond strength, Air abrasion

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Background

The integration of three-dimensional (3D) printing technology into dental practice has revolutionized the fabrication of indirect restorations by enabling faster production, cost-effectiveness, and material efficiency when compared to traditional subtractive manufacturing methods [1, 2]. Among these innovations, 3D-printed permanent resin-based materials have emerged as promising candidates for definitive restorations such as crowns and bridges, owing to their favorable mechanical properties, esthetic performance, and seamless compatibility with digital workflows [3]. These materials are typically composed of cross-linked methacrylate-based resins, inorganic fillers, and photoinitiators, specifically engineered for long-term intraoral application.

Despite these advantages, one of the key challenges in the clinical longevity of permanent 3D-printed resins is their intraoral repairability after chipping, fracture, or marginal failure [4, 5]. In such cases, chairside repair using composite resin is often preferred over complete restoration replacement, offering a conservative and cost-effective solution.

The success of composite resin repair on 3D-printed substrates is influenced by several factors, primarily the surface conditioning technique and the adhesive system employed. Surface treatments such as hydrofluoric acid etching and air particle abrasion have been proposed to enhance micromechanical retention [6]. Airborne-particle abrasion with aluminum oxide, in particular, has demonstrated improved surface topography and higher repair bond strength compared to chemical methods [7, 8].

Moreover, bonding to 3D-printed permanent resins may present different challenges compared to CAD/CAM milled materials, due to differences in filler content and polymer network structure [9]. Adhesive systems containing functional monomers such as 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP), and those that utilize dual-cure or self-cure mechanisms, have been investigated to optimize bonding performance [10]. However, there remains limited comparative evidence regarding the performance of light-cured, self-cured, and dual-cured adhesives specifically for repairing 3D-printed permanent resin materials, especially following standardized mechanical surface pretreatment [7].

However, there is limited evidence directly comparing the performance of different polymerization modes of universal adhesives—light-cure, self-cure, and dual-cure—when repairing permanent 3D-printed resins. To the best of our knowledge, this is the first study to simultaneously evaluate these adhesive strategies following a standardized air abrasion protocol. The novelty of the present work lies in providing new insights into the optimal repair approach for additively manufactured permanent resin restorations, which are increasingly used in clinical practice.

Therefore, the aim of this study was to evaluate the repair shear bond strength of composite resin to different 3D-printed permanent dental resins after standardized air particle abrasion, using three universal adhesive systems: light-cure, self-cure, and dual-cure universal adhesives. The null hypothesis was that neither the type of 3D-printed permanent resin material nor the type of adhesive system would significantly affect the repair bond strength of composite resin to 3D-printed permanent substrates, and no interaction would be observed between these two factors.

Materials and methods

Materials

Two commercially available 3D-printed permanent resin materials and three universal adhesive systems were used in this study. The composition and manufacturer details are presented in Table 1.

3D-printed permanent resins:

- Saremco CrownTec (Saremco Dental AG, Switzerland).
- Bego VarseoSmile Crown Plus (Bego GmbH, Germany).

Universal adhesives:

- G-Premio Bond (GC, Tokyo, Japan) – light-cured.
- Tokuyama Universal Bond II (Tokuyama Dental, Tokyo, Japan) – self-cured.
- Futurabond U (VOCO, Cuxhaven, Germany) – dual-cured.

Methods

Sample size calculation

An a priori power analysis was conducted using G*Power 3.1.9.7 to determine the required sample size. Based on an effect size of f = 0.40 from a previous study, with a significance level of $\alpha = 0.05$ and a power of 0.80, the minimum total sample size was calculated to be 66 [11]. To compensate for potential data loss, 72 specimens were prepared ($n = 12$ per group).

