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Efficacy of fluoride varnishes with different compositions on white spot lesions remineralization

Eficácia de vernizes fluoretados com diferentes composições na remineralização de manchas brancas

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ABSTRACT

Objective: To evaluate the efficacy of different fluoride varnishes on white spot lesions (WSL) remineralization. **Material and Methods:** Polished bovine enamel specimens were obtained (n = 60) and had their initial surface Knoop microhardness (SMH) determined. WSL were created and the SMH was measured again. Then, specimens were allocated into six groups: C – Control (without varnish); BF – Bifluorid 12 (6% NaF + 6% CaF2); DP – Duraphat (5% NaF); PF – Profluorid (5% NaF); FP - Fluor Protector (0.2% NaF + 0.9% difluorsilane); CW - Clinpro White Varnish (5% NaF + 5% TCP). After varnishes application, specimens were immersed in artificial saliva for 24 h. Then, pH-cycling was performed for 8 days and SMH was measured. Data were analyzed by one-way ANOVA and Tukey's test. **Results:** Non-significant differences were observed among the groups at baseline (p = 0.187) and after WSL formation (p = 0.999). After treatments, significant differences were observed among the groups (p = 0.001). Mean % of alteration (SD) and results of Tukey test were: C- 92.40 (12.10)a; PF- 88.66 (10.66)a; FP- 85.90 (14.49)ab; BF- 67.85 (17.86)bc; CW- 66.60 (18.48)c; DP- 58.62 (8.69) c. **Conclusion:** Bifluorid 12, Clinpro White Varnish, and Duraphat showed higher efficacy than artificial saliva in promoting the remineralization of WSL, nevertheless, none of the treatments were able to recover sound enamel baseline microhardness.

KEYWORDS

Dental caries; Fluoride; Fluoride varnishes.

RESUMO

Objetivo: Avaliar a eficácia de diferentes vernizes fluoretados na remineralização de lesões de mancha branca (LMB). **Material e métodos:** Espécimes de esmalte bovino polido (n = 60) foram submetidos à análise de microdureza superficial Knoop (KMH) inicial. Foram então criadas LMB artificialmente e os espécimes foram alocados em seis grupos: C – Controle (sem aplicação de verniz); BF – Bifluorid 12 (6% NaF + 6% CaF2); DP – Duraphat (5% NaF); PF – Profluorid (5% NaF); FP - Fluor Protector (0.2% NaF + 0.9% difluorsilano); CW - Clinpro White Varnish (5% NaF + 5% TCP). Após a aplicação dos vernizes, os espécimes ficaram imersos em saliva artificial por 24h e uma ciclagem de pH foi realizada por 8 dias. Após a ciclagem, KMH final foi realizada. Os dados foram analisados por ANOVA e teste de Tukey (5%). **Resultados:** Não foi observada diferença significante para os grupos após a KHM inicial (p = 0.187) e após a formação de LMB (p = 0.999). Após os tratamentos, diferenças significativas foram observadas entre os grupos (p = 0.001). Valores de média de % de alteração superficial (desvio-padrão) e resultados do teste de Tukey foram: C- 92.40 (12.10)a; PF- 88.66 (10.66)a; FP- 85.90 (14.49)ab; BF- 67.85 (17.86)bc; CW- 66.60 (18.48)c; DP- 58.62 (8.69)c. **Conclusão:** Os vernizes Bifluorid 12, Clinpro White Varnish e Duraphat apresentaram maior eficácia na remineralização das LMB quando comparados à saliva artificial, entretanto, nenhum dos produtos testados foi capaz de recuperar os valores iniciais de microdureza.

PALAVRAS-CHAVE

Cárie dentária; Flúor; Verniz fluoretado.

INTRODUCTION

The fluoride varnishes efficacy on preventing, arresting, and remineralizing initial carious lesions is well established in literature [1]. Its remineralizing and anticaries effect are related to the precipitation of calcium fluoride-like deposits (CaF_2) on dental surfaces acting as a reservoir that slowly releases fluoride over time to interact with de- and remineralization processes [2].

