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Individualised caries prevention with fluoride in children and adolescents – recommendations of Polish experts

Keywords

children, adolescents, fluoride prophylaxis

Summary

In addition to proper diet, the use of fluoride is the primary and effective method for the prevention of dental caries in primary and permanent dentition. Knowledge and compliance with the current guidelines for the use of different strategies and agents containing fluoride compounds is crucial for ensuring safety and efficacy of prevention.

A panel of experts in paediatric dentistry and paediatrics was established as part of the working group of the Polish Branch of Alliance for a Cavity-Free Future (ACFF) to update the position on individual fluoride prevention in children and adolescents in Poland.

We conducted a literature review on the knowledge of fluoride prevention, its use in the paediatric population in Poland, efficacy and safety of fluoride-containing preventive agents, as well as recommendations on fluoride prophylaxis issued by academic organisations and societies in different countries worldwide. The first version of the document was discussed and accepted by the panel of experts on paediatrics and paediatric dentistry on the 4th of April 2019. Update was scheduled for not later than 5 years after publication.

This document includes basic data on the knowledge of fluoride prevention in parents, children and adolescents, the anticariogenic mechanism of fluoride, the safety and efficacy of different methods for individual fluoride prophylaxis, and the principles for its use depending on age and the risk of caries.

Introduction

Proper nutrition, oral hygiene and prophylactic agents containing fluorides are the key elements in the prevention of carious disease. Fluorides are used in mass, group and individual prevention. The World Health Organisation and the World Dental Federation recommend their preventive use, emphasising their efficacy and safety. At the same time, they point to the need to monitor the exposure and to assess their efficacy (1-3).

Individual fluoride prevention may take the following forms:

- oral (tablets or drops) – an endogenous method (supplementation) to improve mineralisation of the developing hard dental tissues,
- external – an exogenous method involving topical application on erupted teeth.

Toothpastes, mouthwashes, foams, gels and varnishes contain different levels of fluoride. They can be used either in a home setting (home prevention) or in a dental office (professional prevention). Caries prevention with fluoride is safe and effective only when the principles of individual preventive method selection are followed, considering exposure to fluoride from other sources, child's age and the risk of caries. According to a survey conducted in 2014 in Poland, 14.0% of dentists do not estimate the risk of caries before selecting preventive strategy. More than a half of respondents believed that fluoride prevention should be used in all patients, 38.9% claimed that it should be used at a high risk of caries and irrespective of age, and 21.3% responded that fluoride should be used only for primary and mixed dentition (4).

It should be emphasised that the basic caries prevention in Poland may be provided as part of public health service (List of general dental benefits for children and adolescents under the age of 18 years as well as List of dental benefits for children older than 6 months of age up to the age of 19 years in the form of 13 age-tailored packages of preventive treatments).

In 2013 and 2015, statements of the Independent Expert Panel on individual caries prevention were published (5, 6). Due to the disseminated false information about harmful effects of fluoride prophylaxis and, at the

same time, new studies on the safety and efficacy of fluoride-containing preventive agents, an update of this document is needed.

Methodology

The working group of The Alliance for a Cavity-Free Future (ACFF) conducted a review of current literature on dental preventive needs of children and adolescents in Poland; the mechanisms of action, efficacy and safety of fluoride compounds in caries prevention in this group of patients, as well as an analysis of recommendations for caries prevention developed by academic societies, such as: American Academy of Paediatric Dentistry (AAPD), European Academy of Paediatric Dentistry (EAPD), American Dental Association (ADA), and World Dental Federation (FDI) (1, 2, 7-9). The obtained data were the basis for the document discussed and approved on the 4th April 2019 by a panel of experts composed of the representatives of the Polish Society of Paediatric Dentistry, Section of Paediatric Dentistry of the Polish Dental Society, and national consultants in the field of paediatric dentistry and paediatrics. The document will be updated not later than 5 years after publication.

Results

Dental caries prevention needs in Polish children

The need for dental caries prevention among Polish children has been confirmed by epidemiological studies conducted since 1987 in collaboration with the World Health Organisation (6-9). Current monitoring studies indicate a 2.5-fold (1.85 to 4.66) increase in the mean number of carious teeth and about 40%-increase (41.1 to 81.9%) in the incidence of caries in children aged 3-6 years. Caries affects about 3.75 teeth in 12-year-olds, and this number increases by 1.08 after 3 years (4.88 at the age of 15 years), and by 1.62 after further 3 years (reaching 6.50 at the age of 18 years) (10-12). The presence of caries in the erupting first permanent molars is alarming: it is found in 8 5-year-olds, 19 6-year-olds and 59 7-year-olds per 100 children examined. When considering the trends in carious disease among 12-year-olds within 27 years (1987-2016), a slight decrease in the frequency (from 89.9 to 85.4%) and severity (4.4 to 3.75) of caries, with significant fluctuations in this period) was observed (10-12).

Recent epidemiological studies have also shown that fluoride prophylaxis is underused among Polish children, it is introduced late and that parental knowledge on the principles of its use is insufficient (10-13).

In 2017, only one in two 3-year-olds had their teeth brushed at least twice daily, 36.4% had their teeth brushed once daily, and 8.8% – only 1-3 times weekly. Unfortunately, one in five parents had no knowledge on whether their child's toothpaste contained fluoride, and 27.5% parents admitted that they used fluoride-free toothpaste. Excessive amount of toothpaste was used in one in three 3-year-olds and only one in three children had their teeth brushed by an adult. Fluoride varnish was used in only 10.7% of children (11). Similarly, many adolescents are uncertain whether their toothpaste contains fluoride. The lack of this knowledge was reported for 43.0% of 12-year-olds (2016), 44.7% of 15-year-olds (2018) and 52.1% of 18-year-olds (2017) (10-12). Nearly half of 12- and 18-year-olds were unaware that the use of fluoride-containing preventive agents helps prevent dental caries and that there are fluoride-containing agents other than toothpastes (10, 12).

