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Time dependence of enamel fluoride acquisition from APF gels II. In vivo study

Stephen H.Y. Wei, BDS (Hons), DDS, MS, MDS, FRACDS
Eilly W.S. Lau, BDS, MDS, FRACDS Faiez N. Hattab, BDS, PhD

Abstract

In vivo enamel fluoride (F) uptake as a function of time after a single application of a new topical APF gel, Minute-Gel™ (gel A), was compared to a control APF gel, Nupro® (gel B). The retained F in enamel after different post-treatment intervals also was assessed. Forty orthodontic patients aged 10-16 with four premolars scheduled for extraction were divided into two subgroups according to post-treatment intervals of 30 min or 24 hr. Enamel F was assessed using an acid-etch biopsy technique as for the in vitro study. The results confirmed the findings of the in vitro study in that: (1) F uptake by dental enamel is time dependent and 4 min of application time resulted in significantly greater F uptake than the 1-minute application; (2) the F retained in enamel after 24 hr was slightly lower than after 30 min, but the difference was not statistically significant; (3) gel B produced a higher enamel F uptake compared to gel A in the same time periods; and (4) the results support the current recommendation of the Council on Dental Therapeutics of the American Dental Association and that 4 min should be used for professional topical F applications.

A new topical APF gel (Minute-Gel™ – Oral-B Laboratories; Redwood City, CA) was introduced in 1985. It was claimed that a 1-minute application time of Minute-Gel increased the enamel F concentration up to 77.4% (12,000 ppm) of that obtained after a 4-minute application (15,500 ppm). The implication of the 1-minute application of Minute-Gel is that dentists can save 3 min of clinical chairside time without sacrificing the efficacy of the agent. In an in vitro study, Wei and Hattab (1987, 1988) found that shortening the application time of Minute-Gel and another conventional APF gel resulted in a significant decrease (2.5-fold) in the uptake of F compared to the 4-minute treatment. Because of the scarcity of scientific data of in vivo enamel F uptake as a function of application times, the present study was carried out to elucidate this relationship.

The aims of this study were to evaluate enamel F uptake after a single application of Minute-Gel and a conventional APF gel in vivo. The primary goal was to assess the F uptake as a function of application time. Additionally, the retained F in enamel after different post-treatment intervals also was assessed. The surface morphology of the enamel surfaces after such topical F treatment was studied by scanning electron microscopy (SEM), but will be the subject of a separate report (Lau 1987).

Materials and Methods

The participants of the study were 40 orthodontic patients aged 10-16 years with life-long exposure to fluoridated water (0.7 ppm) and with no history of topical F application for at least 3 months prior to the study. All patients had 4 premolars scheduled for extraction. The selected teeth were caries free, with no visible cracks, hypoplastic or other defects. The patients were randomly assigned to receive either gel A (Minute-Gel, an APF gel containing 1.23% F from sodium fluoride and hydrogen fluoride at pH 3.5, batch no. XHDT), or gel B (Nupro® — Johnson and Johnson Dental Products Co; East Windsor, NJ, an APF gel containing 1.23% F from sodium fluoride and hydrogen fluoride in 0.1M phosphoric acid at pH 3.0-3.5, batch no. 5M5823).

The study was blind and the 2 products were identified by code, which was not revealed before completion of the study. The 20 patients of each gel group were divided into 2 subgroups according to the post-treatment intervals of 30 min or 24 hr. Prior to topical F application, the teeth were cleaned with a rubber cup and aqueous slurry of pumice. One of the 4 premolars was selected randomly as the control while the 3 remaining teeth were topically treated for either 1, 2, or 4 min on a random basis. After the predetermined application time, the teeth were washed thoroughly with compressed water/air via a triplet syringe for 60 sec. The F-treated tooth was isolated carefully with cotton rolls so that there would be no transfer of the applied F to the remaining teeth. During the first visit, the control

tooth for each patient was extracted. For patients in subgroup 1, F-treated teeth were extracted after 30 min. Patients in subgroup 2 were instructed to retain their normal daily routine of brushing and eating until the next appointment at 24 hr when the remaining teeth were extracted.

The Acid-Etch Biopsy Procedure

The enamel biopsy technique was the same as for the in vitro study (Wei and Hattab 1988). Each tooth was examined under a stereo-dissecting microscope at 30x to assure that the surfaces selected were free of defects before enamel biopsy. The F concentration in the solutions containing the sampled enamel were determined using combination F-ion electrodes (Orion model 960900 — Orion, MA).

