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Dentists' knowledge of fluoride cariostatic mechanisms

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Keywords

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Summary

Introduction. The use of age- and risk-adjusted caries prevention requires up-to-date knowledge on the cariostatic effects of fluoride, as well as the methods and safety of fluoride prophylaxis.
Aim. The aim of the study was to assess dentists' knowledge of the safety and mechanism of anticaries effects of fluoride.
Material and methods. An anonymous questionnaire was conducted among 212 dentists participating in dental training. The questions included in the questionnaire related to knowledge about water fluoridation, fluoride cariostatic mechanisms and the safety of fluoride prophylaxis. The chi-square test and the Spearman's rank correlation coefficient were used for statistical analysis. A significance level of 0.05 was used.
Results. Incorrect knowledge about water fluoridation was demonstrated by 26.9% of respondents in the country and 16.0% of respondents in Europe. Most respondents (80.7%) reported higher efficacy of exogenous vs endogenous anticaries approaches, and more than half of respondents (59.0%) considered the processes of remineralisation and demineralisation as the most important anticaries activity. Almost all respondents (95.7%) agreed that the use of fluoride for caries prevention is controversial, mainly due to its dose-dependent therapeutic or toxic effects (85.4%). According to about 20% of respondents, cariostatic fluoride doses have adverse effects on the general health, mainly in the form of bone fragility (10.4%).
Conclusions. Lack of correct knowledge about the dominant cariostatic effects of fluoride may result in the choice of an inappropriate preventive method or avoiding local application of fluoride preparations for fear of adverse systemic effects, which may in turn lead to increased caries prevalence in a given population.

Introduction

Up-to-date knowledge on the cariostatic effects of fluoride, as well as the methods and safety of fluoride prophylaxis is passed during both undergraduate and postgraduate education (continuing and specialist professional development training courses, conferences, thematic panels) as well as in the form of publications available in professional journals or online. In 2012, the Independent Expert Panel compiled data on the knowledge of the individual anticaries fluoride prophylaxis in children and adolescents. In 2015, an update was performed by developing a monograph entitled "Consensus statement of Polish experts on individual caries prevention with fluoride in children and adolescents". Both monographs were published in professional journals and are available online (1-5). Therefore, correct, up-to-date knowledge of fluoride cariostatic mechanisms may be expected from dental practitioners.

Aim

The aim of the study was to assess dentists' knowledge of the safety and mechanism of anticaries effects of fluoride.

Material and methods

A total of 212 dentists participating in paediatric dentistry conferences were included in the questionnaire. Work experience was up to 5 years for 1/3 (37.3%), more than 20 years for 1/4, 6-10 years for 17.9%, 11-15 years for 9.9%, and 16-20 years for 9.0% of respondents. More than half of dentists had no specialty (59.0%), while the remaining respondents were specialised in paediatric dentistry (12.8%) and conservative dentistry with endodontics or other discipline of dentistry (14.1% each). The majority of respondents declared dental treatment in all age groups (93.4%), while the remaining participants limited their practice to children and adolescents (4.7%) or adults (1.9%).

