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Fluoride's Role in Preventing Dental Caries

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Abstract
Fluoride plays a crucial role in preventing dental caries, particularly in children. Its effectiveness spans pre-eruptive, post-eruptive, systemic, and topical contexts. Fluoride's mechanisms of action include mitigating enamel demineralization, facilitating remineralization of early caries, and inhibiting bacterial activity in dental plaque. Various fluoride delivery modalities exist, ranging from community-based programs like water and salt fluoridation to school-based initiatives such as fluoridated milk and mouthrinse programs. At the individual level, home-based approaches include dietary fluoride supplements, fluoride toothpaste, and mouthrinses. Professionally applied topical fluorides, such as gels and varnishes, provide additional benefits for those at elevated caries risk. The combination of fluoride modalities enhances caries prevention compared to single methods. Fluoride varnish has gained popularity due to its ease of application and reduced ingestion risk, making it suitable for use by non-dental professionals in medical and community settings. Fluoride is considered highly safe at recommended dosages, with dental fluorosis being the most common side effect of chronic excessive intake during tooth development. Strategies to improve compliance with fluoride use include motivational interviewing and building public trust through open, understanding dialogue. Biomarkers like urinary fluoride excretion can assess group-level exposure. Recommendations for minimizing dental fluorosis risk include delaying fluoride toothpaste introduction, using age-appropriate amounts, and considering low-fluoride options for young children. Fluoride works synergistically with other preventive measures like dental sealants and non-fluoride agents to optimize caries prevention across populations.
Keywords: fluoride, dental caries, Oral health, Dental decay

Introduction

Fluoride's presence in the environment and its impact on human health encompass a wide array of disciplines, including medicine, dentistry, environmental and occupational health, toxicology, environmental geology, petrology, geochemistry, economic geology, hydrogeology, and soil science (Ozsvath, 2009).

The distribution of fluoride in the natural environment is highly uneven, primarily due to the geochemical behavior of fluorine, which tends to concentrate in highly evolved magmas and hydrothermal solutions. This phenomenon explains why significant fluoride concentrations are commonly found in syenites, granitoid plutonic rocks, alkaline volcanic rocks, and hydrothermal deposits. Additionally, fluoride can be present in sedimentary formations that include fluoride-bearing minerals originating from parent rocks, fluoride-rich clays, or fluorapatite (Ozsvath, 2009).

Dissolved fluoride concentrations are typically regulated by the solubility of fluorite (CaF2), resulting in elevated levels often being associated with soft, alkaline, and calcium-deficient water bodies.

Fluoride is introduced into the human body through food, inhalation, and products containing fluoride. As a component of the natural environment, fluoride is an integral and constant element in daily life. However, the concentration of fluoride varies significantly between different regions (Kanduti et al., 2016).

Oral health care plays a crucial role in overall health. Dental caries remains one of the most pressing public health concerns. The most effective approach for preventing caries is the application of fluoride to promote the remineralization of the tooth enamel layer (Wong et al., 2011).

Early childhood caries (ECC) is specifically defined as the occurrence of one or more decayed (either noncavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth of a child younger than six years ("Policy on Early Childhood Caries (ECC)," 2016).

Fluoride as a Key Preventive Measure Against Tooth Decay

Fluoride is instrumental in reducing the incidence and severity of dental caries that necessitate restorative dental interventions. This efficacy applies across pre-eruptive, post-eruptive, systemic, and topical contexts. Fluoride operates through several mechanisms ("Recommendations for Using Fluoride to Prevent and Control Dental Caries in the United States. Centers for Disease Control and Prevention," 2001):

- By mitigating enamel demineralization in the presence of acids generated by cariogenic bacteria in dental plaque breaking down fermentable carbohydrates,
- By facilitating the remineralization of early enamel caries, and
- By inhibiting bacterial activity within dental plaque.

Fluoride accumulates in dental plaque as ions derived from saliva, water, toothpaste, mouth rinses, and professional dental products. Despite regular tooth cleaning, residual dental plaque serves as a reservoir of fluoride, enabling remineralization of the tooth surface. High-fluoride applications, such as fluoride varnish, combine with calcium in dental plaque to form calcium fluoride globules. These globules, coated with a phosphate- or protein-rich layer, dissociate gradually in the presence of plaque acids (e.g., lactic and pyruvic acids from bacterial fermentation of carbohydrates), releasing bioavailable fluoride ions over time. This sustained release promotes prolonged protection of the tooth surface (H. Pollick, 2018).

Moreover, increased fluoride concentrations in dentin can inhibit or slow the progression of caries towards the pulp. Fluoride can also be incorporated into the developing teeth when children ingest fluoride toothpaste or consume fluoridated water. Various fluoride delivery modalities exist, ranging from community- and school-based initiatives to home and professional applications (O'Mullane et al., 2016).

Community-Based Fluoride Programs

The global population exceeds seven billion; however, fewer than one billion individuals have access to proven community water or salt fluoridation programs. These initiatives effectively reduce the prevalence and severity of tooth decay, which remains the most common chronic disease among children, with untreated cases affecting up to 95% of certain populations (Beaglehole, 2009).

