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Effect of Resin Coating on Nanoleakage and Shear Bond Strength of Universal Adhesives: Comparison with a Contemporary Two-Step Universal Adhesive- An In Vitro Study

Abstract

Objective: Nanoleakage at the resin–dentin interface adversely affects the longevity of adhesive restorations. Contemporary two-step universal adhesives and resin-coating techniques have been introduced to improve interfacial sealing ability. The objective of the study was to evaluate the effect of resin coating on nanoleakage and shear bond strength of a universal adhesive and compare it with a contemporary two-step universal adhesive.

Methods: Eighty extracted human premolars were randomly divided into four groups (n=20): Group A—G2 Bond Universal; Group B—G-Premio Bond; Group C—G-Premio Bond with resin coating using G-aenial Universal Flo; and Group D—control. Composite restorations were placed using G-aenial Posterior composite. Half of the specimens were evaluated for nanoleakage using Confocal Laser Scanning Microscopy, while the remaining specimens underwent shear bond strength testing using a universal testing machine. Data were analyzed using one-way ANOVA and Bonferroni post hoc tests ($P < 0.05$).

Results: Group A exhibited the lowest nanoleakage, whereas the control group showed the highest. Resin coating significantly reduced nanoleakage compared with the uncoated single-step adhesive ($P=0.001$). The highest mean shear bond strength was observed in Group A (54.85 ± 10.19 MPa), followed by Group C (44.22 ± 12.48 MPa), Group B (42.11 ± 12.50 MPa), and Group D (26.94 ± 1.20 MPa). Group A demonstrated significantly higher bond strength than the control group ($P=0.0001$).

Conclusion: The two-step universal adhesive demonstrated superior interfacial sealing ability. Resin coating significantly improved the performance of the single-step universal adhesive and may serve as a simple strategy to enhance restoration longevity.

INTRODUCTION

Dentin adhesives are classified as three-step, two-step, and single-step systems based on the application of etching, priming, and bonding procedures.[1] Although simplified adhesive systems have gained popularity, concerns regarding their long-term durability persist.[2,3] Universal adhesives contain functional monomers such as 10-MDP, which provide chemical bonding to tooth structure and improve interfacial sealing.[4] G2 Bond Universal is a HEMA-free, two-step universal adhesive designed to enhance interfacial sealing through a more hydrophobic adhesive layer.[5,6] Nanoleakage, caused by microscopic defects within the hybrid layer, can compromise interfacial sealing.[7] In addition, polymerization shrinkage of resin composites may lead to marginal leakage and restoration failure.[8] Resin coating has been proposed to improve interfacial sealing and reduce shrinkage stress.[9-12]

Adhesive dentistry has advanced remarkably ; however, the resin-dentin interface remains a weak point. The complex structure of dentin, nanoleakage often occurs, leading to bond failure and shorter restoration life.

Although previous studies have evaluated universal adhesives, resin coating techniques, and interfacial sealing separately, there is limited evidence directly comparing a contemporary HEMA-free two-step universal adhesive (G2 Bond Universal) with a single-step universal adhesive and the same adhesive modified by resin coating in terms of both nanoleakage and shear bond strength. To the best of our knowledge, no study has simultaneously evaluated these three specific approaches using both nanoleakage assessment by CLSM and shear bond strength testing. The null hypothesis of this study was that there would be no significant difference in nanoleakage or shear bond strength among the contemporary two-step universal adhesive (G2 Bond Universal), the single-step universal adhesive (G-Premio Bond), the resin-coated single-step universal adhesive, and the control group.

Methods

The occlusal surfaces of 80 extracted human premolars were sectioned parallel to occlusal surface to expose the flat occlusal dentin with a carborundum disc using a slow speed handpiece and the samples were randomly divided into 4 groups (20 in each group). The surfaces were polished with wet #600 grit silicon carbide paper for 60 s to create a standardized smear layer.

