IN VITRO STUDY

Effects of 38 Percent Silver Diammine Fluoride on Adhesive Shear Bond Strength of Resin Composite to Permanent Dentin: A Preliminary Assessment

Mikayla Stevens, DDS[1] • Brian R. Morrow, MS[2] • Anne E. Hill, DDS[3] • Craig Volk Vinall, DDS, MDS[4] • Franklin Garcia-Godoy, DDS, MS, PhD, PhD[5]

Abstract: ***Purpose:*** *The purpose of this study was to evaluate the influence of silver diammine fluoride (SDF) on shear bonding with total-etch adhesives.* ***Methods:*** *Thirty non-carious permanent human molars were collected and sectioned, exposing dentin that yielded two samples per tooth. Samples were mounted in resin, roughened, flattened to exposed dentine, and rehydrated (for 24 hours at 37 degrees Celsius). Fifteen samples were randomly allocated to each test group (N equals 15/gp): 3M™ Scotchbond™ Universal Plus Adhesive (SUPA), SDF+SUPA, Prime & Bond elect® Universal (PBE), and SDF+PBE. TPH Spectra® ST composite was utilized in all groups, light-cured, and rehydrated (for 24 hours at 37 degrees Celsius) before shear bond testing was performed. Maximum stress data were statistically analyzed using a two-way analysis of variance and Holm-Sidak post-hoc test (P<0.05).* ***Results:*** *Shear stress (MPa) were: SUPA (26.5±3.0), SDF+SUPA (25.6±7.2), PBE (21.1±5.7), and SDF+PBE (21.7±5.7). Statistically significant differences were only noted between SUPA and PBE (P=0.012).* ***Conclusion:*** *Within the limitations of this study, silver diammine fluoride did not affect the shear bonding of resin composite to dentin.* *(Pediatr Dent 2025;47(2):87-9) Received April 10, 2024 | Last Revision February 5, 2025 | Accepted February 12, 2025*

KEYWORDS: SDF, SILVER DIAMMINE FLUORIDE; SHEAR BOND STRENGTH; RESIN BONDING

Many public health concerns related to disparities in the prevalence and treatment of dental caries are emerging. An increase in caries among children, adolescents, and adults in the United States is evident–particularly in those of lower socioeconomic status and recent immigrants. While a direct cause for the increase is unclear and likely multifactorial, one possible explanation is that the benefits of prevention are not reaching these groups of individuals.[1] Furthermore, even when dental services are available, traditional operative dentistry is often not easy nor safe to perform in young children with severe disease or behavioral difficulties or in individuals with special health care needs.[2]

Contrary to traditional "drill-and-fill" dental treatment options, silver diammine fluoride (**SDF**) is a non-invasive caries management tool. It is approved by the United States Food and Drug Administration for treating tooth sensitivity but is commonly used off-label in dentistry for caries prevention and arrestation. SDF strengthens the tooth structure against bacterial acid byproducts, is bactericidal against multiple species, anddecreases enamel and dentin solubility–perhaps by interfering with the biofilm.[3,6] A systematic review found that 38 percent SDF can effectively arrest caries in children[5] and has also been shown to be effective in caries prevention.[4] Other benefits include that it is affordable, painless, aerosol-free, and simple to use.

For these reasons, SDF is sometimes applied to the exposed dentin of a cavity preparation prior to restoration placement. However, the results of different studies testing its effects on bond strength are controversial.[7] Markham et al.[8] showed that SDF application to enamel and dentin reduced the bond stability of self-etch universal adhesives, while Quock et al.[9] reported that SDF did not affect the bond strength to non-carious dentin.

The purpose of this study was to explore the potential effects of silver diammine fluoride on the shear bond strength of total-etch adhesives to non-carious dentin. Shear bond strength was used in this study because it is a common method for testing adhesive strength in dental tissues.[10,11] The hypothesis was that the SDF treatment would not affect the shear bond strength.

Methods

Thirty non-carious third molars, extracted for clinical indications regarding partial impaction, were collected and stored in distilled water. The collection of human teeth was approved by the Institutional Review Board of the University of Tennessee Health Science Center, Memphis, Tenn., USA (no. 21-08535). All teeth were placed in an ultrasonic bath for 30 minutes and hand-scaled until all debris was removed. Each tooth was sectioned mesiodistally using a high-speed handpiece and diamond disc to expose dentin and allow for two test samples per tooth. Specimens were mounted into cylindrical molds via acrylic resin with the cut side exposed. After curing for 24 hours, specimens were applied to a cast grinder until all excess resin was removed and a roughened, flat surface was obtained. After preparing the tooth surface, the specimens were stored in Dulbecco's D 8662 PBS solution ([**DPBS**]; Sigma-Aldridge, St. Louis, Mo., USA) at 37 degrees Celsius for 24 hours. Sixty specimens were then randomly allocated into four different test

