Effectiveness of Silver Diamine Fluoride in Arresting Early Childhood Caries in Myanmar Preschool Children

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Abstract: ***Objectives:*** The purposes of this study were to investigate the caries arresting effect of silver diamine fluoride (SDF) on primary tooth surfaces, and to assess the effect of SDF on cariogenic bacteria among Myanmar children.

Methods: A 6-month intervention study was conducted for 201 preschool children, who were allocated to two groups; Group A received SDF and sodium fluoride (NaF) applications, and Group B received only NaF application. A clinical oral examination, caries risk tests and oral health education were performed at baseline and 6-month follow-up.

Results: All caries risk test scores significantly decreased in Group A, but no significant changes in Group B after six months. In Group A, the proportion of arrested carious surfaces was 72.0% at 6-month follow-up. Overall, the incisors showed the highest proportion of arrested carious lesions while second molars had the lowest in both arches. The buccal lesions were most arrested by SDF in both anterior and posterior teeth. Lingual lesions in anterior teeth and the distal lesions in posterior teeth were least arrested by SDF.

Conclusion: SDF was effective not only in arresting carious lesions but also in diminishing the quantity of cariogenic bacteria present and acid production.

Keywords: Silver diamine fluoride, Caries risk tests, Arrested carious lesions.

1. INTRODUCTION

Dental caries, one of the most common oral diseases, has been declining among children and adolescents in developed countries [1]. However, dental caries remains epidemic and is a major oral health problem in many developing countries [2,3]. Early and effective treatment of dental caries is important because progression of untreated caries may result in the deterioration not only of children's general health but also of quality of life [4,5].

Myanmar is one of the developing countries in Southeast Asia and children's oral health is in an unfavorable condition. A previous study reported that the prevalence of dental caries in 3-4 years old children was 82.9% with mean dmft of 6.42 [1]. In some neighboring countries, the caries prevalence in children are also high: 79% in Thailand, 89% in Laos, and 66% in China [5]. Despite the high caries prevalence in Myanmar children, no practical measures to prevent and treat dental caries have been taken.

There are various methods to manage dental caries in children including restoration, extraction and use of fluoridated agents, etc. Among these methods, topical application of silver diamine fluoride (SDF) has become the focus of attention because of its effectiveness, low cost and simplicity [6]. SDF is a colorless ammonia solution containing silver and fluoride ions [7], and can arrest early caries by inhibiting dentine demineralization and cariogenic bacteria activities [7-9]. SDF has been developed and used in Japan for preventing and arresting dental caries in children since 1969 [4] and now widely used in many countries including Argentina, Australia, Brazil, China and the United States [8]. There were no reported side effects of SDF such as acute or chronic toxicity, nor significant complications [7].

Although different concentrations of SDF are commercially available, 38% SDF is commonly used because it more effectively arrests dental caries in children than a lower concentration [10]. It has been shown that 38% SDF solution is effective in arresting dental caries of primary teeth [4,7,11,12]. The systemic reviews also suggest that SDF could become a key element of oral health promotion programs for children to meet the WHO Millennium Goals [6, 9]. However, more studies are still necessary to confirm the effect of SDF in various areas of the world [12].

No research on SDF has been conducted in Myanmar yet. The purposes of this study were to investigate the caries arresting effect of SDF on each tooth surface of primary teeth, and to assess the effect of SDF on cariogenic bacteria in plaque and saliva among Myanmar children.

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2. MATERIALS AND METHODS

2.1. Study Population

This study was carried out in Yangon, the former capital city of Myanmar, in 2016. Among twenty-eight preschools in the Yangon area, five preschools were selected for the study based on the census sampling method by the Department of Social Welfare, Ministry of Social Welfare, Relief and Resettlement.

The principals of five preschools were first given an explanation of the study by an investigator. A letter describing the purpose and procedures of the study was then sent to parents or guardians of children aged 3-4 years through the preschools. Parents who allowed their children to participate in the study signed a written consent form.

