Topical Fluorides in Caries Prevention and Management: A North American Perspective

Ernest Newbrun, D.M.D., Ph.D.

Abstract: A review of evidence-based literature indicates incomplete evidence for the efficacy of most measures currently used for caries prevention, with the exception of fluoride varnishes and the use of fluoride-based interventions for patients with hyposalivation. Not all fluoride agents and treatments are equal. Different fluoride compounds, different vehicles, and vastly different concentrations have been used with different frequencies and durations of application. These variables can influence the clinical outcome with respect to caries prevention and management. The efficacy of topical fluoride in caries prevention depends on a) the concentration of fluoride used, b) the frequency and duration of application, and, to a certain extent, c) the specific fluoride compound used. The more concentrated the fluoride and the greater the frequency of application, the greater the caries reduction. Factors besides efficacy, such as practicality, cost, and compliance, influence the clinician’s choice of preventive therapy. For noncavitated smooth surface carious lesions in a moderate caries-risk patient, the appropriate fluoride regimen would be semiannual professional topical application of a fluoride varnish containing 5 percent NaF (22,600 ppm of fluoride). In addition, the patient should use twice or thrice daily for at least one minute a fluoridated dentifrice containing NaF, MFP, or SnF₂ (1,000-1,500 ppm of fluoride), and once daily for one minute a fluoride mouthrinse containing .05 percent NaF (230 ppm of fluoride). If the noncavitated carious lesion involves a pit or fissure, the application of an occlusal sealant would be the most appropriate preventive therapy. The management of the high caries-risk patient requires the use of several preventive interventions and behavioral modification, besides the use of topical fluorides. For children over six years of age and adults, both office and self-applied topical fluoride treatments are recommended. For office fluoride therapy at the initial visit, a high-concentration agent, either a 1.23 percent F APF gel (12,300 ppm of fluoride) for four minutes in a tray or a 5 percent NaF varnish (22,600 ppm of fluoride), should be applied directly to the teeth four times per year. Self-applied fluoride therapy should consist of the daily five-minute application of 1.1 percent NaF or APF gel (5,000 ppm of fluoride) in a custom-fitted tray. For those who cannot tolerate a tray delivery owing to gagging or nausea, a daily 0.05 percent NaF rinse (230 ppm of fluoride) for 1 minute is a less effective alternative. In addition, the patient should use twice or thrice daily for at least 1 minute a fluoridated dentifrice as described above for treatment of noncavitated carious lesions. In order to avoid unintentional ingestion and the risk of fluorosis in children under six years of age, fluoride rinses and gels should not be used at home. Furthermore, when using a fluoride dentifrice, such children should apply only a pea-size portion on the brush, should be instructed not to eat or swallow the paste, and should expectorate thoroughly after brushing. Toothbrushing should be done under parental supervision. To avoid etching of porcelain crowns and facings, neutral NaF is indicated in preference to APF gels for those patients who have such restorations and are applying the gel daily. The rationale for these recommendations is discussed. Important deficiencies in our knowledge that require further research on topical fluoride therapy in populations with specific needs are identified.

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Key words: topical fluoride, fluoride dentifrice, fluoride mouthrinse, fluoride varnish, caries risk, hyposalivation, clinical trials, caries prevention

Water fluoridation is an integral part of any oral health program. The benefits are irrefutable, ranging from 11 to 40 percent less decay, depending on dentition, population, and use of preventive practices. Because foods and beverage products processed in optimally fluoridated areas are consumed in “non-fluoridated” areas (the “diffusion effect”), this may be an underestimation of the total benefit of water fluoridation. Despite the mantra that water fluoridation primarily acts topically, repetition does not make it correct. Findings from epidemiological human studies show that water fluoridation provides both pre- and post-eruptive benefits that are both systemic and topical in combination. Studies in the Netherlands, based on time of exposure to fluoride (pre- and post-eruptive), indicate that fluoride has an important pre-eruptive effect on caries in permanent teeth. Approximal smooth surface caries reduction was attributable to 50 percent pre- and 50 percent post-eruptive fluoride exposure, whereas pit and fissure caries reduction was attributable to 66 percent pre- and 33 percent post-eruptive fluoride exposure. On free smooth surfaces, caries reduction was due to 25 percent pre- and 75 percent post-eruptive exposure to fluoride. Recent Australian studies have confirmed that children exposed to fluoridated water, both pre- and post-eruptive...
tively, had the lowest caries on all surface types. These findings support the policy of water fluoridation as a public health caries preventive measure.8