The respondents completed a voluntary and anonymous questionnaire containing 13 single or multiple choice questions. The questions were formulated as follows: (1) is there any region in Poland with fluoridated water?; (2) is drinking water fluoridation banned in Europe?; (3) is dietary fluoride anticariogenic?; (4) is fluoride inhaled with polluted air anticariogenic?; (5) is fluoride anticariogenic at all if patients are still affected by caries despite using fluoride toothpaste?; (6) fluoride most effectively prevents dental caries due to its topical (exogenous) application; (7) fluoride most effectively prevents dental caries due to its systemic (endogenous) application; (8) the most important anticaries action of fluoride involves: (a) effects on remineralisation and demineralisation, (b) effects on the growth and number of bacteria in dental plaque, (c) effects on bacterial carbohydrate metabolism; (9) the use of fluoride to prevent caries is controversial because: (a) fluoride shows dose-dependent therapeutic and toxic effects, (b) fluoride may show adverse effects on the teeth by causing fluorosis, (c) fluoride may show harmful systemic effects; (10) have there been any studies conducted to assess the effects of cariostatic fluoride doses on human health?; (11) if such studies were conducted, did they show any increase in the prevalence of systemic diseases?; (12) is there any evidence for the relationship between cariostatic fluoride doses and the development of: (a) Down syndrome, (b) neurological disorders, (c) Alzheimer's disease, (d) heart disease, (e) cancer, (f) kidney disease, (g) thyroid disease, (h) increased bone fragility, (i) allergic reactions, (j) reduced IQ, (k) decreased immune responses; (13) are you fully convinced that fluoride preparations reduce the prevalence and severity of caries?

The obtained data were analysed using descriptive statistics, the chi-square test and Spearman's correlation, with a p-value < 0.05 considered significant.

Results

More than 1/4 of the respondents (26.9%) mistakenly believed that fluoridation of drinking water was still performed in some regions of the country, with the percentage decreasing with increasing years of practice, and with the lowest percentage values among respondents specialised in paediatric and conservative dentistry. This relationship was confirmed by significantly negative correlation coefficients (tab. 1 and 2). Among all respondents, 16.0% were convinced that water fluoridation is banned in Europe. The frequency of this misconception was significantly correlated with increasing years of practice, with only 3.8% of dentists practicing for up to 5 years and 1/3 of those practicing for more than 20 years providing an incorrect answer, and significantly less respondents specialised in paediatric dentistry and with no specialty compared to those specialised in conservative dentistry or some other disciplines of dentistry (tab. 2 and 3). Most dentists (66.27%) confirmed that the fluoride contained in food has anticariogenic effects and these answers were not correlated with either professional experience or specialty. A small proportion of respondents (16.5%) mistakenly believed that fluoride inhaled with polluted air has cariostatic properties.

Most respondents (80.7%) considered local application of fluoride preparations as the most effective method of fluoride prophylaxis in caries, whereas 16.0% of respondents reported that both endogenous and exogenous fluoride prevention is necessary, and 3.3% respondents claimed that only endogenous prophylaxis is needed (fig. 1). The conviction about the need for both endogenous and exogenous fluoride prophylaxis was significantly positively correlated with increased professional experience, and was most common among dentists practicing for more than 20 years (24.1%) and those with specialties other than paediatric and conservative dentistry (30.0%) (tab. 1-3). More than half of respondents (59.0%) answered correctly to the question on the major anticaries effect of fluoride (i.e. the effects on remineralisation and demineralization processes), whereas other participants reported simultaneous effects on remineralisation/demineralisation, the growth and number of plaque bacteria, and bacterial carbohydrate metabolism (25.0%) or the effects on remineralisation and demineralization processes combined with an effect on the growth and number of plaque bacteria (3.3%) or bacterial carbohydrate metabolism (11.8%), or bacterial carbohydrate metabolism alone (3.3%) (fig. 2). The frequency of correct answers was significantly positively correlated with professional experience and specialty in paediatric and conservative dentistry (tab. 1).

The vast majority of respondents (95.7%) believed that the use of fluoride for the prevention of caries is controversial, with dose-dependent therapeutic or toxic effects (85.4%), dental fluorosis (72.6%) and harmful systemic effects (67.9%) reported as causes (fig. 3).