A total of 348 preschool children agreed to participate in the study. The inclusion criteria for study enrollment of children were those with at least one enamel or dentine level carious lesion. Among 270 children who met the inclusion criteria, 14 were excluded because they had a medical history of systemic diseases, long-term medications, uncooperative behaviors, and missing information on study variables. Therefore, the study started with 256 children, and 55 children dropped out during the 6-month follow-up. Final number of children who completed the study was 201.

2.2. Study Design

Figure 1 shows the flowchart of this 6-month interventional study. The children of five preschools were allocated to two groups by matching the dentition status at school level: three preschools in the Group A and two preschools in the Group B. At baseline, 134 children in the Group A (mean age= 41.4 ± 3.8 months, boys: 66, girls: 68) received silver diamine fluoride (SDF) and sodium fluoride (NaF) applications while 67

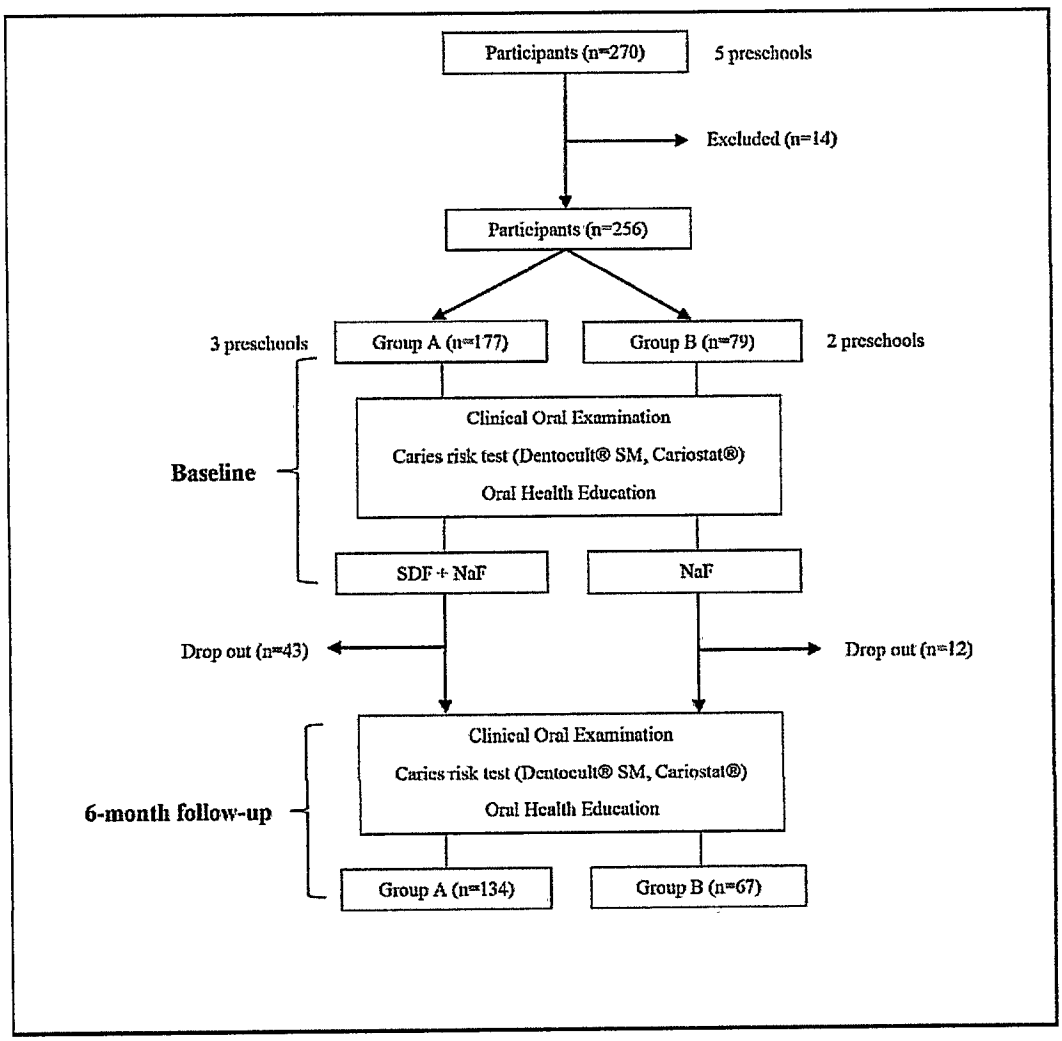

Figure 1: Flowchart of study protocol.

children in the Group B (mean age= 41.7 ± 3.8 months, boys: 35, girls: 32) received only a sodium fluoride (NaF) application.

