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Effects of a Stannous Fluoride-Impregnated Dental Floss on in vivo Salivary Fluoride Levels

Casey C Flatt, RDH, Donna Warren-Morris, RDH, MEd, Steward D Turner, PhD and Jarvis T Chan, DDS, PhD

Casey C. Flatt, RDH, practicing dental hygienist and a graduate from The University of Texas Dental Branch at Houston; Donna Warren-Morris RDH, MEd, associate professor; Steward D. Turner, PhD, associate professor; Jarvis T. Chan, DDS, PhD, professor. Flatt and Warren-Morris are from The University of Texas Dental Branch at Houston; Turner and Chan are from The University of Texas Medical School at Houston.

Purpose. The aim of this in vivo pilot study was to determine the concentration of fluoride retained intra-orally in saliva after flossing with dental floss impregnated with stannous fluoride (SnF_2).

Methods. Participants flossed their teeth ad libitum with 2 premeasured lengths of fluoridated dental floss. Expectorated saliva samples were collected in vials before flossing (PF), immediately postflossing(IPF), at 30 minutes (30), and 1 hour (60) after flossing for analysis with a fluoride-specific electrode and an Orion millivoltmeter. Postflossing samples were compared to the preflossing samples using ANOVA and Tukey's HSD.

Results. Differences between the PF and IPF group means were found to be statistically significant at $p<0.01$. No other significant differences were found between or among any of the groups. Salivary fluoride levels at 60 minutes (60) were similar to those prior to flossing (PF).

Conclusions. It can be concluded that fluoride can be released from flossing with the tested SnF_2-impregnated dental floss elevating salivary fluoride levels for at least 30 minutes. Use of this fluoride-containing dental floss offers an option for delivery of fluoride to individuals at risk for dental caries.

Keywords: dental caries, fluoride, dental floss, stannous fluoride

Introduction

Widespread implementation of fluoride has resulted in a significant decline in dental caries prevalence in recent decades.[1-3] Recent evidence-based guidelines from the American Dental Association recommend fluoride therapies for patients at risk for dental caries.[4] Research has documented that fluoride is effective in preventing dental caries through its ability to enhance remineralization, inhibit demineralization of tooth structure, and inhibit the acid production of cariogenic bacteria such as *Streptococcus mutans (S. mutans)*.[2,5,6] Even low levels of salivary fluoride have been shown to be capable of causing mineral growth in hydroxyapatite.[7,8] Additionally, "the presence of low, but slightly elevated levels of fluoride in plaque and saliva is the predominate means by which fluoride exerts its anti caries effect."[2,5] In addition to fluoride-containing toothpastes and mouthrinses, dental flosses impregnated with fluoride have been shown to increase fluoride concentration

on enamel surfaces.[9,11] Although previous studies have documented the preventive benefits of fluoride-impregnated dental floss and products, there are no reports of analytical data regarding the intra-oral concentration of fluoride ion in saliva after use of this new stannous fluoride-impregnated dental floss.[9-15] This aim of this pilot study is to determine the fluoride level of whole mouth stimulated saliva after use of a new floss impregnated with stannous fluoride. This study is relevant to the practicing dental hygienist in the selection and recommendation of evidence-based preventive therapies for dental caries.

Review of Literature

Fluoride and De/Remineralization

The dental caries process demonstrates the significance of fluoride concentration on the enamel surface. This process involves the dissolution of calcium and phosphate minerals from the enamel or cementum.[6] As long as these minerals are replenished back into the tooth at the same rate as they are lost, net demineralization (loss of intact surface) does not occur.[6] The rate of the demineralization-remineralization process is affected by several factors including: the quality and quantity of saliva; the presence of fluoride; the quality of the diet; the bacteria present; and the quality of the tooth structure itself.[6]

Fluoride can reduce the rate of demineralization by inhibiting the solubility of tooth structures in acid. Fluorapatite [$Ca^{10}(PO_4)_6F_2$] that forms in the presence of fluoride is more resistant to acid than hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$] or carbonated hydroxyapatite.[6] Topical fluoride incorporates into the outer surface of the tooth by chemically bonding with calcium and phosphate; thereby, preventing their loss during acid exposures. Fluoride is also capable of attracting additional calcium and phosphate reserves from the saliva, plaque, and diet for deposit back onto the tooth surface.[6]

