Original Article

Comparison of Microtensile Bond Strength of Glass Ionomer to Carious Primary Dentin After Treatment with SDF and SDF/KI

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Abstract

Introduction: The aim of this *in vitro* study was to compare the microtensile bond strength of glass ionomer to carious dentin in primary molars that were treated with silver diamine fluoride (SDF) to that of primary molars treated with silver diamine fluoride and potassium iodide (SDF/KI). **Methods:** Thirty-nine extracted carious primary molar samples were prepared and divided into two groups. Twenty samples received two applications of SDF and 19 samples received two applications of SDF/KI. All samples were restored with glass ionomer (EQUIA Forte). The samples were tested using a vertical displacement test to evaluate the microtensile bond strength. **Results:** The microtensile bond strength of the glass ionomer to carious dentin was greater in the teeth treated with SDF/KI than in the teeth treated with SDF alone. The results were statistically significant with a p-value <0.001. **Conclusions:** Pretreatment of carious dentin with silver diamine fluoride and potassium iodide resulted in a greater microtensile bond strength to a glass ionomer when compared to carious dentin treated with silver diamine fluoride alone.

Keywords: Bond Strength, SDF, Glass Ionomer

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Introduction

Topical fluoride has been used since the 1960's as an anti-caries agent. It has been delivered via dentifrices, gels, foams, and more recently varnishes. These therapies have all been shown to be effective in the prevention and control of caries. The most recent products to receive approval in the United States by the Food and Drug Administration (FDA) contain silver diamine fluoride (SDF). SDF has been found to be effective in arresting caries in dentin (1). SDF has caries arresting properties that not only cease caries progression but also help prevent new caries lesions from forming (2). Indications for the use of SDF include patients at high risk for caries, patients with medical or behavioral challenges, and those who find access to care difficult (3). An undesirable side effect of SDF is that it causes black staining of caries surfaces (4). While SDF has proven a helpful tool, the esthetic appearance deters parents from using it particularly on the anterior teeth (4). SDF was initially marketed in the United States in 2015 as Advantage Arrest (5).

Silver diamine fluoride with potassium iodide (SDF/KI) (Riva Star, SDI Limited, Bayswater, Australia) was also recently approved in the United States by the FDA (6). The addition of potassium iodide is reported to help reduce the color changing effects of the SDF (6). While the application of KI takes an additional step, its application creates a precipitate, which helps to mask the black color seen with the SDF alone. However, Li et al (7) reported that the effect of KI on the dark staining caused by SDF did not last for 30 months when placed on root caries . Additionally, practitioners have begun to use a technique called Silver Modified Atraumatic Restorative Technique (SMART), in which glass ionomer cement is placed immediately after the application of SDF (8). This technique provides an immediate restoration as well as addressing the esthetic concerns associated with the application of SDF. While the SMART technique is becoming increasing popular as evidenced by its inclusion in many Pediatric Dentistry continuing education courses and online discussions, there are only a few published case reports and very little research evidence for the procedure (9,10). While there are a number of studies which have evaluated the effect of pretreatment of dentin with SDF and SDF/KI on the bond strength of resin composites and glass ionomer cements, few studies have evaluated this in carious primary dentin (11,12). The recent article by Puwanawiroj et al. found that the application of SDF did not affect the bond strength of a glass ionomer cement to carious dentin in primary teeth (12). Additionally, while Knight et al. evaluated the effect of an application of SDF/KI on the bond strength of a glass ionomer cement to permanent tooth dentin (13), the effect of SDF/KI on the bond strength to carious primary tooth dentin has yet to be evaluated. Therefore, the current study was performed to compare the bond strength of glass ionomer to carious dentin in primary molars after the use of SDF alone with the bond strength of glass ionomer to carious dentin treated with SDF/KI. The null hypothesis of the study was that there would be no difference in these bond strengths.

Materials and Methods

The study received approval from the Rutgers Newark Health Sciences IRB prior to its initiation. Carious primary molars were collected in the Department of Pediatric Dentistry, Rutgers School of Dental Medicine. The teeth were properly cleaned and sterilized as per the Rutgers School of Dental Medicine protocol and preserved and stored in a 1% phenol solution. The tooth selection requirements for the study were as follows: primary first or primary second molars, carious lesion present and no visible pupal involvement.

The sample size was based on systematic reviews of 8 studies that utilized methods very similar to the current study. The sample sizes of these previous studies ranged from 5 to 32 samples per group. The majority of the articles with significant results evaluated 10 samples per group. This number was doubled to provide greater power.

