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Effects of silver diammine fluoride on bond strength of adhesives to sound dentin

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This study evaluated bonding of adhesives to dentin treated with silver diammine fluoride (SDF). Micro-shear bond strength (MSBS) to sound human dentin was investigated for 3 adhesive systems: Clearfil SE bond 2 (CSE), and Scotchbond Universal in self-etching (SBU) and phosphoric acid-etching (SBT) modes, following 4 different SDF application protocols (n=10); Control: treated with deionized water. P1: SDF applied for 10-s, no rinse. P2: SDF applied for 10-s, rinsed off after 1-min. P3: superficial dentin polished off after 24-h following P1. MSBS data were obtained after 24-h water storage at 37°C. SDF significantly affected MSBS to dentin depending on the SDF protocol and adhesive system. Rinsing SDF off improved bond strength but superficial refreshing of SDF-treated dentin prior to bonding showed the highest bond strength. The two-step self-etch adhesive (CSE) and the universal adhesive in acid-etching mode (SBT) showed better performance than universal adhesive (SBU) alone on SDF treated dentin.

Keywords: Dentin bond strength, Silver diammine fluoride, Universal adhesive, Self-etching, Total-etching

INTRODUCTION

Although technological advances and novel discoveries in dental materials are made each year, caries persists as a public health problem worldwide[1)]. The frequency and severity of caries in children has generally decreased in recent decades, but this is not true for underserved populations. Those with caries who receive dental care present clinicians with the challenging task of treating dental disease[2)]. Increasing caries rates in children ages 2–5 within underserved populations in the United States (US) are likely to extend into maturity[3)], potentially impacting the eruption of permanent teeth which benefit from a healthy primary dentition thereby requiring orthodontic treatment[4)].

Traditional caries removal by cavity preparation and placement of a restorative material does not address the ultimate cause of caries and is complicated by subjects with multiple advanced lesions. Moreover, dental restorative treatment often requires extensive equipment and materials which may not be available to the populations who are at highest risk for developing the disease. This issue has motivated leaders in public health to seek out novel treatment options to address these needs.

Silver containing compounds such as silver nitrate, silver fluoride (not stabilized by amine groups), silver foils, and silver sutures have been used as antimicrobials for hundreds of years around the world to prevent and treat infections, but their popularity in the US has waned over time[5)]. Silver diammine fluoride (SDF) was originally developed as a caries-arresting agent in Japan around the 1970s[6)] and has become a compound of interest in the United States in recent years as research has shown it to be a cost-effective and simple product to use, resulting in favorable outcomes in the treatment of dental caries[5)]. By limiting the progression of active lesions, ideally this compound would be used to treat carious lesions non-traumatically as an alternative to removing tooth structure[7)]. While SDF's exact mode of action is debated, its effect is certain: SDF reacts with hydroxyapatite to form calcium fluoride and silver phosphate which hardens the structure of existing lesions[8)]. Furthermore, silver and fluoride ions together inhibit formation of carious lesions better than silver nitrate or sodium fluoride alone[7)]. Research on SDF indicates that it has anti-bacterial properties, and that it can be used as a preventative alternative to traditional dental procedures.

SDF was cleared by the US Food and Drug Administration (FDA) in 2014 for use in the US as a desensitizer. Given that its approval by the FDA was so recent, more research is needed to determine how SDF can best be used clinically as a caries-arresting or stabilizing agent.

A recent study suggested that fluoride ions released locally into the interface of composite restoration with bioactive bonding materials could decrease the formation of caries, but the amount of fluoride available to deep tissue from this source is limited[9)]. Additionally, SDF may be a beneficial anticariogenic pretreatment compound for dental tissue prior to the placement of restorative material, preventing formation of recurrent caries[10-12)]. The unique caries arresting quality of SDF has been attributed to its effectiveness in reducing the load of cariogenic bacteria on surfaces of demineralized dentin and within dentinal tubules, which supports its use in treating active lesions[13-15)]. A recent study which examined the effects of various fluoride containing agents in preventing collagen breakdown and demineralization

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of dentin determined SDF to be the most effective, concluding that SDF may promote dentin health in caries affected teeth[15].

