

Fluoride Application Procedures in Orthodontic Practice, Current Concepts

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The increased caries risk underneath and adjacent to orthodontic bands and the potential decay-promoting interproximal environment in direct bonding techniques¹¹ call for maximum use of caries preventive procedures during orthodontic treatment. A preventive program should include the use of topical fluoride, particularly if the patient resides in a nonfluoridated area. It is important, therefore, to know which are the most effective F treatment methods and agents.

Since the early 1940's, hundreds of clinical studies have been conducted to evaluate the effectiveness of different methods of F administration with topical and/or systemic effects. These investigations have led to the development of the various F application methods that are available today. Although topical fluorides are in widespread use, there still remains considerable clinical investigation to be carried out before the full value of these agents can be assessed precisely. In particular, conclusive evidence is lacking as to whether or not a particular regime is superior to others. Only few studies have dealt with comparisons of different agents and/or different application methods, and caries reductions reported by various investigators are by no means directly comparable.

The planning of a rational F therapy for the orthodontist anxious to introduce an optimal caries preventive program in his practice is further complicated by the continuous development of new techniques and principles. This presentation will summarize briefly the

current concepts, particularly with regard to research findings relevant to orthodontics.

F-PROPHYLAXIS PASTES

The use of cleaning and polishing pastes (pumice, zircate and other comparable abrasive pastes) before cementing orthodontic bands may lead to the removal of significant amounts of surface enamel.^{13,38} This loss of enamel is undesirable, since the surface enamel contains higher levels of F and is more resistant to caries than the underlying enamel. The F depleting effect can be compensated for by employing F-pastes, which will provide sufficient amounts of F to maintain or increase the original level in the polished surfaces. In addition, residual paste F may diffuse to caries susceptible areas which are inaccessible to the prophylaxis treatment (pits, fissures and proximal surfaces). The caries reductions obtained from professional application of F-prophylaxis pastes is significant,^{7,13,15,38} particularly when treatment is semiannual, while self-application results in insignificant caries inhibition.^{22,36} Although the F-pastes are superior to non-F abrasive pastes for routine prophylaxis, it is apparent that they cannot replace topical F application in orthodontic practice.

On the other hand, very recent findings indicate that dramatic caries reductions may occur following professional F-paste applications once every second week.²¹ This finding requires further documentation, but F application based upon polishing with rotating instruments appears little suited to orthodontic treatment.

F-containing pastes have also been

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used in conjunction with topical treatments. In evaluating the clinical evidence of such trials it appears that little has been gained by the combination, since the treatment with F-prophylaxis in addition to F topical application has not been shown to be more effective than careful topical F application preceded by a non-F prophylaxis.¹³

TOPICAL F-SOLUTION

A great number of studies have been undertaken to assess the effect of single annual or semiannual topical applications of F preceded by prophylaxis.^{13,15} The three most commonly used topical solutions are: a) 2% neutral sodium fluoride (NaF); b) acidulated sodium fluoride phosphate (APF), at pH about 3 and containing 1.2% F; and c) 8-10% stannous fluoride (SnF₂). Clinical trials and laboratory experiments have variously indicated that each compound is superior in reducing caries. These conflicting reports indicate the need for more precise comparative studies.¹⁶

Of the compounds advocated APF enjoys the greatest popularity at present. In this solution the acidity may enhance the F uptake by enamel, and the excess phosphate appears to have the dual effect of depressing both enamel dissolution and the formation of calcium fluoride thus allowing F deposition in the form of fluorapatite.¹ The rationale for choosing APF is the observation of greater deposition of F in intact enamel from this agent than from other agents.¹⁷ It seems reasonable to assume that the anticaries effect of infrequent applications of high F concentrations is related to elevated F-levels in the enamel,^{1,3} but this has not been shown definitely. On the basis of the theory that the main F effect in reducing caries is to enhance mineralization of hypomineralized enamel, Jean-sonne and Feagin¹⁶ considered NaF to give the most desirable results. Al-

though extensively tested, SnF₂ is less recommended than sodium fluorides, mainly because of its tendency to discolor accumulated soft matter and hypomineralized regions of the teeth. Other disadvantages of SnF₂ are its lack of stability in aqueous solution and its basically disagreeable metallic taste, which is objectionable to many patients.¹⁵

