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The Effect of Silver Diamine Fluoride on Surface Characterization of Demineralized Dentin

Ayat Ahmed Saad [1]; Mohamed A. Kamel [2]; Nermeen K. Hamza [3]; Hanan A. Niazi[4]

Abstract

Purpose: The purpose of this study was to evaluate the effect of Silver Diamine Fluoride (SDF) application on Surface characterization of demineralized dentin using environmental scanning electron microscope (ESEM)

Materials and Methods: A total of 40 teeth were used; the roots of each tooth were cut off at the CEJ. Each tooth was sectioned into 2 halves mesio-distally; resulting in 2 halves per each tooth, with total of 80 halves. The 80 halves were divided into 2 groups (n= 40 halves) according to the type of dentin (either demineralized or sound). Each group was subdivided into 2 subgroups (n= 20) according to SDF application (either with SDF or No SDF). The dentin Specimens (n=40 halves) were placed in artificial demineralizing solution for 72 hours. A small cotton pellet or brush was used to paint approximately one drop of SDF onto the middle dentine of each half for at least one minute then air-dry. After the lesions have been exposed to SDF for the determined period of time, the SDF was rinsed off for 30 seconds with distilled water. Each dentin surface was scanned under environmental scanning electron microscope to obtain images of dentin surface.

Results: ESEM images revealed that on comparing the specimens of sound dentin to demineralized dentin upon SDF application, it was found that SDF was deposited on side walls of dentinal tubules in sound dentin while it was deposited inside the opened dentinal tubules in demineralized dentin.

Conclusion: Upon application of Silver Diamine Fluoride, a deeper penetration of SDF into dentinal tubules of demineralized dentin occurred in comparison to sound dentin

Keywords: SDF, Demineralization, Dentin

(1) Master's student, Operative Dentistry Department, Faculty of Dentistry, Ain Shams University, Cairo, Egypt.
(2) Lecturer, Operative Dentistry Department, Faculty of Dentistry, Ain Shams University, Cairo, Egypt.
(3) Assistant Professor, Operative Dentistry Department, Faculty of Dentistry, MSA University, Cairo, Egypt
(4) Professor, Operative Dentistry Department, Faculty of Dentistry, Ain Shams University, Cairo, Egypt.

Introduction:

Dental caries continues to be a prevalent disease, even in developed nations [1]. Traditionally the discipline and practice of operative dentistry have been intimately linked with our understanding of the caries disease process. Indeed, it has been noted that the primary reason directing operative preparation and filling of a tooth is to repair destruction from a carious lesion [2]. In recent years, advancement in our understanding of the caries disease process [3] and the development of adhesive restorative materials have created the ability to practice with a minimally invasive dentistry philosophy in mind. [4]

Caries-affected dentin possess a structural and chemical alteration when compared to sound dentin as it is a partially demineralized dentin and contain mineral crystals inside the dentinal tubules. Bonding to caries-affected dentin differs from that to sound dentin regarding bond strength, showing poor quality of hybrid layer; although the adhesive monomer infiltrates deeper but there was also an incomplete resin infiltration within hybrid layer. Bonding to dentin depends not only on adhesive systems but also on the dentine bonding substrates. In clinical practice, sound dentin is not the substrate most frequently involved in clinical dentistry. Instead, clinicians usually bond adhesives to irregular carious dentin substrates in which carious dentine is classified into outer carious infected dentine and inner carious affected dentine. Therefore, after caries excavation, the majority of the remaining dentine substrate for bonding is caries-affected dentin [5,6].

Silver diamine fluoride (SDF) is a colourless liquid that has been proposed that its chemical components contribute the following benefits: silver- salts stimulate dentin sclerosis/calcification, silver nitrate acts to kill bacteria and fluoride aids in remineralisation and prevention [7,8]. Recently published studies, report that when applied to cavitated carious lesions with no removal of decayed tooth structure, SDF has demonstrated arrest of caries with no further progression after two to three years [9,10].