Fluoride varnishes are basically delivery vehicles for high amounts of fluoride and usually contain 5% sodium fluoride (NaF) in its formula [1]. Although NaF is present in high concentrations, only 17% of the total fluoride is reported to be soluble to react with tooth surface [3]. The insoluble fluoride is slowly dissolved and released over time during the contact with dental surfaces and this is the major advantage of fluoride varnishes when compared to other topical fluoride protocols used on white spot lesions, like fluoride solutions and gels [4].

The amount of fluoride released over time as well as the kinetics of fluoride release is proved to be related to the different compositions, physical properties, and the presence of different active ingredients besides fluoride [5]. Lately, many sodium fluoride-based products have been supplemented with promising remineralizing substances, such as calcium fluoride, tri-calcium-phosphate (TCP), fluorsilane, xylitol and bioactive particles as an attempt to intensify its efficacy [6-11]. Nevertheless, evidence of this supposed improvement caused by addition of these ingredients are still poor and not well established in literature.

Therefore, the aim of this study was to evaluate the efficacy of fluoride varnishes containing different compounds (sodium fluoride, calcium fluoride, difluorsilane and TCP) on white spot lesions (WSL) remineralization. The null hypothesis tested was that there is no difference in the ability of the tested varnishes to remineralize incipient carious lesions.

MATERIAL AND METHODS

Ethical aspects

The present study was performed using bovine teeth and did not need approval by the Ethical Committee, according to the Federal law #11.794 (Arouca law – 2008), which regulates the scientific use of animals in Brazil.

Enamel specimen's preparation

Cylindrical enamel specimens (3 mm diameter) obtained from freshly extracted bovine incisors were prepared from the labial surface of crowns, using a custom-made diamond trephine mill. The specimens were embedded in acrylic resin (Jet, Clássico, São Paulo, SP, Brazil) using a silicon mold, and were then polished with the aid of a metal holder and aluminum oxide abrasive papers (#1200, 2400 and 4000; FEPA-P, Struers, Ballerup, Denmark) in a polishing device (DP-10, Panambra Industrial e Tecnica SA, São Paulo, SP, Brazil). After each grind paper, specimens were sonicated in deionized water for 5 min. The prepared specimens were examined in stereomicroscope (20X - Carl Zeiss, Stemi 2000, Tokyo, Japan) to verify the absence of cracks or other surface defects and then stored in ultrapure water to prevent dehydration [12,13].

Microhardness measurement

The microhardness determination was performed with a Knoop microhardness tester (FM-700, Future-Tech,Tokyo, Japan) fitted with a 50 g load, which was used to make indentations on enamel surface. The load was applied during 10 s. Three indentations (100 μm distant from each other) were performed in each specimen and then averaged to determine the enamel surface microhardness (SMH) at baseline [12,13].

Specimens' Demineralization

Artificial enamel subsurface carious lesions were created by immersing the specimens in an acidic demineralizing solution for 21 days containing 3 mM $CaCl_2 \cdot 2\,H_2O$, 3 mM KH_2PO_4 and 50 mM CH_3COOH, under constant agitation [14]. The proportion of demineralizing solution per area of enamel was 6.25 mL/mm^2 [15]. After demineralization, a new microhardness measurement was performed and the SMH values were used to allocate the samples into six groups (n=10): C- negative control (without varnish application); DP- Duraphat™ (positive control – Colgate, 5% NaF); PF- Profluorid™ (Voco, 5% NaF); BF- Bifluorid 12™ (Voco, 6% NaF + 6%

CaF_2); FP- Fluor Protector™ (Ivoclar, Vivadent, 0.9% Fluorsilane); CW- Clinpro White Varnish™ (3M/ESPE, 5% NaF + Tri-Calcium Phosphate - TCP).

Fluoride varnishes application

The products were applied according to manufacturer's instructions. The products tested, their specifications and manufacturer's instructions for application are described in Table I. After varnishes application, specimens were immersed in artificial saliva for 24 h so that the varnishes could reach its maximum capacity of reactivity with enamel [16]. No treatment was applied to the control group. The varnishes were then carefully removed using a cotton swab with acetone followed by immersion in deionized water.

