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Effect of Air Abrasion, Diamond Bur Roughening and Hydrofluoric Acid Etching on Shear Bond Strength of Repaired Resin Composites: An In Vitro Study

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Abstract

Background: Composite restorations often fail over time, and repair is a minimally invasive alternative to replacement that preserves tooth structure.

Objectives: To evaluate and compare the effect of various surface treatments on the shear bond strength of repaired dental composite restorations.

Materials and Methods: This experimental in-vitro study was conducted from Jan 24 to Mar 25 after the approval of Review Board of Azra Naheed Dental College, on 60 cylindrical micro-hybrid composite specimens fabricated in Teflon molds, light-cured in 2.5-mm increments, stored in distilled water at 37°C for 24h, and thermocycled for 500 cycles. The samples were divided into to 4 groups (n=15): Group A (silane only), B (air abrasion with 50µm Al_2O_3+silane+adhesive), C (diamond bur roughening+silane+adhesive) and D (9% HF etching+silane+adhesive). A repair layer of the same composite was applied to form bilayer samples. SBS was measured using universal testing machine.

Results: All 60 specimens were tested. The overall SBS was 18±8.07 MPa. Mean SBS (MPa) in the air abrasion group (B) was 30.47±2.03, followed by diamond bur group (C) 18.17±2.10, HF 13.96±1.19 (D) and the control group (A) 9.42±1.20. Surface treatment significantly affected SBS ($p<0.001$). Tukey HSD showed that all pairwise associations were significant ($p<0.001$).

Conclusion: Air abrasion produced the highest repair SBS and the most favorable failure pattern, outperforming diamond bur roughening, HF etching and silane treatment. Air abrasion is the preferred surface treatment for composite repair, however, diamond bur is an acceptable alternative, while HF etching is least favorable as the primary conditioning method.

Keywords: Air Abrasion, Dental; Composite Resins; Dental Restoration, Hydrofluoric Acid; Shear Strength; Surface Properties

Introduction

Resin-based composites have become the dominant direct restorative material because of their superior aesthetics, micromechanical adhesion to the tooth structure, and compatibility with minimally invasive dentistry.1 Composites are being developed and made better continuously especially their chemical make (resins and coupling agents), filler types, and curing methods.[2] Recent advances have improved filler types, concentration and coupling agents, as well as control of polymerization shrinkage and stress especially in the last decade, for restorations in high-load bearing posterior teeth.[2,3]

All dental composite undergo aging processes in the oral environment due to water uptake, hydrolysis of ester bonds in the resin matrix and at the silane-filler interface, thermal fluctuations, and enzymatic degradation of bonded interfaces.[4, 5] Thermal cycling and mechanical fatigue create microcracks and interfacial gaps, which may lead to marginal discoloration, microleakage, secondary caries, and ultimately restoration failure. To manage localized defects, dentists can replace the entire restoration or repair the defective area.[4,6]

A recent study Santos et al., reported that preservation of sound tooth structure reduces cost, shorter treatment time, and better patient satisfaction.[7] Moreover, another observational study by Vandekar et al., reported that repeated repairs can extend the functional life of dental composites for many years.[8] However, the long-term success critically depends on achieving reliable bonding between aged and new composite layers.[4,9]

The surface of an aged composite is chemically and mechanically different as it reduces the number of unreacted double bonds, alters surface energy, and has damaged resin layer with contaminants.[4, 5] Untreated aged surfaces reduced repair bond strength, therefore, to restore bonding, various surface conditioning protocols have been developed that combine mechanical roughening with chemical priming (silane, primers, adhesives).[10]

Among mechanical treatments, air abrasion with alumina has been reported as an effective methods for the repair of the composite.[11] Recent studies on aged bulk-fill or nanohybrid composites have reported that alumina air abrasion followed by universal or conventional adhesives improves shear or microtensile bond strengths than diamond bur roughening or phosphoric acid etching.[12-14] However, diamond bur

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roughening is still widely used and practiced because of its simplicity, availability and less technique senstivity.[14]

The role of hydrofluoric (HF) acid etching on resin composites is less explored. HF is reportedly effective on silica rich ceramics, however, its benefit on composite is inconsistent and reportedly inferior to mechanical methods, especially for highly filled composites.[13] Despite recent evidence, many studies assess only a limited number of surface treatments, employ different composite systems and aging protocols, and use varied adhesive procedures.