The samples were set in a resin mixture using a latch key mold with a 12 mm diameter and 18 mm depth. To lock and unlock the mold an Allen wrench (hex key) was used. The resin mixture was made by mixing Pattern Resin LS (GC America, Chicago, IL) (10 mL) with Dental Acrylic Pattern Resin (GC America, Chicago, IL) (5 mL) so it flowed easily. To prevent sticking of the Pattern Resin to the mold, 3-IN-ONE Multipurpose use oil (WD-40 Company, Summit NJ) was placed in the mold wells. Once each mold was filled completely to the top, the tooth sample was placed to the depth of the cemento-enamel junction (CEJ). To keep the tooth samples parallel and at the proper depth, the investigator used a paint brush with dental rope wax attached to the edges of the mold and the occlusal surfaces of the tooth samples. The resin mixture was allowed to harden. The samples were then placed in artificial saliva. An IsoMet 1000 Precision Saw (Buehler, Lake Bluff, IL) set at 800 rpm was used to remove the cusps of the teeth. The occlusal surface was made completely flat. This step removed any possible mechanical retention due to the molar's anatomy. Using a 7/64 drill bit, a pilot hole was drilled 3 mm deep into the bottom of the resin sample. This hole was used for a self-threading hook-and-eye screw that was used to mount the sample for testing. The samples were removed from the artificial saliva and separated into two groups. (20 samples for SDF (Group 1) and 19 samples for SDF/KI (Group 2).The dentin surfaces were dried but not desiccated using a 3-way air/water syringe. In Group 1 SDF was applied per the following manufacturer's recommendations; Dispense 1 drop into a disposable dappen dish, using a micro sponge brush. Dip brush into SDF and dab on the side of the plastic dappen dish to remove excess liquid before application. Apply SDF directly to the affected tooth surface (14). Any excess SDF was removed with gauze. An application time of one minute per sample was used. The samples were allowed to dry and were then placed into artificial saliva and stored in a dark area at 22ºC. After one week the steps were repeated for the second application. The samples were again placed in artificial saliva. Group 2 was prepared for the application of SDF/KI in a manner identical to the first group. The SDF/KI was applied per the manufacturer's recommendations, which were as follows: Using the silver brush provided, pierce through the foil of the silver capsule and carefully apply the SDF solution to treatment site only. Immediately after, use green brush provided, pierce through the foil of the green capsule and apply a generous amount of the potassium iodide solution to treatment site. Apply same solution to any other tooth surfaces that may have come into contact with the solution from the silver capsule. The potassium iodide solution initially appeared creamy white. The application of the potassium iodide was continued until it turned clear.

Note: Treatment surface initially appears creamy white; keep applying solution from green capsule until it turns clear (15). The samples were then placed into artificial saliva. After one week the steps were repeated for the second application. The samples were again placed in artificial saliva.

All samples were removed from the artificial saliva. GC Cavity conditioner (GC America, Chicago, IL) was applied for 10 seconds. The samples were rinsed and gently dried using a 3-way air water/syringe to avoid desiccating the tooth samples. A T-Band (PulpDent, Watertown, MA), was placed around each tooth sample with at least 2 mm of height extending above the occlusal surface. EQUIA Forte (GC America, Chicago, IL), was applied per the manufacturer's instructions (16).

A hoop peg hook that was 4.5 mm wide x 10 mm in length was placed into the glass ionomer before working time was complete for each sample (Figure 1). The samples were stored in separate artificial saliva containers (SDF and SDF/KI) until they were ready to be tested.

The microtensile bond strength of each sample was tested using a MTS Material Test System 810 (MTS Corporation, Eden Prairie, MN.) The large hook from the bottom of the sample resin was placed into the stationary holding mechanism (Figure 2). Orthodontic wire was thread through the smaller hook and the ends of the wire were attached to the hydraulic holding mechanism. In the station manager, the test was set to zero and the manual control was removed. The testing procedure determined the number of Newtons/mm^2 (N/mm^2) required to break the bond between the glass ionomer and the tooth surface. Once the bond was broken, the test was stopped. The data was recorded for statistical analysis and the controls were reset for the next test and the steps were repeated until all samples were completed.