Bonding of restorative materials to tooth structure has improved significantly with the development of adhesive dentistry over the past several decades. Bonding protocols are generally technique sensitive and clinicians typically avoid any protocol violations that may affect bonding performance. Many variables including moisture control, application, rinsing, and drying times contribute to the overall bond strength in adhesive systems, making the application protocol a crucial part of proper material usage. For example, in the case that SDF is applied prior to restoration as a method to treat residual caries[16] or to prevent caries at the margins of restorations (which remains a major deficiency with current restorative materials[17-20]), investigation of which adhesive application protocol results in superior dentin bond strength will inform future clinical usage.

The purpose of this study was to determine the effect of SDF on the bonding efficacy of commonly used adhesive materials for restorative procedures. Different SDF application protocols were investigated to determine which resulted in the greatest bond strength.

MATERIALS AND METHODS

Materials

Restorative materials used in this study are listed in Table 1. The silver diammine fluoride (SDF; Advantage Arrest, Elevate Oral Care, West Palm Beach, FL, USA) was 38% w/w active ingredient in purified water solution used as pre-treatment for the experimental groups. Three adhesive systems were evaluated by micro-shear bond strength (MSBS) testing: Clearfil SE bond 2 (CSE; Kuraray Noritake Dental, Tokyo, Japan) and Scotchbond Universal (3M, St. Paul, MN, USA) in self-etch (SBU) and phosphoric acid (PA) etching (SBT) modes.

Specimen preparation as shown in Fig. 1

Deidentified human posterior teeth extracted as a part of a treatment plan were obtained from oral surgery offices in the greater Seattle area. The use of human teeth in this study was according to the ethical guidelines set by the University of Washington Human Subjects Division and the Declaration of Helsinki. Teeth were stored in deionized (DI) water containing 0.02% thymol immediately following extraction and used for the purposes of this study within 6 months of extraction. Once determined non-carious according to the International Caries Detection and Assessment System (ICDAS), 10 collected teeth were assorted into each group so that 1 tooth was used to create 1 specimen for experimentation. Each specimen was prepared by removing the roots below the CEJ utilizing a high-speed handpiece with DI water irrigation (X95L, NSK, Ibaraki, Japan). The remaining coronal tooth structure was bonded to an acrylic block with a cyanoacrylate adhesive (Model Repair II Blue, Dentsply Sirona, Tokyo, Japan). The block was then fastened to the placeholder jig designated on a precision low-speed saw (CL-50, Preciso, Taipei, Taiwan) and aligned so that the occlusal

Table 1 Materials

Materials	Type	Composition	Application
Scotchbond Universal Adhesive (3M)	Universal Adhesive	MDP, dimethacrylate resins, HEMA, Vitrebond copolymer, filler, ethanol, water, initiators, silane pH: 2.7	Apply and rub for 20 s; Gently air dry for approximately 5 s; Light cure for 10 s
Scotchbond Etchant (3M)	Phosphoric Acid	32% phosphoric acid pH: 0.5	Apply and rub for 15 s; Rinse off for 15 s
Clearfil SE Bond 2 (Kuraray Noritake)	Two-step Self-etch Adhesive	Primer: MDP, water, HEMA, hydrophilic dimethacrylate, CQ, N,N-Diethanol p-toluidine pH: 2.0 Bond: MDP, Bis-GMA, HEMA, hydrophobic dimethacrylate, CQ, N,N-Diethanol p-toluidine, silanated filler	Apply primer for 20 s, then gently air dry; Apply bonding agent, gently air blow; Light cure for 10 s
Clearfil AP-X (Kuraray Noritake)	Hybrid composite	Bis-GMA, silica fillers, silica-titania fillers (53% filler by volume, 0.04 to 0.6 µm particle size), CQ	Dispense in layers up to 2 mm in thickness; Light cure for 40 s
Advantage Arrest (Elevate Oral Care)	Silver Diammine Fluoride	38% Silver Diammine Fluoride pH: 10	Application protocol varies by experimental groups P1, P2, and P3

Bis-GMA, bisphenol-A-diglycidyl methacrylate; CQ, camphorquinone; HEMA, 2-hydroxyethyl methacrylate; MDP, 10-methacryloyloxydecyl dihydrogen phosphate; TEGDMA, triethyleneglycol dimethacrylate.