Most of respondents (78.8%) confirmed that a research on the effects of cariostatic fluoride doses on the general health had been conducted; 21.7% of participants were convinced that these studies showed an increased incidence of certain systemic diseases. Of the mentioned diseases, fluoride prophylaxis was most often linked with increased bone fragility (10.4%) and allergic reactions (9.4%), and

Tab. 1. Correlation between respondents' answers and years of experience and specialty in paediatric/conservative dentistry

Questions	Years of practice	Paediatric or conservative dentistry with endodontics
Is there any region in Poland with fluoridated water?	r = -0.245; p < 0.05*	r = -0.153; p < 0.05*
Is drinking water fluoridation banned in Europe?	r = 0.318; p < 0.05*	r = 0.093; p > 0.05
Is dietary fluoride anticariogenic?	r = 0.096; p > 0.05	r = -0.039; p > 0.05
Is fluoride inhaled with polluted air anticariogenic?	r = -0.005; p > 0.05	r = -0.008; p > 0.05
Fluoride most effectively prevents dental caries due to its topical (exogenous) application	r = -0.165; p < 0.05*	r = -0.014; p > 0.05
Fluoride most effectively prevents dental caries due to its systemic (endogenous) application	r = -0.011; p > 0.05	r = -0.029; p > 0.05
Fluoride most effectively prevents dental caries due to its endogenous and exogenous application	r = 0.215; p < 0.05*	r = 0.017; p > 0.05
– effects on remineralisation and demineralisation processes	r = 0.146; p < 0.05*	r = 0.162; p < 0.05*
– effects on the growth the number of bacteria in dental plaque	r = -0.113; p > 0.05	r = -0.115; p > 0.05
– effects on bacterial carbohydrate metabolism	r = -0.115; p > 0.05	r = -0.168; p < 0.05*
– all 3 mechanisms	r = -0.125; p < 0.05	r = -0.127; p > 0.05
The use of fluoride to prevent caries is controversial	r = 0.021; p > 0.05	r = 0.108; p > 0.05
– because it shows dose-dependent therapeutic and toxic effects	r = 0.028; p > 0.05	r = 0.102; p > 0.05
– because it may show adverse effects on the teeth by causing fluorosis	r = 0.046; p > 0.05	r = -0.031; p > 0.05
– because it may show harmful systemic effects	r = 0.074; p > 0.05	r = 0.048; p > 0.05
Have there been any studies conducted to assess the effects of cariostatic fluoride doses on human health?	r = -0.126; p > 0.05	r= -0.031; p > 0.05
If such studies were conducted, did they show any increase in the prevalence of systemic diseases?	r = 0.160; p < 0.05*	r = 0.057; p > 0.05
Is there any evidence for the relationship between cariostatic fluoride doses and the development of systemic diseases	r = 0.068; p > 0.05	r = -0.071; p > 0.05
– Down syndrome	r = 0.015; p > 0.05	r = 0.015; p > 0.05
– neurological disorders	r = 0.122; p > 0.05	r = 0.063; p > 0.05
– Alzheimer's disease	r = 0.082; p > 0.05	r = 0.090; p > 0.05
– heart disease	r = 0.010; p > 0.05	r = -0.080; p > 0.05
– cancer	r = 0.080; p > 0.05	r = -0.004; p > 0.05
– kidney disease	r = 0.073; p > 0.05	r = 0.063; p > 0.05
– thyroid disease	r = -0.010; p > 0.05	r = -0.015; p > 0.05
– increased bone fragility	r = 0.182; p < 0.05*	r = 0.008; p > 0.05
– allergic reactions	r = 0.035; p > 0.05	r = 0.074; p > 0.05
– reduced IQ	r = 0.048; p > 0.05	r = -0.017; p > 0.05
– decreased immune responses	r = 0.030; p > 0.05	r = 0.053; p > 0.05
Is fluoride anticariogenic at all if patients are still affected by caries despite using fluoride toothpaste?	r = 0.034; p > 0.05	r = 0.042; p > 0.05
Are you fully convinced that fluoride preparations reduce the prevalence and severity of caries?	r = -0.006; p > 0.05	r = 0.034; p > 0.05

*statistically signifficant

Tab. 2. Significant differences in the frequency of answers to questionnaire questions in the subgroups of professional experience

