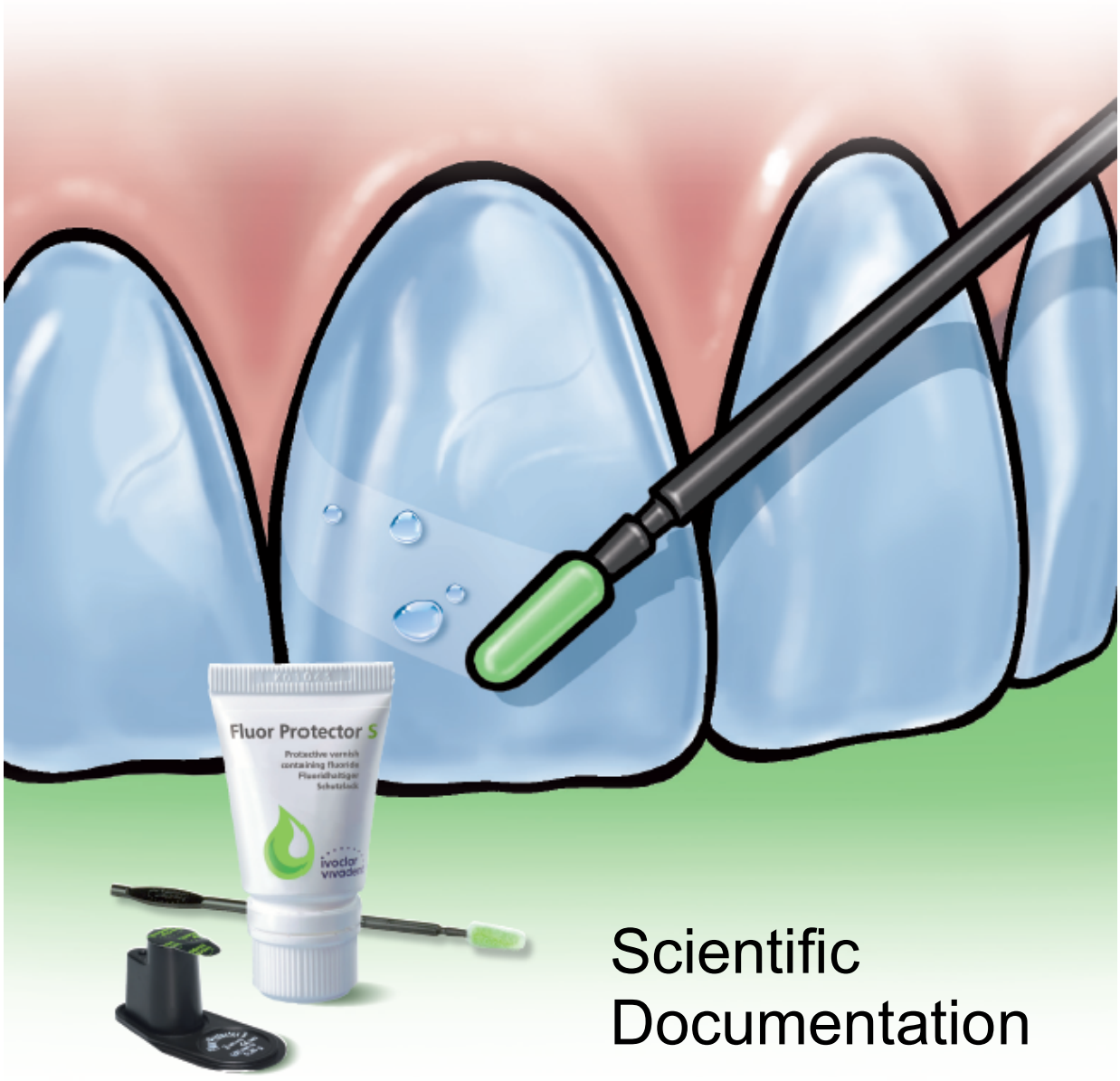
Fluor Protector S



Scientific Documentation

ivoclar vivadent
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1. Introduction

1.1 Fluoride varnishes

Oral health is crucial for overall health. Poor oral health may cause esthetic and functional impairments, pain and finally result in partial or total tooth loss. Caries is one of the most common diseases of the oral environment, affecting 20% of the children aged between 2 and 4 years and more than three quarters of the human population over 18 years of age [1]. One of the most important weapons in the fight against this disease and its consequences has proven to be fluoride.

Fluoride varnishes were first developed around the late 1960s and early 70s. The idea was that by lengthening the time the fluoride is in contact with the teeth the fluoride uptake should be increased and improved [2; 3]. In support, Zero *et al.* state that the primary anti-caries activity of fluoride occurs topically [4]. Moreover, Zimmer *et al.* note that fluoride uptake, reaction and release in enamel are strongly dependent on the duration of contact [5]. By the 1980s, fluoride varnishes were widely used throughout Europe.

The WHO note that fluoride varnishes have a significant caries reducing potential [6]. A Cochrane review of randomised/quasi-randomised controlled trials, comparing fluoride varnishes with placebo or no treatment, concluded that fluoride varnishes exhibited a significant caries-inhibiting effect in both permanent and deciduous dentitions [7].

In-vitro and *in*-vivo studies have also shown that varnishes supply fluoride more efficiently than other topical agents, e.g. gels and foams, with reductions in caries ranging from 50 to 70% [8; 9]. Furthermore, from a toxicological safety point of view, varnishes are preferable, because the bioavailability of fluoride in varnish is relatively low. In contrast, gels may have a bioavailability of almost 100%. Depending on the initial concentration of the formulation examined, plasma peaks of around 1500 ng/ml have been measured. Cousins and Mazze suggested that a plasma level of 850 ng/ml is nephrotoxic [10].

Thus, the primary reason for the wide acceptance of fluoride varnishes is the easy, safe, convenient and well accepted application procedure [11]. According to the American Dental Association, the application of fluoride varnishes is particularly beneficial in subjects with a moderate or high caries risk; for children below the age of 6 years, fluoride varnish is the only recommended fluoridation product due to the low risk of ingestion and undesirable side effects (see Table 1) [12].

Table 1: Evidence-based clinical recommendations for professionally applied topical fluoride *(Adapted from American Dental Association Council on Scientific Affairs [12])*

Risk category	Age category for recall patients		
	< 6 years	6-18 years	> 18 years
Low	May not receive additional benefit from professional topical fluoride application (fluoridated water and toothpaste may be sufficient)		
Moderate	Varnish application at 6-month intervals	Varnish application at 6-month intervals OR Fluoride gel application at 6-month intervals	
High	Varnish application at 3- or 6-month intervals	Varnish application at 3- or 6-month intervals OR Fluoride gel application at 3- or 6-month intervals	

1.2 Fluor Protector S

Fluor Protector S contains 1.5% ammonium fluoride in a varnish base with ethanol and water as solvents. The fluoride content is equivalent to 0.77%, or 7700 parts per million (ppm) in solution. As the solvents evaporate, the fluoride concentration at the tooth surface increases to considerably higher values (nearly 4 times higher, see Fig. 1).

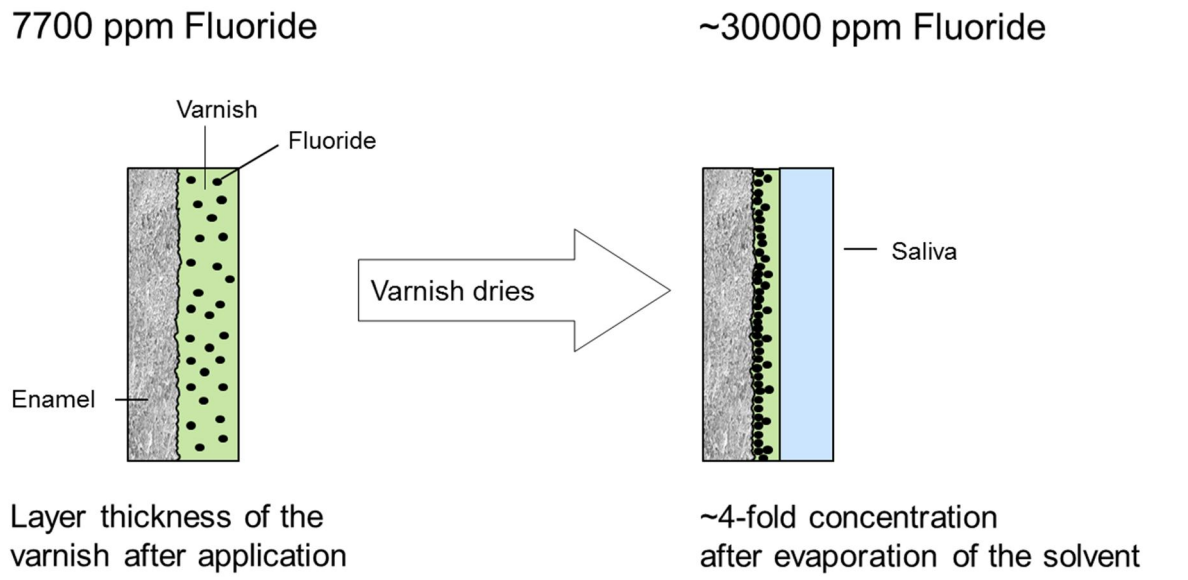


Fig. 1: Fluoride concentration of Fluor Protector S. Fluor Protector S contains 7700 ppm fluoride in solution. After application, the solvent evaporates, resulting in an approx. fourfold increase in the local fluoride concentration at the tooth surface.

