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THE EFFECT OF MINIMALLY INVASIVE TECHNIQUES ON THE MICROSTRUCTURE OF THE ENAMEL IN THE WEDGE-SHAPED DEFECT

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Abstract:

Objective: The aim of the study was to assess the changes in the microstructure of the enamel and its chemical composition in the area of the wedge-shaped defect with the use of minimally invasive technologies in experiments.

Materials and methods: The materials of the assessment were 45 thin sections of the teeth which had been extracted with orthodontic indications and had the wedge-shaped defect within the enamel. The changes in the enamel microstructure with the use of minimally invasive technologies - enamel infiltration Icon (DMG) and closure of the defect with the composite Estelite Asteria (Tokuyama Dental) were studied with the help of the scanning electronic microscope Quanta 200 i 3D FEI (USA) with the energy-dispersive microanalysis system with resolution capability 2,9 nm at 30 kV in dynamics

Results. The structural changes in the enamel depend on the nature of the pathological process, its depth and microstructural changes. A developing pathological process is characterized by the presence of pores, deep cracks in the enamel rods, demineralization areas, linear chaotic defects with clear borders. The changes in the chemical composition of the enamel in the wedge-shaped defect is characterized by the increase in oxygenation by 1.2 combined with the decrease in carbon compounds by 1.4, the decrease in fluorine by 1.2 and the emergence of sulfur, thus most likely confirming the changes in the crystal structure of hydroxyapatite. With the help of the optical microscopy we were able to visualize the structural changes of the enamel within the defect in the samples with infiltration treatment by Icon (DMG) and closure of the defect with restoration. The conclusions concerning the necessity to continue the scientific research of the treatment of the wedge-shaped defect within the enamel were made.

Keywords: wedge-shaped defect, non-carious diseases, thin sections of the teeth, microstructure, non-invasive techniques

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INTRODUCTION:

The prevalence of non-carious diseases of hard tissues of teeth occurring after teething has been rising significantly in the recent years and reaches 60% in some regions of Russia [1,3,8] while being 82% in the world population [2]. Additionally, these diseases are becoming more prevalent among the younger population [3,8]. The steady rise of these diseases in young population indicates that this issue is also a socio-economical one rather than only a medical one [6]. Therefore, it is of particular relevance to assess the quality of dental care and to evaluate the effectiveness of existing treatment techniques [6,10]. The most modern technologies used in medicine and dentistry in particular are non-invasive and minimally invasive ones. However, there is still no methodology for deciding on the right technology in patients with non-carious diseases, specifically with the wedge-shaped defect. As for the treatment to the wedge-shaped defects – in both Russian and foreign literature the most common cases describe radical approaches as treatment of choice. Thus, the rational of the use of minimally invasive and combined methods necessitates performing this study and defines its algorithm [4,6,8].

The minimally invasive treatment method of infiltration for white spot lesion stage of caries is confirmed to be a promising one by numerous laboratory and clinical studies performed worldwide [7,5]. It is currently debatable whether such method is applicable for correction of non-carious defects. The presence of demineralized areas in early stages of the wedge-shaped defect is confirmed experimentally and clinically [8,10].

Objective: To assess the effectiveness of minimally invasive methods for correction of the wedge-shaped defect in experiments.

Materials and methods: In this study, 45 thin sections of teeth (made using microtome HM 450 in vitro) which had been extracted with orthodontic indications and had the wedge-shaped defect within the enamel were assessed. All patients had signed the informed consent to surgical interventions as well as to the assessment of their biological samples in this study. Assessed teeth were mechanically pre-cleaned of plaques; tooth thin sections were placed in the artificial saliva.

Methods: Clinical, analytical, optical, morphological, statistical.

Teeth thin sections were divided into three groups:

First group: 15 samples presenting the wedge-shaped defect within enamel.

Second group: 15 samples infiltrated by minimally invasive technology Icon (DMG).

Third group: 15 samples with the wedge-shaped defect, which were corrected by composite restoration Estelite Asteria (Tokuyama Dental) with the adhesive system Bond Force II (Tokuyama Dental).

Electronic copies showing the enamel microstructure in the wedge-shaped defect were analyzed in various stages of its correction. Results were obtained with the help of the scanning electronic microscope Quanta 200 i 3D FEI (USA) with the energy-dispersive microanalysis system and with high current focused ion beam (FIB) allowing for 3D reconstruction, visualization and object modification. This technology enables us to obtain high quality photographs of non-conductive biological objects without their preliminary preparation. The chemical analysis of the tissues affected by the wedge-shaped defect before and after using minimally invasive techniques was also made.

