Stomatologija, Baltic Dental and Maxillofacial Journal, 14:12-22, 2012

Evidence based toothpaste classification, according to certain characteristics of their chemical composition

Ilze Maldupa, Anda Brinkmane, Inga Rendeniece, Anna Mihailova

SUMMARY

Toothpastes are daily oral care products, the chemical composition of which is constantly changing due to manufacturer's competition. It becomes more and more difficult for dentists to recommend the best toothpaste and for patients to choose one. The objective of this paper was to draw out recommendations based on the best evidence available and to propose a new classification of toothpastes. Publications were searched in PubMed database (published between 1991-2011, limited to English language articles in dental journals). Recommendations for toothpaste choice and usage were developed from the best evidence available.

Key words: toothpaste, classification, caries, gingivitis, hypersensitivity.

INTRODUCTION

Toothpastes are daily oral care products, the chemical composition of which is constantly changing due to manufacturer's competition. Toothpastes are recognized as the best source of fluoride, which most effectively protects both deciduous and permanent teeth from caries [1]. However, fluorides are not the only active ingredients in toothpastes. Also important are the cleaning abilities of toothpaste provided by abrasives [2], the antibacterial qualities, which, in turn, are provided by a variety of substances with different abilities to inhibit the growth of germs in the oral cavity [3], as well as a number of ingredients with specific purposes to solve specific problems. The wide selection of toothpastes and the various ingredients make it difficult for patients to choose the proper toothpaste and complicate the acquisition of dental products by professionals.

Literature provides a number of toothpaste reviews focused on specific conditions, but there had been found only two reviews combining several kinds of dentifrices [4, 5], however no levels of evidence are presented for recommendations given by authors, neither any classification of all toothpastes are proposed.

[*]*Department of Therapeutic Dentistry, Institute of Stomatology, Riga Stradins University*

***Ilze Maldupa**[*] – D.D.S., PhD student*
***Anda Brinkmane**[*] – D.D.S., PhD, assoc. prof.*
***Inga Rendeniece**[*] – D.D.S., PhD student*
***Anna Mihailova**[*] – D.D.S., postgraduate student*

Address correspondence to Ilze Maldupa, IT. Grothusa str. 2, Jelgava, LV – 3002, Latvia.
E-mail address: ilze.maldupa@rsu.lv

Therefore the authors of this study undertook a systematic review of the literature to draw out recommendations based on the best evidence available and a narrative review to propose a new classification of toothpastes.

METHODS

For the systematic review a search in PubMed was performed using terms presented in Table 1, limitations included keywords in title or abstract, English articles in dental journals, dated from 1991-2011. The results included 618 publications, from which 130 were excluded due to incompatibility with a search topic in the stage of abstract evaluation.

To describe each group of proposed toothpaste classification, only publications from last five years were included. Additional search included materials from international conferences (IADR, International Association of Dental Research) theses and symposia materials published within the last 2 years. Article selection criteria and process are shown in Figure 1.

RESULTS

Recommendations were drawn out from papers showing the best evidence in each search – systematic reviews, narrative reviews, randomized controlled trials, clinical trials or combination (Table 1).

The findings of recent literature search are presented according to proposed classification, dividing all toothpastes in five groups.

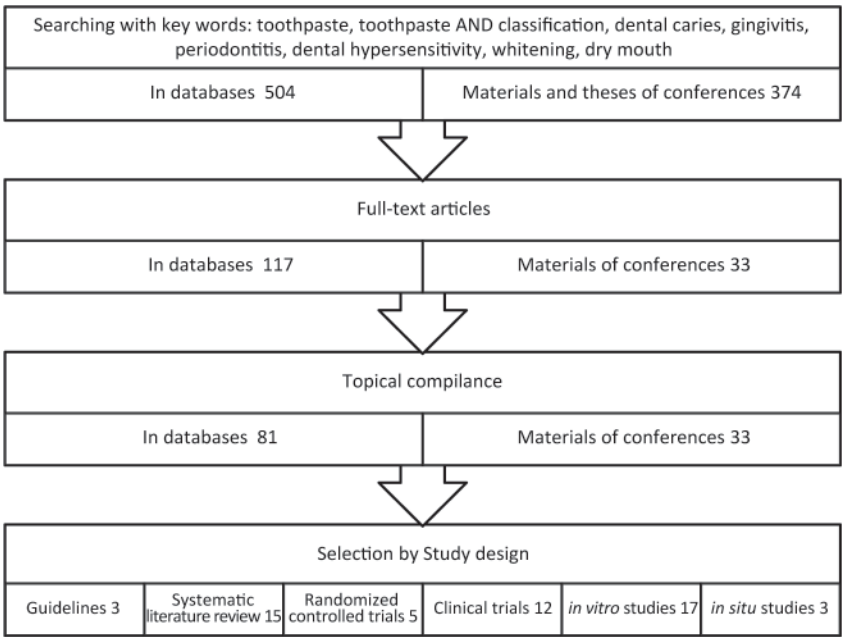

Fig. 1. Flow chart of selection of studies for the narrative review of toothpastes