Professional experience (years)	up to 5	6-10	11-20	> 20	p-value
Is there any region in Poland with fluoridated water?	38.0%	34.2%	18.9%	11.1%	0.003*
Is drinking water fluoridation banned in Europe?	3.8%	13.2%	18.9%	33.3%	0.000*
Fluoride most effectively prevents dental caries due to its endogenous and exogenous application	5.1%	5.3%	5.4%	24.1%	0.001*
Have there been any studies conducted to assess the effects of cariostatic fluoride doses on human health?	83.5%	94.7%	59.5%	75.9%	0.001*
There is evidence for the relationship between cariostatic fluoride doses and the development of cancer	5.1%	0.0%	0.0%	11.1%	0.036*
There is evidence for the relationship between cariostatic fluoride doses and increased bone fragility	7.6%	5.3%	5.4%	24.1%	0.005*

*statistically signifficant

Tab. 3. Significant differences in the frequency of answers to questionnaire questions in the subgroups of different specialty or no specialty

Questions	Specialty				p-value
	Paediatric dentistry	Conservative dentistry with endodontics	Other specialty	No specialty	
Is there any region in Poland with fluoridated water?	18.5%	10.3%	23.3%	33.3%	0.049*
Is drinking water fluoridation banned in Europe?	11.1%	31.0%	26.7%	11.1%	0.017*
Fluoride most effectively prevents dental caries due to its endogenous and exogenous application	7.4%	10.3%	30.0%	6.3%	0.002*
There is evidence for the relationship between cariostatic fluoride doses and the development of					
neurological disorders	3.7%	13.8%	20.0%	4.8%	0.021*
cancer	3.7%	3.4%	16.7%	2.4%	0.010*
increased bone fragility	3.7%	13.8%	26.7%	7.9%	0.014*

*statistically signifficant

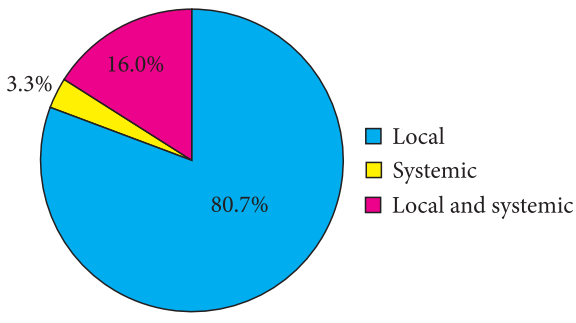

Fig. 1. The percentages of answers regarding the most effective cariostatic methods of fluoride use

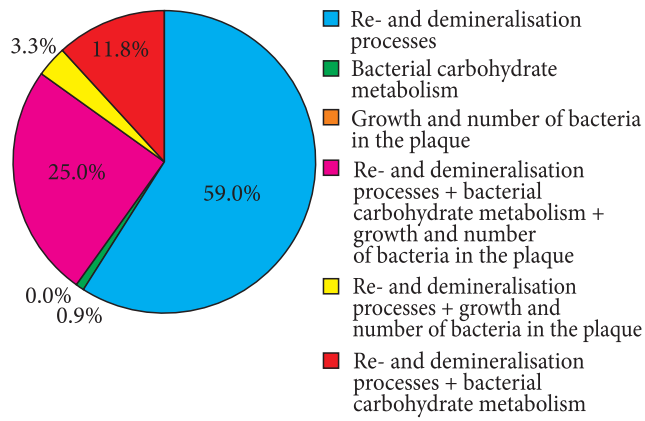

Fig. 2. The percentages of answers regarding the major anticaries fluoride action

