International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page: www.iscientific.org/Journal.html

Effect of SDF Application versus Diode Laser Irradiation on Incipient Carious Lesion's Progression in Primary Molars: A Randomize Clinical Trial

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Abstract

The present study aimed to investigate the effect of two different preventive measures a) Silver diamine (SDF) application, b) Diode laser irradiation, on caries progression of incipient carious occlusal lesions in primary second molars. This clinical trial included two equal study groups of patients, for applying; Group I: SDF application, Group II: Diode laser irradiation, the included second primary molars for intervention were selected with incipient carious lesions graded by International Caries Detection & Assessment System (ICDAS)with scores (0,1,2). The involved molars were followed up for 3, 6, 12 months and ICDAS scores were graded to check for caries progression and arrest. Regarding the caries progression, at 3 months follow up there was no differences scored between the two intervention groups, however at both 6 months and 12 months intervals; SDF group showed less Mean and Median values than Diode laser group, however the difference between the two groups was statistically non-significant for both intervals ($p>0.05$). Intragroup comparison within the same group comparing the caries progression values during the three different tie intervals revealed statistically significant values for both groups ($0.05>p$). In the current study SDF, application to incipient carious lesions had a non-significant higher inhibitory effect on progression in comparison to Diode laser irradiation. SDF and Diode laser irradiation are both preventive measures that could inhibit carious lesion's progression in primary molars.

Keywords: Silver diamine fluoride, Diode laser, incipient carious lesions, primary molars

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Doi # https://doi.org/10.62877/81-IJCBS-24-25-19-81

1. Introduction

Silver diamine fluoride (SDF) is an example for nonrestorative caries treatment, it has been under discussion in dental research since the late 60's [1]. SDF is marketed for dental usage as a 38% solution, with the following constitution; a) Silver: 24-27% (approx.253, 900 ppm), b) Ammonia: 7.5-11%, c) Fluoride: 5-6% (approx.. 44,800 ppm), d) coloring dye: less than 1% , e)Deionized water: less than 62% [2]. SDF reacts with hydroxyapatite (HA) crystals ($Ca10(PO4)6(OH)2$) to form silver phosphate ($Ag3PO4$) and calcium fluoride ($CaF2$) as its major byproducts [3]. The newly formed ($CaF2$) acts as a reservoir for fluorapatite, continuously reacting with (HA) to form fluorohydroxyapatite, which acts on peritubular and intertubular dentin thus improving their resistance against acid decalcification and reduced the acid penetration into the deeper layers of dentin. Fluoride ions from the SDF also mends any lattice imperfection in the existing enamel structure ameliorating their crystallinity, hence promoting remineralization [4-5].

While the fluoride component promotes remineralization, inhibiting the demineralization is secondary to recurrent and ongoing acidic challenges. SDF also prevents dentine collagen degradation through the inhibition of proteolytic peptidases in dentine and saliva. SDF penetrates enamel of about 25 µ and dentin of about 16–200 µ [6]. On application to tooth structure, calcium fluoride, silver phosphate and precipitated protein silver ions leach to the already existing hydroxyapatite transforming it to a more caries resistant tissue [7]. Silver is said to possess an ongoing mode of action on bacteria, "The Zombie Effect" according this is described as when the bacteria that are killed by silver have an apparent biocidal activity against the remaining living bacteria, this could be attributed to; the metallic silver

ions are not deactivated . While killing the bacteria and the fact that the dead bacteria itself acts as a reservoir for metallic silver and cause sustained release of silver afterwards [8].

Regarding clinical application, SDF application is simple, fast, noninvasive, painless: no local anesthesia required, inexpensive, and non−aerosol-generating procedure requiring no sophisticated or expensive equipment it has become widely accepted among clinicians due to its preventive properties, sealing dentinal tubule's ability, and ease of application [9]. Recently, lasers have provided a new method of caries prevention, and laser therapy has been investigated as an alternative method for modifying the tooth surface and increasing its resistance to acids [10]. The effect of laser irradiation on tooth enamel, in combination with fluoride varnish or alone has been evaluated. The outcome shows that combined application of both: laser followed by fluoride has an aggravated impact on Enamel hardness. Laser application prior to fluoride enhances its effect on the enamel structure in its crystalline structure and on the superficial layers by inducing calcium fluoride (CaF2) formation [11].