2.3. Clinical Oral Examination

A dentist and an assistant to help with conducted all the clinical oral examinations at baseline and 6-month follow-up. About 20 children per day were examined over the course of 10 days. Calibration of examination criteria and intervention procedures were made prior to the study. Four surfaces (labial, lingual, mesial, and distal) of anterior teeth and five surfaces (buccal, lingual, mesial, distal, and occlusal) of posterior teeth were assessed using a WHO-CPI probe and a dental mirror with a handheld light. The tooth was classified as sound, active caries, arrested caries, filled or missing. The tooth was recorded as sound if there was no sign of visible cavity formation or the presence of any restoration. A decayed tooth was recorded as having active caries if the carious lesion was soft and could be easily penetrated with the CPI probe, while it was recorded as arrested caries if the carious lesion was hard and could not be penetrated with the CPI probe. A filled tooth was recorded if there was any restoration without secondary caries. A tooth lost due to dental caries was defined as missing.

Oral hygiene status was evaluated on six index teeth (buccal/labial surfaces of teeth 55 or 54, 51, 65 or 64 and 71, and the lingual surfaces of teeth 75 or 74 and 85 or 84) using the criteria of Simplified Oral Hygiene Index (OHI-S) [13]. The debris score was calculated by adding the scores of each index tooth and dividing by the number of index teeth evaluated.

2.4. Caries Risk Tests

After oral examination, the caries risk test was performed by using Dentocult• SM (Oral Care Co. Ltd., Japan) and Cariostat• (DENTSPLY-Sankin K.K. Co. Ltd., Japan) at baseline and at 6-month follow-up. Dentocult• SM determined the colony forming units (CFU) of mutans streptococci in dental plaque and saliva [14,15]. Cariostat• detected the degree of acid production by cariogenic bacteria in the dental plaque [16]. The plaque sample for Dentocult• SM was obtained from four tooth surfaces (buccal surfaces of teeth 55 or 54 and 51, and lingual surfaces of teeth 71 and 74 or 75) using a toothpick, and from saliva by pressing a strip on the dorsum of the tongue five times. For Cariostat•, the plaque sample was collected from buccal surfaces of teeth 54 and 55 by wiping 4-5 times with a sterile cotton swab. The caries risk test vials were incubated at 37°C for 48 hours and the scores ranging from 0 to 3 were evaluated according to the manufacturer's instruction. The score of plaque Dentocult• SM was calculated by adding the scores of four tooth surfaces and dividing by four.

2.5. SDF and NaF Application

SDF (38%, 44,800 ppm F) (Saforide, Toyo Seiyaku Kasei Co. Ltd., Osaka, Japan) and NaF (2%, 9,000 ppm F) (Bee Brand Medico Dental Co. Ltd., Osaka, Japan) were used for the intervention in this study. In Group A, SDF was first applied to enamel or dentine level carious surfaces with an applicator after cleaning teeth with a tooth brush, and then NaF to all sound tooth surfaces with a toothbrush. In Group B, NaF was applied to all tooth surfaces. After application, the children were asked to avoid eating and drinking for one hour.

2.6. Oral Health Education

A 30-minute oral health education was given by the same dentist. Basic knowledge about dental disease and oral hygiene care was delivered to parents, preschool teachers and children using health education materials such as slides and pamphlets at baseline and 6-month follow-up.

2.7. Statistical Analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS 18.0). An independent *t*-test was used to assess mean differences in numbers of teeth, caries status, debris score and caries risk test between the two groups at the baseline or 6-month follow-up. A paired *t*- test was performed to examine the mean changes in caries status, debris score and caries risk test between baseline and the 6-month follow-up. Chi-square or McNemar's tests were used to assess the differences in the distribution of caries prevalence between two groups or the baseline and 6-month follow-up. The level of statistical significance for all tests was set at $P<0.05$.