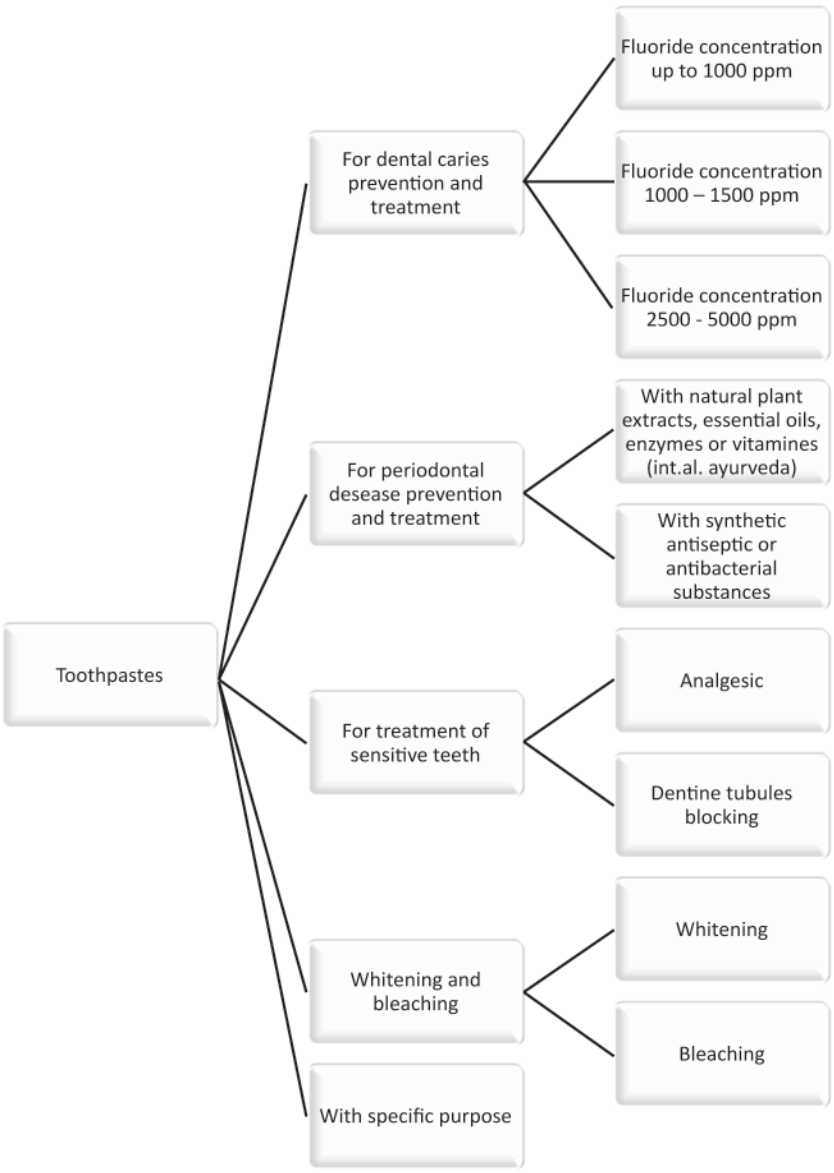

Fig. 2. Toothpaste classification

Toothpaste classification

There is an established toothpaste classification based on certain characteristics of the active ingredients (Figure 2):

1. For caries prevention and treatment

Toothpaste used as a local fluoride source has the best ability to inhibit the development of caries (19-27% reduction of caries) [1], providing remineralization of enamel. Early enamel demineralization is not visible neither clinically, nor with radiological examination, however in chemical level carious decay starts from the moment when the normal exchange of minerals is disturbed, and in most cases the processes of demineralization occurs [6]. In the treatment of such early decay, it is important to follow 2 principles: 1) to reduce the etymological factor – dental plaque and the bacterial biofilm of which it is composed, and 2) to increase the amount of remineralizing substances – the concentration of fluoride [6]. These two principles can be achieved by cleaning the teeth with fluoride toothpaste. The use of fluoride has been shown to be the most effective over the last 20 years, however the regular use of fluoride in early childhood is associated with the development of fluorosis [7].

1.1. Fluoride concentration up to 1000 ppm

In the 1980's, several studies were carried out which showed that children 2-5 years old swallow 30-50% of the toothpaste applied to a toothbrush. These studies were followed by research about the correlation between the fluoride concentration in toothpastes and the spread of fluorosis in permanent teeth. As a result, due to the risk of fluorosis, it was recommended that children use toothpastes with a fluoride concentration of 500-550 ppm [7]. However, not all the study results were equipollent. If toothpastes with normal fluoride concentration (1000-1500 ppm) were studied using unproven research

Table. Recommendations for choice of toothpastes based on the best evidence available

Key words	Results in PubMed	Excluded articles	Guidelines, policies	Systematic reviews	Narrative reviews, expert opinions	RCT	Clinical trials	Cohort studies, Epidemiological studies, Surveys, Interviews	*In situ* studies	*In vitro* or animal studies	Best evidence available: Conclusion
Toothpaste caries fluorides	290	72	4	24	28	45	8	74	14	21	Systematic review: Toothpaste with 1000 to 1500 ppm concentrations is recognized as the most effective fluoride source (Prevented fraction 23% [62]), but for children under 6 years of age decision should balance between risk of caries and fluorosis
Toothpaste caries amine fluoride	11	5	0	0	1	4	0	0	1	0	Randomised clinical trials: Use of amine fluoride toothpaste improves plaque control and reduces the incidence of caries, but there are not enough studies to compare effectiveness between different fluoride formulations. Existing evidence shows AmF to be slightly superior over NaF toothpaste (4.3% of teeth with new white spot lesions compared to 7.2% new lesions in NaF group [63]).
Toothpaste xylitol	17	9	0	1	1	3	0	0	0	3	Systematic review: Xylitol can decrease the incidence of caries for 9.1% [64].
Toothpaste lactoperoxidase	7	2	0	0	0	0	5	0	0	0	Clinical trials: Lactoperoxidase containing toothpastes increases the level of thiocyanate ions in the saliva, but it is not clear if there is some bactericidal effect.
Toothpaste caries chlorhexidine	13	11	0	0	0	2	0	0	0	0	Randomised clinical trials: The use of chlorhexidine containing toothpaste significantly reduced the plaque index and microorganism count.
Toothpaste antibacterial	28	7	0	0	5	4	7	0	0	5	Randomised controlled trials and narrative reviews: Toothpaste with triclosan and copolymer provides superior efficacy in inhibiting the formation of dental plaque
Toothpaste chlorhexidine gingivitis	14	2	0	0	5	6	1	0	0	0	Randomised controlled trials and narrative reviews: Chlorhexidine effectively reduces dental plaque (49-61% when compared to placebo [65]) and gingivitis (31-39% when compared to placebo [65]); can be combined with fluoride in dentifrice.