While studying the wedge-shaped defect samples structural changes in the enamel surface were identified. The presence of cracks in the enamel rods were noticed, their chaotic distribution, width variety and presence of pores in the affected area were also noted. In the area of the wedge-shaped defect there presented distinct lesions with clear borders, which suggested the presence of past focal demineralization (fig. 1). These data are also consistent with the research of DeLaurier et al [9]. Using 6000x magnification we obtained an image of the enamel crack distinctly aligned with enamel rods (fig. 2).

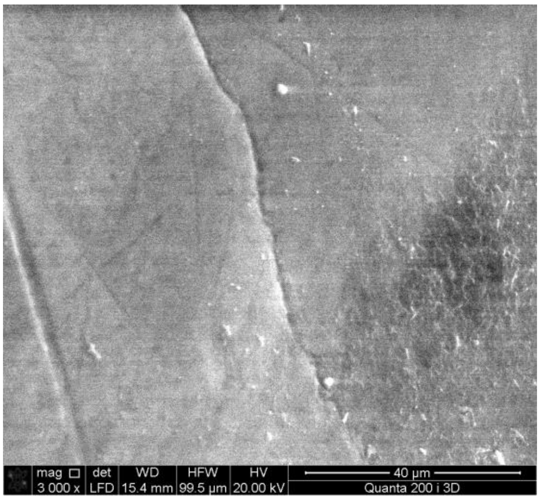

Fig. 1. Enamel surface of the wedge-shaped defect, SEM, x3000

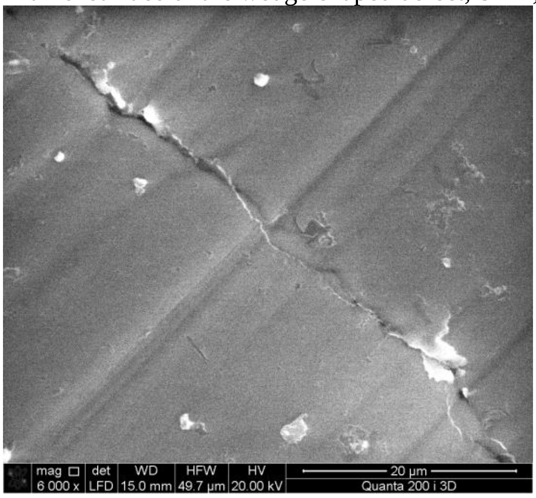

Fig. 2. Enamel surface of the wedge-shaped defect, SEM, x6000

The qualitative and quantitative chemical analysis of the enamel within the wedge-shaped defect was the following: C-21.1±1.5; N-5.09±0.76; O -35.8±1.3; Na – 1.4±0.4; P -12.7±0.9; Cl – 0.7±0.2; Ca- 25.2±1.9; Mg —0.3±0.04 (fig.3).

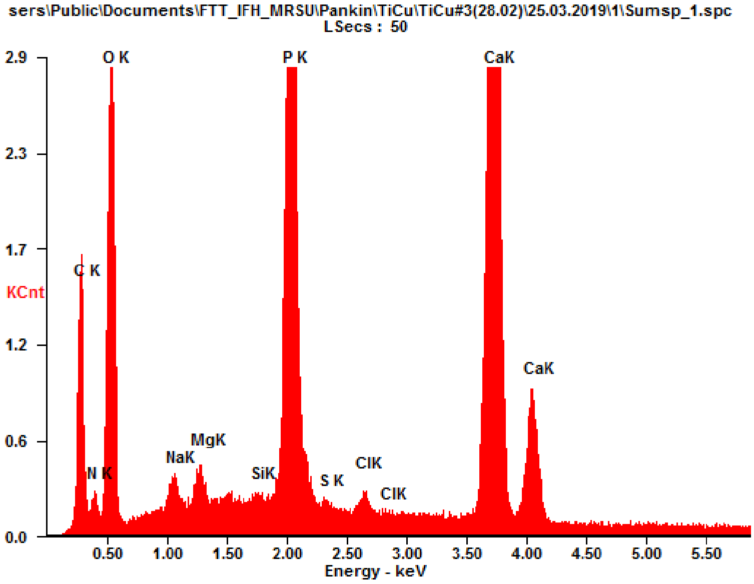

Fig. 3. Chemical composition of the tooth enamel within the wedge-shaped defect.

Chemical composition analysis showed that in the wedge-shaped defect with affected adjacent tissue oxygenation increased by 1.2±0.1, combined with a decrease in carbon compounds by 1.4±0.2, a decrease in fluorine 1.2±0.1 and the emergence of sulfur, thus most likely confirming the changes in the crystal structure of hydroxyapatite. The calcium-phosphorus ratio of 1:0.7 confirmed the presence of demineralizing processes. The loss of mineral components in the area of the wedge-shaped defect and the process progression occur, such patterns being revealed in all stages of dynamic observation. This in turn fully justifies the use of infiltration treatment.