2.8. Ethical Approvals

This study was approved for preschool children by the Department of Social Welfare, Ministry of Social Welfare, Relief and Resettlement, Myanmar (Reg. No. 4252/General/2-17/2015). The study protocol was also approved by Ethical Committee of University of Dental Medicine, Yangon, Myanmar (Reg. No. 1082/AhKhaYa-

2 [Hta] 2015) and Tokyo Medical and Dental University, Tokyo, Japan (Approval No. 1229).

3. RESULTS

3.1. Dentition Status and Debris Score

At the baseline, there were no significant differences in mean age, proportions of boys and girls, and numbers of teeth between Groups A and B. The prevalence of dental caries were 81.3% in Group A, and 76.1% in Group B. No significant difference in caries prevalence was found between two groups. Mean numbers of decayed teeth (dt), missing teeth (mt), filled teeth (ft), dmft, dmfs and debris scores showed no significant differences between two groups (Table **1**).

The prevalence of dental caries significantly increased from baseline to the 6-month follow-up in Groups A and B (p=0.021 and p=0.049). Both groups showed significant increases in dt (p<0.001 and p=0.001), dmft (p<0.001 and p<0.001) and dmfs (p<0.001 and p=0.010) at 6-month follow-up. On the other hand, no significant differences were found in mt and ft at 6-month follow-up compared with the baseline. The dt, dmft and dmfs increased slightly more in Group B than in Group A at 6-month follow-up, but the differences were not significant.

The debris scores significantly decreased from 1.92 ± 0.50 at baseline to 1.30 ± 0.53 at 6-month follow-up in Group A (p<0.001), and from 2.00 ± 0.42 to 1.69 ± 0.53 in Group B (p<0.001). A significantly higher debris score was observed in Group B than in Group A at 6-month follow-up (p<0.001).

3.2. Caries Risk Tests

Table **2** shows the results of caries risk tests at baseline and 6-month follow-up in the two groups. No significant differences were found in Dentocult• SM and Cariostat• scores between the two groups at baseline. In Group A, all caries risk scores were significantly decreased from baseline to 6-month follow-up. The plaque Dentocult• SM decreased from 0.95 ± 0.70 to 0.56 ± 0.51 (p<0.001), and the saliva Dentocult• SM from 0.76 ± 0.80 to 0.62 ± 0.57 (p=0.005). The Cariostat• decreased from 1.61 ± 0.81 to 1.37 ± 0.52 (p<0.001). On the other hand, there were no significant changes in any caries risk tests between baseline and 6-month follow-up in Group B.

Table 1: Dentition Status and Debris Score at Baseline and 6-Month Follow-Up in Two Groups

	Group A (n=134)			Group B (n=67)		
	Baseline	**6 Months**	**p-Value**	**Baseline**	**6 Months**	**p-Value**
Number of teeth	19.96 ± 0.19	19.98 ± 0.21	0.319	19.85 ± 0.58	19.96 ± 0.20	0.146
Caries prevalence	81.3%	87.3%	**0.021**	76.1%	81.4%	**0.049**
dt	5.16 ± 4.49	5.66 ± 4.55	**<0.001**	5.43 ± 4.65	5.94 ± 4.60	**0.001**
mt	0.01 ± 0.08	0.02 ± 0.11	0.319	0.03 ± 0.17	0.06 ± 0.21	0.321
ft	0.06 ± 0.43	0.08 ± 0.42	0.287	0.03 ± 0.17	0.07 ± 0.45	0.388
dmft	5.22 ± 4.59	5.76 ± 4.67	**<0.001**	5.49 ± 4.72	6.07 ± 4.76	**<0.001**
dmfs	10.82 ± 13.69	11.63 ± 13.93	**<0.001**	11.72 ± 11.94	12.42 ± 12.12	**0.010**
Debris score	1.92 ± 0.50	1.30 ± 0.53	**<0.001**	2.00 ± 0.42	1.69 ± 0.53	**<0.001**

Table 2: Results of Caries Risk Tests at Baseline and 6-Month Follow-Up in Two Groups