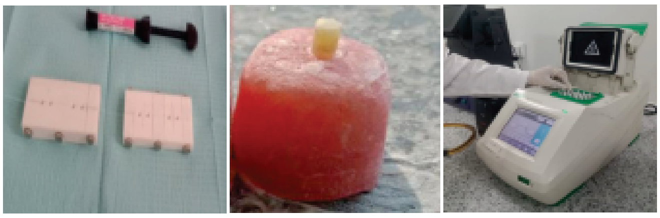
The present study aimed to evaluate compare the effect of four surface treatment protocols i.e., silane only, air-abrasion, diamond bur roughing, and HF etching with silane on the shear bond strength (SBS) of repaired micro-hybrid dental composite restorations.

Materials and Methods

This in-vitro experimental study was done after the approval of the ethical Review Board of Azra Naheed Dental College, from January 2024 to March 2025 with sample preparation at Dental Materials Laboratory, Azra Naheed College of Dentistry and Testing at COMSATS University Lahore.

A total of 60 cylindrical composite samples were fabricated. The sample size was estimated using 80% power of study and 5% level of significance to detect clinically relevant differences in bond strength among four experimental conditions, assuming an effect size derived from previous studies.[10, 14] The sample size was 15 per group, allocated to 4 groups.

A universal light-cured micro-hybrid composite (HeyTEC-MR, universal shade range) was utilized as substrate as well as repair material. Sixty cylindrical samples (5 mm diameter × 5 mm height) were fabricated using custom Teflon molds. The mold was placed between Mylar strips and glass slides to obtain smooth, standardized surfaces. Dental composite was placed in 2.5 mm incremental placement and was light-cured for 40s using an LED curing light (Bluephase; 1000 mW/cm²; 2 mm distance). Excess flash was removed and specimens with visible defects or improper curing were excluded.



(a) (b) (c)

Figure 1: (a) Teflon moulds, (b) Dental composite restoration mounted in acrylic (c) Thermocycling

The samples were kept in distilled water at 37°C for 24h, and later thermocycled for 500 cycles in a temperature range of 5°C and 55°C (dwell time of 20s, transfer time of 10s) according to ISO/TS 11405 to simulate intraoral thermal aging.[15] After aging, samples were randomly distributed to 4 groups (n=15 per group) according to the repair surface treatments.

The group A (Control group) received no mechanical surface treatment, the aged composite surface was rinsed, dried, and conditioned with a silane coupling agent (bis-Silane, BISCO) for 60s, air-dried for 10s, followed by application of the adhesive following the manufacturer guidelines.

In group B (Air Abrasion+Silane+Adhesive) air abrasion was done with 50 μm Al_2O_3 particles (Danville Materials) at 4 bar pressure for 10s at approximately 10 mm distance using a chairside sandblasting device followed by rinsing, gently air-drying, and silane treatment for 60s, followed by adhesive application.

In group C (Diamond Bur Roughening+Silane+Adhesive) the surface roughening done with a medium-grit diamond bur (125 μm) using high-speed hand-piece with water spray to remove the superficial resin layer and create grooves. The surface was rinsed, dried, treated with silane for 60s, air-dried, and then coated with adhesive.

In Group D (9% Hydrofluoric Acid Etching+ Silane+ Adhesive), the aged surface was etched with 9% HF gel for 60s, thoroughly rinsed with water for 30 s and air-dried, followed by silane application for 60s, drying and adhesive application.

In all groups, the same adhesive system and application protocol were used to isolate the effect of surface treatment. For the repair, a secondary Teflon mold (internal diameter 5 mm; height 5 mm) was positioned over the treated substrate. A contrasting shade of HeyTEC-MR composite was packed onto the conditioned surface and light-cured for 40s producing composite–composite "bilayer" samples with a standardized repair interface.

(a) (b) (c) (d)

Figure 2: (a) Silane application (b) Air Abrasion (c) Diamond bur cutting (d) HF Etching

Result

All 60 specimens completed the testing protocol and were included in the final analysis (n=15 per group). The overall SBS was18.00±8.07 (MPa).

The Mean SBS for each group and their comparison using ANOVA are presented in Table 1. SBS of repaired composite was significantly affected by the type of surface treatment ($p<0.001$). Air abrasion showed the highest mean SBS (30.47±2.03 MPa) (Table 1)(Figure 3).