Study design and specimen preparation

A total of 72 disc-shaped specimens (5 mm diameter × 2 mm thickness) were fabricated from two commercially available 3D-printed permanent dental resins. All specimens were fabricated using a DLP 3D printer (T-ROX 3D Dental Resin Printer, Turkey). All specimens were printed in a horizontal orientation, and the bonding procedures were performed on the standardized top surface of the printed discs after post-processing. After printing,

Table 1 Composition and manufacturer information of the 3D-printed resins and adhesive systems used in the study

Material Name	Manufacturer	Country	Composition	Lot Number
Saremco Crowntec	Saremco Dental AG	Switzerland	UDMA- Bis-GMA- TEG-DMA- Inorganic fillers (~ 50–60 wt%)- Photoinitiators-Pigments, stabilizers	F298
Bego VarseoSmile Crown Plus	Bego GmbH	Germany	UDMA- TEG-DMA- Aliphatic dimethacrylates- Microfine ceramic fillers (~ 40–50 wt%)- Photoinitiators- Pigments, stabilizers	602,021
G-Premio Bond	GC	Japan	10-MDP- 4-META-Dimethacrylate monomers- Photoinitiators- Acetone solvent- HEMA-free	2,312,154
Tokuyama Universal Bond II	Tokuyama Dental	Japan	3D-SR monomer-MTU-6-Acetone solvent- HEMA-free- Self-cure catalyst	048B7
Futurabond U	VOCO	Germany	10-MDP- Silane-Multifunctional acrylate monomers- Ethanol solvent- Photoinitiators	2,335,227
Filtek Z250	3 M ESPE	USA	Bis-GMA, UDMA, Bis-EMA, TEG-DMA, zirconia/silica fillers (~ 60 vol%, ~ 82 wt%), photoinitiators, pigments, stabilizers.	NA21630

all specimens were subjected to post-processing protocols according to the respective manufacturer's recommendations. Uncured resin residues were removed by immersing the specimens in 96% isopropyl alcohol for 5 min using an ultrasonic bath. Following cleaning, the samples were air-dried and subsequently post-cured using a light-emitting diode (LED)curing unit (Otoflash G171, NK-Optik, Germany) with two flashes of 1500 light pulses each, under nitrogen atmosphere, to ensure complete polymerization. All samples underwent thermocycling for 5,000 cycles between 5 °C and 55 °C with a 30-second soak period in each bath (SD Mechatronik, Germany). For each resin ($n = 36$), specimens were randomly allocated to three universal adhesive subgroups ($n = 12$). Thus, a total of six experimental groups were established based on the combination of 3D-printed resin material and adhesive system, with 12 specimens per group ($n = 12$):

Group 1 (SC–LCA) Saremco Crowntec + G-Premio Bond (Light-Cure Universal Adhesive).

Group 2 (SC–SCA) Saremco Crowntec + Tokuyama Universal Bond II (Self-Cure Universal Adhesive).

Group 3 (SC–DCA) Saremco Crowntec + Futurabond U (Dual-Cure Universal Adhesive).

Group 4 (BG–LCA) Bego VarseoSmile Crown Plus + G-Premio Bond (Light-Cure Universal Adhesive).

Group 5 (BG–SCA) Bego VarseoSmile Crown Plus + Tokuyama Universal Bond II (Self-Cure Universal Adhesive).

Group 6 (BG–DCA) Bego VarseoSmile Crown Plus + Futurabond U (Dual-Cure Universal Adhesive).

Surface treatment

The bonding surfaces of all specimens were subjected to air particle abrasion (sandblasting) with 50 µm aluminum oxide particles (Korox, Bego, Germany) for 10 s at 2.5 bar pressure, from a distance of 10 mm at a 45-degree angle. Specimens were then rinsed with distilled water for 5 s and air-dried.

Repair procedures

A cylindrical transparent mold (Tygon® tubing, Saint-Gobain Performance Plastics, France; inner diameter: 2 mm, height: 2 mm) was used. To ensure that both ends of the tube were parallel and flat, the tubing was cut using a precision blade on a digital caliper-guided cutting device. During specimen preparation, the tube was carefully positioned at the center of the specimen surface and stabilized using a light finger pressure. Repair composite resin (Filtek Z250, 3 M ESPE, St. Paul, MN, USA) was applied using the following adhesive protocols. All adhesives were applied in accordance with the manufacturers' instructions. The light-curing unit tip was positioned perpendicularly at approximately 1 mm from the adhesive surface, and no mold was present during photoactivation for either light-cure or dual-cure adhesives. The application protocols for each group were as follows:

- **G-premio bond group (light-cured)**: After thoroughly shaking the bottle, a generous amount of G-Premio Bond was applied to the surface using a microbrush and actively rubbed for 10 s. A gentle

air stream was then applied for 5 s to evaporate the solvent and form a uniform thin film. Finally, the adhesive was light-cured for 10 s using a LED curing unit(Woodpecker i-LED curing light, Guilin Woodpecker Medical Instrument Co., China) with an irradiance of 1200 mW/cm². The bonding procedure applied in the G-Premio Bond group is illustrated step by step in Fig. 1.

- **Tokuyama universal bond II group (self-cured)**: Equal amounts of Bond A and Bond B were dispensed and thoroughly mixed on a mixing pad for at least 5 s. The mixed adhesive was applied to the prepared surface using a microbrush and actively rubbed for 10 s to ensure optimal wetting and infiltration. Excess adhesive was gently air-dried for 5 s to form a thin, uniform film without pooling. The adhesive was allowed to self-cure completely without any light activation, as per the self-curing nature of the material. After application, a waiting time of 3 min was allowed to ensure complete self-curing before applying the repair composite resin. The bonding procedure applied in the Tokuyama Universal Bond II group is illustrated step by step in Fig. 2.

- **Futurabond U group (dual-cured)**: The single-dose blister pack was pressed to release the contents into the mixing well. The adhesive was then thoroughly mixed using the applicator brush and applied to the prepared surface. It was actively rubbed into the surface for 20 s to ensure proper infiltration and interaction with the substrate. Excess adhesive was gently air-dried for 5 s to obtain a uniform thin film without pooling. Subsequently, light-curing was performed for 10 s using a LED curing unit to initiate polymerization and allow the dual-curing mechanism to complete. The bonding procedure applied in the Futurabond U group is illustrated step by step in Fig. 3.

After bonding, the repair composite resin(Filtek Z250, 3 M ESPE, St. Paul, MN, USA) was placed into the cylindrical mold in a single increment to avoid voids and excess. A Mylar strip, cut into a small piece, was gently pressed onto the mold to obtain a standardized flat surface. Light curing was performed for 20 s using a Woodpecker i-LED unit (1200 mW/cm²), with the light tip positioned perpendicularly and in direct contact with the Mylar strip, ensuring a standardized and reproducible curing distance. All specimens were stored in distilled water at 37 (± 1) °C for 24 h before testing.

Shear bond strength testing

Shear bond strength was measured using a universal testing machine (Schimadzu IG-IS, Kyoto, Japan) equipped with a chisel-shaped shear testing jig at a crosshead speed of 1 mm/min until failure. The maximum load at failure was recorded, and bond strength (MPa) was calculated by dividing this load by the bonded surface area. The fractured samples were examined at x40 magnification under a stereomicroscope (Olympus, SZ-61, Japan) to analyze the fracture mode.

