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RATIONALE BEHIND A MINIMALLY INVASIVE APPROACH IN THE TREATMENT OF DENTAL FLUOROSIS

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Abstract

Modern epidemiology of dental fluorosis is characterized by its high global prevalence. Dental fluorosis is a chronic disease that develops before teething with prolonged ingestion of water or foods with a high content of fluorine compounds. In Russia, an increased concentration of fluorine in water is detected in more than 20 administrative regions. In addition, endemic areas can be assisted with anthropogenic factors, particularly certain chemical industry. Improvement of the novel treatment methods for fluorosis turns out to be important and relevant. For the treatment of various forms of fluorosis, sufficiently effective materials have been currently developed, characterized by convenience and ease of use, as well as safety for a patient. Their use alone or in combination allows achieving high aesthetic results and maximum patient satisfaction.

The aim of this study is to measure the adhesive strength of the composite filling material to the Icon infiltrant (infiltration concept), as well as to compare it with the adhesion strength of the composite to the enamel using various adhesive systems. Icon was developed by the German company DMG and has been used worldwide since 2000. To assess the adhesive peel strength, 60 teeth with fluorosis and 60 intact teeth were examined. The largest values of the adhesive shear strength were identified in group 2 (the All bond universal adhesive system) and group 4 (the Icon etch), i.e. the approaches which contained MDP polymer. Overall, the results of our experimental study allowed considering the combined usage of the Icon infiltrant and the low-modulus composite material as a promising strategy in a routine dental clinical practice.

Keywords: *dental fluorosis, Icon system, microabrasion, White spot, superficial infiltration.*

Introduction

Dental fluorosis is a chronic disease that develops before teething with prolonged ingestion of water or foods with a high content of fluorine compounds. The disease is considered to be endemic. An analysis of the evidence from domestic and foreign literature convincingly demonstrates the high global prevalence of dental fluorosis.

In particular, according to some authors [*Aguilar-Díaz F et al., 2017; Pérez-Pérez N et al.*, 2017], in Mexican areas with more than 1.5 *mg/l* fluoride in the water, the prevalence of fluorosis ranged from 92 to 100%. In addition, a study by Jarquín-Yñezá and co-authors (2018) in the Mexican state of San Luis Potosi indicates that the prevalence of this pathology reached 100%.

Armas-Vega A.D. and co-authors (2019) re-

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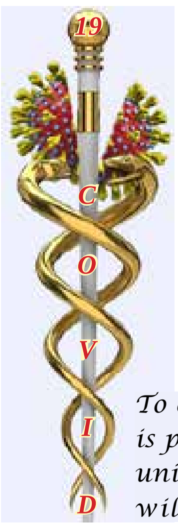
ported a high prevalence of fluorosis (89.96%) in Ecuador, in several provinces of Imbabura, Pichincha and Chimborazo. What is more, fluorosis was found in 63.7% (from 58.5 to 68.5%) of 12-year-old children in the city of Quito, Ecuador) [*Michel-Crosato E et al., 2019*]. An epidemiological study showed an upward trend in morbidity rates from 22% to 65% from 1986 to 2012 in the United States [*Neurath C et al., 2019*].

The high concentration of fluoride in soil and water causes a high incidence of the disease among the child population in African countries. Of note, the prevalence of fluorosis in Kenya was 86% [*Gevera P et al., 2019*], in Tanzania – 48.6% [*Simangwa L et al., 2018*], in the endemic region of Northeast Nigeria – 41.7% [*Idon P, 2018*], and in Ethiopia – 28% [*Demelash H et al., 2019*].

Scientists from India showed the presence of dental fluorosis in 64.3% of adolescents [*Verma A et al., 2017*], the results of researchers from Sri Lanka pointed to 72.9% [*Rajapakse P et al., 2017*], and the data from Chinese scientists 13.4% [*Antonijevic E et al., 2016*].

It is also necessary to note the data of European authors. In a number of European countries (UK, Germany, Serbia, Bulgaria), there were identified certain endemic regions with clinical manifestations of fluorosis of varying degrees [*Momeni A et al., 2007; Pretty I et al., 2016; Kukleva M et al., 2017*]. It is also necessary to note the data of European authors. In a number of European countries (England, Germany, Serbia, Bulgaria), they identified certain endemic regions with clinical manifestations of fluorosis of varying degrees [*Momeni A, 2007; Pretty I et al., 2016; Kukleva M et al., 2017*].

