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Article

The effect of silver diamine fluoride on the microleakage of glass ionomer restoration in primary teeth at different time intervals

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Abstract: Silver diamine fluoride (SDF) has shown effectiveness in hardening tooth structure and killing bacteria. Therefore, it can be used to prevent and arrest dental caries. Riva Star (SDF) treatment alone will stop cavities but will not reverse the cavitation. The Silver Modified Atraumatic Procedure, often known as Smart, is the optimum technique for regaining the tooth's structure and function. Glass ionomer was introduced in (1972) as a new material that has become one of the most widely used materials in restorative dentistry. By releasing fluoride ions, this material has a therapeutic impact on the surrounding tooth structure. Microleakage is the ingress of bacteria, its byproducts, toxins, chemicals, oral fluids, and ions between the margins of the restoration and the cavity walls. Dental restoration lifetime is significantly influenced by microleakage at the tooth-restoration contact. **Material and method:** In this study, we used 32 primary molars, class V cavities prepared on the buccal surface of all teeth. The teeth were divided into 2 groups: Group 1: 16 teeth treated with 38%SDF 8 of them restored directly with GIC filling and the other 8 restored after 14 days; Group 2: 16 teeth as control group left untreated with 38% SDF,8 teeth restored directly and 8 restored after 14 days. Samples were thermocycled, immersed in 2% methylene blue and then sectioned in a buccolingual direction. Dye penetration was measured with a digital camera connected to a stereo microscope. **Result:** results of this study showed a significant difference in microleakage between two-time intervals in which microleakage in GIC filling decreased at 14-day intervals than that of first-day interval in the experimental group, while in the control group, microleakage at 14 days intervals was higher than first-day interval, but it was not significant. **Conclusion:** Pretreatment of the primary teeth with SDF can decrease the microleakage of GIC restoration. If placed after 14 days, the microleakage would be lesser than that if the restoration was placed directly after SDF treatment. Therefore, it is recommended that SDF treatment be done, followed by a permanent restoration after 14 days, so the null hypothesis cannot be accepted.

Keywords: Microleakage, Silver diamine fluoride, Glass ionomer filling, non-invasive dentistry

Introduction

Dental caries is a complex illness that is the result of interaction between tooth structure, the microbial biofilm that has developed on the tooth surface, and sugar consumption..[1] Pathological factors can cause demineralization and remineralization are not in balance, which causes a net loss of minerals from tooth hard tissues and eventually develops into a carious lesion.[1] Complete removal of all carious dental tissues followed by placement of restoration in the cavity has been considered the standard procedure for dental caries treatment. However, this approach has been challenged, as the modern understanding of dental caries is that caries is not an infectious illness to be treated by removing all bacteria through extended cavity preparation. It is recommended to preserve not only sound dental tissues but also tissues with the potential to remineralize, thus maximizing the healing potential of the tooth.[2,3] Nonrestorative treatments, even without removing carious tissue, are options for managing dental caries.[4,5]

Silver diamine fluoride (SDF) is well documented for its essential role in the dental setting. It has been included in the caries management protocols by AAPD [6.] 2014, the US Food and Drug Administration 7 approved SDF as a dentinal sensitivity treatment. Silver diamine fluoride (SDF) has effectively hardened tooth structure and killed bacteria. Therefore, it can be used for both prevention and arrest of dental caries [8]. [9] studied extracted primary teeth with cavities of children who received biannual applications of SDF using micro-computed tomography and scanning electron microscope. The arrested lesions were remineralized by calcium and phosphate ions and had intact collagen fibers. It was suggested that the SDF provides an alkaline environment that promotes the formation of covalent bonds between phosphate ions from saliva and the intact collagen, which becomes a binding site for calcium ions, which leads to apatite nucleation through the collagen [9].

SDF (AgF[NH3]2) is an alkaline solution with a pH between 8 and 10. Silver, fluoride, and ammonia make up its principal ingredients. Ammonia stabilizes the solution, the fluoride promotes remineralization, and the silver acts as an antibacterial agent. [10].

However, SDF's action mechanisms are significantly more complicated. The most typical concentration is 38 percent or 44.800 parts per million of fluoride and 255.000 parts per million of silver [11]. These two substances will cooperate to promote mineralization, limit the demineralization of tooth hard tissues, and lessen the deterioration of the organic section of the dentin. They will also have a bactericidal effect on cariogenic germs. [12].