The phosphate concentration was determined by a double-beam spectrophotometer (Shimadzu model UV-150-02 — Tokyo, Japan) using the one-step malachite green method (Hattab and Linden 1984).

The mean F concentrations were adjusted to standardized depths of 3, 5, and 13.5 μm.

An analysis of variance was used to evaluate the differences in enamel F concentrations between treated and controls with respect to the following factors: (1) topical F agents (gel A vs. gel B); (2) application times (1, 2, and 4 min); and (3) extraction times (30 min vs. 24 hr).

The data were further analyzed by Scheffe's test to determine the level of significance.

Results

Tables 1 and 2 show the F concentration (ppm) and the total F acquired (ppm) after topical F treatment using standardized depths using 30-minute and 24-hour post-treatment extraction times, respectively. From Table 1, it is clear that the F uptake at 3 μm thick was greater after 4 min than 1 min for both gels A and B, at 30-minute extraction time. For gel A, the F concentration at 3 μm after 4 min was 4013 compared to the 1-minute treatment at 3780. For gel B, the F concentration after 4 min was 5433 compared to 4285 ppm after 1 min. There are significant differences between the two F gel treatments at a level of $P < 0.05$ (Table 1). Teeth that were extracted after 4-minute applications of gel B (3504 ppm) gave a higher F uptake than gel A (1520 ppm) under the same conditions. Similarly, at 24 hr after topical F application (Table 2), gel B (3065 ppm) gave a significantly higher F uptake than gel A at 2 min (670 ppm) and 4 min (668 ppm) treatments ($P < 0.05$).

Table 3 shows the effect of F application time on enamel F uptake at the 3 standardized depths for both gels combined. The F uptake after a 1-minute application was significantly lower than after 4 min for layer 1 (29 vs. 54%). The total F uptake after 1-minute (1197 ppm) and 4-minute (2440 ppm) applications was also

TABLE 1. Fluoride Concentrations at the Three Enamel Depths (Standardized for Comparison) of Control (APF-gel Treatment) Enamel Surfaces After 1, 2, or 4 Min Exposure to Topical F Agents

Topical F Agent and Application Time (Extraction at 30 Min)	(N)	*F Concentration (ppm) at Standardized Depths (Means ± SD)* 3 μm	8 μm	13.5 μm	*Acquired F in the Outer 13.5 μm Thick Enamel* ppm	
Gel A						
Control	10	2959 ± 1153	1699 ± 498	1443 ± 477	–	
1 min	10	3780 2234	2076 759	1538 444	1293	
2 min	10	3942 2064	2223 813	1495 439	1559	
4 min	10	4013 1292	2106 518	1505 360	1520	*
Gel B						
Control	10	3152 944	2142 757	1763 733	–	
1 min	10	4285 1301	2420 680	1850 414	1494	
2 min	10	5565 1329	2881 925	2054 764	3443	
4 min	10	5433 ± 1693	3200 ± 1764	1930 ± 623	3504	*

* Significantly different, $P < 0.05$.

TABLE 2. Fluoride Concentrations at the Three Enamel Depths (Standardized for Comparison) of the Control and Experimental (APF-gel Treatment) Enamel Surfaces After 1, 2, or 4 Min Exposure to Topical F Agents

Topical F Agent and Application Time (Extraction at 24 Hr)	(N)	*F Concentration (ppm) at Standardized Depths (Mean ± SD)* 3 μm	8 μm	13.5 μm	*Acquired F in Outer 13.5 μm* ppm	
Gel A						
Control	10	3306 ± 729	2383 ± 728	2077 ± 874	–	
1 min	10	3889 1066	2473 732	1970 710	566	
2 min	10	3727 903	2557 842	2151 850	670	*
4 min	10	4246 964	2855 894	2331 878	1668	*
Gel B						
Control	10	2953 476	2198 440	1928 470	–	
1 min	10	3846 1008	2638 618	2030 479	1435	
2 min	10	4559 1168	2879 656	2284 611	2643	
4 min	10	4824 ± 1127	2984 ± 598	2336 ± 556	3065	

* Significantly different, $P < 0.05$.