- Group A: Two-step universal adhesive — G2 Bond Universal (GC Corp, Tokyo, Japan)
- Group B: Single-step universal adhesive — G-Premio Bond (GC Corp, Tokyo, Japan)
- Group C: Single-step universal adhesive with resin coating (0.5mm) — G-Premio Bond followed by G-aenial Universal Flo Bond (GC Corp, Tokyo, Japan)
- Group D: Control (no adhesive applied)

All bonding agents were applied strictly according to the manufacturer's instructions, followed by light curing. The Gaenial Posterior (GC, Tokyo) composite was placed in increments using Dentsply Teflon mould measuring 2mm diameter and 4mm height and cured. Based on the evaluation performed, half of the specimens from each group had undergone Nanoleakage evaluation and another half for Shear Bond Strength testing.

For Nanoleakage evaluation, samples immersed in 0.1% Rhodamine B dye (Nice Chemicals, India) at 37°C for 24 hours, sectioned into 1-mm-thin slices using Buehler Isomet 3000 linear precision saw and observed under Confocal Laser Scanning Microscope (Olympus FV3000, Japan) at low magnification (10×) using Olympus Dimension CellSens software. Nanoleakage was quantified as the linear depth of Rhodamine B dye penetration (µm) along the resin–dentin interface using the software measurement tool.

For shear bond strength, samples were mounted to acrylic blocks and transferred to a universal testing machine. The load was applied at the junction of dentin and composite at a crosshead speed of 1mm/min.

Statistical Analysis

Data were analyzed using SPSS version 26.0 (SPSS Inc., Chicago, IL, USA) and level of significance was set at $P < 0.05$. Descriptive statistics was performed to assess the mean and standard deviation of the respective groups. Data normality was assessed using the Shapiro–Wilk test. Intergroup comparisons were performed using one-way ANOVA followed by Bonferroni post hoc testing.

Results

- Group A (Two-step): Exhibited the least nanoleakage, significantly lower than all other groups, particularly the control (mean difference = – 814.75 µm, p=0.0001).
- Group B (Single-step): Showed significantly more nanoleakage than Group C (Single-step + Resin Coat), with a mean difference of 71.34 µm (p = 0.001).
- Group C (Single-step + Resin Coat): Demonstrated reduced nanoleakage compared to Single-step alone, confirming the added benefit of resin coating.
- Group D (Control): Recorded the highest nanoleakage values, significantly greater than all adhesive groups.

Representative confocal laser scanning microscopy (CLSM) images showing nanoleakage in the four experimental groups are presented in Figure 1. The mean nanoleakage depth (µm) and standard deviation of the four experimental groups are presented in Figure 2.

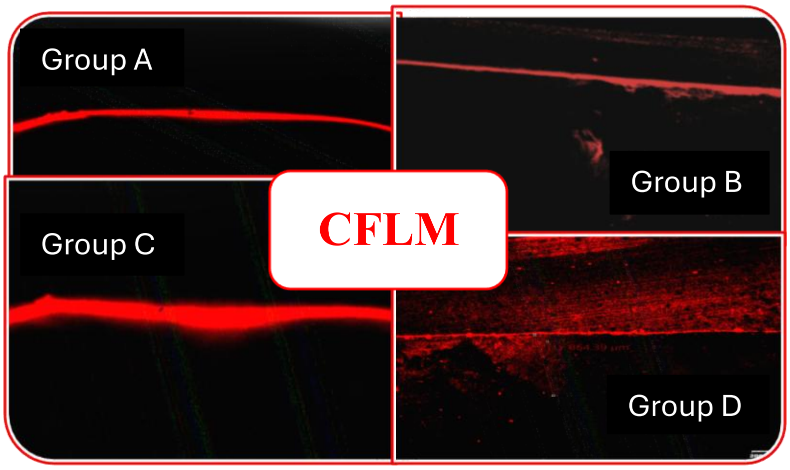

Figure 1. Representative confocal laser scanning microscopy (CLSM) images showing nanoleakage at the resin–dentin interface in the four experimental groups