Water Fluoridation

Water fluoridation is practiced in numerous countries worldwide. As of 2012, over 420 million people globally had access to fluoridated water, either naturally (approximately 50 million) or with adjusted fluoride levels at or near optimal concentrations (approximately 370 million). In the United States, more than 211 million individuals, representing about 75% of the population served by public water systems, had access to fluoridated water (Hung et al., 2023).

A global systematic review by Cochrane demonstrated that the introduction of community water fluoridation results in a 35% reduction in the mean number of decayed, missing, and filled primary teeth and a 26% reduction in permanent teeth. Additionally, the review reported a 15% increase in the proportion of children without decay. Pediatric healthcare providers should encourage families to consume tap water where fluoridation is available (Iheozor-Ejiofor et al., 2024).

Salt Fluoridation

Salt fluoridation is estimated to benefit between 40 million and 280 million people worldwide, predominantly in Europe, South America, and Central America. This method is often suggested for communities with low water fluoride levels and no feasible means to implement water fluoridation. However, no salt fluoridation programs exist in the United States. The benefits and safety of salt fluoridation are comparable to those of water fluoridation (Marthaler, 2013; H. F. Pollick, 2013).

To minimize the risk of dental fluorosis in young children with developing teeth, it is recommended that national fluoride programs adopt only one community-based approach, either water or salt fluoridation (Horowitz, 2000).

School-Based Fluoride Programs

Fluoridated Milk

Although fluoridated milk is not practiced in the United States, it has proven effective in reducing dental caries in primary teeth among schoolchildren in countries such as Japan, Scotland, Israel, and Hungary. Similar programs were evaluated in Louisiana, USA, during the 1950s (Bánóczy et al., 2013; Yeung et al., 2015).

Fluoride Mouthrinse

Due to natural swallowing reflexes, children under six years old may be unable to resist ingesting mouthrinses. However, for children older than six, supervised use of alcohol-free fluoride mouthrinse has been shown to significantly reduce tooth decay in permanent teeth. The safety margin for acute toxicity in school-based programs using 900-ppm fluoride mouthrinse is wide; 10 mL contains only 9 mg of fluoride, which is over ten times lower than the probable toxic dose for a six-year-old child weighing 20 kg (Marinho et al., 2016).

In communities with limited fluoride exposure through water, school-based fluoride mouthrinse programs are recommended. However, their implementation should consider costs and the community's caries status.

Home-Based Fluoride Approaches

Dietary Fluoride Supplements

Prescription fluoride supplements, such as fluoride tablets or drops, have been shown to effectively reduce caries in permanent teeth when used as directed (Tubert-Jeannin et al., 2011). However, their application as a public health strategy is limited due to poor adherence to the recommended daily schedule, and there is insufficient evidence to support their efficacy in preventing early childhood caries (ECC) (Tweetman & Dhar, 2015). In the United States, dietary fluoride supplements may be prescribed (with or without added vitamins) for children at high risk for caries. The appropriate daily dosage depends on the child's age and the fluoride concentration in the water supply (Rozier, Adair, et al., 2010).

Fluoride supplements are not advised for infants younger than six months (or without teeth) or for any children in areas where the water fluoride concentration exceeds 0.6 mg/L. Recommendations for fluoride supplementation based on water fluoride concentration are as follows:

For water containing less than 0.3 mg/L of fluoride:

- No supplements before six months of age
- 0.25 mg per day between 6 months and 3 years
- 0.50 mg per day between 3 and 6 years
- 1 mg per day between 6 and 16 years

For water containing 0.3 to 0.6 mg/L of fluoride:

- No supplements before 3 years of age
- 0.25 mg per day between 3 and 6 years
- 0.5 mg per day between 6 and 16 years

Fluoride Toothpaste

Strong evidence indicates that brushing with fluoride toothpaste twice daily significantly reduces caries in young permanent teeth compared to placebo (Twetman et al., 2003). Evidence also suggests a dose-response relationship, with toothpastes containing 1500 ppm fluoride providing greater caries protection than those with 1000 ppm fluoride (Walsh et al., 2010). However, in the United States, only toothpastes containing 1000 to 1100 ppm fluoride are available without a prescription (Staff, 2009).

Regular brushing with fluoride toothpaste, even at suboptimal fluoride concentrations, from the eruption of the first tooth remains the best clinical practice, as supported by moderate-quality evidence (Twetman et al., 2003). For children under 3 years of age, a smear of toothpaste should be used, while a pea-sized amount is recommended for those over 3 years. Toothpaste should be spit out after brushing without rinsing with water. Parents should discourage the use of non-fluoridated toothpastes for children.

Prescription-Strength Fluoride Toothpaste

High-fluoride toothpastes containing 5000 ppm fluoride have a strong evidence base for use in individuals at high risk for caries (Pretty, 2016). Use in children under 6 years is recommended only when the risk of severe caries-related morbidity outweighs the risk of aesthetic concerns due to fluorosis. For children under 9 years at risk for dental fluorosis, it is advised to rinse with water after using high-fluoride toothpaste. In contrast, regular fluoride toothpaste should be spit out without rinsing with water.