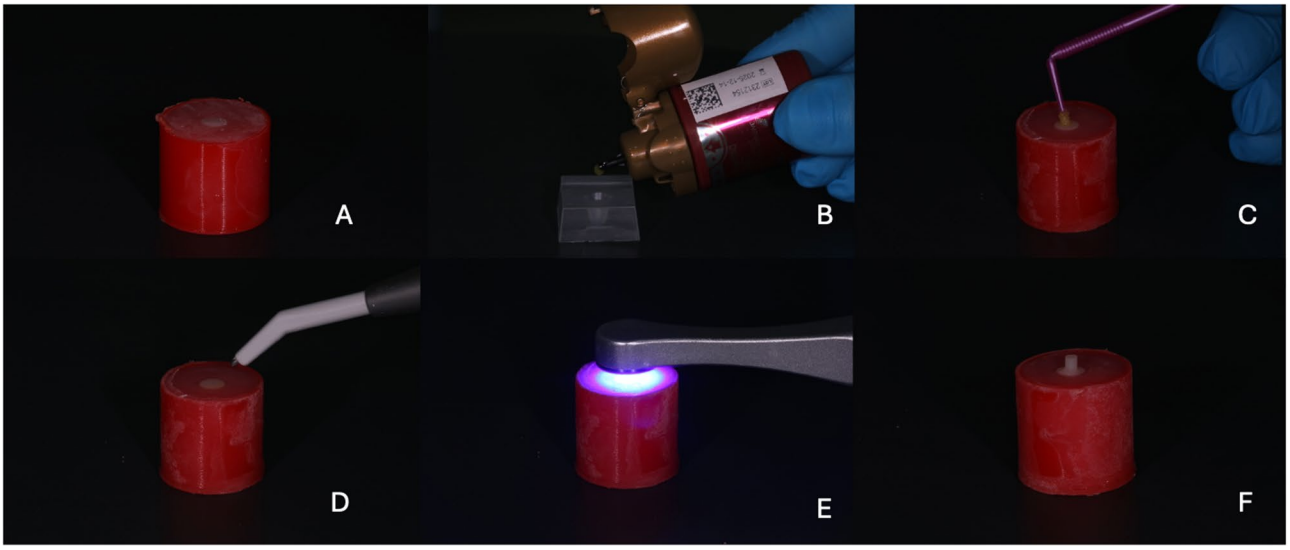


Fig. 1 Application steps of G-Premio Bond light-cure adhesive on specimen surface **A** Standardized specimen surface prior to bonding. **B** G-Premio Bond is dispensed into a dappen dish. **C** Adhesive is applied to the specimen surface using the microbrush and actively rubbed for 10 s. **D** A gentle air stream is applied for 5 s to evaporate the solvent and form a uniform adhesive layer. **E** Light-curing of the adhesive for 10 s using a LED curing unit. **F** Final appearance of the specimen after composite application