Table. Recommendations for choice of toothpastes based on the best evidence available (continued)

Toothpaste chlorhexidine periodontal	4	0	0	0	1	3	0	0	0	0	Randomised controlled trials and narrative reviews: Toothpaste with chlorhexidine can be effective antiplaque agent for nonsurgical periodontal therapy.
Toothpaste triclosan	79	12	0	9	6	29	14	0	2	7	Systematic reviews: Dentifrice containing triclosan and copolymer combination provides a more effective level of plaque control and periodontal health than a conventional fluoride dentifrice (around 23% reduction of both plaque and gingivitis [57]), also leads to slower progression of periodontal disease.
Toothpaste herbal	13	2	0	0	0	6	3	0	0	2	Randomised controlled trials: Toothpaste with herbal ingredients can be used as additional therapy of periodontal diseases or for routine prophylaxis, especially for patients with demand for natural products.
Toothpaste hypersensitivity	50	6	0	2	6	24	2	2	1	7	Systematic reviews: There is no clear evidence for the support of potassium containing toothpastes for dentine hypersensitivity (no significant effect after 6-8 weeks – mean difference in sensitivity score was -1.25 with 95% CI -1.65 to -0.851 [37]). Randomised clinical trials and narrative reviews: Suggests that dentifrices providing occlusion of dentine tubules are superior over potassium containing toothpastes.
Toothpaste whitening	86	21	0	1	6	28	4	0	4	22	Systematic review: Whitening toothpastes with abrasives or additional agents, for examples, enzymes, peroxide or optical agents, give effective removal of extrinsic stains, but use of abrasives leads to removal of the pellicle and increases risk of abrasion and erosion.
Toothpaste dry mouth	6	1	0	0	0	2	3	0	0	0	Randomised clinical trials: Mildly flavoured toothpastes containing betaine, olive oil, xylitol, triclosan, mineral salts and fluorides improves quality of life for patients with dry mouth.

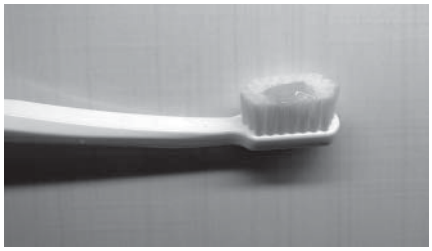

Fig. 3. "Thin smear" layer of toothpaste (0.125 g)

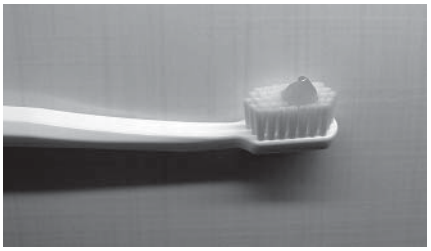

Fig. 4. "Small pea" size amount of toothpaste (0.25 g)

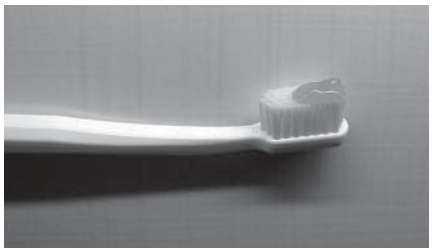

Fig. 5. "Half head" amount of toothpaste (0.5 g)

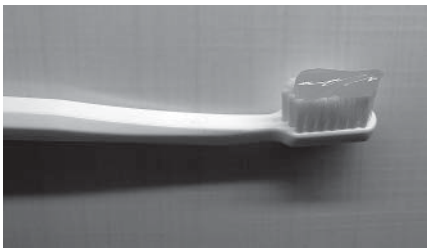

Fig. 6. "Full head" amount of toothpaste (1 g)

methods, it showed an increased prevalence of fluorosis, but the severity was very mild, and caused neither clinical, nor aesthetic problems [7]. Most studies were done in North America, where water fluoridation has been common since the 1950's. However, in articles from the last five years, the effectiveness of such reduced fluoride concentrations is more often compared with the effectiveness of normal fluoride concentration in toothpastes [8-13]. Although one study shows that the effectiveness of 500 ppm and 1000 ppm toothpastes differed in the caries-active children's group, in caries-inactive children's groups the effectiveness was the same [8]. In general, use of toothpastes with a fluoride concentration of not less than 1000 ppm is recommended. In addition, it is proven that toothpastes with fluoride concentrations of 400-550 ppm do not differ from placebo toothpastes [8-13]. There is also evidence that when using 400 ppm or 1450 ppm toothpastes from 1 year of age, but in strict compliance with the "pea size" amount of toothpaste on a toothbrush, the prevalence of aesthetically noticeable fluorosis does not differ between the two groups [14].

1.2. Fluoride concentration 1000-1500 ppm

The ability of toothpastes to reduce caries cited in literature varies from 19-27% [15], however toothpaste with 1000 to 1500 ppm concentrations is recognized as the most effective fluoride source. Local fluoride sources provide only 10% additional caries reduction [16]. According to the latest research data, children from 2-3 years of age swallow 48% of toothpaste, but children from 6-7 years of age swallow 25% of toothpaste. In order to reduce the risk of fluorosis in the most susceptible group (4-6 years of age) it is recommended that they ingest no more than 0.1 mg (it is safer, if it is not more than 0.05 mg) F per 1 kg body mass per day [17]. Figures 3-6 show how many mg of F toothpaste contains, taking into consideration the quantity applied on a toothbrush.

Since it is proven that direct contact of fluorides with the enamel during tooth brushing and the concentration of that fluoride during that contact is most important, it is recommended that younger children use toothpastes with fluoride concentration of 1000 ppm, taking in account the age-appropriate amount [17].

There is also some debate about the effectiveness of various fluoride compounds in toothpastes [18-20]. Althpugh *in vitro* studies show that aminofluorides possess the best capacity to remineralize enamel, followed by sodium fluoride (NaF) and sodium monofluorophosphate (NaMFP) [18, 19], and there were clinical trial on the effectiveness of aminofluorides with positive results carried out in Germany in the 1970's [21], there are not enough evidence to claim any clinically significant difference.

In addition to fluoride, xylitol demonstrates a good anti-caries effect, as well as an antibacterial impact (especially on Streptococcus Mutans), a salivary stimulating effect (enhances salivary buffering effect, reduces sugar clearance time, promotes remineralization) and direct biomechanical effects (prevents enamel mineral loss) [22].

A number of enzymes – lysozyme, lactoperoxidase and glycosil oxidase – have also been proven to work *in situ* against mutant Streptococcus. [23].

1.3. Fluoride concentration 2500-5000 ppm

Higher concentrations in toothpastes can achieve a caries reduction of up to 36% [15]. *In vitro* studies also show that toothpastes with elevated concentrations have a higher ability to remineralize enamel and dentin better than toothpastes with normal concentrations or placebo toothpastes [24, 25].

