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Radiographic Evaluation of Non-Operative Repair Depths for Various Preventive Approaches.

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ABSTRACT

The purpose of this study was to compare the radio-density of the artificially demineralized enamel lesion when using different treatment modalities (topical fluoride application, conventional adhesive, and caries infiltrant). Materials and Methods: Thirty sound human posterior teeth were collected for this study. Teeth were divided randomly into three groups; 10 for each according to the treatment protocol followed: GI (Icon; I), GII (Excite F; EFI) and GIII (Acidulated phosphate fluoride; APF). Demineralization was done to all the samples using the Coca-Cola solution. Then the application of the different treatment agent was done according to the manufacturer's instruction. Standardized digital radiographic images was taken for each sample before, after demineralization and after treatment. Gray scale analysis of periapical radiographs was done to provide information about the degree of radio-density. Results; no significant difference was found between the ICON group (54.1 ± 12.2) and APF groups (53.9 ± 11.6) (the greater gain was observed in ICON group). Both groups showed significant increases in radio-density when compared to Excite-F group (-9 ± 3.7). Conclusion; Resin infiltration technique is a promising micro-invasive approach for treatment of demineralized enamel. Both Resin infiltrants and fluoride application may have the ability to restructure the surface of the enamel crystals and maybe considered as operative materials for the treatment of early lesions.
Keywords: caries infiltrant, conventional adhesive, topical fluoride application, digital radiograph.

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INTRODUCTION

Dental caries is a disease initiated by imbalance between demineralization and remineralization process. Demineralization caused by many pathological factors such as frequent ingestion of fermentable carbohydrates, deficiency of saliva and acidogenic bacteria. The acid which is formed from the plaque on the tooth surface caused enamel defect with intact surface layer and some sub- surface damage. This sub-surface porosity or damage leads to loss of enamel translucency in the phenomena known as white spot lesion. It is softer and whiter than the sound enamel [1]. Most approaches depended on remineralization which is a natural defense mechanism against non-cavitated carious lesions. Intentions to direct the demineralization-remineralization balance toward the remineralization process can be used as a weapon against dental caries [2].

On the other hand; attempts have been made to 'fill' the micro-porosities, so many non-operative techniques were used to arrest the progress of initial caries [1], which includes stimulation of the natural repair process of remineralization by using topical fluoride application [3], Elevation of mineral ion concentration and elevation of local pH [4].

Fluoride therapy has been considered as a cornerstone of caries-preventive strategies; it controls the initiation and progression of carious lesions. The continuous fluoride application can reduce demineralization and enhances remineralization process. However, this technique is not always successful, it faced difficulty for application in proximal lesion and it requires non-compliant individuals, it also needs to be applied in the early stages of lesion development [5, 6]. Fluoride application supply tooth structure with needed minerals, but the tooth is still susceptible to future acid attack [4].

To solve these problems fissure sealant was introduced to protect sound enamel surface [7]. Resin Sealants have been used preventively on the occlusal surface of sound tooth to retard the initiation of caries, but this concept was changed during the last 15 years. Recently, it has been used therapeutically in an attempt to reduce lesion progression and arrest active caries [3, 8].

Increasing the porosity of the enamel surface layer enhance the diffusion of acids into the tooth structure and thus increasing the probability of tooth decay [9]. Accordingly; occluding these pores within the body lesion with resin will hamper access of acids, stop its continuous diffusion through the lesion, and thus decrease the caries progression. Based on this concept, caries infiltration technique was introduced to dentistry in which light curing, low-viscosity resins were applied and infiltrated the initial lesion on the tooth surface, occluded all the micro-pores and rendered the tooth more resistant to further demineralization. Therefore, caries infiltration has been shown to inhibit caries progression under clinical conditions in both primary and permanent teeth [10, 11].

In proximal carious lesions the traditional invasive method used for treatment of these lesions-even if it is initial- leads to massive destruction of sound enamel in order to get access to the decayed parts. The use of caries infiltrant in the form of adhesives or sealants will enhance the reduction of caries progression as it will penetrate at least partially into carious lesions, occlude the pores and strengthen the tooth [9].

