REVIEWS

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The Role of Stabilized Stannous Fluoride and Sodium Hexametaphosphate Contained in Toothpastes in Preventing Tartar Deposition and Tooth Discoloration

Rola stabilizowanego fluorku cyny i sześciometafosforanu sodu zawartych w pastach do zębów w zapobieganiu tworzenia się kamienia nazębnego i przebarwień zębów

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A – research concept and design; **B** – collection and/or assembly of data; **C** – data analysis and interpretation; **D** – writing the article; **E** – critical revision of the article; **F** – final approval of article

Abstract

On the basis of the literature, the paper proves that toothpastes containing stabilized stannous fluoride – sodium hexametaphosphate (SHMP) effectively and safely reduce tartar formation. Inhibition of tartar, and thus the reservoir of the live bacteria, contribute to the reduction of periodontal inflammation. *In vitro* studies have shown that pyrophosphate inhibits the growth and mineralization of dental plaque by a chelate effect of the minerals. Showing a very strong affinity to the surface of hydroxyapatite, strongly bound to the tooth surface and tartar, and coating the new embryos, it inhibits the growth of mineral crystals. Tartar formation can be prevented through regular, proper tooth brushing using not only brushes but also dental floss and dentifrices which contain chemicals preventing calculus formation. The toothpastes remove external stains and their effectiveness is comparable to the whitening ones. They also have bleaching properties which are important because of the aesthetic aspect. SHMP was shown to be highly chemically active agent for stain prevention and reduction of the pellicle conditioning film thicknesses (**Dent. Med. Probl. 2016, 53, 2, 273–277**).

Key words: toothpastes, stannous fluoride, sodium hexametaphosphate, dental calculus.

Słowa kluczowe: pasty do zębów, fluorek cyny, sześciometafosforan sodu, kamień nazębny.

Calculus are calcified deposits on the teeth formed by the continuous presence of dental plaque. The surface of calculus is very rough, which makes oral hygiene more difficult and allows new biofilm to accumulate [1]. Generally, calculus accumulation is the result of inadequate oral care [2].

Calculus creates a strong bond with the tooth surface that can only be removed by a professional dental cleaning. Saliva is the main source of the calcium needed for calculus formation and because the saliva glands are located in the lower jaw, below the tongue, tartar is mainly formed on the back side of the lower front teeth.

How can one prevent the formation of tartar? Primarily through regular, proper tooth brushing using not only brushes but also dental floss and dentifrices which contain chemicals to prevent calculus formation. Dentifrice formulations with anticalculus ingredients inhibit its formation between dental visits, as a result, improved oral hygiene.

Dental calculus could be supragingival or subgingival according to its location relative to the gingival margin. Differences in hardness be-

tween the two types of dental calculus are probably due to differences in the degree of calcification. The content of minerals in the supra- and subgingival calculus have been fully determined and the average is between 37 and 58% [3]. The composition and properties of tartar are very well understood on the basis of research and analytical chemistry [4–6].

A study using light and transmission electron microscopy has demonstrated that supragingival calculus forms a number of different crystalline forms. New crystals are composed of calcium phosphate, which builds up, hardens and forms into tartar. It is very interesting that the observation of the authors has demonstrated the presence of non-mineralized canals linking the extensive gaps (lacunae), places which were littered with bacteria, mainly cocci and rods [7].

On the other hand, the subgingival stone structure was compacted, dense, of uniform mineralization and was observed without channels and lacunae. In trying to explain why the formation of these channels occurs, the authors suggested the contribution of filamentous bacteria in the supragingival plaque, which may have inhibitory properties of mineralization. It was also found that the differences in calcification between different bacterial colonies lead to the mineralization of the superficial layers of plaque, preventing the delivery of minerals into the deeper layers [8, 9]. Moreover, testing tartar samples taken from patients with gingivitis and observed under fluorescence and a confocal laser scanning microscope, when combined with microbiological examination, showed that viable aerobic and anaerobic bacteria were present within supragingival calculus, specifically within the internal channels and lacunae [10].