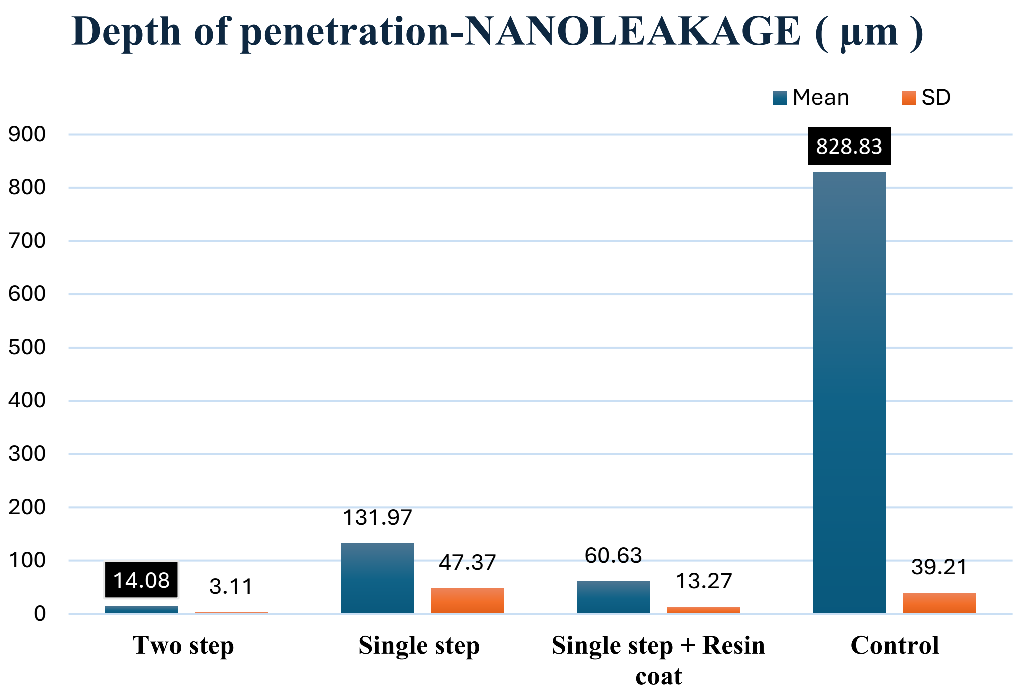

Figure 2.Mean (± SD) nanoleakage depth (µm) of the four experimental groups. The two-step universal adhesive (Group A) exhibited the lowest mean nanoleakage, followed by the single-step universal adhesive with resin coating (Group C), the single-step universal adhesive (Group B), and the control group (Group D), which demonstrated the highest nanoleakage

Group A demonstrated the highest mean shear bond strength (54.85 ± 10.19 MPa), followed by Group C (44.22 ± 12.48 MPa), Group B (42.11± 12.50 MPa), and Group D (26.94 ± 1.20 MPa). Although Group A demonstrated numerically higher bond strength values than Group B and C, the differences were not statistically significant. Statistical analysis revealed that Group A exhibited a significantly higher bond strength compared to Group D ($p = 0.0001$), whereas no statistically significant difference was observed between Group A and Groups B and C ($p > 0.05$). Additionally, both Group B ($p = 0.012$) and Group C ($p = 0.003$) showed significantly greater bond strength values than Group D. However, the difference between Groups B and C was not statistically significant ($p = 1.000$). The descriptive statistics for shear bond strength are presented in Table 2. The mean shear bond strength (MPa) and standard deviation of the four experimental groups are illustrated in Figure 3.

Table 2. Descriptive statistics of shear bond strength (MPa) for the four experimental groups.

