Silver Diamine Fluoride and Fluoride Varnish May Halt Interproximal Caries Progression in the Primary Dentition

Hammersmith KJ* / DePalo JR** / Casamassimo PS*** / MacLean JK**** / Peng J*****

Objective: *The study described the incidence of interproximal caries arrest following SDF and fluoride varnish application in the primary dentition.* ***Study design:*** *A retrospective analysis of dental records including radiographs was conducted for interproximal dental caries in pediatric patients treated with SDF applied with woven floss. Bitewing radiographs and ICCMS™ radiographic scoring criteria were used to assess caries depth in primary teeth at baseline and then at 12-month follow-up examination.* ***Results:*** *This study included 185 interproximal carious lesions in 131 patients treated with SDF. Mean baseline ICCMS™ score for all lesions was 1.50, with an average dmft of 2.9. The majority of carious lesions (n=155, 84.0%) showed radiographic evidence of non-progression at 12-month follow-up. There was no statistically significant difference in caries arrest among primary canines, primary first molars, and primary second molars (P=0.61). Furthermore, there was no statistically significant difference in caries arrest in patients with commercial insurance, Medicaid, or no insurance (P=0.27).* ***Conclusions:*** *SDF application with woven floss was associated with interproximal caries arrest in the primary dentition at 12-month follow-up in this sample of low caries risk children. Tooth type and insurance type were not associated with caries arrest.*

Keywords: *silver diamine fluoride, interproximal caries, primary teeth.*

INTRODUCTION

Interproximal dental caries is common among children. Some studies show interproximal caries may appear as early as 19-21 months of age and increases in prevalence throughout childhood[1,2].

Dentists have several options for managing interproximal caries, ranging from surgical (i.e. intracoronal restorations and crowns) to non-surgical techniques including resin infiltration, fluoride varnish, interproximal sealants, and deferral of care[3-8]. Silver diamine fluoride (SDF) is an additional caries management tool. In addition to treating dental hypersensitivity, SDF has been used off-label to arrest dental caries[9-16]. Systematic reviews found that SDF arrested 66% of primary tooth lesions into dentin and 81% of lesions overall[10,17]. SDF may be as effective or more effective than other minimally invasive and non-surgical restorative techniques in arresting dental caries[13,18-23].

The application of SDF does not require local anesthesia or removal of tooth structure and can be applied by a practitioner or delegated staff member as permitted by regulatory bodies. SDF fits within the scope of minimal intervention dentistry and represents a cost-effective treatment option for interproximal dental caries[24-27]. The ease of application makes SDF suitable for almost all patient populations, including those with developmental, behavioral, or medical considerations that complicate traditional restorative techniques[25,28,29].

*Kimberly J. Hammersmith, DDS, MPH, MS, Clinical Assistant Professor, Pediatric Dentistry, The Ohio State University and Nationwide Children's Hospital, Columbus, OH.
**Joseph R. DePalo, DMD, MS, Pediatric dentist, Columbus, OH.
***Paul Casamassimo, DDS, MS, Professor Emeritus, Pediatric Dentistry, The Ohio State University and Nationwide Children's Hospital, Columbus, OH.
****Jeanette MacLean, DDS; Pediatric dentist, Affiliated Children's Dental Specialists, Glendale, AZ.
*****Jin Peng, MD, MS, PhD, Data Scientist at Nationwide Children's Hospital, Columbus, OH.

Send all correspondence to:
Kim Hammersmith,
Nationwide Children's Hospital
700 Children's Drive, LA Suite 5A, Columbus OH 43205
Phone: 614-722-1561
Fax: 614-722-5671
E-mail:kim.hammersmith@nationwidechildrens.org

A 1981 Japanese clinical trial of 58 children showed decreased incidence and reduced progression of interproximal caries in primary molars treated with SDF applied with unwaxed dental floss at three month intervals[23]. Nevertheless, scientific evidence of its effectiveness on arresting interproximal dental caries in the primary dentition remains limited. The purpose of this study was to describe the incidence of interproximal caries arrest following SDF application in the primary dentition.