The concept of caries infiltration was firstly introduced by the University of Kiel as a micro-invasive approach for initial, non-cavitated caries lesions in both smooth and proximal surfaces. It is marketed under the name Icon® (DMG America Company, Englewood, NJ) [12].

In icon technique, the diffusion barrier was created inside the enamel lesions instead of fissure sealant where the diffusion barrier is only confined to enamel. Furthermore, this technique can prevent cavitation of enamel surface by strengthening the enamel structure. The progression of caries in infiltrated lesion was significantly slower when compared to untreated lesions. [13]. Another advantage of resin infiltration is that the whitish appearance of the demineralized enamel was disappeared after filling their micro porosities with the resin. Moreover, this technique not only arrest enamel lesions, but also improve the esthetic appearance of white spots [14].

Measuring density using a digital radiograph is a non- invasive, painless method that describes mineral gain or loss in dental tissues. The combination of X-ray radiography with digital image provides a tool for longitudinal studies of de- and remineralization of dental enamel [15].

Caries infiltrants when compared to conventional dental adhesives have shown rapid capillary penetration, very low-viscosity, high surface tension and deep penetration in the body of the lesion [16, 17]. However, in spite of the deeper penetration of caries lesions, it has not yet been shown that whether caries infiltrant has an increased capability to stop progression of lesions by properly occluding the porosities of the demineralized lesions than conventional adhesives and perhaps inhibit further attack.Therefore, the aim of the current study was to compare the potential of topical fluoride application, conventional adhesive, and caries infiltrant to increase the density of the demineralized enamel lesion.

MATERIALS AND METHODS

Sample preparation

Thirty sound (caries-free) human posterior teeth extracted for orthodontic purpose were collected for this study. They were washed thoroughly under running water to remove any residual debris and clinically examined to ensure the absence of caries, calculus, or surface defect. The teeth were then stored in 0.1% thymol solution at room temperature until required. Each tooth was mounted in a mold filled with acrylic resin leaving the crown of the teeth exposed. Teeth were then divided randomly into three groups; 10 for each according to the treatment protocol followed: GI (Icon; I), GII (Bonding Agent, Excite F; EF) and GIII (Topical fluoride gel treatment, Acidulated phosphate fluoride; APF). Each tooth in each group was given a specific number.

Sample Demineralization

Following the proposal done by Ehlen*etal.,* 2008 [18] and El-Zainy*et al*, 2012 [19], Beakers were filled with 330ml of Coca-Cola (pH measurements of beverage 2.37); and, placed in a separate beaker and immersed for 25hrs. The Coca-Cola was replaced every 5hrs, and the pH was measured at opening the cans, then it was measured again at the end of the 5hrs.

Application of different treatment agent

In first group (GI); application of Icon (DMG, Hamburg, Germany. Lot 634902) was done following the manufacturers' instructions, where etching of the crown surface was done using the included etchant for 2 min., then it was rinsed off with water for 30 Sec. Air drying of the etched surface was done, then Icon-Dry was applied to the teeth for 30 Sec; air drying again. Icon- Infiltrant was then applied for 3 min., light cured for 40 Sec. Finally; application of another layer from Icon- Infiltrant was done, and Left to set for 1 min and then light cured for 40 Sec.

In the second group (GII); teeth were treated with Bonding agent “Excite-F” which is a total-etch Adhesive system (Ivo Clar Vivadent, fluoride containing dental adhesive patch no. N37926). The samples were etched using 37% Phosphoric acid gel (Pentron clinical Lot. 188499) for 15 sec. then rinsed for 20 sec., dried with air. Bonding agent was then applied to the samples, agitate and air pressed, after that, another layer of bond was applied, air pressed then light cured for 20 Sec.

In the third group (GIII); topical fluoride gel treatment; Acidulated phosphate fluoride (APF) 1.23% F ion (Sultan Topex Lot. 1116998) was used where topical application after drying of teeth was done, the crowns of the teeth were covered by the gel for 4 minutes and agitated into the container having the gel, removing of the gel afterwards was done by cloth followed by rinsing with water after 30 minutes.