	Group A (n=134)			Group B (n=67)		
	Baseline	**6 Months**	**p-Value**	**Baseline**	**6 Months**	**p-Value**
Dentocult® SM Plaque	0.95 ± 0.70	0.56 ± 0.51	**<0.001**	0.72 ± 0.66	0.71 ± 0.63	0.869
Dentocult® SM Tongue	0.76 ± 0.80	0.62 ± 0.57	**0.005**	0.60 ± 0.78	0.72 ± 0.79	0.184
Cariostat®	1.61 ± 0.81	1.37 ± 0.52	**<0.001**	1.39 ± 0.57	1.46 ± 0.53	0.267

3.3. Number of Arrested and Active Carious Lesions at Tooth Level

Caries prevalence by tooth was not significantly different between the two groups at baseline or 6-month follow-up (Figure **2**). The maxillary incisors were most affected, followed by maxillary and mandibular molars. The mandibular incisors were least affected. There were no significant differences in caries prevalence between right and left sides of the dentition.

In Group A, the overall mean number of arrested carious surfaces was 2.68 ± 2.76, and the proportion of arrested carious surfaces was 72.0% (475/660 surfaces) at 6-month follow-up. The proportion of arrested carious surfaces in maxillary teeth was similar to that in mandibular teeth with approximately 70%, although the number of SDF-treated carious surfaces was much higher in maxillary teeth. The proportion of arrested carious surfaces in anterior teeth (80.3%, 419/522 surfaces) was almost twice as high as posterior teeth (42.8%, 59/138 surfaces).

In the maxillary teeth, the lateral incisors had the highest proportion of arrested carious lesions (83.9%, 130/155 lesions), followed by the central incisors (79.8%, 189/237 lesions). The lowest proportion of arrested carious lesions was observed in second molars and only 35.3% (6/17 lesions) was arrested. In the mandibular teeth, the central incisors showed the highest proportion of arrested carious lesions (77.8%, 14/18 lesions), followed by the lateral incisors (73.3%, 11/15 lesions). As with maxillary teeth, the lowest proportion of arrested carious lesions was found in second