[1]*Dr. Stevens is a pediatric dentist in private practice, Blue Spring, Mo., USA.* [4]*Dr. Vinall is an assistant professor and director, Graduate Pediatric Dentistry;* [2]*Dr. Morrow is a senior research specialist and* [5]*Dr. Garcia-Godoy is a professor, both in the Department of Bioscience Research; and* [3]*Dr. Hill is an associate professor, Department of General Dentistry, all in the College of Dentistry, University of Tennessee Health Science Center, Memphis, Tenn., USA.*

Correspond with Dr. Garcia-Godoy at fgarciagodoy@gmail.com

HOW TO CITE:

Stevens M, Morrow BR, Hill AE, Vinall CV, Garcia-Godoy F. Effects of 38 percent silver diammine fluoride on adhesive shear bond strength of resin composite to permanent dentin: A preliminary assessment. Pediatr Dent 2025;47(2):87-9.

groups (N equals 15 per group) in accordance with ISO 29022: 2013 recommendations for sample size.[10] Test groups were as follows:

For group one (control): 3M™ Scotchbond™ Universal Plus Adhesive (**SUPA**; 3M, St. Paul, Minn., USA), specimens were rinsed for five seconds; the entire specimen was at four 15 seconds with 3M™ Scotchbond™ Universal Etchant (**SUE**), rinsed for five seconds, and air dried until damp; SUPA was applied to the entire specimen for 20 seconds with a microbrush, then air dried gently for five seconds followed by a 10-second light cure; TPH Spectra® ST (**TPH**; shade A1, Dentsply Sirona, Konstanz, Germany) was placed on dentin, and light cured for 20 seconds.

For group two, consisting of SDF (Advantage Arrest® SDF 38 percent; Elevate Oral Care, West Palm Beach, Fla., USA) and Intervention+SUPA, the specimen was rinsed for five seconds; SDF was applied to the entire specimen for one minute with a microbrush, then rinsed for five seconds; the entire specimen was at four 15 seconds with SUE, then rinsed for five seconds and air-dried until damp; SUPA was applied to the entire specimen for 20 seconds with a microbrush, then air-dried gently for five seconds followed by a 10-second light cure; TPH was placed on the dentin and light cured for 20 seconds.

For group three (control), which used Prime & Bond elect® Universal Dental Adhesive (**PBE**) (Dentsply Sirona, Konstanz, Germany), the specimen was rinsed for five seconds; the entire specimen was etched for 20 seconds with Etch-37™ w/BAC (E37; 37 percent phosphoric acid with benzalkonium chloride; Bisco Inc., Schaumburg, Ill., USA) and then rinsed for five seconds and air dried until damp; PBE was applied to the entire specimen for 15 seconds with a microbrush and air-thinned for three seconds followed by a 20-second light cure; TPH was placed on the dentin and light cured for 20 seconds.

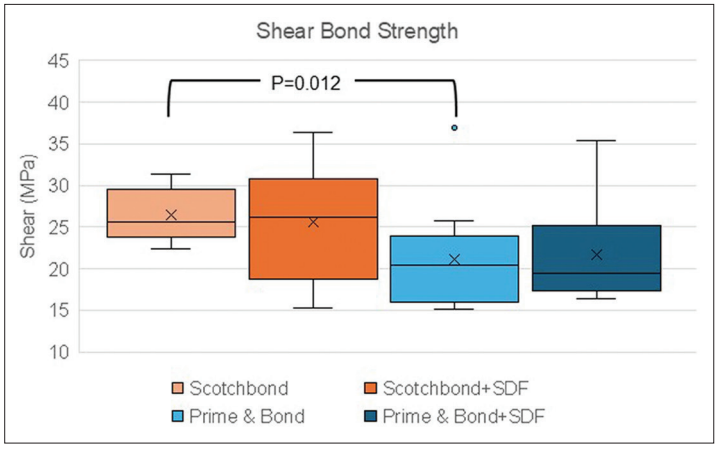

Figure. Box-plot graphical results for shear bonding stress (megapascal, MPa). Samples (N equals 15 per group) for 3M™ Scotchbond™ Universal Plus Adhesive (SUPA) versus Prime & Bond elect® Universal Dental Adhesive (PBE) with and without silver diammine fluoride (SDF) treatments. The box-plot line within the middle of each bar denotes the median values for each group. Boxes represent the inter-quartile range with the first quartile (25th percentile) of the data to the third quartile (75th percentile). The X within each bar symbolizes the mean value of each group. Bars in the plot represent the "whiskers," which are data outside of the inter-quartile range (below the 25th and above the 75th percentiles). The circle standing alone represents an outlier point for Prime & Bond Elect® Universal group. A significant difference (P=0.012) from two-way analysis of variance with Holm-Sidak post hoc test (P<0.05) was also observed between adhesives 3M™ Scotchbond™ Universal Plus Adhesive and Prime & Bond Elect® Universal group, as noted.