Long-term observational studies showed that the level of caries is related to fluoride levels in drinking water. It is estimated, based on more than 100 studies conducted in 23 countries before 1990 that caries reduction due to water fluoridation is 40-50% for primary teeth and 50-60% for permanent teeth. A review of studies conducted between 1990 and 2000 indicates caries reduction of 30-59% for primary teeth and 40-49% for permanent teeth (3). Optimal fluoride level in drinking water for dental protection is estimated at about 0.7 mg/L (0.5-1 mg/L) (3). According to the World Health Organisation, the level should not exceed 1.5 mg F/L. In many regions of the world with trace or low fluoride levels in water, optimal cariostatic levels of fluoride compounds are added to water. It was demonstrated that water fluoridation is an effective and safe method for the prevention of dental caries in both children and adolescents. It was also found that the benefits of water fluoridation for the reduction of caries significantly outweigh potential adverse aesthetic effects, i.e. very mild to mild dental fluorosis. Salt or milk fluoridation is practiced in many regions of the world (e.g. Germany, Switzerland, France, Latin America) (2, 3).

In Europe, artificially fluoridated water is used by 71% of Irish people, 10% of people in Great Britain and Spain, and 3% of people in Serbia, 75% of Americans, 70% of Australians, about 50% of people in New Zealand and 38.7% of Canadians (14).

The majority of people in Poland use water with fluoride content below 0.5 mg/L, i.e. the lower range value recommended by the WHO (1994). Data on fluoride content in drinking water, which were collected based on the current literature, are shown in figure 1 (15-17).

The cited epidemiological data and data on the exposure of Polish society to fluoride in drinking water emphasise the need for enhanced preventive and educational measures focused on the safety, principles and efficacy of fluoride prophylaxis among parents, children and adolescents in Poland. It is also important to involve not only dental personnel, but also medical professionals, class tutors and teachers in these activities. A comparative analysis of questionnaire studies among primary teachers in the years

Fig. 1. Fluoride levels in drinking water in selected Polish cities based on current literature (15-17)

2008 and 2018 showed a lower proportion of respondents who considered fluoride prophylaxis as beneficial (74.5 to 53.6%) (12).

Epidemiological studies have further shown polarisation of dental caries, i.e. the presence of persons with high dental caries rates even when the mean rates are generally low. It therefore seems reasonable to identify high-risk individuals and implement intensive, individualised prevention in this group of patients.

The risk of caries and fluoride prevention

The choice of preventive strategy and the type of fluoride products depends on multiple factors, including age, general health condition, preventive and therapeutic needs, caries risk level, exposure to fluoride from other sources, as well as parental engagement and possibilities. Caries prevention based on the assessment of caries risk level involves the intensification of prevention when the risk increases. Risk estimation is needed before developing an individualised preventive plan.

The risk of caries is understood as the likelihood of new carious lesions and progression of already existing ones in the future. According to the concept of dynamic balance between demineralisation and remineralisation, caries risk estimation is based on the relationship between factors considered to be preventive, i.e. which promote remineralisation (use of fluoride, antibacterial agents and fissure sealants, proper dietary habits, normal salivary flow) and caries indicators (presence of incipient caries in the form of white spots, enamel defects promoting plaque retention, number of fillings placed before 3 years of age) and risk factors for dental caries (the presence of cariogenic bacteria, reduced salivary flow, improper dietary habits), which promote demineralisation (18-20).

There are several tools for caries risk assessment. The American Academy of Pediatric Dentistry (AAPD) proposed the CRA system (Caries Risk Assessment), which consists of three tools for caries risk evaluation, including two to be used by dental practitioners: for children aged 0-5 and > 6 years, and one to be used by non-dental medical professionals for children aged 0-3 years (20). CRA is easily applicable in the clinical practice and enables caries risk evaluation (low, moderate or high). However, it requires a community interview, general medical and dental examination and is largely based on the doctor's knowledge and clinical experience. The use of risk assessment systems additionally increases the awareness of patients and their parents/legal guardians of the causes of carious disease and helps develop medical recommendations.

Cariostatic mechanisms of fluoride

There is ample evidence confirming that fluoride compounds are effective for caries prevention and non-invasive treatment of incipient caries.

Endogenous oral administration of an optimal fluoride dose during tooth development increases fluoride content in the superficial enamel layer, allowing for a stable apatite crystalline structure to be formed. Fluoride has an impact on primary mineralisation of the organic matrix and pre-eruptive enamel maturation. It catalyses a reaction that produces hydroxyapatite, $Ca_{10}(PO_4)_6(OH)_2$. By replacing hydroxyl ions (OH^-), it forms fluoridated hydroxyapatite, $Ca_5(PO_4)_3OH_1$-xFx. It promotes the formation of larger apatite crystals with lower carbonate content. Fluoride is also involved in pre-eruptive enamel maturation, which involves water and protein removal from the primary enamel (21).

Until recently, it was believed that lower susceptibility of enamel to acids is an effect of pre-eruptive fluoride action. However, fluoride content of enamel has no significant effects on the risk of caries. Furthermore, its excess intake may lead to dental fluorosis (3, 21-23). It therefore seems that exogenous effects of fluoride, which ensure systematic delivery of small amounts of fluoride into the oral cavity after tooth eruption, are more important.

The post-eruptive anticariogenic action of fluoride involves:

1. Limiting the effects of cariogenic bacteria by:
   - reduced acid production,
   - reduced plaque deposition on tooth surfaces (by disturbing the synthesis of extracellular bacterial polysaccharides),
   - inhibiting bacterial carbohydrate metabolism (e.g. by reducing enolase activity, impairing glucose transport into cells, and impairing the formation of intracellular storage polysaccharides).

