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FLUORIDES AND ORAL HEALTH

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Background. *The importance of fluorides in caries prevention is discussed in the article and practical recommendations for the use of fluoride containing products are presented.*

Objectives. *The primary objective of this systematic review is to assess the evidence on the comparative effectiveness of topical fluoride therapy (TFT) in the form of toothpastes, mouth rinses, gels and varnishes in prevention of dental caries in children and adolescents.*

Methods. *A systematic electronic literature search was conducted in the PubMed and Web of Science databases using search terms. Current reports in the literature concerning means and methods of use of fluoride-containing medications are considered.*

Results. *A large number of scientific studies, reviews based on them and meta-analyses conclude that the central element of caries prevention, on which the decrease in caries prevalence and caries experience is based, is the regular topical use of fluoride medications for oral cavity.*

Conclusions. *Topical use of fluorides is a key element in successful caries prevention.*

KEYWORDS: **caries prevention; fluoride; mechanisms of action; fluoride side effects.**

Introduction

Dental caries is the most prevalent chronic disease afflicting a significant proportion of the world population, including around 60% to 90% of school-aged children and the vast majority of adults. Untreated caries causes progressive destruction of the crowns of the teeth, often accompanied by severe pain and suffering, especially in children. Thus, it can result in poorer quality of life and general health [1].

Prevention of caries in children and adolescents is considered a priority for dental services and is more cost-efficient than treatment [2, 3].

Dental caries develops because of demineralization of tooth structure by organic acids formed by oral bacteria present in dental plaque through the anaerobic metabolism of dietary sugars. The causal role of sugars in caries is well established. Most caries lesions in children's permanent teeth progress relatively slowly, with an average lesion taking three years to progress through tooth enamel to dentine [4, 5, 6].

The dental caries process is influenced by the susceptibility of the tooth surface, the bacterial profile, the quantity and quality of saliva and the presence of fluoride, which promotes remineralization and inhibits demineralization of the tooth structure. [7].

The caries process can be affected in several ways. One of the most effective methods to prevent caries is promoting remineralization and slowing down demineralization. This can be accomplished with fluoride therapy [8, 9].

However, it should be emphasized that successful caries prevention is based on the general concept of all caries prevention strategies that have been proven to be effective. In addition to topical fluoride use, this means implementation of adequate oral hygiene to reduce cariogenic biofilm and appropriate diet to reduce the intake of low molecular weight carbohydrates, primarily sucrose.

Review

Mechanisms of action of fluorides on teeth.

Three principal mechanisms by which fluoride is considered to inhibit dental caries have been identified. Fluoride reduces the enamel solubility in acid by pre-eruptive incorporation into the hydroxyapatite crystal. It promotes remineralization and inhibits demineralization of early carious lesions. It inhibits glycolysis, the process by which cariogenic

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bacteria metabolizes fermentable carbohydrates [10].

The hydroxyapatite of tooth enamel is primarily composed of phosphate ions (PO_4^{3-}) and calcium ions (Ca^{2+}). In norm, there is a stable equilibrium between the calcium and phosphate ions in saliva and the crystalline hydroxyapatite that comprises 96 % of tooth enamel. When the pH drops below a critical level (approximately 5.5 for enamel, and 6.2 for dentin), it causes dissolution of tooth mineral (hydroxyapatite) in a process called demineralization. When the natural buffer capacity of saliva elevates pH, the minerals are reincorporated into the tooth through remineralization [12, 13].

Under cariogenic conditions, carbohydrates are converted to acids by bacteria in the plaque biofilm. When the pH drops below 5.5, the biofilm fluid becomes undersaturated with phosphate ion and enamel dissolves to restore balance. When fluoride (F^-) is present, fluorapatite is incorporated into demineralized enamel and subsequent demineralization is inhibited.

When fluoride is present in oral fluids (i.e., saliva), fluorapatite, rather than hydroxyapatite, is formed during the remineralization process. ($Ca_{10}(PO_4)6(OH)_2 \rightarrow Ca_{10}(PO_4)6(F)_2$). Fluoride ions ($F^-$) replace hydroxyl groups (OH^-) in formation of the apatite crystal lattice (Fig. 1). In fact, the presence of fluoride increases the rate of remineralization [11].

Fluoride is available from many sources divided into 3 major categories: tap water (and foods and beverages processed with fluoridated water), home administered, and professionally applied.

Effects of topical fluorides on oral bacteria

In addition to its direct mineralizing effect on enamel, fluoride may affect oral plaque bacteria.

