Effect of Silver Diammine Fluoride on Incipient Caries Lesions in Erupting Permanent first Molars: A Pilot Study

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ABSTRACT

Purpose: This study's purpose was to test silver diammine fluoride (**SDF**) in arresting incipient occlusal caries in erupting permanent first molars and to compare it with other approaches.
Methods: Sixty-six first erupting permanent molars were randomly divided into 3 groups: cross tooth-brushing technique (**CTT**), application of SDF, and glass ionomer fissure sealant (**GIC**). The clinical procedures were conducted by the same dentist. Teeth were assessed clinically by 1 blinded examiner using visual inspection at baseline and after 3, 6, 12, 18, and 30 months and radiographically at 6-, 12-, and 30-month follow-up evaluations. The Kruskall-Wallis test was used to compare noninvasive treatments, and the Friedman test was performed to evaluate differences for each group during different follow-up periods.
Results: A reduced number of active caries lesions was noted in all groups. After 3 and 6 months, SDF showed a significantly greater capacity for arresting caries lesions than CTT and GIC. At 18- and 30-month evaluations, no differences were observed among the 3 groups. All groups showed differences between baseline and all follow-up re-examinations.
Conclusions: All the tested techniques are equally efficient in controlling initial occlusal caries in erupting permanent first molars after 30-months of follow-up.
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A worldwide decrease in dental caries in the permanent teeth of children and adolescents has occurred recently.[1] The permanent first molars, however, continue to be the most frequently decayed teeth.[2] The difficult access to posterior teeth, presence of gingival tissue on the occlusal surface, absence of full-occlusion, and incomplete post-maturation of the enamel during the eruption are probably risk factors to dental caries for these teeth. The most important criterion for evaluating caries risk in erupting permanent first molars is the stage of eruption,[3] and its mean time of eruption has been determined to be approximately 15 months.[4]

Alternatives for controlling progression of dental caries on the occlusal surface are currently a concern. Several studies have demonstrated the success of noninvasive therapies in permanent first molars, such as home-based plaque control by cross tooth-brushing, application of cariostatic solution, treatment with varnish fluoride, and fissure sealing.[3,5-9]

Silver diammine fluoride (SDF)—$Ag(NH_3)_2F$—has been an effective cariostatic agent since the 1960s.[10] SDF

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acts simultaneously in inorganic dental structure and in micro-organisms involved in caries lesion formation.[11] Some studies have demonstrated the ability of SDF in arresting dentin caries in primary teeth[12,13] and also in preventing the development of carious lesions in permanent teeth.[8,11,14,15] No controlled clinical trial has been conducted aiming to evaluate the effectiveness of SDF on active initial caries lesions of erupting permanent teeth.

Based on these considerations, the aim of this in vivo pilot study was to test silver diammine fluoride (SDF) in controlling active enamel occlusal caries in erupting permanent first molars and to compare SDF with other noninvasive approaches (cross tooth-brushing technique and fissure sealing with glass ionomer cement).

METHODS

ETHICAL CONCERNS

This study was approved by the Ethics Committee of the School of Dentistry, University of São Paulo and was carried out between 2002 and 2005. The parents of all children provided signed informed consent prior to the clinical interventions. All children and their guardians/parents received general information about oral hygiene and dietary habits regarding prevention and control of dental caries. According to each patient's needs, they were scheduled for dental appointments and restorative treatment.

SAMPLE SELECTION

Sixty-six erupting permanent first molars were selected, each presenting active initial caries without cavitation on occlusal surfaces in a sample of 22 5- to 7-year-olds, each with at least 3 erupting permanent first molars, who were waiting to be treated at the Dental School of the University of São Paulo. Teeth with hypoplastic defects, restorations, or sealants on occlusal surfaces were not included in the sample.

TREATMENT REGIME

One randomly selected molar from each participant was allocated into 1 of 3 groups, and 2 other molars were randomly selected and distributed into the other groups. A different noninvasive technique was applied for each group: CTT, SDF, or GIC. The clinical procedures were conducted by the same dentist in order to standardize the techniques.