The topical application of F should be preceded by a thorough cleaning and drying of the teeth. The teeth should be isolated with cotton rolls and the tooth surfaces should be kept wet with the F solution for a period of 4 minutes by frequent swabbing with cotton applicators saturated with the solution. The F solution should be applied to the teeth of either one quadrant or one-half mouth depending on how large an area may be kept free of saliva in the individual patient. It is essential that no salivary contamination takes place during the application. Rinsing or eating should be avoided for at least one-half hour after the application.

Because the F solutions are tedious to apply in children, techniques have been developed to apply the solution in trays or gel form. In recent years several methods have been developed to increase the retention and penetration of topically applied F. Pretreatment of teeth with dilute phosphoric acid prior to the F exposure will produce a mild etching of the enamel, which seems to result in increased F uptake and a concomitant decrease in caries experience. However, more definite long-term clinical testing is needed to confirm the validity of this finding. Another means of increasing the F uptake is to prolong F contact with the teeth by different coating techniques. These will be dealt with separately below.

With regard to preventing or reducing caries underneath and adjacent to orthodontic bands, several reports are available to indicate the effectiveness of various topical F solutions including SnF₂,^{24,30,41} NaF^{43,44} and APF⁹. In particular, Muhler²⁴ reported a significant anticariogenic effect over a two

year experimental period in orthodontic patients treated with a SnF_2 prophylaxis paste, a single topical application with 10% SnF_2 -aqueous solution, and provided with a SnF_2 -dentifrice. Dimitriadis and Sassouni⁹ recently reported that topical application of APF reduced enamel demineralization underneath loosely fitted orthodontic bands for at least six weeks in 70% of their cases.

In summary, a topical F treatment preceded by thorough cleaning and drying of the teeth may be useful before the insertion of orthodontic appliances. Acid or neutral sodium fluoride solutions applied with painting techniques seem preferable for this purpose. The applications should be made several days prior to the placement of the appliances, and whenever the bands are removed for regular recementations.⁴³ However, F solutions are tedious to apply and F gels may seem more suitable for routine use.

F-GELS

The use of F in gel form may involve professional administration in individually fitted trays as applicators and/or self-application by means of applicators or tooth-brushing. The reports of successful gel application are not so numerous as those describing the use of F solutions, but the methods appear to gain increasing acceptance mainly because of their ease of application compared with standard topical procedures. It was previously maintained that, because of restricted diffusion in gels, the F uptake by the enamel was probably less effective than when using solutions.^{3,22} However, more recent data indicate that APF gels are equally good⁴⁰ or superior to other topical F agents, including APF solutions, in depositing higher F levels in surface enamel and reducing the initiation and extent of carious lesion formation *in vitro*.^{31,32} The gel may be retained on the enamel

surface for longer periods than the solution, and not washed away. In effect, the gel helps in maintaining a F ion reservoir on the enamel surface leading to further uptake.³¹

F-gels are available both as APF, SnF_2 and NaF compounds, but most studies have been made employing APF and SnF_2 .¹⁵ The APF gels for professional administration contain 1.2% F from sodium fluoride in a 0.1 M phosphoric acid aqueous gel with an approximate pH of 3. When available for daily self-application at home, the APF gels generally contain a lower F concentration and a higher pH. Many different brands of APF gels are available with a wide variety of flavors for individual taste and preference.

In the dental office the APF gels may be applied by impression or painting techniques. The former yield the best results, due to more uniform and intimate contact between gel and tooth surface which is essential for F deposition.³² The impression technique is based on the use of individual trays of various kinds (plastic trays with disposable inserts, foam trays, alginate impressions, wax trays, etc.) which should fit tightly around the dental arch. After a thorough prophylaxis and air-drying of the teeth, 2 to 3 ml of gel is placed into the tray which, after insertion, should cover the teeth of one dental arch for 4 minutes. With most new applicators both dental arches may be treated simultaneously. Excess gel and saliva is allowed to flow from the patient's mouth during the application. The tray is then removed and the teeth wiped dry with a cotton swab. Patients are instructed not to eat or rinse during the next 30 minutes.