SDF is an efficacious and safe approach, especially for pediatric patients in both pandemic and post-pandemic periods. Fluoride treatments have long-controlled dental cavities. When fluoride is applied to tooth surfaces, calcium fluoride-like globules form on the tooth surface. Protein phosphate in the mouth stabilizes these globules. [13].

Riva Star (SDF) treatment alone will stop cavities but will not reverse the cavitation. The Silver Modified Atraumatic Technique, often known as Smart, is the best procedure for regaining the tooth's structure and function[14]. Following the usage of SDF by restoration placement, SDF can be employed in a restorative procedure. A silver-modified ART (SMART) restoration incorporates SDF and atraumatic restorative therapy (ART)[15,16].

Amalgam (AMG), conventional glass-ionomer cement (GIC), resin-modified glass-ionomer cement (RMGIC), high-viscous glass-ionomer cement (HVGIC), compomer (CP), and resin composite (RC) are the traditional restorative materials that can be used to restore primary teeth [17].

Wilson and Kent first proposed GIC as a new material in 1972.[18]. It has become one of the most often used materials in restorative dentistry. This "acid–base cement" is created by combining glass powder with a polymeric acid aqueous solution for 2–5 minutes, which causes a setting reaction. By releasing fluoride ions, this substance has a therapeutic impact on the nearby tooth structure. This is why GIC has been utilized in clinical settings for procedures like restorations, luting cements, bases, and liners[19].

Regarding SDF and GIC, there is some proof that GIC can increase SDF's efficacy. In (2021), Eslami et al.[20] proved that in the presence of artificial saliva, one or two treatments of SDF followed by GIC covering might remineralize advanced dentin caries. Other studies revealed that the shear binding strength of GIC with sound dentin was unaffected by SDF. [21] or carious dentin [22]. It could increase GIC's resistance to secondary caries [21]. A systematic review and meta-analysis found that applying SDF beforehand did not impede the bonding of GIC to dentin[23].

Ingress of bacteria, its byproducts, toxins, chemicals, oral fluids, and ions between the margins of the restoration and the cavity walls is known as microleakage. Dental restoration lifetime is significantly influenced by microleakage at the tooth-restoration contact. It might result in pulpal disease, hypersensitivity of the repaired teeth, discoloration at the restoration's borders, and recurrent caries at the restoration's interface.[24,25].

Poor adaptability between the restorative material and the original tooth structure is the primary cause of microleakage. A gap will form between the restorative material and the tooth due to volume changes in the restorative material brought on by cohesive shrinkage during restoration and oral temperature changes following restoration. [19].

The most common technique for measuring sealing ability is the dye penetration method. Because of its inexpensive cost, simplicity of usage, and low molecular weight, which is smaller than bacteria, methylene blue (2%) is more popular. Tests using dyes could detect leakage where bacteria are unable to enter. To assess the amount of infiltration, methylene blue was used as a tracer. Smaller particle size and dentinal tubule permeability might lead to an overestimation of the significance of this infiltration. The estimated area of Methylene blue, which is around 0.52 nm2, is bigger than the average size of a bacterial cell. Since bacteria typically have a diameter of between 0.3 and 1.5 microns, this approach cannot distinguish between too large or too small gaps to prevent bacterial leakage.[27,28].

As stated by the author's knowledge, no previous study was carried out concerning the effects of silver diamine fluoride on the microleakage of composite restoration at different time intervals. The null hypothesis would be that there is no difference in microleakage if the glass ionomer restoration is applied on the same day of 38% SDF treatment or if applied after 14 days from 38% SDF treatment.

Materials and Methods

This research was an in vitro comparative study. It was accomplished at the University of Technology in Baghdad city after obtaining approval from the ethical committee of the College of Dentistry/ University of Baghdad no.553322 in (17.4.2022). Teeth selected in this study were thirty-two primary molars (using G power 3.1.9.7 (A program written by Franz-Faul, Universitat Kiel, Germany) with sound buccal and lingual surfaces [29]. Teeth were collected from special health centers and were placed in 0.1% thymol solution for 24 hours to prevent bacterial growth[30]. They were then cleaned and polished with non-fluoridated pumice31 and stored for over 3 months in distilled water, which was changed weekly. At all stages of the study, the specimens were kept hydrated[32,33]. The root of the teeth was covered by a layer of sheet wax shorter than CEJ to act as soft tissue and as a separating medium between the root and silicon.