2. Supporting remineralisation (fluoride ions attract calcium and phosphates – new dental mineral is formed; the presence of very low F levels (> 0.03 ppm) in the dental environment, which are maintained (at 0.03-0.10 ppm) for several hours after the use of fluoridated toothpaste, are sufficient for increased remineralisation) and inhibiting demineralisation (formation of fluorapatite/ fluorohydroxyapatite which is more resistant to acid damage).

Teeth are composed of hydroxyapatite and carbonate apatite, which shows higher solubility in acids. Partially demineralised carbonate apatite crystals become nucleators to which fluoride ions are absorbed, attracting calcium and phosphate ions. As a result, a fluorapatite-like coating (without carbonate ions) is formed, making the crystal more resistant to dissolution in acids.

After application of products with fluoride content < 50 ppm with acidic or neutral pH (slower formation), fluorohydroxyapatite is formed. Preparations with fluoride content > 100 ppm at acidic pH or > 300 ppm F at neutral pH ensure formation of calcium fluoride (formed with calcium from previously dissolved enamel) which is a reservoir of fluoride ions released during bacterial acid attacks (fig. 2 and 3) (21, 24, 25).

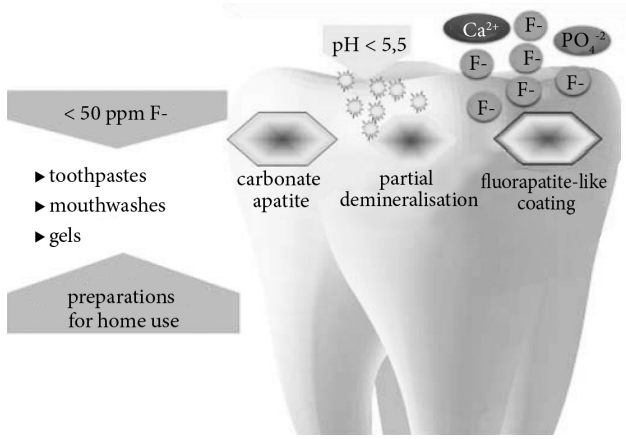

Fig. 2. Formation of more acid-resistant fluorohydroxyapatite with fluorapatite-like coating at low fluoride ion levels in the oral cavity

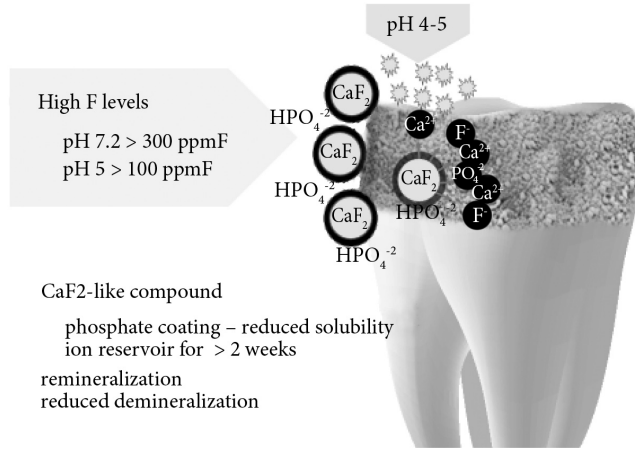

Fig. 3. Formation of calcium fluoride at high fluoride ion levels in the oral cavity

Safety of fluoride use in children

Fluoride should be used carefully and reasonably due to its high cytotoxicity and a very narrow margin between its toxic and therapeutic doses. Neglecting the principles of fluoride caries prevention is a risk factor for acute and chronic poisoning. The WHO underlined the role of fluoride exposure monitoring to assess the balance in the severity of dental caries in children at risk of dental fluorosis resulting from the accumulation of fluoride from various sources. FDI recommends the development of health policies individually for a given country and advises monitoring of the efficacy of caries prevention (1-3).

The risk of dental fluorosis depends not only on fluoride exposure, but also on individual fluoride sensitivity in a given population. That is why mild fluorosis may be observed also in areas where fluoride content in drinking water is within a range considered optimal, i.e. 0.5-1.0 mg/L (3, 22, 23, 26, 27, WHO 1994).

It is assumed that fluorosis is caused by the accumulation of fluoride doses from various sources (e.g. bottled water, tea, fish products, imported food produced in areas with fluoridated water). Excessive fluoride exposure during the so-called critical developmental period, i.e. between 15 and 30 months of age, can cause fluorosis of permanent anterior teeth and first molars, whereas other teeth may be affected at a later age (up to 6 years of age). Fluorosis may be caused by:

- preparation of infant formula using water with high fluoride concentrations (fluoride content in bottled water in Poland ranges from 0.1 to 1.39 mg F/L) (28),
- improper fluoride supplementation (other dietary components should be considered when establishing indications for this type of prophylaxis for a child) (29, 30),
- ingestion of preventive agents that are incorrectly used in children, e.g. applying too much toothpaste on a toothbrush and using products for home prevention with very high fluoride content (31).

The estimated daily intake of dietary and toothpaste fluoride (without fluoride supplementation) for 2-year-olds at fluoride content in drinking water of 1 mg/L vs. fluoride-free water is 0.069 mg F/kg body weight and 0.046 mg F/kg body weight, respectively (tab. 1) (32).

Fluoride content in the diets of 1-4 year olds in 16 cities located in different regions of Poland with its drinking water levels of 0.09-0.32 ppm F was estimated at 0.04 to 0.42 mg/kg (mean level 0.15 ± 0.07 mg/kg), regardless of the season. Daily fluoride intake by a child at this age was estimated at 0.28 (0.09-0.82 mg) (17). Total men fluoride intake with food and toothpaste in children will therefore not exceed the appropriate daily intake, i.e. 0.7 mg F/day for 1-3 year olds (tab. 2).