MATERIALS AND METHODS:

Advantage Arrest 38 % Silver Diamine fluoride (Elevate Oral Care, LLC, USA) was used in this study. A total of 40 molar teeth were used in this study. 80 teeth halves were retrieved from the 40 molars. The 80 halves were divided into 4 groups (n= 10 halves) according to the two levels of investigation, Level 1: Dentin surface, 2 groups (either demineralized or sound), Level 2: SDF application, 2 groups (either with SDF or no

Preparation of dentin specimens:

To create the dentin specimens, the crown was separated from the root using a water-cooled 0.25 mm double-faced diamond disc operated at low speed then each tooth was sectioned into 2 halves mesio-distally using the same disc [11]

Artificial demineralizing solution:

Specimens (n= 40 halves) will be placed in demineralizing solution for 72 hours. It was changed every 24 hours [12]. Demineralizing solution consists of: 2.2 mM Calcium Chloride, 2.2 mM Mono Sodium Phosphate, 0.05 mM Lactic acid and 0.2 ppm fluoride and adjusted at pH 4.5 with 50% sodium hydroxide

Silver Diamine Fluoride (SDF) application:

SDF was immediately applied to the middle dentin of each specimen. In order to standardize the site of application, the width of dentin specimens mesio-distally was measured and divided into 3 equal rows then the length occlusso-gingivally was measured and divided into 3 equal columns. The middle square resulted from the lines intersection was the site of application. A small cotton pellet or brush was used to paint approximately one drop of SDF onto the demineralized dentin for at least one minute then Air-dry. After the lesions have been exposed to SDF for the determined period of time according to manufacture instructions, the SDF is rinsed off for 30 seconds with distilled water [13].

Environmental Scanning Electron Microscope Evaluation (ESEM):

The specimens were investigated under ESEM Model Quanta 250 FEG (Field Emission Gun) attached with EDX Unit (Energy Dispersive X-ray Analyses), with accelerating voltage 30 K.V., magnification14x up to 1000000 and resolution for Gun.1n. (FEI company, Netherlands)

RESULTS:

Upon SDF application, the ESEM images of sound dentin specimens showed the side cutting of dentin covered by smear layer with deposition of SDF on side walls of dentinal tubules as shown in figure (1), While ESEM images of demineralized dentin showed side cutting dentin with deposition of SDF inside the opened dentinal tubules as shown in figure (2).

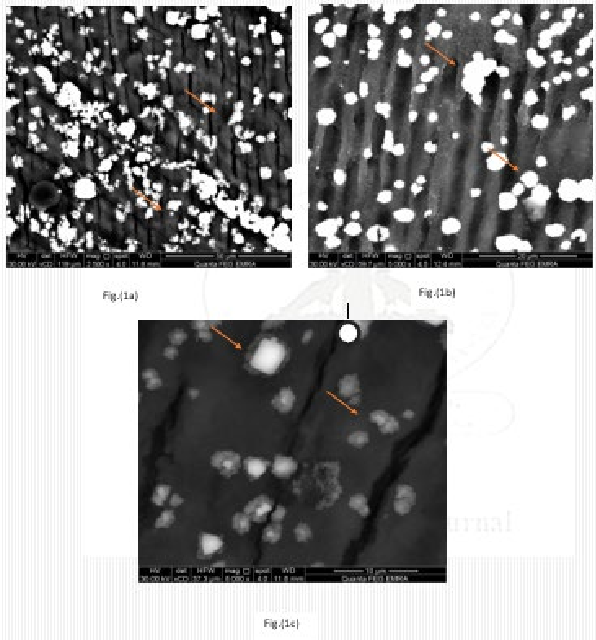

Figure 1: ESEM showing longitudinal section of sound dentin with SDF deposition on dentinal tubules; (1a): at magnification x 2500, (1b): at magnification x 5000, (1c): at magnification x 800

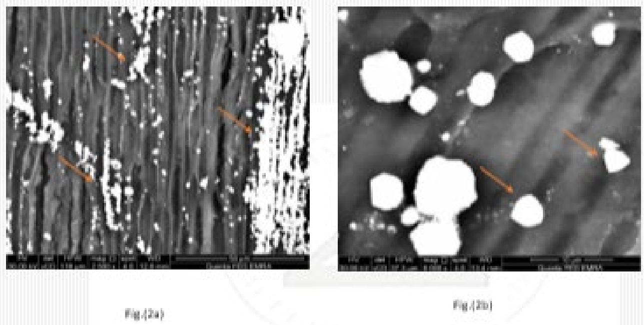

Figure 2: ESEM showing longitudinal section of dentinal tubules in demineralized dentin with SDF infiltration and deposition; (2a): at magnification x 2500, (2b): at magnification x 8000

DISCUSSION:

Dental caries is known as a biofilm-mediated, sugar-driven, multifactorial dynamic disease. This dynamic process involves alternating periods of demineralization and remineralisation of dental hard tissues. The perspective that demineralized dental tissues have potential to be remineralized is increasingly accepted by dental professionals [14]. Therefore, topical application of SDF; is a non-invasive treatment for caries, which has been shown to be effective in arresting dental caries in young children as well as older adults; beside its easy application, low cost and painless procedure. SDF is a colourless alkaline solution consists of two ammonia molecules attached to silver ion, which makes it more stable and less oxidizing than other silver compounds. Combination of silver fluoride in alkaline solution has synergetic effect in arresting dental caries and also it can inhibit demineralization and preserve the collage from degradation (15,16,17). Since SDF has been widely used on dentin surfaces of cavities for management of caries, thus it is essential to explore whether this will affect the bonding of adhesives to dentin. Therefore, the aim of this study was to show the influence of SDF on surface characterization of demineralized dentin

Dentin specimens were cut longitudinally to expose side walls of dentinal tubules that acted as a dental substrate for SDF and bonding agent application. This substrate showed different structural and morphological features (18); including tubule orientation and moisture variation which clarifies why different regions of dentin substrate may exhibit different bond strength values with same adhesive system (19). Furthermore, the dentin specimens were initially demineralized to simulate dentin carious lesions.

There are different concentrations of SDF solution (10%, 12%, 30% and 38%). 38% SDF was the concentration used in this study which was reported as an effective treatment for arresting dental caries (20).

As rinsing of SDF is a critical step in attaining optimal bonding as excess SDF may hinder the penetration of the bonding agent in the intertubular and peritubular dentin to form meshwork with the collagen matrix (21). Therefore, rinsing of dentin specimens after SDF application was done in this study following the protocol of **Horst** *et al.* (21). This protocol showed a significant improvement in the bond strength while on the contrary, **Lutgen's** protocol in not rinse the SDF resulted in a severe decrease of the bond strength and the highest number of adhesive failures (22). Moreover, SDF has pH 10 so when the rinsing step is eliminated, SDF will render the surface a basic nature which will hinder the etching effect of self-etching adhesive leading to bond strength reduction (22).

Environmental Scanning Electron Microscope (ESEM) was used in this study to evaluate the penetration of SDF in dentin specimens due to its ability to produce images showing the alterations occurred in the dentin surface characterization after SDF application (23). In addition to its great benefit in the biological field studies as it aids in investigating the natural state of biological bulk tissues without being coated with any material that may ruin the surface of the specimen (24,25). In contrast to the ultra-high vacuum measuring equipment; scanning electron microscope (SEM) that needs staining of poorly electron dense materials and drying and coating of wet samples which may cause significant structural interference of the specimens (26).

ESEM images revealed deposition of SDF on the side walls of the dentinal tubules as well as intertubular dentin in sound dentin specimens as shown in figure (1) which was supported by **Patel** *et al.* (27) who claimed that upon SDF application, a layer of silver phosphate was deposited inside dentin. In addition to **Chu** *et al.* (28) who reported that upon rinsing, no residual SDF was seen on surface, yet particles may be able to penetrate deeper into dentin up to 50-200 μm due to their small size. Meanwhile our results were opposed by **Sayed** *et al.* (29) who reported the presence of multiple spherical silver particles within the dentinal tubules of sound dentin.

Furthermore, infiltration and deposition of silver granules were seen inside the dentinal tubules of demineralized dentin specimens as shown in figure (2) which was supported by **Knight** *et al.* (15) who detected that silver and fluoride ion can penetrate up to 450 μm within partially demineralized dentin. This was explained by **Matsui** *et al.* (30) who claimed that the silver ions leached out from SDF have great affinity to protein (collagen), so the more exposure of collagen, the more the uptake of silver ions and since demineralized dentin has great amount of exposed collagen so more silver uptake occurred, thus deeper penetration, as well as the removal of smear layer due to demineralization lead to deposition of silver granules deeper inside dentinal tubules which was supported by **Willershausen** *et al* (31), who reported the detection of silver granules into dentinal tubules for depth of up to 30 μm from dentin surface. Furthermore, **Sayed M** *et al.* (29) found that there was lesser penetration of the spherical silver particles into the dentinal tubules of demineralized dentin after storage for 24 hours and 1 week; meanwhile after 1-year storage, there was a deep deposition of the particles in the dentinal tubules which in contradicted with our ESEM findings of demineralized specimens as they were immediately observed without storage.

CONCLUSION:

Within the limitation of this study, it can be concluded that SDF could be deposited on the sides of dentinal tubules. However, dentine demineralization enhances deeper penetration into dentinal tubules.

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