All pairwise comparisons, using post hoc Tukey test, between groups were statistically significant ($p<0.001$, Tukey HSD), indicating that each surface treatment produced a significant level of bond strength. The ranking was Air abrasion > Diamond bur > HF etching > Control (Table 2).

Group / Surface Treatment	n	Mean ± SD (MPa)	F	*p*
A – Control (Silane only)	15	9.42 ± 1.20	430.048	< .001
B – Air abrasion + silane + adhesive	15	30.47 ± 2.03		
C – Diamond bur + silane + adhhesive	15	18.17 ± 2.10		
D – HF etch + silane + adhhesive	15	13.96 ± 1.19		

Table 1. Mean shear bond strength (MPa) by surface treatment and their comparison using one way ANOVA

Comparison	Mean difference (MPa)	*p*	Significance
Control vs Air abrasion	−21.05	<0.001	Significant
Control vs Diamond bur	−8.75	<0.001	Significant
Control vs HF etching	−4.54	<0.001	Significant
Air abrasion vs Diamond bur	+12.30	<0.001	Significant
Air abrasion vs HF etching	+16.51	<0.001	Significant
Diamond bur vs HF etching	+4.21	<0.001	Significant

Table 2: Tukey HSD post hoc test pairwise comparisons between groups

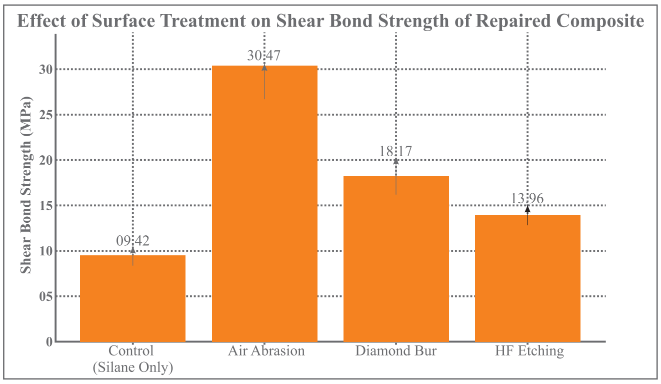


Figure 3: Bar chart of mean SBS for the four groups, illustrating the clear ranking: Control < HF < Diamond bur < Air abrasion.

Discussion

This in vitro experimental study assessed and compared the effect of four surface treatment types on the SBS of repaired composite restorations. Air abrasion with 50 µm Al_2O_3 produced the highest mean SBS (≈30.5 MPa), significantly higher than all other groups and finding was consistent with recent in vitro studies on aged bulk-fill and nanohybrid composites, reporting that alumina air abrasion combined with an adhesive system produce higher repair bond strengths.[12,13,16] Binhasan et al. reported that air abrasion followed by adhesive achieved the highest microtensile bond strength when repairing aged bulk-fill composites, and phosphoric acid alone was inadequate.[12] Bulut et al. reported significantly higher SBS in CoJet-sandblasted specimens compared to laser and untreated groups, especially when combined with a universal adhesive using etch and rinse method.[13] Similarly, Ömeroğlu et al. reported that aged nanohybrid composites, both sandblasting and laser significantly improved SBS with sandblasting ranking among the best-performing protocols.[14]
The air abrasion creates a highly micro-retentive surface by selectively removing the superficial resin layers, exposing filler particles, and generating micro-pits and undercuts which increases surface area ultimately improving wettability, deeper penetration and interlocking of the adhesive.[11,12,17]
Diamond bur roughening reported intermediate SBS values (~18.2 MPa), significantly higher than the control and HF groups. This trend aligns with the literature where bur roughening increases repair bond strength yet underperforms when compared with sandblasting or silica-coating.[13,18,19] Saleh et al. reported that diamond bur abrasion, particularly followed by a suitable adhesive, significantly improved repair SBS of hybrid composites.[18] Fathelbab et al., found that bur abrasion and sandblasting both improved repair strength compared with controls, although the roughing profile differed between the two.[19] Bur roughening produces macro-grooves and irregular scratches, but the smear layer and relatively anisotropic surface may limit optimal adhesive infiltration.18 Within the limitations, diamond bur roughening is still a clinically relevant alternative due to less technique sensitivity and cost effectiveness.[20]
The HF-etched group reported SBS values around 14 MPa, significantly higher than the control but lower than both mechanical treatments. This finding was consistent with the previous literature reporting that HF etching is less effective on resin composites than on silica-based ceramics.[13, 14, 21] The limited effect of HF is likely due to the lower content and accessibility of etchable glass in dental composites; without sufficient silica, HF cannot create the micro-porosities and any initial roughness may degrade after water storage and thermocycling.[21] Therefore, while HF etching may offer some chemical modification, it should not be the primary or sole conditioning method for composite repair and must be used in conjunction with mechanical pretreatment.[22]
From a clinical perspective, the performance in this study was air abrasion > diamond bur > HF etching with air abrasion with 50 µm Al_2O_3 reporting superior results. The acceptable alternative was diamond bur roughening when sandblasting is not available.[21,23]
This study has several limitations like only one micro-hybrid composite material was tested, and the aging protocol consisted of 500 thermocycles and short-term water storage. The extended aging, mechanical fatigue loading, and pH cycling were not evaluated and are recommended for future studies. Moreover, a single adhesive protocol was used in vitro and the results cannot fully replicate the complex intraoral conditions.

