Open Journal of Stomatology, 2025, 15(6), 111-119
https://www.scirp.org/journal/ojst
ISSN Online: 2160-8717
ISSN Print: 2160-8709

Influence of Light Curing and Fluoride Varnish Application on Silver Diamine Fluoride Penetration in Carious Lesions of Primary Teeth

Tatiana Alhwayek, Conner Paul, Braden Patten, Neamat Hassan Abubakr*

School of Dental Medicine, University of Nevada, Las Vegas, NV, USA
Email: *neamat.hassan@unlv.edu

How to cite this paper: Alhwayek, T., Paul, C., Patten, B. and Abubakr, N.H. (2025) Influence of Light Curing and Fluoride Varnish Application on Silver Diamine Fluoride Penetration in Carious Lesions of Primary Teeth. *Open Journal of Stomatology*, **15**, 111-119.
https://doi.org/10.4236/ojst.2025.156010

Received: May 8, 2025
Accepted: June 17, 2025
Published: June 20, 2025

Abstract

Objectives: The present investigation aimed to evaluate the effect of Silver Diamine Fluoride (SDF) treatment, with or without subsequent application of fluoride varnish followed by light curing, on the depth of SDF penetration into the dentinal tubules of primary carious teeth. **Materials and Methods:** Fifty extracted carious primary molars were sectioned into halves, with each section containing carious dentin. These sections were randomly divided into four groups: Group A—application of SDF only; Group B—SDF followed by light curing for 20 seconds; Group C—SDF followed by 5% fluoride varnish without light curing; and Group D—SDF followed by fluoride varnish with light curing for 20 seconds. Penetration depth was measured using a high-resolution microscope at specific sites on each sample both before and after the application. The data were analyzed using ANOVA. **Results:** The results indicated no significant difference in SDF penetration depth with or without light curing, suggesting consistent efficacy in penetrating dental tissues. Similarly, the addition of fluoride varnish did not significantly alter penetration depth, regardless of light curing. **Conclusion:** Light curing or adding 5% fluoride varnish did not significantly influence the depth of the SDF penetration into the carious dentin of primary molars.

Keywords

SDF, Dental Caries, Fluoride Varnish, Primary Teeth, Silver Diamine Fluoride

1. Introduction

Since its introduction in Japan during the 1960s, Silver Diamine Fluoride (SDF) has progressively gained recognition for its dual action in arresting dental caries [1]. The silver component of SDF exhibits antimicrobial properties, inhibiting biofilm formation and eliminating cariogenic bacteria. Additionally, the fluoride component facilitates the remineralization of tooth structures and reduces the potential for future demineralization [1].

Silver Diamine Fluoride (SDF) was introduced in the United States in 2014 when the U.S. Food and Drug Administration approved its use for treating adult dentin hypersensitivity. Despite being used in other countries for decades, it only recently became available in the U.S. [2]. It is currently being used off-label [3] in the US for arresting caries, with this use also being present in Argentina, Australia, Brazil and China [4]. In a study by Horst *et al.*, five indications for the use of SDF were identified: extreme caries risk, challenges related to medical or behavioral management, patients with multiple carious lesions that cannot be treated in a single visit, difficult-to-treat carious lesions, and patients without access to dental care. SDF has demonstrated effectiveness in both primary and permanent dentitions, making it particularly valuable in pediatric and geriatric populations [5]. These are groups where a conventional restorative approach may be challenging. The SDF application approach allows for a simple and cost-effective strategy for the management of carious lesions.

SDF is presented in different concentrations, and it was recommended to be applied biannually. The biannual application of a 38% SDF solution was more likely to arrest advanced cavitated lesions in primary teeth than both the annual application of 38% SDF and the biannual application of a 12% SDF solution [6].

Even with its remarkable benefits, concerns regarding potential adverse effects of SDF remain. Issues such as tooth staining and soft tissue irritation have prompted ongoing research endeavors to optimize SDF formulations and application techniques. Additionally, emerging studies exploring novel adjunctive therapies, combinatorial approaches, and application techniques are being explored in order to enhance the therapeutic outcomes of SDF.