During the study, 8 teeth were excluded because they had been treated invasively or received composites or GIC sealants outside. Finally, groups were configured in the following manner: 18 teeth in the CTT group; 20 teeth in the SDF group; and 20 teeth in the GIC group. All children have used fluoridated toothpaste.

CTT group children and parents received special instructions on an appropriate technique for plaque control on the occlusal surface of partly erupted permanent first molars. The toothbrush was held in the buccolingual direction with the bristles facing toward the occlusal surface and moving in small circular motions.[5] It was recommended to the parents that they should help their children brush their teeth at least once a day.

In the second group (SDF), 10% silver diammine fluoride solution (Cariostatic, Inodon, Porto Alegre, Brazil) was applied to selected erupting molars with small cotton pellets for 3 minutes. Teeth were then washed with a 30-second water spray.[8] Teeth were isolated from saliva with cotton rolls, and mucosa near the treated tooth was protected with petroleum jelly to avoid staining. The application was repeated twice, with an interval of 1 week.

In the GIC group, teeth were sealed with conventional GIC presenting lower viscosity—(Vidrion F, SSWhite, Rio de Janeiro, Brazil) under relative isolation, using cotton rolls for moisture control. The material was mixed in a powder/liquid proportion of 1:1, according to manufacturer's recommendation. This material was inserted using a dental probe, pressed into pits and fissures, and protected with a layer of petroleum jelly. Patients were instructed not to eat for at least 1 hour afterwards. The material was not reapplied in cases of partial or total loss.

EVALUATIONS

The occlusal surfaces of the selected teeth were assessed clinically using visual inspection by 1 trained examiner at the beginning of the study and re-examined after 3, 6, 12, 18, and 30 months. The visual exam was performed in a dental unit with the aid of a light reflector and clinical mirror after cleaning and air-drying for at least 5 seconds. A drawing of each

Table 1. Means of Dental Caries Scores at Baseline and at 3-, 6-, 12-, 18-, and 30-month Follow-up Evaluations for Cross Tooth-brushing Technique (CTT), Application of Silver Diammine Fluoride (SDF), and Sealing With Glass Ionomer Cement (GIC)

Technique	Tooth sample size	Baseline	3-month follow-up	6-month follow-up	12-month follow-up	18-month follow-up	30-month follow-up
CTT	18	3 a	2.3 b	2.1 b	1.9 b, c*	1.0 c	1.4 c
SDF	20	3 a	1.1 b, c*	1.2 b*	1.0 c	1.0 c	1.0 c
GIC	20	3 a	1.8 b, c	2.0 c	1.4 b, d	1.4 b, d	1.3 d

** Represents a statistically significant difference among values within the same column. Different letters express a statistically significant difference among values within the same technique (P<.05).*

evaluated occlusal surface was made to more properly record the location of caries lesions and to allow future comparisons during clinical follow-ups. Additionally, a score to classify the status of each surface was attributed. The examiner was blind to each tooth's treatment. All assessments were done without any information about the patient's baseline and follow-up examination data.

GIC group teeth had only the visible part of the occlusal surface re-examined in the follow-up evaluations. Therefore, only occlusal sites (bottoms and walls of pits and fissures) in which the sealant had been lost or newly erupted parts of the surface could be evaluated. The examiner's criteria were adapted from Carvalho et al[3,5] and included evaluating the activity of enamel lesions, based on the differential clinical appearance of arrested and active caries lesions. Dental caries were recorded as: 0=entire sound surface (normal enamel translucency); 1=surface presenting only arrested lesion(s) (shiny white spot lesions) or with different degrees of brownish discoloration without any opacities around it; 2=a unique surface associating presence of arrested and active lesion(s), considering surfaces that presented sites in different activity status (association of pertinent features for scores 1 and 3); 3=surfaces presenting only active lesions or sites (opaque enamel with a dull-whitish surface; and 4=enamel with loss of continuity of the surface. This adapted criteria differs from the previous one[3,5] because of score 2, which permits considering a surface, with active and arrested sites, that is different from a surface that presents only one of these lesions separately. Consequently, this criteria modification collapses independent characteristics from scores 1 and 3. Figure 1 illustrates each of the scores previously described.