For group four, which used SDF+PBE, thus specimen was rinsed for five seconds; SDF was applied to the entire specimen for one minute using a microbrush; it was rinsed for five seconds; next, the entire specimen was etched for 20 seconds with E37, rinsed for five seconds, and air-dried until damp; PBE was applied to the entire specimen for 15 seconds with a microbrush, air-thinned for three seconds, and light-cured for 20 seconds; TPH was placed on the dentin and light-cured for 20 seconds.

As indicated earlier, the composite used was identical for all groups: TPH was light-cured for 20 seconds. After adhesive and resin application, specimens were rehydrated at 37 degrees Celsius in DPBS solution for 24 hours, then shear bond strength testing was performed on the UltraTester™ Bond Strength Testing Machine (Ultradent, South Jordan, Utah, USA) at a speed of 1.0 mm per minute. Maximum stress data were statistically analyzed with SigmaPlot 14 software (Grafiti LLC, San Jose, Calif., USA) using a two-way analysis of variance and Holm-Sidak post-hoc test, with P<0.05 for significance.

Results

The mean values, standard deviations, medians, and interquartile ranges for each group are presented in box-plot form within Figure. The mean and standard deviation test results for shear bond strength in MPa were26.5±3.0 for SUPA control, 25.6± 7.2 for SDF+SUPA, 21.1±5.7 for PBE, and 21.7±5.7 for SDF+ PBE. Statistically significant differences were only noted between the adhesive control groups–namely SUPA and PBE (P=0.012). The SDF groups were not significant (P=0.912). Therefore, the application of SDF before composite placement did not affect the shear bond strength of either adhesive to dentin for this study.

Discussion

Dental caries is recognized as the most common chronic disease among children in the United States, and improvements in effective prevention and treatment methods are of great public health importance. Adding to the complexity, primary caries removal and tooth restoration with composite resin, even with an intimate adaptation, do not guarantee the prevention of new caries development.[13] Polymerization shrinkage of resin composites may result in marginal gaps that can allow for bacterial leakage, often resulting in secondary caries.[4,13-17] Because silver, as silver nitrate in SDF, has the potential to arrest or reduce secondary caries,[4,18] it has been suggested that SDF be applied to a preparation before placing a resin composite restoration.[4]

There is concern, however, that SDF may negatively affect adhesive bond strength to dentin. Some studies have shown no effect on the bond strength of composites after SDF application,[8] while others have found negative results.[7,18] More specifically, Markham et al.[7] used a dynamic stress method to test bond strength and found that SDF application on enamel and dentin reduced the bond stability of universal adhesives in self-etch mode. However, most other studies use a static stress method to test the shear bond strength of adhesives. For example, Quock et al.[8] tested different adhesives and composites via a static stress method and reported that SDF did not affect the shear bond strength of non-carious dentin. The present study also used a static stress method with different materials and reported similar results. Therefore, in the current study, SDF did not influence the shear bonding strength. Due to

conflicting evidence, differing test methods, and various materials utilized across studies, it is difficult to conclude whether SDF application to preparations before resin placement will affect adhesive bond strength. Further studies should expand upon and evaluate the difference in bond strength with thermocycling, microtensile testing, and failure mode analysis for a compressive perspective.

Limitations to this study include that, clinically, SDF is typically applied to infected and/or affected dentin; however, to better standardize the specimens within this study, only non-carious permanent teeth were tested. This study should be repeated using caries-free primary molars to assess whether the structural differences between primary and permanent dentin affect adhesive bonding strength after SDF application. Further studies should also compare the effect of SDF on the bond strength to carious and sound dentin, although standardization of the carious dentin as a substrate could be a challenge.

Another issue preventing the clinical applicability of SDF application prior to resin placement is the discoloration produced by SDF. The fluoride in SDF acts as a reducing agent and accelerates the deposition of silver phosphate into the enamel and dentin; black discoloration results, revealing that a successful reaction has occurred, preventing the SDF from washing away.[18] Knight et al.[19] suggest that the staining may be eliminated by applying potassium iodide (KI) after the SDF application, but the clinical effectiveness or bond strength to enamel and dentin of SDF/KI needs further evaluation. One study[20] showed that the application of KI after SDF on caries-affected teeth may improve the initial esthetic appearance, but after placement of a glass ionomer restoration potassium iodide did not seem to result in any significant difference in staining. Therefore, further studies could evaluate if placing a thin layer of glass-ionomer before a composite restoration could help mask the dark staining and make SDF application prior to resin restoration placement more clinically applicable.