When microscopically observed thin sections from the second and the third groups showed significant differences.

With the help of the optic microscopy, we were able to visualize the structural changes of the enamel within the defect in the samples with infiltration treatment by Icon (DMG). Thin sections with partial enamel demineralization clearly showed the presence of infiltrate in the affected area, which presented itself with glossier and brighter spots in contrast to the more opaque intact enamel (fig. 4). On the surface of the thin section, such spots have a cellular structure (fig. 5).

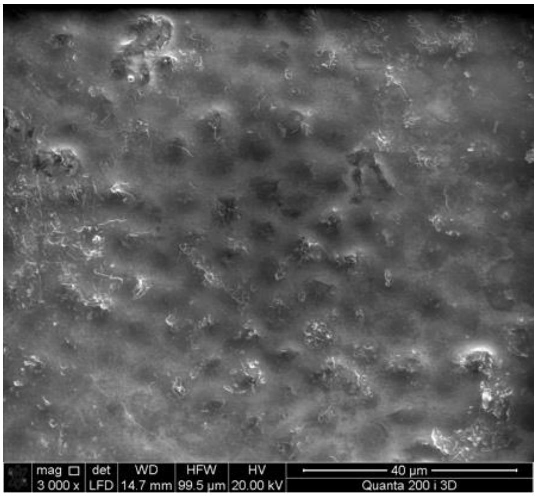

Fig. 4. The surface of the thin section treated with Icon (DMG), SEM, x3000.

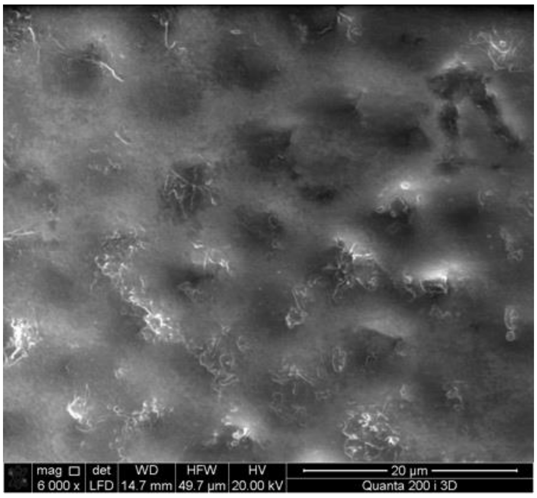

Fig. 5. The surface of the thin section treated with Icon (DMG), SEM, x6000.

The image shows the presence of infiltrate on the walls of the tooth cavity in the form of a lighter line (Fig. 5). This allows us to suggest the high adhesiveness of Icon infiltrate due to the high fluidity of methyl methacrylate resin. However, this technique is not designed for restoration of the missing tissue in the wedge-shaped defect.

The qualitative and quantitative analysis of the chemical composition in the site with applied infiltration is the following: C- 28.2±5.9; O —

33.2±1.5; Na — 0.6±0.04; P — 13.3±0.9;Mg-0.26±0.05; Si- 0.34±0.05; Cl -0.44±0.06; Ca — 23.5±3.3 (fig. 6). The thin layer and high fluidity of the polymer resin explain the minor changes in the chemical composition in comparison with the tissues affected by the wedge-shaped defect. Slight changes in the qualitative and quantitative composition of the enamel after Icon (DMG) infiltration confirm the formation of a thin inert film on the surface of the treating tissue.

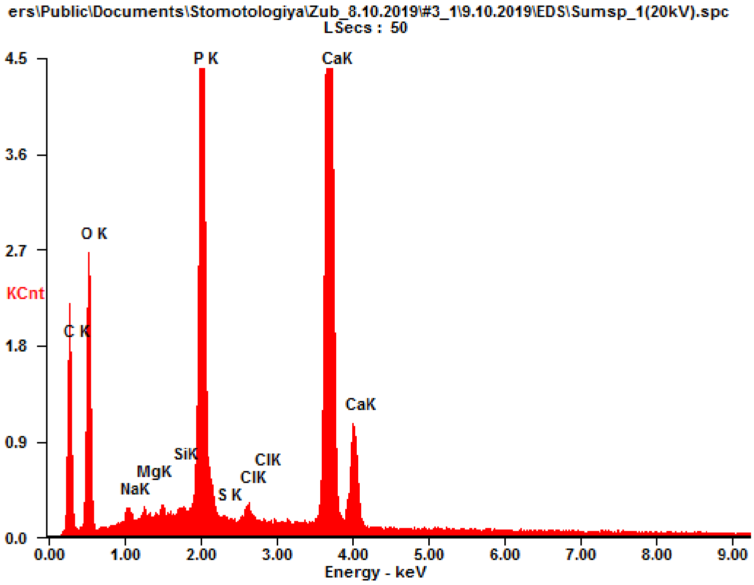

Fig. 6. The qualitative and quantitative analysis of the tooth chemical composition in the site with the use of infiltration.

