

Comparative Evaluation of Lacquer Film Stability Applied to a Surface Fluorination

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Abstract: The characteristics of lacquers for surface fluorination Biflyuorid-12, Ftorlak and Ftor-Lux were evaluated in preclinical conditions during this study. During the evaluation of lacquer film retention stability on the surface of artificially damaged enamel the best performance were shown during the study of Ftor-Lux properties. At the presence of lactic acid solution with the pH of 5.5 ± 0.02 , at the temperature of $37.0 \pm 0.2^\circ\text{C}$, Biflyuorid-12 lacquer film covered 57.2% of the visual field, Ftorlak and Ftor-Lux lacquers covered 45.5 and 67.1% of the visual field, respectively.

Key words: Surface fluorination, electric chemistry, film stability, visual field, Russia

INTRODUCTION

A stable trend towards the reduction of the number of persons suffering from caries disease and its complications (Steiner *et al.*, 2010; Grez *et al.*, 2015; Dobloug and Grytten, 2015) is noted in a number of industrialized countries. However, the use of complex methods for caries diagnosis indicates that currently the carious lesions of posterior teeth are very common (Da Silva *et al.*, 2015). Despite the considerable efforts of experts for the improvement and the implementation of prevention programs, the level of dental health among Russian Federation population should be recognized as a low one. According to the results of epidemiological survey conducted in 2013-2014 92.95% of Russians suffer from tooth decay. The prevalence of dental caries reaches 46% among 3 years old children and this figure rises to 96% among 6 years old children (Jurbenko and Sahakyan, 2014).

Study objective: The laboratory evaluation the film retention stability formed by the lacquers Biflyuorid 12 (VOCO, Germany), Ftorlak (Raduga-R, Russia), Ftor-Lux (Tehno Dent, Russia) used for the surface fluorination of artificially damaged enamel.

MATERIALS AND METHODS

During the evaluation of film retaining stability on the sections of remote masticatory teeth with artificially damaged crowns ($n = 30$), we used the scanning ion-electron microscope Quanta 200 3D with the detector

of secondary electrons. An image was captured using a digital camera with a high-sensitivity matrix Digiview II. The compounds were incubated in a dry-air electric thermostat TC-1/80 SPU. Babaeian *et al.* (2009) and Rastegar *et al.* (2009) proposed a modified color based model to track the objects in occluded seen.

During the simulation of physical and chemical properties of the medium corresponding to the oral cavity conditions, the following reagents were used: lactic acid solution with the concentration of 0.02 mol dm^{-3} ; distilled water according to GOST 6709; hydrochloric acid solution with the concentration of 1 mol dm^{-3} according to GOST 3118; sodium hydroxide solution with the concentration of 1 mol dm^{-3} according to GOST 4328.

The removed teeth were purified in an ultrasonic bath with distilled water for 15 min and were dried with a jet of air. Then, using the binocular glasses at 20-fold magnification, the enamel integrity was checked. The teeth with cracks and structural abnormalities were rejected. The teeth taken for the study were strengthened vertically in the plate made of cold-curing plastic.

Enamel defect contours with the area of $3.0 \times 3.0 \text{ mm}$ were marked on each tooth using the coarse grain bur 806. The 314.011 on the vestibular and buccal (lingual) surfaces. The layer with the thickness of 1.0-1.5 mm was removed on the enamel inside the contour using the fine grain bur 806, 314, 110. The sections were microscoped, determining the field of view area. With the increase by 3000 times the area is equal to 8699 mm^2 . The 199.2 ± 7.3 enamel prisms were visualized in the view field. The amount of enamel prisms defined in two fields of view was taken into account in each defect for statistical