In 21 regions of the Russian Federation, an increased concentration of fluorine in water is detected [*Sultanov R, 2016*]. Particularly, a rise in the concentration of fluorine in the Moscow syneclise (Moscow, Tver and Ryazan regions) and in the Ural basin (Sverdlovsk and Chelyabinsk regions) is due to a certain composition and structure of rocks. Endemic areas in the Moscow, Vladimir, Vologda, Ryazan regions, the Republic of Mordovia, the Udmurt Republic are associated with anthropogenic sources - glass factories, in the Kirov, Kostroma regions - with plants producing organophosphate fertilizers, in the Sverdlovsk, Kemerovo, Irkutsk regions, the Krasnoyarsk territory, the Republic Khakassia, Republic of Karelia) - with plants producing aluminum and cryolite.



The frequency of fluorosis among children living in the Central Federal District of Russia was quite high [*Kuzmina E et al., 2015*]. For example, in Zelenograd (a large administrative unit of the city of Moscow), clinical signs of fluorosis were diagnosed in 44% of children aged 12 years. The following cities were characterized by higher numbers: 46% in Krasnogorsk, 57% in Ramenskoye, 77-87% in Tver.

Dental fluorosis may be associated with excessive intake of fluoride into the body during the enamel formation. Findings of Makeeva I.M. and co-authors (2017) suggest that the optimal concentration of fluorine in water is 0.7-1.0 *mg/l*. The fluorine from 0.8 to 1 *mg/l* is accompanied by minor violations of the enamel structure in 10-12% of inhabitants of the endemic area, while at a concentration of 1.0-1.5 *mg/l* fluorosis occurs in 20-30%. At a concentration of 1.5-2.5 *mg/l*, fluorosis was diagnosed in 30-45%, and at a concentration of more than 2.5 *mg/l*, this disease was detected in 90% of the population.

According to the International Classification of Dental Diseases based on ICD-10, fluorosis was designated by the code K00.30 (K00.3 - mottled teeth).[3.75]

A color change is known to be a central diagnostic sign of this disorder. One can reveal a matte shade of teeth in dental fluorosis, and the color of the enamel can vary from white to yellow or dark brown streaks and spots. In erosive and destructive forms, enamel defects, abrasion and destruction of the crown are observed.

Of great significance, changing the color of teeth due to fluorosis results in psycho-emotional problems and a decrease in the quality of life of patients [*Garcia-Perez A et al., 2017*]. Therefore, improvement of the novel treatment methods for fluorosis turns out to be important and relevant. In particular, considerable attention now is attributed to the minimally invasive approach, which is based on the maximum preservation of hard tissues and allows achieving a significant aesthetic result.

A violation of the enamel mineralization in fluorosis necessitates remineralization therapy. However, this treatment option does not provide immediate aesthetic results and requires a patient to firmly adhere to a regimen for the application of a preparation. In addition, remineralization occurs only superficially, and a body of the lesion remains porous. These facts can explain the unpredictability of results following remotherapy as well as the persistence of the color of a white spot [*Zawaideh F, 2014*].

To eliminate discoloration limited to the superficial enamel layer, Croll T.P. proposed the microabrasion method in 1993. This approach implies applying an acid and an abrasive agent to the surface of an affected tooth. The thickness of the removed enamel layer during microabrasion reaches up to 200 micrometers, depending on the concentration of the acid and the duration of a procedure [*Croll T et al., 2009*].

For microabrasion, one can use Opalustre gel (Ultradent, USA), which contains 6.6% hydrochloric acid and silicon carbide microparticles. After isolation of soft tissues, treatment is carried out using rubber cups Opal Cups at low speed of the contra-angle for 10-20 seconds on each tooth. The number of applications of Opalustre gel depends on a degree of enamel staining [*Nahsan F et al., 2011*]. Researchers in different countries have developed recommendations on the frequency of application of the substance. Celik E. and colleagues (2013) suggested treating the enamel 5 times for light staining, and up to 10 applications for moderate to severe staining. Similarly, Akulovich A.V. and Yalyshev R.K. (2015) recommends up to 5 applications of Opalustre Gel per microabrasion session. After a course of microabrasion, it is necessary to conduct remineralizing therapy in individual mouthguards for 1 month.

The location of the subsurface zone of hypomineralized enamel under a layer of well-mineralized enamel in fluorosis substantiates administration of the infiltration technique. With this pathology, such a procedure may be feasible using the Icon system (an acronym for Infiltration concept). The Icon (DMG) system includes the following key components:

- Icon-Etch: 15% hydrochloric acid, pyrogenic silicic acid, surfactants;
- Icon-Dry: 99% ethanol (rectified ethyl alcohol - contains 95.57%, absolute ethyl alcohol - 99.9% alcohol content);
- Icon-Infiltrant: methyl methacrylate, initiators, additives.

The method is built on the removal of the enamel superficial layer with 15% hydrochloric acid, followed by filling the hypomineralized focus with a mixture of synthetic resins. Since these resins have certain rheological properties (low viscosity), a higher penetrating power (high penetration coefficient) can be achieved. As a result of impregnation with the infiltrant and its polymerization, the porous demineralized enamel is filled with polymer resin, which changes the refraction of light and ensures the achievement of an aesthetic result after infiltration.

