Clinical application of fluorescence lasers to evaluate the efficacy of arresting caries with silver diamine fluoride

Vo Truong Nhu Ngoc*, **Ha Noi Medical University*,
Bui Viet Hung,** ***108 Institute of Clinical Medical and Pharmaceutical Sciences*,
Bui Huu Tuan,***** ****ThaiBinh University of Medicine and Pharmacy*

Summary

Objective: This clinical trial used fluorescence lasers to assess the effectiveness of Silver Diamine Fluoride (SDF) in preventing active dentin caries in baby teeth. *Subject and method:* Preschool children aged 3 to 5 years old with at least one active dentin caries lesion were selected from a SOS Children's Village in Vietnam. A total of 32 children with 126 caries lesions were treated with 38% SDF, applied only once. DIAGNOdent pen 2190 - Kavo device and sharp sickle-shaped probes were used to evaluate lesions independently at certain timepoints including: Before the intervention and 5 minutes, one day, and one week after the intervention. For the evaluation of treatment results, the caries lesions were diagnosed as prevented if their surfaces were hard and difficult to probe or the measured laser index ≤ 20, while the lesions were assessed as active if they were soft and easy to probe or the measured laser index > 20. *Result:* In general, before SDF was applied, all decayed tooth surfaces had soft dentin and laser indexes > 30. The average value of laser index measured on caries lesions was significantly reduced from 88.2 (SD = 9.3) at baseline to 19.6 (SD = 13.7) at one week after intervention ($p<0.001$, χ^2 test). Based on fluorescence laser method, the caries arrest rates were 80.2%, 73.2% and 70.6% respectively for the post-intervention periods, while the assessment by probes for caries arrest rates were 82.5%, 80.2% and 77.8%, respectively ($p<0.05$, χ^2 test). The difference between the two methods was due to some caries lesions that were smooth and hard on probing but still have laser index > 20. *Conclusion:* The fluorescence laser device can be applied clinically to assess the effectiveness of preventing caries with SDF, the evaluation results are more accurate than the lesion probe method.

Keywords: Silver diamine fluoride, fluorescence laser, caries, preventive dentistry, clinical trial.

1. Background

Early childhood caries (ECC) is defined as the occurrence of one or more caries lesions, tooth loss related to caries, or the presence of restored decayed tooth surfaces in the children's temporary teeth under 71 months of age [1]. It is also considered the most common pediatric diseases, affecting more than 60% of children worldwide [2, 3]. According to a study in Vietnam in 2016 on 369 children aging 4 year old, 91.9% children had ECC, of which 77% had dentine decay, S-ECC prevalence is 64.0%. This showed that there is a great need for decay treatment to arest the decay progression [4]. Despite significant advances in restorative dentistry, therapeutic interventions for children still face many challenges because young children are often uncooperative with invasive procedures. Furthermore, due to lack of funding and resources so access to dental services for children is often limited, especially in areas with difficult circumstances. As a result, decayed baby teeth are frequently left untreated, affecting children's oral health [5-7].

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***Correspondence to:** Bui Huu Tuan - Thaibinh University of Medicine and Pharmacy*
***Email**: buituan.rhm@gmail.com*

In response to the increase of ECC, many countries have recently used Silver Diamine Fluoride (SDF) as an effective strategy to prevent tooth decay. The SDF mechanism is based on the antibacterial ability of silver and the ability to remineralize tooth structure with high fluoride content in its composition [8-10]. A systematic review by Chibinski et al showed that SDF's caries prevention efficiency is 89% (95% CI: 49-138%, p<0.00001) higher than any other materials or placebos [11, 12]. The advantages of SDF are minimally invasive, painless, simple technique and low cost. Therefore, SDF is considered an appropriate product to apply to young children and communities with limited dental care [13]. However, one of the disadvantages of SDF is that it does not fill carious lesions like conventional filling materials, so the treatment results are often questioned by the children's parents and sometimes even are both dentists who have access to the SDF for the first time. Convincing the dentist to use a new medical device such as SDF for the first time is sometimes difficult without a method having objective and visual evaluation.