Table I - List of the varnishes tested in the study and their composition, according to manufactures

Product	Manufacturer	Instructions for use	Fluoride concentration (%)	Additional active ingredients
Duraphat	Colgate – Palmolive (New York - USA)	- Clean and dry tooth surface; - Apply an evenly layer over the tooth with a micro applicator;	5% NaF	-
Profluorid	Voco (Cuxhaven – Germany)	- Clean and dry tooth surface; - Apply an evenly layer over the tooth with a micro applicator.	5% NaF	-
Cilinpro White Varnish	3M/ESPE (St. Paul – USA)	- Clean and dry tooth surface; - Open the unit-dose package and dispense the content onto the round application guide on the back of the foil pouch box; - Use the applicator brush to thoroughly mix the varnish; - Apply an evenly layer over the tooth with a micro applicator.	5% NaF	< 5% Tri-Calcium Phosphate
Bifluorid 12	Voco (Cuxhaven - Germany)	- Clean and dry tooth surfaces; - Shake biofluorid 12 container; - Apply an evenly layer over the tooth with a micro applicator.	6% NaF	6% Calcium Fluoride
Fluor Protector	Ivoclar Vivadent (Liechtenstein - Swiss)	- Clean and dry tooth surface; - Open the ampoule containing the varnish; - Apply an evenly layer over the tooth with a micro applicator.	0.2% NaF	0.9% Difluorosilane

pH cycling regimen

The pH-cycling (2 h in the demineralizing solution and 22 h in the remineralizing solution) was performed for 8 days [17]. The demineralizing solution (pH 5.0) was composed by 0.05 mol/L acetate buffer obtained from dissolution of acetic acid and 1.28 mmol/L Ca, 0.74 mmol/L P, and 0.03 μg F/mL prepared from the salts Ca $(NO_3)2.4H_2O$, KH_2PO_4 and NaF, respectively. The remineralizing solution (pH 7.0) consisted of 1.5 mmol/L Ca, 0.9 mmol/L P, 150 mmol/L KCl, 0.05 μg F/mL in 0.1 mol/L of Tris buffer [18]. After four days of pH cycling, the solutions were renewed. At the end of the ph-cycling, SMH was measured again, exactly as described above to determine the enamel surface Knoop microhardness after treatments. The % of SMH alteration were calculated using the following formula:

$$(SM_{Hafter\ WSL} / SMH_{after\ treatment})*100.$$

Statistical analysis

One-way ANOVA and Tukey's tests were applied on sound enamel and after demineralization (WSL) data, in order to evaluate if values were evenly distributed among the groups before treatments. After treatments, statistical analysis was applied on %SMH alteration values. A significance level of 5% was set. Analyses were performed with statistical software STATISTICA for Windows (Stat Soft Inc, Tulsa, OK, USA).

RESULTS

The SMH values for sound enamel, demineralized enamel (WSL), after treatments and the %SMH alteration are shown in Table II. Non-significant differences were observed in sound enamel SMH values ($p = 0.187$) and in SMH values after WSL formation ($p = 0.999$). The %SMH alteration comparing mean values after WSL and after treatments showed significant differences among the groups ($p = 0.001$). The mean values (SD) of %SMH alteration and results of Tukey's test are presented in Table II and Figure 1.

Among the products tested, only Profluorid and Fluor Protector groups showed non-significant differences when compared to the control group. The varnishes Bifluorid 12, Clinpro White Varnish and Duraphat showed lower %SMH alteration compared to the control group, demonstrating higher WSL remineralizing capacity.

