Shear Bond Strength of Glass Ionomer Cement after Silver Diamine Fluoride Application to Primary Molars: *In-Vitro* Study.

A Thesis

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ABSTRACT

Aim:

The aim of this *in vitro* study was to investigate and compare shear bond strength of Glass Ionomer cement to carious dentin of primary molars after the application of three different types of Silver Diamine Fluoride therapy: Silver Diamine Fluoride 38% (SDF), Silver Diamine Fluoride 38% with Potassium Iodide (SDF/KI), and Silver Fluoride Aqua with Iodide (AgF/KI).

Materials and Methods:

Extracted carious teeth were collected from Tufts University School of dental medicine. Sample size calculation was based on the pilot study results, total of 40 teeth were included and randomized into four groups (N= 10). Teeth were mounted and cut using Isomat saw, carious part of the tooth was exposed for the experiment. Control group: teeth received glass ionomer restoration. First test group received Silver Diamine Fluoride 38% (SDF), second test group received Silver Diamine Fluoride 38% with Potassium Iodide (SDF/KI), third test group received Silver Fluoride Aqua with Iodide (AgF/KI). Three test groups then received glass ionomer restoration and all four groups were tested for shear bond strength using Instron Machine. Mean and standard deviation were calculated, Welch's ANOVA and the Games-Howell test for pairwise comparisons were used.

Results:

Comparison between control group of glass ionomer restoration used directly on dentin and all test groups of SDF therapy shows that shear bond strength is decreased when caries arresting medicaments used, regardless of the type. This reduction is statically significant.

Conclusion:

Within the limitation of this laboratory study, it can be concluded that SDF application in all three forms reduced shear bond strength of glass ionomer cements to extracted primary molars with natural caries.

DEDICATION

This work is dedicated to those people who supported me throughout my journey.

To my beloved parents Mohammed and Sultana, to the guiding light and source of inspiration in my life. To the great parents who raised me, loved me, and whose good example have taught me to work hard for the things I aspire to achieve.

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INTRODUCTION

Dental Caries in the Pediatric Population:

Dental caries is a multifactorial infectious disease that is caused by the interaction of bacteria and sugary diet producing an acidic oral environment. The acidity of the oral environment with time will cause demineralization of tooth structure (1) Mutans Streptococci and *Lactobacilli* species are strongly implicated and associated with dental caries. In fact, Mutans Streptococci when acquired early during childhood life is linked with high caries activity (2). Earlier studies believed that infants can only acquire Mutans Streptococci from their mothers when their first primary tooth erupts, which is during the first window of infectivity between age 19 and 33 months (3). However, more recent studies demonstrated and proved that Mutans Streptococci can start colonizing the mouth earlier than that which is during the pre-dentate stage of infants. The acquisition of the bacteria to the oral cavity of infants can be through vertical and/or horizontal mode of transmission (4). Based on a recent systematic review and meta-analysis on the horizontal mode of transmission, there is evidence proving that children who live at the same home or school have the same genotype of Mutans Streptococci. The systematic review also found that those children who shared more than one genotype of the bacteria had higher caries risk than those who shared only one genotype (5).

Early childhood caries is defined by the American Academy of Pediatric Dentistry as "the presence of one or more decayed (non-cavitated or cavitated lesions), missing teeth (due to caries), or filled tooth surfaces in any primary tooth in a child 72 of months age or younger. In children younger than 3 years of age, any sign of smooth-surface caries is indicative of severe early childhood caries (S-ECC). From ages 3 through 5, one or more cavitated, missing teeth (due to caries), or filled smooth surfaces in primary maxillary anterior teeth, or decayed, missing, or filled score of ≥4 (age 3), ≥5 (age 4), or ≥6 (age 5) surfaces constitute S-ECC (6).

Despite implementing preventive dentistry programs, dental caries is still considered one of the most common infectious diseases and if not treated and managed properly, will lead to the occurrence of dental emergencies like tooth abscesses and pain. When such emergencies happen among the pediatric population, specifically among very young patients, general anesthesia may be required for proper behavior management and safe delivery of dental treatment (2).

Although dental caries in the younger age group is preventable and reversible, if left untreated will lead to many negative sequalae such as pain, reduction of growth, high cost of treatments and low self-esteem of the suffering child (7,8). Some factors such as lack of access to care, lack of knowledge and absence of simple preventive strategies are responsible for the oral health decline and high caries risk in the younger population (8).

In the past, the only known treatment approach to carious lesions was traditionally through the surgical approach, which requires cycles of drilling and periodic replacement of restorations due to the recurrence nature of the disease (9). On the other hand, nowadays more emphasis is being put on the preventive approach, which is basically to modify and stop the lesion from occurring and progressing, this can be achieved through individualized preventive regimen and routine (9).

There is an ideal chance to implement these preventive dental strategies very early on to the child's life through the interactions between the parents/caregivers with the medical team. Health care providers play an important role in dental preventive programs and are expected to provide parents/caregivers with proper education, simple intervention if needed and referral to a pediatric dentist as soon as the first primary tooth erupts (8).

Silver Diamine Fluoride Therapy:

There has been an increase in the use of Silver Diamine Fluoride therapy (SDF) as caries arresting medicament, especially to the primary dentition. The arresting process occurs through two main mechanisms of action: first, the fluoride ions enhancing mineral formation and hardening of tooth structure. Second, by inhibiting the enzyme (Matrix metalloproteinase inhibition) that breaks down and disintegrates tooth structure (10). The ability to enhance the mineral component of the tooth structure is attributed to the formation of silver phosphate precipitate and calcium fluoride (11).

Laboratory studies have shown that SDF possesses antimicrobial abilities through the inhibition of the monospecies biofims of *Streptococcus mutans, Actinomyces naeslundii, Streptococcus sobrinus* and *Lactobacillus acidophilus* (12). One study demonstrated that the inhibition process can also include multispecies biofilm of *S. mutans, S. sobrinus, Lactobacillus rhamnosus, L. acidophilus,* and *A. naeslundii* on samples of dentin tooth structure that is treated by SDF therapy. (13) This antimicrobial effect is through the release of silver ions; these ions will stop the growth of the bacteria and affect the metabolic activity of the dental plaque (14)(15).