In fact, there have been many clinical trials to evaluate the effectiveness of arresting caries with SDF. However, most of the previous studies were evaluated based on lesion probing with sharp sickle - shaped probes. Accordingly, a carious lesion is recorded as prevented if its surface is hard and difficult to probe, otherwise it would be an active caries lesion. The limitation of this method is that the diagnostic results are highly dependent on the assessor's clinical experience such as seeing and tactile sensation. In addition, probes can sometimes cause further damage to cavities that have not been prevented, causing irritation and fear in children. This can lead to the children's uncooperativeness in subsequent treatment interventions [14].

Another method can be applied to evaluate the therapeutic efficacy of the SDF is to observe the changes of the lesions. The hallmark of this method is that the prevented caries lesions will be dyed black due to the precipitation of silver phosphate. However, this sign is not specific because only about 70% of the lesions change color after SDF application and some of them are still active when assessed with the probes [11, 15].

To overcome the disadvantages of the above methods, in this study we used fluorescence laser device to evaluate the caries treatment results with SDF. Previously, there were studies demonstrating the effectiveness of fluorescence lasers in caries diagnosis with sensitivity and specificity over 90% [16]. However, in the listed studies, the authors used fluorescent lasers in the caries diagnosis, but did not apply the device to evaluatetreatment results. Therefore, demonstrating the effectiveness of fluorescent lasers in the early assessment of caries treatment outcomes is our main research goal.

In this application, the treatment results will be displayed through the change of the laser indexes measured on the caries lesions at the timepoints before and after the SDF application. Accordingly, the evaluation results are expected to be more accurate, objective and convincing than traditional observation and probing methods.

2. Subject and method

2.1. Participants

This study was conducted from a SOS Children's Village in the north of Vietnam, where disadvantaged children live and study. The village is located in Thai Binh province and is the 16th SOS village in Vietnam. In the village, there is an SOS kindergarten with a capacity of 100 children attending each year. Most of the children attending are orphans, abandoned and unfortunately lost the care of their original families, the rest are disadvantaged children living in the vicinity of the village. According to Vietnamese regulations, the child's caregivers have the right to decide whether or not to allow the child to participate in the research, just like the child's parents.

Selection criteria:

Healthy preschool children aged 3-4 years old.

Having guardian's consent.

Having at least one progressive caries lesions which is grade 3 according to the ICCMS classification and have a measured laser index > 30.

Exclusion criteria:

Children with severe systemic diseases or uncooperative with the dental examination and treatment.

Children with a history of allergies to silver and fluoride.

2.2. Method

The study was designed according to a controlled clinical trial method. Fluorescence laser device was used to evaluate caries treatment results and compare with traditional assessment methods such as visual inspection and probe examination.

2.3. Ethical consideration

This research was approved by the Ethics Board of Thai Binh University of Medicine and Pharmacy (code: 591). The participating children received oral health education from a dental professional and were regularly reinforced by kindergarten teachers. Participants may also leave the study at any time by notifying the investigator without affecting their original benefits from participating in the study. The study will be stopped immediately if the therapeutic intervention causes serious side effects on the child's systemic health. To minimize risks, all participating children are treated by the same experienced dental professional. Research results will be feedback to the guardians of the children and the school. All information related to research subjects is kept confidential and only disclosed in the form of data.

2.4. Sample size

The sample size was calculated based on the decays prevention rate with 38% SDF, which was determined to be 86% according to the study by Gao et al, 2016 [12]. Applying formula:

$$n = Z^2_{(1-\alpha/2)} \frac{p(1-p)}{d^2}$$

n: Sample size.

$Z_{1-\alpha/2}$ = 1.96 for 95% confidence interval.

p = 0.86 based on the decays prevention rate is 86%.