Another advantage of the formulation of Fluor Protector S is the ease of application. In contrast to high-viscosity varnishes in natural resin (e.g. Duraphat), the low viscosity of Fluor Protector S ensures that the entire tooth surface is reliably wetted (see Fig. 2). Due to its low viscosity, Fluor Protector S even gains access to proximal surfaces without difficulty. Finally, the varnish hardens to a clear transparent film on the tooth surface, providing a highly esthetic result.

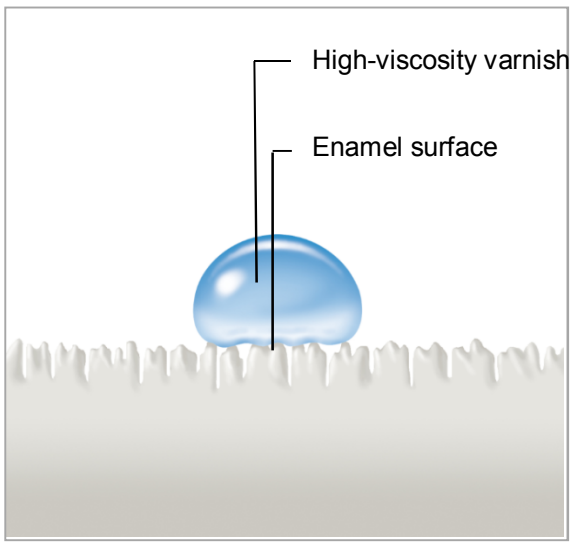


Fig. 2a: Flow properties of high-viscosity varnishes. High-viscosity fluoride varnishes sit on the enamel surface and wet the tooth only to a limited degree.

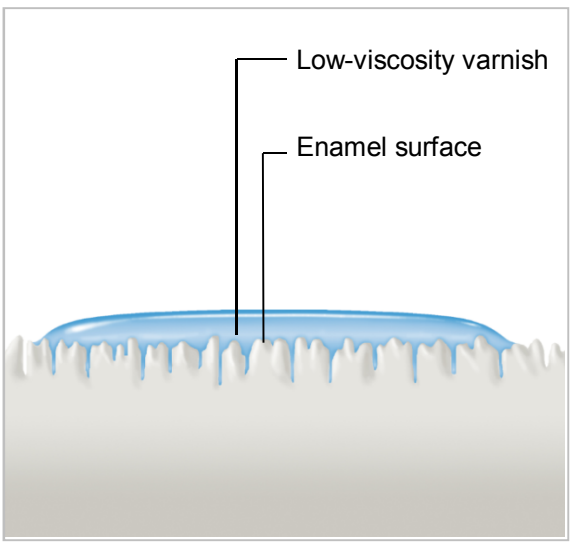


Fig. 2b: Flow properties of low-viscosity varnishes. Low-viscosity fluoride varnishes, e.g. Fluor Protector S, feature ideal flow and wetting properties and spread easily on the tooth surface.

Fluor Protector S is suitable for patients of all age groups and is professionally applied by dentists or skilled personnel. Unless otherwise indicated, a twice yearly application is sufficient.

Fig. 3: Fluor Protector S. Fluor Protector S is available in the high-yielding multi-dose dispensing tubes (left) and individual single-dose units (right). Using the Vivabrush G applicator supports the application of a thin layer.

1.3 Indications

Indications for fluoride varnishes can be divided into the categories below, but they are not entirely separate from each other:

- **Treatment of hypersensitive teeth / tooth necks**
- **Remineralisation of initial caries lesions / inhibition of demineralisation**
- **Long-term caries prophylaxis**
- **Protection from erosion**

Countless *in-vitro* and *in-vivo* studies and over 30 years of successful clinical experience attest to the efficacy of fluoride varnishes for these indications.

1.4 Working principles of fluoride

1.4.1 Fluorapatite and calcium fluoride layer formation

The benefits of fluoride in preventing enamel demineralisation, promoting remineralisation, reducing plaque growth and consequently helping to prevent dental caries are well documented [13].

In the past, the inhibition of caries by fluorides was ascribed to the reduced solubility of enamel due to the incorporation of fluoride ions into the crystal lattice of enamel in the form of fluorapatite (see Fig. 4).

Hydroxyapatite		Fluorapatite
$[Ca_3(PO_4)_2]_3 \cdot Ca(OH)_2$	$\leftrightarrow$	$[Ca_3(PO_4)_2]_3 \cdot Ca(F)_2$

Fig. 4: Conversion of hydroxyapatite to fluorapatite. In the presence of fluoride ions, the hydroxyl ion (OH^-) of the hydroxyapatite can be exchanged by fluoride (F^-), yielding fluorapatite.

Though important, this is now known to have a more limited effect, with general acceptance that the primary anti-caries activity of fluoride occurs via a different mechanism, i.e. the formation of a calcium fluoride layer over the teeth [4; 14].

Depicted in Fig. 5a, demineralisation refers to the loss of calcium and phosphate ions from the tooth structure that occurs during an acid attack by cariogenic bacteria. Fluoride can help prevent this mineral loss.

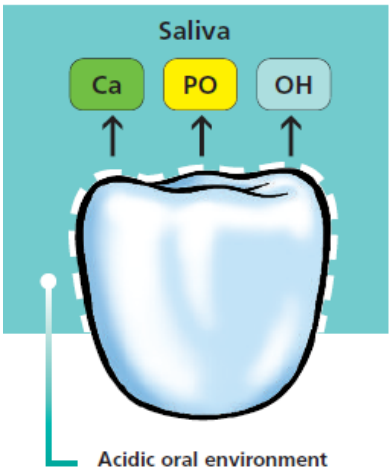


Fig. 5a: Demineralisation without fluoride protection

At acidic pH, enamel is demineralised via the release of calcium (Ca^{2+}) and phosphate ions (HPO_4^{2-}) into the saliva.

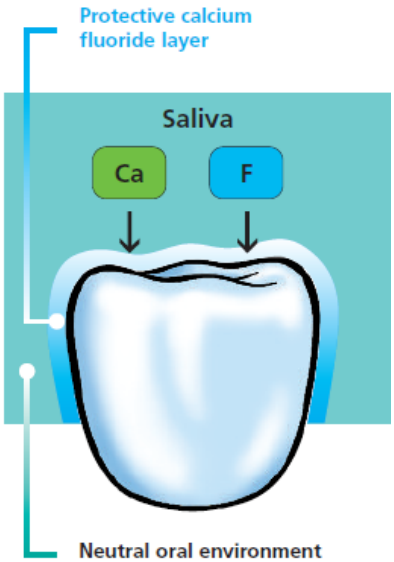


Fig. 5b: Protective calcium fluoride layer

After application of fluoride, a protective calcium fluoride layer (CaF_2) forms.

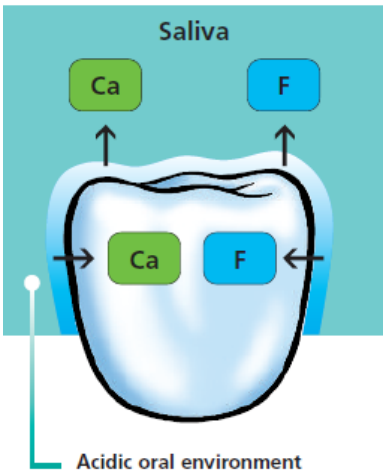


Fig. 5c: Bioavailability of fluoride

At low pH, calcium (Ca^{2+}) and fluoride (F^-) ions are released. The tooth structure is no longer attacked directly. The calcium fluoride layer forms a depot releasing fluoride over time to the saliva.