2. For periodontal disease prevention and treatment

The cause of gingivitis and periodontitis is bacteria in dental plaque, so there are two main rules for the prevention of these diseases: 1) remove plaque regularly, thus preventing the growth of bacteria on the biofilm and 2) prevent the growth of bacteria, thus inhibiting formation of plaque and tartar. The

first rule is insured by a mechanical cleaning of the teeth, but in order to prevent bacterial growth, manufacturers add various antiseptic and antibacterial substances to toothpaste – triclosan, chlorhexidine, hydrogen peroxide, baking soda, Povidone Iodine, zinc citrate and others [3].

2.1. With natural plant extracts, essential oils, enzymes or vitamins (including Ayurvedic)

Toothpastes containing natural plant extracts showed similar antibacterial effectiveness as chlorhexidine containing toothpastes [26]. The body's immune response, which takes place in the case of periodontal tissue inflammation, causes damage to the host tissue. Topically used antioxidants may prevent the negative effects of the immune response on tissue without hindering their effect on microorganisms [27].

2.2. With synthetic antiseptic or antibacterial substances

The ability of triclosan to lessen signs of gingivitis has been proven in several studies [3, 28]. It not only prevents growth of both Gr (+) and Gr (–) bacteria, but also reduces the ability of fibroblast to produce inflammatory cytokines and mediators. Copolymer strengthens the effect of triclosan [28]. A systematic review of a medium quality [29] also concluded that a triclosan/copolymer dentifrice provides a more effective level of plaque control than a fluoride dentifrice [30]. Studies show that triclosan does not develop germ resistance and does not change the normal micro flora [28]. It has also been disproven that the use of triclosan-based toothpaste can change the balance of thyroid hormones [31], however potential adverse effects like triclosan-adapted cross-resistance with antibiotics still should be investigated [32]. Compared to chlorhexidine it is easier to combine triclosan with other toothpaste ingredients. It also does not reduce remineralizing or diminish the antibacterial quality of fluorides [28]. The antibacterial quality of chlorhexidine is associated the prevention of glucose transport in bacteria cells [33]. Although the ability of chlorhexidine to inhibit the growth of pathogenic micro-organisms has been proven, a number of undesirable side-effects have been observed: 1) pigmentation of teeth and composite restoration, 2) dryness and desquamation, 3) temporary taste changes, 4) potential allergic reactions, 5) intensified formation of tartar [34].

3. For treatment of sensitive teeth

3.1. Analgesic toothpastes

Toothpastes containing potassium saline maintain a high K+ extracellular level, thus preventing re-polarization of the nerve cell membrane and inhibiting the transmission of impulses without causing changes in the pulp [35]. Improvement was observed in 85% of the cases [36]. Toothpaste, which is composed of 5% or 10% potassium nitrate, can decrease tooth sensitivity for up to 4 weeks [35]. It is believed that potassium salts also possess oxidizing properties, thus blocking the dentin tubules by crystallizing them, but there is no evidence of this. [35] In other studies even after 30% KNO_3 applications, the flow of solution in dentin tubules was only slightly altered, which causes serious doubt about the ability of potassium salt to block the tubules [35]. However the authors of the Cochrane systematic review do not find sufficient evidence of the clinical efficacy of potassium salts in the reduction of dentin hypersensitivity [37].

3.2. Dentin tubule blocking toothpastes

Fluoride compounds, by providing remineralization, increase dentin resistance against acids. A precipitation of fluoride compounds is created that blocks dentin tubules [35]. Stannous fluoride possesses the ability to block tubules, forming SnF_2 and CaF_2, and the ability to form a protective layer on the tooth surface, by creating a reaction of Sn^{2+} ion with sodium, calcium and phosphate compounds and forming Sn-Na hexametaphosphate [35, 38]. It has been proven that with the increase of fluoride ion concentration in enamel, there is also an increase of enamel microhardness [20]). In addition, by adding calcium and phosphate ions, they combine with the fluoride ions on the enamel surface and form an amorphous calcium phosphate, which in addition to blocking tubules, also smoothes the tooth surface, achieving an even more effective reduction of sensitivity [39]. However, it is difficult to combine these ions, as they tend to react in the tube of toothpaste, forming non-effective compounds [39]. As previously mentioned, some authors have discovered that toothpastes containing potassium can also block dentin tubules, but they explain this by the presence of abrasives in toothpaste. Even cleaning teeth with distilled water can create a layer of chips which can block the opened dentin tubules [40]. The analgesic effect of toothpaste may also be improved by adding additional substances, the size of whose particles can penetrate the dentin tubules, and which are stable enough in case of mechanical and chemical irritants. For example, *in vitro* studies have proven that toothpastes containing calcium sodium phosphosilicate or NovaMin block dentin tubules noticeably better than toothpastes with potassium salts. These effects continue even when the tooth is placed in artificial saliva [40].

Toothpastes containing arginine also yield good results in the reduction of dentin hypersensitivity –

they can block the dentin tubules. In several studies it has been proven that the clinical hyposensitive effect of arginine is greater than that of potassium salts [41-44] and fluoride [45, 46]. *In vitro* trials with arginine-based toothpaste have shown better blocking of the tubules than with strontium chloride [47].

Strontium chloride can block the dentin tubules [35], but in recent literature evidence of the effectiveness of strontium acetate-based toothpaste is mentioned more often. *In vitro* studies of strontium acetate clearly show better results than arginine [48] and in randomized controlled clinical studies, acetate shows markedly higher effectiveness than toothpastes containing sodium fluoride and silica dioxide [49], but only a slightly better effect (p=0.0391,when checking tactile sensitivity) than toothpastes containing arginine [50].

4. Whitening and bleaching toothpastes

Whitening toothpastes are mentioned most often in literature. Their main purpose is the removal of plaque, either mechanically or chemically [2]. However, in some dentifrices there are added chemicals that provide a bleaching effect, therefore in this toothpaste class there are two definite subclasses – whitening toothpastes and bleaching toothpastes.

4.1. Whitening toothpastes

By removing stained plaque, teeth will regain their natural whiteness. Plaque can be removed by abrasive substances or by enzymes that stick to proteins in the pellicle, thus facilitating the removal of stained plaque [2, 4, 52].