A specially fabricated plastic mold was used and painted with nail polish with colors to code each group. Elastomeric Silicon impression material was placed in a plastic mold, and teeth were mounted in the silicon with a level shorter than CEJ[34].

In order to standardize the cavity preparation for all the specimens, a modified dental surveyor was used. A high-speed handpiece was attached to the movable arm of the surveyor in such a way that the long axis of the bur was kept perpendicular to the long axis of the tooth during the preparation. The cavity preparation was a class V cavity on the buccal surface of the teeth with a width of 3mm mesiodistally, length of 2mm occlusal-gingivally and depth of 2mm, with no mechanical retention and under air-water cooling preparation[35]. The depth was standardized using diamond depth-oriented bur (depth cutter 2 mm). The bur was replaced after four teeth preparations [36]. The cavity's depth and width were checked by a digital caliper and periodontal probe [37]. To standardize the width and length of the cavity, a disposable band and retainer were used in which a window (3mm x 2mm) was cut in the band and placed over the buccal surface of the tooth [35]. The teeth were numbered and randomly distributed using (Random Number List Generator - TextMagic) and then distributed according to SDF treatment and time of restoration application into two main groups. Group I was sub-grouped into two groups (group I.a: 8-teeth treated with 38% riva star SDF and directly restored with self-cure glass ionomer filling group I.b:8-teeth untreated with SDF and self-cure glass ionomer filling placed directly). Group II was also sub-grouped into two groups (group II.a:8-teeth treated with 38% riva star SDF and stored in artificial saliva for 14 days[44] and then removed from artificial saliva and rinsed with copious water and dried and then restored with self-cure glass ionomer filling, while group II.b:8-teeth after cavity preparation stored in artificial saliva for 14 days[44] and then removed and as group 1. b rinsed and dried and then restored with self-cure glass ionomer filling. After cavity preparation, the cavity was rinsed and dried with a triple syringe, and then 32 teeth were prepared for SDF application. 38% SDF/KI was applied according to manufacturer instructions, SDF (1st liquid) for 10 seconds by using a micro brush and timed with a stopwatch; then, after applying KI (2nd liquid), wait till the color of the solution changed from milky white to clear. After applying each substance, all specimens were left for 3 minutes and then washed for 10 seconds with excess volumes of distilled water prior to air drying for 10 seconds with intense pressure from a dental air syringe.[36]. The cavities in the control group were not treated with SDF.

Self-cure glass ionomer filling material (SDI, Australia) was mixed according to the manufacturer's instructions by mixing one spoon of powder and two drops of liquid after setting the filling (2-3 minutes). It was also finished and polished with a polishing bur. All the specimens were removed from the plastic mold, and the teeth were then placed in distilled water for 24 hours at 37ºc and then submitted for thermocycling[25]. A thermocycler device was used for thermocycling to simulate the thermal changes that occur in the oral cavity and result in changes between cavity restoration and tooth surface. Thermocycling was carried out by soaking the specimens alternatively into (5-55 ±1~2Cº) water bath chambers with [30] seconds immersion time in each bath and 10 seconds transition time for 500 cycles according to [38,40], (ISO/TS (E) 11405:2003. All the specimens of each group were thermocycled at the same time. The machine has two chambers, one for cold water and one for hot water. All the samples were dried, and double layers of nail polish were applied to the samples to cover the entire tooth surface except for 1mm around the restoration margins. The teeth's root apices were sealed with sticky wax before being submerged in 2% methylene blue dye for 24 hours. The samples were then cleaned and dried under running water. 35 The samples were immersed in clear epoxy resin to form blocks; this was done by fabricating a mold using a specially fabricated plastic mold with dimensions (3x2x1) cm. Epoxy resin was used instead of acrylic because it is easier to manipulate and does not generate heat during its setting, which may affect the tooth and the restoration [36]. The teeth were then sectioned using a sectioning saw device and 0.01 disc with water coolant; the sectioning was done with the long axis of the tooth into two sections. The teeth were sectioned in a bucco-lingual direction at the center of the filling [35,36].