Sealed teeth were also observed by one trained examiner in the same aforementioned clinical conditions. The criteria adopted to evaluate sealant retention were: R1=total retention of sealant on the occlusal surface; and R2=partial or total absence of sealant on occlusal surface.

Bitewing radiographs of all patients were taken at 6, 12, and 30 months using bitewing holders. They were evaluated with standardized illumination conditions. If a lesion was located in the dentin, it was added to score 4 of the visual criteria. When score 4 was identified visually and/or radiographically, the noninvasive treatment was interrupted and patients were scheduled for restorative procedures.

After 30 months, the permanent first molars of all children were in full occlusion, which was checked by articulation paper.

STATISTICS

The statistical unit considered in this study was the tooth. The differences among noninvasive treatments were analyzed using the Kruskall-Wallis test, employing the scores obtained in the clinical examination. For analyzing differences for each group during the follow-up, the Friedman test was performed. The significance level for all the tests was $P<.05$.

RESULTS

A general reduction in active lesions was noted in all studied groups ($P<.05$). Table 1 shows the means of scores at the baseline and follow-up examinations.

After 3 and 6 months, SDF (score means=1.1 [3 m] and 1.2 [6 m]) showed a greater capacity for arresting the caries lesions than CTT (2.3 in 3 m and 2.1 in 6 m; $P<.001$) and GIC (score mean=1.8 in 3 m, $P<.01$; 2.0 in 6 m, $P<.001$; Table 1). Other groups present no statistical differences at this time ($P>.05$; Table 1).

At the 12-month follow-up examination, SDF (score mean=1.0) and GIC (score mean=1.4) were equivalent at arresting the lesions ($P>.05$), but both were more efficient than CTT (score mean=1.9). At 18- and 30-month evaluations, no differences were observed among the 3 groups ($P>.05$; Table 1).

All groups showed differences between baseline and follow-up re-examinations (Table 1). The total retention rates for GIC sealants were 32% and 9%, respectively, for 6-month and 30-month evaluations.

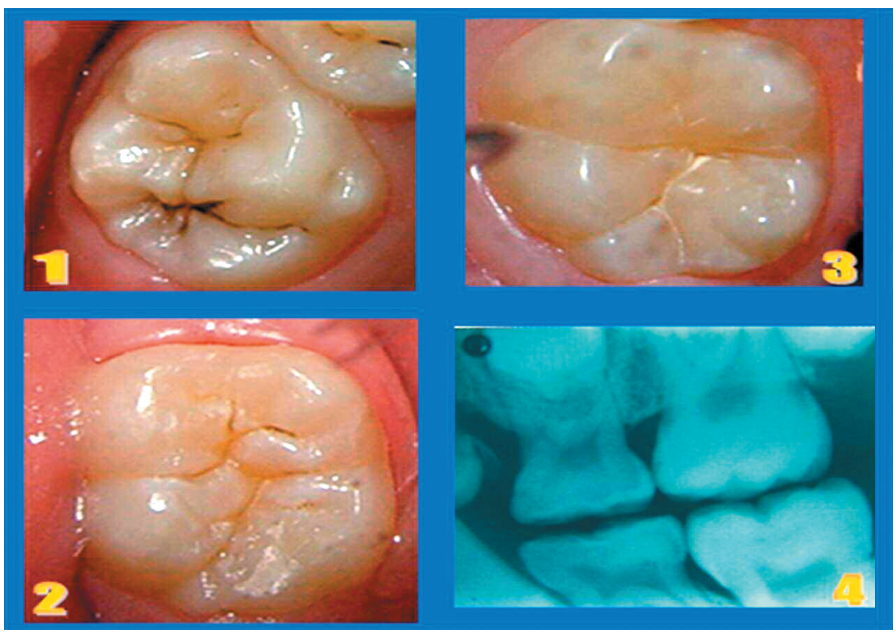

Figure 1. Scores used in the caries activity assessment adapted from Carvalho et al.[3,5]