These findings are of great clinical importance because calculus could be a reservoir of pathogenic periodontal bacteria [11, 12]. Incomplete removal of supragingival calculus may expose these reservoirs of possible pathogenic bacteria and be a factor in the recurrence of periodontal diseases after treatment.

The first chemical compound added to a toothpaste that controlled tartar formation was pyrophosphate [13]. *In vitro* studies have shown that pyrophosphate inhibits the growth and mineralization of dental plaque via a chelate effect of the minerals. Showing a very strong affinity to the surface of hydroxyapatite, strongly bound to the tooth surface and tartar, and coating the new embryos inhibited the growth of mineral crystals [14–16]. In turn, based on clinical studies, White et al. confirmed a significant reduction in dental plaque compared to the control paste (restricting the mineral formation by approx. 40–50%) [17].

Another form of pyrophosphate is sodium hexametaphosphate (SHMP). It is a polymer with an average of twenty-one repeating subunits, giving it a stronger attraction to calcium hydroxyapatite in enamel and dentin relative to pyrophosphates, which have two phosphate units. Therefore, the SHMP ability to inhibit both calculus and stain formation at the enamel surface is better. The results of *in vitro* studies show the HSMP in solution had a strong affinity for HAP surfaces as well as good inhibitory activity of HAP crystal growth. Hexametaphosphate dentifrice showed decreased mineralization. The reduction was 69% after topical applications of HSPM [18].

Results of clinical studies carried out by Liu et al. [19] on a group of 551 participants, (duration of the study – 8 months), demonstrated significantly higher tartar inhibition upon use of the experimental SHMP paste compared to the control one.

A new toothpaste formula containing stannous fluoride with SHMP in a very low water formulation has made it possible to obtain the maximal biochemical availability of stannous fluoride, which is stabilized and afforded advanced protection against the formation of tartar and stains on tooth surfaces. It was also possible to obtain a pleasant taste, which is not without significance for the users.

Shiff et al. [20] made a clinical assessment of a toothpaste (0.454% stabilized stannous fluoride/13% SHMP) and compared it to a marketed, tartar control, 0.30% triclosan/0.243% NaF/2% copolymer dentifrice. The study subjects were 81 participants with the ability to form at least 1.5 mm of calculus on the anterior mandibular teeth (lingual surface) in an 8-week pre-test phase following dental prophylaxis. The Volpe-Manhold Index [21] was used to measure calculus on the lingual surfaces of the lower 6 anterior teeth. The Lobene index [22] was used to measure the stain on the facial surfaces of 12 anterior teeth. Subjects were randomized to either SnF_2/SHMP dentifrice or the control one, and used the toothpaste twice a day for 6 months. The examination for calculus and stain was done again after 3 and 6 months. The results showed a 54% reduction in calculus accumulation at month 3 and a a 56% reduction at month 6. No appreciable extrinsic stain accumulation was noticed. Almost the same results were obtained by Winston et al. [23], who observed a 50% reduction of calculus formation after 3 months of using the above dentifrice formula by 142 participants and 55% reduction after 6 months.

Subsequent clinical studies when a similar research protocol was used have shown a 70% reduction of calculus formation both at month 3

Table 1. Clinical studies evaluating stannous fluoride and SHMP dentifrices on calculus formation and extrinsic whitening

