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A comparison of oral fluoride retention following topical treatments with APF gels of varying viscosities

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Abstract

Ten adult volunteers each received six topical fluoride applications using techniques which varied in gel viscosity and type of tray employed. The amounts of fluoride applied, recovered from the mouth, and retained in the mouth were calculated for each treatment. The value of suction applied during fluoride application and the value of patient expectoration following topical F treatment also were investigated. The tray system with an absorptive liner significantly reduced the amount of gross oral-retained fluoride for 2 of the 3 gels. The use of suction during the 4-min application procedure and immediately following it, significantly reduced the retained fluoride dose below gross retained F regardless of tray type or gel viscosity. Expectoration following topical F treatment resulted in significantly less orally retained fluoride than had remained after suction. Expectoration of high and intermediate viscosity fluoride gels was more effective in reducing the final net value of orally retained F than expectoration of a low viscosity gel. The use of an absorptive liner was a less influential determinant of orally retained F than gel viscosity after expectoration. Use of suction devices and expectoration are recommended and use of a high or medium viscosity gel in conjunction with these may provide an additional adjunct in reducing oral F retention and ingestion.

Studies with adults and children have shown substantial oral retention and ingestion of fluoride following professional application of APF gels topically.[1-8] Currently, these products are the most popular forms of professionally applied fluoride and most of them contain 1.23% F ion, the equivalent of 12,300 ppm or 12.3 mg of fluoride per ml of product. Disposable mouth trays which carry the fluoride gel to the mouth and retain it there during the course of treatment provide an especially simple method of coating the teeth with fluoride. A problem encountered in topical fluoride application and one which is not negated by the use of fluoride in a gel form, is the fact that fluoride product is swallowed during the course of topical application. Of particular concern are the levels of fluoride ingested by young children.

LeCompte and Doyle studied the effects of various fluoride application trays and patient expectoration following treatment on the net amounts of fluoride retained orally by children.[1] Using 1.23% APF gel, they reported significantly less orally retained fluoride resulting from the use of trays containing an absorptive liner compared to unlined application trays ($p < .01$). Additionally, patient expectoration proved to be a significant factor in reducing the net oral retained fluoride dose ($p < .01$).

Recently, LeCompte and Rubenstein[7] conducted a study in which the difference in net oral retained fluoride obtained after use of an APF gel and a gel identified as thixotropic by its manufacturer was evaluated. Results of this study showed significantly less orally retained fluoride with thixotropic gel application. This conclusion was specifically related to the fact that expectoration of a thixotropic gel was more effective in reducing retained fluoride than expectoration of a nonthixotropic gel. A thixotropic gel, by definition, exhibits increased flow characteristics under pressure; it is a quality which is independent of the gel's viscosity. The viscosities of the various gels studied in the current investigation differ and are not necessarily related to their thixotropic qualities.

Scientifically founded guidelines for the application of APF topical fluoride in the dental office setting have not been established firmly. The purposes of professionally applied fluoride are to attain enamel resistance to demineralization, increase the potential for remineralization, and diminish bacterial activity

at the tooth surface by a topical mechanism rather than systemic. Therefore, an experimental design which provides information as to how the amount of fluoride swallowed may be minimized is essential to our search for an optimal technique. The major purpose of this study was to evaluate oral fluoride retention following the use of APF gels of varying viscosities. Specifically, insight will be gained regarding:

1. Oral fluoride retention after topical application using 3 varying viscosity APF topical gel systems
2. The effectiveness of suction devices in reducing oral fluoride retention of the 3 different gels
3. The benefit of expectoration in reducing oral fluoride retention
4. Oral fluoride retention using the 3 gel products with 2 different tray systems (foam-lined and unlined).