DISCUSSION

Erupting permanent first molars can be particularly susceptible to caries due to being in infraocclusion. This position makes brushing with a conventional toothbrush more difficult and reduces self-cleaning by functional use of the tooth. In fact, a peak in caries susceptibility can be detected 1 to 3 years after emergence of the permanent first molar in individuals with a high risk

for developing caries.[16] Therefore, this study's main purpose was to evaluate the therapeutic effect of an alternative therapy, the SDF solution, on active enamel occlusal caries in erupting teeth. Its preventive action on pits and fissures was previously described,[14] but no study has tested the ability of this solution to arrest initial caries lesions.

Concerning this study's design, the presence of active enamel caries lesions was required in the inclusion criterion during the sample's composition,[17] which could have limited the sample size. On the other hand, the caries progression was evaluated by scores and—not only considering the presence of caries lesions—what contributed to the power/significance of the study. The selection of active lesions as the baseline permits properly evaluating the therapeutic effects of noninvasive techniques instead of only preventive ones.

A split-mouth study, as used in this case, permits the comparison of efficiency of test and control materials—considering the exact same patient conditions and caries risk parameters (sucrose consumption, oral hygiene, access to fluorides).[18] On the other hand, it is not possible to exclude a possible carry-over effect among the different approaches. Considering that GIC may act as a reservoir of fluoride ions and release these ions constantly, teeth which were not sealed with GIC could have been influenced by GIC fluoride releasing in caries arrestment lesions. Nevertheless, clinical studies have still exhibited confusing data about cariostatic effects of fluoride-releasing materials. Hence, it is not clear whether cariostatic effects achieved from an increase in fluoride in plaque and saliva are sufficient to prevent or inhibit caries lesions.[18]

In this pilot study, 3 teeth and 3 techniques were assessed for each patient, which adds analytical complications. Additionally, a higher number of participants would be desirable. Despite these limitations, the good results obtained encourage further research with a higher number of subjects that assesses SDF and other techniques in homologous pairs of teeth.

Visual indexes have been developed to evaluate lesion activity. The criteria adopted in this study were slightly simplified, but they also consider the activity status of lesions. The index used by Carvalho et al[3,5] was modified to differentiate surfaces that presented simultaneously active and inactive sites from those which presented only active or inactive lesions. This was because earlier studies considered different sites in the same tooth, while in the present study, the status of the entire occlusal surface was recorded. Considering noncavitated enamel lesions, a clinical visual assessment could be considered as a sole diagnostic method, whereas interproximal radiographs could not contribute significantly in caries clinical trials.[17,19] This explains why radiographic exams were only performed in some follow-ups in order to detect caries lesion progression from enamel to dentin that had not been detected clinically.

With the exception of the SDF, the other tested groups represent some of the most common choices made by dental professionals to control active caries. Cross tooth-brushing has been noted as an effective means of controlling occlusal plaque[20] and arresting occlusal initial caries.[3,5] The use of fluoride toothpastes seems to exert a protective effect on occlusal surfaces, considering the rate of transitions from carious to sound areas, particularly in young permanent dentition.[21] On the other hand, the GIC sealant is a frequently effective alternative adopted by dentists to control active enamel lesions.[22,23] This is especially true in erupting teeth in which humidity control is more complicated and discourages the use of composite fissure sealants. In our study, SDF presented good results in arresting active caries lesions, even at 3 months. Although all applied techniques in this study have successfully reversed the activity status of lesions on occlusal surfaces of erupting permanent first molars, the use of SDF showed better results in inactivating caries in a short period of time. This was because more expressive differences were observed in this group at first re-evaluations. Other studies have observed the effectiveness of SDF in preventing caries development in permanent first molars.[10,15]

Despite the absence of previous research on the arrestment of enamel caries lesions with SDF, other studies using this solution have been performed on dentin cavities of primary teeth and have shown SDF's effectiveness in inhibiting the progression of the lesions.[8,12,13] Based on these facts and our study's results, the use of SDF in active enamel lesions can also be recommended.

