ORIGINAL RESEARCH

Assessment of Nanosilver Fluoride Application on the Microtensile Bond Strength of Glass Ionomer Cement and Resin-modified Glass Ionomer Cement on Primary Carious Dentin: An *In Vitro* Study

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Abstract

Background and objectives: Nanosilver sodium fluoride (NSF) has recently gained popularity in dentistry as an alternative to silver diamine fluoride (SDF) due to its drawbacks of staining the tooth black and possibly causing soft tissue injury, which has been eliminated in NSF due to the nanoparticle size of silver. This study aims to assess the microtensile bond strength of glass ionomer cement (GIC) and resin-modified glass ionomer cement (RMGIC) with pretreatment of NSF on extracted primary carious teeth.

Materials and methods: Teeth were stored in 10% formalin. The roots were severed, and the pulp chambers were cleaned. The occlusal enamel was ground, reducing the dentin thickness by 1 mm. The specimens were covered with nail varnish, leaving only the area of flat dentin exposed. Caries were induced microbiologically by inoculating *Streptococcus mutans*. Group I—NSF with GIC restoration, group II—NSF with RMGIC restoration, group III—restoration with GIC, and group IV—restoration with RMGIC. After different surface treatments of the carious dentin were performed, each specimen was placed in the testing jig of a universal testing machine and stressed in tension at a crosshead speed of 1 mm/minute until bond failure was observed. They were air-dried and placed under a scanning electron microscope. The failure modes—adhesive, cohesive, and mixed failure were recorded for statistical evaluation.

Results: Maximum results of microtensile bond strength were seen in the pretreatment group with NSF sealant, followed by RMGIC restoration, and the least results were observed in the conventional GIC restoration group. Of all the types of failures in our study, adhesive was the maximum type.

Interpretation and conclusion: The microtensile bond strength of pretreatment with NSF showed higher values when compared to conventional restorations of GIC and RMGIC. The failure modes in each group were not significantly varied. Pretreatment with NSF will prevent secondary caries formation, and the restorations will also be stronger.

Keywords: Glass ionomer cement, Microtensile bond strength, Nanosilver sodium fluoride, Prevention, Resin-modified glass ionomer cement, Secondary caries.

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Introduction

Fluoridated dental products have been successful in preventing caries through dental intervention observed over the decades.[1,2] Silver diamine fluoride (SDF) has been showing promising results so far with its antibacterial and remineralizing properties.[3–5] The mechanism of action of SDF is said to be the strengthening of tooth structure under attack by the acid byproducts of bacterial metabolism due to the presence of fluoride in it. It also affects the imbalance of the local environment by killing bacteria and interfering with biofilm, which demineralizes dental tissues.[6] Hence, SDF has become a great asset in the prevention of dental caries. Despite that, there are minor drawbacks seen with SDF, such as transient gingival irritation and metallic taste.[7] It can't help prevent the progression of caries after the pulp is involved; therefore, the application of SDF is not advised in such cases. Apart from all these disadvantages, the paramount side effect is dark staining of the carious tooth, which is esthetically not pleasing.[8]

Advanced materials are being developed, to prevent the staining caused by SDF application.[9–12] One such material is nanosilver sodium fluoride (NSF).[13] It is said to be an experimental yellowish solution, proved to be stable for at least 3 years.[14] It contains sodium, silver nanoparticles (AgNPs), and chitosan. It is said to be a low-cost material and ecofriendly in nature.[14] This material doesn't lead to black staining, as the AgNPs don't form oxides with the oxygen in the demineralized enamel surfaces, as stated by Santos et al.[14] It has also been proven to be effective against *S. mutans* and has no cytotoxic effects on human erythrocytes.[13] It is also effective in arresting caries[14]

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and prevention of dental biofilm formation.[15] AgNPs can cause oxidative stress by penetrating the bacterial cell wall through electrostatic attraction.[16] It is said that the size of AgNPs is inversely proportional to the surface area in contact with bacterial cells—the smaller the AgNPs, the higher the antimicrobial effect, and they prevent discoloration.[17]

The current understanding of the caries process is mostly driven by the metabolic process of plaque that leads to demineralization, emphasizing the need to restrict the carious lesion rather than totally excavating dentinal caries.[18,19] Hence, conservative caries excavation techniques have been developed, in which only firm or soft dentin is removed.[20]

As previously stated, resin-modified glass ionomer cement (RMGIC) is the suggested restorative material for primary molar teeth.

It is preferable to standard glass ionomer cement (GIC) because of its stronger binding strength, reduced moisture sensitivity, which results in decreased solubility and disintegration.[21]

However, the microtensile bond strength of conventional GIC or RMGIC restoration after NSF sealant application has not previously been explored, the purpose of this study is to determine the influence of NSF application on the microtensile bond strength of GIC and RMGIC on the primary carious dentin of removed molars.