Even at very low levels, fluoride participates in the remineralization process. In a study conducted by Ingram et al, the mean ppm F in saliva was 0.0175 (± 0.006). At this low level, they found that "mineral crystallite growth resulted with preferential calcium uptake by hydroxyapatite mineral," suggesting that salivary fluoride plays an important role in remineralization.[8] A previous study found no correlation between enamel fluoride uptake and caries reduction.[16] Studies have shown that salivary fluoride levels of 0.03 ppm enhanced remineralization of tooth structures up to an optimal level of 0.08 ppm.[17-20] Other studies have demonstrated a reduction in demineralization of tooth structures at levels of 0.024 ppm F at a pH as low as 4.3.[18-20] It has also been reported that fluoride products initially cause a high level of fluoride in saliva that decreases with time, but can be retained at therapeutic concentrations of 0.03-0.1 ppm F for 2-6 hours.[21,22] Patients with xerostomia were shown to maintain levels for even longer periods due to a low salivary flow rate.[23] Featherstone et al reported that fluoride present in the oral fluids at the time of acid attack can "travel with the acid down into the sub-surface of the tooth, adsorb to the crystal surface and protect it against being dissolved."[2]

Fluoridated Products and Saliva

Studies have reported that salivary fluoride levels can be elevated to therapeutic levels with the use of fluoridated mouthrinses, toothpastes, and chewing gums.[22,24-28] Fluoridated chewing gums were shown to increase levels by up to 50% for 20 minutes.28 Fluoridated dentifrices of 1100 ppm F increased the salivary fluoride levels for 60-120 minutes.[21,22,24-27] Other studies have shown that toothpicks impregnated with fluoride increase the fluoride concentration of saliva in approximal areas and are capable of releasing approximately 0.15 mg F for 2 minutes after use.[29] Kashani et al found that the use of a fluoride-impregnated toothpick or floss (not the test floss in this study) increased the approximal salivary fluoride levels similar to, or somewhat higher than, those resulting from the use of a fluoridated mouthrinse or dentifrice.[30] Other studies comparing administration methods of administering fluoride to inter-proximal areas reported that toothpicks

and dental floss impregnated with fluoride elevated salivary fluoride levels in approximal areas for up to 60 minutes after use.[13,31,32]

Fluoride Effects on Bacteria

Several studies have reported that less acid is produced by bacteria on the tooth surface after an application of SnF_2.[33-37] It is theorized that the stannous (Sn^2+) ion in saliva reacts and oxidizes thiol groups, thereby preventing bacterial metabolism of carbohydrates or glycolysis.[35,38] One of these studies reported that the stannous ion accumulates in bacterial plaque via interactions with anionic bacterial polymers.[38]

Kashani et al reported that toothpicks impregnated with 8% SnF_2 or 2% chlorhexidine lowered the salivary S. mutans count after 2 days by 73% and 99%, respectively. They reported that there was a small effect on delaying the recolonization of salivary *S. mutans* for a 3-week period.[30] Keene et al found that the addition of SnF_2 to dental floss had a dramatic effect on lowering *S. mutans*.[15] Further, studies have also confirmed the efficacy of fluoride for the growth prevention of S. mutans in vitro.[9,32-37] Ota et al found that SnF_2 significantly reduced the ability of *S. mutans* to cohere to one another after adhering to the tooth; thereby, potentially reducing plaque quantity.[39] Additionally, the use of fluoride-impregnated dental floss has been shown to significantly reduce the number of interproximal *S. mutans* organisms while increasing the fluoride content of the enamel.[10,11,14]

The purpose of this study was to determine the concentration of fluoride in whole mouth stimulated saliva at various time intervals following flossing with a commercially- available stannous fluoride impregnated dental floss.