In orthodontic practice the F gel procedure may conveniently be carried out in conjunction with taking impressions for study models. Either the new commercially available disposable foam trays or an extra set of snap alginate impressions (just covering the crowns of the teeth) may be most suitable applicators. In both cases the two dental arches can be F treated simultaneously (provided low flange trays are used) thus reducing total F

treatment time to four minutes. The benefits of using alginate impressions for APF gel application is substantiated. Free Ca ions in the alginate may bind some F along the interface between alginate and F gel, but the layer of gel in contact with the teeth is not affected.³² The extra set of impressions is recommended because of difficulties (at least with some brands of APF gel) in washing away remaining gel from the alginate impressions before casting.

Until recently the use of SnF₂ gels was hampered by instability in aqueous media. This problem was overcome by stabilizing SnF₂ in a glycerin solution.

The only study reported so far on the use of F gels in preventive dentistry for orthodontic patients is a short-term experiment by Landry and Shannon²⁰ who recently found significantly reduced enamel solubility when a water-free 0.4% SnF₂ gel was self-applied daily. In this technique the gel was placed on the toothbrush, distributed into all tooth surfaces, and swished about the mouth for 10 seconds immediately after brushing with the customary dentifrice at bedtime. An extended study³⁴ showed that, while 58% of orthodontic patients not using the gel had slight, but diagnosable demineralizations when the bands were removed after 18-24 months, only 2% of 51 patients who used the SnF₂ gel daily had any evidence of demineralization under similar conditions. As the basic taste of the SnF₂ gel was modified, and the concentration of the stannous ion apparently did not stain the outer mineralized surface enamel layers,^{20,33} this method may prove useful in orthodontic patients.

In summary, mainly because of its convenience of application, topical F gel treatment in the dental office may substitute topical painting with F solutions before insertion and recementation of orthodontic appliances. The use

of APF gel application is recommended as a routine procedure in orthodontic practice. Unsupervised daily self-application of F gels, although not extensively tested, is undoubtedly effective in reducing caries and may be used as an alternative to daily rinsing with F solutions. Further comparative studies are needed before definite recommendations can be given.

F-MOUTH RINSES

In children undergoing orthodontic treatment, both mouth rinses and tablets may be recommended for topical or topical + systemic F effects. The relative effectiveness of mouth rinses and tablets is incompletely studied. Recent findings indicate that rinses may constitute the optimal method of F administration.¹ Another important advantage of such administration is that methodical rinsing, plus regular attention, has been found to stimulate children's interest in oral hygiene to a great extent.¹⁸

The cariostatic effect of mouth rinses with dilute F solutions seems to depend on both the rinse frequency and the F concentration. Daily rinsing, rather than weekly or fortnightly, should be recommended. Not only is the anticaries effect much greater, but the procedure is also easier to remember for the patients. The most widely used agents for daily rinses are 0.05% NaF (250 ppm F), APF containing 0.1 M phosphate at pH 3-4 (200 ppm F), and 0.1% SnF₂ (250 ppm F).

Torell and Ericsson³⁵ found a reduction in DMFS of about 50% in 10-year-old children who rinsed daily for 2 years with 10 ml of 0.05% NaF. Other authors^{1,10,14} later have reported that the anticaries effects of NaF and APF is similar in magnitude, despite a greater deposition of F in intact enamel from the APF rinse. It is conceivable, however, that frequent applications of

low F concentrations could be effective through mechanisms not related to elevated F levels in the enamel.^{1,5,27} Only part of the retained F from a rinse is taken up by the teeth, whereas most of it is likely to be retained and/or absorbed elsewhere in the oral cavity or swallowed. Particularly, F bound in plaque may act as a reservoir of F and have a cariostatic effect. The need for additional studies on the intraoral action of F is obvious. The use of SnF₂ rinses has been shown to produce caries reduction even in children living in water-fluoridated areas, but suffers from the disadvantage of causing yellow pigmentation of the teeth in patients with poor oral hygiene.²⁹

During orthodontic treatment daily rinsing at home should be performed immediately following the last tooth-brushing. It is important that the teeth are cleaned so that the solution can come in direct contact with the enamel surface. The children should hold from 5 to 10 ml (according to agent and mode of administration) of the solution in the mouth for 1-2 minutes, straining it through the interproximal spaces, and then expectorate.