Materials and Methods

The Institutional Research Ethics Committee's ethical criteria were followed throughout all of the techniques used in this investigation. The study included 80 primary molars, 20 in each group, which were allocated randomly into four groups. Primary molars extracted for orthodontic reasons that have no dental cavities or only carious lesions on the outer enamel, as well as preshedding movable or retained primary molars, were included. The teeth were preserved in 10% formalin. The roots were cut, and the pulp chambers were cleansed.

The occlusal enamel was ground, reducing the dentin thickness by 1 mm. The specimens were coated in nail polish, leaving only the flat dentin exposed. Caries were induced microbiologically by inoculating *S. mutans* MTCC 497 (in fake saliva).

- Group I (experimental): Caries-induced flat dentin surface was treated with NSF using a microbrush for 2 minutes, rinsed for 30 seconds with distilled water, and then restored with GIC.
- Group II (experimental): Caries-induced flat dentin surface was treated with NSF using a microbrush for 2 minutes, rinsed for 30 seconds with distilled water, and then restored with RMGIC.
- Group III (control): Caries-induced flat dentin surface was restored with GIC.
- Group IV (control): Caries-induced flat dentin surface was restored with RMGIC.

After different surface treatments of the carious dentin, each specimen was placed in the testing jig of a universal testing machine and strained in tension at a crosshead speed of 1 mm/minute until bond failure was detected.

They were air-dried and placed in scanning electron microscope. The failure modes were described as adhesive failure, cohesive failure, and mixed failure and recorded for statistical evaluation.

Results

First, the data were subjected to a normality test (Shapiro–Wilk test). Once the data appeared to show normal distribution, they were further tested using parametric standards by applying analysis of variance (ANOVA) with *post hoc* Bonferroni analysis. Table 1 compares the microtensile bond strength among the groups using the ANOVA test. This table shows the minimum value of microtensile bond strength to be in specimens of the group that received conventional GIC restoration, at 2.45, while the highest values were observed in the group that underwent pretreatment with NSF followed by RMGIC restoration.

The comparison of microtensile bond strength among the groups is shown in Figure 1, which depicts that the samples pretreated with NSF showed better results or higher microtensile bond strength than their conventional restoration groups.

In Table 2 it shows the distribution of the modes of failure among the groups. The conventional GIC group had a maximum

Table 1: Comparison of the microtensile bond strength among the groups using ANOVA

Groups	*N*	*Minimum*	*Maximum*	*Mean*	*Standard deviation*	*p-value*
GIC	20	2.45	10.98	6.82	3.09	0.001*
RMGIC	20	5.00	18.97	10.45	3.86	
NSF sealant + GIC	20	8.20	15.76	11.59	2.51	
NSF sealant + RMGIC	20	14.65	27.65	22.00	3.86	

*, Significant

Table 2: Distribution of the modes of failure among the groups

Groups		*Modes of failure*			
		Adhesive	*Cohesive*	*Mixed*	*Total*
GIC	Count	7	3	10	20
	%	35	15	50	100.0
RMGIC	Count	12	3	5	20
	%	60	15	25	100.0
NSF sealant + GIC	Count	19	0	1	20
	%	95.0	0	5.0	100.0
NSF sealant + RMGIC	Count	3	11	6	20
	%	15.0	55.0	30.0	100.0
Total	Count	41	17	22	80
	%	51.3	21.3	27.5	100.0

Chi-square value: 37.08; *p*-value: 0.001

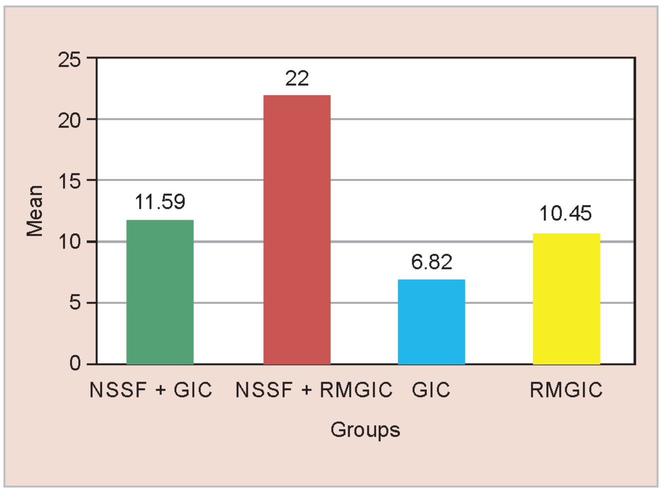

Fig. 1: Comparison of the microtensile bond strength among the groups

of mixed failures. The conventional RMGIC restoration group had a maximum of adhesive failures. The group pretreated with NSF followed by restoration with GIC had maximum adhesive failures. The group pretreated with NSF followed by RMGIC restoration had a majority of cohesive failures.