Fluoride Mouthrinse

Daily fluoride mouthrinses for home use typically contain 225 ppm fluoride, compared to the higher 900 ppm concentration used in weekly school-based programs. Fluoride mouthrinses are recommended for children over 6 years who no longer exhibit the swallowing reflex and who are at moderate to high risk for caries, regardless of fluoride levels in drinking water. It is suggested to rinse for 1 to 2 minutes and spit out the solution without rinsing with water afterward. Studies have demonstrated caries prevention benefits from fluoride rinsing both with and without prior toothbrushing (LeCompte & Doyle, 1985).

Professionally Applied Topical Fluoride

Fluoride Gels

High-concentration fluoride gels, professionally applied in dental clinics, are a widely used method to prevent dental caries in both children and adults who are at elevated risk for decay, regardless of whether they live in fluoridated or non-fluoridated areas. The application of fluoride gel containing 12,300 ppm fluoride as acidulated phosphate fluoride significantly reduces caries in both primary and permanent teeth (Marinho et al., 2015). Fluoride gel is applied using trays that remain on the teeth for approximately 4 minutes. During application, suction is used to minimize swallowing.

Precautionary measures during fluoride gel application include:

1. Using only the necessary quantity of fluoride solution or gel
2. Positioning the patient upright
3. Employing efficient saliva aspiration equipment
4. Ensuring the patient thoroughly expectorates after the procedure

These measures effectively reduce swallowed fluoride to less than 2 mg, posing minimal risk. However, fluoride varnish has increasingly replaced gels due to ease of use and lower risk of ingestion (LeCompte & Doyle, 1985).

Fluoride Varnish

Fluoride varnish has been demonstrated to be as effective as fluoride gel in preventing caries (Seppä et al., 2009). Its growing preference is attributed to its simplicity of application and reduced risk of ingesting excessive doses, particularly in young children. Professionally applied 5% sodium fluoride varnish (22,600 ppm fluoride) can remineralize early enamel caries (Gao et al., 2016), potentially avoiding the need for restorations.

Application involves brushing the varnish onto clean, dry teeth in clinics, medical offices, or community settings, particularly for children at high caries risk (e.g., WIC or Head Start programs). The process takes about one minute, and the varnish sets quickly. Patients are instructed to consume soft foods and avoid brushing and flossing for the remainder of the day to maintain varnish efficacy. The frequency of application varies based on caries risk, with intervals of 3 to 6 months (Azarpazhooh & Main, 2008). Although technically an off-label use, as the U.S. Food and Drug Administration (FDA) has approved varnish for treating hypersensitivity, extensive evidence supports its effectiveness in caries prevention (Beltrán-Aguilar et al., 2000; Weintraub et al., 2006).

Application by Primary Care Providers

The FDA categorizes fluoride varnish products as medical devices for cavity lining and hypersensitivity treatment, though they are often used off-label for caries prevention. The safety of fluoride varnish allows it to be applied by various medical professionals, such as nurses or physician assistants, without specialized equipment.

Given that young children visit primary care providers (PCPs) more frequently than dentists, PCP visits present an opportunity to address oral health early. The American Academy of Pediatrics recommends 11 PCP checkups before age two, facilitating the integration of dental care into medical practice. Programs like *Into the Mouths of Babes* in North Carolina have demonstrated the effectiveness of this approach. This program reimbursed physicians for providing dental screenings, applying fluoride varnish, and counseling parents for children under age three. It reduced Medicaid hospital episode costs by 32% (Rozier, Stearns, et al., 2010; Stearns et al., 2012; Tellez & Wolff, 2016).

Combination of Fluoride Modalities

When topical fluorides such as mouthrinses, gels, or varnishes are used in addition to fluoride toothpaste, they achieve a modest reduction in caries compared to toothpaste alone (Marinho et al., 2004a). These additional topical applications are typically recommended for individuals at moderate or high caries risk, factoring in other fluoride exposures. Clinical trials suggest that the effectiveness of topical fluoride treatments increases with the frequency and number of applications (Beaglehole, 2009).

Preference for Fluoride Modalities

Fluoride toothpaste is comparable in effectiveness to mouthrinses or gels for preventing dental caries in children. No definitive evidence indicates that fluoride varnish is superior to mouthrinses, nor is there clear data comparing the effectiveness of varnishes, gels, and rinses (Marinho et al., 2004b). For children with existing caries or those at high risk, health professionals should advise parents to supervise twice-daily use of age-appropriate fluoride toothpaste and obtain consent to apply fluoride varnish. Fluoride mouthrinses should only be recommended for children capable of spitting without swallowing the solution.