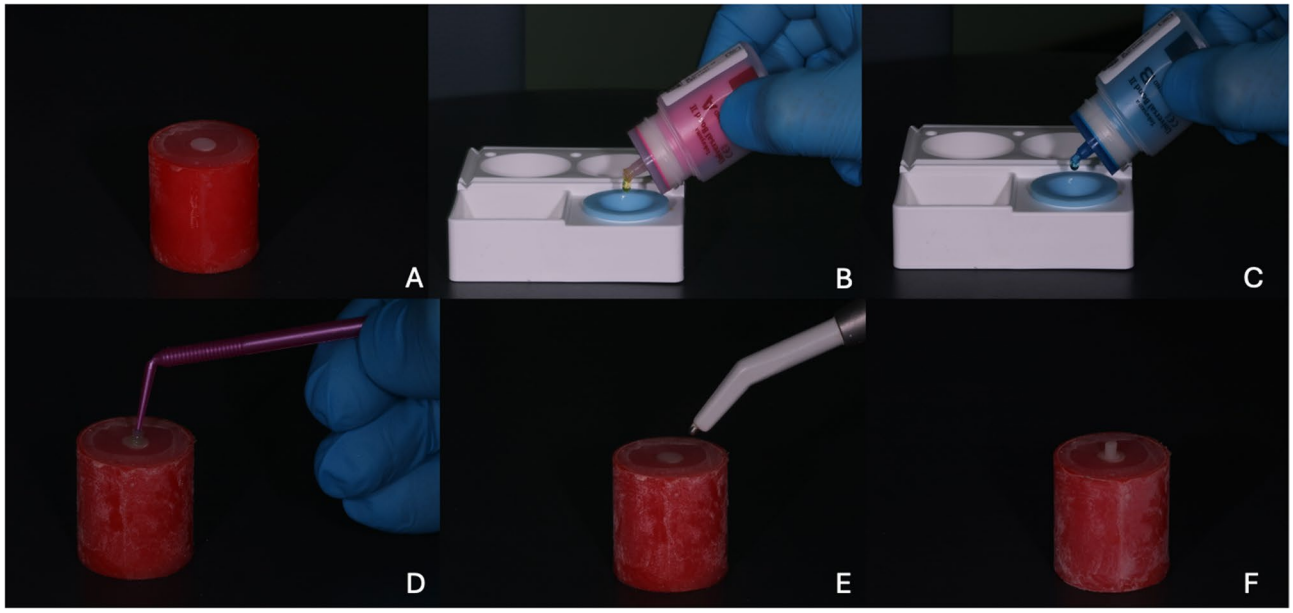


Fig. 2 Application steps of Tokuyama Universal Bond II self-cure adhesive on specimen surface **A** Standardized specimen surface prior to bonding. **B** Equal amount of Tokuyama Universal Bond II Part A is dispensed onto the mixing well. **C** Equal amount of Part B is dispensed. **D** The two components are mixed thoroughly for at least 5 s and applied to the specimen surface using a microbrush with active rubbing for 10 s. **E** Excess adhesive is gently air-dried for 5 s to form a uniform adhesive layer. **F** Final appearance of the specimen after composite application

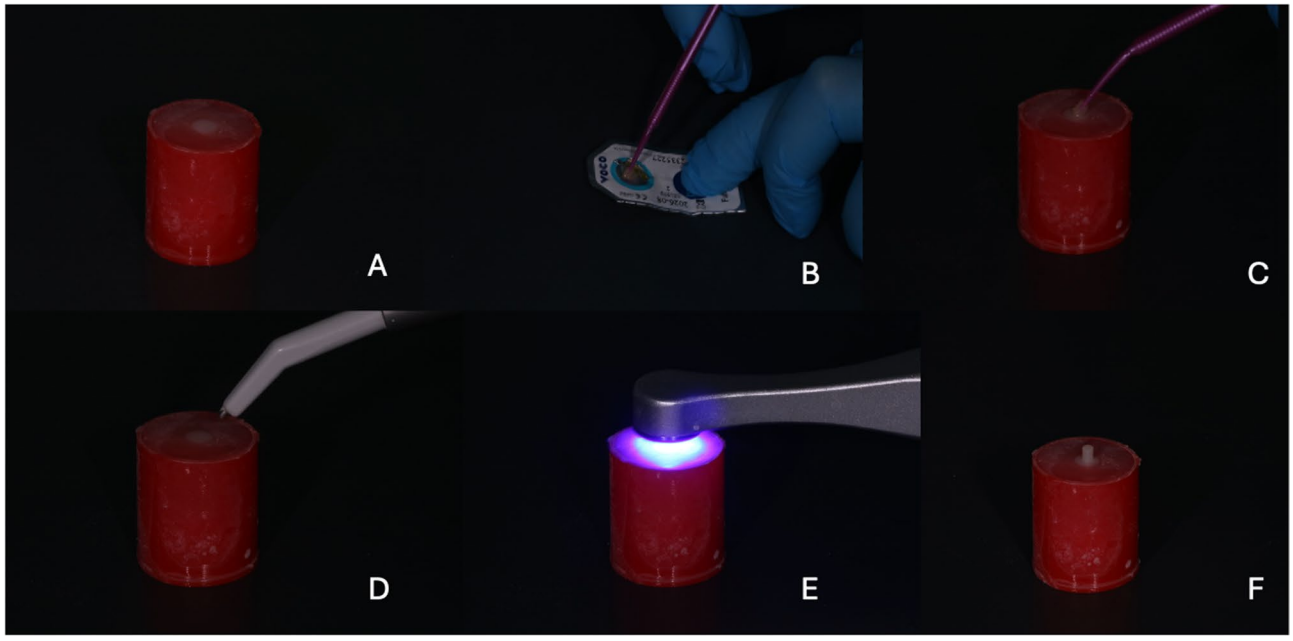


Fig. 3 Application steps of Futurabond U dual-cure adhesive on 3D-printed specimen surface **A** Standardized specimen surface prior to bonding. **B** Futurabond U single-dose blister pack is activated to release the adhesive into the mixing well. **C** The adhesive is applied to the specimen surface using a microbrush and actively rubbed for 20 s to ensure proper infiltration. **D** A gentle air stream is applied for 5 s to obtain a uniform adhesive layer without pooling. **E** Light-curing is performed for 10 s using a LED curing unit to initiate the dual-curing mechanism. **F** Final appearance of the specimen after composite application