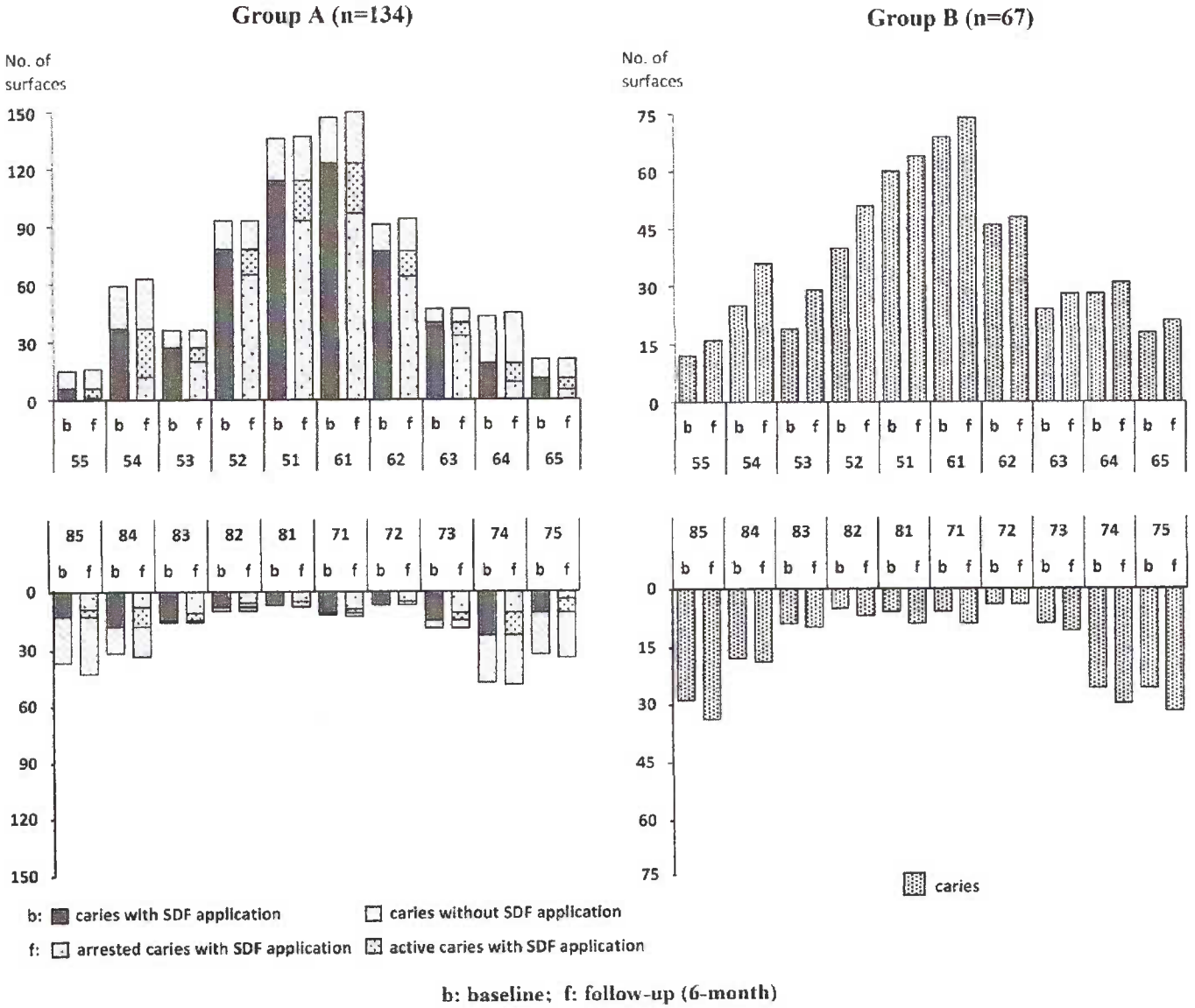

Figure 2: Number of arrested and active carious lesions at tooth level.

molars and only 45.8% (11/24 lesions) was arrested caries.

3.4. Number of Arrested and Active Carious Lesions at Tooth Surface Level in Group A

The arrested and active carious lesions at tooth surface level in Group A are shown in Figure **3**. Overall, SDF was most effective in arresting lesions on buccal surfaces in both anterior and posterior teeth. The lingual lesions in anterior teeth and the distal lesions in posterior teeth were least affected by SDF.

In the maxillary teeth, the mesial surfaces had the highest proportion of arrested caries lesions with 85% (85/100 lesions), followed by 80% of labial lesions in central incisors. In lateral incisors and canines, labial lesions showed the highest proportion of arrested caries with 89.4% (42/47 lesions) and 86.8% (33/38 lesions) while lingual lesions were the lowest with 69.4% (25/36 lesions) and 55.6% (5/9 lesions). The highest proportion of arrested carious lesions was found on buccal lesions in molars, but only half of them were arrested. The proportion of arrested caries in occlusal lesions was 42.3% (11/26 lesions). The proximal lesions were least arrested in molars (14.8%, 8/54 lesions).

In the mandibular teeth, all carious lesions in anterior teeth were effectively arrested. Over three quarters of buccal lesions in anterior teeth were arrested, which had the highest proportion of arrested carious lesions. Similarly, buccal lesions in molars also showed the highest proportion of arrested caries with 85.7% (6/7 lesions), followed by occlusal lesions with 47.4% (18/38 lesions). No lingual lesions were arrested in molars, and distal lesions were also scarcely arrested (16.7%, 1/6 lesions).

4. DISCUSSION

This is the first interventional study to evaluate the caries arresting effect of SDF on each tooth surface in Myanmar children. The present study supported the evidence of previous studies, which demonstrated the effectiveness of SDF application in arresting dental caries [4,6-8,17].

The overall caries prevalence in study children was very high; about 80% of the children had caries. The pattern of caries prevalence at individual tooth level did not show much difference between children with and without SDF application. The prevalence was the highest in the maxillary incisors, as reported in previous studies [18, 19]. Caries status worsened from baseline to 6-month in both groups of children. Although NaF was applied to all erupted sound teeth at baseline, newly erupted teeth without fluoride exposure or even teeth with fluoride exposure might develop caries during the six months. This result suggests that it is necessary to make further efforts to stop new caries occurring.