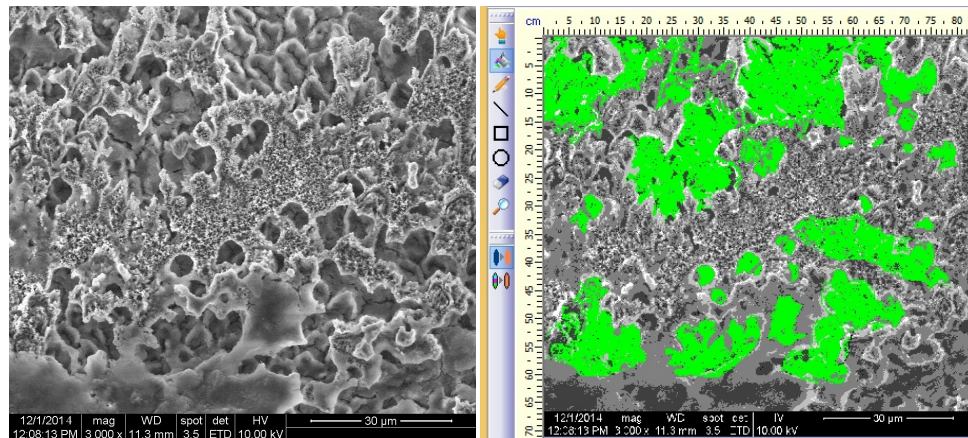


Fig. 1: a) Visualization of partially resorbed film of ftor-lux lacquer covering an artificially created enamel defect a month after the application of lacquer and the presence in an acidic environment; b) Visualization of partially resorbable ftor-lux lacquer film after the processing by the program Lpsquare

processing. Thereafter, 30 teeth were divided into three equal groups. According to the instructions, the artificial defects were covered with the following lacquers: Biflyuorid 12, Ftorlak, Ftor-Lux. The quality of film forming was evaluated by microscopy.

The lactic acid solution at the volume of 5 dm³ (5 L) was prepared and poured into 10 containers. The pH of lactic acid solution was tested immediately before the immersion of samples, achieving the value of 5.5±0.02. If necessary, pH was adjusted with sodium hydroxide or hydrochloric acid solutions.

Three fortified teeth were immersed in each of three containers. These teeth had artificial tooth enamel defects, covered by the films of various lacquers. The teeth were set in a thermostat which supports the mouth temperature (37.0 + 0.2)°C and they were left there for a month. On the completion of the exposure the samples were placed on filter paper and were left at the room temperature for 12 h to evaporate the liquid. After the drying of samples using a scanning ion microscope and a digital camera a defect area image was obtained. In order to compare the film retention stability formed by fluorinating varnishes subjected to a prolonged exposure with acidic environment the following algorithm was implemented:

- The number of open enamel prisms was determined in each field of view. Then, knowing the total number of enamel prisms, we calculated the number of sealed prisms. An average value was counted
- The resorbed areas of the film were selected formed after exposure in the acidic environment and their area was determined using the computer equipped by LpSquare program. Knowing the area of the field of view and the resorbed surface area, the area of preserved film was determined which allowed us to make the conclusion about its retention stability

RESULTS AND DISCUSSION

The visualizations of artificial defects covered by Biflyuorid varnish-12 after the end of the study 105.85±2.67 ($r \leq 0.05$) of enamel prisms appeared to be sealed, -53.2% of their total number are in the field of view. 97.16±3, 21 ($r \leq 0.05$) of enamel prisms were sealed on the visualizations of artificial defects covered by Ftorlak lacquer and 124.35±3.81 ($r \leq 0.05$) of enamel prisms were covered by Ftor-Lux which was equal to 48.8 and 62.3%, respectively.

The amount of spaces for resorbed film plots concerning the lacquer Biflyuorid-12 was defined within the 3724.73±29.21 mm² ($r \leq 0.05$) and the area with sealed enamel prisms 4974, 36±42.48 mcm² ($r \leq 0.05$) which made 57.2% of the field of view area.

The amount of spaces free from Ftorlak film was equal to 3957. 94±33.68 mcm² ($r \leq 0.05$). At that the film preserved at 4741.06±37.18 mcm² ($r \leq 0.05$) which corresponded to 45.5% of the enamel surface in the field of view.

The presence of the lacquer Ftor-Lux is not revealed at 2860.17±19.7 mcm² ($r \leq 0.05$). At that, it is visualized by 67.1% of the view field which made 5838.83±46.94 mm² ($r = 0.05$). The visualization of the field of view with a partially preserved film of Ftor-Lux lacquer is shown on Fig. 1a, b.

The data characterizing the stability of film retaining on the surface of the artificially damaged enamel by lacquers applied for the surface fluorination are presented in Table 1.

The emergence and the development of carious disease is the consequence of the effect on hard tissues of teeth acids produced by biofilm bacteria, leading to the loss of equilibrium due to demineralization and remineralization processes (Sirak and Sirak, 2013;

Table 1: The correlation of resorbed and remaining portions of lacquer film on the surface of artificially damaged enamel after the exposure in the test environment during a month

Evaluation criteria	*Biflyuorid-12	*Ftorlak	*Ftor-Lux
Number of sealed enamel prisms (pcs)	105.85±2.67	97.16±3.21	124.35±3.81
Number of gaping enamel prisms (pcs)	93.35±2.35	102.0±1.29	74.85±1.65
Area of resorbed sites (mcm ²)	3724.73±29.21	3957.9±33.68	2860.17±19.7
The area occupied by sealed enamel prisms (mcm ²)	4974.36±42.48	4741.0±37.18	5838.83±46.94