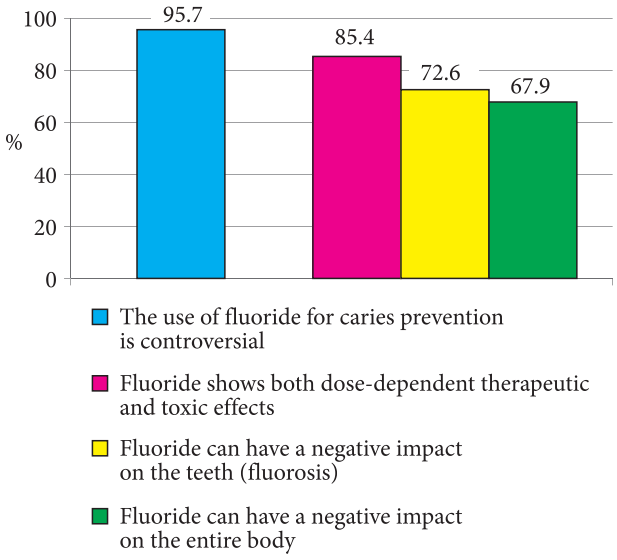

Fig. 3. The percentages of answers regarding the controversial use of fluoride to prevent dental caries

least frequently with Down's syndrome (1.4%) (fig. 4). The increasing number of years of practice was correlated with increasing number of dentists convinced about the relationship between cariostatic fluoride doses and bone fragility (tab. 1), with about 1/4 of respondents with more than 20 years of practice (24.1%) and those with specialty other than paediatric and conservative dentistry (26.7%) expressing such an opinion (tab. 2 and 3). The relationship between prophylactic fluoride doses and increased prevalence of cancer was most often reported by respondents with more than 20 years of practice (11.1%) and those of specialty other than paediatric and conservative dentistry (16.7%) (tab. 2 and 3). The causal relationship between cariostatic fluoride and neurological disorders was most often confirmed by dentists with a specialty other than pediatric or conservative dentistry (20.0%) (tab. 3).

The same percentage of respondents (93.4%) confirmed that fluoride preparations and toothpastes prevent caries.

Discussion

Fluoride has been used for caries prevention for more than 70 years. The commencement of artificial fluoridation of drinking water (December 25, 1945, Grand Rapids, USA) is considered the date of fluoride introduction into prophylaxis. In Poland, fluoridation of tap water was introduced in 1967 (Wrocław). About 2.5 million inhabitants used this mass prophylaxis; however, water fluoridation was discontinued in 1996 (6). At present, no water fluoridation is performed in the country; however, a natural content of fluorine in the range of 0.3-1.0 ppm or over 1-3 ppm is reported in some regions (7-9). Despite this fact, over 1/4 of respondents answered affirmatively to the question regarding current fluoridation of water. A similar lack of knowledge was shown by dentists from Texas, USA, with 2.4% of respondents unaware of whether most of their patients consumed fluoridated water (78.1% of Texas inhabitants used fluoridated water at the time of this study) (10).

A total of 16.0% of respondents mistakenly believed that water fluoridation was banned in European countries. Currently, artificially fluoridated water is used by about 2% of the European population in countries such as the United Kingdom (10%), Ireland (71%), Spain (10%) and Serbia (3%) (11). Therefore, fluoridation of water is not banned in Europe; however, its implementation requires compliance with specific legislative requirements for a given country, i.e. decisions of the minister of health and/or the community's consent (12).