Frequency of Professionally Applied Fluoride Use

For dental practitioners, it is advised that new patients presenting with active caries, irrespective of age, undergo an initial series of four professionally applied topical fluoride treatments within a 2- to 4-week timeframe. If preferred, the first application may be preceded by professional cleaning (prophylaxis), while the subsequent three applications should follow thorough tooth brushing to eliminate plaque and debris. This series can be conveniently integrated with other preventative measures such as plaque control, dietary guidance, and initial restorative plans developed for these patients. After completing the initial series, patients should receive single topical fluoride applications at intervals of 3, 6, or 12 months, depending on their caries risk status ("Professionally Applied Topical Fluoride," 2006).

Comparison Between Fluoride Varnish and Dental Sealants

Dental sealants, applied by oral health professionals, are recommended for sealing the pits and fissures of primary and permanent molars before any visible signs of decay appear. The oral health objectives outlined in *Healthy People 2020* emphasize increasing the proportion of children aged 3 to 5 years receiving sealants on one or more primary molars, children aged 6 to 9 years receiving sealants on permanent first molars, and adolescents aged 13 to 15 years receiving sealants on one or more permanent molars.

Both fluoride varnish and dental sealants are considered effective in preventing caries for individuals at elevated risk. While fluoride primarily protects smooth tooth surfaces, sealants safeguard pits and fissures. The two methods are complementary rather than alternatives. However, in a community-based oral health initiative targeting high-caries-risk children aged 6 to 7 years, the caries-preventive efficacy of fluoride varnish after 36 months was found to be comparable to that of dental sealants, provided sealants were properly maintained (Chestnutt et al., 2017).

Strategies to Improve Compliance with Fluoride Use

There has been an increase in parents refusing topical fluoride treatments for their children during preventive dental and medical visits. This trend is largely driven by misinformation available online, propagated by anti-fluoridation groups. Such misinformation falsely links fluoride to numerous conditions and diseases, including AIDS, Alzheimer's disease, cancer, Down syndrome, genetic damage, heart disease, reduced intelligence, kidney disease, osteoporosis, and bone fractures. These claims have been comprehensively refuted through authoritative, evidence-based sources such as the American Dental Association's *Fluoridation Facts* (2018) (Chi, 2017).

Studies suggest that families who participate in motivational interviewing are more likely to adhere to recommended fluoride varnish protocols compared to those receiving traditional education and counselling (Weinstein et al., 2006).

A focus group study examining public attitudes toward fluoridation reached the following conclusions:

- Fluoride proponents should prioritize individual choice whenever feasible.
- Individual choice may be overridden when significant benefits and safety for the broader community are demonstrable.
- Scientific evidence supports fluoridation as both beneficial and safe.

Building trust is paramount, and recommendations include:

1. Acknowledging public concerns about fluoride and treating them seriously.

2. Avoiding a sole focus on correcting factual errors without addressing the underlying worries, as this approach can exacerbate mistrust.
3. Engaging in discussions that prioritize understanding public concerns and finding shared values rather than emphasizing corrective or promotional messaging.

Biomarkers of Fluoride Exposure

While fluoride levels in plasma, saliva, and urine offer some insights into fluoride exposure, current evidence is insufficient to recommend these as reliable biomarkers for individual exposure. However, daily urinary fluoride excretion can serve as a useful biomarker for assessing group-level fluoride exposure. Standards exist for urinary fluoride excretion, indicating low, optimal, and high levels of exposure.

Safety of Fluoride

In the dosages referenced here, fluoride is considered highly safe. A Tolerable Upper Intake Level (UL) of 0.10 mg/kg/day was established for infants, toddlers, and children up to 8 years old, based on a lowest-observed-adverse-effect level of 0.10 mg/kg/day for moderate enamel fluorosis and an uncertainty factor of 1 (Intakes, 1997). This value should not be interpreted as a limit to prevent acute toxicity, which is substantially higher approximately 5 mg/kg, or 50 times the UL. It should also not be construed as a limit for occasional exposures, such as those occurring with the application of fluoride varnish. The UL for fluoride is age- and weight-dependent, ranging from 0.7 mg/day to 2.0 mg/day in younger children based on body weight. For children older than 9 years and adults, the UL is set at 10 mg/day, as the crowns of all permanent teeth, aside from wisdom teeth, are fully formed by that age (Intakes, 1997).

The most frequent side effect of chronic excessive fluoride intake in children under 9 years old is dental fluorosis. Non severe forms of dental fluorosis are not harmful to health and, in fact, are associated with an increased resistance to dental caries (Iida & Kumar, 2009).

Dental Fluorosis

Dental fluorosis is a condition characterized by changes in the mineralization of the dental hard tissues caused by prolonged ingestion of fluoride during the tooth development period before eruption (the first eight years of life for most permanent teeth, excluding third molars). Once the teeth erupt, dental fluorosis is defined as a nonfluorotic alteration in the appearance of teeth. The likelihood of dental fluorosis is minimal (near zero) at fluoride concentrations below 2 mg/L in drinking water (Whitford, 2011). Enamel hypoplasia, a distinct condition, may sometimes be mistaken for dental fluorosis (Sabokseir et al., 2016).