Table II - Mean values (±SD) of SMH at baseline, after WSL, after treatment and % of SMH alteration. Statistical analyses were applied on baseline, WSL, and %SMH alteration values (different letters show significant differences in columns – p<0.05)

Groups	Baseline (mean ± SD)	WSL (mean ± SD)	Treatment (mean ± SD)	% Alteration (mean ± SD)
Control	327.05 ± 19.77[a]	83.41 ± 26.96[a]	88.94 ± 23.68	92.40 ± 12.10[a]
Profluorid	341.39 ± 22.37[a]	83.47 ± 23.93[a]	93.63 ± 23.38	88.66 ± 10.66[a]
Fluor Protector	348.40 ± 27.36[a]	83.89 ± 23.26[a]	97.95 ± 20.28	85.90 ± 14.49[ab]
Bifluorid 12	327.79 ± 17.48[a]	84.07 ± 24.93[a]	126.01 ± 27.01	67.85 ± 17.86[bc]
Clinpro WV	330.09 ± 19.84[a]	84.55 ± 24[a]	127.86 ± 17.07	66.60 ± 18.48[c]
Duraphat	337.30 ± 21.51[a]	83.13 ± 23.65[a]	142.01 ± 37.55	58.62 ± 8.69[c]

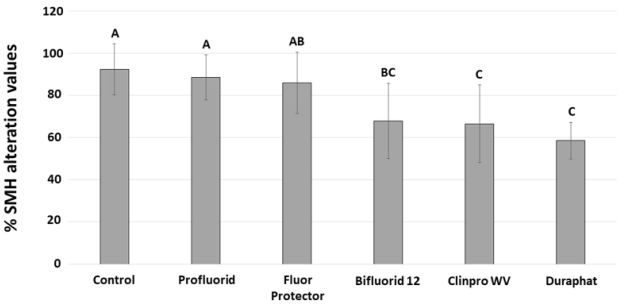

Figure 1 - Knoop SMH values (mean ± SD) for all groups after treatments. Different letters mean statistically significant differences.

DISCUSSION

In this study, we evaluated the efficacy of fluoride varnishes containing different active ingredients in its formulation on enamel remineralization using the SMH analysis. Microhardness has been widely used for measuring enamel demineralization over the years, because it is simple, quick, and non-destructive, enabling the measurement of the specimens in different times of the study [19]. Nevertheless, a limitation of this study is that indentations were performed only on the specimens' surface and thus, are not able to detail the subsurface changes [20]. Significant differences on surface microhardness were found after treatment of WSL with the different products, thus, the null hypothesis was rejected. There were no significant differences in SMH means after artificial carious lesions regarding to the specimens allocated to the different treatment groups, showing the homogeneous distribution of the demineralized specimens among the tested groups.

The comparison between the SMH of WSL and the values obtained after treatment with the varnishes was performed to assess the ability of each product to remineralize incipient enamel lesions, and lower values of %SHM alteration means higher remineralizing ability. Our results demonstrated a significantly lower surface microhardness alteration of the specimens exposed to Bifluorid 12™, Clinpro White Varnish™, and Duraphat™ products.

The application of the 5% NaF-based varnish (Duraphat™) resulted in significantly higher SMH of the incipient caries lesions when compared to saliva, Profluorid™ (5% NaF) and Fluor Protector™ (0.2% NaF + 0.9% Difluorosilane). This was somehow expected considering that this product is known as the gold standard commercial varnish for prevention and treatment of dental caries [21]. The efficacy of Duraphat™ has been attributed to its proven ability to form CaF_2-like reservoirs by the interaction of fluoride present in its formulation with dental minerals, which allows the formation of CaF_2-like deposits on enamel surface [22]. The fluoride released from CaF_2-like deposits during biofilm pH drop can replace tooth hydroxyapatite mineral loss in the form of fluorapatite decreasing further demineralization and enhancing remineralization processes [23]. The reaction with enamel is proved to be time-dependent, reaching its maximum effectiveness after 24 h [16], and it is usually recommended by clinicians to be left over tooth surface overnight before brushing [24]. Although effective, this product presents as disadvantages the yellowish

color of the film formed on dental structure, and sticky texture that difficult the application over all tooth surface area [24]. Also, its use has been related to potential stain of dental restorations by penetration of the product in marginal micro cracks or surface defects [25].