But unlike a carious spot, the zone of hypomineralization during fluorosis is located deeper, and this increases resistance to the infiltration process [*Shahroom N et al., 2019*]. Consequently, to provide access to a hypomineralized zone and the subsequent deeper penetration of the infiltrant, the treatment of a dental surface with hydrochloric acid should be repeated several times until a visual change in color occurs [*Bharath K et al., 2014*]. In addition, the authors proposed extending the exposure to hydrochloric acid in fluorosis [*Gugnani N et al., 2012*].

Also, a number of authors recommend a combination of microabrasion and subsequent infiltration in the treatment of deep white spots [*Giannetti L et al., 2018*].

An interesting concept for the treatment of white spots was proposed by Attal J.P. and co-authors (2014). With respect to this approach, in the treatment of mild forms of fluorosis, the authors used surface infiltration with the treatment of Icon Etch, Icon Dry and Icon Infiltrant according to a well-known algorithm. The authors described the implementation of deep infiltration in the absence of results, as well as in moderate and severe forms of fluorosis. In this case, the surface of a stain is treated with a powder containing aluminum oxide, then infiltration is carried out and the surface is covered with a composite filling material.

In the light of the scientific facts presented, it seems important and reasonable to study the adhesive strength of a composite filling material to the Icon infiltrant and then compare the strength with the adhesive strength of the composite to enamel when using various adhesive systems.

In this study, we measured the adhesive strength of the composite filling material to the Icon infiltrant, and then we compared it with the adhesion strength of the composite to the enamel using various adhesive systems.

Material and methods

To assess the adhesive peel strength, 60 teeth with fluorosis and 60 intact teeth were examined. Teeth affected by fluorosis were randomized into 4 groups of 15 teeth each (Groups 1, 2, 3, 4), and intact teeth were divided into 4 groups of 15 teeth in each group (Groups 5, 6, 7, 8). In order to examine the adhesive strength, a defect was created. For this, a center of the vestibular surface was treated with a powder based on aluminum oxide with a particle size of 27 micrometers at a distance of 1 cm for three seconds using a sandblaster (Rondoflex, KAVO, Germany).

After that, in groups 1 and 5, a dental surface was treated with orthophosphoric acid (Travex gel, Omegadent, Russia), the 5th generation adhesive system Optibond solo plus (Kerr, Italy) was applied, and polymerization was carried out for 20 seconds. The next step was the application of low-modulus composite material Estelite flow quick (Tokyama dental, Japan) in the form of a bar 4×3×3 *mm* in size and polymerized for 20 seconds. After making the first bar, we took an impression from it with the help of the Speedex silicone mass. The impression was cut longitudinally so that subsequent samples were poured in the same shape.

In groups 2 and 6, a surface was treated with phosphoric acid (Travex gel, Omegadent, Russia), the All bond universal adhesive system (Bisco, USA) was applied, and polymerization was carried out for 20 seconds. After that, we applied the low-modulus composite material Estelite flow quick (Tokyama dental, Japan) in the form of a bar 4×3×3 *mm* in size and polymerized for 20 seconds.

In groups 3 and 7, an enamel surface was treated with Icon etch (DMG, Germany) thrice for three minutes using a special nozzle Icon vestibular (DMG, Germany), washed off with water and dried after each application. We then applied Icon dry for 30 seconds and Icon infiltrant for 3 minutes, removed excess material and cured for 40 seconds. After that, Icon infiltrant was reapplied for 1 minute, excess material was removed and polymerized for 40 seconds. Further, without polishing a surface, the low-modulus composite material Estelite flow quick (Tokyama dental, Japan) was applied to a surface of the infiltrant in the form of a bar 4×3×3 *mm* in size and polymerized for 20 seconds.

In groups 4 and 8, we treated an enamel surface with Icon etch (DMG, Germany) three times for three minutes using a special nozzle Icon vestibular (DMG, Germany), rinsed with water and dried after each application. Then Icon dry was applied for 30 seconds and Icon infiltrant for three minutes, excess material was removed and cured for 40 seconds. After that, Icon infiltrant was reapplied for one minute; excess material was removed and polymerized for 40 seconds. Further, without polishing the surface, a low-modulus composite material containing the MDP monomer, Constic (DMG, Germany) was applied to the surface of the infiltrant in the form of a bar 4×3×3 *mm* in size and polymerized for 20 seconds.

After the composite bars were fixed, we measured their length, width, and height. Then the samples were placed in distilled water in a thermostat at a temperature of 37°C for 24 hours. After preparing the samples, we measured the adhesive shear strength.