TABLE 3. F Uptake by Dental Enamel at Standardized Depths According to Time of Topical F Application

Time of Application (min)	Layers	(N)	F Concentrations (ppm)	F Uptake (ppm)	F Uptake (%)
	L_1	(40)	3092 ± 842	–	
Control	L_2	(40)	2106 649	–	
	L_3	(40)	1803 680	–	
1	L_1	(40)	3950 1442	857.36 *	29 ± 37 *
	L_2	(40)	2401 703	295.73 *	16 24
	L_3	(40)	1847 540	44.03	7 24
	Total			1197.12 *	
2	L_1	(40)	4448 1554	1355.83	48 49
	L_2	(40)	2635 830	529.43	30 43
	L_3	(40)	1996 724	192.98	15 34
	Total			2078.23	
4	L_1	(40)	4629 1336	1536.54	54 45 *
	L_2	(40)	2786 1104	680.77	34 30
	L_3	(40)	2026 ± 700	222.78	17 ± 27
	Total			2440.09 *	

* Significantly different from control, $P < 0.05$. Figures joined by brackets, are significantly different.

significantly different ($P < 0.05$). The enamel F uptake in the 24-hours post-treatment were generally less than that of the 30-minute treatment group. However, the difference in uptake between the 24-hour and 30-minute group was not statistically significant.

Discussion

It should be noted that in the in vivo study, slightly shallower standardized depths of enamel biopsy were used. This was done in order that the results of the in vivo study could be more appropriately compared to other in vivo enamel biopsy studies. It was deemed more important to compare the in vivo results to other in vivo studies reported in the literature rather than to our in vitro study.

The present data showed that the average F concentration at the first layer of untreated enamel was 3092 ± 842 ppm. In fluoridated communities with 1 ppm F, previous studies (Mellberg et al. 1970; Wei et al. 1976; Keene et al. 1980) have shown that the outermost enamel surface contains around 3000 ppm F. The data in this study are in agreement with these findings.

Recently, the role of topical F in "healing" incipient lesions has been emphasized and well documented by many studies (Ramsey et al. 1973; Arends and Schuthof 1975; Larsen et al. 1977; Chandler et al. 1982; Silverstone 1982; Mellberg and Nicholson 1986; Goorhuis and Purdell-Lewis 1986). The remineralization capacity of incipient lesions under the influence of F could be related to their greater affinity for F uptake in the surface and subsurface enamel in comparison to the adjacent sound enamel (Clarkson et al. 1986; Hicks et al. 1986). Consequently, the presence of increased levels of F in enamel lesions may prevent lesion progression and enhance the degree and rate of remineralization, resulting in reversal or "healing" of the lesion. The retained F in enamel after the 24-hour post-treatment interval as indicated in this study has a significant implication on the remineralization of incipient carious lesion (Hattab and Wei 1987).

Fluoride uptake by enamel in the 3 standardized depths increased with respect to time of topical application. The F uptake in layer 1 and layer 2 was significantly higher ($P < 0.05$) in the 4-minute group than the 1-minute group. The total F uptake (i.e., layer 1 + 2 + 3) between the 1-minute and 4-minute group was also significantly different. The difference was approximately twofold in magnitude (1197 ppm compared with 2440 ppm). In an in vitro study on the uptake of ^{18}F by human enamel from APF solution (Joyston-Bechal et al. 1973), it was shown that the F uptake after 4 min was about 1.2-fold more than after 1 min. Similarly, Wefel and Wei (1979) reported that 4-minute treatments with APF gels increased the F uptake at enamel depths of 1.9-3.6 μm to an average of 1.34-fold more than after a 1-minute treatment. The results of this study are in agreement with these previous investigations. The slightly lower magnitude of F uptake obtained in this in vivo study is related to the saliva washing effect for 30 min as well as the 24-hour, post-F treatment. Despite the saliva washing effect which is inevitable, topically applied F still resulted in a significant F increment in the outer surface of the enamel. This kind of "availability" of F in the enamel surface and in the immediate micro-environment is reassuring because it may work through the various mechanisms of action of topically applied F agents to exert the caries inhibitory effects (Brown and Konig 1977).

The results of this study (Wei et al. 1988) also support earlier in vitro reports (Joyston-Bechal et al. 1973; Duckworth and Braden 1967; Wei and Hattab 1987, 1988) that the uptake of F by enamel is a diffusion-controlled process and is therefore time dependent. It is therefore highly desirable to use a longer F application time to maximize the protection conferred by topical F agents (Wei 1985). The results of this study support the recommendation of the Council on Dental Therapeutics (1984) in that 4-minute application times should be employed

during topical F treatment. From this study, gel A did not produce a significantly higher F uptake after just 1 min of topical F application compared to teeth treated for 4 min. The difference in F uptake between gel A and gel B probably could be related to the manufacturer's formulation. Fluoride agents may differ in pH, F concentration, and F-containing compounds and gelling bases. The amount of F uptake probably is dependent upon a summation of the effects of these factors (Wei 1985). The advertisement for the promotion of gel A which claimed 12 times the minimum F uptake in just 1 min is misleading to clinicians who are not usually familiar with such findings.