Human saliva is usually saturated with calcium, such that following a topical application of fluoride, hardly soluble calcium fluoride (CaF_2) forms and a calcium fluoride-like layer precipitates over the treated tooth surface (Figs 5b and 6).

$$Ca^{2+} + 2\ F^- \longrightarrow CaF_2$$

Fig. 6: Formation of calcium fluoride. After the application of fluoride varnish, fluoride ions and calcium ions (Ca^{2+}) contained in the saliva precipitate to form calcium fluoride (CaF_2).

It has been shown that CaF_2 particles adhere especially well to porous surfaces such as fissures and demineralised areas [15]. The adsorption of hydrogen phosphate ions additionally stabilizes the CaF_2 layer [14; 16]. At neutral pH, the CaF_2 layer is practically insoluble and may remain on the teeth for months [17].

Under acidic conditions, e.g. after carbohydrate intake and bacterial metabolism, the CaF_2 layer releases fluoride and calcium ions (Fig. 5c). The fluoride ions may remain in the saliva or settle in free spaces on the crystal lattice of the tooth structure, producing fluorapatite or fluor-hydroxyapatite, which is more stable to acid than hydroxyapatite. Fluoride ions dissolved in saliva prevent fluoride attached to the enamel from being dissolved by acids [18]. The CaF_2 layer functions therefore as a pH-controlled fluoride reservoir and is the most important supplier of free fluoride ions during the cariogenic attack [14].

Studies show that the fluoride uptake, reaction and release in the enamel are strongly dependent on the duration of contact with the fluoride agent [19]. There is no distinct difference in the caries-preventive effects of concentrate fluoride solutions, gels or varnishes

[11]. However, as fluoride varnishes adhere to tooth surfaces preventing immediate loss after application, they may be optimal in this respect.

In conclusion, fluoride provides protective action through the control of the demineralisation and remineralisation processes. Via the deposition of a calcium fluoride layer at the tooth surface, fluoride hampers acidic demineralisation of the tooth structure and promotes remineralisation.

1.4.2 Anti-plaque activity

Bacterial biofilms and dental plaque are a prerequisite for the development of caries and periodontal disease. In addition to strengthening the enamel, fluoride can help reduce plaque growth and activity. The formation of the CaF_2 layer has been suggested to impair plaque development [20]. Moreover, fluoride also reduces the cariogenic lactic acid formation in plaque bacteria, such as *Streptococcus mutans,* by impairing bacterial glucose uptake and glycolysis [21; 22]. However, chlorhexidine exerts a considerably higher anti-microbial effect than fluoride [23].

2. Composition

Fluor Protector S

Protective varnish containing fluoride

Standard - Composition (in w/w %)

Ethanol / Water	73.4
Polymer, Additive	25.0
Ammonium fluoride	1.5
Saccharin, mint aroma	0.1

Physical properties

	Typical values
Residue on drying	25 – 28 w/w%
Fluoride content:	
In solution	7‘700 ppm
In residue on drying	29‘000 ppm
pH value	5.0 – 6.5

3. *In-vitro* investigations and clinical experience

3.1 Enamel fluoridation

The remineralising, caries-preventive and anti-erosive effect of fluoride-containing dental care products is based on the fluoridation of enamel. Both calcium fluoride formation at the tooth surface and incorporation of fluoride ions into the hydroxyapatite lattice help strengthen and protect the enamel.

The study below measured and compared the degree of fluoridation after the application of different fluoride varnishes.

Table 2 lists the products tested in the study including properties such as fluoride concentration and source of calcium.

Table 2: Overview of the fluoride varnishes tested

Product name	Manufacturer	Fluoride content according to manufacturer's information / ppm	Fluoride source, additives
Fluor Protector S	Ivoclar Vivadent	7'700	NH_4F (ammonium fluoride)
Duraphat	Colgate	22'600	NaF (sodium fluoride)
Clinpro White Varnish with TCP	3M ESPE	22'600	NaF / TCP (tricalcium phosphate)
MI Varnish	GC Corp.	22'600	NaF / CPP-ACP (casein phosphopeptide - amorphous calcium phosphate)
Bifluorid 10	Voco	46'980	NaF / CaF_2 (calcium fluoride)
Flairesse	DMG	22'600	NaF

3.1.1 Measurement of superficial (alkali-soluble) fluoride

Aim: To quantify the superficial alkali-soluble fluoride (i.e. calcium fluoride layer) formed on the enamel surface.

Investigator: Ivoclar Vivadent R&D, Schaan, Liechtenstein (2013)

Method: The study was performed according to the method described by Caslavska [24]. Samples were produced from bovine teeth and demineralised in diluted lactic acid (1h, pH 4,4). Subsequently, the samples were sealed (excluding the enamel surface) using Heliobond. The unsealed enamel surface was coated with varnish. After one hour, 1 ml of artificial saliva was added and then the samples were stored at 37°C. One hour later, the varnish was removed from the enamel with ethanol or acetone. The latter was used for colophonium-containing varnishes such as Duraphat. After that, the samples were thoroughly

rinsed with water and checked for varnish residues. Subsequently, they were immersed in 1 ml of 1 M KOH at room temperature for 24h to allow the release of alkali-soluble fluoride. Before measurement of the fluoride content with an ion selective fluoride electrode, the solution was neutralized with 1 ml of 1 M HNO_3. Subsequently, TISAB II buffer solution was added. At least 6 samples were examined for each material. Enamel treated with water was used as the negative control. The fluoride concentrations measured were expressed as ratios according to the size of the sample surface-areas treated (µg/cm^2).

Results: The individual fluoride varnishes resulted in varying degrees of fluoridation on the enamel surface. The use of Fluor Protector S led to the highest fluoridating effect after one hour. It is noteworthy that Fluor Protector S achieved a better result than varnishes with a higher fluoride concentration.

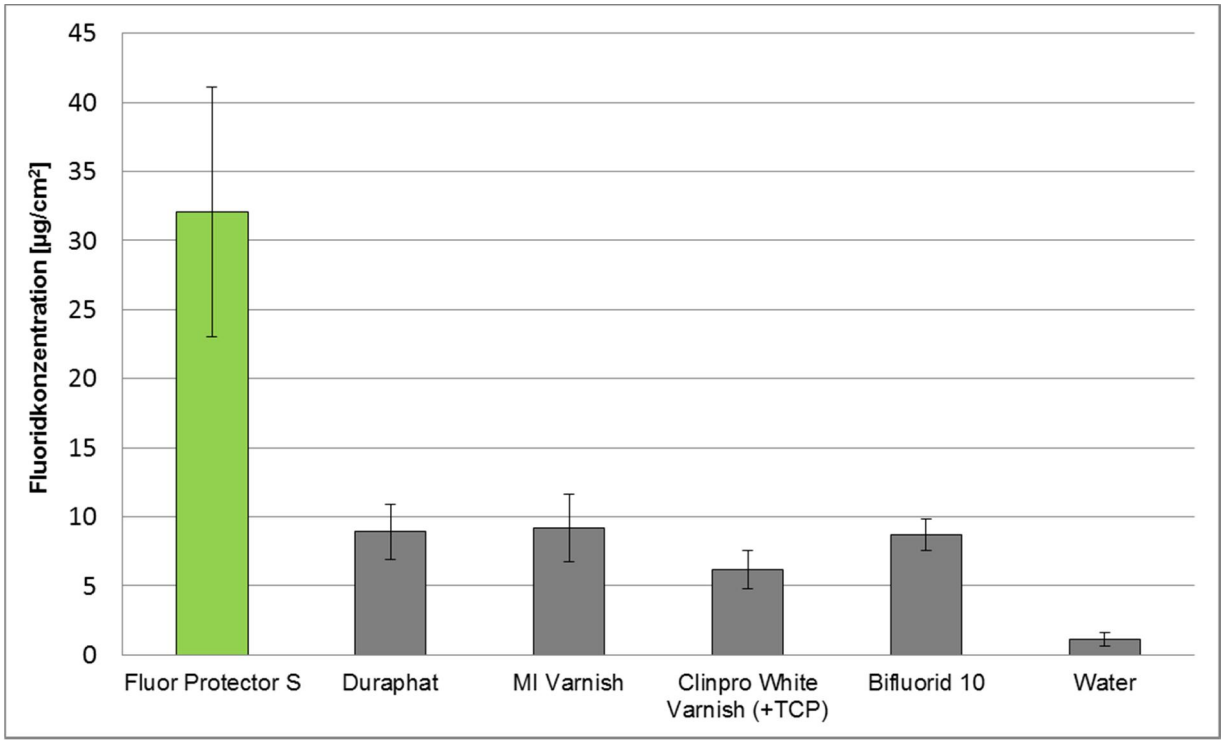


Fig. 7: Superficial, alkali-soluble fluoride one hour after treatment with fluoride varnishes. The fluoridating effect of individual varnishes differs. Fluor Protector S achieved the highest fluoridation. The choice of competitor products related to their importance in the market.