Considering both safety and efficacy of fluoride prophylaxis, academic societies, including EAPD, AAPD, ADA and FDI, developed evidence-based standards for fluoride usage in children (1, 2, 7-9). The following aspects were considered when developing the recommendations:

- possible daily fluoride intake including its water, food and preventive agents,
- daily adequate intake (AI) of fluoride (tab. 2),
- upper intake level (UL) of fluoride that causes no observed adverse effects in the form of dental fluorosis (no-observed-adverse-effect-level).

Based on the correlations between fluoride intake and the occurrence and severity of fluorosis, it has been estimated that moderate fluorosis occurs at an intake of 0.1 mg F/kg body weight daily in less than 5% of the population (tab. 2) (33, 34).

The currently acknowledged principles of caries prevention with fluoride are to avoid excessive endogenous fluoride exposure and intensify preventive measures depending on the level of caries risk. Excessive (over-optimal) endogenous intake of fluoride in the period of the risk of fluorosis should be avoided, particularly in children below 6 years of age, by:

- limiting the amount of toothpaste with 1,000 ppm F (0.1% F) and using it in children under the age of 8 years under parental supervision, as well as using

Tab. 1. Estimated daily intake of dietary and toothpaste fluoride in 2-year-olds, including fluoride supplementation (32)

	Estimated daily intake (range) mg F/kg BW	
Drinking water fluoride mg/L (ppm)	1 ppm	0 ppm
Diet (including water and beverages)	0.046 (0.038-0.046)	0.023 (0.015-0.023)
Toothpaste 1000 ppm F	0.023 (0-0.154)	0.023 (0-0.154)
Total	0.069 (0.038-0.20)	0.046 (0.015-0.177)
Fluoride supplementation	–	0.038
Including fluoride supplementation	0.069 (0.038-0.20)	0.084 (0.054-0.215)

Tab. 2. Adequate intake and upper intake level depending on child's age (33, 34)

Age	**Adequate fluoride intake (AI) in mg/day (AI)**	**Upper intake level of fluoride in mg/day (UL)**
0-6 months	0.01	0.7
6-12 months	0.5	0.9
1-3 years	0.7	1.3
4-8 years	1.0	2.2
9-13 years	2.0	–
14-18 years	3.0	–

toothpastes containing 5,000 ppm F (0.5% F) from the age of 16 years as recommend by a dentist,
- introducing fluoride mouthwashes, gels and foams after the age of 6 years (fluoride varnishes can be used with no age restriction),
- restricted use of endogenous caries prevention methods (7-9, 35-37).

Dental fluorosis is a developmental disorder manifesting with hypomineralisation (porosity) caused by excessive fluoride exposure during amelogenesis (mainly in the phase of matrix formation, secretion and maturation). Mild fluorosis is manifested by white, linear opacities usually on the incisive edges or cusp apices. The mildest forms may be indistinguishable on dental surfaces without previous drying. Mild-to-moderate fluorosis is characterised by a lower susceptibility to caries (3, 27, 34, 38). Severe dental fluorosis is observed in regions with high fluoride content in drinking water (> 2 ppm F). There is no evidence indicating that the use of fluoride toothpastes at the age of 12 or 15 months increases the risk of fluorosis compared to children who start using fluorinated toothpaste at a later age (39). Also, there is no scientific evidence for the impact of cariostatic fluoride doses on an increased incidence of osteosarcoma, increased symptoms of neurotoxicity, reduced intelligent quotient (IQ), thyroid diseases, kidney diseases, Down syndrome, haematological cancers, atherosclerosis or hypertension (26, 27, 40). There is no evidence suggesting that fluoride prevention used in accordance with the guidelines poses any risk for patients with kidney diseases (41).

Principles of individual caries prevention for children and adolescents in Poland

Children at a low risk of caries should receive basic caries prevention: tooth brushing twice daily using fluoride toothpaste, effective plaque removal, and cariostatic diet (7-9, 35-37). Moderate-to-high risk of caries is an indication for "enhanced caries prevention", both at home and dental office setting.

Endogenous caries prevention

Strong evidence to support the efficacy of fluoride supplementation in the prevention of primary teeth caries is missing. Its use in children aged 6-16 years causes a 24% reduction in the severity of caries in permanent teeth (42).

Fluoride supplementation can be used in children at a moderate risk. It is contraindicated in children at low risk of dental caries. Before recommending fluoride supplementation, it is necessary to assess potential sources of fluoride, as well as the quality of cooperation with parents/guardians since administering tablets must be strictly and systematically supervised on a long-term basis (22, 23).

Sucking or chewing fluoride tablets before swallowing is beneficial since it provides an additional topical cariostatic action of fluoride (8, 9). The EAPD does not recommend fluoride tablets or drops for children younger than 2 years of age if drinking water contains < 0.3 mg of F/L; for levels 0.3-0.6 mg F/L, it is not recommended for children up to 3 years of age who use fluorinated toothpaste, whereas a dose reduced by a half to 0.25 mg F is recommended for older children. According to the AAPD and APA, fluoride supplementation may be considered in children over 6 months of age if water fluoride content is < 0.3 mg/L and the risk of dental caries is moderate-to--high, but only if the parents are engaged and cooperative (7, 9, 37).

A team of Polish experts recommend that endogenous supplementation should be considered in children over 3 year of age who are at a high risk of caries (tab. 3) when drinking water fluoride is content below 0.3 mg/L. This method is contraindicated below the age of 3 years and in young children who systematically brush their teeth twice daily using fluoride toothpaste, regardless of water fluoride content.

Fluoride supplementation should be considered in children with asthma if there are contraindications to topical fluoride agents and in mentally disabled children (42, 43).

Approaches of different academic societies to fluoride supplementation are summarised in table 4.