Radiographic Evaluation and analysis:

Standardized reproducible periapical radiographs for each sample were done before (baseline) and after demineralization and after treatment using the tested materials. An indirect digital image radiographic system; the DBS-win software (Fig 1), which is a part of the recently introduced Vista Scan system (Durr Dental Bietigheim, Bissingen, Germany) (Fig 2) was followed in this study to obtain and calculate pixel gray measurement (mineral content change) using the image processing software figure (3). The image plate was exposed by the x-ray machine (Orix-65 mobile x-ray machine, ARDET Srl, Italy) at 70 Kilovolt, 8 mA for (0.08) seconds. The exposure parameters were fixed for all the samples before and after each treatment. The image plate was inserted into the flatbed scanner and the radiographic image was displaced within seconds on the computer screen and then saved in a digital folder. For each sample, information including sample phase, group, no. and whether this radiographic image is before or after treatment, were recorded. All this information was written in the form of text comment that is saved with each image.

Drawing a line parallel to the long axis of tooth performed linear density measurements. The line extended from the incisal edge /cusp tip of the tooth to the cemento-enamel junction. Gray scale analysis of periapical radiographs provides valuable information about the degree of radio-density. The term density refers to the degree of whiteness of the radiographic image. The radiographic image consists of points or pixels, each having a certain density value. The density value is between 0 and 256 pixels. The greater the value, the brighter (whiter) the pixel. The gray level along each line was recorded at the beginning of the line, at the middle, and at the end. The average of the three readings of one line was calculated to obtain the mean average gray level along this line. The mean value of the readings of the five lines was calculated to present the density value. Comparison between gray densities prior to treatment, post application, was done to determine the changes in gray density for all study groups.

The saved images of each sample were interpreted as mentioned previously to evaluate and record the pixel gray measurement (mineral content change). The lines started 2mm from the proximolabial or proximolingual line angle either mesially or distally.

Statistical analysis

Data were presented as mean and standard deviation (SD) values. Data showed a parametric distribution; so the one-way ANOVA test was used to compare between the three groups. Tukey's test was used for pairwise comparisons between the groups when the ANOVA test is significant.

The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

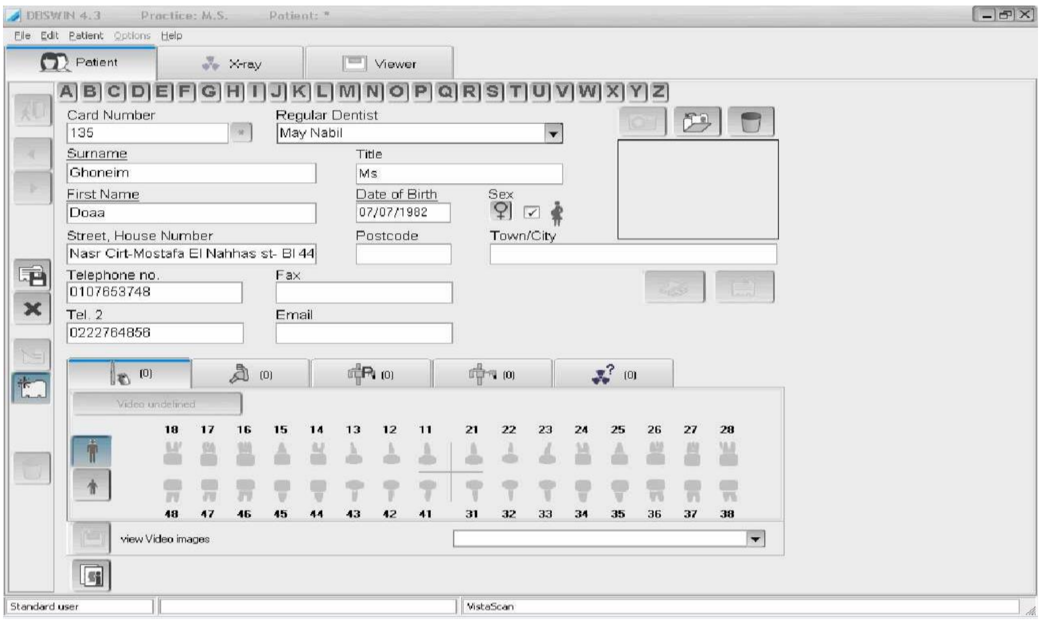

Figure (1): Active sample card on DBS-Win software.