Public health initiatives aim to minimize fluoride exposure to the level necessary to achieve optimal benefits. For example, in 2015, the recommended fluoride concentration in drinking water was adjusted to a uniform standard of 0.7 mg/L across the United States, partly in response to the increased prevalence of dental fluorosis reported in NHANES studies ("U.S. Public Health Service Recommendation for Fluoride Concentration in Drinking Water for the Prevention of Dental Caries," 2015). Similarly, in 1994, the recommended dosages for prescription fluoride supplements were revised due to evidence linking earlier recommendations to higher rates of dental fluorosis ("Recommendations for Using Fluoride to Prevent and Control Dental Caries in the United States. Centers for Disease Control and Prevention," 2001).

Acute Fluoride Toxicity

Acute fluoride toxicity manifests as nausea, vomiting, muscle spasms, abdominal pain, and in severe cases, coma, convulsions, and cardiac arrhythmias. It can result from inappropriate ingestion of excessive fluoride products, such as multiple doses of prescription fluoride supplements at once or swallowing high concentrations of topical fluoride gels during professional applications without adequate suction or spitting (Sabokseir et al., 2016). Immediate intervention is required in such cases (Bayless & Tinanoff, 1985).

Chronic fluoride toxicity is characterized by symptoms such as stiffness and joint pain, indicative of skeletal fluorosis, which typically arises from prolonged fluoride exposure over many years in areas where drinking water or personal wells have high fluoride concentrations. The U.S. Environmental Protection Agency (EPA) has established primary and secondary maximum contaminant levels of 4 mg/L and 2 mg/L, respectively, for naturally occurring fluoride in drinking water. Community water systems are required to notify consumers if fluoride levels exceed the secondary limit so that parents and caregivers can ensure children under 9 years old avoid regular consumption of such water, thereby preventing moderate to severe dental fluorosis. Regulations in the United States also require individual well owners to test their water regularly.

Recommendations on Infant Formula Use

There is limited evidence suggesting that fluoride in infant formula reconstituted with fluoridated water could contribute to enamel fluorosis, though other factors, such as swallowing fluoride toothpaste during tooth development, may also explain the association (Hujoel et al., 2009). Dentists and other primary care providers (PCPs) are encouraged to advise parents and caregivers of infants using powdered or liquid concentrate formulas to continue reconstituting them with optimally fluoridated water, while acknowledging the potential risk of enamel fluorosis (Berg et al., 2011).

The Centers for Disease Control and Prevention (CDC) advises that parents may opt to use low fluoride bottled water, labelled as deionized, purified, demineralized, or distilled (without added fluoride post-treatment, as mandated by the Food and Drug Administration), when preparing infant formula to reduce the likelihood of fluorosis. Following the U.S. Public Health Service's (USPHS) recommendation to standardize community water fluoridation to 0.7 ppm, the risk of enamel fluorosis from reconstituting infant formula with fluoridated water is expected to decline.

Recommendations to Reduce Dental Fluorosis

1. Delay the introduction of fluoride toothpaste until the child is between 18 and 36 months of age, unless the child is identified as being at an elevated risk for dental caries (Forum on Fluoridation, 2002; Health Canada, 2010; Australian Research Centre for Population Oral Health, 2012) (O'Mullane et al., 2016).
2. Apply a "smear" of fluoride toothpaste (approximately 0.1 mg of fluoride) for children under 3 years of age, and a pea-sized amount (about 0.25 mg of fluoride) for children aged 3 years and older (SIGN, 2014; Public Health England, 2014; ADA Council on Scientific Affairs, 2014) (O'Mullane et al., 2016).
3. While not available in the United States, some countries endorse the use of low-fluoride toothpaste for younger children. For instance, the 2012 Australian guidelines recommend toothpaste containing 500–550 ppm fluoride for children aged 18 months to 5 years (EAPD, 2009; Australian Research Centre for Population Oral Health, 2012).

In addition to dental sealants, which are highly effective in preventing pit and fissure caries, nonfluoride agents like chlorhexidine and xylitol wipes or rinses may provide supplementary therapeutic benefits. These agents can help prevent, arrest, or potentially reverse dental caries, but they are not intended to replace established fluoride-based caries prevention methods (Rethman et al., 2011; Wang et al., 2017).

Conclusion

Fluoride remains a cornerstone of dental caries prevention due to its proven effectiveness in remineralizing enamel and reducing demineralization. Its diverse applications—ranging from community-based water fluoridation programs to professionally applied topical treatments—highlight its versatility in addressing various levels of caries risk. While concerns about fluoride-related conditions such as dental fluorosis and toxicity exist, they are generally associated with excessive or prolonged exposure, which can be mitigated by adhering to established guidelines.

Public health recommendations emphasize the judicious use of fluoride, particularly in children, to balance caries prevention with the minimal risk of fluorosis. The introduction of strategies like the appropriate timing and quantity of fluoride toothpaste, combined with motivational interviewing and public education, can further enhance compliance and trust. As evidence evolves, fluoride continues to demonstrate a significant role in improving oral health outcomes, reinforcing the need for its integration into both dental and medical practices.