Two of the questions addressed by Bader et al. are the effectiveness of strategies to arrest or reverse the progress of initial lesions before they become cavitated, and the most effective interventions to mitigate the caries attack in persons identified as being at high risk of caries.9 The authors limited themselves to the consideration of reports concerning methods applied in a professional setting and, in evaluating management of high-caries-risk patients, to only those studies where the subjects had been thus identified, based on past caries experience and/or bacteriological testing. They did not include hyposalivation as a criterion of high caries risk, perhaps because there is considerable variability in what constitutes normal salivary flow rate.10,11 Individuals with severe salivary gland dysfunction are at high risk of developing caries.12-14 The exact cut-off with respect to what constitutes a low salivary flow rate varies throughout the literature, such as 0.10 to 0.16 ml/min for whole unstimulated saliva.15-19 Measuring salivary flow rates can be time-consuming and difficult to standardize if the patient has hyposalivation. Monitoring secretory function longitudinally can be incorporated by dentists as a routine examination procedure and can be a valuable adjunct to oral diagnosis.10

In the management of high-caries-risk patients, the review concluded that the evidence supporting the use of fluoride varnishes in caries prevention was fair, while other fluoride therapeutic agents showed nonsignificant small protective benefits, but the data were incomplete.9 In a review of seven studies of patients with hyposalivation, Newbrun found that the treatment protocols employed had all used self-applied topical fluoride agents, sometimes in combination with chlorhexidine, but had varied considerably in the type, concentration, duration, and frequency of the fluoride agent used.20 The form of self-application also had varied, from rinsing to brushing-on of gels to the use of custom-fabricated individual mouth trays. Most studies had used small numbers of patients and had not had a true control group. Assignment of patients to treatment groups was not always random. The extent of patient compliance had varied, doubtlessly because of differences in the populations as well as in the practicality and acceptability of the regimens.

Discussion

Findings from extensive clinical trials on the efficacy of fluoride dentifrices and/or other self-applied fluoride agents, as well as on professionally applied fluoride treatments, are relevant to strategies to arrest initial lesions and the most effective interventions in treating high-caries-risk persons. Not all fluoride agents and treatments are equal. Different fluoride compounds, different vehicles, and vastly different concentrations of fluoride have been used with different frequency and duration of application (Table 1). All of these variables influence the clinical outcome with respect to caries prevention. The efficacy of topical fluoride depends on a) the concentration of fluoride used, b) the frequency with which it is applied and the duration of application, and c) the specific fluoride compound used.21,22

Regarding the concentration of fluoride used, most fluoride dentifrice studies have shown a dose/response effect,21,23 and the trends in clinical effectiveness of professionally applied topical fluoride agents are similar (Table 2).24-26

With respect to the frequency of topical fluoride application, in studies using the same commercial stannous fluoride dentifrice, the efficacy of unsupervised once-per-day or ad libitum use was about a 21 percent caries reduction,27,28 whereas the efficacy of supervised thrice-per-day use was about a 45 percent caries reduction29,30 (Table 3). Marthaler found that in studies using fluoride brush-on gels or solutions, those that employed fifteen or more applications per year had 40 to 50 percent caries reductions, whereas those with four to five

Table 1. Range of therapeutic fluoride concentrations used to prevent caries

<table>
<thead>
<tr>
<th>Method/vehicle</th>
<th>Fluoride concentration (ppm F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water supplies</td>
<td>0.7-1.2</td>
</tr>
<tr>
<td>Fluoridated salt</td>
<td>200-250</td>
</tr>
<tr>
<td>Mouthrinse, daily</td>
<td>230</td>
</tr>
<tr>
<td>Dentifrices, children</td>
<td>250-500</td>
</tr>
<tr>
<td>Mouthrinse, weekly</td>
<td>920</td>
</tr>
<tr>
<td>Dentifrices, adult</td>
<td>1,000-1,500</td>
</tr>
<tr>
<td>Self-applied gels or rinses, prescription</td>
<td>5,000</td>
</tr>
<tr>
<td>Professionally applied solutions (NaF)</td>
<td>9,200</td>
</tr>
<tr>
<td>Professionally applied solutions, gels, foams (APF)</td>
<td>12,300</td>
</tr>
<tr>
<td>Professionally applied solutions (SnF2)</td>
<td>19,500</td>
</tr>
<tr>
<td>Professionally applied varnishes</td>
<td>22,600</td>
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</tbody>
</table>
applications per year were less efficacious. Eklund et al. failed to demonstrate an association between frequency of use of professionally applied topical fluoride and the placement of interproximal restorations. The reason may be that dentists’ propensities to place restorations overwhelmed any preventive effect of the topical fluoride applications. This analysis of dental insurance claims assumed that all topical fluoride applications were made according to “standard practice” and had the same efficacy.