®SPSS, Inc., an IBM Company.

Figure (2): Vista Scan System

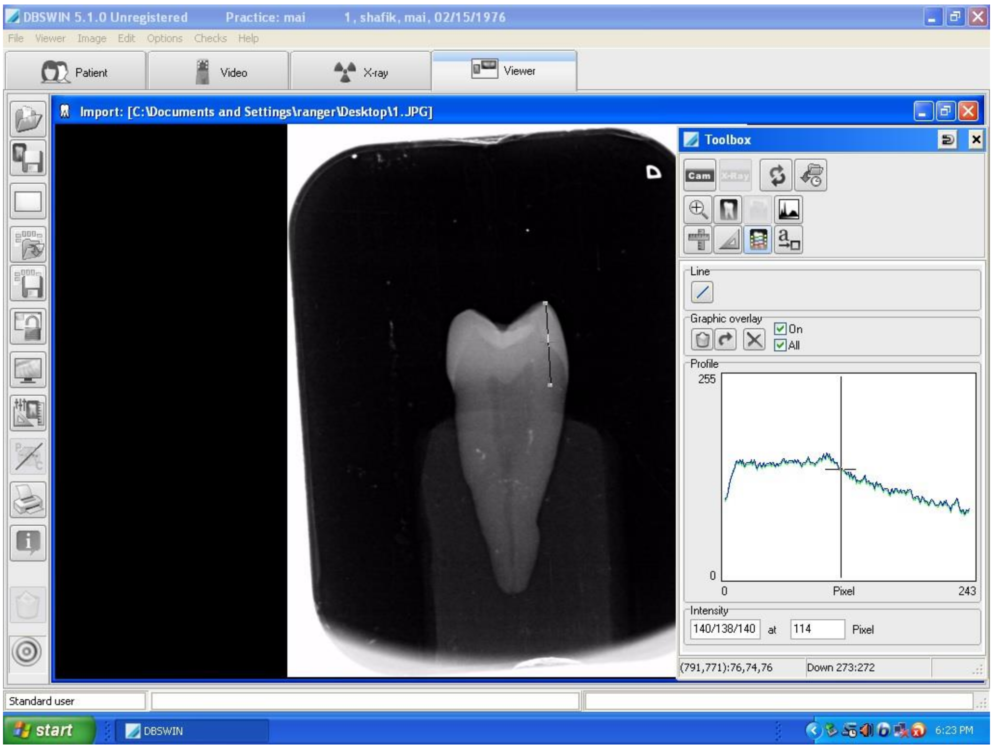

Figure (3): Densitometric radiographic measurement of enamel density using DBS-Win software on the Buccal surface of a premolar.

RESULTS

In Table (1) and Fig (4); an illustration (comparing the mean radiographic changes between each material for baseline, demineralization and post ttt), there was an insignificant decrease in the radiographic density for readings of baseline, demineralization in all groups (from 58.2 ± 4.7 to 40.1 ± 1.6) for the Icon, (from 56.8 ± 6.2to 40.8 ± 5.1) and for Excite-F (from 54.8 ± 14.5 to 40.9 ± 9.9) for APF.

For the *ICON* group, there was a statistically highly significant difference between the "after demineralization" and the "post treatment" measurement. Where the "after demineralization" measurement was 40.1 ± 1.6, while the "post treatment" measurement was 89.3 ± 4.5.

Regarding the *Excite-F* group, there was a statistically significant difference between the mean of the "after demineralization" and that of the "post treatment" measurement. Where the mean "after demineralization" measurement was 40.8 ± 5.1 and the mean "post treatment" measurement was 51.6 ± 5.2. For the *APF* group, there was a statistically highly significant difference between the "after demineralization" and the "post treatment" measurement. Where the "after demineralization" measurement was 40.9 ± 9.9 and the "post treatment" measurement was 83 ± 17.2.