Table 2 SBS values (Mean ± SD) of 3D-printed permanent resins according to different adhesives

Materials/Adhesives	Light-cure	Self-cure	Dual-cure
Saremco Crowntec	14.28 ± 1.23^{aA}	17.32 ± 1.55^{bA}	16.11 ± 1.42^{bA}
Bego VarseoSmile Crown Plus	15.74 ± 1.31^{aB}	19.2 ± 2.11^{cB}	18.03 ± 1.86^{bB}

The limit of significance among adhesives (a–c) and between 3D-printed materials (A–B). $P < 0.05$

The failure modes observed in this study were classified as follows: adhesive failure, defined as separation at the interface between the permanent resin and the composite; cohesive failure, defined as fracture occurring within either the permanent resin or the composite resin itself; and mixed failure, characterized by a combination of adhesive and cohesive failure, with more than half of the composite remaining attached to the permanent resin surface [10].

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics software (version 26.0; IBM Corp., Armonk, NY, USA). The normal distribution of the data was confirmed using the Shapiro–Wilk test, and the assumption of homogeneity of variances was verified with Levene's test. A two-way analysis of variance (ANOVA) was conducted to evaluate the effects of different 3D-printed materials (Saremco Crowntec and Bego VarseoSmile Crown Plus) and universal adhesive systems (light-cure, self-cure, and dual-cure) on repair bond strength. When significant differences were detected between factors, post hoc comparisons were performed using the Tukey HSD test. The distribution of failure modes among groups was analyzed using the Chi-square test. A significance level of $p < 0.05$ was adopted for all analyses.

Results

The shear bond strength values for each material and adhesive combination are summarized in Table 2. According to two-way ANOVA and Tukey HSD post hoc tests, the differences among groups were statistically significant ($p < 0.001$).

Two-way ANOVA results indicated that both the type of 3D-printed material ($p = 0.002$) and the adhesive system ($p < 0.001$) had statistically significant effects on SBS. However, the interaction between material and adhesive type was not statistically significant ($p = 0.243$).

Post hoc analysis using the Tukey HSD test demonstrated significant pairwise differences among the adhesive systems. Self-cure universal adhesive exhibited significantly higher SBS values compared to both dual-cure ($p = 0.0049$) and light-cure universal adhesives ($p < 0.001$). Dual-cure universal adhesive also showed significantly higher SBS than the light-cure universal adhesive ($p = 0.0176$).

Table 3 Distribution of failure modes among experimental groups

Group	Adhesive Failure	Mixed Failure	Cohesive Failure
SC–LCA	12(100.0%)	0 (0.0%)	0 (0.0%)
SC–SCA	5(41.7%)	2(16.7%)	5(41.7%)
SC–DCA	6 (50.0%)	6 (50.0%)	0 (0.0%)
BG–LCA	12(100.0%)	0 (0.0%)	0 (0.0%)
BG–SCA	3 (25.0%)	9(75.0%)	0 (0.0%)
BG–DCA	9(75.0%)	3 (25.0%)	0 (0.0%)

SC Saremco Crowntec, *BG* Bego VarseoSmile Crown Plus, *LCA* Light-cure adhesive, *SCA* Self-cure adhesive, *DCA* Dual-cure adhesive

The distribution of failure modes is presented in Table 3. Chi-square analysis revealed that the differences in failure mode distribution among groups were not statistically significant ($p > 0.05$).

Discussion

The findings of this study demonstrated that both the type of 3D-printed permanent resin material and the adhesive system significantly influenced the repair shear bond strength values. Statistical analysis revealed a significant effect of material type ($p = 0.002$) and adhesive system($p < 0.001$), whereas no significant interaction was observed between these two factors. Accordingly, both null hypotheses, which stated that neither the 3D-printed material nor the adhesive system would affect the repair bond strength, were rejected.