Methods and Materials

A convenience sample was recruited from a class of 38 second-year dental hygiene students enrolled in the University of Texas Dental Branch at Houston School of Dental Hygiene. All 30 volunteers were female and ranged from 21-32 years of age. The students volunteered as study participants as part of their community dental health course in research design and methodology. On the morning of the study, participants were instructed to refrain from using any fluoride-containing oral products. Participants were excluded if they had brushed, flossed, or rinsed with a fluoridated oral product within 3 hours of sampling or if they reported an allergy to stannous fluoride. Two participants were excluded from the analysis due to unusually elevated salivary fluoride levels in their preflossing samples (0.31 and 0.25 ppm) since this could indicate the use of fluoridated products. All participants had a minimum of 28 teeth.

Participants were asked to floss their teeth *ad libitum* with 2 premeasured lengths of fluoridated dental floss (FlossRx, Omni Pharmaceuticals, West Palm Beach, Fla.) for 90 seconds total. They were instructed to use a different strand for each arch. No further instructions were given regarding flossing technique. The manufacturer information on the package states that the floss delivers 2-4 mg SnF_2 per 2 21-inch strands.

Individual stimulated saliva samples were collected in numbered vials prior to flossing, immediately after flossing, and at 30 and 60 minutes after flossing. Participants were asked to expectorate into vials until 10 ml were collected. Fluoride measurements were conducted for each sample with a fluoride specific electrode (Orion Model 960900) coupled to a millivolt meter (Orion model 811) and recorded for comparison. One individual, not blind to study design, was trained and calibrated to use the equipment and performed all measurements. Only the study PI had the code identifying the numbered vials to both study participants and testing sequence: PF, IPF, 30, or 60. The electrode and meter were tested and calibrated with standard fluoride solution prior to the study.

The study was approved by the institution's Committee for the Protection of Human Subjects. Consent forms were signed and individual participant information was kept confidential.

Statistical Analysis

The quantitative difference between preflossing salivary fluoride levels and postflossing salivary fluoride levels represent the amount of fluoride released by the floss and retained intra-orally during flossing. Comparisons of mean fluoride levels were made between and among the groups with multiple comparison ANOVA using Tukey's HSD Method.

Results

Results are shown in Table I and are reported in ppm F. Means and standard deviations were computed for each group: preflossing (PF), immediately postflossing (IPF), 30 minutes postflossing (30), and 60 minutes postflossing (60). Tukey's HSD intervals for significance were calculated for comparison between groups at the p=0.01 level and found to be 1.21 ppm. In other words, if the difference between group means was 1.21 ppm or greater, the difference was statistically significant. Table I shows that the only statistically significant differences found were between the PF and IPF groups. No other significant differences were found between or among any of the groups. Salivary fluoride levels at 60 minutes (60) were similar to those prior to flossing (PF).

Table I. Comparison of salivary fluoride levels after flossing with fluoridated dental floss.

Preflossing (PF)	Immediately Post Flossing (IPF)	30 minutes Post Flossing (30)	60 minutes Post Flossing (60)
0.12	7.03*	0.23	0.16
0.09	2*	0.18	0.11
0.1	2.79*	0.13	0.1
0.11	6.16*	0.42	0.24
0.09	4.22*	0.19	0.12
0.08	5.86*	0.15	0.11
0.07	9.35*	0.13	0.09
0.16	5.31*	0.22	0.13
0.09	5.91*	0.12	0.08
0.1	8.27*	0.14	0.1
0.11	6.27*	0.18	0.13
0.09	1.96*	0.12	0.09
0.08	10.2*	0.12	0.09
0.08	2.74*	0.2	0.09
0.09	5.2*	0.2	0.13
0.09	2.97*	0.12	0.1
0.09	2.17*	0.12	0.1
0.11	2.96*	0.1	0.09
0.09	12.64*	0.1	0.1
0.13	6.91*	0.22	0.16
0.1	7.76*	0.15	0.13
0.09	9.3*	0.14	0.1
0.08	4.45*	0.11	0.09
0.08	7.58*	0.13	0.09
0.08	4.86*	0.16	0.11
0.07	7.39*	0.15	0.11
0.08	1.31*	0.12	0.12
0.13	5.18*	0.17	0.13
Mean (sd)			
0.1 (0.02)	5.67 (2.80)	0.16 (0.06)	0.11 (0.03)

*Indicates a significant difference.
Means and standard deviations (n=28) given.
Tukey's HSD for comparison between groups at the 0.01 significance level was 1.21 ppm F.