Conclusion: Fluor Protector S provides a high degree of enamel fluoridation – even if the fluoride concentration is lower than in high-dosage formulations, the fluoridating effect of Fluor Protector S is higher.

3.1.2 Measurement of structurally bound fluoride

Aim: To quantify the amount of structurally bound fluoride incorporated into the hydroxyapatite crystals of dental enamel.

Investigator: Ivoclar Vivadent R&D, Schaan, Liechtenstein (2013)

Method: The samples that were previously used to determine the superficial fluoride content were dried and re-sealed with Heliobond.

Subsequently, 1 ml of 0.1 M perchloric acid ($HClO_4$) was added and the uppermost enamel layer (approx. 100 µm) was removed by etching for 15 minutes. Subsequently, 5 ml of TISAB II buffer solution was added and the fluoride content of the solution was measured with an ion selective fluoride electrode.

Results: The individual fluoride varnishes achieved different degrees of structurally bound enamel fluoridation (see Fig. 8). Fluor Protector S showed again the highest fluoridating effect after one hour.

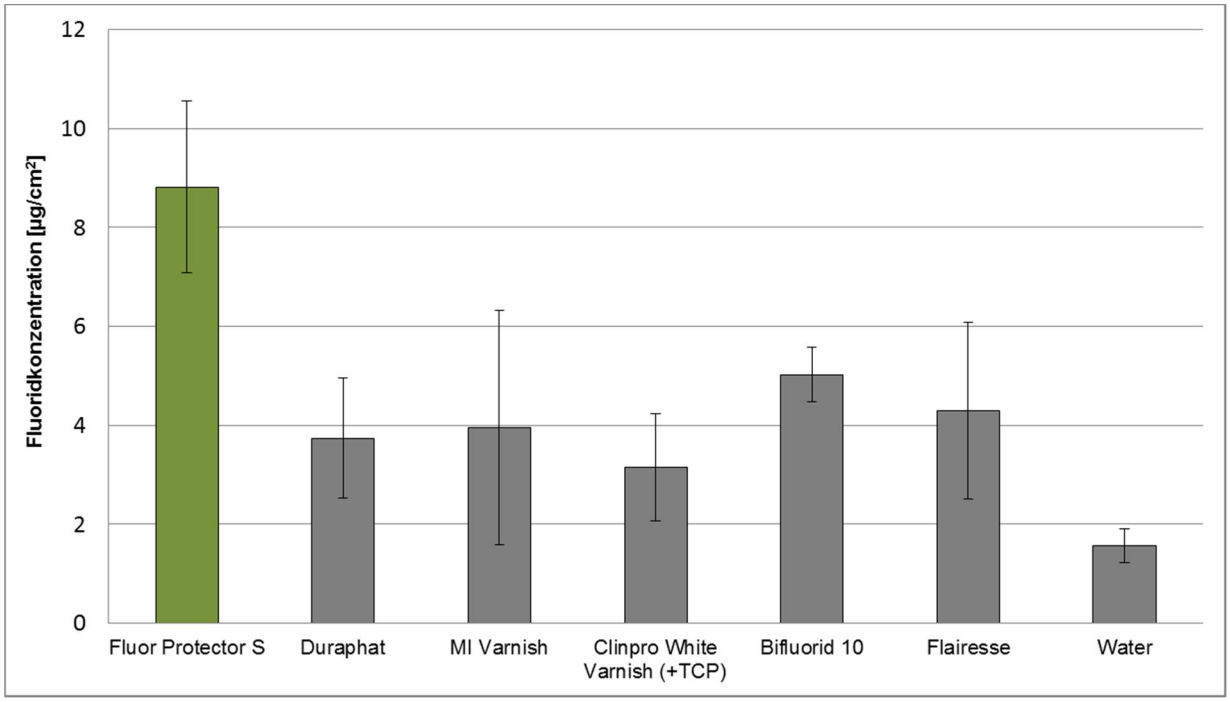


Fig. 8: Structurally bound fluoride one hour after treatment with fluoride varnishes. The fluoridating effect of the individual fluoride varnishes differs: Fluor Protector S achieved the highest fluoridation. The choice of competitor products related to their importance in the market.

Conclusion: Fluor Protector S achieved high concentrations of structurally bound fluoride and, consequently, provides a high level of enamel protection.

3.1.3 Scanning electron microscopic investigations

Aim: To visualize the fluoridation on enamel surfaces with a scanning electron microscope

Investigator: Ivoclar Vivadent R&D, Schaan, Liechtenstein (2013)

Method: Cylindrical samples measuring 4 mm in diameter were drilled from ground and polished bovine teeth and demineralised in lactic acid at pH 4.4 for one hour.

The demineralised enamel surfaces were treated with various fluoride varnishes except for the negative control (see Table 3). The varnish was allowed to dry for 5 minutes. Subsequently, the samples were immersed in artificial saliva for one hour at 37°C. After having been removed from the artificial saliva, they were turned in pure ethanol (Fluor Protector S) or acetone (all the other varnishes) to remove the varnish and then briefly rinsed with water. After the samples had been dried with compressed air, the enamel surfaces were evaluated with a

scanning electron microscope (SEM). In addition, an EDX (Energy Dispersive X-Ray) analysis was performed to identify the chemical compounds contained in the structures under investigation. These examinations were carried out to detect the possible presence of calcium fluoride.

Table 3: Overview of the fluoride varnishes examined

Product	Manufacturer	Fluoride concentration [ppm]	Fluoride source
Fluor Protector S	Ivoclar Vivadent	7'700	NH_4F
Duraphat	Colgate	22'600	NaF
MI Varnish	GC Corp.	22'600	NaF
Clinpro White Varnish + TCP	3M-ESPE	22'600	NaF

Results:

Demineralised enamel shows the typical structure of hydroxyapatite prisms (see Fig. 9). After application of Fluor Protector S, spherical structures can be observed on these crystals. These structures are calcium fluoride-like precipitates, which may also contain phosphate. Similar surface modifications could not be identified on the other samples. The Duraphat samples contained a few individual particles, which may represent fluoride precipitates or residues, and the MI Varnish samples exhibited a few agglomerated particles, possibly originating from CPP-ACP molecules (casein phosphopeptide - amorphous calcium phosphate), from fluoride or from its byproducts. An elemental analysis with EDX revealed that after application of Fluor Protector S, the enamel contained a large amount of fluoride. No other fluoride varnish achieved similarly high fluoride values (see Fig. 10).