MATERIALS AND METHOD

This study was approved by the Institutional Review Boards at Nationwide Children's Hospital (study ID: IRB17-01054) and the Ohio State University (study ID: 2018N0012), both in Columbus, OH. The retrospective study included a convenience sample of patients with interproximal dental caries treated with SDF in a single, private pediatric practice (Affiliated Children's Dental Specialists, Glendale, AZ) between January 1, 2015 and April 1, 2018. Due to the retrospective study design, no placebo control group was available. Inclusion criteria required the following:

1. Dental caries on the mesial or distal surface of a primary canine or primary molar, as diagnosed by bitewing radiographs;
2. Carious lesions treated with SDF applied with woven floss; and
3. Bitewing radiographs exposed prior to SDF application and at a 12-month follow-up appointment.

Teeth were excluded from the study if:

1. The SDF-treated carious lesion did not have an adjacent proximal contact;
2. The interproximal lesion involved the marginal ridge such that SDF was applied by microbrush instead of floss;
3. The interproximal surface was clinically noted as non-carious (such as enamel hypoplasia);
4. The interproximal surface had been restored prior to SDF application, as in the case of SDF being used to treat secondary caries;
5. Bitewing radiographs were non-diagnostic, did not show open contacts, or not available for comparison, including cases when limited patient cooperation prevented obtaining bitewing radiographs at either baseline or 12-month follow-up.

SDF Application

For all SDF applications, petroleum jelly (Vaseline®, Unilever US, Englewood Cliffs, NJ) was applied extra-orally to prevent inadvertent staining of the lips or face. The carious teeth were cleaned of debris or plaque, isolated using cotton rolls and absorbent cellulose triangles, dried with compressed air, and woven floss (either GUM Expanding Dental Floss®, Sunstar Americas Inc., Schaumburg, IL or Super Floss®, Oral-B, The Procter & Gamble Company, Cincinnati, OH) was placed between the teeth at the site of the lesion(s). A single drop of SDF was placed into a plastic dappen dish, a microbrush was dipped into 38% SDF (Advantage Arrest™, Elevate Oral Care, West Palm Beach, FL), and SDF was applied to the woven floss buccally, lingually, and occlusally to the contact area until the woven floss was saturated. The floss remained between the teeth for 60 seconds, then was removed and fluoride varnish (Kolorz ClearShield® 5% NaF, DMG America, Ridgefield Park, NJ or FluoriMax® 2.5% NaF, Elevate Oral Care, West Palm Beach, FL) was applied over the treated contact. SDF and fluoride varnish were re-applied at 6-month intervals.

Data Abstraction

Descriptive data were abstracted from patient records for all patients meeting inclusion criteria. At the initial SDF application, the following demographic and clinical characteristics were abstracted: age, gender, insurance type, date of visit, and which teeth and tooth surfaces were treated. Data abstraction was completed using REDCap (Research Electronic Data Capture)[30].

Assessment of caries arrest

To assess caries arrest, bitewing radiographs taken prior to initial SDF application and at the 12-month follow-up visit were obtained from patient records. Radiographs were taken according to American Dental Association guidelines and captured using F-speed dental film (INSIGHT Super Poly-Soft Packets, Carestream Dental LLC, Atlanta, GA) and processed according to manufacturer recommendations. A single, calibrated and blinded board-certified pediatric dentist measured the depth of each interproximal lesion treated with SDF, assigning each lesion an ICCMS™ (International Caries Classification and Management System) score between RA0 and RA6 according to ICCMS™ radiographic scoring criteria[31] (Figure 1). Examiner calibration consisted of a review of the scoring criteria and training using 10 bitewing radiographs with interproximal caries. The examiner was blinded to patient identifiers and date of visit, ensuring blinding to visit type (baseline or 12-month follow-up). Intra-rater reliability was assessed by having the examiner re-score bitewing radiographs from 14 randomly selected patient charts with a total of 87 lesions[32,33]. If the 12-month follow-up ICCMS™ score was less than or equal to the baseline score, the carious lesion was considered arrested; if greater, the carious lesion was considered not arrested.