Methods and Materials

This study with 10 adults (24–35 years) compared oral F retention following each of 6 application techniques using 3 varying viscosity APF gels (low, medium, and high) in 2 types of application trays (foamlined vs unlined). At least 1 week transpired between each subject's fluoride treatments. Techniques A-F are identified as follows:

A: Low viscosity gel[a] + Unlined Tray
B: Low viscosity gel + Lined Tray
C: Medium viscosity gel[b] + Unlined Tray
D: Medium viscosity gel + Lined Tray
E: High viscosity gel[c] + Unlined Tray
F: High viscosity gel + Lined Tray

All 3 F gels reportedly contain 1.23% F. Analysis of the F gels showed them to vary from 1.23 to 1.32% F. Analysis of the flow characteristics of the 3 F gels was conducted, demonstrating their relative viscosities.[9]

During each of the 6 techniques, a total of 4 g of APF gel or 49.2–52.8 mg of fluoride was introduced into the oral cavity via foam-lined trays[d] or styrofoam trays with no liner[e] (2 g/tray). In each instance, both maxillary and mandibular trays were inserted simultaneously and were left in place for 4 min during which time a saliva ejector was placed within the mouth to evacuate oral fluids. Further, for 30 sec immediately following the F treatment, high-speed suction was applied intraorally to collect retained oral fluids. The suctioning procedures were performed with a portable dental unit[f] capable of trapping all evacuated fluids into a plastic container. Previous pilot studies have documented the reliability of this unit.[10]

Following each suctioning procedure, 100 ml of distilled water was suctioned through both slow-speed (saliva ejector) and high-speed hoses to flush residual APF gel and saliva from the system. All solutions were trapped in the plastic container. All suctioning samples were brought to a final volume of 250 ml by addition of distilled water prior to fluoride analysis. Immediately following the suctioning procedures, each volunteer expectorated into a container of 80 ml of distilled water for up to 1 min. All expectorate samples were brought to a final volume of 100 ml by adding the appropriate amount of distilled water prior to F analysis.

The amount of APF gel was determined gravimetrically, and the mg of fluoride applied, recovered from the mouth, and retained in the mouth were calculated in all instances. Following a given 4-min application procedure, the trays were placed in 200 ml of distilled water, and, after at least 24 hr, all solutions were analyzed for fluoride ion content using the ion-specific electrode.[g] All data are expressed as a mean ± standard error of the mean (SEM). Student Newman Keuls tests and paired *t* tests were used to determine statistically significant differences.

The study was approved by the Human Assurance Committee of the Medical College of Virginia, Virginia Commonwealth University. The procedures, possible discomforts or risks, and possible benefits were explained fully to the human subjects involved, and their informed consent was obtained prior to the investigation.

Results

The amounts of fluoride (x ± SEM) applied, recovered, and retained in the mouth during the APF application in Technique A are shown in Figure 1. When 4.0 g of low viscosity APF gel or 51.8 mg of fluoride were applied to the teeth in unlined trays, an average of 21.2 mg of fluoride was recovered with the trays and 30.6 mg of F were retained in the mouth. Additionally, 21.1 mg of F were recovered with the suctioning procedures resulting in an average retained F dose of 9.5 mg. An additional 4.1 mg of F were recovered in the expectorate resulting in a final net-retained F dose in Technique A of 5.4 mg. This

[a] Luride APF — Colgate Palmolive: Chicago, IL.
[b] Gel-II APF Thixotropic — Coopercare, Inc: Fairfield, N.J.
[c] Nuflor APF gel — Johnson & Johnson: East Windsor, N.J.
[d] Top-Form Tray — Hoyt Labs: Norwood, MA.
[e] Econo-Tray — Hoyt Labs: Norwood, MA.
[f] Porta-Cart 305 — Adec: Newberg, OR.
[g] Model 94-09 — Orion Research, Inc: Cambridge, MA.

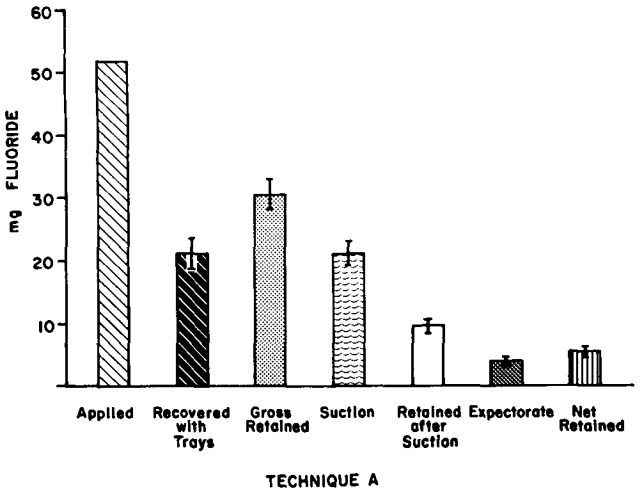

FIG 1. Fluoride applied, recovered, and retained before and after suction and expectoration utilizing a low viscosity APF gel with an unlined tray.