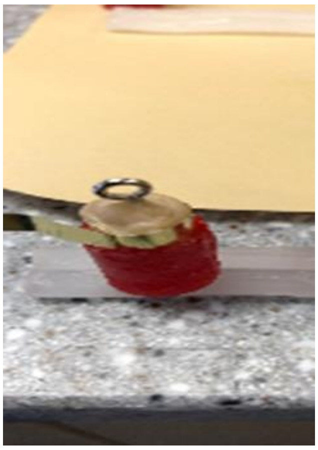


Figure1. Peg Hook Embedded in the Glass Ionomer

Figure2. MTS Material Test System

Results

After preparing and testing 39 samples the results showed that a greater force was needed to break the bond in the SDF/KI group than in the SDF group. The results were as follows: Group 1, (SDF treated tooth samples) required a mean of 56.60 (± SD 29.80) N/mm^2 to break the bond of the glass ionomer to the tooth surface. (Figure 3) Group 2, (SDF/KI treated tooth samples) the N/mm^2 required to break the bond of the glass ionomer to the tooth surface was 100.58 (± SD 41.53) (Figure 4). A visual evaluation of the fracture point showed that the samples treated with SDF usually presented with adhesive failures at the junction of the tooth surface and the glass ionomer. In comparison, the samples treated with SDF/KI, which required higher forces to fracture the bond, typically presented with fractures within the restoration versus failures at the glass ionomer/ tooth interface.

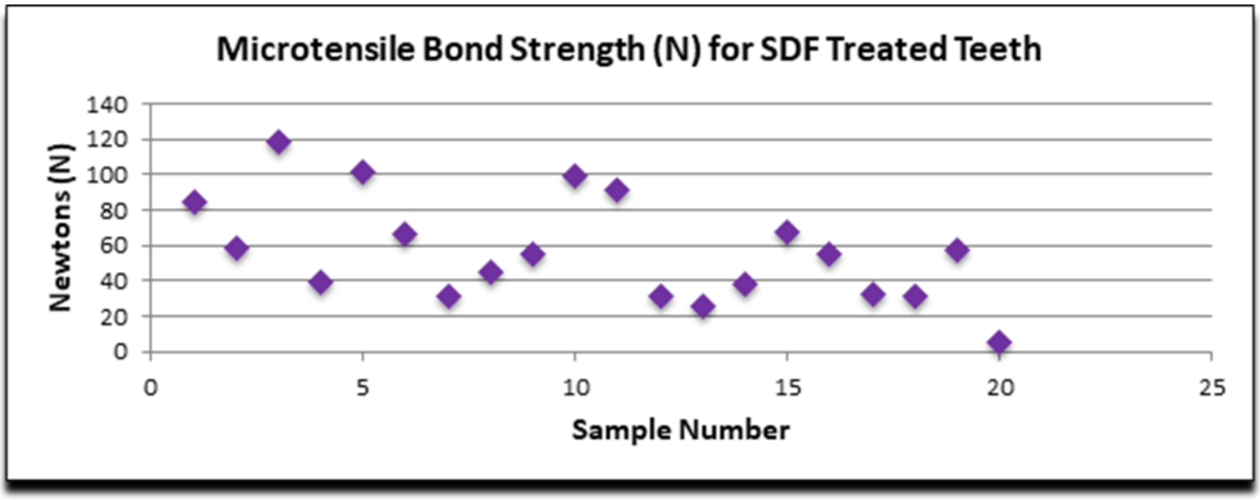


Figure 3: Microtensile Bond Strength (N) for Silver Diamine Fluoride Treated Teeth