Many Laser types have been used in combination with fluoride in combination with fluoride in previous studies the best outcome is still an ongoing dilemma. Diode laser has a lot of important characteristics such as ease of application, smaller size less thermal action and above all lower cost. Few studies have investigated diode laser's effect on enamel structure .Few have discussed its action on primary teeth, it is believed that the caries development pattern and its prevention in primary teeth somehow different from that in adult permanent teeth [11]. Irradiated surfaces show higher surface roughness when comparing to untreated surfaces, where 3 layers could be described within the lased surface 1)unchanged enamel crystals in the tooth's internal surface, 2)fused crystals in the intermediate area 3) hexagonal hydroxyapatite columns, isolated by irregular voids plus micro-cracks in the outermost surface [12].

Among the huge varieties of dental lasers now available, diode laser is the most convenient for usage in pediatric dentistry. They are more common among dental practitioners for the following, high cost effectiveness, very small size and easy usage in everyday clinical practice as regards to fiber delivery system [13]. Previous studies described diode laser effect on deciduous teeth enamel as causing melting then re-solidification this assumption proposes the increased resistance of irradiated enamel against acids therefore assuming the effective role in preventing dental caries initiation or progression [14]. Due to the diversity of materials tools used for dental caries prevention, longitudinal clinical studies are needed to evaluate the effectiveness of such materials. Nowadays, there is insufficient evidence regarding the absolute method/ tool for caries prevention, so, the aim of this in vivo study is to identify the impact of SDF and diode laser on the progression of dental caries.

2. Materials and Methods

2.1. Sample size

The sample size was calculated using G*power 3.1.9.2 Software. The sample size calculation was based on SDF effectiveness in arresting caries in primary teeth from a previous study [15]. The power of the t-test was calculated to be 95%, using a two-tailed significance level of 5%. The calculated sample size will be eight patients per group for a total of sixteen. The sample size was increased by 30% to 11 patients per group (22 in total) to compensate for dropouts.

2.2. Intervention

Application of Diode laser and SDF on the retentive occlusal pits and fissures and the followed for 3, 6, 12 months. Groups: Group A: SDF application, Group B: Diode laser application.

2.3. Inclusion criteria

Cooperative children aged 6-8 years old with good oral hygiene, with absent restorations or prior sealants on the selected teeth. Teeth with grades 0, 1 , 2 according to (ICDAS) : International Caries Detection and Assessment System will be included [16].

2.4. Exclusion Criteria

Children with known allergies or sensitivities to silver products mentally challenged, uncooperative, having bad oral hygiene, possessing molars with severe forms of hypoplasia or fluorosis or with deleterious oral habits, affecting occlusion will be excluded. The objectives and steps of the study as well as the possible discomfort and benefits will be explained, and a written informed consent must be obtained from the parents prior to treatment commencement.

2.5. Procedural Steps

A) Clinical examination will be done using a dental mirror and aided by the tactile detection of a dental explorer under LED illumination.

B) Selected teeth will be randomly assigned to different groups.

C) Prophylactic polishing for the selected molars will be done using a polishing brush/cone under running water in a slow speed hand piece to remove dental bio- film and salivary pellicle. The selected teeth will be isolated by rubber dam throughout the procedure.

D) For group A: Silver diamine fluoride was applied using a micro brush to the occlusal surface of the isolated molars, left for 3 minutes, then the excess material was blotted by a piece of cotton followed by rinsing with water for 30 seconds.

For Group B: Primary molars were irradiated using diode laser irradiation of 980 nm wavelength, 2 W power for 15 seconds, in pulsed contact mode wave and with an optic fiber transmission system. The fiber tip was positioned perpendicular to the pit and fissure areas, and irradiation was performed in a uniform motion [17]. Both groups will be instructed not to eat and drink for 1 hour after the application.

E) The same operator did all follow-up and examination procedures to ensure standardization. Moreover, all patients received oral health education regarding dietary and oral hygiene habits.