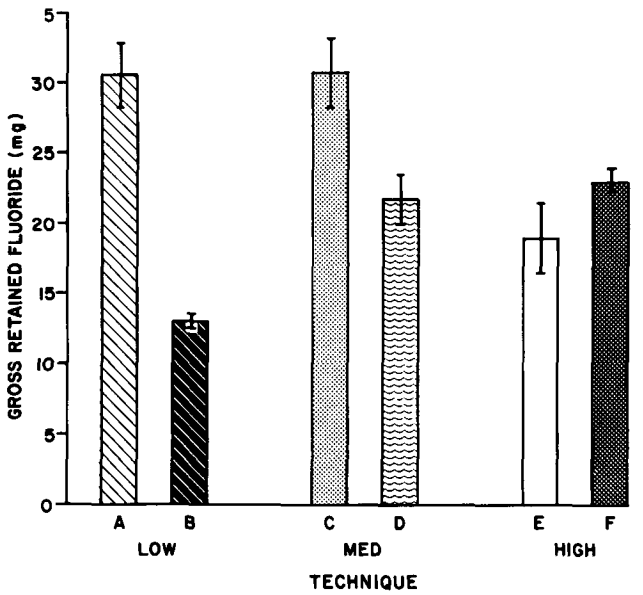

FIG 2. Fluoride retained by subjects following removal of trays (A, C, and E, unlined; B, D, and F, lined).

same analysis was done for each of the 6 application techniques (A-F).

The average gross-retained fluoride following the 6 application techniques ranged from 13.1 to 30.7 mg (Fig 2). These data represent the average amount of fluoride available for ingestion if no means of suction or expectoration are utilized. Techniques A and C resulted in the greatest gross-retained F and were significantly different from all other techniques ($p < .001$). Technique B resulted in the least gross-retained F dose (13.1 mg) which was significantly less than all other techniques ($p < .001$).

The doses of retained F, after suction (Fig 3), were statistically less than the gross-retained values ($p < .001$). The average values ranged from 6.2 to 11.9 mg. Technique C resulted in the greatest orally retained F dose after suction. It was statistically different only from Technique E which resulted in the least retained fluoride level ($p < .05$).

Figure 4 depicts the final net-retained oral F doses which ranged in value from 1.7 to 7.4 mg. These represent the milligrams of fluoride retained by the individual after suction and 1 min of expectoration. Statistical significance exists between Technique E, which resulted in the least amount of retained fluoride and Techniques B and C which resulted in the greatest amounts of orally retained F ($p < .01$).

The amounts of fluoride applied, recovered, and retained in the mouth during topical application us-

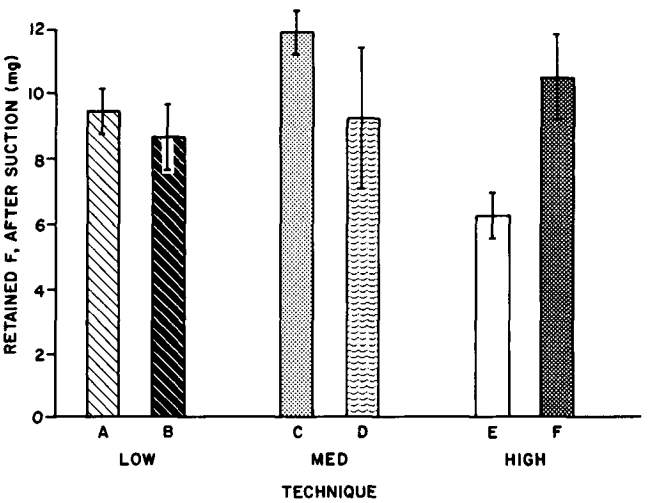

FIG 3. Fluoride retained by subjects following suctioning procedures.