There was a statistically significant difference between the mean radiographic changes after treatment of both ICON (89.3 ± 4.5) and Fluoride gel (83 ± 17.2) with the mean of the Excite adhesive (51.6 ± 5.2).

Table (1): a comparison in the radiographic density between the three groups using one-way ANOVA test

Application	***ICON*** ***Caries infiltrate***	***Excite-F*** ***Total etch bond***	***APF*** ***Acidulated phosphate fluoride***	***P*-value**
Baseline	58.2 ± 4.7	56.8 ± 6.2[b]	54.8 ± 14.5	**0.823**
After demineralization	40.1 ± 1.6	40.8 ± 5.1	40.9 ± 9.9	**0.978**
Post treatment	89.3 ± 4.5 [a]	51.6 ± 5.2 [b]	83 ± 17.2 [a]	**<0.001***

*: Significant at P ≤ 0.05

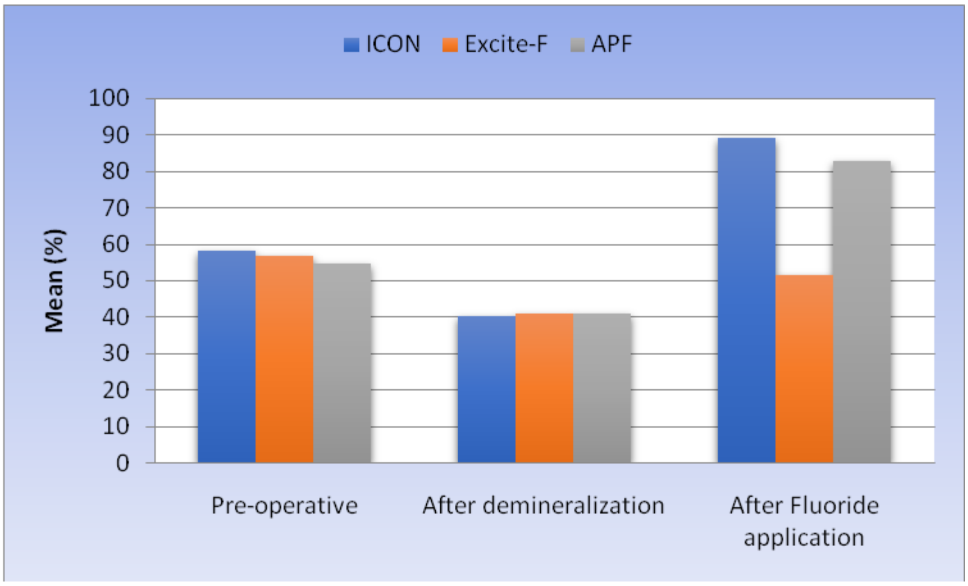

Figure (4): Mean values of radio-density in the three groups during the study

Table (2), (3) and fig (5) showed the mean percent radio-density change of the three tested materials groups from the base line.

The results showed that there was highly statistical significant difference between the mean percent radio-density changes of the three tested materials groups (*P*-value = 0.001). The ***ICON*** group showed the highest radio-density as represented by the gray scale with mean percent radio-density change 54.1 ± 12.2. On the other hand, there was an insignificant difference in the mean percent radio-density change between ***ICON*** (54.1 ± 12.2) and ***APF*** groups (53.9 ± 11.6) when compared to ***Excite-F*** group (-9 ± 3.7).