There are no published controlled clinical trials in which the same concentration of a topical fluoride agent has been tested for varying durations of application. In vitro testing of both NaF and APF solutions has shown that fluoride uptake is time related, and in the case of APF solutions the most rapid uptake occurs during the first four minutes. Although some manufacturers claim that their brand of gel or foam will provide near maximum uptake in one minute, these products lack testing for clinical efficacy. Therefore, the recommended duration of application of APF agents should be four minutes. Fluoride varnishes adhere to tooth surfaces, permitting prolonged fluoride exposure and uptake. Meta-analysis of the efficacy of fluoride varnishes by Helfenstein and Steiner found a mean caries reduction of 38 percent for fluoride varnishes. In their review of evidence-based literature, Bader et al. reported incomplete evidence for the efficacy of most measures currently used for caries prevention, with the exception of fluoride varnishes.

Earlier studies may not meet contemporary criteria for inclusion in an evidence-based review. Nevertheless, there is a consistency of results in that the more concentrated the fluoride and the greater the frequency of application, the greater the caries reduction. The fact that topical treatments differ in efficacy is often ignored by some who think all such treatments are equivalent. Other factors besides efficacy, such as safety, practicality, cost and compliance, influence the clinician’s choice of preventive therapy.

### Recommendations for Therapy

#### Treatment of Noncavitated Carious Lesions

Let us assume a) that a noncavitated carious lesion occurs in a moderate-caries-risk patient and b) that it involves a smooth surface. The appropriate fluoride regimen would be semiannual professional topical application of a fluoride varnish, containing five percent NaF (22,600 ppm of fluoride), to the noncavitated carious lesion. If the patient is to be treated more than twice per year, then a fluoride varnish should be applied at each visit. In addition, the patient should use at least twice daily for minimally one minute a fluoridated dentifrice containing NaF, MFP, or SnF₂ (1,000-1,500 ppm of fluoride) and once daily for one minute a fluoride mouthrinse containing 0.05 percent NaF (230 ppm of fluoride). The agents, the fluoride concentrations, and the frequency and duration of use are all important in the outcome. Many clinicians think that if a carious lesion is detectable radiographically, even if the surface appears intact, it has already advanced beyond the radiolucency and therefore should be restored. Histo logic and microradiographic findings indicate that caries is usually more advanced than it appears in clinical

<table>
<thead>
<tr>
<th>Study</th>
<th>Brushing frequency</th>
<th>Subject ages (years)</th>
<th>Study length</th>
<th>DMFS reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jordan 1959</td>
<td>1x day</td>
<td>8-12</td>
<td>2 years</td>
<td>21</td>
</tr>
<tr>
<td>Horowitz 1966</td>
<td>1x day + ad libitum</td>
<td>6-10</td>
<td>2 years</td>
<td>21</td>
</tr>
<tr>
<td>Peffley 1960</td>
<td>3x day</td>
<td>10-15</td>
<td>2 years</td>
<td>46</td>
</tr>
<tr>
<td>Bixler 1962</td>
<td>3x day</td>
<td>12-16</td>
<td>8 months</td>
<td>45</td>
</tr>
</tbody>
</table>

*Crest™

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### Table 2. Comparative effectiveness of professionally applied topical fluoride agents

<table>
<thead>
<tr>
<th>Agent</th>
<th>Fluoride concentration (ppm F)</th>
<th>Average effectiveness%</th>
<th>% caries reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2% NaF</td>
<td>9,200</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>APF (1.2% F)</td>
<td>12,300</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>8% SnF₂</td>
<td>19,500</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>Fluoride varnish</td>
<td>22,600</td>
<td>38</td>
<td>38</td>
</tr>
</tbody>
</table>