ICCMS™ score	Description of radiolucency*
RA0	No radiolucency
RA1	Radiolucency in the outer ½ of enamel
RA2	Radiolucency in the inner ½ of the enamel ± dentin-enamel junction
RA3	Radiolucency limited to the outer 1/3 of dentin
RA4	Radiolucency reaching the middle 1/3 of dentin
RA5	Radiolucency reaching the inner 1/3 of dentin
RA6	Radiolucency into the pulp

Figure 1: ICCMS™ radiographic scoring system for interproximal caries[31]

*Indicates depth of interproximal caries on bitewing radiograph

Statistical Analysis

Descriptive statistics of the study cohort were generated using mean and frequency values. ICCMS™ score of arrested versus not arrested lesions were compared at baseline and at 12-month follow-up using Wilcoxon signed-rank tests. Baseline DMFT score of arrested versus not arrested lesions were also compared using Wilcoxon signed-rank tests. The associations between caries arrest status and independent variables (tooth type and insurance type) were examined using Fisher's exact test. P-values <0.05 were considered statistically significant. All analyses were conducted using R 3.4.3.[34]

RESULTS

This analysis included 131 patients with 185 carious lesions in primary teeth. Descriptive statistics are summarized in Table 1. The mean patient age was 7.1 years and 99 (53.5%) lesions were in female patients. The majority of lesions were in patients with commercial dental insurance (n=131, 73.5%), with the remaining in patients with Medicaid (n=27, 15.2%) or no insurance (n=20, 11.8%). The greatest percentage of carious lesions was in primary second molars (n=101, 54.6%), while the remaining lesions were in primary first molars (n=73, 39.5%) and primary canines (n=11, 5.9%) (Table 2). The mean baseline dmft score was 2.9 (range 0-14). About half of the patients received SDF re-application after the initial application but before the six-month visit.

Table 1: Descriptive statistics of lesion cohort

	Total sample (%)	Baseline dmft, mean (range)
Age	7.1 (4, 13)*	2.9 (0, 14)
Gender		
Female	99 (53.5%)	2.4 (0,9)
Male	86 (46.5%)	3.7 (0,11)
Insurance type		
Commercial	131 (73.6%)	3.3 (0,9)
Medicaid	27 (15.2%)	2.2 (0,11)
No insurance	20 (11.2%)	0.5 (0,3)
Baseline dmft	2.9 (0, 14)**	

*Mean age in years (range).

Table 2: Distribution of carious lesions by tooth type

Tooth type	N (%)	Baseline dmft, mean (range)
Primary canine	11 (5.9%)	5.3 (0, 11)
Primary first molar	73 (39.5%)	2.5 (0, 8)
Primary second molar	101 (54.6%)	3.1 (0, 8)

Caries arrest status at 12-months

Linear weighted kappa statistic (0.741) demonstrated good intra-examiner reliability for ICCMS™ radiographic scoring. Table 3 illustrates the majority (n=155, 84.0%) of carious lesions showed caries arrest at the 12-month follow-up. The mean baseline ICCMS™ score in the arrested group (1.51) was not statistically different than the mean ICCMS™ score in the not arrested group (1.50) (p=0.87). The lesions that progressed increased from mean ICCMS™ score of 1.50 to 2.70 during the study period.

Caries arrest factors in the primary dentition

Differences in caries arrest status according to tooth type are shown in Table 4. There was no statistically significant difference in caries arrest among primary canines, primary first molars, and primary second molars (p=0.61). Furthermore, no statistically significant difference in caries arrest was observed between lesions in patients with commercial insurance, Medicaid, or no insurance (p=0.27).

Table 4: Caries arrest in the primary dentition

Tooth Type	Not arrested	Arrested	p-value*
Primary canine	2 (18%)	9 (82%)	
Primary first molar	14 (19%)	59(81%)	0.6059
Primary second molar	14 (14%)	87 (86%)	
Insurance Type	**Not arrested**	**Arrested**	**p-value***
Commercial	20 (15%)	111 (85%)	
Medicaid	6 (22%)	21 (78%)	0.2708
No Insurance	1 (5%)	19 (95%)	

*Statistical significance defined as p≤0.05.