Delta (d): Error occurred in data selection (d = 0.12).

From the formula, the sample size has been calculated (n = 32 children) with 126 decays lesions were identified at baseline.

2.5. Intervention

After baseline examination, eligible decayed tooth surfaces received 38% SDF (e-SDF, K L Dental LLP, India) application, applied only once.

The process of applying SDF is done through the following steps:

1. The child is placed supine on the table with a cloth bib covering the chest.

2. Clean the cavities with a small brush without removing the carious dentin.

3. Separate the decayed teeth from the cheeks and tongue with cotton rolls and dry the area with gauze.

4. Use microsponge to get the SDF and apply it directly onto the decayed tooth surfaces. The waiting time is one minute for SDF to be absorbed, then remove excess with cotton rolls.

5. Take out the isolation cotton and let the child rinse mouth gently

6. Remind children not to eat or drink in the next 30 minutes.

a. Before b. After

Figure 1. Before and after applying SDF

2.6. Outcome measures

DIAGNOdent pen 2190-Kavo device and sharp sickle - shaped probes were used to evaluate lesions independently at certain timepoints including: before the intervention and 5 minutes, one day, and one week after the intervention.

For the evaluation of treatment results, the caries lesions were diagnosed as prevented if their surfaces were hard and difficult to probe or the measured laser index ≤ 20 (According to manufacturer), while the lesions were assessed as active if they were soft and easy to probe or the measured laser index > 20.

DIAGNOdent pen 2190-Kavo device [14, 15].

Operation principle: DIAGNOdent is a diagnostic tool based on laser fluorescence which measures the difference between the fluorescence of normal and carious dental tissue. DIAGNOdent gives each tissue a different score thus, reducing human error.

Process of use: DIAGNOdent was used according to the manufacturer's recommendations. Cylindrical sapphire tips that are compatible with tooth surfaces were mounted to the device and calibrated with a standard ceramic block supplied by the manufacturer. Before each measurement, the machine was reset to zero and calibrated on a sound and smooth enamel surface. After gentle drying for 5 sec, the tip of the device was placed on the surface of caries lesions and moved around its vertical axis. Each examiner performed three measurements for each test site and recorded the mean values. The cut-off points were applied to interpret the measurements and were coded as follows:

Table 1. Diagnostic scale with DIAGNOdent pen 2190 device

According to the manufacturer:

Cutoff limits	Diagnosis
0-14	Sound
15-20	Enamel caries or non progressive caries
≥ 21	Dentin caries or progressive caries

[1]Limit value of the device is from 0-99.

Figure 2. DIAGNOdent pen 2190 device

2.7. Statistical analyses

The data were entered with Epidata 3.1 software and analyzed with SPSS 23.0 software according to the medical statistical method. The analyzes were performed at the tooth surface level and the data were presented as frequencies, percentages, mean and standard deviation (SD). The chi-square test was used to express the difference in caries arrest rates with SDF between two independent methods of assessment based on lasers and probes, the analysis results were recorded to be statistically significant with the value of $p<0.05$. To evaluate the reliability of surveyors in diagnosing caries lesions and evaluating treatment outcomes, we used Kappa statistics. Accordingly, if the kapa index is greater than 0.75 it corresponds to a high degree of concordance, while a value between 0.4 and 0.75 indicates moderate and below 0.4 is considered low.

3. Result

A total of 32 preschool children including 19 boys and 13 girls with 126 caries lesions were treated with 38% SDF. At baseline, all decayed tooth surfaces had soft dentin and laser index > 30. Their meanage was 3.8 (±0.5 [SD]) years old.

Partition of caries lesions

At the tooth level: The caries lesions were more concentrated in the incisors and canines, accounting for 61.2%.

At the tooth surface level, carious lesions were distributed as follows: Mesial (29.1%), occlusal (26.3%), labial and buccal (19.2%), distal (15.7%), and lingual (9.7%) surfaces. Nearly all lesions showed the occurrence of plaque on the surface.