	N	Mean	SD	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
GROUP A	10	54.8510	10.1895	3.22221	47.5619	62.1401	40.57	62.90
GROUP B	10	42.1060	12.5045	3.95428	33.1608	51.0512	25.31	57.29
GROUP C	10	44.2190	12.4770	3.94560	35.2934	53.1446	23.14	57.13
GROUP D	10	26.9440	1.19968	.37937	26.0858	27.8022	25.64	28.40
F Value (One way Anova test)					12.68			
P Value					0.0001*			

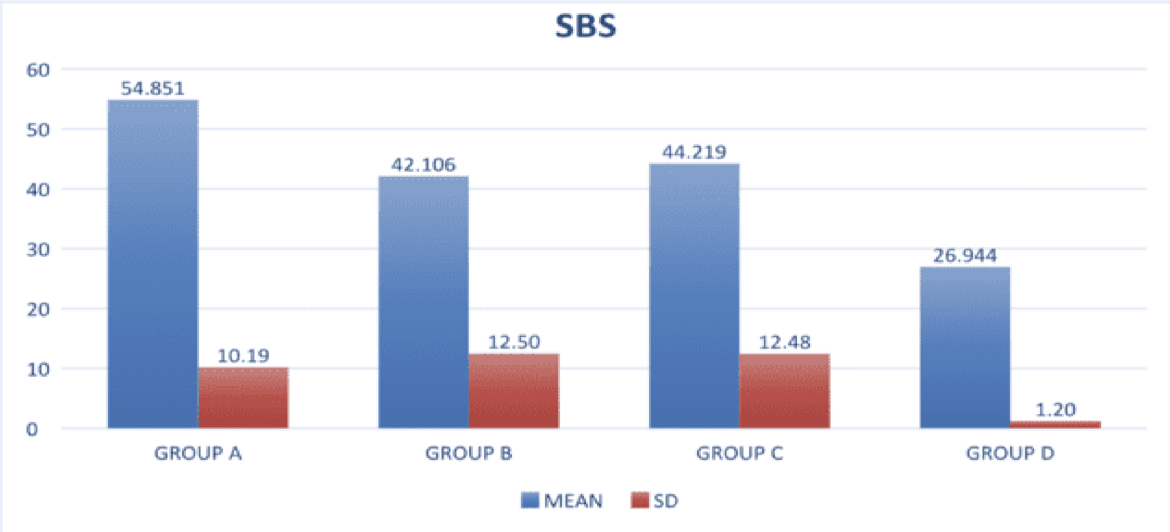

Figure 3. Mean (± SD) shear bond strength (MPa) of the four experimental groups.

Discussion

The primary objective of adhesive restorative materials is to establish a tight and durable bond to dental substrates. Given the rapid development and continual introduction of new adhesive systems, assessing their bond degradation and restoration durability is crucial[13]. The present study directly compared a single-step universal adhesive with and without resin coating against a contemporary two-step universal adhesive to evaluate their effects on nanoleakage and shear bond strength.

The present study compared the nanoleakage of a two-step universal adhesive (G2 Bond Universal), a single-step universal adhesive (G-Premio Bond), and a single-step universal adhesive with an additional resin coating. The results demonstrated that the two-step universal adhesive exhibited the least nanoleakage, followed by the resin-coated single-step adhesive, while the single-step adhesive alone showed the highest nanoleakage. These findings highlight the critical roles of application protocol and adhesive formulation in determining the sealing effectiveness of resin–dentin interfaces.

The superior performance of the two-step universal adhesive is consistent with previous studies, which have shown that separating the priming and bonding steps enhances resin infiltration, reduces phase separation, and improves polymer crosslinking, thereby minimizing permeability of the adhesive layer.[14] The superior performance of G2 Bond Universal may be attributed to its separate primer and bond application, lower water content, HEMA-free chemistry, higher degree of conversion, thicker hydrophobic adhesive layer, and reduced water permeability. These characteristics contribute to improved resin infiltration and reduced interfacial degradation. In particular, the HEMA-free and more hydrophobic formulation of G2 Bond Universal improves resistance to hydrolytic degradation, may contribute to improved long-term interfacial sealing, as reported in previous studies.[15] This is corroborated by Daneshpooy et al.,[16] who reported that G2 Bond maintained higher microtensile bond strength than G-Premio even after accelerated aging. Such interfacial sealing is essential, as nanoleakage pathways can allow water movement, enzymatic degradation, and eventual loss of adhesion.[17]