DISCUSSION

Results indicate the majority of interproximal dental caries in primary teeth treated with SDF in this sample showed radiographic evidence of caries arrest at a 12-month follow-up. The overall caries arrest rate (84%) is consistent with a recent study of the radiographic progression of caries following SDF application and a meta-analysis of SDF-induced caries arrest[10,35]. Caries arrest at a 12-month follow-up is clinically significant in children because SDF may provide the option to defer or delay treatment under sedation or general anesthesia, give children the opportunity to demonstrate improved cooperation or behavioral maturation, or allow the opportunity for some primary teeth to exfoliate without surgical management. For lesions that did progress following SDF treatment, radiographically the caries approached the outer 1/3 of dentin, on average, at 12-month follow up. One could argue that even when caries progressed, it did so slowly.

Table 3: Caries arrest at 12-month follow-up

	N (%)	Baseline ICCMS™ score, mean (range)	12-month ICCMS™ score, mean (range)	Baseline dmft, mean (range)
Arrested lesions	155 (84%)	1.51 (0, 4)	1.12 (0, 4)	2.9 (0, 11)
Not arrested lesions	30 (16%)	1.50 (0, 3)	2.70 (1, 5)	3.0 (0, 8)
p-value*		0.87	<0.001	0.86

*Statistical significance between mean baseline ICCMS™ scores defined as p≤0.05

One might hypothesize that patients with Medicaid insurance would have higher dmft than patients with commercial insurance, but our study population exhibited the opposite. Lesions on primary canines were associated with a higher dmft but there was no statistically significant difference in arrest rate. As neither insurance type nor tooth type were associated with caries arrest, these results may suggest SDF represents a meaningful caries management tool for interproximal caries in the primary dentition, independent of socioeconomic status or caries history. This will need to be confirmed by future placebo-controlled and randomized controlled studies.

Interestingly, mean ICCMS™ radiographic scores at baseline in the carious lesions that arrested at the 12-month follow-up were not statistically different than those that were not arrested at the 12-month follow-up (Table 3). This finding suggests additional studies are needed to determine which factors contribute to caries arrest and which factors contribute to caries progression following SDF application, so that dentists can better appreciate the most appropriate clinical uses for SDF.

Strengths of this study include the large sample size, both in terms of number of patients and teeth. The composition of the study population in this suburban private pediatric practice also makes the findings generalizable to other private practices. Lastly the study's longitudinal component, which allowed us to study caries arrest at a 12-month recall, sheds some light on potentially meaningful radiographic recall intervals following interproximal SDF application with woven floss.

This study also has several limitations. Although the ICCMS™ radiographic scoring system offers an objective characterization of interproximal dental caries depth, the determination of the score remains somewhat subjective. The retrospective design allowed no control groups or alternative treatment groups for comparison. The single-arm study design is limiting, but it is justified by the limited knowledge of the clinical efficacy of SDF as a treatment for interproximal caries in the primary dentition. Prospective, placebo-controlled studies are needed to evaluate the effectiveness of SDF on arresting interproximal caries and in comparison to other treatment options.

Additionally, the total amount of SDF placed onto the tooth was not controlled, and some patients were treated for multiple lesions, increasing their total dose. It is unknown how much residual fluoride effect from SDF or glass ionomer restorations present on other teeth affected the lesions in our study. This study could not control for changes in home oral hygiene practices or other factors that may have contributed to caries arrest, nor could it exclude any carious lesions that may have arrested prior to the baseline radiographic examination. It is impossible to separate the effects of SDF and the fluoride varnish applied afterwards. It is possible that no treatment or fluoride varnish alone may have produced the same results[36]. While inclusion criteria required bitewings with open contacts, these radiographs were not taken using a standardized positioning device, so there may have been variations in angulation affecting ICCMS™ scores.

Finally, the relatively low mean baseline ICCMS™ (1.51 and 1.50 for arrested and not arrested lesions respectively) and dmft (2.9) scores limit the generalizability of the results to lesions of similar depth in patients of similar caries risk. According to the ICCMS™ radiographic scoring criteria, interproximal caries with a score $\leq$ RA2 indicates a carious lesion confined to inner 1/2 of enamel $\pm$ dentin-enamel junction. It is possible that, in a low to moderate caries risk population, these lesions may not have progressed without any intervention. Further work is needed to study caries arrest for deeper interproximal lesions or lesions with open proximal contacts where SDF can be directly applied with a tool other than floss.