Conclusions

The surface treatment had a highly significant effect on the SBS of repaired micro-hybrid composite restorations. Air abrasion with 50 µm Al_2O_3, followed by silane and adhesive, produced the highest SBS indicating a strong and reliable repair interface. Diamond bur roughening significantly improved SBS compared with control and HF etching, but remained inferior to air abrasion. Hydrofluoric acid etching with silane provided only limited improvement suggesting limited suitability. Clinically, air abrasion should be considered the preferred surface treatment for repairing aged composite restorations when available, whereas diamond bur roughening is an acceptable alternative.

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References

01. Bompolaki D, Lubisich EB, Fugolin AP. Resin-based composites for direct and indirect restorations: clinical applications, recent advances, and future trends. Dental Clinics. 2022;66(4):517-36. https://doi.org/10.1016/j.cden.2022.05.003

02. Al-Ibrahim I, Shono N, Al-Saud L, Al-Nahedh H. Five years of restorative resin-based composite advancements: a narrative review. BMC Oral Health. 2025;25(1):1061. https://doi.org/10.1186/s12903-025-05816-7

03. Aminoroaya A, Neisiany RE, Khorasani SN, Panahi P, Das O, Madry H, et al. A review of dental composites: Challenges, chemistry aspects, filler influences, and future insights. Composites Part B: Engineering. 2021;216:108852. https://doi.org/10.1016/j.compositesb.2021.108852

04. Szczesio-Wlodarczyk A, Sokolowski J, Kleczewska J, Bociong K. Ageing of dental composites based on methacrylate resins—A critical review of the causes and method of assessment. Polymers. 2020;12(4):882. https://doi.org/10.3390/polym12040882

5. Zhou H, Yuan Y, Luo C, Wang Q, Li Z, Chen M, et al. The Role of Oral Environmental Factors in the Degradation of Resin-Dentin Interfaces: A Comprehensive Review. Journal of Dentistry. 2025:105839. https://doi.org/10.1016/j.jdent.2025.105839

6. Ferracane J. Models of caries formation around dental composite restorations. Journal of dental research. 2017;96(4):364-71. https://doi.org/10.1177/0022034516683395

7. Santos MJMC, Zare E, McDermott P, Santos Junior GC. Multifactorial contributors to the longevity of dental restorations: an integrated review of related factors. Dentistry Journal. 2024;12(9):291. https://doi.org/10.3390/dj12090291

8. Vandekar M, Pendse G, Toprani N, Shitole N, Pannikar P, Chadchan P. Longevity of Repair Versus Replacement of Partially Fractured Direct Composite Restorations in Permanent Teeth: A Systematic Review and Meta-Analysis. Cureus. 2025;17(7):e88307. https://doi.org/10.7759/cureus.88307

9. Kanzow P, Wiegand A. Retrospective analysis on the repair vs. replacement of composite restorations. Dental Materials. 2020;36(1):108-18. https://doi.org/10.1016/j.dental.2019.11.001

10. Gajski P, Par M, Tarle Z, Marovic D. Effect of Silane-Containing adhesives on repair bond strength between fresh and aged composite Materials—A pilot study. Materials. 2024;17(18):4646. https://doi.org/10.3390/ma17184646

11. Németh KD, Told R, Szabó P, Maróti P, Szénai R, Pintér ZB, et al. Comparative Evaluation of the Repair Bond Strength of Dental Resin Composite after Sodium Bicarbonate or Aluminum Oxide Air-Abrasion. International Journal of Molecular Sciences. 2023;24(14):11568. https://doi.org/10.3390/ijms241411568