4.1.1. Whitening toothpastes with abrasive substances

The performance of these toothpastes is based on the size and hardness of the molecules of the added abrasive substance, which are harder than the stain molecules. As a result, the stains are removed. Overall, the cleaning process is affected by the hardness, size, shape and concentration of the particles and the pressure used in brushing the teeth [2]. Usually such toothpastes are of medium (RDA – 60-100) or high (RDA>100) abrasiveness. The most commonly used abrasive substances are silica dioxide, hydrated silica dioxide, calcium carbonate, calcium phosphate di-hydrate, calcium pyrophosphate, alumina oxide, perlite (70-75% silica dioxide) and sodium bicarbonate, which, together with the toothbrush bristles, remove the outer stained plaque, but do not change the color of the teeth. The problem with this is that the abrasive substances are effective only in places which can be reached by the toothbrush bristles therefore the effect is very slight on proximal surfaces and near the gum lines, as well as with compressed teeth [2].

4.1.2. Whitening toothpastes with chemicals

Surface stains can be reduced by adding various chemicals to toothpaste. Most of the stain molecules are included in the pellicle, which contains protein. Therefore enzymes such as protease and papaine create a whitening effect. This affects all locations where the toothpaste penetrates – including proximal surfaces and near gum lines which are difficult to reach with a toothbrush. Sodium pyrophosphate, sodium tripolyphosphate and other pyrophosphates can bind with the enamel, dentin on tartar and absorb the stain molecules, creating a whitening effect [2].

4.2. Bleaching toothpastes

Also bleaching toothpastes contain chemicals, most commonly – hydrogen peroxide or calcium peroxide (Calprox) [2, 4]. When peroxides touch the tooth surface or penetrate the tooth tissue, they break down the stain molecule, providing a bleaching effect. Various bleaching systems – for home use or professional ones – also contain these substances [51]. When adding peroxides to a toothpaste it should be noted that the concentration is small (usually 1% hydrogen peroxide or 0.5-0.7% calcium peroxide), and that there is a short exposure time [51], therefore there is a lack of evidence about whether such toothpastes can improve the internal tooth color. They certainly bleach the pellicle on the tooth surface [2].

5. Toothpastes with a specific purpose

Some manufacturers claim to produce toothpastes to treat specific conditions, and such products do not belong to classification groups mentioned previously. Toothpastes containing olive oil, betaine and xylitol can stimulate salivary secretion when at rest, thus increasing the basal rate of salivary secretion [53]. In case of xerostomia, the mucous membrane is more sensitive and more vulnerable so one should avoid irritating toothpastes, such as those that contain strong essential oils and foaming substances [54], but antioxidants and enzymes such as lactoperoksidase, lysozyme, lactoferrin and glycozyloksidase are advisable. These ensure salivary function [23].

The other example of toothpastes claim to solve specific problems, are antiviral products. It has been proven that lariphan can mobilize the body's natural immune responses, providing antiviral and immunomodulatory activity. This also inhibits the penetration and growth of pathogenic bacteria [55, 56]. Since the oral mucosa is a pathway for infection, it is likely that regular use of lariphan-containing toothpaste can prevent the formation and progression of inflammation caused by viruses and bacteria. This could be an effective prevention and treatment

of stomatitis (particularly herpetic), gingivitis and periodontitis.

DISCUSSION

Toothpastes for caries prevention and treatment

Fluoride containing toothpastes are recognized as the best source of fluoride, which most effectively protect deciduous teeth and permanent teeth from caries [1]. There are not enough randomized controlled clinical trials, which would compare the clinical caries preventive effect of aminofluoride toothpastes and non-organic fluoride toothpastes. It is also proven that during dental cleaning, the fluoride concentration in contact with the enamel [17] is more important than the total amount of fluoride in the mouth. This suggests that all substances that dilute toothpaste, i.e the release of saliva, also reduce fluoride re-mineralization. Strong spices and irritants can increase the secretion of saliva which causes a salivary protective reaction. Irritants include such substances as sodium lauryl-sulfate, which is the most common foaming substance added to toothpastes [54]. Aminofluorides also possess surface active substance properties, however no negative irritation has been observed.

Toothpastes for periodontal disease prevention and treatment

Careful mechanical remove of plaque is the mainstay of periodontal disease prevention, however toothpastes with triclosan and copolymer combination reduces dental plaque and symptoms of gingivitis [57], this support recommendation to use such dentifrices for prevention and treatment of periodontal diseases. There is not enough evidence about dentifrices with chlorhexidine.

Toothpastes for sensitive teeth treatment

Although there are several clinical and *in vitro* studies showing the efficacy of potassium salts, in the Cochrane systematic review, no evidence was found showing the efficacy of potassium nitrate [35]. All toothpastes containing substances that block the dentin tubules, were shown to have the best analgesic effects. In recent literature, there have been several articles about arginine and strontium acetate. This is reflected in the timing of toothpastes containing these substances appearing on the market. These toothpastes are produced by two competing companies. All the research is financed by these companies, therefore it is difficult to evaluate that research objectively. However using existing information, it is possible to analyze these results. It has been proven that tooth brushing itself results in some dentin tubule blockage, due to the created layer of chips, but each added substance can enhance this effect [40]. As mentioned above, fluoride compounds, as well as silicates, arginine and strontium salts possess this tubular blocking effect. One *in vitro* study, sponsored by Colgate, shows that asinine has a better effect than strontium chloride (Sensodyne original) or strontium acetate (Macleans sensitive) [47], but in another *in vitro* study, sponsored by Sensodyne, toothpaste containing strontium acetate (Sensodyne) shows better dentin tubules blocking ability than arginine (Colgate) [48]. In another independent study comparing a calcium sodium phosphosilicate-containing toothpaste (Novamin) with a potassium nitrate, sodium fluoride, and silica dioxide containing toothpaste (Sensodyne) and a potassium citrate, sodium monofluorophosphate and silica dioxide containing toothpaste (Colgate), the best results were returned by Novamin and Sensodyne toothpastes, while the Colgate toothpaste (with a very similar composition to the Sensodyne toothpaste) was most effective at tubular blocking, but when inserted into artificial saliva or an acid solution, this efficacy was lost [40]. This shows that the overall composition of the toothpaste plays the most important role, and possibly, the particular fluoride compound. Therefore it is possible that the Sensodyne toothpaste with strontium acetate and the more effective fluoride compound [54] is more effective than Macleans sensitive toothpaste with strontium acetate, and therefore, it is more effective than an arginine-containing toothpaste. However, randomized clinical trials show only minor clinical efficacy of strontium acetate-containing toothpaste when compared to arginine-containing toothpaste [50].