Some published reviews have reported that after two applications of SDF therapy, clinician should expect 50% caries arrest in preschool children and 70% in primary school-aged children (16). Currently and available in the market, Silver Fluoride can be present in alkaline solution as SDF ranging from 10% to 38% or in Aqueous solution (AgF) (10)(17).

The application of SDF therapy is simple and inexpensive supporting the concept of minimal invasive dentistry. Thus, utilizing SDF in caries management protocol seems to be the most appropriate option for young, uncooperative, and socially challenged population (17).

One side effect of using SDF is the temporary tattoo that occurs if during the application process it contacts soft tissue accidently. However, these dark skin or mucosal lesions will resolve within 2-14 days and are usually not a concern. On the contrary, hard tissue discoloration to the carious lesion is permanent and the dark stains will not resolve (15).

This major drawback to its application was addressed and studied by many researchers and various companies. In fact, two known published techniques have been introduced in the literature to overcome the discoloration. First technique is to completely mask the black color by placing an adhesive restoration such as glass ionomer cement (GIC) with Atraumatic Restorative Technique (ART). The technique is known clinically as the Silver Modified Atraumatic Restorative Technique (SMART) (12). Glass ionomer cement is commonly the material of choice in this technique because it can offer chemical bonding to tooth structure via the acid-based chemical reaction that occurs. Some of the reported advantages of this technique besides color masking, is restoring function as well as aesthetics. It is also believed that the SMART technique can help eradicate cariogenic bacteria, maintain pulp vitality, and promote the remineralization process. It was also reported that parental satisfaction was increased after placing tooth-colored restoration to teeth treated by SDF (12).

The second technique is the follow up treatment of potassium Iodide salt (KI) immediately after applying conventional SDF solution. The second step of applying potassium Iodide is intended to eliminate excess silver particles producing a white reaction (18). However, this extra step alone is not enough, and it is recommended that teeth that received potassium Iodide should be planned to be restored with a SMART technique subsequently. The reason is that exposure to light can discolor the carious lesion despite applying Iodide salt (KI) as a second layer (19).

Another side effect of the use of SDF is the irritation and burns to the gingivae and surrounding soft tissues when in contact due to a high pH value of about 13. Because of that concern the manufacturer produced ammonia-free Silver Fluoride solution (Riva Star Aqua). The aqueous solution free from the ammonia base will produce a better taste and less soft tissue irritation (19). The Riva Star Aqua system includes a potassium Iodide as a second step to reduce stains and discoloration as well.

Shear Bond Strength:

Shear bond strength is a laboratory test that is used simply to test the adhesion of dental adhesive materials. Using the shear bond strength test *in Vitro* will help to estimate and predict the performance of adhesive dental material and correlate the data to clinical use. The shear bond strength test is carried out using a universal testing machine, Instron (20).

Studies have been published on microleakage, shear and microtensile bond strength of Resin restorations and Resin-Modified Glass Ionomer cements to carious dentin of primary teeth after applying SDF (15,21–24). Other studies investigated shear bond strength of Glass Ionomer Cements to carious dentin after applying SDF with or without Iodide (12,25). However, there are no published papers that are currently available in the literature discussing shear bond strength of Glass Ionomer Cements to carious dentin after the application of different types and forms of SDF therapy. Silver Diamine Fluoride 38% (SDF), Silver Diamine Fluoride 38% with Potassium Iodide (SDF+KI), and Silver Fluoride Aqua with Potassium Iodide (AgF+KI).

AIMS AND HYPOTHESIS

Aims

The aim of this *in vitro* study was to investigate and compare shear bond strength of Glass Ionomer Cements to carious dentin of primary molars after application of three different types of Silver Diamine Fluoride therapy: Silver Diamine Fluoride 38% (SDF), Silver Diamine Fluoride 38% with Potassium Iodide (SDF+KI), and Silver Fluoride Aqua with Iodide (AgF+KI).

Hypothesis

Using different types of SDF therapy before the placement of adhesive restorative material such as (Glass Ionomer) will not affect the shear bond strength of the restorative material to the tooth structure.

Significance of the Study:

Results of this bench study will help guide future studies and investigations about the different types and forms of SDF therapy when used before placing Glass Ionomer restorations to primary dentition.

Results can help pediatric dentists understand the effect of different types and forms of SDF therapy on shear bond strength of glass ionomer cements to primary dentition.

MATERIALS AND METHODS

Research Design:

This *in vitro* study was conducted at the Gavel Laboratory, Tufts University School of Dental Medicine (TUSDM), Boston, MA, USA. Research work started after obtaining Ethical approval from the committee of the internal research department.

This bench study intends to test shear bond strength of Glass Ionomer Cements to carious dentin structure of primary molars as a control group and compare it to three test groups. The three test groups received different types of Silver Diamine Fluoride solutions as caries arresting medicament prior to the Glass Ionomer restorations. The three different types are: Silver Diamine Fluoride 38% (SDF), Silver Diamine Fluoride 38% with Potassium Iodide (SDF+KI), and Silver Fluoride Aqua with Iodide (AgF+KI).

Teeth Selection and Preparation:

Previously extracted human primary molars were obtained from the pediatric department of Tufts University School of Dental Medicine, Boston, MA, USA. Teeth collection process was conducted in full accordance with the rules and regulations of human subjects in the pediatric dentistry department, Tufts University School of Dental Medicine, Boston, MA, USA.

Teeth were collected in a de-identified manner and cannot be linked in any way to the patient it came from. All collected teeth were initially wiped with 2*2 piece of gauze to clean off all residual soft tissues attached to it immediately after extraction. Teeth then were stored in a sealed plastic container and in saline solution, the container was kept in a secured area within the pediatric department. At the end of the day, the container was picked up for final storage and disinfection process of teeth at 4° Celsius in the Gavel Lab.