Table (2): Change in gray scale density in the three groups

GI (icon) Pre-application	GI (icon) Post-application	GII (adhesive) Pre	GII (adhesive) Post	GIII (topical fluoride) Pre	GIII (topical fluoride) Post
63%	88%	59%	62%	66%	73%

Table (3): Mean ± standard deviation (SD) values and results of one-way ANOVA test for comparison between % changes in the three groups

Application	***ICON***	***Excite-F***	***APF***	***P*-value**
After demineralization	-30.8 ± 3.9	-28.3 ± 3.6	-24.9 ± 4.5	0.066
After treatment	54.1 ± 12.2 [a]	-9 ± 3.7 [b]	53.9 ± 11.6 [a]	**<0.001***

**: Significant at P ≤ 0.05, Different letters in the same row are statistically significantly different*

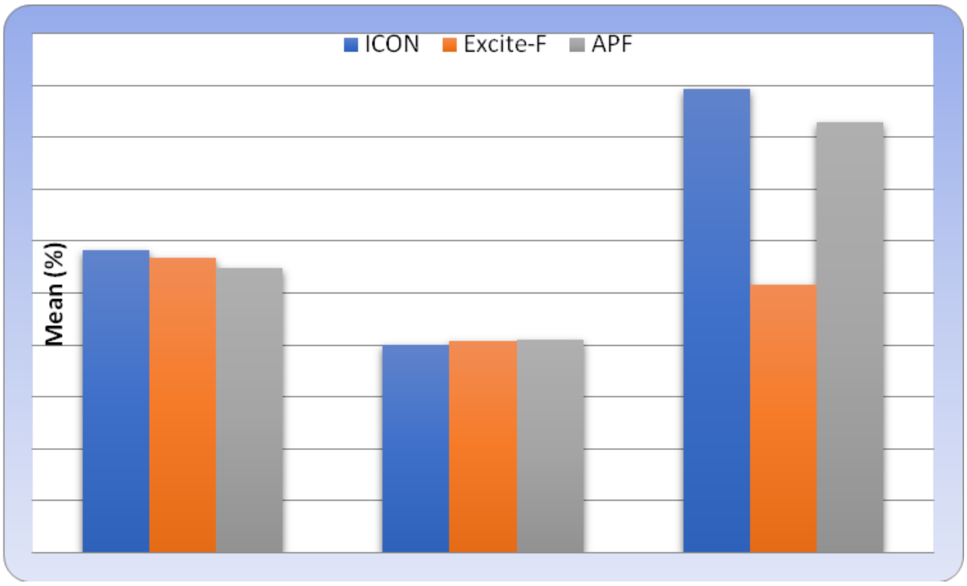

Figure (5): Mean values for comparison between radio-density of the three groups

DISCUSSION

The aim of the present study was to compare the increase in density of the artificially demineralized enamel lesion when using different treatment modalities (topical fluoride application, conventional adhesive, and caries infiltrant)

In the present study de- and remineralization process was monitored using Digital radiographic density measurement which combined X-ray-radiography with digital image processing to describe the amount of minerals gained into the tooth structure using different treatment modalities [15]. Vista Scan-system was used to monitor density changes and measures treatment outcomes. Following tooth exposure, the digital image was produced using DBS-Win software program with a phosphor image plate, which enables accurate pixel gray measurement of different dental tissues. This technique provides lower radiation dose and accurate image analysis [20].

On comparing the percent of radio density (the change in gray scale density) that occurred after application of testing materials, the result of this study showed that no significant difference was found between group I treated with ICON and group III treated with topical fluoride gel (the greater gain was observed in ICON group). Both groups showed significant increases in radio-density when compared to group II treated with adhesive system.

The increase in radio-density in group III, which was treated with topical fluoride application was in accordance with Neto et al. in 2009 [21], Diamanti et al. in 2010 [22] and Diamanti et al. in 2011 [23] as these studies have shown that fluoride (1450, 2800 or 5000 ppm) containing toothpastes promoted remineralization and inhibited demineralization, of both enamel and dentin substrates more effectively, than the calcium and phosphorus containing toothpastes (calcium sodium phosphosilicate toothpaste) and other non-fluoridated toothpastes (control). This result is not actually surprising since it has been suggested that, surface adsorption of fluoride and ionic exchange with surface hydroxyl ions was done after topical application of High fluoride concentration on the demineralized surface. This fluoride enhances rapid precipitation of minerals and obturation of the enamel surface pores that connect with the underlying demineralized lesion with formation of new reinforced surface on the crystal remnants [24, 25].