Whitening and bleaching toothpastes

Although in several studies whitening toothpastes show the ability to improve tooth color, they have several side effects [2]. The most significant is enamel and dentin abrasion, which in turn leads to increased tooth sensitivity. A key indicator of toothpaste abrasiveness is RDA – the larger the number, the greater the potential of dentin abrasiveness. [58]. Dentin abrasion significantly increases when the concentration of abrasive substances in toothpaste is increased. [59]. This also increases the potential of enamel abrasion, and, although in no particular study was this statistically significant, it may have clinical significance [59]. Of course, teeth have a natural defense mechanism against abrasion – pellicle, the presence of which on tooth surfaces reduces the abrasive effect of toothpaste on enamel [60]. Therefore it is best to avoid mechanical tooth

cleaning after consuming acidic foods or drinks, as they may dissolve the pellicle and can combine abrasive and erosive defects. This should be taken into account when analyzing research. More precise results will come with *in situ* or in vivo studies [36]. When applied to the surface of a titanium implant, abrasives in a neutral or alkaline medium are shown to have a negative effect, but in the presence of acid, the implant surface is not damaged [61]. For a patient who has had tooth replacement with implants, the use of whitening abrasive toothpaste is not recommended.

There are not enough observational studies about bleaching systems for home-use, including bleaching toothpastes. Therefore, when recommending such toothpastes to patients, all possible side effects should be taken into account – including increased tooth sensitivity and gum irritation [51] as well as more abrasive tooth tissue loss, if the bleaching compounds in toothpaste are combined with abrasive substances [58].

Toothpastes with specific performance

Some of toothpastes on the market have specific characteristics, which do not belong in the previously described classifications. Since xerostomia increases the risk of caries, fluoride is an essential requirement, but, in addition to it fluoride toothpastes should also contain substances that partly replace salivary function – mainly lubrication and antibacterial functions [53].

Although there are not enough clinical trials on the effectiveness of lariphan-containing toothpaste, current publications indicate that such toothpastes could be recommended to patients prone to herpetic infection or autoimmune reactions – aphtae.

IMPLICATION TO RESEARCH

There are not enough good quality systematic reviews and in some topics even randomized clinical trials addressing the following research questions:

- Is there any difference in clinical effectiveness of toothpastes with different fluoride formulations;
- Is fluoride toothpaste with xylitol more effective than conventional fluoride dentifrice;
- Is there any clinical effect after use of enzyme containing toothpastes;
- Are toothpastes with chlorhexidine effective in prevention and treatment of periodontal diseases;
- Is there any evidence to add herbal extracts in dentifrices;
- Are toothpastes with chemicals able to occlude dentinal tubules effective in reducing teeth sensitivity;
- Does the risk/benefit proportion supports usage of whitening toothpastes.

There are still several toothpastes available in the market claiming to have some special effect without having any evidence in literature.

REFERENCES

1. Marinho VCC, Higgins JPT, Sheiham A, Logan S. One topical fluoride (toothpastes, or mouthrinses, or gels, or varnishes) versus another for preventing dental caries in children and adolescents (Review). *Cochrane Database Syst Rev* 2009;1:1-15.
2. Joiner A. Whitening toothpastes: A review of the literature. *J Dent* 2010;38:17-24.
3. Jung-Te Lin, Chung-Hung Tsai, Li-Chiu Yang, Yu-Chao Chang. Clinical efficacy of phase I therapy combined with a triclocan/copolymer dentifrice on generalized chronic periodontitis. *J Dent Sci* 2010;5:216-20.
4. Davies R, Scully C, Preston AJ. Dentifrices - an update. Med Oral Patol Oral *Cir Bucal* 2010;15(6):e976-82.
5. Ciancio SG. Controlling biofilm with evidence-based dentifrices. *Compend Contin Educ Dent* 2011;32:70-6.
6. Gonzalez-Cabezas C. The Chemistry of caries: remineralization and demineralization events with direct clinical relevance. *Dent Clin N Am* 2010;54:469-78.
7. Burt BA. The Changing patterns of systemic fluoride intake. *J Dent Res* 1992;71:1228-37.
8. Lima TJ, Ribeiro CC, Tenuta LM, Cury JA. Low-fluoride dentifrice and caries lesion in children with different caries experience: a randomized clinical trial. *Caries Res* 2008;42:46-50.
9. Twetman S. Caries prevention with fluoride toothpaste in children: an update. *Eur Arch Paediatr Dent* 2009;10:162-7.
10. Scottish dental clinical effectiveness programme. prevention and management of dental caries in children. Dundee dental education center; 2010.
11. New Zealand Guidelines Group. Guidelines for the use of fluorides. Wellington: New Zealand Ministry of Health; 2009.
12. Rasines G. Fluoride toothpaste prevents caries in children and adolescents at fluoride concentrations of 1000 ppm and above. *Evid Based Dent* 2010;11:6-7.
13. Wong MCM, Glenny AM, Tsang BWK, Lo ECM, Worthington HV, Marinho VCC. Topical fluoride as a cause of dental fluorosis in children (Review). *Cochrane Database Syst Rev* 2010;6:1-26.
14. Travener JA, Davies GM, Davies RM, Ellwood RP. The prevalence and severity of fluorosis in children who received toothpaste containing either 440 or 1450 ppm F from the age of 12 months in deprived and less deprived communities. *Caries Res* 2006;40:66-72.
15. Walsh T, Worthington HV, Glenny AM, Appelbe P, Marinho VC, Shi X. Fluoride toothpastes of different concentrations for preventing dental caries in children and adolescents (Review). *Cochrane Database Syst Rev* 2010;(1):CD007868.
16. Marinho VCC, Higgins JPT, Sheiham A, Logan S. Combinations of topical fluoride (toothpastes, mouthrinses, gels, varnishes) versus single topical fluoride for preventing dental caries in children and adolescents (Review). *Cochrane Database Syst Rev* 2009;1:1-15.
17. Ellwood RP, Cury JA. How much toothpaste should a child under the age of 6 years use. *Eur Arch Paediatr Dent* 2009;10:168-74.
18. Wolfgang AH, Haase A, Hacklaender J, Gintner Z, Bánóczy