12. Binhasan M, Althobaiti F, Alyami R, Aljabri K, Alabbas T, Barakah H. Effect of surface treatments on repair bond strength of aged bulk-fill resin composites. Polymers. 2025;17(17):2326. https://doi.org/10.3390/polym17172326

13. Bulut A, Bala O, Akgül S. The effect of different treatment protocols on shear bond strength in resin composite restoration repair. BMC Oral Health. 2024;24(1):1279. https://doi.org/10.1186/s12903-024-04918-y

14. Ömeroğlu MK, Çam M, Doğruer I, Kaynar ZB. The effect of different surface treatments and adhesive systems on shear bond strength in universal nanohybrid composite resin repair. BMC Oral Health. 2025;25(1):1-10. https://doi.org/10.1186/s12903-025-05807-8

15. Herrmann G, Reimann S, Daratsianos N, Weber A, Keilig L, Nadal J, et al. Comparison of different standardised bond strength tests and the influence of glycine powder treatment in composite resin repairs. International Dental Research. 2020;10(2):36-43. https://doi.org/10.5577/intdentres.2020.vol10.no2.2

16. Dederichs M, Badr Z, Viebranz S, Nietzsche S, Schulze-Späte U, Schmelzer A-S, et al. Effect of surface conditioning on the adhesive bond strength of 3D-printed resins used in permanent fixed dental prostheses. Journal of Dentistry. 2025;155:105621. https://doi.org/10.1016/j.jdent.2025.105621

17. Hadilou M, Dolatabadi A, Ghojazadeh M, Hosseinifard H, Alizadeh Oskuee P, Pournaghi Azar F. Effect of Different Surface Treatments on the Long-Term Repair Bond Strength of Aged Methacrylate-Based Resin Composite Restorations: A Systematic Review and Network Meta-Analysis. BioMed Research International. 2022;2022(1):7708643. https://doi.org/10.1155/2022/7708643

18. Saleh SA, Hashem D, Salem RM. Effect of aging and different surface treatments on repair bond strength of hybrid resin composites. The Open Dentistry Journal. 2023;17(1):1-8. https://doi.org/10.2174/0118742106263441231012112236

19. Fathelbab YN, Hasan MM, Abdalla AI. Repair of bulk-fill composite after different surface treatments. Tanta Dental Journal. 2024;21(2):216-22. https://doi.org/10.4103/tdj.tdj_32_23

20. Chuenweravanich J, Kuphasuk W, Saikaew P, Sattabanasuk V. Bond durability of a repaired resin composite using a universal adhesive and different surface treatments. The Journal of Adhesive Dentistry. 2022;24:b2288293. https://doi.org/10.3290/j.jad.b2288293

21. Almutairi MA, Salama FS, Alzeghaibi LY, Albalawi SW, Alhawsawi BZ. Surface treatments on repair bond strength of aged resin composites. Journal of International Society of Preventive and Community Dentistry. 2022;12(4):449-55. https://doi.org/10.4103/jispcd.JISPCD_99_22

22. Yin H, Kwon S, Chung SH, Kim RJY. Performance of universal adhesives in composite resin repair. BioMed Research International. 2022;2022(1):7663490. https://doi.org/10.1155/2022/7663490

23. Kuşdemir M, Yüzbasioglu E, Toz-Akalın T, Öztürk-Bozkurt F, Özsoy A, Özcan M. Does Al2O3 airborne particle abrasion improve repair bond strength of universal adhesives to aged and non-aged nanocomposites? Journal of Adhesion Science and Technology. 2021;35(21):2275-87. https://doi.org/10.1080/01694243.2021.1882779

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Author Contributions

1. **Lubbabah Ibrahim:** Conceptualization of the study, Study Design, Data Collection, Literature Review, Article writing and Fundings.
2. **Hira Asghar:** Supervision, Conceptualization of the study, Study Design, Development of research methodology, Data Analysis, Article writing and Critical Review.
3. **Hammad Hassan:** Supervision, Conceptualization of the study, Data collection, Data Analysis, Article writing, and Critical Review.
4. **Saadia Bano Lone:** Study Design, Development of research methodology, Data Analysis, Critical Review and Literature Review.
5. **Fatima Zahra Ali:** Study Design, Development of research methodology, Literature Review and Article writing.
6. **Amna Younas:** Data Collection, Literature Review, Article writing and Fundings.