Furthermore, Chow et al. in 2000 [26] suggested that after one minute of fluoride solution application, free Fluoride ions are released gradually with the continuous formation of CaF_2. Also, un-dissociated SiF_6^{-2} may precipitate on enamel and dentin pores and release free F ions that react with Ca^{+2} ions to form firmly bounded Fluoro-apatite. This improves remineralization especially at high fluoride concentrations (tenCate et al. in 1991 [27], Hicks et al. in 2004 [28] and Yamazaki and Margolis in 2008 [29].

The principle of infiltrating lesions at the early stages of development and subsequent changes in porosity was demonstrated by Robinson et al. [1976] [30]. Several studies on artificial caries lesions have demonstrated that commercially available adhesives infiltrated the micro-pores of the demineralized lesion and produce a considerable reduction of lesion progression [4, 9, 31]. But these materials did not provide mechanical support for the porous tissue, and therefore increasing the risk of subsequent cavitation [4]. “Excite-F” is the adhesive system that was chosen for this study as it was the fastest penetrating resin when compared to five commercially available adhesives [17].

Caries infiltrant introduced to fill the gap between noninvasive and minimally invasive treatment of initial caries [32]. These materials exhibit many properties as low viscosity, high surface tension and cosmetically accepted. These properties allow the infiltrant to completely penetrate, fill, reinforce, and stabilize the demineralized enamel without drilling or sacrificing healthy tooth structure [33]. Many studies assessed the therapeutic effects of resin infiltration vs. adhesive system for controlling caries progression; most of these studies were in agreement with our result which revealed superior results for resin infiltrant [13,34].

This result may be attributed to the use of hydrochloric acid etching in caries infiltrant (ICON group) which totally remove the surface layer of carious enamel (pseudo-intact surface layer). This layer has high mineral content that act as diffusion barriers against infiltrant penetration [35, 36]. Many researchers have reported that the penetration depth of hydrochloric acid etching is more than twice (58 µm) that of phosphoric acid, which used for etching of “Excite-F” adhesive system. On the other hand, phosphoric acid etches only the outermost 25µm of the surface which promote superficial penetration of the adhesive into carious lesion [31, 37].

There is a high correlation between the square root of the penetration coefficient of a resin material and lesion progression. The high success rate of the ICON may also attribute to the increase amount of TEGDMA in the resin infiltrant which have high penetration coefficients that promote adequate penetration into enamel pores [38]. ANDREJ M. et al [33] reported in their review article that a resin infiltration depth of 60 µm was sufficient to prevent further demineralization. Resin infiltrants are capable of penetrating several 100 µm into natural caries lesions [9].

The philosophy of using 99% ethanol (ICON Dry) in drying process of ICON system will help decreasing the viscosity and contact angle of the infiltrant and thus allow (TEGDMA) to infiltrate into a demineralized wet enamel or dentine, and improve the efficacy of penetration of the hydrophobic infiltrate to get a well-defined, resin-infiltrated layer [38, 39].

On the other hand, Gomez et al. [40] reported that adhesive sealing system produces an irregular pattern of infiltration which could be attributed to the high viscosity of sealants that make it difficult for penetration into the micro-porosities of the enamel lesion. Robinson C. 2001 [4] used different available adhesive materials to infiltrate the porosities of artificial enamel lesions; they found that only 60% of the lesion pore volume had been occluded. He also concluded that adhesives will not add mechanical strength to the lesion and would be more easily displaced from the surface.

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In spite of the result that no significant difference was found between the ICON group and topical fluoride application, but ICON offers some advantages compared with the fluoridation approach. First, an improvement in the appearance of the lesion even if it is deep because of deep penetration of the resin infiltrant into the lesion, second, instant esthetic improvement [14].

CONCLUSION

- Resin infiltration technique is a promising micro-invasive approach for treatment of demineralized enamel.
- Both Resin infiltrant and fluoride application may have the ability to restructure the surface of the enamel crystal and may be considered as reparative materials for the treatment of early lesions.

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