Discussion

This sample of dental hygiene students presented with preflossing salivary fluoride levels above the reported therapeutic level of 0.03 ppm F with a range of 0.07-0.13.17 The study participants reported that they had not used a fluoridated

product for 3 hours prior to sampling. All of these subjects reported the regular use of fluoridated toothpaste and were drinking water fluoridated at the 0.7ppm F level (Greater Houston area). In the study conducted by Ingram et al, subjects refrained from using fluoridated products for 18 hours prior to sampling and the mean ppm F was 0.0175 (± 0.006). This level was lower than that in the present study where the subjects were asked to refrain from use of fluoridated products the morning of the study.[8] This baseline salivary fluoride level was comparable to those reported in 2 previous studies.21,22 Two other previous studies reported baseline salivary fluoride levels much higher than those in this study with a range of 1.1-1.9 ppm F.[24,27] However, baseline values vary with populations and have no impact on level increases since they merely serve as a reference point for comparison.

The results of the salivary fluoride levels immediately postflossing ranged from 1.3 ppm F to 12.64 ppm F. These levels had dropped to a range of 0.1 ppm F to 0.42 ppm F after 30 minutes and were back to preflossing levels at 60 minutes. With the test floss, this study did not confirm the findings of previous studies reporting an elevation of salivary fluoride levels for 60-120 minutes. 21,22, 27,29 These previous studies dealt with highly concentrated dentifrices (1100 ppm F) and rinses (228 ppm F). It is possible that removing saliva from the mouths to test for the IPF could have potentially reduced the salivary fluoride levels measured at 30 minutes and 60 minutes. Future studies could test the salivary levels initially at 60 minutes to prevent this proposed interference and possibly test oral fluids from approximal areas as well.

The large range in IPF fluoride levels may be explained by a difference in flossing technique by some of the individuals. It is possible that using more of the surface area of the floss could result in the release of more fluoride into the mouth. If the individual did not move along the floss to a new area of floss for each tooth, less fluoride potentially could be released and the converse would result in more. Each individual was instructed to floss for 90 seconds to control for this variable. Future studies could include flossing instructions to use a certain amount of the floss strands, but this study was only interested in the results of usual, everyday flossing technique.

The manufacturer reports that 2-4 mg of fluoride is available from the 2 strands of floss and this study demonstrated that it can be released during use. The floss comes pre-packaged with 2 21-inch strands of floss individually wrapped. The floss is available only through a dental office, therefore, patient education can be given to reduce the risk of toxicity or fluorosis for small children as with all fluoridated products. Patients with a risk for dental caries may benefit from the fluoridated floss for mechanical plaque removal, fluoride delivery to interproximal areas, and increase in their salivary fluoride levels.

The use of a stannous fluoride-impregnated dental floss offers an option to the dental hygienist in the selection of evidence-based preventive dental products and techniques. Further research could focus on enamel uptake and actual caries reduction resulting from the use of this fluoridated dental floss over time. Additionally, the test floss should be studied more closely to determine if delivery of fluoride to the interdental areas reduces interproximal caries and/or bacterial loads. Guidelines on the use of this specific floss in children are needed to prevent toxicity and dental fluorosis.

Conclusions

It can be concluded that a therapeutic amount of fluoride can be released from flossing with the tested SnF_2-impregnated dental floss and that salivary fluoride levels are elevated for at least 30 minutes. Use of this fluoride-containing dental floss offers an option for delivery of fluoride to individuals at risk for dental caries.

Notes

Correspondence to: Donna Warren-Morris, RDH, MEd at donna.p.warren@uth.tmc.edu.

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