Mouth rinses may give a significant caries reduction in teeth that have been erupted for a considerable length of time, but the F effects would be greatest in teeth erupting after the treatment has been initiated. Shortly after eruption the enamel is highly reactive, probably partly attributable to the incomplete mineralization of the crystallites that have not yet attained their maximum size, and partly to the composition of the mineral phase, which changes from a more soluble and somewhat amorphous mineral to a more insoluble and better crystallized phase.²⁵ The use of daily applications of low F concentrations during orthodontic treatment seems essential. Daily F rinses may be valuable particularly as protection against demineralization underneath loosened bands, and to enhance the mineraliza-

tion of partly demineralizing enamel surfaces adjacent to the bands. Moreover, Wish³⁹ has recently found that low molecular weight substances, such as F in F rinse solutions, may penetrate orthodontic cements which would indicate that caries protection may be obtained even on enamel surfaces covered by the bands. In direct bonding techniques, where caries protection by the orthodontic bands on interproximal surfaces is lacking and proper oral hygiene is obstructed by the archwire, the value of regular F supplementation is evident.

Ingestion of the rinse solution may have a beneficial effect on unerupted teeth, even if started shortly before eruption,¹ as evidenced by experiments in which children 8-11 years of age living in areas with nonfluoridated water were given 1 mg F per day administered in a 5 ml mouth rinse solution that was swallowed. Whenever the aim is pre-eruptive effects of F administration, the F content of the drinking water, other F sources, and the age of the patient must be taken into consideration. For orthodontic patients approximately 10-12 years old at start of treatment, a total dose of 2 mg per day may be administered.³ Because of incomplete knowledge of possible side effects resulting from ingestion of the various components in commercial rinse solutions, however, it might be safer to supplement F rinsing with F-tablets to obtain the combination of topical and pre-eruptive effects.

Of particular interest for orthodontists is the finding of von der Fehr *et al.*³⁷ that experimentally produced buccal and lingual demineralizations on human teeth were reversed by daily mouth rinses for two months with 0.2% NaF solutions and good oral hygiene measures. Similar demineralizations may appear following orthodontic treatment. A reversal, at least in part, of such defects may be expected by the use of

daily mouth rinses for 2-4 months with 0.2% NaF after the removal of the appliances.^{43,44}

In summary, daily rinsing with dilute NaF or APF solutions has a dual effect of effective caries inhibition and stimulating hygiene interest, and is recommended as a routine for all patients throughout the treatment and retention periods. Topical F applications are appropriate also for orthodontic patients living in fluoridated areas. A pre-eruptive effect may be obtained by ingestion of the rinse solution, or by the use of a combination of rinsing and F tablets.

F-TABLETS

For many years clinical experimentation has demonstrated that daily intake of F tablets (NaF or APF) may cause a constant pre-eruptive F uptake in the enamel without any undesirable side effects.²⁷ This might be the case whenever a constant systemic dose of F is desired, particularly in nonfluoridated areas.

Studies on F supplementation administered as pills or tablets (0.5-1 mg per day according to age) have shown caries reductions in permanent teeth of 20-40% when started at 6-9 years of age.²⁸ The caries inhibition may be the result of a daily topical effect on erupted teeth, followed after swallowing by a systemic effect on developing tooth structures. The relationship between the anticaries effects of the topical and the systemic parts is uncertain. Bibby *et al.*⁴ found caries reduction from the use of tablets that were dissolved in the mouth, but not from pills that were swallowed whole. More recent studies indicate that caries prevention from the use of chewable tablets is obtained mainly in teeth exposed to the administered F pre-eruptively or shortly after eruption.^{1,27}