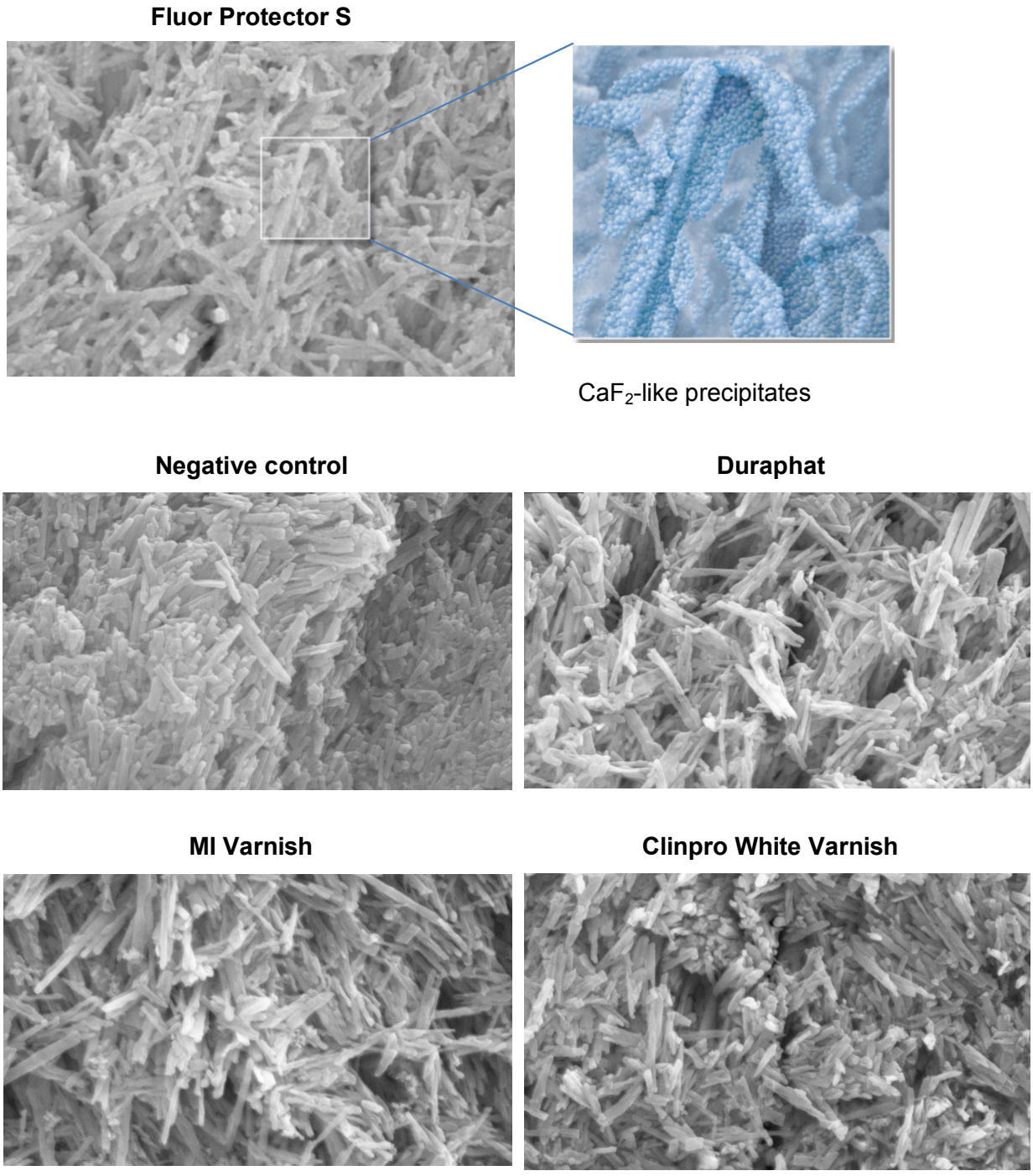


Fig. 9: Calcium fluoride formation on enamel after treatment with fluoride varnishes. Scanning electron microscope images of demineralized enamel (negative control) and enamel after treatment with various fluoride varnishes and immersion in artificial saliva for one hour. After application of Fluor Protector S, deposits on the enamel prisms are clearly visible. Magnification: 30'000x.

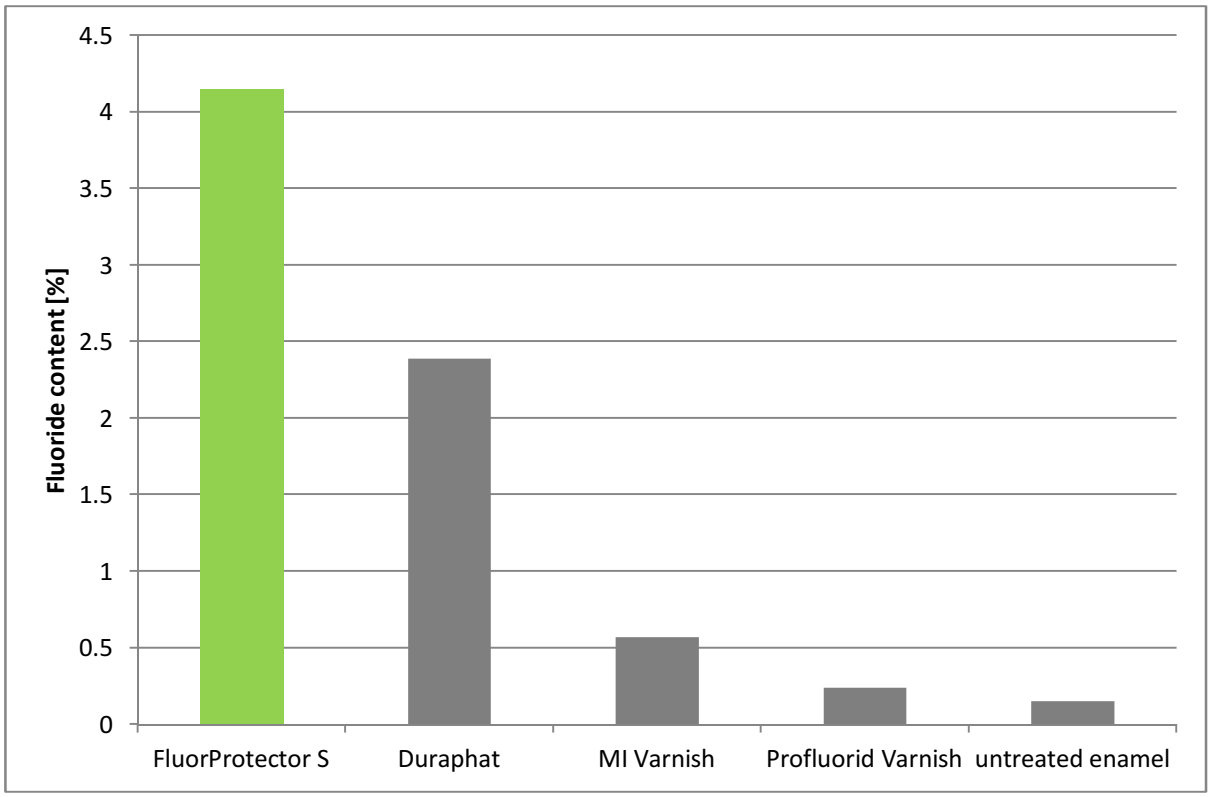


Fig. 10: Fluoride content in enamel after 1-hour treatment with fluoride varnishes. EDX analysis. Fluor Protector S resulted in the highest content of fluoride (in per cent by weight).

Conclusion: Fluor Protector S forms calcium fluoride and fluoridates the enamel.

3.2 Treatment of hypersensitive cervicals / reduction of dentin permeability

Hypersensitive cervicals are a common occurrence. Not just painful, hypersensitive teeth may lead to the neglect of oral hygiene. Hypersensitivity can usually be traced back to exposed dentin tubules. The circumstances leading to exposed dentin are manifold and include gingival recession, periodontitis, bruxism, erosion, professional tooth cleaning, scaling and root planning and even bleaching treatments, which may lead to a temporary loss of the smear layer.

The hydrodynamic theory of tooth sensitivity as described by Brännström is widely accepted as the explanation [25]. The theory concludes that certain stimuli such as temperature changes, sweet foods or osmotic activity elicit pressure changes in the dentin. This causes bidirectional fluid flow within the dentin tubules, which activates the dental nerves. *In-vivo* studies have revealed that the response of the pulp is related to the pressure exerted and thus to the rate of fluid movement [26].

Consequently, there are two main approaches to treating hypersensitive teeth: blocking the dentin tubules to prevent fluid movement, or inhibiting the neuronal transmission of the stimuli. The first mechanism – blocking of the dentin tubules – is employed by the large majority of products currently available.