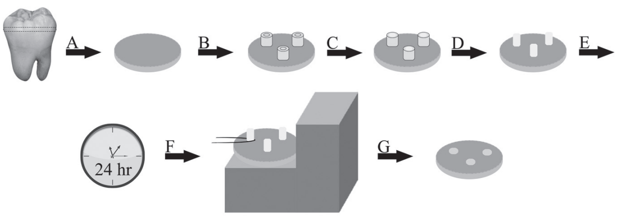

Fig. 1 Schematic showing steps of specimen preparation prior to MSBS testing.
A: Coronal disc isolated from tooth, polished, and pre-treated according to protocol. B: Adhesive system applied to disc, tubing placed, and light cured for 20 s. C: Composite packed into tubing and light cured for 40 s. D: Tubing removed so only composite cylinders remain. E: Discs stored in incubator at 37°C for 24 h. F: P3 groups only: composite cylinders removed, disc repolished, and steps B–E repeated. Cylinders subjected to micro-shear testing using wire-loop technique. G: Mode of failure observed for each cylinder.

table of the tooth was parallel to the cross-sectioning plane. A low-speed diamond blade (Isomet 11-4244, Buehler, Lake Bluff, IL, USA) was used to remove the occlusal enamel to expose a uniform layer of dentin, with a second cross-section to create coronal dentin discs approximately 2 mm in thickness (1 discs per extracted tooth). A digital caliper (Mitutoyo, Tokyo, Japan) was used to precisely measure the thickness of all tooth slices produced (1.99±0.19 mm). The bonding surface of each disc was wet-polished with #600 SiC paper (3M) for 50 repetitions in a figure-eight pattern and briefly rinsed with water to create a uniform smear layer of dentin across all specimens. Prepared tooth surfaces were lightly air-dried with oil-free compressed air for 5 s with care not to desiccate the specimen prior to application protocols. Oil-free compressed air was exclusively used in this study.

SDF application protocols

P1: This protocol followed SDF manufacturer's instructions. 1–2 drops of solution were dispensed into a mixing well, transferred directly to the tooth surface with a microbrush, and applied for 10 s. Specimens were air-dried for 5 s prior to bonding.

P2: This protocol followed Horst *et al.*[21]. 1–2 drops of solution were dispensed into a mixing well, transferred directly to the tooth surface with a microbrush, and applied for 10 s. SDF was allowed to absorb for 1 min. After 1 min, excess SDF was removed with a cotton Q-tip (Unilever North America, Englewood Cliffs, NJ, USA) and specimens were rinsed with water for 15 s then air-dried for 5 s prior to bonding.

P3: This protocol was novel to this study. Prepared tooth surfaces were first treated according to protocol P1 (above), then placed in a storage receptacle containing DI water and stored for 24 h at 37°C. Superficial dentin was polished off in 50 cycles of figure-eight repetitions using #600 grit SiC paper. Specimens were then briefly rinsed as before and air-dried for 5 s prior to bonding.

Control groups: DI water, instead of SDF, was applied to prepared tooth surfaces by microbrush applicator for 10 s and air-dried for 5 s.

Control and SDF application protocols P1, P2, and P3 were applied to 10 specimens per adhesive system for a total of 12 groups: Clearfil SE bond 2 (CSE), and Scotchbond Universal in both self-etch (SBU) and PA-etching (SBT) modes.

For the CSE groups, 1 drop of primer was dispensed into a well, applied to the bonding surface of the specimen for 20 s using a microbrush applicator, and air-dried for 5 s. One drop of bonding agent was then applied in a similar manner for 10 s and blown thin for uniformity with oil-free compressed air.

For the SBU groups, 1 drop of universal adhesive was added to a mixing well and applied to the bonding surface of the specimen for 20 s using a microbrush applicator. The adhesive was lightly blown thin with oil-free compressed air for 5 s to create a uniform layer of material.

For the SBT groups, Universal etchant was applied to the bonding surface of the specimen for 15 s, rinsed with water for 15 s, and air-dried for 5 s. 1 drop of Universal Adhesive was added to a mixing well, transferred to the bonding surface of the specimen using a microbrush, and applied for 20 s. The adhesive was lightly blown thin with oil-free compressed air for 5 s to create a uniform layer of material.