Bifluorid 12™ and Clinpro White varnish™, which contain calcium and calcium + phosphate, respectively, in their compositions, presented similar results to Duraphat™ (5% NaF). The combination of 6% NaF and 6% CaF_2 present in Bifluorid 12™ is intended to favor the formation of a calcium fluoride-like layer, as an attempt to provide a strong and lasting fluoride release [26]. Despite of offering more calcium binding sites for fluoride, the presence of CaF_2 in product's composition did not increase the amount of CaF_2 deposits on enamel surface [26] and thus, did not improve the varnish remineralization potential compared to the NaF only product, as also observed in a previous clinical study [6].

Although the literature shows no significant difference in the protective effect comparing calcium-enriched fluoride varnishes with NaF only, additional measurements of loosely bound fluoride on tooth surface, as well as fluoride uptake by enamel may be necessary to investigate its potential of forming additional calcium fluoride deposits on tooth surface [8].

Clinpro White varnish presents a lower concentration of insoluble and soluble fluoride than Duraphat [27]. Despite of this, it showed similar efficacy on enamel remineralization, which is in accordance with the literature [5,8]. This finding might be explained by the fact that a high amount of calcium and phosphate from this product is readily available for interaction with dental tissues [5,8]. The inclusion of the functionalized TCP ingredient in NaF formulations seems to result in a more acid-resistant mineral when compared to fluoride alone [28], due to its capacity to release calcium and phosphate when in contact with saliva, increasing the amount of these minerals. It has been also reported that NaF/TCP varnish shows higher efficacy in inhibiting incipient enamel lesions than NaF only varnish [29].

Fluoride interaction with enamel has been shown to decrease exponentially with time, and the presence of TCP might help to extend fluoride interaction with enamel, therefore enhancing lesion remineralization [30] due to its low viscosity that facilitates its contact with tooth surface. As the material deposits over all tooth surfaces, more varnish is supposed to be exposed to saliva, which would allow more calcium, phosphate and fluoride to be released on tooth surface. Nevertheless, no significant difference was found for Duraphat and Clinpro White Varnish™. It may be pointed out, as an advantage of this product, that the whitish color of the layer applied to the tooth, favors its esthetic appearance.

The other product composed of 5% NaF tested in this study was Profluorid™. It is commercially available in a single application tube with different flavors. This varnish showed significantly lower ability to remineralize incipient caries lesions than Bifluorid™, ClinPro White Varnish™ and Duraphat™. Even though the percentage of sodium fluoride found in Profluorid™ and Duraphat™ is similar, the difference in remineralizing potential might be attributed to the distinct levels of fluoride released and interactions with enamel by the different varnishes, which can affect their behavior. The different types of additives or resin carriers (e.g. natural vs. synthetic) used to formulate the varnishes are shown to influence fluoride ion diffusion [5,8].

The varnish containing 0.9% difluorsilane and polyurethane as base with ethyl acetate and isoamyl propionate solvents, showed lower effective remineralizing potential, similar to artificial saliva and Profluorid™. This might be related to the low concentration of fluoride (0.1%), which according to the manufacturer, is equivalent to 1000 ppm in solution and concentrate on the tooth surface as the solvents evaporate.

Although the comparison among the different tested products is difficult to achieve,

three out of five products tested (Bifluorid 12™, Clinpro White Varnish™ and Duraphat™) were able to promote remineralization of WSL. Nevertheless, it has to be highlighted that some aspects found in in vivo conditions, such as salivary flow clearance and lesion depth may directly influence varnishes role in de/remineralization process, and thus must be considered in further studies.

CONCLUSION

Based on the limitations of this in vitro study, it could be concluded that the varnishes Bifluorid 12™ (6% NaF + 6% CaF2), Clinpro White Varnish™ (5% NaF + 5% TCP) and Duraphat™ (5% NaF) were able to effectively remineralize WSL, in contrast to Profluorid™ (5% NaF) and Fluor Protector™ (0.2% NaF + 0.9% difluorsilane). However, none of the products tested were able to recover the baseline microhardness of sound enamel.

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Conflict of interest

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

Regulatory Statement

N/A

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