The penetration of microleakage was confirmed by the visualization of a blue line at the occlusal and cervical interface between the tooth and the restoration by two observers using a stereomicroscope at magnification 20X[41]. The extent of microleakage was measured by a captured image using a digital camera connected to the stereomicroscope at 20x magnification [41]. The image was saved as JPEG, and using Optika Vision Lite 2.1 software, dye penetration was measured in mm[34]. Both sections were measured, and the greatest microleakage was recorded. The measurements were made by one calibrated operator blinded to treatment allocations. The extent of microleakage was calculated according to the following formula[43]:

It/Lt The ratio of infiltration in mm in which:

It=Io+Ic

Io: The extent of dye that has penetrated the occlusal edge.

Ic: The extent of dye that has penetrated the cervical margin.

Lt: In millimeters, the entire length of the tooth-to-restoration interface

Statistical analysis

Data were described, analyzed, and presented by using Statistical Package for Social Science (SPSS version -22, Chicago, Illinois, USA), minimum, Maximum, mean and Standard deviation(SD), cluster chart bars, inferential statistics are: Shapiro Wilk test, Levene test and General linear model (Factorial Analysis of Variance), the accepted level of significance was at $p< 0.05$.

Results

A normality test was carried out, as shown in Table 1, to examine the sample distribution. This Table indicated that the micro-leakage variable is generally distributed among the groups according to time interval and with or without SDF.

	Time	Shapiro-Wilk					
		SDF					
		Without			With		
		Statistic	df	P value	Statistic	df	P value
	1st-	0.848	8	0.055	0.911	8	0.360

	day						
	14- day	0.906	8	0.328	0.897	8	0.271

Table 1. Normality test of microleakage among time and SDF in GIC.

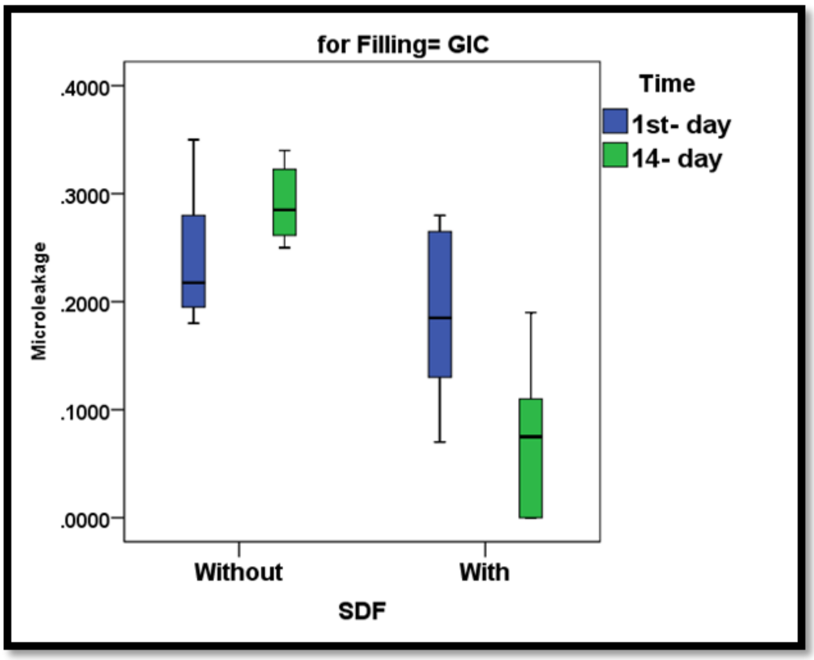

Figure 1. Normality test of microleakage among time and SDF in GIC.

Results above show that microleakage was generally distributed among filling, time and presence or absence of SDF using the Shapiro- Wilk test at p>0.05.

Results as illustrated in Table 2 when SDF was not applied, although microleakage was found to be more at 14 days than on the first day, the result was not significant; while groups were treated with SDF, the opposite finding occurred in which microleakage was found to decrease at 14 days than that at the first day with the significant result and large effect size.

SDF	Time	Minimum	Maximum	Mean	±SD	F	P value	Effect size.
Without	1st- day	0.180	0.350	0.239	0.064	1.807	0.184	0.031
	14- day	0.250	0.340	0.291	0.035			
With	1st- day	0.070	0.280	0.189	0.079	9.559	0.003*	0.146
	14- day	0.000	0.190	0.070	0.068			

*=significant at p<0.05, ^=not significant at p>0.05.

Table 2. Descriptive and statistical test of microleakage among time by SDF in GIC.