All cases were clinically evaluated after 3, 6 and 12 months of application. In subsequent visits, after any plaque and debris present on the tooth had been removed with a piece of gauze, the tooth was air-dried, dental caries progression was analyzed in the two study groups using the ICDAS classification.

2.6. Statistical analysis

Ordinal data were presented as frequency and percentage values. Numerical data were presented as mean,

standard deviation (SD), median and interquartile range values (IQR). Inter and intragroup comparisons were analyzed using Freidman's test followed by Nemenyi post hoc test. The significance level was set at $p<0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.3.2 for Windows [1].

3. Results and discussion

3.1. Results

Inter, intragroup comparisons and summary statistics for caries progression in groups (A) and (B) are presented in table (1) and in figures (1) and (2)

A-Intergroup comparisons: For both groups' values were equal on 3 months follow up, at 6- & 12-months interval values for Group (B) were higher than Group (A) however within all intervals 3,6 & 12 months, there was no significant difference between both groups ($p>0.05$).

B-Intragroup comparisons: Within both groups, values at 12 months interval were greater than 6 months interval and both there greater than 3 months interval .There was a significant difference between values measured at different intervals, with value measured after 12 months being significantly higher than that measured at 3 months ($p<0.05$).

3.2. Discussion

Occlusal Caries affecting pits and fissures is the most prevalent type of dental caries affecting both childhood and adolescence [18]. This higher susceptibility is justified by their specific anatomical shape that includes grooves and pits facilitating food remnants accumulation thus providing a more favorable niche for caries. This could be worsened in children due to the difficulty to brush this region, due to the poor motor skills [19]. The recent reduction in dental caries incidence is more related to improved oral hygiene [20], and continuous exposure to fluorides and sealing of occlusal surfaces of teeth [21]. For the success of these preventive measures, precise diagnosis, sufficient knowledge of the properties of the materials used, caries risk assessment. Proper diagnosis, determination of caries risk, knowledge regarding the properties of materials employed, ,application of sealants at the appropriate time and proper technique followed by caries activity control via periodic checkups are all necessary for the success of preventive treatment [22]. Therefore, it is necessary to apply caries control measures so as to minimize the incidence and progression of dentaecay on occlusal surfaces [23].

Among the available preventive methods is topical Fluoride application and Pits and fissure sealing. Occlusal sealants are most commonly fluid resins able to flow and fill into pits and fissures penetrating the micropores created following of acid-etching the enamel surface, therefore physically isolating the occlusal surfaces. The preventive effect is totally dependent upon the sealant's retention in pits and fissures [20]. The current study attempted to apply a novel biomimetic approach in pediatric dentistry discussing two preventive approaches. In 2018 a study [19] comparing between multiple different preventive approaches including SDF application, adopted the same split mouth study design in the same patient specimen, to help minimize different variables between patients, and unify patient related confounding factors and to attribute the results directly to the different interventions applied to each group. In 2022 a systematic review [24] concluded that SDF 38% was found effective in arresting active carious lesions in primary molars, through a 12 month duration follow up.

The authors ranked SDF before Atraumatic Restorative Technique (ART) and Sodium fluoride (NaF) varnish in delaying caries progression. SDF effectiveness was increased when re-applicated biannually. Enamel irradiation by diode laser increased resistance against caries demineralization, in an invitro [25] study utilizing an (809 nm) diode laser treatment irradiating enamel in primary teeth, but was still less effective when compared to conventional fluoride varnish application. In an invitro study the combined effect of diode laser [26] and silver diamine fluoride on preventing enamel demineralisation and cariogenic bacteria inhibition was tested, with the conclusion that the combined treatment provided enhancement in preventive effect, the study attributed the success of the combination treatment of both interventions to being readily available and affordable for most clinicians. However, the type of diode laser used (450 nm) was different from the one used in our study (980 nm). An In vivo study [27] used SDF and diode laser under Stainless steel crowns placed by the hall technique, to treat remaining affected dental tissue, they attributed the higher success rate achieved to their antibacterial effect on carious enamel and dentin and their inhibitory action on Streptococcus mutans.