Following the disinfection process, teeth were kept in a 10% aqueous bleach solution for five days. Final step was to merge and soak collected teeth in an artificial saliva solution that was composed chemically of ($KH_2PO_4+NaN_3+KCL+CaCl_2+MgCl_2$) until the start day of the study. Throughout the study period, teeth were kept in the artificial saliva solution and were placed in an incubator (Thermo Fisher Scientific CO_2 incubator, Waltham, Mass, USA) at 37˚C to resemble and mimic oral environment.

Inclusion Criteria:

1- Extracted or naturally exfoliated first and second primary molars.
2- Extracted due to dental caries into the dentin (cavitated) and diagnosed as code five, according to the ICDAS II (the International Caries Detection and Assessment System) caries diagnosis criteria (26).

Exclusion Criteria:

1- Teeth with extensive dental caries extending into the pulp clinically; corresponding to code six, according to the ICDAS II (26).
2- Teeth with previous restorations.
3- Teeth with previous SDF treatment.
4- Teeth with developmental anomalies or dentinal defects such as (amelogenesis/ dentinogenesis imperfacta, dentin hypoplasia, etc.).

Sample Size Calculation:

The sample size calculation was made after conducting a pilot study of 20 teeth in four groups, five teeth in each as shown in the figure (Figure 1). Using the pilot study outcomes with a significant level set for $\alpha = 0.0083$ and 80% power, a sample size of 10 teeth per group with total of 40 teeth in the study was included.

Randomization:

Total of ($N = 40$) extracted teeth that met the inclusion criteria were included in the study and were numbered as shown in the figure from 1 – 40. (Figure 2).

Teeth were randomly divided into four groups of 10 teeth following the “sample” function of R 4.3.0 (R Foundation for Statistical Computing, Vienna, Austria) (Figure 2).

Each single tooth was kept in a separate plastic container and in the artificial saliva solution and was marked by a two-digit number, the first number with black ink indicates the sample number (1- 40) and the second number with a color indicates the group that the tooth was randomly assigned to (1-4).

Randomization of the teeth ensured that each tooth had an equal chance of being allocated to either one of the four groups, to eliminate any selection bias.

Study Groups and Material Used (Table 1):

Gtoup1 - Control group: Glass ionomer restoration (SDI, Riva Self-Cure, Bulk Fill Glass Hybrid Restorative System, Australia) was placed directly into the carious dentin of the tooth. (Figure 3).

Group 2 - Test group 1: the carious dentin surfaces were treated with a 38% SDF solution (Advantage Arrest, Elevate Oral Care, West Palm Beach, FL) using a microbrush (Kerr, Orange, Calif., USA) (Figure 4) for one minute then gentle compressed air was applied until medicament was dry and the tooth was kept isolated for 3 minutes then placed back into its plastic container within the artificial saliva and back to the incubator to mimic oral environment. After 24 hours (25), each sample received its final Glass ionomer restoration (SDI, Riva Self-Cure, Bulk Fill Glass Hybrid Restorative System, Australia).

Group 3 - Test group 2: the carious dentin surfaces were treated with SDF/KI solution (Riva Star, SDI North America Inc. Itasca, IL), (Figure 5). Solution from silver capsules was applied to the demineralized surfaces, after that immediately, saturated KI solution from the green capsules was applied to the treatment site until creamy white turned clear, gentle compressed air was applied until medicament was dry and the tooth was kept isolated for 3 minutes then placed back into its plastic container within the artificial saliva and back to the incubator to mimic oral environment. After 24 hours (25), each sample received its final Glass ionomer restoration (SDI, Riva Self-Cure, Bulk Fill Glass Hybrid Restorative System, Australia).

Group 4 - Test group 3: the carious dentin surfaces were treated with AgF solution (Riva star Aqua, SDI, Victoria, Australia), (Figure 6). Solution from silver-blue capsules was applied to the demineralized surfaces, after that immediately, saturated KI solution from the green capsules was applied to treatment site until creamy white turned clear, gentle compressed air was applied until medicament was dry and the tooth was kept isolated for 3 minutes then placed back into its plastic container within the artificial saliva and back to the incubator to mimic oral environment. After 24 hours, each sample received its final Glass ionomer restoration (SDI, Riva Self-Cure, Bulk Fill Glass Hybrid Restorative System, Australia).

Specimen Preparation and Manipulation:

After randomization, teeth were mounted to self-curing acrylic resin material (Ortho-Jet™ for Orthodontic Appliances) (Figure 7). that was poured into plastic cube tray with each tooth positioned apically as shown in the figure (Figure 8). Each tooth was placed into the resin vertically with the apical surface dipped down until it reached the mold's lid. Once the resin sat, mounted samples were then removed from the plastic tray mold. Samples were sliced vertically with minimal amount of deformation into a two halves, exposing the carious dentin surface using slow-speed saw with a water-cooled diamond blade IsoMet 1000 (Buehler, Lake Bluff, IL., USA) (Figure 9).

The half that shows the carious lesion was picked up as one sample and cleaned with gauze and saline. The surface that was cut was then polished under running water with 600-grit carbide paper to expose the carious lesion clearly.

Silver Diamine Fluoride Application:

Samples were cleaned with gauze and air dried with gentle flow of compressed air for all groups.

Test group 1: The 38% SDF solution dispensed into a disposable plastic dappen dish that comes with the product. The microbrush was bent and used as an applicator to apply the SDF directly to the carious lesion for one minute.

Test group 2: Riva Star step 1, using the silver brush provided by the company, the foil of the silver capsule was pierced, and the solution was applied to the carious lesion. Immediately after, Riva Star step 2 was applied, using the green brush the foil of the green capsule was pierced and the solution of the green capsule was applied to the carious lesion until the creamy white precipitates turned clear.