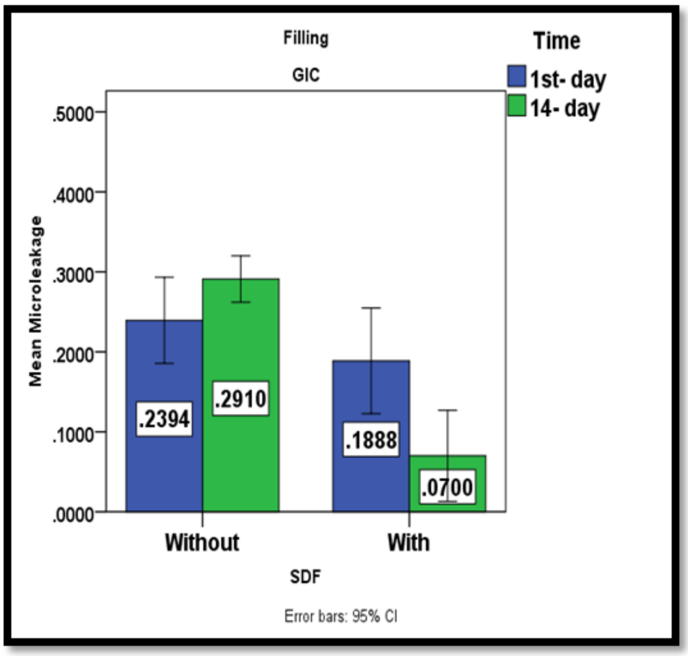

Figure 2. Microleakage over time by SDF in GIC.

Time	SDF										
	Without				With						
	Minimum	Maximum	Mean	±SD	Minimum	Maximum	Mean	±SD	F	P value	ES
1st-day	0.180	0.350	0.239	0.064	0.070	0.280	0.189	0.079	1.737	0.193^	0.030
14-day	0.250	0.340	0.291	0.035	0.000	0.190	0.070	0.068	33.109	0.000*	0.372

Table 3. Descriptive and statistical test of microleakage among SDF by time in GIC.

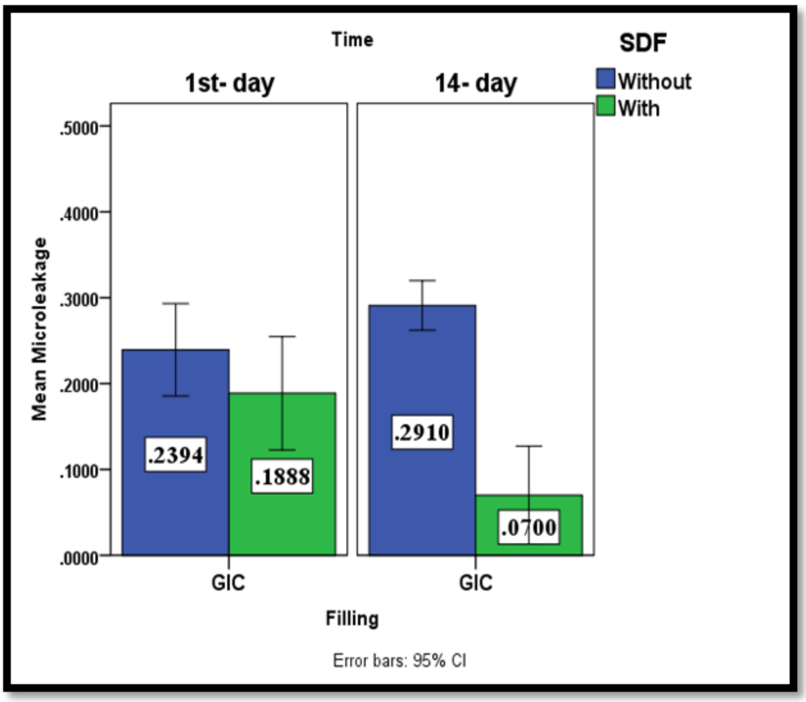

Figure 3. Microleakage among SDF by time in GIC.

Glass ionomer filling applied at 1 day without pretreatment with SDF microleakage was greater than that when using SDF but with no significant result. At 14 days, the GIC showed more microleakage in samples without pretreatment with SDF than if using SDF with a significant finding and large effect size.

Discussion

This study was carried out to evaluate the effects of 38% silver diamine fluoride on the microleakage of glass ionomer filling at different time intervals. Microleakage studies are still the most often used test method to get a rough sense of the quality of a new material or combination of materials, even if the role of microleakage in restoration failure is still controversial.[45].