Exogenous (topical) fluoride caries prevention

Home prevention

The use of toothpaste containing fluorine compounds, alone or in combination with water fluoridation, was considered one of the greatest public health achievements in the world. The World Dental Federation (FDI) calls all countries to provide universal access to fluoride toothpaste to combat dental caries and improve oral and general health (2).

Brushing teeth twice daily with fluoride toothpaste, in the morning and in the evening after the last

Tab. 3. Dosage of fluoride tablets and drops proposed by the Team of Polish Experts

Age	Recommended daily fluoride dose [mg]
0-35 months	0
3-6 years	0.25
7-16 years	0.5

Tab. 4. Approaches to fluoride supplementation of various organisations and academic societies worldwide

Organisation	Recommendations
AAPD (American Academy of Pediatric Dentistry)	Risk of caries and water fluoride content below 0.6 ppm F; additional dietary fluoride sources should be considered
ARCPOH (Australian Research Center for Population Oral Health)	No supplementation is recommended
EAPD (European Academy of Paediatric Dentistry)	High risk of dental caries, doses depending on age and water fluoride content
NZGG (New Zealand Guidelines Group)	Risk of caries in children > 3 years
Public Health England	Not recommended. Instead, tooth brushing twice daily using toothpaste containing 1000 ppm F or more
SIGN (Scottish Intercollegiate Guidelines Network)	"Sufficient evidence to recommend is missing as opposed to fluoridated toothpastes"
WHO (World Health Organization)	Depending on age and water F content (< 0.3 ppm, half of the dose for water fluoride content of 0.3-0.5 ppm)

meal (immediately before bedtime), is the basic method for the prevention of carious disease. This practice should be initiated as soon as the first tooth appears in the oral cavity, regardless of the risk of caries. Children under the age of 8 years should have their teeth brushed by parents/legal guardians. Also, an adequate amount of toothpaste should be applied to the toothbrush. Older children should be supervised by an adult when brushing their teeth.

An unsupervised child is likely to apply and swallow an excessive amount of toothpaste (fig. 4), as well as to ineffectively remove dental plaque (biofilm) due to the lack of manual skills. Tooth brushing with fluoride toothpaste is the only form of home prevention for children below 6 years of age. For older children and adolescents, especially those at an increased risk of dental caries, home prevention may additionally involve the use of a mouthwash containing 225 to 900 ppm F, while adolescents aged > 16 years may use toothpaste with high fluoride content (5,000 ppm F) (7, 8 35, 36).

For anticaries action of fluoride toothpaste to be increased, excess toothpaste should be spat out instead of rinsing with water. Parents and legal guardians should be instructed on the adequate amount of toothpaste applied on a toothbrush. According to surveys conducted in Poland, excessive amounts of toothpaste are applied by 80% of parents of children younger than 2 years and 75% of parents of 2-6 year olds. Furthermore, parents

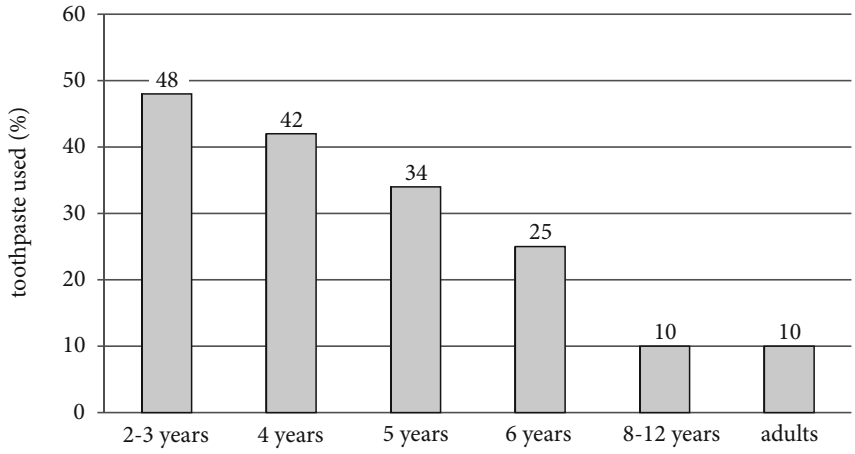

Fig. 4. Amount of swallowed toothpaste during tooth brushing depending on age (44)

do not adjust the amount of toothpaste depending on fluoride content (45).

Toothpastes containing 1,000 ppm F and more have been demonstrated to show preventive efficacy.

Caries reduction ranges from 19 to 27% for toothpastes containing 1,000-1,250 ppm F, 27 to 44% for toothpastes containing 2,400-2,800 ppm F, and 40 to 50% for toothpastes containing 5,000 ppm F. The efficacy of toothpastes containing 440/500/550 ppm F has not been confirmed (46).

An optimal dose of fluoride is 0.05 mg/kg body weight daily. When using a pea-sized amount of toothpaste instead of a smear, the potential amount of fluoride delivered to children more than doubles. A 2-year-old child weighing 15 kg, who brushes the teeth twice daily with a smear of toothpaste and swallows the entire amount, receives 0.2 mg F, which constitutes a dose of 0.013 mg/kg body weight. If the same child brushes the teeth twice daily with a pea-sized amount of toothpaste and swallows the entire amount, he or she receives 0.5 mg F which makes up a dose of 0.033 mg F/kg body weight (tab. 5). Children also receive fluoride in foods and beverages. Considering additional potential sources of fluoride and the risk of fluorosis during tooth development, the ADA and FDI recommend using a smear of toothpaste (1,000 ppm F) from the first tooth up to the age of 3 years, followed by a pea-sized amount at 3-6 years of age. This is aimed to maximise the benefits of caries prevention and reduce the risk of fluorosis compared with the previous recommendations which stated that a pea-sized amount of fluoride toothpaste should be used from the age of 2 years (36, 47).