In restorative dentistry, the ability to repair an existing restoration provides a significant clinical advantage by minimizing the disadvantages associated with replacement procedures, which often require more extensive cavity preparation and increased treatment costs [11]. From the perspective of minimally invasive dentistry, deciding to repair rather than replace a restoration after radiographic and clinical evaluation is considered an important treatment approach [12]. The success of a repair procedure relies primarily on the adhesion between the pre-existing restoration and the newly added resin composite [13]. This adhesion is influenced by the surface treatment applied to the aged restoration, the adhesive system selected, and the properties of the repair material [11].

Previous studies have reported that surface pretreatments, such as roughening with burs, aluminum oxide or silica-coated particles, laser irradiation, and acid etching, can significantly enhance micromechanical interlocking [14]. In routine clinical practice, rotary instruments such as burs are often preferred for surface roughening due to their simplicity and accessibility. However, in the present study, air abrasion was chosen as the pretreatment method because it provides a more standardized and reproducible roughening effect, thereby reducing operator variability. Supporting this approach, several investigations have demonstrated that air abrasion improves

micromechanical retention and results in higher repair bond strength on resin-based substrates compared to bur roughening [15, 16]. Thus, air abrasion was employed to ensure both clinical relevance and methodological standardization in the experimental design.

In addition to mechanical roughening, it has been reported that chemical pretreatments such as silane application, primers, and adhesive systems are required to achieve effective chemical bonding [17, 18]. In this study, the shear bond strength (SBS) test was selected to evaluate the bonding effectiveness of repaired 3D-printed materials, as it has been considered a reliable and straightforward in vitro method for assessing bond strength in previous research [19, 20].

The superior performance of the self-cure universal adhesive (Tokuyama Universal Bond II) can be attributed to its chemical polymerization mechanism, which may enhance monomer interaction and conversion within the methacrylate-rich matrix of 3D-printed substrates [10, 21]. Additionally, the absence of 2-hydroxyethyl methacrylate (HEMA) in the formulation and the inclusion of functional monomers such as MTU-6 could improve chemical bonding to both hydrophilic and hydrophobic resin components [22].

In our study, the light-cure adhesive system exhibited the lowest bond strength for both 3D-printed materials. The reduced bond strength observed in the light-cure adhesive group may also be attributed to factors intrinsic to the adhesive system. Light-cure adhesives are highly susceptible to oxygen inhibition at the surface, which can compromise polymerization and result in a lower cross-link density [23]. In addition, incomplete solvent evaporation prior to photoactivation may leave residual solvent in the adhesive layer, further weakening the bond [24]. Moreover, unlike self-cure and dual-cure systems, light-cure adhesives lack a chemical polymerization component, which may limit their interaction with the less reactive methacrylate groups of 3D-printed resins [25, 26]. These factors combined could explain the inferior bonding performance of light-cure adhesives compared with chemically activated systems.

In this study, the dual-cure adhesive (Futurabond U) showed intermediate bond strength values. This outcome may be explained by its formulation characteristics, such as the balance between light- and chemically initiated polymerization pathways, the concentration of functional monomers like 10-MDP, and the viscosity of the adhesive, which together influence its interaction with the 3D-printed resin substrate [25, 26]. While the additional chemical curing component supports polymerization, differences in adhesive composition compared with the self-cure system may have limited its overall performance.

The observed differences in repair bond strength between the two 3D-printed resins can be attributed to their distinct compositional and structural characteristics. Saremco CrownTec contains approximately 50–60 wt% inorganic fillers with a highly cross-linked methacrylate matrix, which may limit monomer diffusion and interfacial adaptation during repair. In contrast, Bego VarseoSmile Crown Plus incorporates a lower filler load (40–50 wt%) and aliphatic dimethacrylates with lower viscosity, potentially facilitating better infiltration and chemical interaction with self-cure adhesives. Previous studies have similarly demonstrated that filler content, resin chemistry, and degree of conversion strongly influence the repair bond strength of resin-based materials [6, 7, 27]. These differences likely explain why higher bond strength values were achieved with Bego VarseoSmile Crown Plus in the present study.