Group 4 samples: Riva Star Aqua step 1, using the silver-blue brush provided by the company, the foil of the silver-blue capsule was pierced, and the solution was applied to the carious lesion. Immediately after, Riva Star Aqua step 2 was applied, using the green brush the foil of the green capsule was pierced and the solution of the green capsule was applied to the carious lesion until the creamy white precipitates turned clear.

All test samples were cleaned and dried after the caries arresting medicaments were applied for one minute. Excess material was removed using cotton pellet and gentle flow of compressed air. The area was kept isolated to air dry for three minutes. The application process of the SDF followed the manufacturer's instructions and the chairside guidelines of the American Academy of Pediatric Dentistry guidelines (23).

Glass Ionomer Restoration Application:

Glass ionomer restorations were applied to the test samples 24 hours after the caries arresting medicament was applied along with the control group (25). Two millimeters of polytetrafluoroethylene (PTFE Tube) was cut and used to form a cylindrical button for the restoration material to be placed on top of the flat carious dentin surface of all samples, the back end of the microbrush was used as a plunger to condense the restorative material into the PTFE tube. Following the instruction sheet of the manufacturer, the restoration was light cured for 10 seconds with LED light-cure unit (Bluephase, Ivoclar Vivadent, NY, USA). A silicone spray was used to facilitate the removal of the plastic tube once the restorative material has sat as shown in the figure (Figure 10, 11).

Digital caliper was used to confirm the diameter of the restorative button for each specimen (Figure 12).

Each sample was then transferred back into its plastic container within the artificial saliva and back to the incubator 37˚C (Thermo Fisher Scientific CO2 incubator, Waltham, Mass., USA) (Figure 13) for 24 hours to allow complete setting of the glass ionomer restoration before testing for shear bond strength (25).

Shear Bond Strength Testing:

Specimens were tested for shear bond strength with a universal testing machine, Instron device 68TM-10 model (Instron, Norwood, MA) (Figure 14). Shear load was directed with a sharp blade parallel to the bonded interface at speed of 0.5mm/min until the occurrence of restoration failure.

Force needed to reach debonding stage of the glass ionomer restoration was documented in Newtons (N) and the bond strength was measured in Megapascals (MPa) as shear bonding strength (Figure 15) (25). Shear bond strength was documented in MPa following the equation = the maximum failure load in Newtons (N)/surface area of the bonded interface (mm^2). The surface area (A) was calculated from the following equation: $A = \pi r^2$ where π is a constant value=3.14 and r is radius (15).

Statistical Analysis:

Mean and standard deviation of shear bond strength (MPa) was calculated for the four subgroups. To assess normality, Kolmogorov-Smirnov test was used followed by Levene's test to examine equality of variances. Since Levene's test was statistically significant, Welch's ANOVA and Games-Howell test for pairwise comparisons were used. SPSS version 29 was used for all the statistical analysis mentioned. The significant level was set at $\alpha = 0.05$ and P-values less than 0.05 was considered statistically significant.

RESULTS

Shear Bond Strength:

Mean and standard deviation of the shear bond strength for each group reported in (Table 2). Welch's ANOVA test reported to be 19.5 and was statistically significant, overall p value less than <0.001.

Multiple Comparison Tests:

Comparison between control group of glass ionomer restoration used directly on dentin and all test groups of SDF therapy shows that shear bond strength is decreased when dentin medicaments used regardless of the type (Figure 16). This reduction is statistically significant.

When comparing control group to SDF group the shear bond strength is decreased from mean of 9.95 MPa to 4.91 MPa and this reduction was statistically significant (p value = 0.014).

When comparing control group to SDF/KI and AgF/KI groups, shear bond strength is reduced from 9.95 MPa to 2.66 MPa and 2.63 MPa respectively. This reduction is statically significant with a p value of 0.001 for both comparisons.

Difference in shear bond strength between SDF/KI group and AgF/KI group was not statistically significant, (p value = 1.00).

Comparison of different types of SDF therapy shows that conventional SDF group had reduced shear bond strength of the restorative material the least.

Mean shear bond strength of the SDF group when compared to SDF/KI or AgF/KI group is reduced from 4.91 MPa to 2.66 MPa and 2.63 MPa respectively, (p value <0.001). This reduction for both groups is statistically significant.

DISCUSSION

This study intended to investigate shear bond strength of glass ionomer restoration when used directly on carious dentin of primary molars after applying different types of SDF therapy. Results of this laboratory study indicate that there is a statistically significant reduction of the shear bond strength when applying conventional SDF prior to the placement of glass ionomer restoration. Even higher reduction rate was noted when using the new materials, either SDF with Iodide or Silver Fluoride Aqua with Iodide. It is worth mentioning that these findings are based solely on laboratory experiments and should not be used alone without the support of clinical based trials.

Findings of this paper were contrary to what was found by Zhao I *et al.* in their laboratory work that was published in 2019 (25). They tested the shear bond strength of glass ionomer cements after the use of SDF with or without Iodide. They reported 2.6 ±1.1 mean shear bond strength for the control group that received water only. However, in our study the control group received glass ionomer restorations directly without water application and the mean shear bond strength for our control group is 9.95 ± 4.03. They mentioned in their paper shear bond strength value of 2.3 ± 0.9 MPa for the SDF group compared to 4.91 ± 0.89 MPa in our study, and 3.00 ± 1.4 MPa for the group that received SDF with Iodide compared to 2.66 ± 1.20 MPa in our findings. Their results indicate that the reduction rate in the shear bond strength was not statistically significant after the use of SDF with or without Iodide, (p value = 0.217). Variations between the findings could be related to different study protocols and laboratory steps. For instance, teeth used in their study were third molars and demineralization of dentin was introduced chemically in the laboratory. However, in the current laboratory work, extracted primary teeth with natural caries were used. It is known that when comparing artificially demineralized dentin to natural caries, many differences can be found. First, the microstructure of natural caries is more complex and second, mineral crystals that reduce fluid movement within the dentinal tubules are found only within natural caries and not in artificially demineralized dentin. These factors could play a crucial role in the shear bond strength and in the adhesive properties of the glass ionomer restoration and could explain the current controversy (25).