Oral plaque bacteria secrete acids onto tooth surfaces (the byproducts of carbohydrate fermentation), which initiates tooth demineralization. The entry of fluoride into the bacterial cell interferes with acid production, thus reducing, potential enamel destruction. [14, 15, 16].

In addition, fluoride can prevent the attachment of microorganisms to the surface of the tooth. This effect is demonstrated, in particular, by fluorides of tin and amine. This can reduce formation of plaque that contributes to tooth decay.

Streptococci that cause caries bind glucan on tooth enamel surfaces by means of glucan-binding molecules called lectins. Fluoride interferes with this specific binding and thus inhibits bio-film formation by the streptococci that demineralize enamel. The fluoride ion also

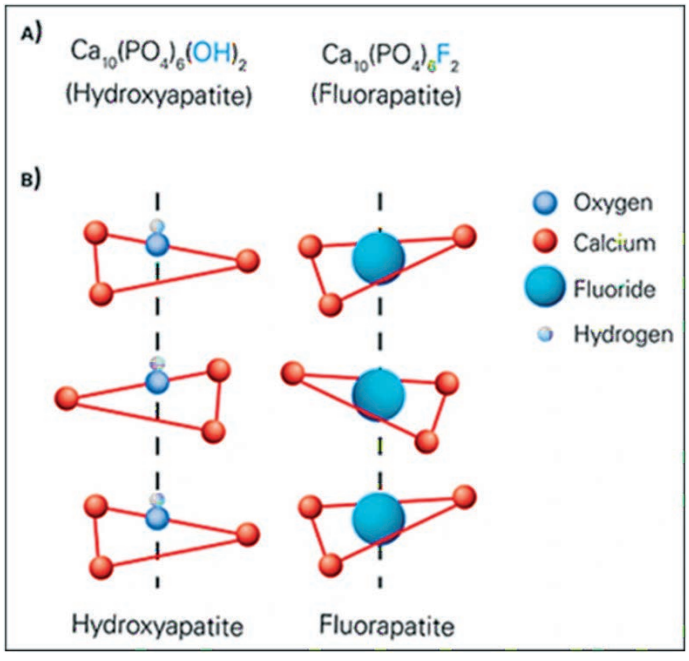

Fig. 1. Fluorapatite formation. (A) Fluoride ions (F^-) replace hydroxyl groups (OH^-) in hydroxyapatite to form fluorapatite in the tooth enamel.
(B) A portion of the apatite crystal lattice shows replacement of hydroxide for fluoride. (Adapted from: Posner, 1985.20).

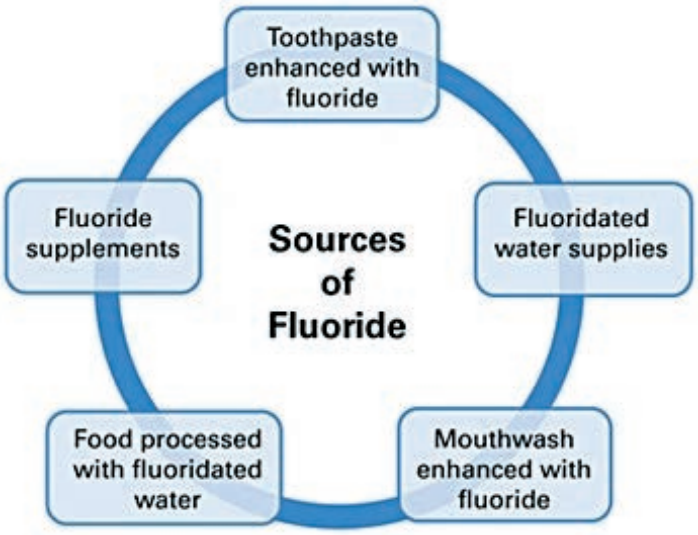

Fig. 2. Sources of fluoride in the environment.

inhibits chain formation (growth) in streptococci and effects physiological capabilities of the micro-organism to metabolize sucrose. However, these effects are manifested only in high fluoride concentrations, making the fluoride an expected process for caries reduction in remineralization [17].

In concentrations of fluoride administered orally via toothpastes or rinses, the clinical effect of inhibiting bacterial metabolism is insufficient to have an appreciable effect on caries development.