In addition to SDF, the application of 5% Sodium Fluoride (NaF) varnish on the area of the tooth treated with SDF has been shown to increase the rate of caries arrest [7]. They saw an increase in the rate of caries arrest in pediatric teeth from 73.2% up to 77.7% after the NaF varnish application. NaF can help with the remineralization and cessation of the caries growth through two main mechanisms. First the NaF helps to more rapidly grow Fluorapatite crystals on the surface of the tooth through drawing in Ca ions for crystal formation [8]. In addition to this fluoride can become harmful to bacteria in the acidic environments they produce through entering the bacteria and inhibiting metabolic functions [9]. Both of these are benefits seen after carious activity has begun. This is also of importance since research by Clemens *et al.* has shown that SDF SDF provides a simple and highly effective nonsurgical alternative to traditional restorative dental treatment for young children. It holds significant potential to help the dental public health community address dental caries in at-risk populations [10]. NaF varnish in addition to the SDF increases the chances of remineralization of both the enamel and the dentin. Finally, the addition of the 5% NaF varnish acts as a barrier for the recently placed SDF. The SDF solution has greater success with increased contact with the tooth. Saliva can dilute the solution leading to decreased outcomes, but also unwanted staining of other oral tissues from the solution spreading. It additionally acts to cover the foul, bitter taste that is associated with the treatments [11] [12]. This can help increase patient acceptance of future applications, since repeated applications are necessary.

The use of LED curing lights after application of SDF have led to changes in the success of the SDF penetration [13]. With or without these additional interventions the SDF was able to penetrate into the carious tooth structure. Other studies have shown that the presence of SDF alone increases the hardness of the treated dentin [14]-[16]. Toopchi *et al.* [13] found that following the dental curing the SDF led to increased silver precipitation into the infected dentin 2.6 times greater than if the dental curing light had not been used. Additionally, they found that the dentin hardness was 26% greater than the control in the areas that had the curing light. Additionally, NaF varnish is often placed over areas of SDF application, but this technique is not standardized. The technique was evaluated to assess potential treatment outcome benefits instead of the compliance factor for which it is often attributed. Incorporating light curing and fluoride varnish application with SDF has been proposed to enhance its therapeutic efficacy. This approach may improve fluoride uptake, minimize discoloration, and promote the formation of a more durable protective layer, thereby optimizing clinical outcomes. The aim of this investigation is to evaluate the effect of SDF treatment, with and without subsequent application of fluoride varnish and light curing, on the depth of SDF penetration into the dentinal tubules of primary carious teeth. The aim of this investigation is to assess the impact of SDF treatment, with and without subsequent fluoride varnish application and light curing, on the depth of SDF penetration into the dentinal tubules of primary carious teeth.

2. Materials and Methods

The calculated sample size for this study was 40 teeth, determined based on a significance level (α) of 0.05, a statistical power of 80% ($\beta = 0.2$), and data derived from a previously published reference study [17]. The sample size was increased to 50 teeth to compensate for loss or fractures. Fifty extracted primary molars with cavitated carious lesions were collected from pediatric clinics at the University of Nevada, Las Vegas. Only teeth exhibiting visible cavitation due to caries were included in the study. The teeth were thoroughly cleaned to remove any residual tissue or debris. Prior to experimentation, the teeth underwent sterilization according to standard protocols. Before sectioning, the teeth were disinfected and stored in artificial saliva (Pickering Laboratories, CA, USA). The 50 teeth were sectioned into halves using a water-cooled diamond bur, ensuring that each section contained carious tissue, thereby providing a consistent basis for comparative analysis (**Table 1**).

Table 1. Examined materials that were applied over the carious lesion.

Materials	Brand	Composition	Lot Number
SDF	SDI RivaStar (Bayswater, Australia)	35% - 40% Silver Fluoride, 15% - 20% Ammonia, Balanced with water	11731571
Fluoride Varnish	Young D-Lish (Algonquin, Illinois) Green Apple, 0.4 mL	10% - 25% Ethanol, 2.5% - 5% Sodium Fluoride	2314579

SDF penetration depth was measured both before and after treatment application using a digital microscope (VR-3100; Keyence, Japan) at standardized, predetermined locations. These locations were selected at fixed distances from the cavity margin, ranging from 250 µm to 650 µm depending on the extent of the carious lesion, to ensure consistency across all samples. For each specimen, measurements were taken at two equidistant points along the longitudinal section, and the average value was calculated. Following the initial measurements, the same halves of the teeth in Groups B and D were immediately light-cured for 20 seconds using a VALO LED curing light (Ultradent, UT, USA), which emits high-intensity, multiwavelength light in the 385 - 515 nm range. SDF penetration depth was then reassessed at the same marked locations. Figure 1 has been added to illustrate the measurement protocol and standardization of measurement sites. SPSS 24 (SPSS, IBM) was used for statistical calculations. Analysis of the data was performed using analysis of variance (ANOVA) to detect changes between the groups and within the groups.