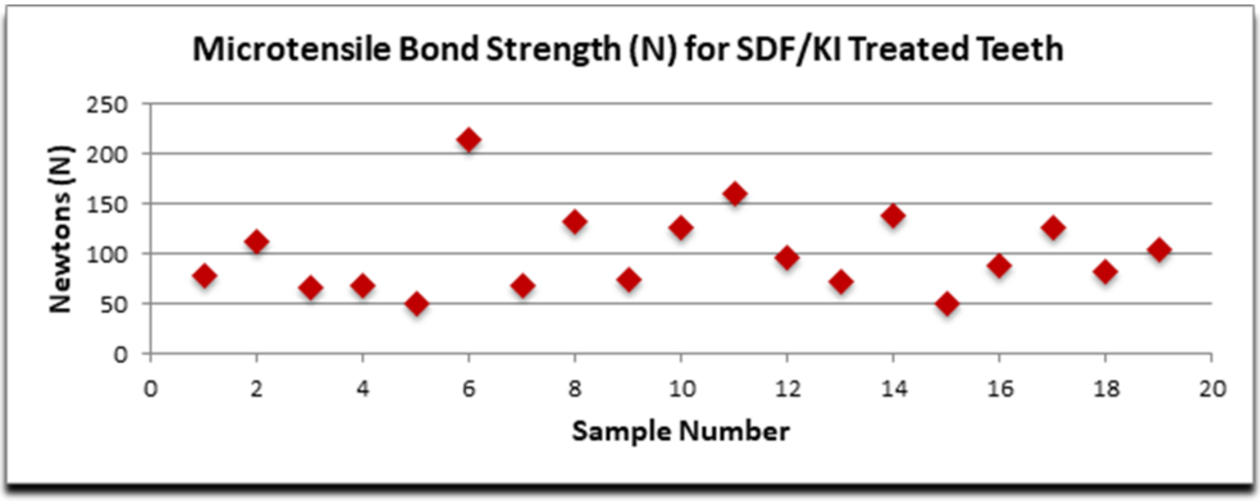


Figure 4: Microtensile Bond Strength (N) for Silver Diamine Fluoride with Potassium Iodide Treated Teeth

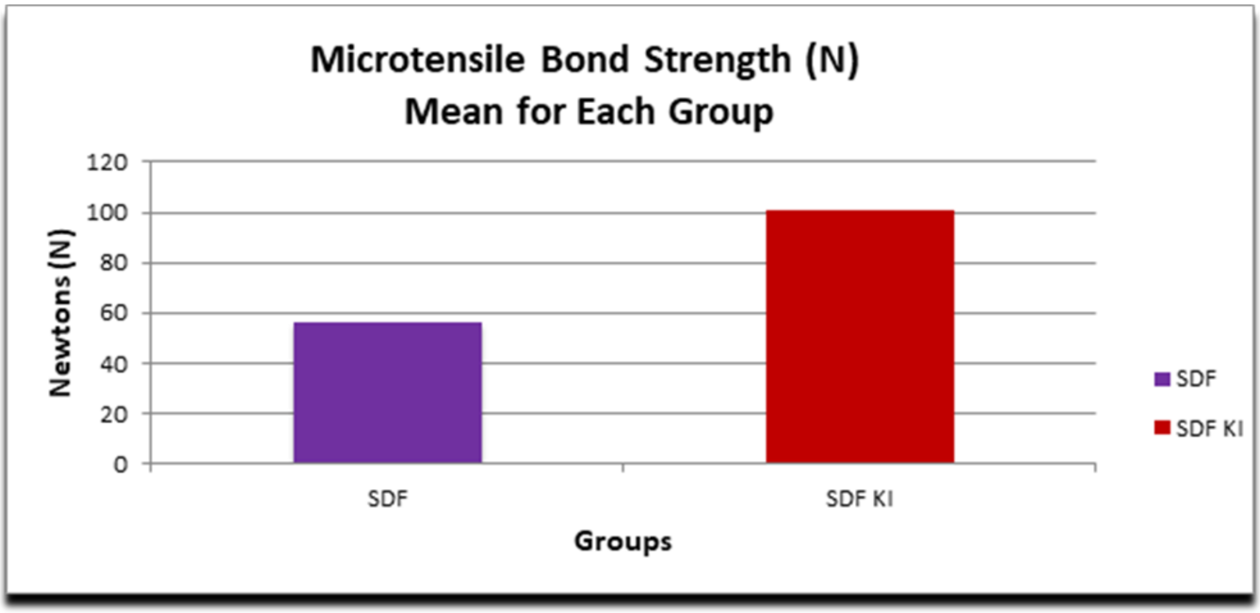
In the current study the small hook embedded in the glass ionomer cement would start to straighten after 100 N/mm^2 was applied. When this occurred during the test, the test was paused and the screw was bent to allow for further testing.

Table I shows results with means and standard deviations for both groups.

Table I: Comparison of Microtensile Bond Strength

Microtensile Bond Strength (N)	Group	Number	Mean	Standard Deviation	P-Value
	SDF	20	56.6	29.8	0.001
	SDF KI	19	100.58	41.53	

The results were analyzed as numerical data and the independent variable was categorical data with two levels. A statistical analysis was performed using the IMG SPSS Statistics Data Editor. An independent samples t-test indicated that the two groups were statistically significantly different with a P-value <0.001. Graph 1 shows the means for each group.



Graph 1: Microtensile Bond Strength (N) Mean for Each Group

Discussion

Pediatric Dentistry is moving towards minimally invasive caries treatment. Techniques utilized to accomplish this include sealants, composite restorations, resin infiltration, and ITR (Interim Therapeutic Restorations) (17). A relatively recent technique which involves preservation of tooth structure as well as an esthetic restoration is the SMART technique which combines the use of SDF to arrest caries and a glass ionomer cement restoration for esthetics (8, 9, 10). While this technique has the benefit of minimal tooth reduction as well as the caries arresting property of both SDF and a glass ionomer cement, little research has been performed on the combined effects of these products (8, 9, 10).

