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Short Communication

Fluoride Varnishes: Why They Work & What to Look For

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As a dental student or professional, you are likely (very) familiar with the use and benefits of fluoride varnishes. Originally developed in Europe, there now appears to be general consensus of the anti-caries benefits provided by fluoride varnishes, and this is supported, for instance, by the World Health Organization along with individual countries and government agencies [1-5]. And though the United States Food & Drug Administration does not formally recognize the anti-caries benefits of fluoride varnishes, this does not preclude other US agencies from recognizing anti-caries benefits, including the American Dental Association (ADA), American Academy of Pediatric Dentistry (AAPD), Centers for Disease Control & Prevention (CDC), and many state-based health programs. Recently, the US Preventive Services Task Force recommended "that primary care clinicians apply fluoride varnish to the primary teeth of infants and children starting at the age of primary tooth eruption" [5]. Expanding on this recommendation, the ADA recognizes 5% NaF (i.e. 2.26% F^- ion) varnish treatments confer caries prevention benefits when given at least twice per year for children younger than six years of age and also for children and teenagers up through 18 years of age; and, 5% NaF varnish treatments are also recommended for prevention against root caries in adults when administered at least twice per year [2]. Therefore, fluoride varnishes seem beneficial to all age groups, with a particular focus on high-risk caries populations, especially children [1-6].

Given the ever-growing use of fluoride varnishes over existing preventive measures, such as fluoride gel, one might enquire as to the relative efficacy among fluoridated treatments. At present, systematic reviews do not necessarily favor on modality over another [6]; however, there is strong support favoring implementation of at least one fluoride modality, including water fluoridation, fluoride toothpaste, fluoride mouthrinse, fluoride gel, and fluoride varnish, all of which scored the strongest recommendations by the United States CDC for caries prevention and control for those most at risk of dental decay [4].

In many countries, including the United States, clinicians are favoring the use of fluoride varnishes over fluoride gels, especially among children with developing and primary dentition. A major reason for the switch is many believe there is a reduced risk of accidental ingestion of fluoride during the onerous fluoride gel treatment; not to mention that despite the pleasing flavors of the fluoride gels, a most common complaint is the gagging that the gel induces as it remains molded to the teeth for the duration of the treatment (often, at least 20 minutes). Separately, because of the relative short application time (which can be at little as one minute with proper technique), this aligns with the often time-constrained responsibilities of dental clinicians and assistants. Even further, this is a most convenient preventive measure administered by nurses, nurse practitioners, and/or physicians as part of government- and/or school-sponsored health programs, and can be readily incorporated into the routine appointments for children as part of the 'dental home' (which, for example, the AAPD recommends for the child before the end of their first year [3]).

So, there is broad agreement that fluoride varnishes are a useful and supported modality for caries prevention and control. We also understand that fluoride varnishes may save us valuable clinical time while providing reduced patient health risks and discomfort.

But why a fluoride varnish? In terms of the modality only – that is, we're not considering possible health risks, patient discomfort or even faster application times – what makes a varnish fundamentally different compared to a toothpaste or gel format? What is often quickly glossed over, misunderstood or simply missing is the reasoning why a varnish is even used – or, arguably, needed – to deliver fluoride.

The simplest answer to this question is that the varnish prolongs fluoride-enamel exposure better than gel, rinse or paste formats. This is important, of course, as fluoridated enamel is less soluble compared to fluoride-free enamel, and also functions as a reservoir to thwart deleterious action of cariogenic microbes.

But, there is more to this story. Brudevold., *et al*. published in 1956 that unless the enamel is mottled, fluoride is not evenly distributed, which the outer layers of enamel (~ 50 μm) generally having more fluoride than the inner layers (again, unless mottled enamel is considered) [7]. When contacted with water for prolonged time, or exposed to the acidic pH action of food, drink and microbes, of course minerals (including fluoride!) are lost from the enamel lattice. Necessary reintroduction of fluoride in the oral environment is therefore one reason that daily brushing with fluoridated toothpaste can be an effective caries-related counter measure.

But why isn't one high-fluoride treatment enough and what is/are the underlying cause(s) afflicting longer fluoride-enamel interfacing?? In addition to routine fluoridated exposure (e.g. toothpaste), professional recommendations still suggest at least two fluoride varnish treatments (for the high-risk populations especially).

Observing that the greatest loss of fluoride from enamel (e.g. two-thirds) occurs within the first 24 hours after topical treatment (e.g. from an acidulated fluoride gel or rinse treatment), several independent researchers in the 1960s identified the key for enamel to retain fluoride is to prolong fluoride-enamel exposure [8-10]. These findings were noteworthy, as they suggested the exposure of a high concentration of fluoride to the teeth is not the primary factor affecting stability of the enamel lattice; nor is it about the most rapid delivery of fluoride to the oral environment, as this will rapidly clear from the mouth. Even further, it is not about the presence of insoluble minerals/salts precipitated on the tooth surface, as for instance, this does not necessarily provide sufficient acid-resistance to the underlying enamel lattice.