References

Azarpazhooh, A., & Main, P. A. (2008). Fluoride varnish in the prevention of dental caries in children and adolescents: A systematic review. *Journal of the Canadian Dental Association*, *74*(1), 73–79. Scopus.

Bánóczy, J., Rugg-Gunn, A., & Woodward, M. (2013). Milk fluoridation for the prevention of dental caries. *Acta Medica Academica*, *42*(2), Article 2. https://doi.org/10.5644/ama2006-124.83

Bayless, J. M., & Tinanoff, N. (1985). Diagnosis and treatment of acute fluoride toxicity. *Journal of the American Dental Association (1939)*, *110*(2), 209–211. https://doi.org/10.14219/jada.archive.1985.0246

Beaglehole, R. (2009). *The oral health atlas: Mapping a neglected global health issue*. FDI World Dental Federation.

Beltrán-Aguilar, E. D., Goldstein, J. W., & Lockwood, S. A. (2000). Fluoride Varnishes: A Review of Their Clinical Use, Cariostatic Mechanism, Efficacy and Safety. *The Journal of the American Dental Association*, *131*(5), 589–596. https://doi.org/10.14219/jada.archive.2000.0232

Berg, J., Gerweck, C., Hujoel, P. P., King, R., Krol, D. M., Kumar, J., Levy, S., Pollick, H., Whitford, G. M., Strock, S., Aravamudhan, K., Frantsve-Hawley, J., Meyer, D. M., & for the American Dental Association Council on Scientific Affairs Expert Panel on Fluoride Intake From Infant Formula and Fluorosis. (2011). Evidence-Based Clinical Recommendations Regarding Fluoride Intake From Reconstituted Infant Formula and Enamel Fluorosis: A Report of the American Dental Association Council on Scientific Affairs. *The Journal of the American Dental Association*, *142*(1), 79–87. https://doi.org/10.14219/jada.archive.2011.0032

Chestnutt, I. G., Playle, R., Hutchings, S., Morgan-Trimmer, S., Fitzsimmons, D., Aawar, N., Angel, L., Derrick, S., Drew, C., Hoddell, C., Hood, K., Humphreys, I., Kirby, N., Lau, T. M. M., Lisles, C., Morgan, M. Z., Murphy, S., Nuttall, J., Onishchenko, K., … Chadwick, B. L. (2017). Fissure Seal or Fluoride Varnish? A Randomized Trial of Relative Effectiveness. *Journal of Dental Research*, *96*(7), 754–761. https://doi.org/10.1177/0022034517702094

Chi, D. L. (2017). Parent Refusal of Topical Fluoride for Their Children: Clinical Strategies and Future Research Priorities to Improve Evidence-Based Pediatric Dental Practice. *Dental Clinics of North America*, *61*(3), 607–617. https://doi.org/10.1016/j.cden.2017.03.002

Gao, S., Gong, J., & Feng, Y. (2016). Equivalent damping for displacement-based seismic design of pile-supported wharves with soil–pile interaction. *Ocean Engineering*, *125*, 12–25. https://doi.org/10.1016/j.oceaneng.2016.08.006

Horowitz, H. S. (2000). Decision-making for national programs of community fluoride use. *Community Dentistry and Oral Epidemiology*, *28*(5), 321–329. https://doi.org/10.1034/j.1600-0528.2000.028005321.x

Hujoel, P. P., Zina, L. G., Moimaz, S. A. S., & Cunha-Cruz, J. (2009). Infant Formula and Enamel Fluorosis: A Systematic Review. *The Journal of the American Dental Association*, *140*(7), 841–854. https://doi.org/10.14219/jada.archive.2009.0278

Hung, M., Mohajeri, A., Chiang, J., Park, J., Bautista, B., Hardy, C., & Lipsky, M. S. (2023). Community Water Fluoridation in Focus: A Comprehensive Look at Fluoridation Levels across America. *International Journal of Environmental Research and Public Health*, *20*(23), 7100. https://doi.org/10.3390/ijerph20237100

Iheozor-Ejiofor, Z., Walsh, T., Lewis, S. R., Riley, P., Boyers, D., Clarkson, J. E., Worthington, H. V., Glenny, A.-M., & O'Malley, L. (n.d.). *Water fluoridation for the prevention of dental caries—Iheozor-Ejiofor, Z - 2024 | Cochrane Library*. Retrieved November 21, 2024, from https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD010856.pub3/full

Iida, H., & Kumar, J. V. (2009). The Association Between Enamel Fluorosis and Dental Caries in U.S. Schoolchildren. *The Journal of the American Dental Association*, *140*(7), 855–862. https://doi.org/10.14219/jada.archive.2009.0279

Intakes, I. of M. (US) S. C. on the S. E. of D. R. (1997). Fluoride. In *Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride*. National Academies Press (US). https://www.ncbi.nlm.nih.gov/books/NBK109832/