Systemic use of fluorides

The correct way to use fluorides is that the body ingests fluorides through the digestive tract and passes them through the gastrointestinal tract. The fluorides are absorbed into the blood circulation and then transferred to the tissues such as teeth and saliva to prevent caries. There are four main methods in the systemic use of fluorides, which are water fluoridation, salt fluoridation, milk fluoridation, and fluoride tablets.

Water Fluoridation. Fluorides are present naturally in all water sources. Community water fluoridation is the process of adjusting the fluoride content of fluoride-deficient water to the recommended level for optimal dental health, which is currently recommended at 0.7 parts fluoride per million parts water. Water fluoridation is an effective and inexpensive means of obtaining the fluoride necessary to prevent tooth decay.

Water fluoridation continues to be effective in reducing tooth decay by 20-40 % in children and adults, even in the era of widespread availability of fluoride from other sources, such as fluoride toothpaste [18, 19, 20].

Table 1 provides some of the fluoride salts that are commonly used for a 'systemic method'.

Local treatment with fluorides

Toothpaste with fluorides

Tooth brushing with fluoride toothpaste is close to an ideal public health method that is convenient, inexpensive, culturally approved, widespread and available [21, 22].

It is scientifically proven and substantiated that fluoride toothpaste has preventive effect of caries for people of all ages.

Table 1. Fluoride compounds and concentrations that are usually used in different 'systemic' fluoride methods (Source: Sampaio & Levy, 2011)

F-methods	F-compounds	F-concentrations
Water fluoridation	Hydrofluorosilicate (FSA), sodium fluorosilicate, sodium fluoride	0.7-1.2 mg/L
Salt fluoridation	Potassium fluoride, sodium fluoride	250-300 mg/kg
Milk fluoridation	Sodium fluoride or disodium monofluorophosphate	5 mg/L
Dietary	F-supplements sodium fluoride, acidulated phosphate fluoride, potassium fluoride, calcium fluoride	0.25-1.0 mg/day

The fluoride concentration of over-the-counter (OTC) toothpaste ranges from 1000 to 1100 mg/kg. This translates into 1 mg of fluoride in a 1-inch (1 g) strip of paste. Therefore, a pea-sized amount of toothpaste containing 1000 to 1100 mg/kg fluoride would have approximately 0.25 mg of fluoride. The use of fluoride toothpaste should begin with the eruption of the first tooth. For children younger than 3 years, the recommended amount is a smear or grain of rice size (approximately 0.1 mg of fluoride) (Table 2) [23].

Table 2. Recommended fluoride toothpastes for children

From Guidelines on the use of fluoride for caries prevention in children: an updated EAPD policy document

Age (years)	(mg/kg F)	Frequency	Amount (g)	Size
First tooth-up to 2 years	1000	Twice daily	0.125	Grain of rice
2-6 years	1000*	Twice daily	0.25	Pea
Over 6 years	1450	Twice daily	0.5–1.0	Up to full length of brush

*Note. *For children, 2-6 years old, 1000+ fluoride concentrations may be considered based on the individual risk of caries.*

Mouthwashes with fluoride

A new strategy developed for toothpastes can also be used to mouthwashes. A new generation of fluoride rinses is expected to contain soluble calcium salts that help retain fluoride in the mouth to release over time. The concept of including soluble calcium in the pre-rinse before a fluoride rinse is proved to increase the amount of fluoride in saliva almost fivefold 1 hour after the rinse compared to a rinse containing NaF at the same fluoride concentration [24, 25, 26].

Over-the-counter (OTC) fluoride rinse provides a lower concentration of sodium fluoride than toothpaste or varnish. The concentration is most commonly 230 mg/kg (0.05% sodium fluoride).

Fluoride varnish is a concentrated topical fluoride applied to the teeth that sets on contact with saliva. Advantages of this modality are that it is well tolerated by infants and young children, has a prolonged therapeutic effect, and can be applied by both dental and nondental health professionals in a variety of settings. The concentration of fluoride in varnish is 22 600 mg/kg (2.26 % fluoride ion), and the active ingredient is sodium fluoride.

There are cogent clinical data that prove anti-caries effectiveness of F-containing varnish. Recent studies have shown that F-containing varnish has long-term effectiveness in preventing caries. [27, 28].

The primary cariostatic effect of F-varnish is caused by the effect of fluoride on the chemical stability of the tooth mineral that converts the enamel to fluorapatite, which is much less susceptible to acid attack than the enamel. For prevention of caries of permanent teeth, it is recommended to use F-containing varnish with an interval of 6 months. For children not at risk of caries, F-varnish may not be useful; however, the risks of therapy are low and the benefits outweigh the risks [29].