Discussion

In the past few years, nanotechnology has gained a lot of popularity in dentistry. Nanoparticles have been shown to have a wide range of applications in their physical and chemical properties, such as shape, surface charge, and hydrophobicity, which can be reformed or altered as per the objective. These formulations can be in several forms, such as gel, paste, or aqueous solutions, with high patient acceptance and ease of administration. These metals and metal oxides have been of great interest concerning dental caries due to their bactericidal effects.[22] The rationale for the effectiveness of NSF is the combination of the individual properties of chitosan, fluoride, and AgNPs.[22]

Fluoride has been used in dentistry in a variety of ways, such as in varnishes, sodium fluoride (NaF), stannous fluoride (SnF_2), and acidulated phosphate fluoride (APF) gel. It is also a major constituent in many dental and oral healthcare products, such as toothpaste, mouthwash, and gels.[23–27]

Silver diamine fluoride and NSF are similar in that they are inexpensive and more affordable for low socioeconomic groups. SDF has been shown to promote remineralization and inhibit demineralization by increasing dentin hardness and has an excellent bactericidal effect. However, it has a significant disadvantage of staining the teeth black, which is unesthetic to most patients. This staining is caused by the presence of silver phosphate and silver sulfide precipitates in it.[28] Dos Santos et al.[12] have reported through their studies that SDF and NSF have similar caries arrest rates after a 1-year follow-up.[14]

Nanosilver particles seem to play a significant role in this process, as discussed earlier in the literature. AgNPs possess great bactericidal and bacteriostatic properties against *S. mutans* and *Lactobacillus acidophilus* pathogens present inside the oral cavity.[29] These AgNPs have also shown another very unique and excellent property: these particles do not oxidize, therefore, they do not cause any black staining of the oral and dental tissues.[30] Pretreatment with NSF is a preventive measure against new caries formation because of its antimicrobial and remineralizing properties. Therefore, this can be used in cases of mass treatment. NSF has been used by various authors as a pretreatment option.[31–33]

One of the most potential materials in pediatric dentistry is GIC. It is a versatile material with the properties of being bioactive due to the ion exchange that occurs after the setting of the material. It also promotes adhesion to the tooth structure along with the release of fluoride ions.[34] GICs can be used not only for restorations but also for core buildup and cementation purposes. This material is advantageous in caries-susceptible individuals as it is radiopaque, can release fluoride, and has reasonable esthetics.[35] Poor mechanical properties, lack of command cure, and moisture sensitivity are a few of the minor drawbacks of GICs that have been compensated with newer advancements, giving rise to a new material like RMGIC, which has been proven to be a successful alternative, especially in posterior restorations, including those in primary teeth.[34] RMGICs have been known to bond to the smear layer of dentin.[36] RMGIC has overcome the minor difficulties in GIC, but due to the addition of resin in the cement, it is less biocompatible than conventional GIC.[37,38]

A handful of studies have investigated the bond strength of GIC to carious dentin, of which a few studies concluded that the mean bond strength of GICs to carious dentin is comparable to that of normal dentin.[39,40] However, other studies have shown that when RMGIC was used as a restorative material, the mean bond strength was higher in teeth without caries compared to cariogenic teeth or specimens.[41,42] RMGIC has a stronger mean bond strength compared to conventional GIC restoration on carious dentin, as per our study.[40,43,44] This could be due to its better mechanical properties and the formation of a hybrid layer.[45,46] Our study showed similar results in the pretreatment groups. The microtensile bond strength test has been accepted worldwide as the most reliable method to check the bond strength of any restorative material to dentin.[47] Therefore, the same test was used in our study.

The maximum mixed failure mode of specimens was seen in restorations with conventional GIC, which is in accordance with a study done by Palma-Dibb et al.,[38] who concluded this in their study comparing restorations with noncarious dentin, attributing the considerably lower bond strength of restorations with carious dentin. They observed this phenomenon with both conventional GIC restoration and RMGIC. Based on the results of this study, NSF could be recommended for use as a pretreatment solution before restorative material of RMGIC or GIC, which aligns with *in vitro* and *in vivo* studies.[31–33] However, more studies should be conducted on the same *in vivo* and for a longer duration.

Conclusion

Some points that we have concluded from our study:

- The microtensile bond strength of pretreatment with NSF showed higher values when compared to conventional restorations of GIC and RMGIC.
- The highest microtensile bond strength was observed with the specimens pretreated with NSF followed by the RMGIC group, while the least results were seen in the conventional GIC restoration group.

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