SDF therapy is an effective caries-arresting medicament. However, dark discoloration that follows its application to primary and permanent dentition limited its use. For that reason, the application of Iodide step has been introduced to the market to resolve and reduce the staining problem (24). In our study, findings suggest that the groups that received Iodide treatment had less value of the shear bond strength of the glass ionomer restoration and the reduction is statistically significant. In theory, it has been proposed that using Iodide to absorb excess silver ions and therefore reduce stains, may in fact reduce the antimicrobial action of the material as well (25)(10). A systematic review that was published in 2021 reported promising antimicrobial protentional of the SDF with Iodide but also highlighted that the studies that were included in the review had many limitations and further research is needed (24).

The effect of saturated Iodide solution on reducing stains of SDF is not fully understood yet (25). Systematic review paper published in 2020 reported some positive effects of dark stain reduction but the evidence was insufficient to prove and show obvious clinical benefits (26). For that reason, further clinical based studies are required to clearly investigate the benefit of using Iodide solution and help clinicians make better clinical judgements.

SDF generally contains silver, fluoride, ammonia and are alkaline solutions with a pH range of 9-10. The Riva Star products have very high pH reaching 13 and when in contact with soft tissue can cause gingival burns (19). To reduce the soft tissue irritation and to improve taste of the solution, the manufacturer produced ammonia-free products that is Silver Fluoride Aqua with Iodide (AgF/KI). In this study, the group of samples that received Ag/KI had the least value of shear bond strength of the glass ionomer restoration. Since the material is new to the market and was released recently, not enough studies were found to compare the findings and discuss material properties further.

Sealing caries lesions after applying SDF therapy with adhesive restoration is called Silver Modified Atraumatic Restorative Technique (SMART) (27). The SMART technique can offer children with a temporary solution to carious lesions and offer the benefit of arresting caries and restoring tooth structure for better oral function. The SMART technique offered a quick and safe option for dental treatment during the pandemic time of COVID-19 virus. Using hand instruments and minimally invasive dentistry was very crucial to reduce aerosols and helping patients to receive dental care with less risk of infection or community transmission (27). In the current paper, glass ionomer material was chosen as the restorative material of choice for the SMART technique test because in the pediatric community the fluoride releasing effect is favorable and ideal (25). However, in this paper reduction of the shear bond strength was found when using different types of SDF therapy prior to the placement of glass ionomer restoration.

Other papers found that the microtensile bond strength of glass ionomer restoration was not adversely affected by SDF therapy (28). Another study done by Quock *et al.* found that SDF therapy did not produce any effect on the resin restorations used after (29). These variations could be due to different dental materials that were used and dissimilarities between study protocols.

Main strength of this paper was that dentin demineralization process was not introduced in the laboratory and that teeth with natural caries were picked up for the experiment. Natural caries has more complex nature that cannot be mimicked with chemical processes in the laboratory. Another strength was that Silver Fluoride Aqua product was tested, this product is relatively new and recent to the market and not enough studies have been published about it.

Some limitations of this study could be due to involving one investigator only who was responsible for performing the experiments and recording the outcome data, so blinding was not possible to avoid bias. Another limitation was that flat surface was used to apply the glass ionomer restoration after cutting the mounted samples with Isomat saw, this step was necessary to be able to conduct the shear bond strength test using the Instron Machine. However, clinically in the oral cavity, carious part of the tooth that receives caries arresting medicaments and adhesive restorations is not flat and has many inclinations. This factor could play a role in affecting the value of the shear bond strength of any restorative material. Therefore, randomized clinical trials with sufficient follow up periods are needed to understand effect of applying different types of SDF therapy on shear bond strength of glass ionomer cements to primary molars.

CONCLUSION

Within the limitation of this laboratory study, it can be concluded that SDF application in all three forms negatively affects shear bond strength of glass ionomer cements to extracted primary molars with natural caries.

A conclusion can be drawn that applying SDF reduces shear bond strength and when applied with Iodide or in the Aqua solution with Iodide it reduced shear bond strength more and the reduction is statistically significant. Based on the findings, Glass Ionomer restorations show better shear bond strength to carious dentin of primary molars if no caries arresting medicaments is used before restoration placement. However, these findings are based solely on laboratory experiments and further research is required.

FIGURES AND TABLES

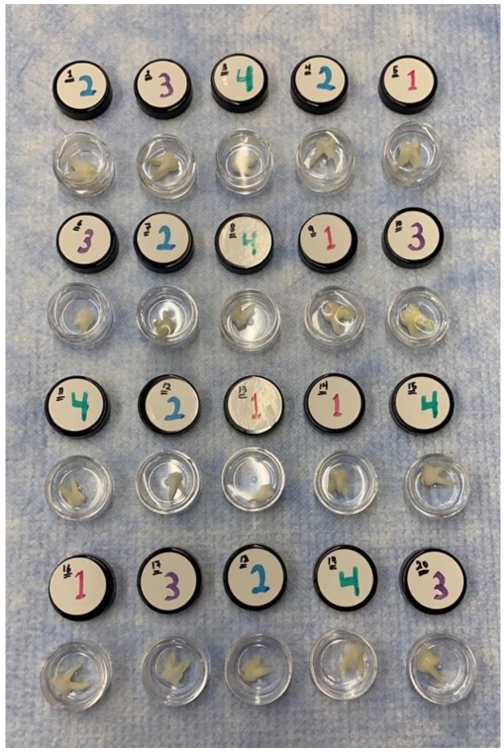

Figure 1: Samples of the pilot study, Randomized teeth, five teeth per group, total of 20 teeth.