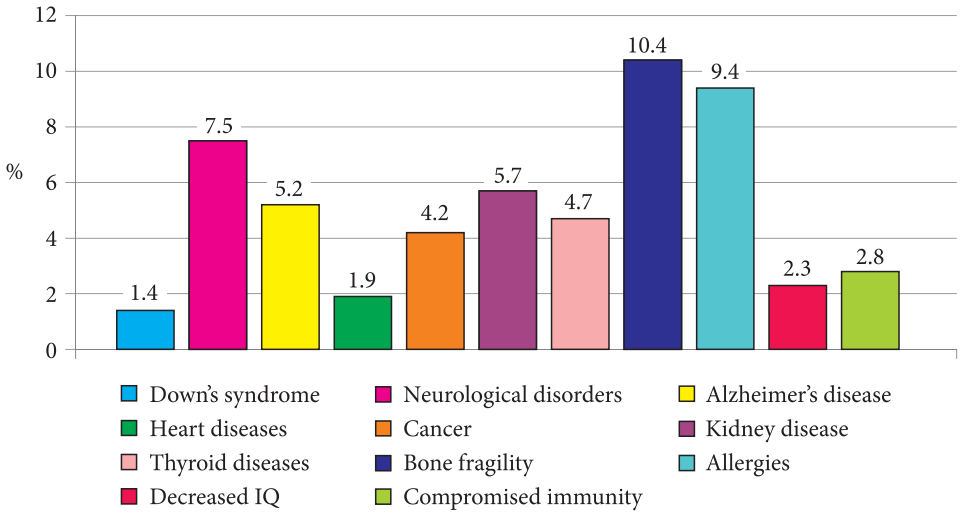

Fig. 4. The percentages of affirmative answers regarding the proven relationship between cariostatic fluoride doses and the development of certain diseases

Food content of fluoride is generally low; therefore only low fluoride levels are usually ingested (0.02-0.29 ppm), e.g. fruit, milk and dairy products, bread, cereals. Higher amounts are found in, among other things, tea, sea fish, crustaceans, canned fruit, and very high levels are found in fish meal, which is used as feed for some of the farm animals (21-761 ppm) (13). Additionally, the food content of fluoride depends on the material of the cookware in which it is prepared, e.g. Teflon cookware is a significant source of fluoride (14, 15). It is estimated that the daily intake of fluoride from all sources (food, water, fluoride toothpastes) with a cariostatically low and optimal content of fluorine in water does not exceed the acceptable upper intake level in all age groups (15). Since the intake of fluoride with food is low in the non-fluorinated water regions, its cariostatic effects are negligent. However, most of respondents (62.7%) were convinced about such effects.

Fluoride enters the atmosphere mainly from industrial sources, domestic coal stoves and gases emitted in the regions of volcanic activity (12). In highly industrialised regions, typical daily inhalation intakes are in the range 10-40 µg/day (15, 16). Although there is no evidence that fluoride inhalation causes a significant threat for the general population or has any anticaries effects (15), such an opinion was expressed by 16.5% of respondents.