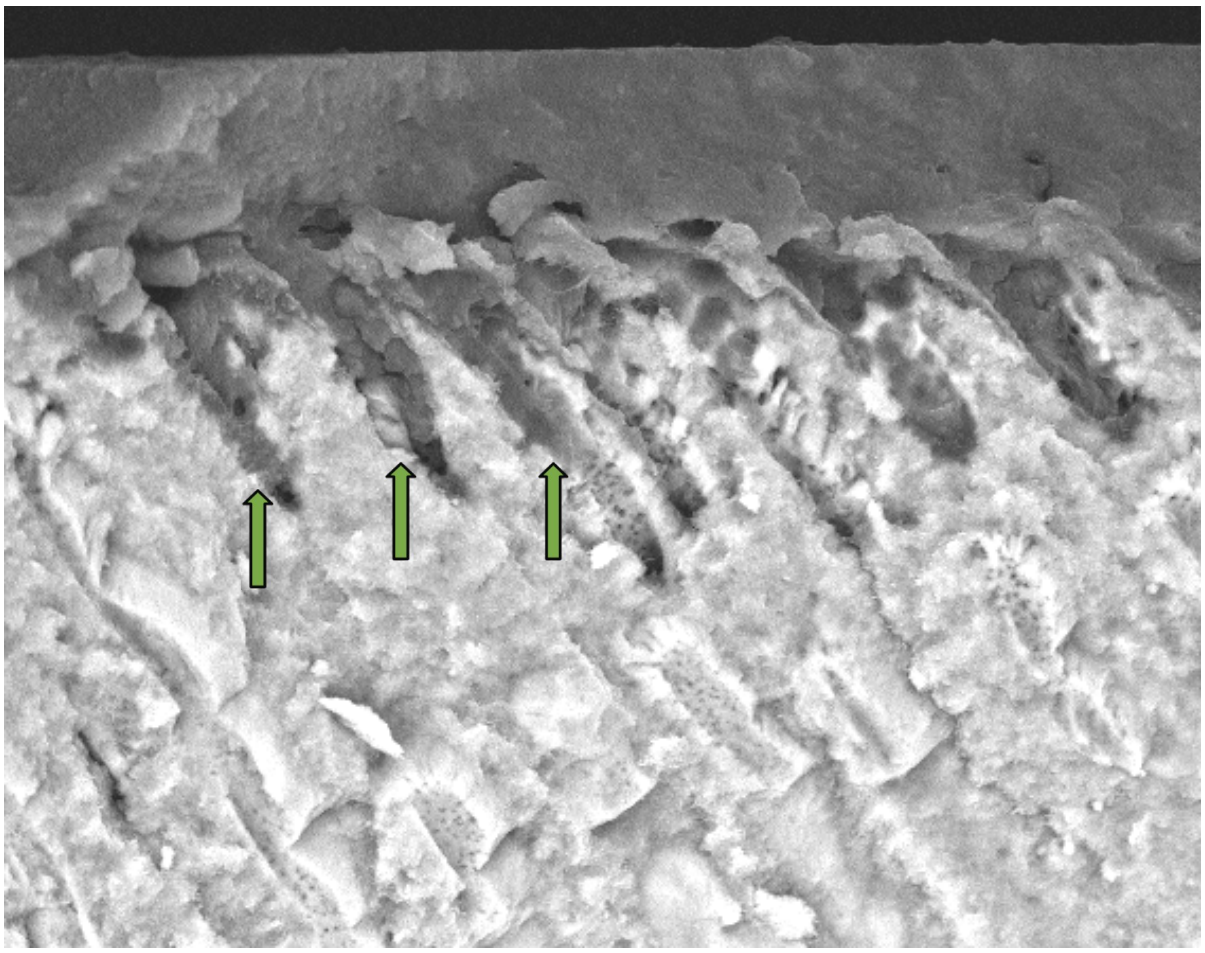


Fig. 11: Blocking of dentin tubules with Fluor Protector S: The low-viscosity varnish can easily penetrate into the dentin tubules (see arrow). Elemental analysis confirmed that the material in the tubules is Fluor Protector S. Scanning electron micrograph; magnification: 1000x. R&D, Ivoclar Vivadent, Schaan.

Fluor Protector S also operates via blocking open dentin tubules. Given its low viscosity, the varnish is able to penetrate well into the tubules (up to 10 µm) and to block the entrances mechanically (see Figure 11).

Investigator: Professor Dr G. Grégoire, Toulouse, France (2012)

Method: How effectively the dentin tubules are blocked can be assessed quantitatively by means of dentin permeability testing as described by Pashley. This method measures the flow of fluid through dentin discs with and without application of varnish. The reduction in dentin permeability was measured in human dentin after the use of Fluor Protector S and compared with Duraphat. In addition, a varnish that featured the same formulation as Fluor Protector S but did not contain fluoride (placebo varnish) was also used. Each sample acted as its own control. First, the samples were etched with phosphoric acid and then the dentin permeability was measured, representing hypersensitive teeth with open dentin tubules. Subsequently, the varnishes were applied and the decrease in dentin permeability was measured against the baseline value (open tubules).

Results: All three products – placebo varnish, Duraphat and Fluor Protector S - provided a clear decrease in dentin permeability. With 35.8%, Fluor

Protector S resulted in the highest reduction. No significant differences were discovered between the three varnishes in a statistical analysis using Duncan's test. The fact that the placebo varnish also had an effect indicates that the mechanical blockade created by the varnish layer is mainly responsible for the reduction in dentin permeability.

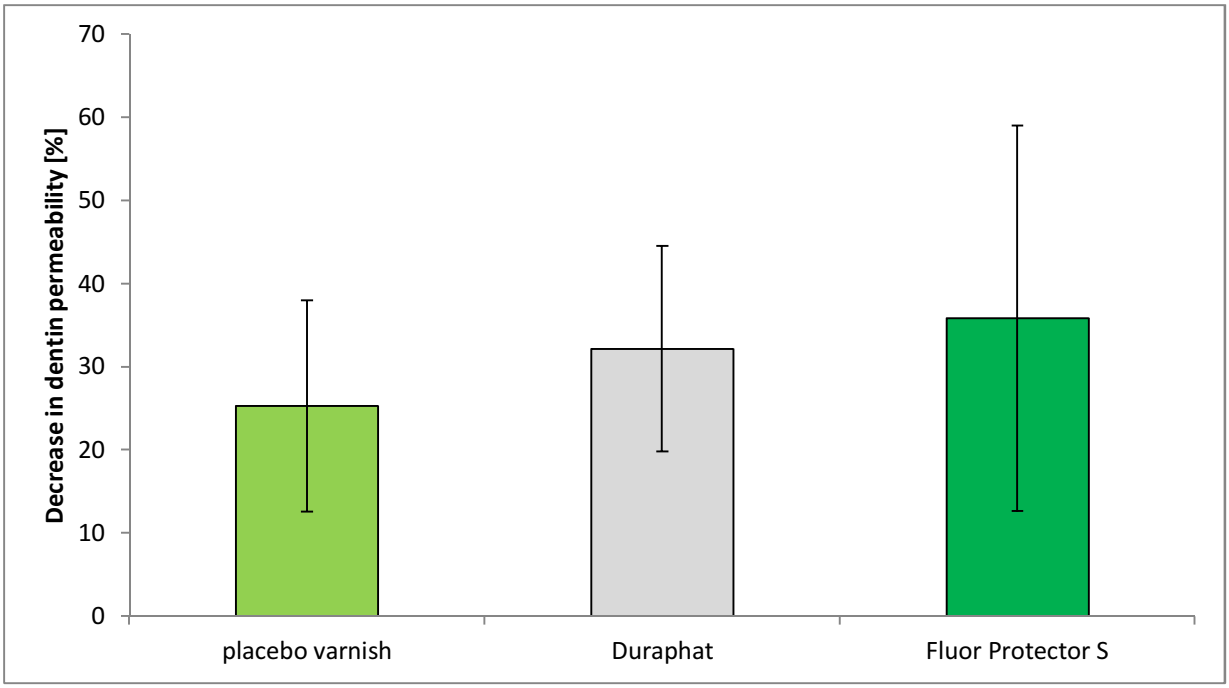


Fig. 12: Decrease in dentin permeability after treatment with fluoride varnishes. Fluid flow through human dentin samples was measured after etching (= open tubules) and treatment with various fluoride varnishes (placebo varnish = Fluor Protector S without fluoride, Duraphat, Fluor Protector S). The chart shows the decrease in percentage after treatment with varnish against open tubules.

Conclusion: Application of Fluor Protector S results in the blocking of dentin tubules and, consequently, helps alleviate hypersensitivity.

3.3 Protection from erosion

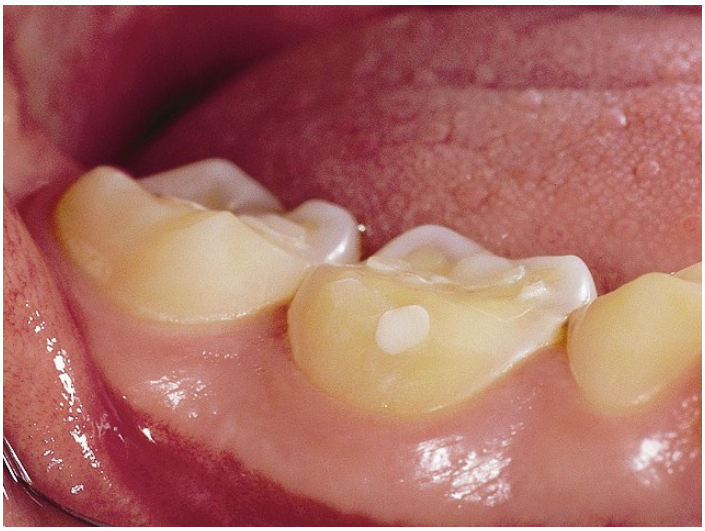


Fig. 13: Erosion of the teeth in a teenager after frequent intake of acidic soft drinks. Frequent ingestion of highly acidic food or beverages (citrus fruits, soft drinks) as well as specific pathological conditions involving frequent vomiting may lead to the erosion of teeth. The exposure of the dentin (yellow) may cause hypersensitivity and discoloration of the teeth.