*The data characterizing the stability of the films formed by lacquers for surface fluorination are reliable at $r \leq 0.05$

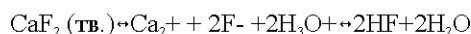
Sushchenko *et al.*, 2012; Ulitovsky, 2014). The effect of fluorine-containing lacquers is extremely important in terms of enamel primary damage prevention and in the cases of developed and recurrent caries progression. Electrochemical processes take place in an acidic environment which involve the release of Ca and P ions, resulting into the change of valence angle configuration in a hydroxyapatite crystal. Due to the deformation of the crystal loses its strength and becomes less resistant to a long-term chemical resistance.

In order to prevent the development of carious disease and restore crystal lattice enamel different means are used containing fluoride, calcium compounds and phosphates. Fluorides play a key role in the prevention and the treatment of dental caries (Rodionova, 2014). They promote the recrystallization of enamel, the incorporation and the retention of calcium and phosphate ions. The enamel remineralization develops fluorapatite with a certain level of acid resistance. Lacquer is one possible means of dental caries local prevention which is used for the extension period of fluoride impact on enamel.

From the hydromechanical point of view the feature of fluorinating lacquers is the ability of film development. The developed film is the reservoir and the provider of fluoride ions which stimulate the formation of fluorapatite and the process of hard tissue remineralization.

Tehno Dent (Russia) company suggested to use Ftor-Lux lacquer containing three active fluorinating components with varying degrees of solubility: sodium fluoride, calcium fluoride and aminoftorid. The lacquer composition includes: a film former and a thickener of natural origin and solvents. A film is developed after the application of lacquer and solvent volatilization on a tooth surface, slowly resorbable by saliva and releasing fluoride ions in a prolonged way. The electric chemistry composition is capable to maintain fluorine concentration of 300 ppm at least in the vicinity of a tooth surface covered with lacquer (Kuzmina *et al.*, 2014). The aminoftorid introduced into lacquer is a new generation fluorinating agent: it provides an immediate formation of calcium fluoride globules on the enamel surface. The molecule of fluorine organic compound N¹-octadecyltrimethylenediamine-N₁N₁N¹ (2 ethanol)-dihydrofluoride consists of hydrophilic (water soluble)

portion in the form of amino group, a hydrophobic portion with the hydrocarbon chain and fluoride ion which binds calcium ions easily. Aminoftorid prevents calcium loss and reduces enamel permeability immediately after the lacquer application on a the tooth. The developed lacquer film resorbing in saliva during the first day releases fluoride ion from a soluble sodium fluoride which saturates the liquid near the enamel prism crystals, resulting in fluid chemical equilibrium restoration and prevents the imbalance between the process of enamel demineralization and remineralization. The concentration of fluoride ions necessary for remineralization mechanism launch, supports the third fluorinating agent of the composition-calcium fluoride. Calcium fluoride is almost insoluble in a neutral medium and the acidic environment of an oral cavity (pH is 5.5 or less) increases its solubility as a fluoride ion reacts with the hydrogen ions. Consequently, two equilibria are established in a saturated solution of calcium fluoride:



In accordance with the principle of Le Chatelier's acidic environment leads to hydrogen fluoride concentration increase. Fluoride ion concentration decrease caused by this is partially offset by the shift of the first equilibrium to the right. Thus, the solubility of calcium fluoride is increased which makes it a stable source of calcium ions and fluorine (Tanganov, 2005). An optimal combination of three fluorides slows down the process of glucose decomposition, triggers the enamel remineralization mechanism and provides a reliable protection against caries (Lussi and Hellwing, 2016). A natural thickener facilitates the uniform distribution of fluorinating agents in a thin film layer. A film former and a thickener develop an insulating barrier against thermal, chemical and tactile irritants.

CONCLUSION

After the exposure in lactic acid solution for one month the sections of enamel treated with Ftor-Lux lacquers demonstrate 124.35±3.81 closed enamel prisms, the sections treated with Ftorlak lacquer-97.16±3.21, Biflyuorid-12 lacquer-105.85±2.67 of enamel prisms.

The impact of acidic environment leads to the resorption Biflyuorid-12 lacquer films by $3724.73 \pm 29.21 \text{ mcm}^2$ Ftorlak- $3957.9 \pm 33.68 \text{ mcm}^2$, Ftor-Lux- $2860.17 \pm 19.7 \text{ mcm}^2$

The results obtained during the study, allow us to recommend Ftor-Lux lacquer for an effective prevention of caries.

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