(ICDAS) identifies various carious lesions regarding their clinical visual appearance. It was designed to provide high content validity through measuring different "carious process" stages rather than just the 'decayed' stage. The assessment of lesion activity (active - arrested) is also important for treatment decisions, especially when preventive methods are planned. ICDAS provides an accurate and reproducible method to detect early lesions and also to detect changes in longitudinal follow-up [28]. ICDAS I was developed in 2002 and was later modified to ICDAS II in 2005. The ICDAS I and II criteria incorporate concepts from the research conducted by Ekstrand et al [29] and other caries detection systems described in the systematic review conducted by Ismail et al [30]. The ICDAS categorizes dental caries into a variable number of discrete and predictable categories based upon the histological extent of the lesion within the tooth. ICDAS identifies caries lesions based on their clinical visual appearance [31-32].

ICDAS II description for coronal primary caries levels, depends on drying of the tooth surface for detecting non cavitated lesions followed by visual intraoral examination zaided by a ball ended explorer to remove any remaining plaque and debris, and to check for surface contour, minor cavitation or sealants and is carried out on clean and dry teeth. Water usually clogs the pores in carious teeth and the similar refractive index of tooth and water obscures the detection of early white spot lesions. The usage of a sharp explorer is not justified because no additional accuracy is provided and it may damage the enamel surface covering the early carious lesions [33-34]. The ICDAS detection codes for coronal caries range from 0 to 6 depending on the severity of the lesion. There are minor variations between the visual signs associated with each code[35]. The usage of a specific type of diode laser (980nm) limits the results of this study to a specific type of laser among a wide spectrum of devices with different parameters and multiple modes of action.

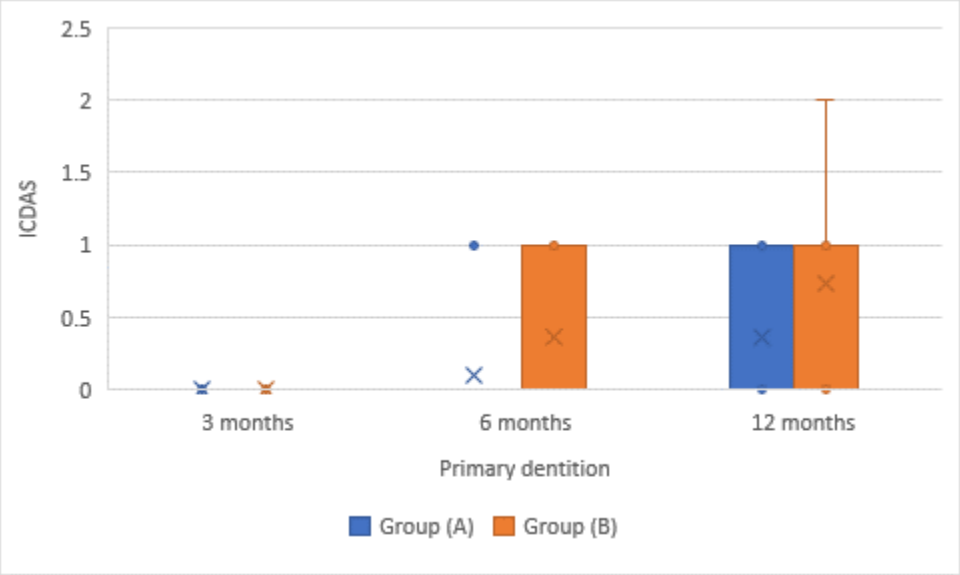

Figure 1. Box plot showing caries progression in groups (A) and (B).