Conclusions

The following conclusions can be derived from the results of this study.

1. Fluoride uptake by dental enamel is time dependent and 4 min of application resulted in significantly greater F uptake than after 1 min of application.
2. There was slightly less F retained in the enamel after 24 hr compared with 30 min, but the difference was not statistically significant.
3. Gel B (Nupro) appears to give a higher F uptake than gel A (Minute-Gel) in the same time period.
4. The results support the current recommendation of the ADA Council on Dental Therapeutics in that professionally administered topical fluoride applications using an APF gel should be applied to the teeth for a period of 4 min.

This work is based on a portion of a thesis submitted to the University of Hong Kong for the master of dental surgery (MDS) degree in the Department of Children's Dentistry and Orthodontics by Dr. Eilly W.S. Lau. This work was supported by funds of the Research Committee, Faculty of Dentistry, University of Hong Kong.

Dr. Wei is a professor and head, Dr. Lau is a part-time clinical lecturer, and at the time of the study Dr. Hattab was senior research assistant, children's dentistry and orthodontics, University of Hong Kong. Presently, Dr. Hattab is affiliated with the Dept. of Pedodontics, Jordan University of Science and Technology, Irbid, Jordan. Reprint requests should be sent to: Dr. Stephen H.Y. Wei, Dept. of Children's Dentistry and Orthodontics, Faculty of Dentistry, University of Hong Kong, The Prince Philip Dental Hospital, 34 Hospital Rd., Hong Kong.

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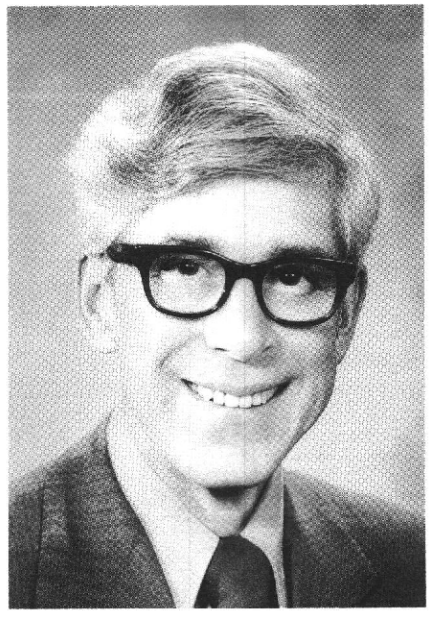
Pioneer in Pediatric Dentistry: Bernard Smith



DR. BERNARD SMITH, a native Californian, was born in Oakland on November 15, 1920. After being graduated from high school, he attended St. Mary's College in California from 1938 to 1940.

In 1940 Dr. Smith matriculated in the Physicians and Surgeons Dental School in San Francisco, and received the DDS degree in 1944. From 1944 to 1946 he was in the United States Naval Reserves.

During his early years in practice, he became interested in dental care for children, and in 1946 he entered the University of Michigan's Graduate School where he received the master of science degree in pediatric dentistry in 1948. He returned to practice in Oakland and at that time he was the first university educated pediatric dentist to practice in California.

In 1948 he joined the staff of the College of Physicians and Surgeons and in 1960 was appointed assistant professor at the University of California Dental School.

Dr. Smith is a Diplomate of the American Board of Pediatric Dentistry and has served the American Academy of Pediatric Dentistry as a member of the Board of Trustees, president, secretary, and treasurer. He is a charter member of the K.A. Easlick Graduate Society, Association of Pedodontic Diplomates. He served the Alameda County Dental Society as a member of the Board, as president and secretary.

Dr. Smith's hospital affiliation includes the Children's Hospital Medical Center of Northern California where he has been a Trustee since 1982, chief of the Dental Service (1958-1963), and secretary to the Medical Staff Board (1965-1970).

He is a member of the Advisory Board, St. Albert's College, Oakland (1976-present); member Advisory Board, St. Vincent's Day Home, Oakland (1974-present); member Advisory Board, Family Aid to Catholic Education, Oakland (1978-present).

Dr. Smith is a member of the American and California Dental Associations, American Society of Dentistry for Children, San Francisco Dental Society, and East Bay Pediatric Society. He is also a member of Omicron Kappa Upsilon.

Ralph L. Ireland, DDS, MS
Historian Emeritus