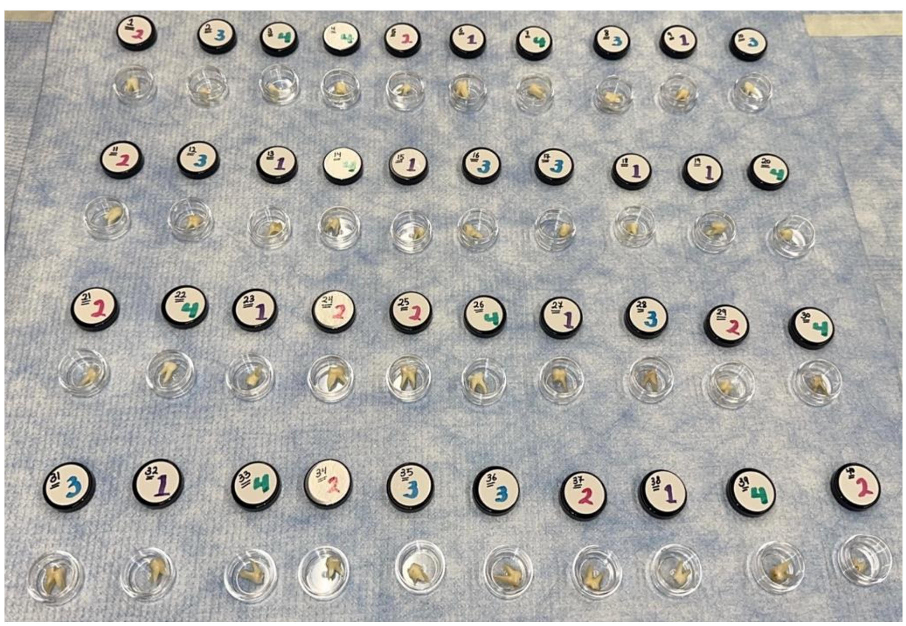

Figure 2: Total of 40 teeth numbered from 1-40, randomized into 4 groups, ten teeth in each group.
Group 1: control group, group 2: Silver diamine fluoride 38% (SDF), group 3: Silver Diamine Fluoride 38% with Potassium Iodide (SDF/KI), group 4: Silver Fluoride (AgF/KI).

Figure 3: Glass ionomer restoration (SDI, Riva Self-Cure, Australia).

Figure 4 : 38% SDF solution (Advantage Arrest, Elevate Oral Care, West Palm Beach, FL).

Figure 5: SDF/KI solution (Riva Star, SDI North America Inc. Itasca, IL).

Figure 6: AgF/KI solution (Riva star Aqua, SDI, Victoria, Australia).

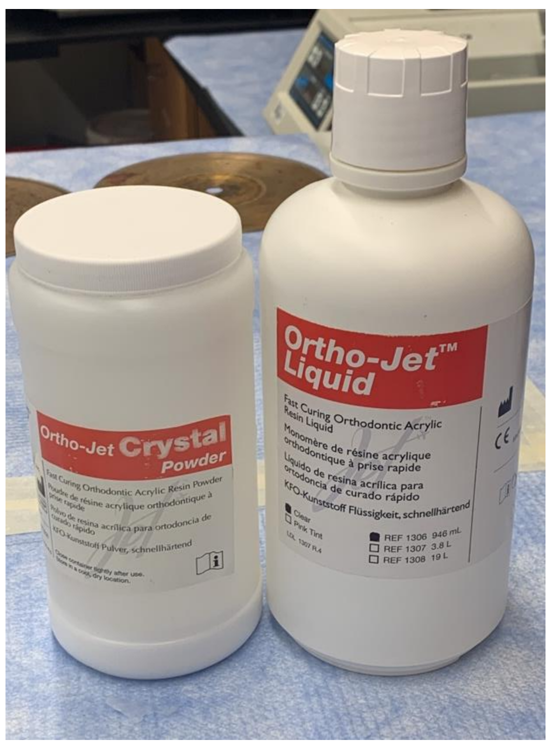

Figure 7: Self-curing acrylic resin material (Ortho-Jet™ for Orthodontic Appliances).

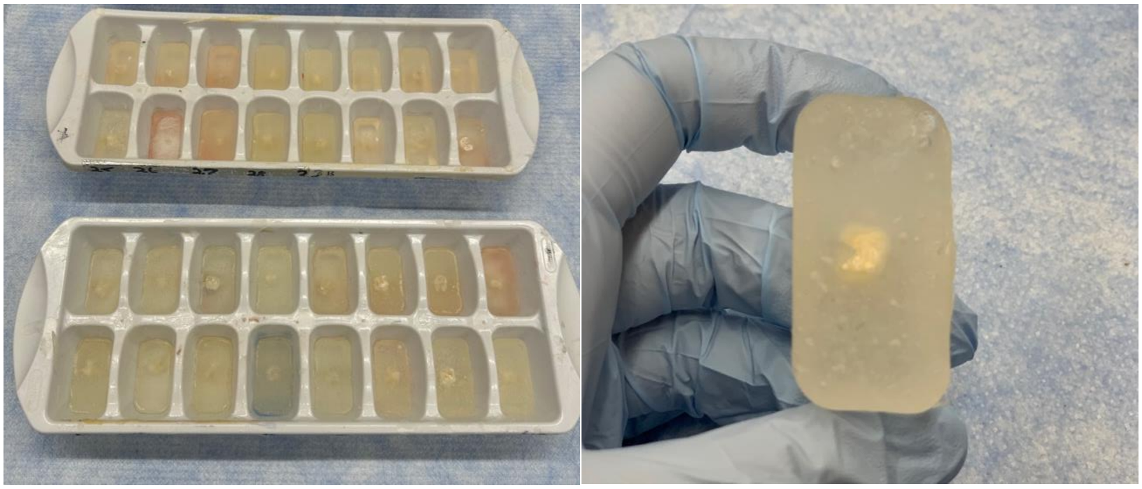

Figure 8: Teeth poured into plastic cube tray with each tooth positioned apically.