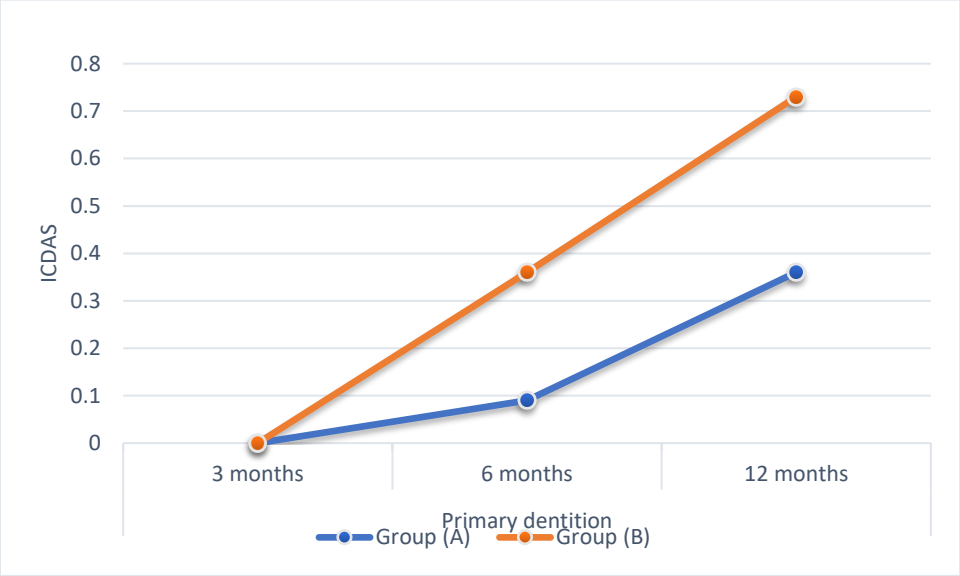

Figure 2. Line chart showing caries progression in groups (A) and (B) (primary dentition).

Table 1. Inter, intragroup comparisons and summary statistics for caries progression in groups (I) and (II)

Interval	Measurement	Group (A)	Group (B)	p-value
3 months	**Mean±SD**	0.00±0.00^{B}	0.00±0.00^{B}	**1ns**
	Median (IQR)	0.00 (0.00) ^{B}	0.00 (0.00) ^{B}	
6 months	**Mean±SD**	0.09±0.30^{AB}	0.36±0.50^{AB}	**0.149ns**
	Median (IQR)	0.00 (0.00) ^{AB}	0.00 (1.00) ^{AB}	
12 months	**Mean±SD**	0.36±0.50^{A}	0.73±0.65^{A}	**0.129ns**
	Median (IQR)	0.00 (1.00) ^{A}	1.00 (1.00) ^{A}	
p-value		**0.039***	**0.004***	

Values with different superscript letters within the same **vertical column** are significantly different *; significant (p<0.05) ns; non-significant (p>0.05).

Specifying a certain age group (six-eight) year old patients could affect the type of data concluded in the study, where in older age groups the incidence of incipient carious lesions could be greater owing to the longer service time of these teeth or could be smaller owing to improved hygiene and less sweetened diet cravings among older age groups. The decreased incidence could be further affiliated to the increased forces of occlusion by time leading to more tooth wear among the primary dentition leading to more shallow, less stagnating occlusal fissures and grooves [36].

4. Conclusion

In the present study, two approaches preventive were applied to primary molars aiming to arrest and decrease incipient caries lesions and preventing their progression. Primary molars treated with SDF showed less values according to ICDAS scores when compared to similar follow up intervals in the primary molars irradiated with Diode laser regarding carious progression during 3, 6 ,12 months follow up. This study was conducted in a split mouth design, such that the confounding factors responsible for caries progression become unified as both interventions were conducted in the same patient. The difference between the two groups can be attributed to the dual action of SDF acting as a remineralizing and bacteriostatic agent, while diode laser resolidifies and causes restructuring of the enamel composition irradiated and has an antibacterial effect on the oral microbiota inhabiting fissures and grooves. Both treatment modalities can be used to control incipient caries progression. The limitation of the study could be the usage of low parameters of diode laser, different parameters could function in a unique way.

Clinical significance

Incipient carious lesions can be controlled at an early stage leading to less need for restorative dental treatment and decreasing cost and effort for treatment in the daily practice.

List of Abbreviations

SDF: Silver Diamine Fluoride
ICDAS: International Caries Detection & Assessment System.

Acknowledgement

I would like to thank the beautiful patients and their parents whom I conducted my study with. I would like to thank my Dear Supervisors Professor Doctor Noha Samir Kabeel, Head of The Pediatric Dentistry and Dental Public Health Department at the Faculty of dentistry British University in Egypt , and Doctor Basma Gamal Awad: Lecturer of Pediatric Dentistry and Dental Public Health Department at the Faculty of dentistry , Ain Shams University , for their close guidance and fruitful contributions in this study

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