F-DENTIFRICES

A large number of F dentifrices have been introduced on the market in recent years. The ones most commonly used contain sodium monofluorophosphate (NaPO_3F), NaF, SnF_2 or amine fluorides. The F ion concentrations are generally equivalent to approximately 0.1%. Provided the F is not bound tightly to the constituents, all have proved to be effective. The per cent caries reduction obtained in the different studies cannot easily be compared, and at present there are no definite data from controlled clinical studies to indicate the superiority of any single F dentifrice. However, the abrasiveness may vary with the composition of the dentifrice. The use of F dentifrices can and should be combined with other forms of F administration, and the uptake by enamel of dentifrice F during toothbrushing is limited.^{2,36} But even in areas where the drinking water contains optimal levels of F one may obtain a significant caries reduction in addition to the anticariogenic effect produced by the fluoridated water.¹²

In summary, the regular use of a F dentifrice should be recommended to all patients undergoing orthodontic treatment in addition to other forms of F administration.

F-CEMENTS

Silicate cement restorations slowly release fluorides and protect surrounding enamel from secondary caries. Attempts have also been made to add F agents (mostly SnF_2 or $\text{Na}_2\text{PO}_3\text{F}$) to the liquid or solid components of orthodontic cements including zinc phosphate,⁴¹ silicophosphate,¹¹ reinforced zinc oxide eugenol⁴² and carboxylate cements.⁸

The addition of F may seem beneficial, partly because the acid in cement liquids has the potential to etch the enamel surface. However, available

data do not indicate that orthodontic cements in the consistency routinely used in the clinic will predispose to demineralization. The results of *in vitro* studies with F-cements indicate an increased uptake and deep penetration of F into the enamel underneath the cemented bands. However, controlled long-term clinical studies have not yet been reported. Further experimentation will probably result in improved F-cements for clinical application.

COATING TECHNIQUES AND F-VARNISHES

The topical application of F predisposes to the formation of readily soluble calcium fluoride (CaF_2) crystals on the enamel surface. In the presence of moisture an appreciable part of the CaF_2 formed is soon eliminated (within 24 hours),¹⁹ but the residual CaF_2 is gradually converted to stable fluorapatite.²⁵ This reaction usually involves only a thin surface layer of enamel. Therefore, topical application must be repeated since ionic exchange rapidly decreases the F content of the superficial layers.

A number of new coating techniques aim at prolonging the period of F contact with the teeth to enhance the uptake and penetration of F and allow a greater conversion of hydroxyapatite to fluorapatite. Their mode of action includes either a) "sealing" of F into occlusal and/or smooth surfaces with long-lasting adhesive sealant after topical application of F,⁸ or b) coating of tooth surfaces with F-releasing varnishes adhering to the tooth surface for a period of 24 hours to several weeks.¹⁹

The final judgment of these products must await confirmation of the results obtained in further clinical testing. However, the beneficial effect of F sealing in orthodontic patients is substantiated. During *in vivo* experiments on direct bonding of plastic attachments,

Newman and Cimasoni²⁶ achieved a significant F uptake down to a depth of at least 60 microns when the enamel surface was pretreated with APF for 1 minute and covered for two to three months with an adhesive containing NaPO_3F .

With regard to F-varnishes no reports are available in orthodontic patients. However, even a non-F varnish coating of the enamel before cementation of bands has been found to give some protection.²³

OTHER METHODS

Other means of F supplementation in orthodontic patients include the use of elastics containing 10% NaF.⁴² Additional research is needed to evaluate the effectiveness and the appropriateness of such F application.

DISCUSSION

Cariou lesions underneath orthodontic bands may be due to loosening, improper band fit, faulty cementation, lack of recementation, unrestored cavities, etc., while demineralizations adjacent to the bands are rather caused by improper oral hygiene and diet. Whatever the causative factors, the increased caries risk demands maximal use of preventive procedures, particularly for patients in nonfluoridated areas. Although other measures are also important, the use of fluorides currently remains the best approach to the prevention of dental decay.