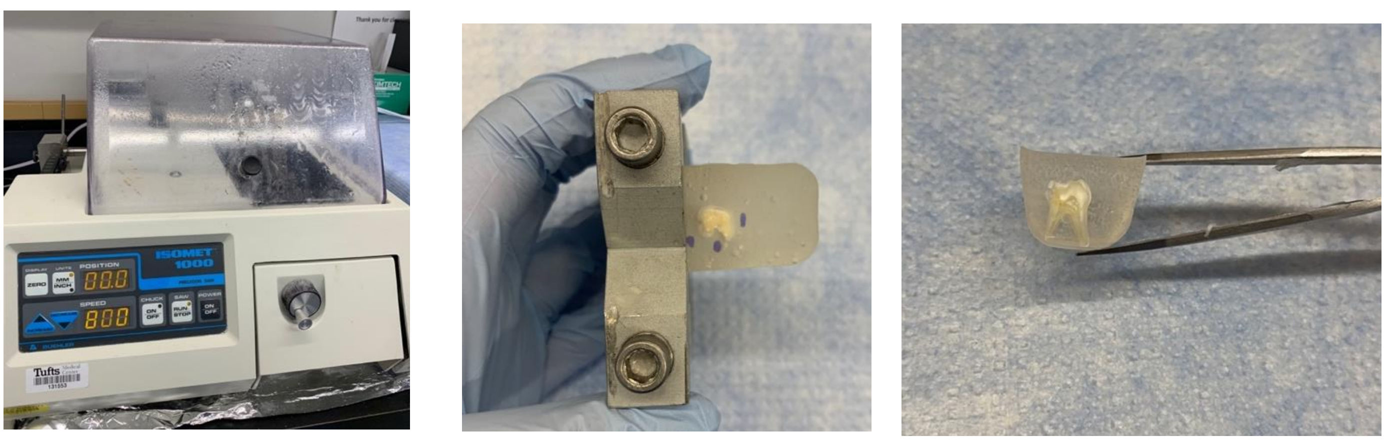

Figure 9: Slicing mounted samples vertically using slow-speed saw with a water-cooled diamond blade IsoMet 1000 (Buehler, Lake Bluff, IL., USA)

Figure 10: polytetrafluoroethylene (PTFE Tube) and silicone spray.

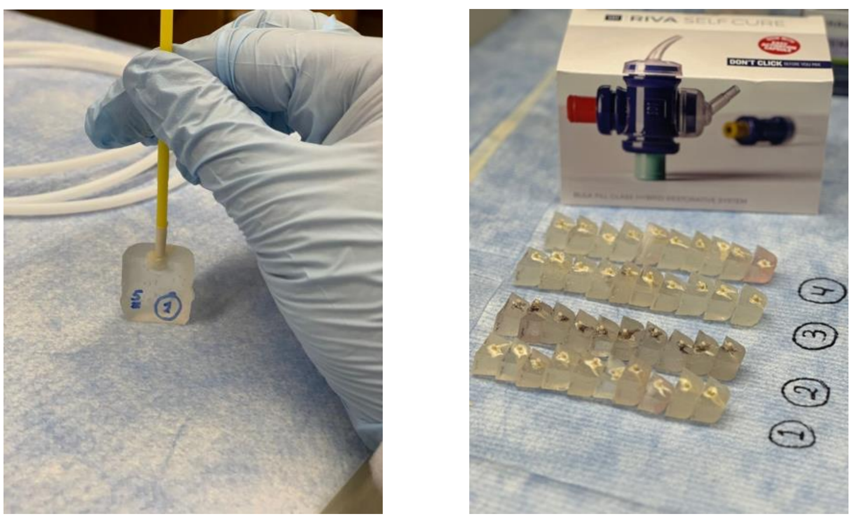

Figure 11: Microbrush used as a plunger for the restorative material, all samples after receiving the restorative material button.

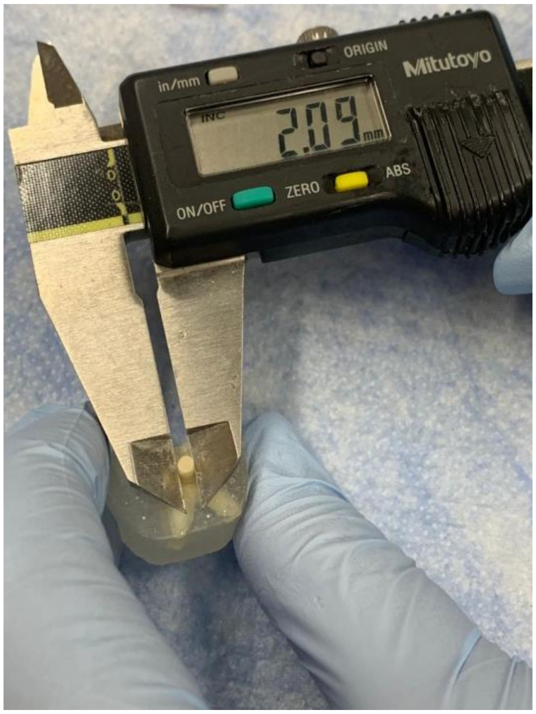

Figure 12: Digital caliper used to confirm diameter of the restoration.

Figure 13: Thermo Fisher Scientific CO2 incubator, Waltham, Mass, USA) at 37˚C.

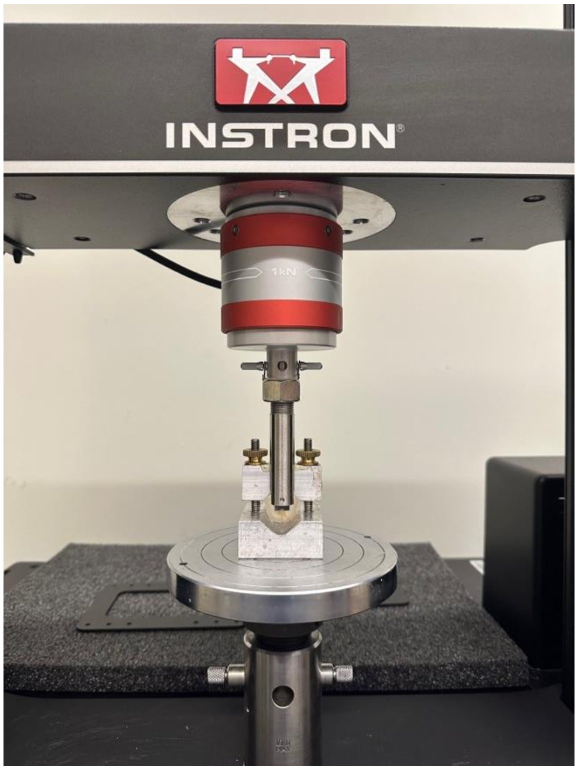

Figure 14: Instron device 68TM-10 model (Instron, Norwood, MA).