The unique microstructure of 3D-printed resins may also contribute to bonding differences. These materials are constructed in a layer-by-layer fashion, which can create interlayer interfaces that are less densely polymerized, affecting overall adhesion [28, 29]. Additionally, manufacturer-specific differences in filler load, monomer chemistry, and degree of conversion lead to variable surface energy and bonding potential [30]. Bego VarseoSmile Crown Plus, for instance, contains higher ceramic filler content and lower viscosity, potentially allowing better diffusion and chemical interaction with self-cure adhesives [27, 31].

The observed failure modes further support the SBS results. Light-cure adhesive predominantly exhibited adhesive failures, suggesting weaker interfacial adhesion. In contrast, self-cure and dual-cure groups showed more mixed and cohesive failures, indicative of improved bond integrity and mechanical interlocking. This aligns with previous reports emphasizing the superior interfacial performance of chemically activated adhesives, particularly when combined with mechanical pretreatments such as airborne particle abrasion [6, 7, 10].

A limitation of the present study is that it was conducted under in vitro conditions, which do not fully replicate the complex oral environment where factors such as saliva, enzymes, pH fluctuations, and dynamic occlusal forces may influence bonding performance. Moreover, a relatively short aging protocol was employed; therefore, to obtain more representative and reliable results, future investigations are recommended to incorporate extended aging methods such as prolonged water storage, cyclic loading, or additional thermomechanical fatigue. Another limitation is that only two commercially available 3D-printed permanent resin materials (Saremco CrownTec and Bego VarseoSmile Crown Plus) were evaluated, restricting the generalizability of the findings to other materials with different monomer compositions

and filler contents. Similarly, only three universal adhesives were tested, and other adhesive formulations or the use of specific primers were not considered. In terms of methodology, shear bond strength was the only mechanical test applied; additional tests such as microtensile bond strength, push-out, or fatigue loading would provide a more comprehensive evaluation of the adhesive interface. Finally, microstructural and chemical analyses (e.g., SEM, AFM, FTIR) were not performed, which limits further insights into the micromechanical and chemical bonding mechanisms.

From a clinical perspective, these results underscore the importance of selecting adhesive systems based on the restoration material and intraoral conditions. Furthermore, while immediate bond strength is critical, long-term durability must also be considered. Future studies should employ extended aging protocols, including prolonged water storage, cyclic loading, and thermomechanical fatigue, to assess the stability of the adhesive interface over time [24, 32, 33].

Conclusion

Self-cure universal adhesives showed the highest repair bond strength to 3D-printed permanent resins, especially when used with Bego VarseoSmile Crown Plus. The adhesive type and material significantly affected bonding outcomes. These results highlight the importance of selecting appropriate adhesive systems in clinical repair of additively manufactured restorations.

Abbreviations

SBS	Shear Bond Strength
SC	Saremco Crowntec
BG	Bego VarseoSmile Crown Plus
LCA	Light-Cure Adhesive
SCA	Self-Cure Adhesive
DCA	Dual-Cure Adhesive
MPa	Megapascal
3D	Three-Dimensional
10-MDP	10-Methacryloyloxydecyl Dihydrogen Phosphate
HEMA	2-Hydroxyethyl Methacrylate
UDMA	Urethane Dimethacrylate
Bis-GMA	Bisphenol A Glycidyl Methacrylate
TEGDMA	Triethylene Glycol Dimethacrylate
SD	Standard Deviation
LED	Light Emitting Diode
ANOVA	Analysis of Variance

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Contributions

EYM: Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation. SYA: Writing – review & editing, Validation, Methodology, Formal analysis, Data curation, Conceptualization. CYÇ: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Investigation, Data curation, Conceptualization.

Author contributions

YILDIRIM MANAV, E: Conceptualization, Data Curation, Formal analysis, Methodology, Investigation, Writing - Original Draft, Writing- Review and EditingYAZICI AKBIYIK, S: Conceptualization, Data Curation, Writing- Review and Editing, Supervision.YIKICI ÇÖL, C: Conceptualization, Methodology, Data Curation, Investigation, Writing- Review and Editing, Supervision.

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Data availability

Data available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

Ethics, Consent to Participate, and Consent to Publish declarations: not applicable.

Competing interests

The authors declare no competing interests.

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