The methods and materials used in the treatment of caries to remove it will leave a substrate that will affect the sealing of restorative materials, affecting the life span of restorations. The adhesive restoration that is applied following caries removal may be affected by the amount of residual decay, the thickness of the smear layer, the width of the dentinal tubules, and abnormalities on the cavity walls and edges.[47].

Although GIC cannot prevent microleakage at the tooth/restoration interface in an in vitro setting, the material may perform well in clinical settings because of its ability to release fluoride and delay or stop the development of secondary carious lesions, which are the real clinical threat posed by microleakage [46].

Moreover, compared to in vivo research, in vitro microleakage tests are extremely simple to conduct and successfully distinguish the quality of various materials in terms of their microleakage-resisting potentials [55]. Class V cavities were employed in this investigation since their preparation was minimal and restoration was more accessible than other classes, reducing method sensitivity and operator-related variability [56]. Also, the c-factor of class V is high, which makes microleakage and excludes the occlusal loading effect on microleakage. The primary problem in these types of cavities is leakage in the gingival margin[42]Thermocycling used in this study was to simulate the thermal oral changes effect on restoration and aging effect of restoration that will make mismatch between restoration and tooth structure and will affect on adhesive bond and subsequently microleakage. This was in agreement with other researchers, who stated that thermo-cycling acted the same as intra-oral temperature variations and subjected the tooth restorations to temperature extremes compatible with the oral cavity[57,58,59].

In this study, measuring microleakage was done by image analysis to get quantitative results instead of the conventional scoring method. The relative merit of this approach was that there is no need for scoring by separate examiners, consensus scoring in borderline cases, or statistical procedures for determining inter-examiner reliability [60].

This study aligns with Soliman et al.,2020 [6]who found no significant difference in microleakage of GIC between teeth treated and not treated with SDF when they used primary teeth in their study.

The microscope shows cracks and voids in self-cured GIC filling. This may be due to the cohesive strength of glass ionomer cement being found to be lower than adhesive strength; the material's porous nature may be an essential factor that enhances the potential for microleakage [61].

Craig et al. (2012)[48] suggested that application of SDF/KI to dentin could precipitate proteins in the dentinal tubules, block dentinal tubules by forming deposits of calcium fluoride and reduce dentin tubule patency by the formation of silver iodide[50,] Sadek et al.2007 [49] showed that the use of potassium tetraoxalate, a tubule occluding agent increased the bond strength of total-etch adhesives to dentin. SDF/KI could have produced a similar kind of tubule occlusion and may be the reason for the decrease in microleakage in the experimental groups compared to the control groups.

According to the results of this study, it was shown that delay in restoration placement would decrease microleakage, which means that bonding strength was increased at the second interval. This disagreed with Patel et al. (2020) [51], who said that delayed application of (SDF+KI) does not affect the bond of restorative material to dentin. The effect of saliva may explain the decrease in microleakage after 14 days. In contrast, saliva is essential to the development of caries remineralization. Proline- and tyrosine-rich proteins in this buffered environment, supersaturated in calcium phosphate, prevent the excessive nucleation of apatite phases. [53,54]. Because both species are present in the hydroxyapatite unit cell, salivary calcium and phosphate ion activity are essential. Therefore, saliva offers a protective and reparative environment for teeth, and this may be the cause of decreased microleakage in samples that were treated with SDF and stored in artificial saliva, so the dual effect of SDF and artificial saliva can enhance remineralization and occluding of dentinal tubules and therefore decrease microleakage after 14 days.

The result came in agreement with Auychai et al.,2021 [52], who said that restoration should not be placed after SDF treatment in the same visit and suggested the incorporation of SDF with GIC to eliminate extra visits.

The data in the literature primarily originate from research on permanent teeth because few papers have been published on primary teeth, which might lead to considerable changes from the current study's findings. In terms of the determination of the depth of the microleakage, the methodology used in the current study is similar to that of the previous investigations presented here.

Conclusion

The present study's findings conclude that pretreatment with SDF can decrease the microleakage of GIC restoration. If placed after 14 days, the microleakage would be lesser than that if the restoration was placed directly after SDF treatment. Therefore, it is recommended that the SDF treatment be done, followed by a permanent restoration after 14 days, so the null hypothesis cannot be accepted.

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