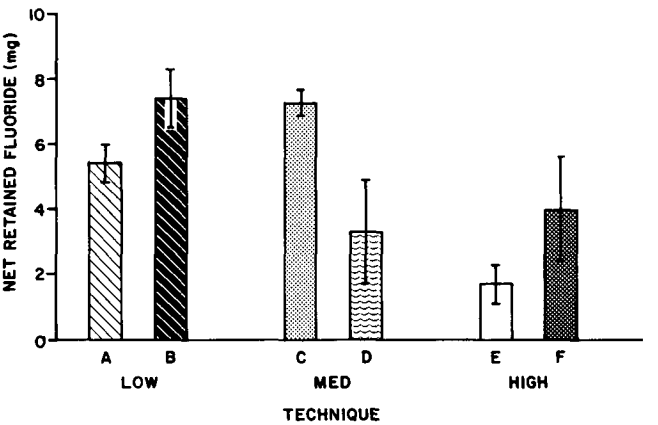

FIG 4. Fluoride retained by subjects following suction and expectoration.

ing techniques A through F are summarized in Table 1.

Discussion

The average quantities of fluoride not recovered from the oral cavities of these subjects in the various techniques ranged from 6.2 to 11.9 mg after suction and from 1.7 to 7.4 mg following suction and expectoration. The bioavailability of ingested fluoride in fasting individuals has been reported to be 100%.[8] Previous investigations[2,4] have shown that virtually all of a retained oral F dose is swallowed and subsequently absorbed in fasting individuals. The side effects from ingestion of amounts of fluoride in the range observed in this study have been discussed in previous publications.[2-4,10] These include increased urinary F concentration which may cause a short-term, transitory solute concentration defect as well as elevated plasma F levels which may have potential effects on developing enamel. Also, ingestion of fluoride may be related to the clinical observation of complaints of nausea and occasional vomiting in children following topical F administration.

Analysis of gross-retained F in this study reveals that when no suction or expectoration is utilized, the best result, i.e. the least orally retained fluoride occurs with a low viscosity gel in a lined tray, whereas the worst result, i.e. the greatest orally-retained F dose, occurs with a low or medium viscosity gel in an unlined tray. The value of a lined tray was observed in previous investigations[1,7] which concluded that the absorptive liner probably functions in retaining fluoride gel which might otherwise have been lost to the oral cavity.

Values for F retained after suction ranged from 6.2 to 11.9 mg with both the lowest and the highest values obtained with techniques which used unlined trays (Techniques C and E). Examination of these values reveals that once suction is employed, the use of a lined tray no longer provides an advantage in reducing oral-fluoride retention. With respect to viscosity, the data show that the most viscous of the 3 gels allowed for least fluoride retained after suction but only with an unlined tray (Technique E). The runniest gel, i.e. low viscosity gel, provided intermediate levels of fluoride retained, whereas the intermediate viscosity gel provided the greatest amount of retained F. Based upon these observations, the authors cannot draw parallels between gel viscosity and quantity of fluoride retained in the mouth after suction. Since it is not possible to attribute significance to the use of a lining when suction accompanies the procedure, it is evident that emphasis must be placed on the absolute effectiveness of suction in reducing orally-retained F regardless of gel viscosity or tray type.

Expectoration reduces the quantity of orally-retained F even further. The values of net-retained F after suction plus expectoration ranged from 1.7 to 7.4 mg. The largest value of retained F is obtained with Technique B, which is interesting since this technique had resulted in orally-retained F values that were consistently low prior to expectoration. It also should be noted that less fluoride was expectorated in this technique than in all others (1.2 mg F). This may be explained by the possibility that a large portion of the net-retained F dose obtained in this technique was swallowed by the subjects prior to expectoration. This may occur possibly because of this gel's low viscosity. Increased swallowing tendency also may be a result of low viscosity in conjunction with the gel's low pH (3.2) causing increased salivary flow. In contrast, it was observed that the greatest quantities of fluoride retrieved in expectorate were obtained with Techniques C, D, E, and F which utilized medium and high viscosity gels.