The discovery of the relationship between fluoride and caries reduction in the population gave rise to a question whether the anticaries effects of fluoride occur before or after tooth eruption or perhaps at both these time points. Endogenous prophylaxis (fluoridated water, fluoride tablets/drops, fluoridated salt, fluoridated milk) was initially recommended based on the assumption that pre-eruptive fluoride effect was the dominant one. The pre-eruptive effects of fluoride were explained as follows: optimal fluoride exposure during tooth development increases enamel content of fluoride, which is incorporated in hydroxyapatite (to form fluorapatite), hence its resistance to acid dissolution (lower critical pH compared to hydroxyapatite, 4.5 vs 5.5). Furthermore, the crystal structure of apatite shows increased stability, promoting favourable morphological changes of the teeth (more rounded cusps and shallower grooves on the chewing surface). This theory was supported with clinical research showing lower caries reduction (by 20-30%) following topical fluoride application vs. fluoridated water (50%). However, the reduction of caries in the regions of fluoridated water was reinterpreted in the following years (17-22). It was found, among other things, that there was no clear relationship between fluoride content in the superficial enamel layer and caries, that the *in vitro* development of caries in the teeth from the region with low and optimal fluoride levels in water was similar, that the cariostatic effect decreases after discontinuation of fluoridated water, that there was a post-eruptive effect of fluoride intake (i.e. reduced caries in children with dental development and mineralisation prior to residence in a region with fluoridated water), and that carious lesions develop in enamel comprised exclusively of fluorapatite (shark teeth) in an *in situ* study (17, 20-22). In the 1980s, it was found that fluorides control caries mainly by local effects (23). When present in low levels in oral fluids during acid attack, they are absorbed on the surface of apatite crystals, thus inhibiting demineralisation. When the pH returns to neutral, traces of fluoride cause the supersaturation of mineral ions with regard to fluorohydroxyapatite, which accelerates the remineralisation process. The mineral formed after the nucleation of partially dissolved crystals preferentially incorporates fluorine and excludes carbonate, which results in the formation of enamel that is more resistant to further acid action. It was also demonstrated that after applying preparations with higher fluoride concentrations (> 100 ppm) on enamel, granular calcium fluoride is formed, which is prevented from dissolving by the protein phosphate coating in saliva. Calcium fluoride is important as a reservoir of fluoride ions, which are released when the oral environment becomes acidic, and therefore when they are most needed (17, 23-25). Laboratory studies have shown that fluorides inhibit the carbohydrate metabolism of *Streptococcus* spp. and *Lactobacilli* spp., especially at low pH at which fluoride in the form of hydrogen fluoride (HF) is transported to a bacterial cell. After accumulation in the cell, the fluoride inhibits two enzymes, i.e. enolase and adenosine triphosphatase, which releases protons and inhibits the transport of glucose into the cell. These effects were demonstrated in cellular cultures, but are probably absent at low fluoride levels in the oral cavity (17, 25). Interfering with bacterial adhesion on dental surfaces, reducing the number of mutans streptococci in dental plaque, and affecting their acidity may be another possible mechanism of local fluoride action. However, the *in vivo* antibacterial activity of fluoride has not been explained so far, and nor has the contribution of such effects to caries prevention (17, 25, 26). Therefore, the current concept of the inhibitory effects of fluoride on caries is based on its post-eruptive action, i.e. the presence of low levels of fluoride ions in the enamel/plaque interphase, which directly change the dynamics of tooth mineral dissolution and reprecipitation, while other mechanisms are of secondary importance.

In our study, 80.7% of dentists were of the opinion that post-eruptive effects of fluoride dominate over its pre-eruptive activity, with the frequency of correct answers negatively correlated with the increasing professional experience, but unrelated to specialty in paediatric or conservative dentistry. By contrast, only 5% of dentists from Texas answered correctly to this question, with no relationship between the answers and the type of practice (general, public or paediatric dentistry) (10). In our study, only 59.0% of respondents considered the effects on remineralisation and demineralisation as the major anticaries effect. Yoder et al. (27) showed a significantly lower proportion of correct answers provided by dentists from Indiana, USA (25%) despite the guidelines on fluoride prophylaxis available

for several years. A total of 82.9% of dentists from Taiwan claimed that reminalisation of initial carious lesions is the most important fluoride mechanism (28). In Kuwait, 49.0% of dentists were convined that water fluoridation was the most effective method for caries prevention, indicating pre-eruptive fluoride action as the dominant anticaries mechanism (29).

Despite the lack of scientific evidence for the relationship of cariostatic fluoride doses and an increased incidence of certain diseases (12, 13, 15), 21.7% of respondents were convinced that such doses contribute to the increased prevalence of certain diseases, bone fragility (10.4%), allergic reactions (9.4%) and neurological disorders (7.5%) in particular. Despite these misconceptions, 93.4% of dentists were convinced that fluoride preparations reduce the prevalence and severity of dental caries. Earlier studies demonstrated a similar percentage of dentists (94.6%) convinced about the efficacy of fluoride prophylaxis (30).

It may be concluded that despite the available guidelines for fluoride prevention, the knowledge of dentists in this field is not fully satisfactory. Lack of proper knowledge on the predominant cariostatic effects of fluoride may result in an inappropriate choice of the method of prevention or lack of local application of fluoride preparations for fear of adverse systemic effects. This may consequently lead to increased dental caries in the population.

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Conflict of interest

None

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