Kanduti, D., Sterbenk, P., & Artnik, B. (2016). FLUORIDE: A REVIEW OF USE AND EFFECTS ON HEALTH. *Materia Socio-Medica*, *28*(2), 133–137. https://doi.org/10.5455/msm.2016.28.133-137

LeCompte, E. J., & Doyle, T. E. (1985). Effects of suctioning devices on oral fluoride retention. *Journal of the American Dental Association (1939)*, *110*(3), 357–360. Scopus. https://doi.org/10.14219/jada.archive.1985.0336

Marinho, V. C., Chong, L.-Y., Worthington, H. V., & Walsh, T. (2016). Fluoride mouthrinses for preventing dental caries in children and adolescents. *Cochrane Database of Systematic Reviews*, *2021*(2). https://doi.org/10.1002/14651858.CD002284.pub2

Marinho, V. C., Higgins, J. P., Sheiham, A., & Logan, S. (2004a). Combinations of topical fluoride (toothpastes, mouthrinses, gels, varnishes) versus single topical fluoride for preventing dental caries in children and adolescents. *Cochrane Database of Systematic Reviews*. https://doi.org/10.1002/14651858.CD002781.pub2

Marinho, V. C., Higgins, J. P., Sheiham, A., & Logan, S. (2004b). One topical fluoride (toothpastes, or mouthrinses, or gels, or varnishes) versus another for preventing dental caries in children and adolescents. *Cochrane Database of Systematic Reviews*. https://doi.org/10.1002/14651858.CD002780.pub2

Marinho, V. C., Worthington, H. V., Walsh, T., & Chong, L.-Y. (2015). Fluoride gels for preventing dental caries in children and adolescents. *Cochrane Database of Systematic Reviews*, *2021*(2). https://doi.org/10.1002/14651858.CD002280.pub2

Marthaler, T. M. (2013). Salt fluoridation and oral health. *Acta Medica Academica*, *42*(2), Article 2. https://doi.org/10.5644/ama2006-124.82

O'Mullane, D. M., Baez, R. J., Jones, S., Lennon, M. A., Petersen, P. E., Rugg-Gunn, A. J., Whelton, H., & Whitford, G. M. (2016). Fluoride and oral health. *Community Dental Health*, *33*(2), 69–99. Scopus. https://doi.org/10.1922/CDH_3707O'Mullane31

Ozsvath, D. L. (2009). Fluoride and environmental health: A review. *Reviews in Environmental Science and Bio/Technology*, *8*(1), 59–79. https://doi.org/10.1007/s11157-008-9136-9

Policy on Early Childhood Caries (ECC): Classifications, Consequences, and Preventive Strategies. (2016). *Pediatric Dentistry*, *38*(6), 52–54.

Pollick, H. (2018). The Role of Fluoride in the Prevention of Tooth Decay. *Pediatric Clinics of North America*.

https://www.academia.edu/110554536/The_Role_of_Fluoride_in_the_Prevention_of_Tooth_Decay

Pollick, H. F. (2013). Salt fluoridation: A review. *Journal of the California Dental Association*, *41*(6), 395–397, 400–404. Scopus.

Pretty, I. A. (2016). High Fluoride Concentration Toothpastes for Children and Adolescents. *Caries Research*, *50*(Suppl. 1), 9–14. https://doi.org/10.1159/000442797

Professionally applied topical fluoride: Evidence–based clinical recommendations. (2006). *The Journal of the American Dental Association*, *137*(8), 1151–1159. https://doi.org/10.14219/jada.archive.2006.0356

Recommendations for using fluoride to prevent and control dental caries in the United States. Centers for Disease Control and Prevention. (2001). *MMWR. Recommendations and Reports: Morbidity and Mortality Weekly Report. Recommendations and Reports*, *50*(RR-14), 1–42.

Rethman, M. P., Beltrán-Aguilar, E. D., Billings, R. J., Burne, R. A., Clark, M., Donly, K. J., Hujoel, P. P., Katz, B. P., Milgrom, P., Sohn, W., Stamm, J. W., Watson, G., Wolff, M., Wright, J. T., Zero, D., Aravamudhan, K., Frantsve-Hawley, J., Meyer, D. M., & for the American Dental Association Council on Scientific Affairs Expert Panel on Nonfluoride Caries-Preventive Agents. (2011). Nonfluoride caries-preventive agents: Executive summary of evidence-based clinical recommendations. *The Journal of the American Dental Association*, *142*(9), 1065–1071. https://doi.org/10.14219/jada.archive.2011.0329

Rozier, R. G., Adair, S., Graham, F., Iafolla, T., Kingman, A., Kohn, W., Krol, D., Levy, S., Pollick, H., Whitford, G., Strock, S., Frantsve-Hawley, J., Aravamudhan, K., & Meyer, D. M. (2010). Evidence-Based Clinical Recommendations on the Prescription of Dietary Fluoride Supplements for Caries Prevention: A report of the American Dental Association Council on Scientific Affairs. *The Journal of the American Dental Association*, *141*(12), 1480–1489. https://doi.org/10.14219/jada.archive.2010.0111