MSBS test

The protocol for MSBS testing was based on previous reports[22,23]. Three 1 mm tall Tygon tubes (Saint-Gobain Performance Plastics, Courbevoie, France) with an internal diameter of 0.79 mm were placed on the dentin of each specimen and irradiated with a dental curing unit (XL3000, 3M) for 20 s. Composite (Clearfil AP-X, Kuraray Noritake, Tokyo, Japan) was placed within each Tygon tube and irradiated for 40 s with a dental curing unit. Tygon tubes were carefully removed from the composite cylinders with a scalpel and specimens were stored in DI water for 24 h at 37°C prior to testing.

After 24 h, specimens were removed from the incubator, air-dried, and secured to the testing apparatus using a cyanoacrylate adhesive (Zapit, Dental Ventures of America, Corona, CA, USA). A compact testing machine (Bisco, Schaumburg, IL, USA) was used in conjunction with a thin steel wire loop (0.20 mm) to obtain datum for each cylinder. The wire was looped around an individual composite cylinder at the junction between tooth and adhesive and placed under progressive load as the wire was pulled at a speed of 1.0 mm/min perpendicular to the cylinder until failure. Care was taken to ensure that the wire loop remained at the appropriate location of bond interface for the duration of the test. The average of three MSBS replicates were calculated for each tooth specimen. If a composite cylinder debonded prior to testing (pre-test failure or PTF), then value of zero was assigned to that cylinder. The load at failure in kilograms was recorded and calculated in terms of MPa by accounting for the cross-sectional area of each cylinder.

Observing mode of failure

After each failure event, the surface of the specimen was viewed under stereo microscope at 5×, evaluated, and categorized as adhesive, dentinal, or mixed failure. Adhesive failures were classified as those that occurred purely within the adhesive system or composite cylinder away from the original tooth structure, which created a convexity. Dentinal failures were classified as those that occurred purely within the tooth, which created a concavity. Mixed failures were classified as those that occurred in both the bonding system and the original tooth structure, which created a mottled surface appearance.

Statistical analysis

The mean and standard deviation for each group were calculated. Data were subject to Kolmogorov-Smirnoff analysis to examine normal distribution, in which case two-way ANOVA and *post hoc* tests using adhesive system and SDF application protocol as factors. Bonferroni's method of adjusting for multiple comparisons were applied to analyses. All analyses were performed at the statistical significance level of α=0.05.

Scanning electron microscopy (SEM)

Additional teeth (n=6) were used for SEM observation of the dentin interface with the adhesives in each group. A 2-mm-thick composite buildup was bonded to dentin discs prepared in an identical manner as those prepared for the MSBS test. Specimens were stored in DI water at 37°C for 24 h and then cross-sectioned through the bonded interface using the diamond saw. Cross-sections were embedded in epoxy resin, polished sequentially using #600–#2000 SiC papers followed by diamond pastes with particle sizes of 6, 3, 1, 0.25 µm, gold-sputter coated and observed at 1,500× under 10kV SEM (JSM-6010PLUS/LA, JEOL, Tokyo, Japan).

RESULTS

MSBS

Results for all groups are summarized in Table 2 and Fig. 2. Several specimens in P1 protocol recorded average value of zero due to PTF of all three cylinders. Multiple zero vales affected the normal distribution of the data, which violated the perquisite for the parametric analysis. These values were excluded from the statistical analysis (Table 2). Two-way ANOVA suggested that type of adhesive used, SDF protocol and their interaction were all significant factors (p<0.05). Both P1 and P2 resulted in bond strength values significantly lower than controls for all adhesive systems (p<0.05). Overall, P1 resulted in the greatest reduction in MSBS for all adhesives compared to controls (p<0.001), especially so for SBU and CSE groups, which showed several instances of premature failures. SBT