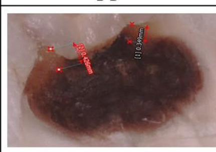
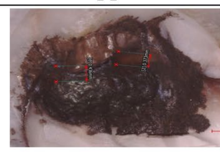
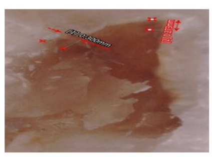
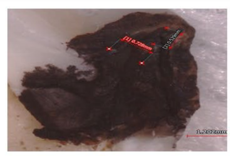
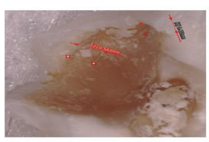
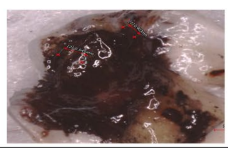
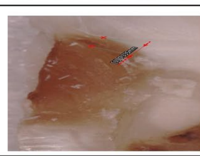
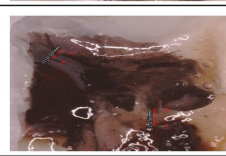
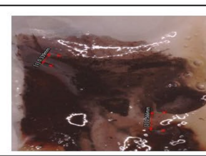
Group	Pre-application	Post application	Post light curing
Group A			No light curing was conducted for this group
Group B			
Group C			No light curing was conducted for this group
Group D			

Figure 1. All examined groups pre and post treatments.

3. Results

All treatment groups were assessed for the depth of penetration of SDF into carious primary molars. The results showed no significant difference in the depth of SDF penetration pre- and post-light curing. Similarly, there was no significant difference in penetration depth when SDF was combined with fluoride varnish, whether or not light curing was applied. High-magnification imaging of the samples post-treatment, using the VHX 7000N Digital Microscope (Keyence, Japan), revealed the presence of SDF within the dentinal tubules (**Figure 2**).

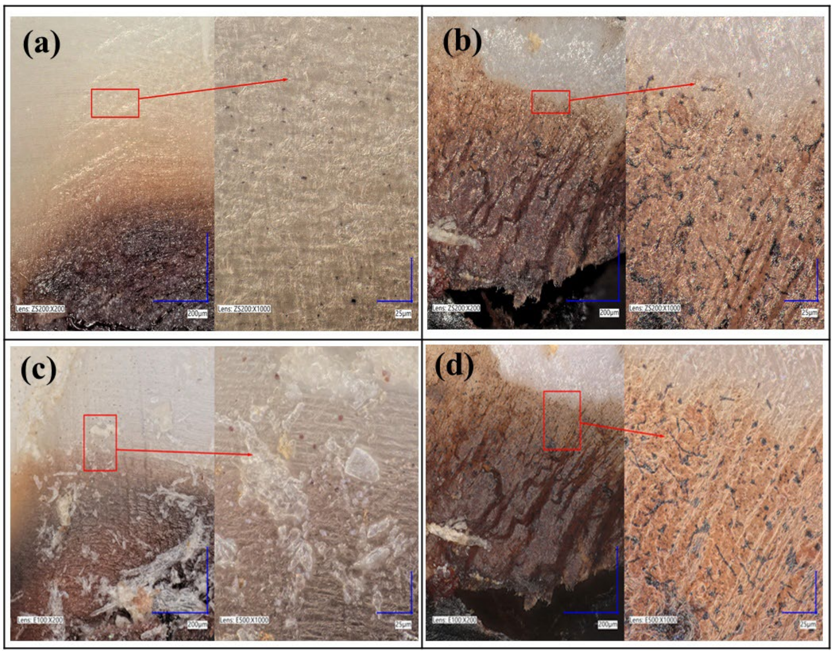


Figure 2: Treatment groups under higher magnification (200 - 1000 μm, using VHX-7100 Camera, E20, E100, E500 Lenses Keyence, USA). *(a) SDF only; (b) SDF + cure; (c) SDF + varnish; (d) SDF + varnish+ cure.

4. Discussion

Evidence suggests that SDF is highly effective in managing caries in both primary and permanent dentitions [5]. Recently, there has been an interest in the use of light-curing with SDF to enhance its penetration into the dentin and increase the hardness of dentin in carious teeth. The observed increased hardness of the dentin following the light-curing may offer significant benefit justifying its use.