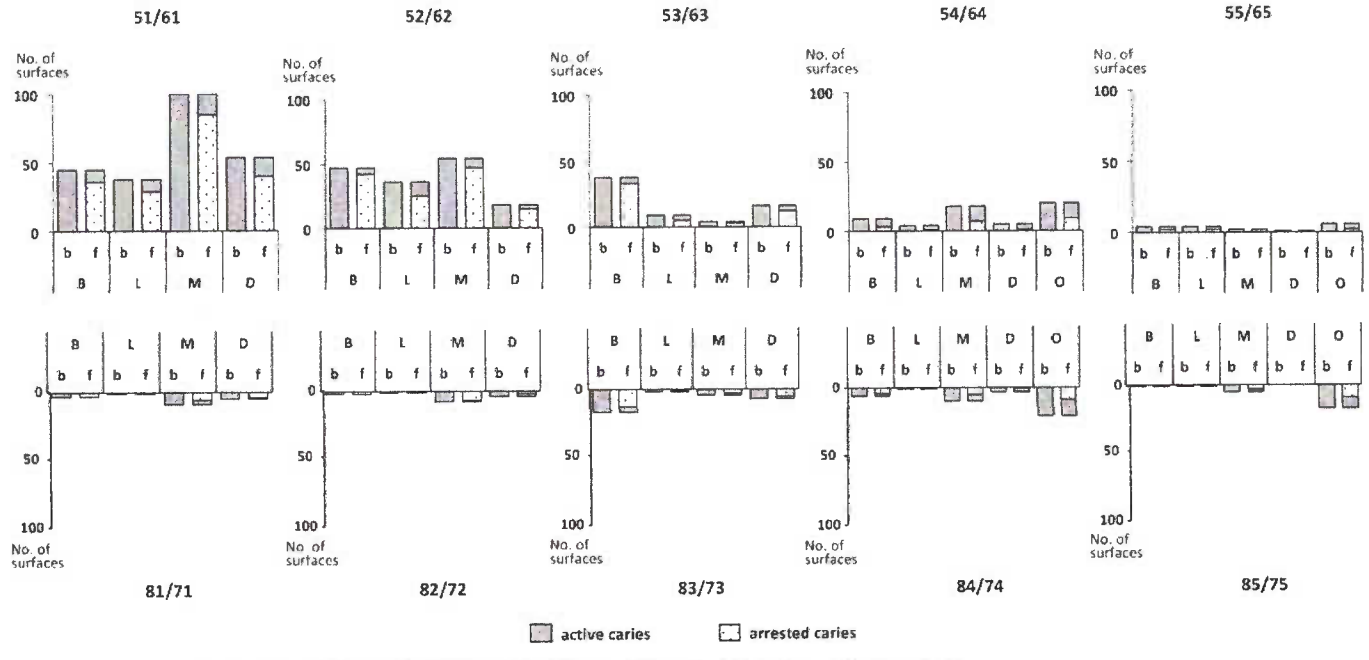

Figure 3: Number of arrested and active carious lesions at tooth surface level in Group A.

Regarding the arrest of existing carious lesions by SDF, a quite high proportion of carious surfaces was arrested. Many carious surfaces of maxillary incisors and canines were targets for SDF application because of the high caries prevalence in the present study. Even though maxillary and mandibular molars had high caries prevalence, the lesions were too deep or too severe to apply SDF. SDF is recommended to be used for enamel or dentine level carious lesions because deep carious lesions might be accompanied by unfavorable complications from SDF application. Consequently, the number of SDF applications to carious surfaces was fewer in molars.

It is widely accepted that SDF exerts its caries arresting effect by hardening enamel or dentine caries [17]. High concentration of fluoride and silver ions from SDF form silver phosphate on tooth surfaces, and arrest caries progression [17,20]. The proportion of arrested carious lesions was similar in the maxillary and mandibular dentitions. On the other hand, the effect of SDF on the anterior teeth was twice as large as on posterior teeth. The possible reason is that SDF application to anterior teeth is easy and less likely to be affected by saliva contamination during the SDF application. In contrast, keeping good oral hygiene in posterior teeth is difficult because those teeth have complicated surface morphologies such as pits and fissures.