Orthodontic treatment procedures are generally started after the age when enamel formation takes place (up to the age of 8 years if the third molars are excluded). After this time there is little or no risk for dental fluorosis and the body may tolerate, within reasonable limits, elevated systemic and topical F doses without damage. The hazards of overdosage through the topical F application methods recommended seem

I. BEFORE INSERTION OF FIXED APPLIANCES

- 1) APF-GEL TREATMENT (ASSOCIATED WITH IMPRESSION TAKING), AND
 - 2) DAILY MOUTH RINSING WITH 0.05 % NaF
- (CARIES PRONE PATIENTS SHOULD RINSE TWICE DAILY)

II. THROUGHOUT PERIOD OF ACTIVE TREATMENT

- DAILY RINSING WITH 0.05 % NaF
(CARIES PRONE PATIENTS SHOULD RINSE TWICE DAILY)

III. AFTER REMOVAL OF FIXED APPLIANCES

A) ROUTINE PATIENTS:

DAILY RINSING WITH 0.05 % NaF

B) PATIENTS HAVING RECEIVED DEMINERALIZATIONS DURING TREATMENT:

DAILY RINSING WITH 0.2 % NaF FOR 2-4 MONTHS, FOLLOWED BY
DAILY RINSING WITH 0.05 % NaF

IN ADDITION TO F-MOUTH RINSES ALL PATIENTS SHOULD USE A F-DENTIFRICE THROUGHOUT THE TREATMENT PERIOD

TABLE I

Routine F application procedures used for all patients receiving fixed appliance therapy at the Oslo University Department of Orthodontics (F content of drinking water below 0.10 ppm).

negligible, even in areas where the drinking water is fluoridated.

As mentioned, conclusive evidence as to whether or not a particular F regime is superior to others is lacking, mainly because of lack of comparative studies of different F agents and/or different application methods, and because caries reductions reported by various investigators are not directly comparable. However, having evaluated the available F application methods with regard to clinical effectiveness, safety and practical applicability, the program outlined in Table I is now prescribed for all patients receiving fixed appliance therapy at the University of Oslo Department of Orthodontics. As discussed above, the purpose of the initial APF gel treatment is to ensure a great F uptake by the surface enamel prior to banding. The daily rinses at home with 0.05% NaF serve to maintain the F content and to enhance the mineralization of demineralized tooth surfaces during the treatment period, and the 0.2% NaF rinse is used for reversal of evident white spot lesions when the bands have been removed. The procedure was not selected to represent the only method for F supplementation to orthodontic

patients, but has proven to be simple, practical and efficient.^{43,44}

As new evidence becomes available, the foregoing conclusions should be subjected to review and possible revision.

SUMMARY

A survey is given of present knowledge of different methods of fluoride administration with emphasis on practical measures of proved value for orthodontic patients. The review covers different F administration procedures by dental personnel and self-application and includes the use of prophylaxis pastes, topical solutions, gels, mouth rinses, dentifrices, tablets, cements, coatings, varnishes, etc.

Some recommendations are given as to optimal programs in orthodontic practice based upon evaluations of clinical effectiveness, safety and ease of application. Some caries reduction has been obtained from professional application of F prophylaxis pastes, but F pastes cannot replace topical F application. Treatment with F gels or solutions preceded by thorough cleaning and drying of the teeth is advocated before the placement of appliances and at recementations. Because F solutions are tedious to apply, and not more effective than F gels, the latter are preferable. APF gel application is suited in conjunction with impression taking. Daily self-application of SnF₂ gels undoubtedly is effective in reducing caries in orthodontic patients. However, daily NaF or APF mouth rinses may have the dual effect of caries inhibition and stimulating hygiene interest and are more thoroughly tested. In addition to the other forms of F administration, a F dentifrice should be used regularly. Daily F application is appropriate also for orthodontic patients in fluoridated areas. *In vitro* studies with F cements indicate a great F uptake by the enamel, but controlled, long-term clinical

studies are lacking. Also the final judgment of a number of new coating techniques and F varnishes must await further clinical testing, although a beneficial effect of F sealing in orthodontic patients is substantiated.

In conclusion, APF gel application before insertion of appliances and at regular recementations plus daily rinsing with dilute NaF or APF solutions throughout the periods of treatment and retention plus the regular use of a F dentifrice is recommended as a routine procedure for all orthodontic patients.

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