Clinical observations and subjective evidence suggest that the use of curing light after drying appears to improve caries arrest in posterior areas not exposed to natural light, as light-cured surfaces immediately darken, and dental light curing has been associated with increased precipitation of silver ions in the infected dentin layer of the carious lesion. Light exposure significantly accelerates the rate of color change in dentin treated with SDF [2] [13] [17]-[19]. However, this might indicate that the dental curing light does not significantly penetrate the deeper layers of the carious lesion beyond the surface layer of the infected dentin.

The dark coloration of the infected dentin may have limited the penetration depth of the curing light. Since dental light curing accelerates the reduction of the silver solution, omitting the curing light could allow more time for the solution to penetrate the carious lesion, releasing ions more gradually before reduction occurs. It has been reported that light curing triggers the precipitation of silver ions into metallic silver. The silver ions in SDF partially bind with specific amino acids in the collagen of exposed dentin and are subsequently reduced to metallic silver. This process significantly impacts the color of the dentin, leading it to darken or turn black following the application of SDF. The increase in silver particle size is associated with this darkening of color [19]. It is important to note that the penetration depth observed in ex vivo studies may overestimate the actual depth of penetration in clinical settings. This discrepancy is likely due to sample dehydration and the absence of outward positive pressure in non-extracted teeth [20].

Previous studies have demonstrated that when light curing is applied to SDF, as opposed to SDF alone, there is a marked increase in dentin hardness beneath the carious lesion [13] [19] [21]. The dentin hardness increase is likely due to the silver high polarizing capacity, that contributed for well-built bonding to oxygen, sulfur and phosphate groups resulting in silver oxide, silver sulfide, and silver phosphate after disclosure of light [21]. The enhanced dentine hardness suggests a stronger and denser tooth structure within the carious lesion, that may help to prevent further advancement of decay [2].

A recent systematic review found that silver ion precipitation in SDF with light curing was significantly higher in the infected dentine compared to SDF alone, with no differences observed in affected or sound dentine. It is possible that the accelerated reduction of silver ions caused by light curing does not allow sufficient time for penetration into the deeper layers of the carious lesion, resulting in less penetration depth and increased silver precipitation in the infected dentine [22].

In the current investigation, the depth of SDF penetration into carious primary molars remained consistent regardless of light curing. Statistical analysis revealed no significant difference in penetration depth before and after curing, indicating the efficacy and reliability of SDF treatment. This finding aligns with Lau *et al.* (2021), who concluded that there was no significant difference in silver penetration depth between groups treated with SDF alone and those treated with SDF combined with light curing in non-carious primary molars in an *in vitro* study [23]. However, the differing results concerning SDF penetration into carious dentine may be attributed to variations in sample preparation, dehydration, the type of teeth used in the studies, and the extent of demineralization [17].

NaF varnish is known for its ability to remineralize enamel caries, while silver diamine fluoride (SDF) is effective in arresting dentine caries [7] [24]. Consequently, the combination of these agents may enhance the caries arrest rate across different stages of caries progression. Applying NaF over SDF could also prolong the contact time of SDF with the carious lesion, reducing the impact of oral environmental factors such as salivary flow [12]. This approach has been shown to be particularly effective in achieving a higher caries arrest rate in moderate carious lesions [16].

The present investigation's results indicated that the application of NaF varnish did not significantly change the penetration depth of SDF. The penetration was assessed based on visual changes in color and surface roughness observed under a microscope at 50x magnification. Adding fluoride varnish to SDF treatment did not significantly alter the penetration depth into dental tissues. Before and after light curing, fluoride varnish did not result in notable changes in penetration depth when compared to SDF treatment alone. While this study provides valuable insights, further research is warranted to investigate additional factors that may influence the interaction between SDF, fluoride varnish, and light curing. A key limitation of the present ex vivo study is the lack of information regarding the patients from whom the extracted primary teeth were obtained. Moreover, as an *in vitro* investigation, it does not fully replicate the complexities of the oral environment. Therefore, long-term clinical studies are essential to evaluate the durability of SDF treatment outcomes and to identify any potential adverse effects, which are critical for informing evidence-based clinical practice.

5. Conclusion

Within the limitations of this study, it can be concluded that the depth of silver diamine fluoride penetration into carious primary molars was not significantly affected by the use of light curing, whether applied to SDF alone or in combination with fluoride varnish. These findings suggest that the use of additional steps such as light curing or varnish application may not be necessary to enhance SDF efficacy in terms of dentin penetration. This has important clinical implications, particularly for pediatric dentists and practitioners in public health settings, where simplifying treatment protocols can improve efficiency, reduce costs, and increase access to care for underserved populations.