Courtesy of Dr C. Stecksén-Blicks

There is some evidence that the presence of erosion is increasing in developed societies. Enamel erosion (see Fig. 13) affects all ages, with a somewhat more pronounced rate of erosion in younger age groups [27]. A case control study by Jarvinen *et al.* including 106 cases with erosion and 100 controls found the most important risk factors to be ingestion of citrus fruits (more than twice daily), vomiting daily, consumption of soft drinks, apple vinegar ingestion, use of sport drinks, gastric symptoms and xerostomia [28].

Aim: To evaluate the effect of Fluor Protector S on bovine enamel erosion by lactic acid

Investigator: Ivoclar Vivadent R&D, Schaan, Liechtenstein (2013)

Method: Bovine teeth were embedded, ground and polished. After the samples had been treated with varnish and water (control) respectively, they were immersed in artificial saliva at 37°C for 4 hours. Subsequently, the varnish was removed with ethanol. To simulate erosion processes, the teeth were stored in lactic acid for 30 minutes, rinsed and dried. Subsequently, the lactic acid erosion solution was analysed. Since the hydroxyapatite of enamel is composed of calcium and phosphate, the amount of acid-dissolved enamel can be quantified by determining the calcium and phosphate content of the erosion solution. For this purpose, chemical substances that form coloured complexes with the ions are added to the solution and the resulting colour is measured photometrically. Arsenazo III reacts with calcium to form a bluish-purple complex whose absorbance can be measured at a wavelength of 650 nm. Phosphate is also measured at 650 nm in a malachite green phosphate assay. Three readings were performed for each of the three samples.

Results: Figure 14 shows the amount of calcium and phosphate dissolved from the enamel by erosive acid attacks in the different test groups. It can clearly be seen that the erosion solution of the specimen treated with Fluor Protector S contains less calcium and phosphate than the solution of the teeth treated with fluoride-free placebo-varnish or water. In other words, after the application of Fluor Protector S less enamel was dissolved by erosion than in the non-fluoridated comparison groups.

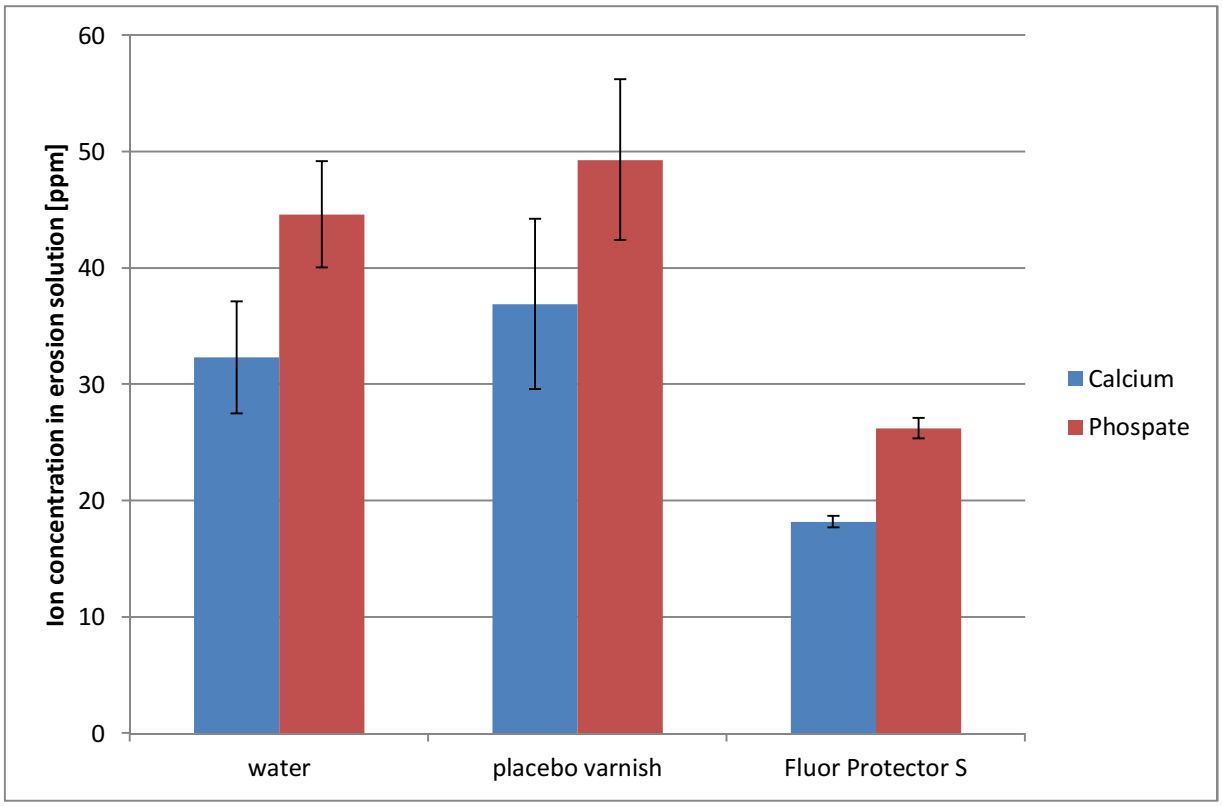


Fig. 14: Calcium and phosphate concentration in erosion solution: After an acid attack, the erosion solution of the teeth treated with fluoride varnish contains a clearly lower calcium and phosphate concentration than the erosion solution of the teeth treated with water or placebo varnish.

Conclusion: Fluor Protector S reduces the amount of tooth enamel dissolved by erosive processes.

3.4 Resistance to discoloration on contact with food

Investigator: Ivoclar Vivadent R&D, Schaan, Liechtenstein (2013)

Method: Embedded bovine teeth with exposed polished enamel were used for this test. A coating of Fluor Protector S was applied to the right half of the enamel. After drying in the air for one minute, the enamel was immersed in artificial saliva at 37°C for 15 minutes and then in water, black tea or red wine. Visual assessment was carried out after one and five minutes.

Results: After 5 minutes of immersion, the varnish layer did not show any discoloration (see Fig. 15). The varnish remained completely intact on all test samples. The untreated enamel of the “red wine” specimen contained imperfections, which became slightly discoloured (see Figure 15). *(Note: The partial white discoloration of the varnish layer only developed after the sample was removed from the medium and dried.)*

Fig. 15: Discoloration test with Fluor Protector S: After 5 minutes of immersion in water – black tea – coffee – red wine (clockwise from top left), the varnish layer did not show any discoloration. The untreated enamel of the "red wine" sample contained imperfections, which had become slightly stained.

Conclusion: Fluor Protector S provides not only an esthetic result immediately after application but it is also resistant to discoloration through the consumption of food.

3.5 Compatibility with tooth whitening materials

Treatments to whiten teeth with hydrogen peroxide quite often lead to hypersensitive teeth. A fluoride varnish can be very useful in such a situation because it obstructs the dentin tubules and, consequently, blocks the pain-inducing stimuli. In addition, the fluoride contained in the varnish strengthens the enamel.

The Research department at Ivoclar Vivadent tested the compatibility of Fluor Protector S in conjunction with the VivaStyle tooth whitening materials. The varnish did not discolour under the influence of oxygen radicals. Consequently, the application of Fluor Protector S after whitening treatments can be recommended.

3.6 Compatibility with restorative materials

Fluoride varnishes play a particularly salient role in caries prevention in patients with a high caries risk. However, these patients often already have one or more restorations. If a fluoride varnish is applied, it is desirable that the esthetic qualities of the existing direct composite or indirect ceramic restorations are not altered or impaired.

Investigator: Ivoclar Vivadent R&D, Schaan, Liechtenstein (2013)

Method: The composite Tetric Evo Ceram (TEC) and the ceramic IPS e.max CAD were selected as restorative materials for this test. Fluor Protector S was applied to the test sample, allowed to dry and

then stored in water at 37°C for 24 hours. After the varnish had been removed, the appearance (shade, gloss) was evaluated against an untreated sample.