J, Gaengler P. Effect of pH of amine fluoride containing toothpastes on enamel remineralization in vitro. *BMC Oral Health* 2007;5:3-8.
19. Wolfgang AH, Dorow A, Langenhorst S, Gintner Z, Bánóczy J, Gaengler P. Effect of fluoride toothpastes on enamel demineralization *BMC Oral Health* 2006;6:1-7.
20. Fowler CE, Gracia L, Edwards MI, Rees GD, Brown A. Fluoride penetration from toothpastes into incipient enamel erosive lesions investigated using dynamic secondary ion mass spectrometry. *J Clin Dent* 2009;20(Spec Iss):186-91.
21. Künzel W, Franke W, Treide A. [Clinical-radiological parallel control of a longitudinal study of the anti-caries effect of aminofluoride applied locally for 7 years in a double-blind test]. *Zahn Mund Kieferheilkd Zentralbl* 1977;65(6):626-37.
22. Bär A. Caries prevention with xylitol. A review of the scientific evidence. *World Rev Nutr Diet* 1988;55:183-209.
23. Hannig C, Spitzmüller B, Lux HC, Altenburger M, Al-Ahmad A, Hannig M. Efficacy of enzymatic toothpastes for immobilisation of protective enzymes in the in situ pellicle. *Arch Oral Biol* 2010;55:464-9.
24. Tschoppe A, Zandim DL, Sampaio JEC, Kielbassa AM. Saliva substitute in combination with high-concentrated fluoride toothpaste: Effects on demineralised dentin in vitro. *J Dent* 2010;38:207-13.
25. Diamanti I, Koletsi-Kounari H, Mamai-Homata E, Vougiouklakis G. Effect of fluoride and calcium sodium phosphosilicate toothpastes on pre-softened dentin demineralization and remineralization in vitro. *J Dent* 2010;38:671-7.
26. Martinus JV, Henk JB, Debbie J, Anje MS, Frank A, Henny CM. Efficacy of natural antimicrobials in toothpaste formulations against oral biofilms in vitro *J Dent* 2011;39:218-24.
27. Battino M, Ferreiro MS, Armeni T, Politi A, Bompadre S, Massoli A, et al. In vitro antioxidant activities of antioxidant-enriched toothpastes. *Free Radic Res* 2005;39:343-50.
28. Blikhorn A, Bartold PM, Cullinan MP, Madden TE, Marshall RI, Raphael SL, et al. Is there a role for triclosan/copolimer toothpaste in the management of periodontal desease? *Br Dent J* 2009;207:117-25.
29. Mickenautsch S, Yengopal V. Extent and quality of systematic review evidence related to minimum intervention in dentistry: essential oils, powered toothbrushes, triclosan, xylitol. *Int Dent J* 2011;61:179-92.
30. Davies RM, Ellwood RP, Davies GM. The effectiveness of a toothpaste containing triclosan and polyvinyl-methyl ether maleic acid copolymer in improving plaque control and gingival health: a systematic review. *J Clin Periodontol* 2004;31:1029-33.
31. Allmyr M, Panagiotidis G, Sparve E, Diczfalusy U, Sandborgh-Englund G. Human exposure to triclosan via toothpaste does not change CYP3A4 activity or plasma concentrations of thyroid hormones. *Basic Clin Pharmacol Toxicol* 2009;105:339-44.
32. Aiello AE, Larson EL, Levy SB. Consumer antibacterial soaps: effective or just risky? *Clin Infect Dis* 2007;45(Suppl 2):S137-47.
33. Ribeiro LG, Hashizune LN, Maltz M. The effect of different formulations of chlorhexidine in reducing levels of mutants streptococci in the oral cavity: a systematic review of the literature. *J Dent* 2007;35:359-70.
34. Bailey D, Adams G, Marinho VCC, Tsao C, Hyslop A, Morgan M. Chlorhexidine interventions for the prevention of caries in adults (protocol). *Cochrane Database Syst Rev* 2009;3:1-5.
35. Bartold PM. Dental hypersensitivity: a review. *Aust Dent J* 2006;51(3):212-218.
36. Shen SY, Tsai CH, Yang LC, Chang YC. Clinical efficacy of toothpaste containing potassium citrate in treating dentin hypersensitivity. *J Dent Sci* 2009;4:173-7.
37. Poulsen S, Errboe M, Lescay Mevil Y, Glenny AM. Potassium containing toothpastes for dentine hypersensitivity (Review). *Cochrane Database Syst Rev* 2008;8:1-17.
38. Hooper SM, Newcombe RG, Faller R, Eversole S, Addy M, West NX. The protective effects of ttothpastes against erosion by orange juice: Studies in situ and in vitro. *J Dent* 2007;35:476-81.
39. Charig AJ, Thong S, Flores F, Gupta S, Major E, Winston AE. Mechanism of action of desensitizing fluoride toothpaste delivering calcium and phosphate ingredients in the treatment of dental hypersitivity. Part II: comparison with a Professional treatment for tooth hypersensitivity. *Compend Contin Educ Dent* 2009;30:622-4, 626, 628
40. Wang Z, Sa Y, Sauro S, Chen H, Xing W, Ma X, et al. Effect of desensitising toothpastes on dentinal tubule occlusion: A dentine permeability measurement and SEM in vitro study. *J Dent* 2010;38:400-10.
41. Yin W, Li X, He S, Ma H, Hu D, Zhang YPZ, et al. Extrinsic stain removal eficacy of a new desensitizing dentifrice containing 8.0% arginine, calcium carbonate and 1450 ppm fluoride. Am J Dent 2010;23 Sp Is:36A-40A.
42. Ayad F, Ayad N, Zhang YP, DeVizio W, Cummins D, Mateo LR. Comparing the efficacy in reducing dentin hypersensitivity of a new toothpaste containing 8.0% arginine, calcium carbonate, and 1450 ppm fluoride to a commercial sensitive toothpaste containing 2% potassium ion: an eight-week clinical study on canadian adults. *J Clin Dent* 2009;20(Spec Iss):10-16.
43. Docimo R, Montesani L, Maturo P, Costacurta M, Bartolino M, DeWizio W, et al. Comparing the efficacy in reducing dentin hypersensitivity of a new toothpaste containing 8.0% arginine, calcium carbonate, and 1450 ppm fluoride to a commercial sensitive toothpaste containing 2% potassium ion: an eight-week clinical study in Rome, Italy. *J Clin Dent* 2009;20(Spec Iss):17-22.
44. Schiff T, Delgado E, Zhang YP, DeWizio W, Cummins D, Mateo LR. The clinical effect of a single direct application of a dentifrice containing 8.0% arginine, calcium carbonate, and 1450 ppm fluoride on dentin hypersensitivity: The use of a cotton swab applicator versus the use of a fingertip. *J Clin Dent* 2009;20(Spec Iss):131-6.
45. Ayad F, Ayad M, Delgado E, Zhang YP, DeWizio W, Cummins D, et al. Comparing the efficacy in providing instant relief of dentin hypersensitivity of a new toothpaste containing 8.0% arginine, calcium carbonate, and 1450ppm fluoride to a benchmark desensitizing toothpaste containing 2% potassium ion and 1450ppm fluoride, and to a control toothpaste with 1450ppm fluoride: A three-day clinical study in Mississauga, Canada. *J Clin Dent* 2009;20(Spec Iss):115-122.
46. Nathoo S, Delgado E, Zhang YP, DeWizio W, Cummins D, Mateo LR. Comparing the efficacy in providing instant relief of dentin hypersensitivity of a new toothpaste containing 8.0% arginine, calcium carbonate, and 1450ppm fluoride to a benchmark desensitizing toothpaste containing 2% potassium ion and 1450ppm fluoride, and to a control toothpaste with 1450ppm fluoride: A three-day clinical study in New Jersey, USA. *J Clin Dent* 2009;20(Spec Iss):123-30.
47. Anonymous. Comparison of the effectiveness of Colgate Sensitive Pro-relief and two strontium-based commercial toothpastes in occluding dentin tubules measured using hydraulic conductance. *Clinical Evidence*: Colgate Sensitive Pro-Relief Desensitizing Products with Pro-Arginin Technology 2010; IADR General Session Barcelona. p. 19-20.
48. Addy M, Smith SR. Dentin hypersensitivity: A overview on which to base tubule occlusion as a management concept. *J Clin Dent* 2010;21(Spec Iss):25-30.
49. Earl JS, Ward MB, Langford RM. Investigation of dentinal tubule occlusion using FIB-SEM milling and EDX. *J Clin Dent* 2010;21(Spec Iss):37-41.
50. Mason S, Hughes N, Sufi F, Bannon L, Maggio B, North M, et al. A comparative clinical study investigating the efficacy of a dentifrice containing 8% strontium acetate and 1040 ppm fluoride in a silica base and a control dentifrice containing 1450 ppm fluoride in a silica base to provide immediate relief of dentin hypersensitivity. *J Clin Dent* 2010;21(Spec Iss):42-8.
51. Hasson H, Ismail A, Neiva G. Home-based chemically-induced whitening of teeth in adults (Review). *Cochrane Database Syst Rev* 2008;4:1-22.
52. Baig A, He T, Buisson J, Sagel L, Suszcynsky-Meister E, White DJ. Extrinsic whitening effects of sodium hexametaphosphate-a review including a dentifrice with stabilized stannous fluoride. *Compend Contin Educ Dent* 2005;26:47-53.
53. Ship JA, Mccutcheon JA, Spivakovsky S, Kerr AR. Safety and effectiveness of topical dry mouth products containing olive oil, betaine, and xylitol in reducing xerostomia for polypharmacy-induced dry mouth. *J Oral Rehabil* 2007;34:724-32.
54. Mason SC. New in vitro and in situ evidence for a toothpaste formulated for those at risk from erosive tooth wear. *J Clin Dent* 2009;20(Spes Iss):175-7.