Effectiveness of 38% SDF in arresting decays:

There was a significant decrease in laser index measured on the surface of caries lesions at the time before and after the intervention.

Table 2. Laser indexes were measured at the time before and after the intervention

Before (Mean± SD)	After (Mean ± SD)		p
88.2 ± 9.3	5 minutes	13.8 ± 11.5	<0.001
	24 hours	18.7 ± 10.2	
	1 week	19.6 ± 13.7	
Chi-squaretest			

Based on fluorescence laser method, the decays arrest rates were 80.2%, 73.2% and 70.6% respectively for the post-intervention periods, while the assessment by probes for caries arrest rates were 82.5%, 80.2% and 77.8%, respectively (p<0.05).

Table 3. The caries arrest rates were evaluated based on the laser index and lesion probe

After the intervention	Laser n/N (%)	Probe n/N (%)	p
5 minutes	101/126 (80.2)	104/ 126 (82.5)	
24 hours	92/126 (73.2)	101/126 (80.2)	<0.05
1 week	89/126 (70.6)	98/126 (77.8)	
n: The number of arrested decayed tooth surfaces (n = 126) Chi-square test			

4. Discussion

There were statistically significant differences in the caries prevention rates between two evaluation methods based on fluorescence lasers and probes. The difference is due to some post-intervention caries lesions that became smooth and hard on probing but still had laser indexes > 20, meaning that these lesions were arrested based on the probe assessment but were not arrested according to the laser device's diagnostic criteria. This showed that the use of fluorescence laser reduced the diagnostic error of the probe method, which is highly dependent on the evaluator's senses and clinical experience. The above statement is also consistent with the results from previous studies showing that the accuracy and objectivity of the laser device in diagnosing caries is superior to the observation method or lesion exploration [16].

Another advantage of the fluorescence laser when compared with traditional methods is that the results of caries treatment with SDF can be clearly seen through the changes of the laser indexes displayed on the screen of the device, at the timepoints before and immediately after the intervention. Being able to see the results of treatment immediately plays an important role in convincing the children's parents and even both dentists in the effectiveness of the SDF's caries treatment. In addition, when evaluating with fluorescence lasers, we put on eye protection glasses for children so that they can observe the

light emiting from the device head, which reminds them of the light sticks of supermans. In fact, most of the children showed great interest instead of apprehension when exposed to sharp probes, which often causes dental fear syndrome in children. In Vietnam, a study on dental fear syndrome in 7-year-old children showed that 34.85% of 132 children participating in the study were afraid of going to the dentist, and the common fears of children were needles and sharp dental instruments. This study also showed that children with dental fear often lead to uncooperative behaviors and interfere with dentists in treating caries; Furthermore, if the methods of diagnosing and treating tooth decay are not thoroughly and appropriately adjusted to the shy kids, it will continue to be an uncomfortable experience and exacerbate the children's dental phobia. As a result, children with dental phobia had a 1.7 times higher rate of serious caries lesions than children without the syndrome [10]. Other studies around the world have also shown that dental fear is very common in young children [1]. According to the study by Suman Panda et al., the dental phobia significantly predicts the presence of untreated carious lesions in children. Specifically, this study demonstrated that children who were afraid of going to the dentist and were afraid of dental treatments had two times higher rates of untreated caries than children who were not afraid. One explanation has been suggested that children are afraid of pain and afraid of painful dental instruments, so they do not want to go to the dentist, thereby increasing the presence of tooth decay [5]. Thus, it is necessary to minimize the use of dental instruments which are not child-friendly, especially sharp tools such as needles or probes, so that children can cooperate more easily for treatment.