Results: Changes in shade or lustre were not visible to the naked eye in any of the two restorative materials (see Fig. 16).

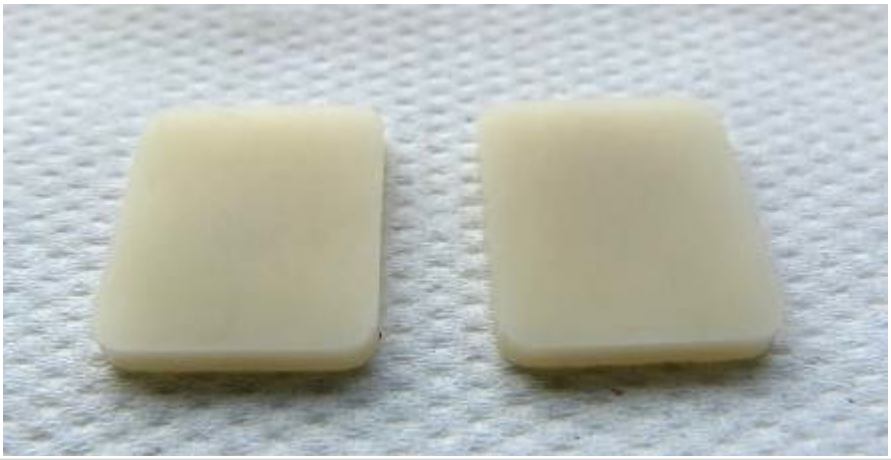
	Untreated	Treated
IPS e.max CAD, Shade A2		
Tetric Evo Ceram Shade A3		

Fig. 16: Compatibility with restorative materials: The images of the specimens after treatment with Fluor Protector S do not show any visible differences compared with the untreated specimens. The scratches on the "treated" Tetric Evo Ceram sample were already present before the treatment.

Conclusion: Fluor Protector S maintains the esthetic appearance of tooth-coloured restorations.

3.7 Adhesion to enamel

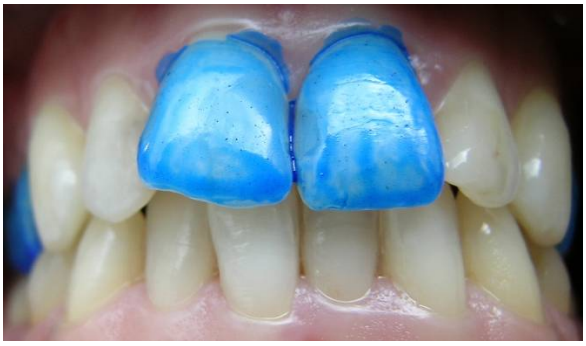
Given its innovative formulation and low-viscosity consistency, Fluor Protector S is not only easy to apply but it also adheres well to tooth surfaces, providing ample time for the fluoride to reach the enamel before the varnish rubs off from eating, drinking and tooth cleaning. This is illustrated in a test for which the colourless clear varnish was dyed a bright blue colour using cosmetic colour pigments and then applied to individual teeth in a volunteer.

Investigator: Ivoclar Vivadent R&D, Schaan, Liechtenstein (2013)

Method: Fluor Protector S was dyed with Pigment Blue 15:1 and applied to the incisors (11, 21) and posterior teeth (24, 25, 26) in a volunteer using a Vivabrush. Subsequently, the teeth were photographed. The remaining teeth were treated with undyed varnish. After the varnish had dried for one to two minutes, the volunteer was allowed to close the mouth. Additional pictures were taken after 5, 60, 150, 210 and 330 minutes. Lunch was eaten in the time between 150 and 210 minutes.

Results: Immediately after application, the varnish had a shiny, wet appearance. After drying and contact with saliva, it looked rather matt. The entire facial tooth surface was covered with a thin, even varnish layer. When examined at 60 and 150 minutes, the varnish was still completely present over the entire surface. After lunch, the varnish was only slightly worn away along the incisal margins. However, the varnish layer remained complete at the proximal areas, which are particularly susceptible to caries. At 330 minutes, or at 5½ hours, more varnish had been lost – however, still more than 50% of the varnish surface area remained intact. The same applies to the posterior teeth, a glimpse of which can be seen at the sides of the images.

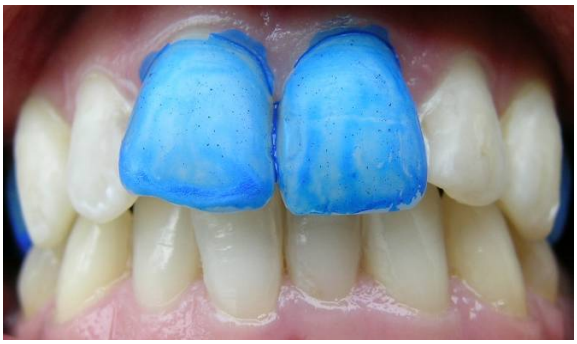
Immediately after application



After 5 minutes

After 60 minutes

After 150 minutes



After 210 minutes (including mealtime) **After 330 minutes**

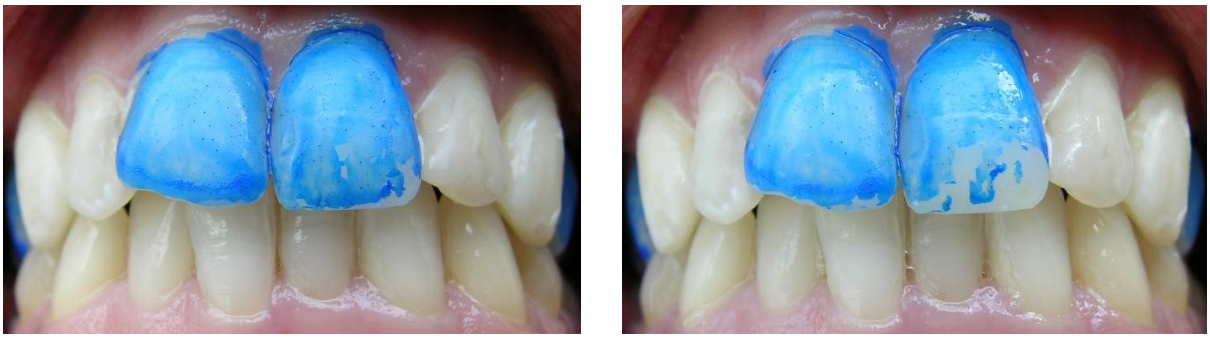


Fig. 17: Adhesion of Fluor Protector S to enamel: Blue-dyed varnish was applied to individual teeth and photographed at various intervals. Between “150 minutes” and “210 minutes”, the volunteer ate lunch. Fluor Protector S remained on large sections of the tooth surfaces even after more than 5 hours.

Conclusion: Fluor Protector S adheres very well to the enamel and, consequently, provides a continued supply of fluoride over a long period of time.

4. Biocompatibility

4.1 Cytotoxicity

The cytotoxicity of extracts of Fluor Protector S was examined in a direct cell contact test according to ISO 10993 using the mouse cell line L929. No cytotoxic potential was observed in any of the concentrations tested [29; 30].

4.2 Acute toxicity

All the main components of Fluor Protector S are of low acute toxicity (LD_{50} oral > 2000 mg/kg bodyweight). The toxic dose of fluoride is 32 to 64 mg/kg for adults and 5 mg/kg for children. The fluoride content of Fluor Protector S is 0.77% (7'700 ppm) in the liquid varnish and 30'000 ppm in the dried varnish. This means that it would require 6.5 g of Fluor Protector S to cause a toxic reaction in a child of a bodyweight of 10 kg. Only 0.25 g of varnish is required for a regular application. There is therefore no danger of poisoning if the varnish is applied at the recommended dose.

4.3 Sensitization and irritation

Only two components of Fluor Protector S may have a slight sensitizing potential: peppermint oil and ethyl alcohol. However, these substances are used in many dental products and are tolerated well by most patients.

Fluor Protector S may cause slight reversible irritation to the mucous membrane. A note to this effect has been included in the Instructions for Use.

4.4 Genotoxicity

An AMES reverse mutation assay was performed on bacterial cells using extracts of Fluor Protector S. No evidence for mutagenicity was detected [31; 32].

4.5 Conclusion

When administered as recommended, Fluor Protector S is toxicologically safe for patients and users.

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Issue: February 2013