A tooth surface level investigation found that buccal lesions treated by SDF application were highly arrested in both maxillary and mandibular teeth. It may be because buccal surfaces are easy to access, not only by SDF but also by oral hygiene instruments, in addition to being less likely to be contaminated by saliva. Less than half of the occlusal lesions were arrested by SDF. The dental plaque tends to accumulate on occlusal surfaces of posterior teeth, which may reduce the effect of SDF. Lingual or distal lesions were the least arrested by SDF, as in a previous study [21]. Difficulty in SDF application to those surfaces is considered one of the reasons. In maxillary central incisors, the mesial surfaces had the highest proportion of arrested caries. Previous studies reported that it was difficult to arrest caries on proximal surfaces [20, 21]. These areas are susceptible to rapid caries progression because it is hard to remove dental plaque and to completely apply SDF to tight proximal contact points [20]. However, in this study, enough space existed between mesial surfaces of maxillary central incisors due to caries progression, therefore, SDF could be applied thoroughly.

The debris scores decreased after six months in both groups of children. This was probably partly because caregivers and children understood the importance of regular tooth brushing and mouth rinsing after meals for removal of dental plaque and debris, after receiving the oral health education. Oral hygiene is a significant predictor of dental caries compared with other oral health related risk factors [22,23], and proper oral hygiene practice can reduce the accumulation of dental plaque on tooth surfaces [24]. The debris score in children who received both NaF and SDF application was lower than those with only NaF application at the 6-month follow-up. All caries risk test scores also decreased after six months in children with NaF and SDF applications, whereas no significant change was observed in children with just NaF application. Cationic fluoride preparations could reduce the acidogenic capacity of dental plaque formation [25]. In addition, higher concentrations of fluoride could decrease plaque accumulation more than lower concentrations of fluoride [26].

Silver ions in SDF are also considered to be associated with the result. Fluoride ions mainly affect the tooth surface while silver ions act on cariogenic bacteria [6,27]. Silver ions can prevent biofilm formation by inhibiting DNA replication and disrupting the membrane transport function of cariogenic bacteria [28]. Among Streptococci species, *Streptococcus mutans* is the most predominant cariogenic bacterium of dental caries [29,30]. An in vitro study indicated that SDF could prevent the proliferation of *S. mutans* in the oral biofilms. Further, SDF can inhibit plaque acid production by means of a direct inhibitory effect on the metabolic activity of cariogenic bacteria [26] and a reduction of other species in the oral cavity [15]. Higher amounts of fluoride from NaF and SDF and silver ions from SDF may contribute to the reduction of dental plaque and suppression of cariogenic bacteria as well as decreases in acid production.

There are minor drawbacks to SDF application. SDF causes a black discoloration of carious lesion [7, 31] when silver phosphate is exposed to sunlight or reducing agents [8,20]. Another concern is dental fluorosis due to the high fluoride concentration (44,800 ppm) of SDF [32]. However, because only a very small amount of SDF is applied to carious lesions, no studies have reported dental fluorosis resulting from SDF application.

The limitation of this study was that the sample could not represent the whole population of Myanmar

preschool children because the study was conducted only in five preschools of the Yangon area. However, this six-month intervention study could provide useful information about the caries arresting effect of SDF at tooth surface level and its suppressive action against cariogenic bacteria in young children in Myanmar. Adequate oral hygiene practice, caries treatment and preventive measures such as SDF and fluoride application programs should be implemented to improve oral health in Myanmar children. In addition, oral health education aiming at positive behavioral changes including dietary habits should be provided to parents, guardians and preschool teachers, as well as children.

5. CONCLUSION

It was concluded that SDF was effective not only in arresting carious lesions but also in diminishing the quantity of cariogenic bacteria present and the degree of acid production. Therefore, SDF application should be more utilized in children with early childhood caries especially in developing countries. However, since the caries arresting effects of SDF differ according to tooth surface, provision of other oral health measures such as oral health education to parents, teachers as well as children and appropriate dental treatments would be necessary to comprehensively control the carious status.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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