The effectiveness of the intervention in this study was assessed much earlier than in other clinical trials with SDF. Specifically, we evaluated at the timepoints immediately after the intervention and one week after the intervention instead of six months or one year like previous studies. The average caries prevention rate at 6 months after intervention in previous studies was about 65.9% (95% CI: 41.2%-90.7%, p<0.001) [7, 9, 11]. The higher rate recorded in this study may be due to the response of SDF was strongest in the first days after the intervention.

This study showed that the effectiveness of arresting caries with 38 % silver diamine fluoride tends to decrease over time. Specifically, the caries arrest rate based on the assessment of the fluorescence laser device is 80.2% at 5 minutes after the intervention but has decreased significantly to 70% after one week. These results suggest that a one-week follow-up to re-evaluate treatment outcomes is necessary. If the caries lesions show no signs of being arrested (i.e.measured laser index on the surface of the lesion > 20), they should be reapplied with 38% SDF immediately rather than six months later. Our assessment is similar to an earlier recommendation of the American Academy of Pediatric Dentistry (AAPD) on guidelines for the use of SDF. Accordingly, carious lesions treated with SDF should be re-examined after 2-4 weeks to evaluate the effectiveness of the intervention. If serious caries lesions show no signs of being prevented, lesions should be re-treated with SDF immediately at the visit. For follow-up treatments, the AAPD recommends applying SDF every 6 months; Repeat treatments are essential as it has been shown to increase the caries capture rate of SDF [9-11].

This trial also showed the safety of SDF when applied to young children. During the intervention and follow-up, we did not find any serious side effects affecting the overall health of the children. The most common adverse effect is SDF permanent darkening of carious lesions. However, this is easily accepted with the baby teeth. The results of this study are consistent with previous reports that SDF did not cause serious side effects among children [11].

One of the disadvantages of SDF is that the bitter taste of SDF can make children uncomfortable and lead to uncooperative behavior. To overcome this phenomenon, in addition to isolating the damaged teeth well with cotton rolls, we need to pay attention to the technique of taking SDF. In our experience, when we take the SDF, we put one drop in a porcelain cup and use a small cotton swab to

get the SDF. After dipping a sufficient amount of SDF, we placed the tip of the cotton swab on the side of a cup, a dry area without SDF with an angle of about 45 degrees to let the excess SDF flow down. By doing so, we controlled the excess amount of SDF and at the same time saved materials, thereby avoiding the SDF falling into the mouth, causing discomfort to the child and causing mucosal damage. In addition, this also helps to prevent the SDF from spilling onto the dental chair, damaging the surface of the dental chair and the costumes of the doctors and assistants.

The restrictions of this study are the small sample size and short follow-up time.

However, our main research objective in this study was to early evaluate the effectiveness of caries prevention with SDF through the application of fluorescent lasers, an evaluation device that provides accuracy and objectivity to persuade doctors to use SDF more widely as well as convince children's parents to use SDF to prevent the development of caries in necessary cases. Beside, in the next stage of the study, we also plan to expand the sample size and continue to use fluorescence lasers to evaluate the effectiveness of 38% SDF at 6 months and one year after the intervention.

5. Conclusion

Both evaluation methods showed the effectiveness of 38% SDF in preventing active dentin cays of baby teeth among kindergarten children. Evaluation results based on fluorescence lasers were more accurate and objective than the lesion probe method. Therefore, it is possible to apply clinically the fluorescence laser device to assess the efficacy of SDF in preventing caries.

Author Contributions:

V.T.N. Ngoc, Supervisor, contributed to the idea formation, research orientation, and edited the manuscript seriously. B.H. Tuan, contributed to the idea formation, data collection and analysis, drafted and edited the manuscript seriously. B.V. Hung, Supervisor, contributed to data interpretation, critically edited the manuscript.