References	Study subjects (n)	Duration of the study	Index used	Results of the study
Liu et al. [19] 2002	551 Only SHMP	8 months (2 + 6)	Volpe-Manhold	After 6 months, the study group exhibited calculus inhibition ($p< 0.01$) compared to the control group
Shiff et al. [20] 2005	81	6 months	Volpe –Manhold (mm) Study control Initial – 16.66 15.88 3 m. 5.41 11.74 6 m. 6.92 15.79 $p < 0.0001$	After 3 months, 54% of calculus reduction, after 6 months – 56%
Winston et al. [23] 2007	142	6 months	Volpe –Manhold (mm) Study control Initial – 26.96 27.79 3 m. 7.43 14.96 6 m. 9.27 20.78 $p < 0.001$	After 3 months – 50% calculus reduction, after 6 – 55%
He et al. [24] 2008	77	6 months	Volpe Manhold Lobene Stain (significantly lower compared to the control after 3 months ($p < 0.01$)	After 3 and 6 months, 70% calculus reduction
Milleman et al. [25] 2011	75	3 months	Volpe Manhold	After 6 weeks – 30.3% of calculus reduction, after 3 months – 26.5%
He et al. [28] 2007	52 – study 1 58 – study 2	3 weeks 6 weeks	Lobene Stain The average value significantly lower after 3 and 6 weeks ($p < 0.0001$)	a significant level of activity removing external discoloration
Terezhalmy et al. [29] 2007	29 – study 1 30 – study 2	2 weeks	Lobene Stain	A significant reduction of discoloration compared to the initial values Study 1 – 61.8% and 96.6% control Study 2 – 61.9% and 94.4% control
Terezhalmy et al. 2011	59	3 weeks 6 weeks	Lobene Stain (LSI) + control 3 weeks 1.59 1.52 6 weeks 2.05 2.13	improving discolored sites Week 3 – 95% comp. to 90% + control Week 6 – 99% comp. to 100% + control
Amini et al. [31] 2015	30	3 weeks: two step SnF_2 paste and H_20_2 gel	Lobene Stain Gingival Bleeding Index (GBI)	100% subjects – improvements of stain 97% subjects – improvements in gingivitis
Amini et al. [32] 2015	61	1 week two step SnF_2 paste and H_20_2 gel	LSI GBI	Significant ($p= 0.0001$) improvement of gingivae and stain status compared to the control

and 6 [24], and 30.3% reduction at week 6 and 26.5% at month 3 [25].

Pyrophosphates are also the most common agents responsible for whitening control, which is a chemical mechanism [26, 27]. The ability of this agent increases with the length of the molecule. During absorption to mineral sites, they desorb portions of the adsorbed proteins, *i.e.* pellicle proteins containing stain chromogens. Longer molecules with a longer molecular weight have more binding sites, giving them a greater chance of adsorption and retention on the tooth surface. SHMP's multiple binding sites results in its ability to remove extrinsic surface discoloration and inhibit new chromogens from being adsorbed into proteins in the pellicle. SHMP was shown to be a highly chemically-active agent for stain prevention [26] and reduction of pellicle conditioning film thicknesses [27].

Numerous clinical trials have been carried out, comparing the scope of stain removal by the dentifrice with a stabilized SnF_2-SHMP to a positive control whitening dentifrice [28–30]. The results have shown (always two independent clinical trials) that the Lobene stain scores were significantly reduced by 61.8% and 96.6% for the SnF_2/SHMP group and the control group, respectively, in study 1; and 61.9% and 94.4% for the

SnF_2/SHMP group and the control group, respectively, in study 2 (two weeks study) [29]. Other experiments demonstrated a comparable extrinsic stain removal efficacy of the stannous fluoride dentifrice with SHMP relative to the positive control one [28, 30].

Recent data from studies presented at the IADR 2015 congress show attempts to determine the relationship between the therapeutic and aesthetic two-stage action of SnF_2 dentifrice and then a gel with 3% H_2O_2 [31, 32]. After three weeks of using the above formulations, improvement in both the state of the gums and the aesthetic appearance of teeth was achieved, which indicates the correlated effect of the two components [31]. There were no side effects, and short, 1-week, randomized study, which involved 61 patients, showed a significant reduction in surface discoloration and gingivitis only after application of a toothpaste and the gel with hydrogen peroxide. The control dentifrice containing sodium monofluorophosphate showed no such action [32].

Conclusions: Toothpaste containing stabilized stannous fluoride – sodium hexametaphosphate – effectively and safely reduces the tartar formation. Tartar inhibition, and thus the reservoir of the live bacteria, contributes to the reduction of periodontal inflammation. The toothpaste removes the external stains and its effectiveness is comparable to whitening toothpastes. It also has bleaching properties which are important because of the aesthetic aspect.

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