*Effectiveness estimates from Horowitz⁹, van Rijkom⁸, and Helfenstein⁸.
radiographs. Others suggest that if the enamel surface is intact, small lesions detected radiographically need not be restored immediately and that restoration can be delayed or avoided if adequate preventive procedures are carried out. Any such noncavitated carious lesions need to be monitored regularly to ensure that preventive treatment is effective and that the lesions are not progressing. Elderton has proposed a decision tree for the clinical management of carious lesions in which caries is judged to be arrested, active, or unable to be judged. Only in the latter two instances are the criteria for restorative treatment fulfilled. One should not decide whether or not to restore on the basis of an individual tooth surface, but rather on the evaluation of the patient’s caries risk as a whole.

Pit and fissure tooth surfaces require special assessment and management. The application of sealants to early fissure lesions produces an immediate bactericidal effect, grossly reducing the number of viable bacteria in carious dentin beneath the sealant. If a noncavitated carious lesion involves a pit or fissure, pre-eruptive fluoride exposure is more effective than topical fluoride. Accordingly, the application of occlusal sealants would be the most appropriate preventive therapy.

Management of High-Caries-Risk Patients

The management of a high-caries-risk patient requires the use of several preventive interventions and behavioral modifications, not just the use of topical fluorides. For children over six years of age and adults, both office and self-applied topical fluoride treatments are recommended. For office fluoride therapy at the initial visit, a high-concentration agent, either a 1.23 percent F APF gel (12,300 ppm of fluoride) for four minutes in a tray or a 5 percent NaF (22,600 ppm of fluoride) varnish, should be applied to the teeth. Since the application frequency is important in determining efficacy, four such applications per year have been recommended. Self-applied fluoride therapy should consist of a daily five-minute application of 1.1 percent NaF or APF gel (5,000 ppm of fluoride) in a custom-fitted tray. For those who cannot tolerate a tray delivery owing to nausea, a daily 0.05 percent NaF rinse (230 ppm of fluoride) for one minute is a less effective alternative. Also, patients should use a fluoridated dentifrice at least twice a day for treatment of noncavitated carious lesions. To reduce the risk of fluorosis, children under six years should not use fluoride rinses. When using a fluoride dentifrice, they should apply a pea-size portion on the brush, be instructed not to swallow the paste, and expectorate thoroughly. Toothbrushing should be under parental supervision. To avoid etching of porcelain crowns and facings, neutral NaF is indicated for those patients who have such restorations and are applying the gel daily.

Recommendations for Research

Noncavitated carious lesions and patients diagnosed as being at high caries risk must be treated; it is unethical to perform studies with placebo control groups. Many different fluoride agents (NaF, APF, SnF₂, organic fluorides, and fluoride varnishes) have been tested for topical use in caries prevention. The duration and frequency of application have varied. No head-to-head comparisons of regimens and agents have been published. At the Clinical Investigations and Patient Care Branch of the National Institute of Dental and Craniofacial Research (NIDCR), the center with the largest number of patients at high risk of caries, these agents were used interchangeably in managing patients’ dental problems, but their efficacy was not compared. To obtain sufficient numbers of patients, NIDCR should issue a multicenter contract to test different fluoride agents and different durations and frequencies of application, with respect to relative effectiveness, cost, practicality, and acceptability in caries prevention and reversal. The protocol should be specified and methods of application and evaluation standardized to ensure uniformity of the different center studies. Assignment of patients to different treatment modalities must be randomized and examiners blinded as to the treatment regimen. For high-caries-risk patients, other agents besides fluoride should be tested as adjuncts, and the best ways of behavioral modification to achieve good dietary and oral hygiene habits should be determined.

Although the evidence for the efficacy of fluoride interventions in the prevention and management of caries may be incomplete or only fair, the clinician needs some guidelines in treating patients at risk. Specific agents and methods of use must be recommended, but at present such recommendations seem to be based on empirical clinical discernment. The recommendations listed above are my judgment call based on integration of data from extensive clinical trials on the efficacy of fluoride dentifrices and other self-applied fluoride agents and on professionally applied fluoride treatments.
REFERENCES