Before using fluoride toothpaste in children < 2 years of age, the ADA recommends consultation with a dentist. Different opinions on the use of toothpastes in children are presented in table 6. The current guidelines of FDI, which are also recommended by Polish Experts, concerning the usage of fluoride toothpaste in areas where drinking water contains ≤ 1 mg F/L are presented in table 7.

High fluoride toothpaste contains 2,800 and 5,000 ppm F. Toothpastes with 1.1% of fluoride in the form of sodium fluoride, i.e. 5,000 ppm F or 0.5% F (5 mg F/g), are available in Poland. High fluoride concentrations in toothpaste increase oral fluoride levels compared to conventional fluoride toothpastes, which contributes to reduced demineralisation and increased remineralisation processes, resulting in a clinically proven cariostatic effect. These products are recommended for home use in children older than 16 years of age with a high risk of caries, who require intensive prevention with fluoride, including:

- patients with fixed braces,
- patients at a high risk of caries in whom previous oral hygiene was insufficient,
- incipient caries within the crowns and roots despite everyday regular usage of standard fluoride toothpastes,
- exposed dentine after scaling and other dental procedures,
- in patients with xerostomia (36).

Their use ensures increased fluoride delivery without the need to change everyday hygiene practices. Toothpastes with high fluoride content should be used every day, twice or three times daily for at least 3-6 months instead of conventional fluoride toothpaste. The amount to be applied to a toothbrush is a 2 cm long band.

Studies assessing toothpastes with 5,000 ppm F have shown their beneficial effects on teeth. For instance, it was confirmed that carious lesions are remineralised after 2 weeks of usage, enamel mineral loss is reduced and that the toothpaste has beneficial effects on enamel in patients with fixed braces (48, 49). According to Nordström, using toothpastes with 5,000 ppm F without

Tab. 5. Evidence for safety of fluoride toothpastes (36)

Age	Amount of 1,000 ppm F toothpaste	Amount of fluoride delivered at singe use	Amount of F delivered with toothpaste when brushing teeth twice daily	Body weight (kg)	Daily F dose delivered with toothpaste (brushing twice daily)	Adequate F intake per body mass 0.05 mg/kg/day
6 months	Smear (0.1 g)	0.1 mg	0.2 mg	6	0.033 mg/kg	< 0.05 F/kg/day
12 months	Smear (0.1 g)	0.1 g	0.2 mg	10	0.02 mg/kg	< 0.05 F/kg/day
2 years	Smear (0.1 g)	0.1 g	0.2 mg	15	0.013 mg F/kg	< 0.05 F/kg/day
2 years	Pea-sized (0.25 g)	0.25 mg	0.50 mg	15	0.033 mg/kg	< 0.05 F/kg/day

Tab. 6. Opinions of different academic societies and organisations on the use of toothpastes in children

Organisation	Recommendations
AAPD (American Academy of Pediatric Dentistry)	– < 3 years, not more than a smear/a grain of rice – 3-6 years, not more than a pea-sized amount – no recommendations on toothpaste fluoride content
ARCPOH (Australian Research Center for Population Oral Health)	– fluoride toothpaste not recommended below the age of 18 months – 18 months-6 years, toothpaste with 500-550 ppm F – > 6 years, toothpaste with 1,000-1,500 ppm F, spitting out the toothpaste after brushing instead of rinsing – risk of caries, non-fluoridated water, toothpaste containing > 1500 ppm F
EAPD (European Academy of Paediatric Dentistry)	– < 24 months, 500 ppm F, pea-sized amount, twice daily – 2-6 years, 1000 ppm F, pea-sized amount, 2 twice daily – > 6 years, 1450 ppm F, 1 cm band
NZGG (New Zealand Guidelines Group)	– 1000 ppm F regardless of child's age – < 6 years, smear – > 6 years, pea-sized amount
Public Health England	– < 3 years, up to 1,000 ppm F, smear – 3-6 years, up to 1,000 ppm F, pea-sized amount – 0-6 years, high risk,1,350–1,500 ppm F – ≥ 7 years,1,350–1,500 ppm F – 10-16 years, high risk, 2,800 ppm F – ≥ 16 years, high risk, 5,000 ppm F
SIGN (Scottish Intercollegiate Guidelines Network)	– < 18 years, 1,000-1,500 ppm F – high risk: < 10 years, high risk, 1500 ppm F; 10-15 years 2800 ppm F; ≥ 16 years, high risk, 2800 ppm F or 5000 ppm F
WHO (World Health Organization)	– toothpastes with 500 ppm F are ineffective; A 6% increase in caries reduction is obse-rved for 1,000 ppm F vs 500 ppm F toothpaste

Tab. 7. FDI guidelines on the use of fluoride toothpastes, depending on the risk of dental caries

Age (years)	Toothpaste amount		F content in toothpaste (ppm F)	
			Risk of caries	
			low	High
0.5-3	grain of rice		1,000	
3-6	pea-sized		1,000	1,450
6-10	half/full length of toothbrush		1,000-1500	1,500
10-12			1,500	2,800*
12-16			1,500	2,800*
16-18			1,500	5,000
> 18			1,500	5,000

*toothpastes not available in Poland, toothpastes up to 1500 ppm F are recommended

rinsing the oral cavity with water after brushing doubles the salivary levels of fluoride and reduces plaque deposition compared to toothpastes containing 1,450 ppm F (49). For 14-16-year-old adolescents with active caries, the use of 5,000 ppm F toothpastes results in a slower progression of caries (by 40%) compared to conventional toothpastes (49).