Rather, the limiting factor relates to a) the inability of fluoride to penetrate throughout the enamel structure (despite the porosity of enamel, fluoride's penetration is restricted due to a combination of enamel matrix and fluoride ion characteristics), and b) the relatively 'open oral system' environment where the teeth are not isolated from the oral cavity but are constantly engaging the tongue, lips, saliva, etc. Consistent with laws of thermodynamics where nature favors minimum energy (i.e. at standard temperature and pressure), it is thermodynamically unfavorable for two distinct regions (i.e. a fluoride-rich region and a fluoride-free region) to exist in equilibrium. Because the tooth cannot shuttle fluoride ions throughout its structure and because it is not isolated from the oral environment, in the open oral system, fluoridated enamel naturally forces the expulsion of fluoride to the relatively fluoride-free surroundings as it strives to attain thermodynamic equilibrium. As a result, it is highly unlikely to achieve a lasting fluoride-rich region without repeated exposures to topical fluoride. This is further frustrated, of course, by enamel dissolution factors arising from consumption of foods and beverages, microbial activity, etc.

Recognized only a *posteriori*, physical barriers were then applied to the teeth after fluoridated treatment as a means of forcing fluoride retention to the enamel surface [1,9-11]. In effect, this approach created temporary thermodynamic isolation of the teeth from the oral environment, and proved successful in preventing bulk loss of fluoride after immediate treatment. Among the experimental barriers used were beeswax, nail polish and cavity liner [10]. Backed with data demonstrating fluoride needed additional incentive to remain on the tooth, commercial innovations came shortly thereafter: Schmidt published on a water-insoluble resin system comprising 5% sodium fluoride and soluble in ethanol, known as Duraphat® (which was later acquired by Colgate) in 1964, with clinical efficacy realized soon afterwards, while the benefits of a novel polyurethane system comprising 1% difluorosilane, then known as Vivadent Fluor Protector (now known as Ivoclar Vivadent, with different versions available, including ammonium fluoride) were demonstrated in 1975 [1,11].

The above discussion is important as it helps explain the origin and purpose of fluoride varnish, and also provides perspective to the various commercial fluoride varnishes available today. Most of these varnish manufacturers appeal to dental/medical professionals on the basis of 'rapid/fast release', 'greater fluoride-ion release', 'higher enamel uptake', or the inclusion of additional agents that may pre-

cipitate on the tooth. Those manufacturers relying on such claims unfortunately miss the purpose of a fluoride varnish and instead are effectively creating what I consider to be a varnish-gel hybrid system that can be described as 'rapidly releasing lots of fluoride resulting in high fluoride uptake'; and, if the varnish has additional agents (e.g. calcium and phosphate), then the varnish is supposed to encourage 'precipitation' onto the tooth surface. However, these claims are problematic, as it muddles the purpose of a fluoride varnish. For instance, varnishes that promote 'rapid release' may in turn sacrifice the durability and thickness of the varnish system itself. Also, massive enamel fluoride uptake can create undesirable gradients that drive fluoride from the tooth: in actuality, the outer layers of enamel can only take in so much fluoride, with much of it unable to be integrated effectively into the tooth – this begs the question: "where does all the excess fluoride go?" Thermodynamically speaking, if the fluoride is dumped to the enamel surface in a large deposition event, the resulting gradient will naturally drive expulsion of fluoride to the oral environment (since fluoride is unable to diffuse deeper into the enamel structure!). So, one can surmise that much of the excess fluoride becomes cleared/swallowed, especially if the varnish system flows very readily and easy. Finally, varnishes should not be designed as an adhesive to stick precipitated, insoluble mineral to the enamel surface, as this still does not prevent dissolution of the underlying enamel surface by acids, and may lead to other complications (poor mineralization, soft tissue irritations, calculus accumulation, etc).

As a dental researcher* intimately familiar with the scope and performance of many of the commercial varnishes available today, I believe it's insightful for me to provide at least a refresher, and possibly some new information, regarding the purpose of fluoride varnishes. Importantly, my recommendations to the dental/medical professional and community are to be mindful of the intent of the fluoride varnish and exercise caution with manufacturers' marketing claims. In my opinion, I recommend varnishes that display the following properties of an 'ideal' varnish system:

- Maintain a physical barrier for a given period of time (e.g. 4, 8, even 12 hours); and,
- Provide controlled release of low fluoride levels to the tooth (i.e. steady exposure of low-levels of fluoride provide clinical benefits while manifesting reduced risk for fluoride ingestion; note: rapid- and/or high fluoride-release properties do not mirror the purpose of a varnish and may pose unnecessary health risks); and,
- Encourage mineralization with the enamel structure; additional mineralizing agents are OK as long as they do not encourage robust precipitation - those that can integrate with the enamel are best.

Disclosure: As a scientist who developed the 'TCP' ingredient contained in the 3M Oral Care Vanish™/Clinpro™ varnish systems, I support their clinical use; however, these systems may or may not be applicable in all situations.

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