Rozier, R. G., Stearns, S. C., Pahel, B. T., Quinonez, R. B., & Park, J. (2010). How A North Carolina Program Boosted Preventive Oral Health Services For Low-Income Children. *Health Affairs*, *29*(12), 2278–2285. https://doi.org/10.1377/hlthaff.2009.0768

Sabokseir, A., Golkari, A., & Sheiham, A. (2016). Distinguishing between enamel fluorosis and other enamel defects in permanent teeth of children. *PeerJ*, *4*, e1745. https://doi.org/10.7717/peerj.1745

Seppä, L., Leppänen, T., & Hausen, H. (2009). Fluoride Varnish versus Acidulated Phosphate Fluoride Gel: A 3-Year Clinical Trial. *Caries Research*, *29*(5), 327–330. https://doi.org/10.1159/000262086

Staff, P. D. R. (2009). *The ADA/PDR Guide to Dental Therapeutics* (Fifth edition). PDR Network.

Stearns, S. C., Rozier, R. G., Kranz, A. M., Pahel, B. T., & Quiñonez, R. B. (2012). Cost-effectiveness of Preventive Oral Health Care in Medical Offices for Young Medicaid Enrollees. *Archives of Pediatrics & Adolescent Medicine*, *166*(10), 945–951. https://doi.org/10.1001/archpediatrics.2012.797

Tellez, M., & Wolff, M. S. (2016). The Public Health Reach of High Fluoride Vehicles: Examples of Innovative Approaches. *Caries Research*, *50*(Suppl. 1), 61–67. https://doi.org/10.1159/000443186

Tubert-Jeannin, S., Auclair, C., Amsallem, E., Tramini, P., Gerbaud, L., Ruffieux, C., Schulte, A. G., Koch, M. J., Rège-Walther, M., & Ismail, A. (2011). Fluoride supplements (tablets, drops, lozenges or chewing gums) for preventing dental caries in children.

Cochrane Database of Systematic Reviews, *2019*(11). https://doi.org/10.1002/14651858.CD007592.pub2

Twetman, S., Axelsson, S., Dahlgren, H., Holm, A.-K., Källestål, C., Lagerlöf, F., Lingström, P., Mejàre, I., Nordenram, G., Norlund, A., Petersson, L. G., & Söder, B. (2003). Caries-preventive effect of fluoride toothpaste: A systematic review. *Acta Odontologica Scandinavica*, *61*(6), 347–355. Scopus. https://doi.org/10.1080/00016350310007590

Twetman, S., & Dhar, V. (2015). Evidence of effectiveness of current therapies to prevent and treat early childhood caries. *Pediatric Dentistry*, *37*(3), 246–253. Scopus.

U.S. Public Health Service Recommendation for Fluoride Concentration in Drinking Water for the Prevention of Dental Caries. (2015). *Public Health Reports®*, *130*(4), 318–331. https://doi.org/10.1177/003335491513000408

Walsh, T., Worthington, H. V., Glenny, A.-M., Appelbe, P., Marinho, V. C., & Shi, X. (2010). Fluoride toothpastes of different concentrations for preventing dental caries in children and adolescents. *Cochrane Database of Systematic Reviews*. https://doi.org/10.1002/14651858.CD007868.pub2

Wang, Y., Li, J., Sun, W., Li, H., Cannon, R. D., & Mei, L. (2017). Effect of non-fluoride agents on the prevention of dental caries in primary dentition: A systematic review. *PLOS ONE*, *12*(8), e0182221. https://doi.org/10.1371/journal.pone.0182221

Weinstein, P., Harrison, R., & Benton, T. (2006). Motivating mothers to prevent caries: Confirming the beneficial effect of counseling. *The Journal of the American Dental Association*, *137*(6), 789–793. https://doi.org/10.14219/jada.archive.2006.0291

Weintraub, J. A., Ramos-Gomez, F., Jue, B., Shain, S., Hoover, C. I., Featherstone, J. D. B., & Gansky, S. A. (2006). Fluoride Varnish Efficacy in Preventing Early Childhood Caries. *Journal of Dental Research*, *85*(2), 172–176. https://doi.org/10.1177/154405910608500211

Whitford, G. M. (2011). Acute toxicity of ingested fluoride. *Monographs in Oral Science*, *22*, 66–80. https://doi.org/10.1159/000325146

Wong, M. C. M., Clarkson, J., Glenny, A.-M., Lo, E. C. M., Marinho, V. C. C., Tsang, B. W. K., Walsh, T., & Worthington, H. V. (2011). Cochrane reviews on the benefits/risks of fluoride toothpastes. *Journal of Dental Research*, *90*(5), 573–579. https://doi.org/10.1177/0022034510393346

Yeung, C. A., Chong, L. Y., & Glenny, A.-M. (n.d.). *Fluoridated milk for preventing dental caries—Yeung, CA - 2015 | Cochrane Library*. Retrieved November 21, 2024, from https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD003876.pub3/full