Anticariogenic protection is also enhanced by using fluoride mouthwashes. Their preventive efficacy is estimated at about 26% (50, 51). Studies have shown that mouthwashes with higher fluoride content remineralise incipient caries more effectively (52, 53). Fluoride mouthwashes are recommended for children older than 6 years of age with a moderate-to-high risk of caries (tab. 8) (50, 51, 54, 55). They are particularly recommended in children with fixed braces, prosthetic appliances or with reduced salivary flow (56). There are no uniform guidelines as to their use with respect to tooth brushing. A mouthwash containing at least 100 ppm F used after brushing allows appropriate levels of fluoride ions delivered with fluoride toothpaste to be maintained in the saliva and dental plaque. It also increases the efficacy of cleaning interproximal spaces. Fluoride mouthwashes can be used after brushing or on other occasions, providing additional health benefits. It is recommended to use approximately 10 mL of mouthwash. Mouthwashes containing approximately 100 ppm F are to be used at least twice daily, those containing 225 ppm F – once daily, and those containing 900 ppm F – once a week. Mouthwash use by children should be supervised by parents until they are assured that the product is not swallowed (57-59).

Professional prevention

Professional prevention with fluoride is used in children at an increased risk of dental caries. Gels, foams and varnishes should be used in a dental office setting. The recommendations of Polish experts on the use of fluoride products in children at a higher risk of caries are presented in table 8. ADA recommendations are summarised in tables 9 and 10 (36). Gels/foams or varnishes should be applied twice a year at a moderate risk of caries and 4 times a year at a high risk of caries.

The efficacy of fluoride gels in reducing dental caries of permanent teeth was estimated at 28%. Most researchers evaluated gels containing acidified fluorophosphate or amine fluorides. The efficacy of fluoride varnishes with 5% NaF (22,600 ppm F) is approximately 33% for primary teeth and 46% for permanent teeth (51, 54, 60). Only 3 studies conducted in China assessed fluoride foams, showing their efficacy of 24% for primary teeth and 41% for the smooth surfaces of first permanent molars (weak scientific evidence) (54).

Due to the risk of swallowing, gels and foams can be used only in children older than 6 years of age. During the procedure, an individual application tray with an adequate amount of the product (2-4 mL or approximately 40% of tray's volume) and saliva ejector should be used. The child should be positioned with the head tilted forward and should spit out saliva for 30 seconds after application. The product should be applied for 4 minutes (8, 60). The patient should refrain from eating and drinking for 30 minutes after application. In the case of foam, an amount corresponding to 1/5 of gel mass is sufficient for covering the teeth (54).

The use of varnishes is not age-restricted (tab. 8) (61-64). However, recommended doses should be used. Single doses of fluoride varnish containing 5% NaF (22,600 ppm F) are: 0.10 mL for infants, 0.25 mL for children older than 1 year and with primary teeth, 0.40 mL for children with mixed dentition, and 0.50 mL for those with permanent teeth. Application of 0.5 mL of 5% NaF varnish delivers 3-11 mg of fluoride (toxic dose is probably 5 mg/kg body weight). Fluoride varnish is the most concentrated fluoride product used in Europe, and contains almost twice as much fluoride as the APF gel, but poses no health risk. It was demonstrated that the maximum plasma fluoride concentration after application of

Tab. 8. Recommendations of Polish experts on the use of gels/foams, varnishes and mouthwashes

Age	Risk of caries	Mouthwash	Gel/foam	Varnish*
Children younger than 6 years of age	moderate	no	no	twice a year*
	high	no	no	4 times a year*
Children older than 6 years of age and adolescents*	moderate	yes	twice a year*	twice a year*
	high	yes	4 times a year*	4 times a year*

*gels/foams or varnishes

Tab. 9. ADA recommendations on the use of fluoride products in children at an increased risk of caries (36)

	Professional application (dental office)		Use at home	
Age	**Recommended**	**NOT recommended**	**Recommended**	**NOT recommended**
≤ 6 years	– 2.26% fluoride varnish (22,600 ppm F) at least every 3 or 6 months	– 0.1% fluoride varnish (1,000 ppm F) – 1.23% fluoride foam (APF)		– 0.09% mouthwash (900 ppm F) at least once a week or – 0.5% gel or fluoride toothpaste (5,000 ppm F) twice daily
6-18 years	– 2.26% fluoride varnish (22,600 ppm F) at least every 3 or 6 months or – 1.23% acidulated fluoride gel (APF*) (12,300 ppm F) for 4 minutes at least every 3 or 6 months	– 0.1% fluoride varnish (1,000 ppm F) – 1.23% fluoride foam (APF) (12,300 ppm F)	– 0.09% mouthwash (900 ppm F) at least once a week or – 0.5% gel or fluoride toothpaste (5,000 ppm F) twice daily	
> 18 years	– 2.26% fluoride varnish (22,600 ppm F) at least every 3 or 6 months or – 1.23% acidulated fluoride gel (APF) (12,300 ppm F) for 4 minutes at least every 3 or 6 months		– 0.09% mouthwash (900 ppm F) at least once a week or – 0.5% gel or fluoride toothpaste (5,000 ppm F) twice daily	

APF – acidulated phosphate fluoride

Tab. 10. Evidence-based clinical recommendations for professional topical application of fluoride products (36)

Risk level	Age < 6 years	Age 6-18 years	Age > 18 years
Low	Additional benefit from the use of professional fluoride products might not be obtained	Additional benefit from the use of professional fluoride products might not be obtained	Additional benefit from the use of professional fluoride products might not be obtained
Moderate	2.26% fluoride varnish (22,600 ppm F) every 6 months	2.26% fluoride varnish (22,600 ppm F) every 6 months or 1.23% APF fluoride gel (12,300 ppm F) every 6 months	2.26% fluoride varnish (22,600 ppm F) every 6 months or 1.23% APF fluoride gel (12,300 ppm F) every 6 months
High	2.26% fluoride varnish (22,600 ppm F) every 3 months	2.26% fluoride varnish (22,600 ppm F) every 3 months or 1.23% APF fluoride gel (12,300 ppm F) every 3 months	2.26% fluoride varnish (22,600 ppm F) every 3 months or 1.23% APF fluoride gel (12,300 ppm F) every 3 months