Fluoride varnishes are not only effective from the point of view of primary prevention of caries development, but also have a positive effect in terms of secondary prevention in cases of already existing initial caries. At this point, regular use of fluoride varnish combined with regular oral hygiene can often stop caries (preventing further mineral loss) [30].

Side effects of Fluorides

Excessive exposure to Fluorides is associated with a number of health issues:

– Dental fluorosis.
– Skeletal fluorosis.
– Thyroid problems.
– Neurological problems.
– Other health problems.
– Fluoride poisoning.

There is a distinction between acute and chronic effects (Fig. 3).

Acute toxic effect as a result of swallowing a large amount of fluorine-containing oral care products, as well as by children, may cause at least a temporary manifestation of dizziness and nausea.

Infants and preschool children may suffer from enamel fluorosis, the risk of which increases with increased constant fluoride intake. Fluorosis can develop only at the stage of enamel formation; in other age groups, this side effect from the use of fluoride is nor provoked.

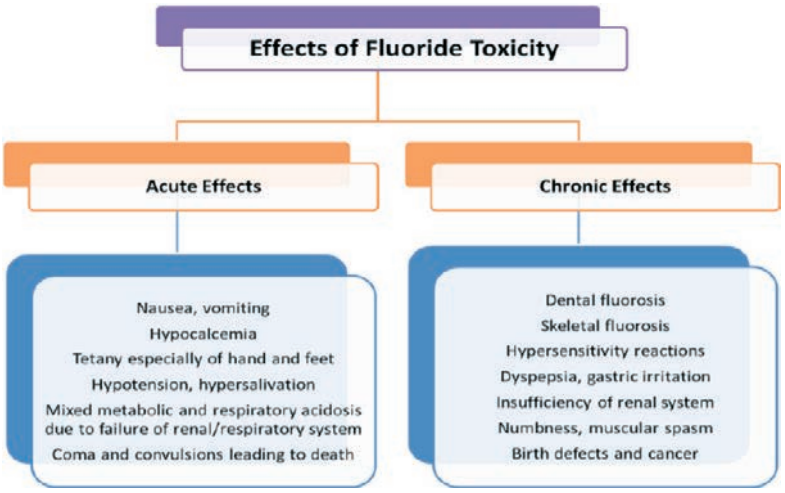

Fig. 3. Effects of fluoride toxicity.

Conclusions

Fluorides are regarded as effective materials for control of dental caries which can benefit both prevention and treatment. Topical application of fluorides is a key element in successful caries prevention.

Conflict of Interests

Authors declare no conflict of interest.

Authors' Contributions

Svitlana Boitsaniuk – investigation, formal analysis, writing – original draft; *Mariana Levkiv* – formal analysis, writing – reviewing and editing, data curation.

ФТОРИДИ І ЗДОРОВ'Я ПОРОЖНИНИ РОТА

С. І. Бойцанюк, *М. О. Левків

ТЕРНОПІЛЬСЬКИЙ НАЦІОНАЛЬНИЙ МЕДИЧНИЙ УНІВЕРСИТЕТ ІМЕНІ І. Я. ГОРБАЧЕВСЬКОГО МОЗ УКРАЇНИ, ТЕРНОПІЛЬ, УКРАЇНА.

Вступ. *У статті обговорюється важливість застосування фтору для профілактики карієсу та представлені практичні рекомендації щодо застосування препаратів фтору.*

Мета. *Основною метою цього систематичного огляду є оцінка доказів щодо порівняльної ефективності місцевої фторотерапії (МФП) у вигляді зубних паст, ополіскувачів, гелів та лаків у профілактиці карієсу зубів у дітей та підлітків.*

Методи. *Здійснено систематичний електронний пошук літератури в базах даних PubMed та Web of Science за пошуковими термінами. Розглянуто поточні повідомлення в літературі, які стосуються засобів та методів застосування фторвмісних препаратів.*

Результат. *Велика кількість наукових досліджень, оглядів на їх основі та метааналізів приходять до висновку, що центральним елементом профілактики карієсу, на якому ґрунтується це зниження поширеності карієсу та досвіду розвитку карієсу, є регулярне місцеве застосування препаратів фтору в порожнині рота.*

Висновок. *Місцеве застосування фторидів є ключовим елементом успішної профілактики карієсу.*

КЛЮЧОВІ СЛОВА: **профілактика карієсу; фтор; механізм дії; побічні ефекти фтору.**

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