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References

1. American Academy of Pediatric Dentistry Council on Clinical Affairs (2016) *Policy on Early Childhood Caries* (ECC): Unique Challenges and Treatment Options. Pediatric. Dent 38: 55-56.
2. Duangthip D, Gao SS, Lo EC, Chu CH (2017) *Early childhood caries among 5-to 6-year-old children in Southeast Asia*. Int Dent J 67(2): 98-106.
3. Dickson-Swift V, Kenny A, Gussy M, de Silva AM, Farmer J, Bracksley-O'Grady S (2017) *Supervised toothbrushing programs in primary schools and early childhood settings: A scoping review*. Community Dent Health 34(4): 208-225.
4. Seow WK (2018) *Early Childhood Caries.* Pediatr Clin North Am 65(5): 941-954.
5. Meyer F and Enax J (2018) *Early Childhood Caries: Epidemiology, Aetiology, and Prevention*. Int J Dent 2018: 1415873.
6. Chen KJ, Gao SS, Duangthip D, Lo ECM, Chu CH (2018) *Managing Early Childhood Caries for Young Children in China*. Healthcare (Basel) 6(1):11.
7. Zhao IS, Gao SS, Hiraishi N, Burrow MF, Duangthip D, Mei ML, Lo EC, Chu CH (2018*) Mechanisms of silver diamine fluoride on arresting caries: a literature review*. Int Dent J 68(2): 67-76.
8. Burgess JO and Vaghela PM (2018) *Silver Diamine Fluoride: A Successful Anticarious Solution with Limits*. Adv Dent Res 29(1): 131-134.
9. Horst JA (2018) *Silver Fluoride as a Treatment for Dental Caries*. Adv Dent Res 29(1): 135-140.

10. Duangthip D, Fung MHT, Wong MCM, Chu CH, Lo ECM (2018) *Adverse Effects of Silver Diamine Fluoride Treatment among Preschool Children.* J Dent Res 97(4): 395-401.
11. Chibinski AC, Wambier LM, Feltrin J, Loguercio AD, Wambier DS, Reis A (2017) *Silver Diamine Fluoride Has Efficacy in Controlling Caries Progression in Primary Teeth: A Systematic Review and Meta-Analysis.* Caries Res 51(5): 527-541.
12. Gao SS, Zhao IS, Hiraishi N, Duangthip D, Mei ML, Lo ECM, Chu CH (2016) *Clinical Trials of Silver Diamine Fluoride in Arresting Caries among Children: A Systematic Review*. JDR Clin Trans Res 1(3): 201-210.
13. Sheehy EC, Brailsford SR, Kidd EA, Beighton D, Zoitopoulos L (2001) *Comparison between visual examination and a laser fluorescence system for in vivo diagnosis of occlusal caries*. Caries Res 35(6): 421-426.
14. Duruturk L, Ciftçi A, Baharoğlu S, Oztuna D (2011) *Clinical evaluation of DIAGNOdent in detection of occlusal caries in newly erupted noncavitated first permanent molars in caries-active children*. Oper Dent 36(4): 348-55.
15. Serdar Akarsu e al (2018*) In Vitro Comparison of ICDAS And DIAGNOdent Pen in The Diagnosis and Treatment Decisions of Non -Cavitated Occlusal Caries. ODOVTOS-Int*. J. Dental Sc 21: 67-81.
16. Fung MHT, Duangthip D, Wong MCM, Lo ECM, Chu CH (2018*) Randomized Clinical Trial of 12% and 38% Silver Diamine Fluoride Treatment*. J Dent Res 97(2): 171-178.
17. Contreras V, Toro MJ, Elías-Boneta AR, Encarnación-Burgos A (2017) *Effectiveness of silver diamine fluoride in caries prevention and arrest: a systematic literature review*. Gen Dent 65(3): 22-29.
18. Milgrom P, Horst JA, Ludwig S, Rothen M, Chaffee BW, Lyalina S, Pollard KS, DeRisi JL, Mancl L (2018) *Topical silver diamine fluoride for dental caries arrest in preschool children: A randomized controlled trial and microbiological analysis of caries associated microbes and resistance gene expression*. J Dent 68: 72-78.