CONCLUSIONS

1. In a low caries risk population, SDF and fluoride varnish application two to three times in a 12-month period resulted in arresting 84% of interproximal carious lesions.
2. Caries arrest was not associated with tooth type or insurance type.
3. Dentists may consider SDF a caries management tool for interproximal caries in the primary dentition, particularly when caries is confined to the dentin-enamel junction.
4. Additional placebo-controlled studies are required to better describe caries arrest following SDF application and the effectiveness of SDF as a treatment modality.

ACKNOWLEDGEMENTS

The authors acknowledge the contributions of the Sunstar/American Academy of Pediatric Dentistry Post-Graduate Research Fellowship, Delta Dental Foundation, Dr. Jennifer Moreland, and Ms. Ann Salvator.

REFERENCES

1. Douglass JM, Tinanoff N, Tang JM, Altman DS. Dental caries patterns and oral health behaviors in Arizona infants and toddlers. Community Dent Oral Epidemiol;29(1):14-22. 2001.
2. Forsling JO, Halling A, Lundin SA, et al. Proximal caries prevalence in 19-year-olds living in Sweden. A radiographic study in four counties. Swed Dent .;23(2-3):59-70. 1999.
3. Kabakchieva R, Gateva N, Mihaylova H. Non-operative treatment of non-cavitated approximal carious lesions of permanent children's teeth. Journal of IMAB–Annual Proceeding Scientific Papers;20(5):626-630. 2014.
4. Jiang H, Bian Z, Tai BJ, Du MQ, Peng B. The effect of a bi-annual professional application of APF foam on dental caries increment in primary teeth: 24-month clinical trial. J Dent Res;84(3):265-268. 2005.
5. Martignon S, Ekstrand KR, Ellwood R. Efficacy of sealing proximal early active lesions: an 18-month clinical study evaluated by conventional and subtraction radiography. Caries Res;40(5):382-388. 2006.
6. Abuchaim C, Rotta M, Grande RH, Loguercio AD, Reis A. Effectiveness of sealing active proximal caries lesions with an adhesive system: 1-year clinical evaluation. Braz Oral Res;24(3):361-367. 2010.
7. Meyer-Lueckel H, Bitter K, Paris S. Randomized controlled clinical trial on proximal caries infiltration: three-year follow-up. Caries Res;46(6):544-548. 2012.
8. Ekstrand KR, Bakhshandeh A, Martignon S. Treatment of proximal superficial caries lesions on primary molar teeth with resin infiltration and fluoride varnish versus fluoride varnish only: efficacy after 1 year. Caries Res;44(1):41-46. 2010.
9. Chu CH, Lo EC, Lin HC. Effectiveness of silver diamine fluoride and sodium fluoride varnish in arresting dentin caries in Chinese pre-school children. J Dent Res;81(11):767-770. 2002.
10. Gao SS, Zhang S, Mei ML, Lo EC, Chu CH. Caries remineralisation and arresting effect in children by professionally applied fluoride treatment–a systematic review. BMC Oral Health;16:12. 2016.
11. Llodra JC, Rodriguez A, Ferrer B, Menardia V, Ramos T, Morato M. Efficacy of silver diamine fluoride for caries reduction in primary teeth and first permanent molars of schoolchildren: 36-month clinical trial. J Dent Res;84(8):721-724. 2005.
12. Yee R, Holmgren C, Mulder J, Lama D, Walker D, van Palenstein Helderman W. Efficacy of silver diamine fluoride for Arresting Caries Treatment. J Dent Res;88(7):644-647. 2009.
13. Zhi QH, Lo EC, Lin HC. Randomized clinical trial on effectiveness of silver diamine fluoride and glass ionomer in arresting dentine caries in preschool children. J Dent;40(11):962-967. 2012.
14. Crystal YO, Niederman R. Silver Diamine Fluoride Treatment Considerations in Children's Caries Management. Pediatr Dent;38(7):466-471. 2016.