Peel adhesive strength was determined using an Instron universal testing machine (USA) with a traverse speed of 0.8 *mm/min*. Peel adhesive strength was determined using an Instron universal testing machine (USA) with a traverse speed of 0.8 *mm/min*.

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This apparatus allows you to determine the force applied to a sample for separation, (F), expressed in newtons (N). This apparat allows you to determine the force applied to the sample for separation, (F), expressed in newtons (N).

This tool allows you to determine the force applied to the sample to pull off, (F), expressed in Newtons (N).

The data were analyzed using the Instron Bluehill 3 software. The peel adhesion strength Σ was calculated using the formula: $\Sigma = 3Fl/bh^2$, where F is the force in Newtons (N) applied to the composite bar at which the peel occurred; The data were processed using the Instron Bluehill 3 software. The peel adhesion strength Σ was calculated using the formula: $Σ=3Fl/bh^2$, where F is the force in Newtons (N) applied to the composite bar at which the peel occurred;

TABLE 1

Comparison of adhesive shear strength in the studied groups.

S, MPa	Median (IQR)	Min	Max	Mean (±SD)	Difference in means (95% CI)
Group 1	19.13 (17.41-20.26)	17	24	19.11±1.84	1 vs 5 -0.45 (-2.15 to 1.24)
Group 2	26.35 (25.45-27.58)	18	28	25.82±2.48	2 vs 6 -0.003 (-2.15 to 2.16)
Group 3	20.12 (18.88-21.47)	16	24	20.12±2.08	3 vs 7 -0.71 (-2.97 to 1.53)
Group 4	26.69 (24.74-27.82)	23	30	26.43±2.07	4 vs 8 -0.65 (-2.27 to 0.97)
Group 5	19.15 (17.29-21.69)	16	25	19.56±2.62	-
Group 6	25.63 (22.89-27.69)	21	33	25.83±3.23	-
Group 7	21.43 (17.96-23.24)	13	27	20.84±3.69	-
Group 8	27.75 (26.03-28.52)	21	29	27.08±2.25	-

The data were processed using Instron Bluehill 3 software. Peel adhesion strength Σ was calculated by the formula: $Σ=3Fl/bh^2$, where F is the force in Newtons (N) applied to the composite bar at which the peel occurred;

l is the length of the bar in m^2; l is the length of the bar in m^2;

l - bar length in m^2;

b is the width of the bar in m^2; and b is the width of the bar in m^2;

b - bar width in m^2;

h - is the height of the bar in m^2. Peel adhesive strength (Σ) was expressed in N/m^2 or in megapascals (MPa).

Statistical analysis: Descriptive statistics included mean with standard deviation (SD), median, and interquartile range for continuous variables and frequency, and percentage for categorical variables. Statistical tests were 2-sided, with p values of 0.05 or less considered statistically significant. *P* values should be interpreted cautiously because of multiple comparisons, and if necessary, *p* values were adjusted. We computed 95% confidence intervals (CI) for the difference in means. All observed data were included in data summaries and analyses. Statistical analyses were conducted using IBM SPSS Statistics 26.

RESULTS

Peel adhesive strength Σ was expressed in N/m^2 or in megapascals (MPa).

The table represents the data on the adhesive shear strength in the studied groups.

The largest values were identified in groups 2 and 4, i.e. the approaches which contained MDP (Methacryloyloxydecyl dihydrogen phosphate) polymer. Kruskal-Wallis test for the adhesive strength for the affected teeth gave us $\chi^2 = 34.19$, $p<0.0001$. Hence there was a good evidence for significant overall difference between the comparison groups. To determine which specific groups had significant differences, it was necessary to conduct a pairwise comparison of all groups. After using Mann-Whitney U-test and recalculating the significance level *p* as an adjustment for multiple comparisons ($p=0.0083$), we revealed significant differences in the following pairs: group 1 vs 2, groups 1 vs 4, groups 2-3, and groups 3-4.

We have compared the efficacy of the adhesion systems provided by various manufacturers including the Icon system. For the three approaches, a similar composite material was administered. Furthermore, we have quantified the effect of the Icon system combined with a distinct composite material. The results obtained allowed us to conclude that there were no differences in the adhesive strength of the composite material to enamel when using the same method of adhesive fixation in the intact teeth and those with fluorosis. We found out statistically significant differences ($p<0.0001$) in terms of adhesive peel strength when applying the universal adhesive system and low modulus composite material. In addition, similar results were obtained with a combination of an infiltrant and a low-modulus composite material Constic containing an MDP monomer.

Conclusion

The results our experimental study allowed considering the combined usage of the Icon infiltrant and the low-modulus composite material as a promising strategy in a routine clinical practice. In turn, appropriate studies are in progress now and will be presented in the following papers.

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