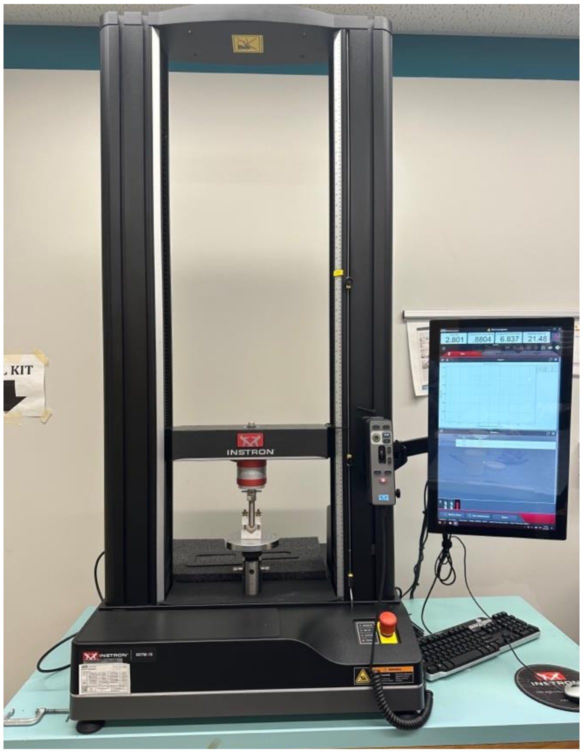

Figure 15: Shear bond strength documented in MPa (MN/m2).

Table 1: Dental materials used for the study protocol.

Dental material	Application process
Restoration: (SDI, Riva Self-Cure, Bulk Fill Glass Hybrid Restorative System, Australia).	After teeth were dried with gentle compressive air and no acid etch used neither a conditioner. Capsule activated and mixed in an amalgamator for 10 seconds before placing the capsule in the applicator. Material was light cured for 10 seconds.
SDF: (Advantage Arrest, Elevate Oral Care, West Palm Beach, FL).	After teeth were dried with gentle compressive air, drops were dispensed in a plastic dispenser and microbrush used for application of the medicaments to the tooth structure. Application time (1 minute).
SDF/KI solution: (Riva Star, SDI North America Inc. Itasca, IL).	After teeth were dried with gentle compressive air, solution from silver capsules was applied to the demineralized surfaces. Immediately after, KI solution from the green capsules was applied to treatment site until creamy white precipitates turned clear.
AgF/KI solution: (Riva star Aqua, SDI, Victoria, Australia).	After teeth were dried with gentle compressive air, solution from silver-blue capsules was applied to the demineralized surfaces. Immediately after, KI solution from the green capsules was applied to treatment site until creamy white precipitates turned clear.

Table 1 Dental materials used for the study protocol

Table 2: Shear bond strength mean and standard deviation of the groups with the P value and the multiple comparison tests.

Group number	Sample Size	Mean	Standard deviation
Control group (GIC)	10	9.95 MPa	4.03 MPa
Test group 1 (SDF)	10	4.91 MPa	0.89 MPa
Test group 2 (SDF/KI)	10	2.66[A] MPa	1.20 MPa
Test group 3 (AgF/KI)	10	2.63[A] MPa	0.96 MPa

Table 2 Shear bond strength mean and standard deviation of the groups with the P value and the multiple comparison tests.
Means sharing a letter are not statistically different.
Overall p value < 0.001

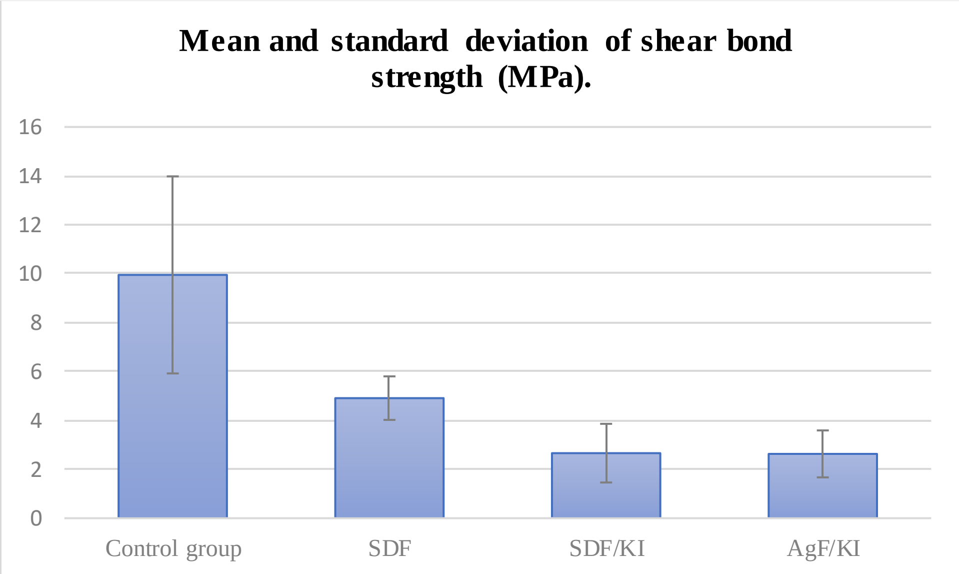

Figure 16: Mean value of shear bond strength (MPa).

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