Resin coating of single-step adhesives significantly reduced nanoleakage compared to the uncoated group. This observation supports the “resin-coating technique” introduced for indirect restorations, in which the application of an additional hydrophobic resin layer improves hybrid layer quality, protects against stress, and enhances marginal sealing.[18] The coated adhesive likely functioned as a stress-absorbing intermediate layer because of its low modulus of elasticity, supporting the "elastic cavity wall" concept proposed by Pongprueksa et al.,[19] who demonstrated that low-viscosity resin liners could reduce polymerization shrinkage stress and minimize interfacial leakage. This observation is also in agreement with the "resin-coating technique" introduced by Inokoshi and Hosoda, in which the application of a thin resin layer improved marginal adaptation and enhanced the sealing ability of restorations. Our results suggest that a simple modification to the adhesive protocol may significantly improve the clinical performance of single-step adhesives, which are otherwise prone to nanoleakage due to their highly hydrophilic nature.

The higher nanoleakage observed with the single-step universal adhesive in this study aligns with reports that simplified one-bottle adhesives, while convenient, are more permeable and susceptible to water sorption.[20] Their hydrophilic composition and incomplete solvent evaporation hinder optimal polymerization, leaving nano-porosities that act as fluid-conducting channels. Over time, these nanospaces may accelerate collagen degradation and compromise the hybrid layer. Biomodification strategies, such as using chitosan nanoparticles, grape seed extract, or chlorhexidine, have been proposed to improve hybrid layer resistance and reduce nanoleakage.[21] Similarly, deproteinization with biocompatible agents such as ascorbic acid has also been shown to reduce nanoleakage by enhancing resin infiltration.[22] These adjuncts could be explored in future research in combination with universal adhesives.

From a biological perspective, the reduced nanoleakage achieved with two-step or resin-coated adhesives may also promote the formation of acid–base resistant zones, leading to the concept of "super dentin" and "super enamel".[23-24] These reinforced zones are capable of resisting secondary caries and preserving tooth structure, highlighting the long-term clinical benefits of improved adhesive sealing. The control group was included primarily to establish baseline nanoleakage and bond strength values in the absence of adhesive treatment.

The present findings suggest that the performance of simplified universal adhesives may be enhanced through modification of the adhesive protocol. Interestingly, resin coating improved the performance of the single-step adhesive, although it did not completely match the sealing ability achieved by the two-step universal adhesive. Based on the findings of the present study, the null hypothesis was rejected, as significant differences were observed among the experimental groups.

Limitations And Future Perspectives

This in vitro study does not fully reproduce oral conditions such as pulpal pressure, loading, and aging. Future studies should test long-term aging, biomodified adhesives, and clinical trials to validate resin coating and two-step universal adhesives.

Conclusions

Within the limitations of this in vitro study, the two-step universal adhesive demonstrated the lowest nanoleakage and the highest shear bond strength among the tested groups, indicating superior sealing ability at the resin-dentin interface. The application of a resin-coating layer over a single-step universal adhesive significantly reduced nanoleakage and improved bond performance compared with the uncoated single-step adhesive.

These findings suggest that both adhesive composition and application protocol play a critical role in the integrity of the resin-dentin interface. While the two-step universal adhesive provided the most favorable overall performance, the resin-coating technique may serve as a simple and effective strategy to enhance the clinical performance of simplified single-step universal adhesives.

From a clinical perspective, when optimal interfacial sealing is desired, clinicians may consider the use of a contemporary two-step universal adhesive or the incorporation of a resin-coating layer with single-step universal adhesives to improve restoration longevity and predictability. Further long-term aging studies and clinical investigations are required to validate these findings under intraoral conditions.

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None.

Conflicts Of Interest

No potential conflict of interest relevant to this article was reported

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