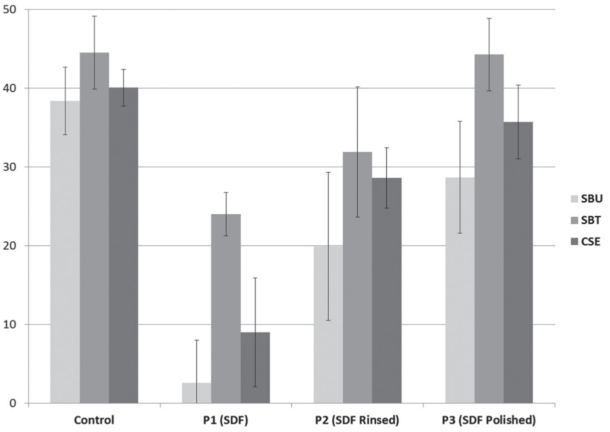

Fig. 2 Bar graph representing results of MSBS tests by protocol and adhesive system used.
Error bars demonstrate standard deviation of each group.

Table 2 MSBS results by protocol and group

Protocol	SBU	SBT	CSE
Control	38.4±4.3 a,A	44.5±4.6 b,F	40.0±2.3 ab,J
P1 (with PTF)*	2.6±5.4 (8/10)	24.0±2.7 (0/10)	9.3±6.9 (3/10)
P1	12.8±1.7 c,BC	24.0±2.7 d,G	12.9±3.7 c,K
P2	19.9±9.4 e,DC	31.9±8.2 f,H	28.6±3.8 f,L
P3	28.7±7.1 g,E	44.3±4.6 h,F	35.7±4.7 i,J

Groups designated by the same letter are not significantly different; lowercase letters within rows (within protocols); uppercase letters within columns (within adhesive systems), two-way ANOVA with pair-wise comparisons using Bonferroni correction.
*PTF=pre-test failures, where a zero bond strength value was recorded for the specimen. The number in parenthesis indicates total number of PTF specimens. This row was not included in ANOVA statistical analysis.

showed the greatest performance difference under the P1 protocol, with more than double the bond strength of the two other adhesives. MSBS was improved under P2 compared to P1, which was statistically significant for both SBT and CSE groups ($p<0.05$). These two adhesives performed similarly under P2 ($p>0.05$). Bond strength values best recovered under protocol P3, which were not significantly different from controls for SBT and CSE adhesives ($p>0.05$), but were still significantly lower than control for SBU adhesive ($p<0.005$).

Mode of failure

Modes of failure for all groups are summarized in Fig. 3. The mode of failure for controls appeared similar for among adhesive systems. The greatest frequency of adhesive failures occurred under P1, with the largest percentage of PTFs ascribed to SBU. Fewer adhesive failures were observed for P2 and even less for P3, shifting to a majority of mixed failures particularly in the SBT and CSE groups. No PTFs were experienced with P2 and P3 protocols.

SEM imaging

Figure 4 compares selected micrographs taken using SEM and shows the relative amounts of SDF present when comparing control and P1 specimens. Images of P1, which did not include a rinsing step, revealed a surface film of SDF and particles within dentinal tubules. No discernable amount of SDF was observed using P2 when compared to controls (images not shown).

DISCUSSION

Results of this study are both agreeable and contradictory to previously published findings. Two contradictory studies reported that application of 38% SDF had no statistically significant effect on the micro-tensile bond strength of resin composite to non-carious dentin[24] and improved shear bond strength of glass ionomer cement[16]. The methodology used by Quock *et al.*[24] was different than that of this study and included a rinse step twice as long as that used in this study (30 s *vs.* 15 s), different adhesive systems and fewer samples. While conclusions related to bond strength were different from this study, the findings were in line with P2 results in the current study, which showed SBT and CSE experimental groups to be similar. Although MSBS was measured in this study, differences in test methodology are not expected to produce such contradictory results, as concluded by comparing results of this study with dentin bond strengths of the universal adhesive system in self-etch and PA-etching modes reported in a systematic review and meta-analysis[25]. While some may consider micro-tensile, rather than micro-shear, testing to be the preferred method of bond strength studies, micro-shear still offers reliable data in understanding the effect of dental materials on bonding. For the purposes of this study, micro-shear offered practical laboratory advantages of user-friendly preparation and time scheduling considerations.