Previous studies have investigated the effects of SDF and SDF/KI on the bond strength of dental adhesives and glass ionomer cements. In general, authors found that the application of SDF or SDF/KI either decreased the bond strength of dental adhesives or had no effect (11, 18, 19, 20, 21). When the effect of SDF or SDF/KI on the bond strength of glass ionomer has been evaluated, most studies have found either an increase in the bond strength or no effect (12, 13, 20, 21, 22).

Glass ionomer cements adhere to dentin via two mechanisms. Micromechanical interlocking occurs after the application of a polyalkenoic acid conditioner. This is due to the increase in surface area when micro-porosities are created. Additionally, true chemical bonding takes place when the carboxyl groups of the polyalkenoic acid bond to the calcium in the hydroxyapatite (23).

When evaluating the effects of SDF application on the bond strength of a glass ionomer to dentin, several factors must be considered:

SDF causes the formation of fluorapatite crystals in the dentin which are more closely packed with fewer voids compared to hydroxyapatite (24). SDF also increases the microhardness of the dentin (24). While this combined with a possible decrease in ion exchange from the acid base reaction, could theoretically lower the bond strength of the glass ionomer, studies have shown that SDF does not lower the bond strength (12). It has been postulated that increased bond strength produced after the use of SDF alone could be due to the formation of silver phosphate bonding to the carboxylic acid in the glass ionomer (25, 26). It is also suggested that this increase could be due to a hardened dentin surface, reduced collagen degradation, or fixation of the dentin proteins (25). Increasing the microhardness of the dentin may enhance the micromechanical interlocking of the glass ionomer to dentin (27). Additionally, after application of SDF both silver and silver oxide are present on the surface of the dentin. This may improve the bond strength as the glass ionomer bonds to metal as well (27).

When evaluating the effects of SDF/KI on the bond strength of a glass ionomer to dentin, it is important to take into account the chemical reaction proposed by Nguyen et al. (28):

$$Ag(NH_3)2F(aq) + KI(aq) \rightarrow AgI(s)+2NH_3(g)+F^-(aq)$$

The question that this reaction raises, is whether the formation of silver iodide will enhance or reduce the bond strength between the dentin and a glass ionomer. While it has been inferred that the silver iodide precipitate formed when SDF application is followed by KI reduces bond strength (13), the opposite has also been proposed. It has been suggested that the silver iodide produced in the above reaction may reduce dentin tubule patency. This is the proposed rationale for the reduction in dentin hypersensitivity seen with the use of SDF/KI (29). Dentinal fluid has been proposed to weaken the tensile bond strength with a glass ionomer (30) Therefore the silver iodide may decrease the dentinal fluid flow, thus increasing bond strength. Another possible explanation for the increase in bond strength when SDF/KI was used in the current study is that the carboxylic acid in glass ionomer cements may bond to the silver iodide precipitate in the dentinal tubules, thus creating a stronger bond (25). Additionally, applying SDF/KI to dentin prior to the placement of a glass ionomer cement has been shown to increase the depth and concentration of fluoride into demineralized dentin (31). This deep penetration of fluoride could contribute to increased bond strength after the use of SDF/KI as well.

The results of the present study show that SDF/KI can be used prior to the placement of a glass ionomer restoration in carious primary teeth. Future studies should continue to evaluate the bond strength of different types of restorative materials including resin composites, glass ionomer cements, and resin modified glass ionomer cements after the use of SDF and SDF/KI in primary teeth. These studies should be performed in teeth with caries lesions, as this simulates the clinical use of these materials. Ideally, long-term in vivo studies need to be performed on the use of a glass ionomer cement after application of SDF and SDF/KI in carious teeth to evaluate the evidence for this procedure.

The results of this study add information to the developing database of information in the field of minimally invasive caries removal. This is important as we evolve into healthcare providers who integrate patients' esthetic desires with evidence based clinical procedures

Conclusion

This *in vitro* study found that a glass ionomer cement had a significantly stronger bond to carious dentin surfaces of primary molar teeth treated with silver diamine fluoride and potassium iodide than to those teeth treated with silver diamine fluoride alone.

Conflicts of interest

There are no conflicts of interest to disclose.

Acknowledgements

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