Acknowledgements

The authors would like to acknowledge Joel Leslie, Engineer of Advanced Microscope Technology at Keyence Corporation of America, for his invaluable assistance with imaging the samples.

Author Contribution

Conceptualization: T.A. and N.H.A Investigation: T.A., C.P., B. P., N.H.A. Formal Analysis: T.A. C.P., and N.H.A Validation: Tatiana Alhwayek, T.A., C.P., B. P., N.H.A. Draft of manuscript: T.A. C.P., and N.H.A. And Project Administration: N.H.A.. All authors approved the final version of the manuscript.

Ethical Policy and Institutional Review Board Statement

The research was reviewed and approved by Ethics Committee of the UNLV, SDM

(IRB#: UNLV-2024-361).

Data Availability Statement

The data that support the study results are available from the author (Dr. Neamat Hassan Abubakr e-mail: neaamat.hassan@unlv.edu on request.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Fung, M.H.T., Duangthip, D., Wong, M.C.M., Lo, E.C.M. and Chu, C.H. (2017) Randomized Clinical Trial of 12% and 38% Silver Diamine Fluoride Treatment. *Journal of Dental Research*, **97**, 171-178. https://doi.org/10.1177/0022034517728496

[2] Duangthip, D., Fung, M.H.T., Wong, M.C.M., Chu, C.H. and Lo, E.C.M. (2017) Adverse Effects of Silver Diamine Fluoride Treatment among Preschool Children. *Journal of Dental Research*, **97**, 395-401. https://doi.org/10.1177/0022034517746678

[3] Gao, S.S., Amarquaye, G., Arrow, P., Bansal, K., Bedi, R., Campus, G., *et al.* (2021) Global Oral Health Policies and Guidelines: Using Silver Diamine Fluoride for Caries Control. *Frontiers in Oral Health*, **2**, Article ID: 685557. https://doi.org/10.3389/froh.2021.685557

[4] Chu, C.H. and Lo, E.C.M. (2008) Promoting Caries Arrest in Children with Silver Diamine Fluoride: A Review. *Oral Health and Preventive Dentistry*, **6**, 315-321.

[5] Horst, J.A., Ellenikiotis, H. and Milgrom, P.L. (2016) UCSF Protocol for Caries Arrest Using Silver Diamine Fluoride: Rationale, Indications and Consent. *Journal of the California Dental Association*, **44**, 17-28. https://doi.org/10.1080/19424396.2016.12220962

[6] Fung, M.H.T., Duangthip, D., Wong, M.C.M., Lo, E.C.M. and Chu, C.H. (2016) Arresting Dentine Caries with Different Concentration and Periodicity of Silver Diamine Fluoride. *JDR Clinical & Translational Research*, **1**, 143-152. https://doi.org/10.1177/2380084416649150

[7] Gao, S.S., Zhang, S., Mei, M.L., Lo, E.C. and Chu, C. (2016) Caries Remineralisation and Arresting Effect in Children by Professionally Applied Fluoride Treatment—A Systematic Review. *BMC Oral Health*, **16**, Article No. 12. https://doi.org/10.1186/s12903-016-0171-6

[8] Featherstone, J.D.B. (1999) Prevention and Reversal of Dental Caries: Role of Low Level Fluoride. *Community Dentistry and Oral Epidemiology*, **27**, 31-40. https://doi.org/10.1111/j.1600-0528.1999.tb01989.x

[9] Van Loveren, C. (1990) The Antimicrobial Action of Fluoride and Its Role in Caries Inhibition. *Journal of Dental Research*, **69**, 676-681. https://doi.org/10.1177/00220345900690s131

[10] Clemens, J., Gold, J. and Chaffin, J. (2017) Effect and Acceptance of Silver Diamine Fluoride Treatment on Dental Caries in Primary Teeth. *Journal of Public Health Dentistry*, **78**, 63-68. https://doi.org/10.1111/jphd.12241

[11] Abdellatif, E.B., El Kashlan, M.K. and El Tantawi, M. (2023) Silver Diamine Fluoride with Sodium Fluoride Varnish versus Silver Diamine Fluoride in Arresting Early Childhood Caries: A 6-Months Follow up of a Randomized Field Trial. *BMC Oral Health*, **23**, Article No. 875. https://doi.org/10.1186/s12903-023-03597-5

[12] Martin, H., Patterson, B., Mittermuller, B.A., Lee, V. and Moffatt, M.E. (2020) The Effectiveness of Silver Diamine Fluoride and Fluoride Varnish in Arresting Caries in Young Children and Associated Oral Health-Related Quality of Life. *Journal of the Canadian Dental Association*, **86**, 1488-2159.