Conclusions

Based on this study's results, the following conclusions can be made:

1. The application of 38 percent silver diammine fluoride to non-carious dentin of permanent human molars did not the affect shear bond strength of resin composite.
2. Further studies are needed to investigate SDF's effects on bonding to carious permanent and primary teeth with the inclusion of thermocycling, microtensile testing, and failure mode analysis.

Acknowledgment

This research did not receive any financial support. The authors of this manuscript have no conflict of interest to declare.

References

1. Bagramian RA, Garcia-Godoy F, Volpe AR. The global increase in dental caries: A pending public health crisis. Am J Dent 2009;22(1):3-8.
2. Crystal YO, Niederman R. Silver diamine fluoride treatment considerations in children's caries management. Pediatr Dent 2016;38(7):466-71.
3. Mei ML, Li QL, Chu CH, Lo EC, Samaranayake LP. Antibacterial effects of silver diamine fluoride on multi-species cariogenic biofilm on caries. Ann Clin Microbiol Antimicrob 2013;12:4.
4. Patterson T, Ismail HS, Hicks J, Garcia-Godoy F. Secondary caries adjacent to bulk fill resin composite restorations lined with fluoride agents. Am J Dent 2023;36(3):111-7.
5. Gao SS, Zhao IS, Hiraishi N, et al. Clinical trials of silver diamine fluoride in arresting caries among children: A systematic review. JDR Clin Trans Res 2016;1(3):201-10.
6. Crystal YO, Niederman R. Evidence-based dentistry update on silver diamine fluoride. Dent Clin North Am 2019;63(1):45-68.
7. Jiang M, Mei ML, Wong MCM, Chu CH, Lo ECM. Effect of silver diamine fluoride solution application on the bond strength of dentine to adhesives and to glass ionomer cements: A systematic review. BMC Oral Health 2020;20(1):40.
8. Markham MD, Tsujimoto A, Barkmeier WW, et al. Influence of 38% silver diamine fluoride application on bond stability to enamel and dentin using universal adhesives in self-etch mode. Eur J Oral Sci 2020;128(4):354-60.
9. Quock Rl, Barros JA, Yang SW, Patel SA. Effect of silver diamine fluoride on microtensile bond strength to dentin. Oper Dent 2012;37(6):610-6.
10. ISO. ISO 29022:2013; Dentistry–Adhesion: Notched-edge shear bond strength test. Confirmed in 2024. Available at: "https://www.iso.org/standard/45285.html". Accessed March 7, 2025.
11. el-Kalla IH, García-Godoy F. Bond strength and interfacial micromorphology of compomers in primary and permanent teeth. Int J Paediatr Dent 1998;8(2):103-14.
12. Markham MD, Tsujimoto A, Barkmeier WW, et al. Influence of 38% silver diamine fluoride application on bond stability to enamel and dentin using universal adhesives in self-etch mode. Eur J Oral Sci 2020;128(4):354-60.
13. Barata JS, Casagrande L, Pitoni CM, De Araujo FB, Garcia-Godoy F, Groismann S. Influence of gaps in adhesive restorations in the development of secondary caries lesions: An in situ evaluation. Am J Dent 2012;25(4):244-8.
14. García-Godoy F, Flaitz CM, Hicks MJ. Secondary caries adjacent to amalgam restorations lined with a fluoridated dentin desensitizer. Am J Dent 1998;11(6):254-8.
15. Garcia-Godoy F, Krämer N, Feilzer AJ, Frankenberger R. Long-term degradation of enamel and dentin bonds: 6-year results in vitro vs. in vivo. Dent Mater 2010;26(11): 1113-8.
16. Pinna R, Usai P, Filigheddu E, Garcia-Godoy F, Milia E. The role of adhesive materials and oral biofilm in the failure of adhesive resin restorations. Am J Dent 2017;30 (5):285-92.
17. Llodra JC, Rodriguez A, Ferrer B, Menardia V, Ramos T, Morato M. Efficacy of silver diamine fluoride for caries reduction in primary teeth and first permanent molars of schoolchildren: 36-month clinical trial. J Dent Res 2005; 84(8):721-4.
18. Lutgen P, Chan D, Sadr A. Effects of silver diammine fluoride on bond strength of adhesives to sound dentin. Dent Mater J 2018;37(6):1003-9.
19. Craig GG, Powell KR, Cooper MH. Caries progression in primary molars: 24-month results from a minimal treatment programme. Community Dent Oral Epidemiol 1981;9(6):260-5.
20. Knight GM, McIntyre JM, Craig GG, Mulyani, Zilm PS, Gully NJ. An in vitro model to measure the effect of a silver fluoride and potassium iodide treatment on the permeability of demineralized dentine to Streptococcus mutans. Aust Dent J 2005;50(4):242-5.