In addition, of the 4 techniques resulting in the lowest values of net-retained F, 3 consisted of high and medium viscosity gels. Of these 4 techniques, 2 consisted of lined trays and 2 employed unlined trays. Of the 3 techniques resulting in the greatest amount of orally retained F, 2 utilized the free-flowing, low viscosity gel. One of these utilized a lined tray and the other an unlined tray. Thus in this study, although statistical significance exists only between the 2 techniques resulting in the greatest retained F and

Table 1. Milligrams of Fluoride (X ± SEM) Applied, Recovered, and Retained in Six Topical Fluoride Application Techniques

Technique	*Applied**	*Recovered In Trays*	*Gross Retained*	*Recovered By Suction*	*Recovered After Suction*	*Recovered In Expectorate*	*Net Retained*
A	51.8	21.2 ± 2.4	30.6 ± 2.4	21.1 ± 2.2	9.5 ± 0.7	4.1 ± 0.6	5.4 ± 0.6
B	51.8	38.7 ± 0.3	13.1 ± 0.3	4.4 ± 1.2	8.7 ± 1.0	1.2 ± 0.2	7.4 ± 0.9
C	52.8	22.1 ± 2.4	30.7± 2.4	18.8 ± 2.2	11.9 ± 0.7	4.6 ± 0.6	7.3 ± 0.4
D	52.8	31.0 ± 1.8	21.8 ± 1.8	12.7 ± 2.8	9.2 ± 2.2	6.9 ± 1.8	3.3 ± 1.6
E	49.2	30.3 ± 2.4	18.9 ± 2.4	12.7 ± 2.1	6.2 ± 0.7	5.0 ± 0.7	1.7 ± 0.6
F	49.2	26.3 ± 0.7	22.9 ± 0.7	12.5 ± 1.3	10.4 ± 1.3	6.7 ± 1.4	4.0 ± 1.6

* Note: Although all F products tested claimed to contain 1.23% F ion, actual concentrations varied from 1.23 to 1.32%. Mg of F applied varied from 49.2 to 52.8 in 4 g of gel.

the technique which resulted in the least retained F, there was a propensity for more of the runny consistency, low viscosity gel to be swallowed than the intermediate and high viscosity gels. The viscosity of gel was more important in determining the final net F retention than the type of tray used. The type of tray is probably only significant if no suction or expectoration is used.

Fluoride in excess of 2 mg was available for ingestion by the subjects in all but 1 instance with 2 techniques resulting in a final net-retained F dose in excess of 7 mg. Clinically, substantial elevations in body fluid fluoride concentrations would result from all of these techniques.[4] Therefore, it may be desirable to develop topical fluoride products which contain F ion in concentrations less than 1.23%. Then children would be subjected to less increased body fluid levels of fluoride than currently experienced while continuing to benefit from the topical content of F ion with their teeth. Current investigations of this possibility are under way.[11]

The following guidelines relative to professional application of APF gels are recommended. First, fluoride application trays typically can hold maximally between 3 and 5 g of APF gel each; therefore, no more than 2 g of APF gel (approximately 40% of tray capacity) should be dispensed. Even more conservative amounts should be considered for small children. Second, because patients may inadvertently swallow excess F during 4-min topical application procedure, the use of a saliva ejector during the procedure is highly recommended. Third, following the 4-min application procedure, the patient should be requested to expectorate thoroughly for 30 sec - 1 min regardless of whether high-speed suction is utilized. Expectoration is probably the single most effective way of reducing excess orally retained fluoride.

Conclusions

This study reinforced the value of suction and expectoration following a 4-min topical fluoride application. It also suggested that expectoration was particularly effective in reducing the amount of orally-retained F when a medium or high viscosity gel had been applied. The 3 techniques which resulted in the least orally retained F utilized intermediate and high viscosity gels and of the 3 resulting in the greatest retained F, 2 consisted of the free-flowing, low viscosity gel. It is possible that the intermediate and high viscosity gels adhere to teeth better than the low viscosity, free-flowing gel which may be taken up by oral fluids and more readily swallowed before the patient has the opportunity to expectorate.

Topical fluoride application with commercially available APF gels containing 1.23% F ion should be accompanied by use of a saliva ejector and followed by 30 sec - 1 min of expectoration. This study provides evidence that such a treatment protocol will reduce the amount of fluoride inadvertently swallowed. It also exposes the inability to provide topical fluoride treatment without simultaneous ingestion of fluoride. Special care should be taken to minimize this ingestion, especially in young children with developing enamel.

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