[13] Toopchi, S., Bakhurji, E., Loo, C.Y. and Hassan, M. (2021) Effect of Light Curing on Silver Diamine Fluoride in Primary Incisors: A Microscopic *ex Vivo* Study. *Pediatric Dentistry*, **43**, 44-49.

[14] Chu, C.H., Mei, L., Seneviratne, C.J. and Lo, E.C.M. (2011) Effects of Silver Diamine Fluoride on Dentine Carious Lesions Induced by *Streptococcus mutans* and *Actinomyces naeslundii* Biofilms. *International Journal of Paediatric Dentistry*, **22**, 2-10. https://doi.org/10.1111/j.1365-263x.2011.01149.x

[15] Lee, J.J., Nettey-Marbell, A., Cook, A., Pimenta, L.A.F., Leonard, R. and Ritter, A.V. (2007) Using Extracted Teeth for Research: The Effect of Storage Medium and Sterilization on Dentin Bond Strengths. *The Journal of the American Dental Association*, **138**, 1599-1603. https://doi.org/10.14219/jada.archive.2007.0110

[16] Prakash, M., Kang, Y.H., Jain, S. and Zandona, A.F. (2021) *In-Vitro* Assessment of Silver Diamine Fluoride Effect on Natural Carious Dentin Microhardness. *Frontiers in Dental Medicine*, **2**, Article ID: 811308. https://doi.org/10.3389/fdmed.2021.811308

[17] Karnowakul, J., Punyanirun, K., Jirakran, K., Thanyasrisung, P., Techatharatip, O., Pornprasertsuk-Damrongsri, S., *et al.* (2022) Enhanced Effectiveness of Silver Diamine Fluoride Application with Light Curing on Natural Dentin Carious Lesions: An in Vitro Study. *Odontology*, **111**, 439-450. https://doi.org/10.1007/s10266-022-00755-z

[18] Zhi, Q.H., Lo, E.C.M. and Lin, H.C. (2012) Randomized Clinical Trial on Effectiveness of Silver Diamine Fluoride and Glass Ionomer in Arresting Dentine Caries in Preschool Children. *Journal of Dentistry*, **40**, 962-967. https://doi.org/10.1016/j.jdent.2012.08.002

[19] Sayed, M., Matsui, N., Hiraishi, N., Inoue, G., Nikaido, T., Burrow, M.F., *et al.* (2019) Evaluation of Discoloration of Sound/Demineralized Root Dentin with Silver Diamine Fluoride: *in- Vitro* Study. *Dental Materials Journal*, **38**, 143-149. https://doi.org/10.4012/dmj.2018-008

[20] Li, Y., Liu, Y., Poster, W.J., Nguyen, O.M., Bromage, T.G., Walters, M.A., *et al.* (2019) Assessment of Silver Penetration and Distribution in Carious Lesions of Deciduous Teeth Treated with Silver Diamine Fluoride. *Caries Research*, **53**, 431-440.

[21] Hassan, M., Bakhurji, E. and AlSheikh, R. (2021) Application of Er, Cr: YSGG Laser versus Photopolymerization after Silver Diamine Fluoride in Primary Teeth. *Scientific Reports*, **11**, Article No. 20780.

[22] Min, S.N., Duangthip, D. and Detsomboonrat, P. (2024) Effects of Light Curing on Silver Diamine Fluoride-Treated Carious Lesions: A Systematic Review. *PLOS ONE*, **19**, e0306367. https://doi.org/10.1371/journal.pone.0306367

[23] Lau, L., *et al.* (2021) Effect of Surface Preparation and Light Curing on Penetration of Silver Particles from 38% Silver Diamine Fluoride in Dentin of Primary Teeth: An *in Vitro* Evaluation. *American Journal of Dentistry*, **34**, 44-48.

[24] Crystal, Y.O. and Niederman, R. (2016) Silver Diamine Fluoride Treatment Considerations in Children's Caries Management. *Pediatric Dentistry*, **38**, 466-471.