15. Rosenblatt A, Stamford TC, Niederman R. Silver diamine fluoride: a caries "silver-fluoride bullet". J Dent Res;88(2):116-125. 2009.
16. Gold J. Silver Diamine Fluoride Arrests Caries in Primary Teeth. J Evid Based Dent Pract;18(1):88-90. 2018.
17. Gao SS, Zhao IS, Hiraishi N, et al. Clinical Trials of Silver Diamine Fluoride in Arresting Caries among Children. JDR Clinical & Translational Research;1(3):201-210. 2016.
18. Duangthip D, Chu CH, Lo EC. A randomized clinical trial on arresting dentine caries in preschool children by topical fluorides—18 month results. J Dent; 44:57-63. 2016.
19. Beltran-Aguilar ED. Silver diamine fluoride (SDF) may be better than fluoride varnish and no treatment in arresting and preventing cavitated carious lesions. J Evid Based Dent Pract;10(2):122-124. 2010.
20. Dos Santos VE, de Vasconcelos FM, Ribeiro AG, Rosenblatt A. Paradigm shift in the effective treatment of caries in schoolchildren at risk. Int Dent J;62(1):47-51. 2012.
21. Braga MM, Mendes FM, De Benedetto MS, Imparato JC. Effect of silver diammine fluoride on incipient caries lesions in erupting permanent first molars: a pilot study. J Dent Child (Chic);76(1):28-33. 2009.
22. Chibinski AC, Wambier LM, Feltrin J, Loguercio AD, Wambier DS, Reis A. Silver Diamine Fluoride Has Efficacy in Controlling Caries Progression in Primary Teeth: A Systematic Review and Meta-Analysis. Caries Res;51(5):527-541. 2017.
23. Tsutsumi N. Studies on Topical Application of Ag(NH3)2F for the Control of Interproximal Caries in Human Primary Molars 3. Clinical trial of Ag(NH3)2F on interproximal caries in human primary molars. Jpn J Pediatr Dent;19(3):537 -545. 1981.
24. Schwendicke F, Meyer-Lueckel H, Stolpe M, Dörfer CE, Paris S. Costs and effectiveness of treatment alternatives for proximal caries lesions. PLoS One.;9(1):e86992. 2014.
25. Crystal YO, Marghalani AA, Ureles SD, et al. Use of Silver Diamine Fluoride for Dental Caries Management in Children and Adolescents, Including Those with Special Health Care Needs. Pediatr Dent;39(5):135-145. 2017.
26. Duangthip D, Fung MHT, Wong MCM, Chu CH, Lo ECM. Adverse Effects of Silver Diamine Fluoride Treatment among Preschool Children. J Dent Res;97(4):395-401. 2018.
27. Horst JA. Silver Fluoride as a Treatment for Dental Caries. Adv Dent Res;29(1):135-140. 2018.
28. Horst JA, Ellenikiotis H, Milgrom PL. UCSF Protocol for Caries Arrest Using Silver Diamine Fluoride: Rationale, Indications and Consent. J Calif Dent Assoc;44(1):16-28. 2016.
29. Wright JT, White A. Silver Diamine Fluoride: Changing the Caries Management Paradigm and Potential Societal Impact. N C Med J;78(6):394-397. 2017.
30. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform;42(2):377-381. 2009.
31. Pitts NB, Ismail AI, Martignon S, Ekstrand K, Douglas G, Longbottom C. ICCMS™ guide for practitioners and educators. London: King's College London. 2014.
32. Kaji AH, Schriger D, Green S. Looking through the retrospectoscope: reducing bias in emergency medicine chart review studies. Ann Emerg Med;64(3):292-298. 2014.
33. Liddy C, Wiens M, Hogg W. Methods to achieve high interrater reliability in data collection from primary care medical records. Ann Fam Med. 2011;9(1):57-62.
34. R: A language and environment for statistical computing (version 3.4.3) [computer program]. Vienna, Austria: R Foundation for Statistical Computing; 2017.
35. Horst J, Duffin S, Sanchez S, Bratland M. Radiographic Changes Following Treatment of Dental Caries with Silver fluoride. CDA Journal;46(1):105-112. 2018.
36. Urquhart O, Tampi MP, Pilcher L, et al. Nonrestorative Treatments for Caries: Systematic Review and Network Meta-analysis. J Dent Res;98(1):14-26. 2019.