5% NaF varnish in young children is only 1/7 of the peak values observed after the use of 1.25 APF gel (61-63). Studies in children aged between 12 and 15 months showed that baseline plasma fluoride level was 13 ± 9 µg/L immediately after the application of 5% NaF varnish and 21 ± 8 µg/L 5 hours after application. Peak serum fluoride level after treatment was 57 ± 22 µg/L, with 20 ± 4 µg/kg retained. The amount of retained fluoride not secreted in urine was 253 times lower. This results from both more precise amount of applied varnish and its adherence to tooth surfaces as well as slow elimination from tooth surfaces, release and swallowing. Fluoride varnish used 2 to 4 times a year with 3- or 6-month intervals in children below 6 years of age does not contribute

to the development of fluorosis or acute poisoning (63, 65, 66). Furthermore, unintended swallowing of varnish is less likely compared to other products with high fluoride concentrations (gels, foams). Therefore, it may be safely used in young children (67). Approaches to the use of fluoride varnishes in various countries worldwide are summarised in the table 11.

5% NaF varnish is easy and quick to apply. No saliva ejectors or professional plaque removal are needed. Routine tooth brushing followed by drying e.g. with ball of cotton wool, is sufficient. The oral cavity should not be rinsed after application, and there is no need to "dry" the teeth since it hardens upon contact with saliva. The patient is allowed to close their mouth immediately after the procedure and simply leave the dental office. Varnish application ensures high fluoride levels remaining in contact with the enamel for 1 to 7 days, which is significantly longer compared to fluoride gel or foam (10-15 minutes). The manufacturer of high-fluoride varnish (22,600ppm) recommends to avoid chewing food and tooth brushing for 4 hours. However, research shows and experts recommend that patients should avoid hard foods for 2 hours after application and refrain from tooth brushing on the day of varnish application.

In the case of varnish containing 1.5% ammonium fluoride (7,700 ppm F), it is recommended to remove dental deposits, isolate teeth from saliva and dry dental surfaces with an air spray. After application, the varnish should be allowed 1 minute to dry. No mouth rinsing is recommended. Patients should refrain from eating and drinking for 1 hour.

Fluoride tables or other topical agents with high fluoride content should be avoided for 2 days after application.

After varnish application, more fluoride is retained in demineralised, rather than in healthy enamel (55, 66). Apart from fluoride incorporation into the hydroxyapatite crystalline network and formation of fluorapatite, calcium fluoride (in the form of granules) is also formed. It stabilises pellicle proteins and, as a result, phosphates at neutral pH. When pH drops, calcium fluoride dissolves and releases fluoride ions, thus acting as a prolonged source of fluoride after application.

First generation fluoride varnishes are varnishes containing 5% NaF, i.e. 2.26% F (22,600 ppm F). Second generation varnishes additionally contain amorphous calcium phosphate (ACP) or fluoride and casein phosphopeptide-amorphous calcium phosphate (CPP-ACP), which increase fluoride release and absorption and remineralisation, as well as obstruct the dentinal tubules; therefore, they are effective in the treatment of dentinal hypersensitivity. ACP-based fluoride varnishes may also contain chlorhexidine with antibacterial and remineralising properties or arginine and chlorhexidine with anti-acid, antibacterial and remineralising effects. There are also varnishes containing tricalcium phosphate (TCP) and an active form of tricalcium phosphate (fTCP), sodium-calcium phosphosilicate (CSPS), sodium trimetaphosphate (TMP) or calcium glycerophosphate (CaGP). These varnishes are currently under clinical assessment for their efficacy. Studies have shown that fluoride varnishes containing ACP, TCP, CSPS inhibit demineralisation and increase remineralisation of the enamel (68). Scientific evidence supporting the anticariogenic efficacy of fluoride varnishes containing 0.9% difluorosilane (1,000 ppm F) is lacking (36). However, the efficacy of varnish containing 1.5% ammonium fluoride (i.e. 7,700 ppm F) in preventing dental caries of

Tab. 11. Approaches to the use of fluoride varnishes in various countries worldwide

Organisation	Recommendations
AAPD (American Academy of Pediatric Dentistry)	– high risk of caries, at least every 6 months, primary and permanent teeth – age < 6 years and older
ARCPOH (Australian Research Center for Population Oral Health)	– age < 10 years, high risk of caries
EAPD (European Academy of Paediatric Dentistry)	– 2-4 times a year, primary and permanent teeth
NZGG (New Zealand Guidelines Group)	– age > 12 months, high risk of caries, every 6 months on all erupted teeth
Public Health England	– age >3 years, twice a year – since birth and older children at a high risk of caries, twice a year
SIGN (Scottish Intercollegiate Guidelines Network)	– at least twice a year

primary teeth has been confirmed (69). After drying, this varnish delivers about 30,000 ppm F. There is an ongoing randomised trial assessing the efficacy of this varnish in preventing caries in permanent teeth.

Conclusions

It is beyond doubt that fluoride prophylaxis is effective for preventing dental caries in both primary and permanent teeth, and that the use of preventive fluoride agents is safe for children as long as it complies with the developed guidelines. There is evidence confirming the efficacy of both various forms of agents containing different concentrations of fluoride compounds, as well as the combined use of another preventive strategy. Compared to fluoride toothpaste alone, combination of fluoride toothpaste with another method increases the chance of dental caries reduction: 48% for fluoride varnish, 14% for fluoride gel, 7% with for mouthwash. In general, it is believed that dental caries reduction after a simultaneous use of toothpaste and another preventive strategy (varnish/gel/mouthwash) is higher on average by 10% (95% CI 2-17%) (53). In addition to proper diet, fluoride prophylaxis remains the primary method for the prevention of dental caries.

Conflict of interest

None

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