55. Silin DS, Lyubomska OV, Ershov FI, Frolov VM, Kutsyna GA. Synthetic and natural immunomodulators acting as interferon inducers. *Curr Pharm Des* 2009;15:1238-47.
56. Denisov AA, Korobovtseva YS, Karpova OM, Tretjakova AV, Mikhina LV, Ivanov AV, et al. Immunopotentiation of live brucellosis vaccine by adjuvants. *Vaccine* 2010;28S:F17-22.
57. Blinkhorn A, Bartold PM, Cullinan MP, Madden TE, Marshall RI, Raphael SL, et al. Is there a role for triclosan/copolymer toothpaste in the management of periodontal disease? *Br Dent J* 2009;207:117-25.
58. Macdonald E, North A, Maggio B, Sufi F, Mason S, Moore C, et al. Clinical study investigating abrasive effects of three toothpastes and water in an in situ model. *J Dent* 2010;38:509-16.
59. Franzo D, Philpotts CJ, Cox TF, Joiner A. The effect of toothpaste concentration on enamel and dentine wear in vitro. *J Dent* 2010;38:974-9.
60. Joiner A, Schwarz A, Philpotts CJ, Cox TF, Huber K, Hannig M. The protective nature of pellicle towards toothpaste abrasion on enamel and dentine. *J Dent* 2008;36:360-8.
61. Hossain A, Okawa S, Miyakawa O. Surface texture and composition of titanium brushed with toothpaste slurries of different pHs. *Dent Mater* 2007;23:186-92.
62. Walsh T, Worthington HV, Glenny AM, Appelbe P, Marinho VC, Shi X. Fluoride toothpastes of different concentrations for preventing dental caries in children and adolescents. *Cochrane Database Syst Rev* 2010;(1):CD007868.
63. Øgaard B, Alm AA, Larsson E, Adolfsson U. A prospective, randomized clinical study on the effects of an amine fluoride/stannous fluoride toothpaste/mouthrinse on plaque, gingivitis and initial caries lesion development in orthodontic patients. *Eur J Orthod* 2006;28:8-12.
64. Hayes C. The effect of non-cariogenic sweeteners on the prevention of dental caries: a review of the evidence. *J Dent Educ* 2001;65:1106-9.
65. Santos A. Evidence-based control of plaque and gingivitis. *J Clin Periodont* 2003;30(Suppl.5):13-6.

Received: 05 05 2011
Accepted for publishing: 18.03.2012