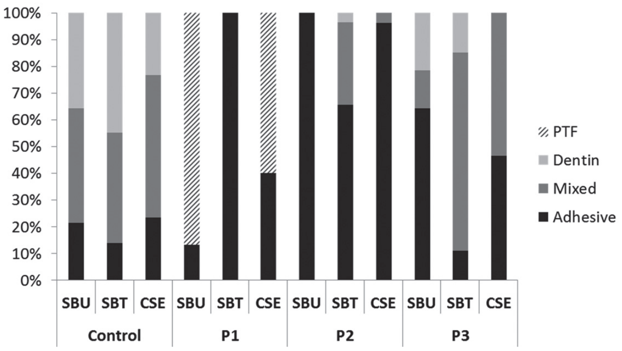

Fig. 3 Distribution of failure modes by protocol and adhesive system used.
PTF indicates the cylinders debonded prior to MSBS test.

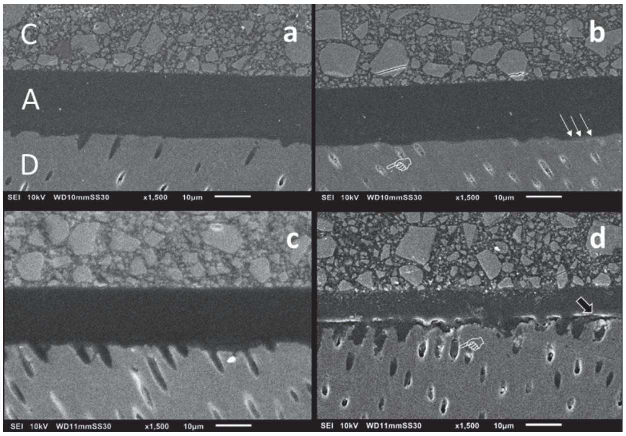

Fig. 4 Micrographs showing cross-sections of bonded interfaces in this study.
Images “a” and “c” on the left panel show CSE and SBT controls, respectively. Images “b” and “d” on the right panel show CSE and SBT P1 protocol (no rinse), respectively. C, A, and D demarcate composite, adhesive, and dentin layers, respectively. The white arrows point to the SDF deposits interfering within the hybrid zone of CSE, the black arrow indicates deposits of SDF over a wider area of hybrid layer in etched dentin with SBT and hands point to dentinal tubules infiltrated by SDF.

Koizumi *et al.*, who investigated the effect of SDF and potassium iodide (KI) on dentin bond strength recently, reported similar findings reported in this study although KI was additionally used[26]. KI was investigated in their work because of its ability to decrease dark staining caused by SDF, which was applied immediately after SDF and prior to bonding. It was determined that the application of SDF/KI generally decreased bond strengths, affecting self-etch systems the most and 37% PA etching systems the least. Koizumi *et al.* hypothesized that PA was responsible for removing the precipitate formed by the SDF/KI application thus recovering some bond strength. A similar recommendation to slightly refresh SDF/KI treated dentin with a diamond bur were made.

The P1 SDF application protocol, which did not include the rinse step included in protocol P2, resulted in severely reduced bond strength ($p<0.05$) and the greatest number of adhesive failures and PTFs. The adhesive could not form a stable bond to dentin, most likely due to excessive amounts of SDF present. The rinsing step appears to be the distinguishing factor contributing to bonding efficacy of SDF application protocols. SDF can interfere with the ability of the primer and bonding agent to impregnate peritubular and intratubular dentin to form a meshwork with the underlying collagen matrix. Rinsing away excess SDF is a crucial step in achieving optimal bonding which is essential for the longevity of composite restorations. Of particular note, both the published SDF application protocol[21)] and the original SDF product instructions (Saforide, Bee Brand Medico Dental, Osaka, Japan) specify a rinsing step in the application protocol, whereas the manufacturer's instructions for the SDF product used in this study do not suggest a rinsing step after application.

It is also noteworthy that the pH of SDF is around 10, according to the manufacturer (Table 1). Particularly for P1, where SDF is not rinsed after application, the surface can be rendered excessively basic, hampering the etching function of the self-etching adhesive and interfering with PA and therefore, reducing the bond strength.