The more immediate ability of SDF to arrest caries could be related to the association of organic and inorganic effects observed when SDF solution is applied and CaF_2, Ag_3PO_4 and Ag-protein are formed on a tooth surface. The Ag-protein inhibits the growth of some cariogenic bacteria and the formation of dental plaque, whereas CaF_2 develops a protective action on enamel, resulting in fluoride storage on the surface.[11]

This cariostatic agent generally stains the surface black because of the silver phosphate, a by-product of the reaction of SDF with hydroxyapatite, which assumes a black color when exposed to light.[11] The stain can also be attributed to a reaction to salivary pellicles.[14] Our study showed a discoloration of all teeth on which the product was used and also the inactivation of all lesions on their occlusal surfaces, which suggests that the discoloration observed with the use of SDF could be associated with arresting carious lesions. Despite the fact that black stains were more frequent in the SDF group, they also occurred in other groups, which is similar to findings described by Llodra et al.[8] As expected in any study carried out with sealants, GIC group teeth were clearly noticed among others. Considering the loss of sealant during the study's period, however, this influence was extremely minimized. Thus, the blinded nature of the examination was not affected.

Comparing the SDF group with others in a short-term evaluation allowed us to designate it as having a faster effectiveness. Nevertheless, the other treatments presented similar efficacy after longer periods. After 12 months, for instance, it was observed that both SDF and GIC treatments

were more effective than CTT in controlling occlusal caries. In a longer analysis, however, all noninvasive techniques were equally effective in controlling enamel caries in erupting permanent molars. This agrees with the results found by Arrow,[6] who compared tooth-brushing instruction and motivation to sealant application for 24 months. By contrast, other authors have observed that unsealed occlusal surfaces with early enamel lesions had a greater potential for developing a dentinal lesion than those sealed with GIC.[22] Other studies that included sound occlusal surfaces have evidenced a higher increment of caries in the control group than the test group (sealed with GIC).[7]

Despite the loss of most GIC sealants in this study, reapplication was not performed, considering the conventionally adopted practice in research protocols.[23] Knowing that the efficiency of this technique could not be associated with the retention of sealant material, this clinical procedure would result in an additional waste of time and money.[7] In fact, residual particles of GIC are usually found at the bottom of the fissures, in spite of their apparent absence.[24]

The reduction of active lesions in all studied groups suggests a general trend of inactivation of enamel caries, provided that erupting teeth gain full occlusion with their antagonist independently of the noninvasive technique chosen. Functional usage of teeth, in addition to improving access for tooth-brushing, promoted arrestment of lesions initiated during eruption.[25] Furthermore, the 30-month period adopted exceeded the mean eruption time attributed to this group of teeth.[4] At the end of the study, all teeth presented functional occlusion.

According to a long-term analysis, inactivation of enamel caries was not technique-dependent in the present study. Nevertheless, CTT implies an active participation of children and their parents, and GIC sealant is a more time-consuming technique than the application of SDF. Furthermore, SDF promotes a faster arrestment of caries lesions. Therefore, SDF could be an excellent alternative to prevent cavitation in active caries lesions more prone to progress.

CONCLUSIONS

Based on this study's results and limitations, the cross tooth-brushing with fluoride dentifrice, silver diammine fluoride (**SDF**), and glass ionomer fissure sealant techniques are equally efficient in controlling initial occlusal caries in erupting permanent first molars after 30 months of follow-up. SDF, however, shows a faster ability to inactivate lesions compared to the other noninvasive techniques tested.

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