Figure 4 compares images taken using SEM and shows the relative amounts of SDF present when comparing control and P1 specimens. Images of specimens subjected to P1, which did not include a rinsing step, revealed a thick surface film of SDF and SDF within dentinal tubules. Others have reported similar findings using SEM by showing SDF deposits covering the dentin layer and within the dentinal tubules to a depth of 20 μm[27)]. By contrast, no appreciable amount of SDF was observed for specimens subjected to P2 when compared to controls (micrographs not shown). After SDF was absorbed by the tooth, the subsequent rinsing step presumably flushed excess SDF from the superficial peritubular and intratubular dentin. Any residual SDF was not be visible using SEM after rinsing, however its presence was confirmed given that extensive staining of tooth structure was observed. Residual SDF in this group may not be visible by SEM due to the small size of SDF particles and their ability to penetrate dentin by more than 200 μm[28)] as demonstrated in primary teeth. Others have reported fluoride and silver ions detectable up to 450 μm within partially demineralized dentin[13)] of permanent teeth so, similarly, rinsing appears only to remove the superficial SDF remaining after treatment. This can be viewed as a positive attribute of SDF because a therapeutic effect may still be achieved even after rinsing.

Whereas rinsing (protocol P2) significantly improved bond strength after SDF application for the adhesives examined in this study, measured bond strengths were still lower than those of controls. Our novel protocol consisted of refreshing of the dentin following SDF application and resulted in the greatest bond strength of all protocols tested. Only a very superficial (0.1 mm) layer of dentin needed removal with #600 grit SiC paper to achieve bond strengths similar to those of controls for SBT and CSE groups. This suggests that SDF is of highest concentration at the most superficial layer of dentin and thus its effect on bonding is most impactful in this area. This layer can be removed mechanically to produce fresh substrate for improved bonding. By refreshing the dentin superficially, surface deposits are removed, but the penetrated deposits in tubules will likely remain. Therefore, after the caries arresting therapeutic effect of SDF is achieved, dentin need only be slightly polished to re-establish typical bond strengths. Recommending this protocol for clinical use requires further investigation particularly involving carious dentin substrates.

To avoid an inherent rinsing step after PA-etching with Scotchbond Universal, etching was done prior to application of SDF for P1 (no-rinse protocol). The rationale for modifying P1 this way was twofold: first, replication of P1 and P2 data for the SBT adhesive system was prevented and second, the SBT group using P1 would not have a distinct advantage over SBU and CSE groups by receiving a 15 s post-etch rinse. The bond strength of SBT using P1 remained greater than that of SBU and CSE presumably because PA-etching chemically removed more of the smear layer prior to application of SDF than self-etching did after SDF application. SEM images of a SBT P1 specimen showed deep dentinal furrows that were created by etching which increased the surface area available for adhesive bonding, substantially more so when compared to the self-etching result of CSE. This effect is most apparent for specimens subjected to the P1 protocol because of the increased quantity of SDF present under this protocol which impedes the self-etching attribute upon which SBU and CSE adhesives rely to establish bonds and further explains the observed greater percentage of de-bonding events for these groups.

Further investigation and/or modification of the SDF application protocol is needed to determine how best to combine SDF application with adhesive restorations in a manner that maintains the advantages of each. Within the limitations of this short-term laboratory study, refreshing dentin prior to bonding appeared to be the most effective protocol for bonding to SDF-treated dentin, supported by Koizumi *et al.*[26)].

While this study is useful in evaluating bonding to SDF-treated dentin, that adhesion to carious dentin is less successful than adhesion to healthy dentin is well established[29)]. Thus, further investigation as to bonding efficacy to carious dentin treated with SDF is necessary. In addition, further studies should evaluate the effects of SDF in combination with other restorative materials such as glass ionomer and resin-modified glass ionomer.

CONCLUSION

This study investigated the effect of SDF on the MSBS to dentin of commonly used adhesive systems in conjunction with different SDF application protocols. Overall, SDF demonstrated a negative effect on bonding, the severity of which strongly correlated with the application protocol used. Rinsing after SDF application led to improved bond strength compared to non-rinsing groups. Removal of the superficial layer of SDF treated dentin recovered bond strength values similar to those observed for controls for multi-step adhesive protocols SBT and CSE.

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