In this group the calcium-phosphorus ratio is 1.6:1 indicating the process stability and its shift to a dynamic improvement, the enamel composition becoming more similar to a healthy one (t-statistics, 4.6 - probability of null hypothesis <5%, Pearson correlation coefficient - weak-positive 0.15 < 0.5).

While studying the samples from the third group it was confirmed that light-curable composite material Estelite Asteria (Tokuyama Dental) combined with the 7th generation adhesive system Bond Force II (Tokuyama Dental) (fig. 7) leads to the full restoration of the hard-tissue defect within the enamel.

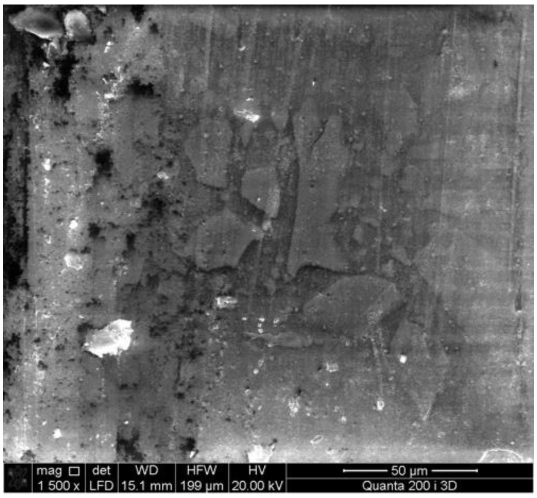

Fig. 7. The surface of the thin section restored with Estelite Asteria (Tokuyama Dental), SEM, x1500.

Thus, while microscopically visualizing the architectonics of the affected sites - the filling material is clearly present on the affected tooth, but the restoration is permeated by microcracks throughout its length (fig. 8).

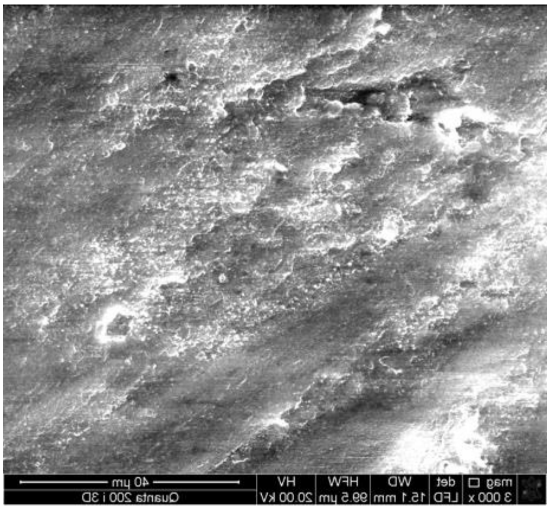

Fig. 8. The surface of the thin section restored with Estelite Asteria (Tokuyama Dental), SEM, x3000.

In the images of the samples treated with Estelite Asteria (Tokuyama Dental) a tight contact between the filling material and the tooth tissues is clearly seen, which confirms the high level of adhesion. The transition area between the filling material and the tooth tissue is dense and shows no presence of macro- or micro cracks (fig. 9).

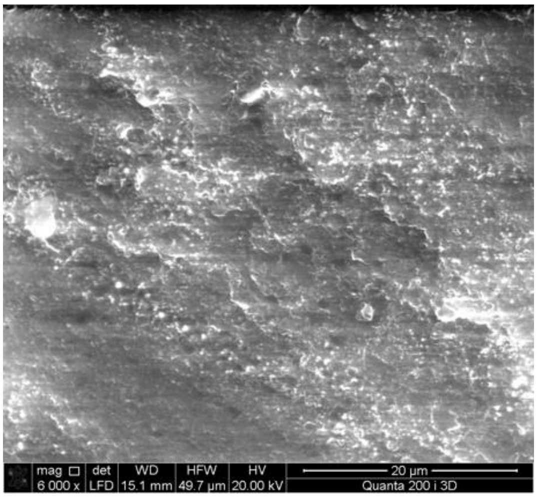

Fig. 9. The surface of the thin section restored with Estelite Asteria (Tokuyama Dental), SEM, x6000.

However, the demineralized lesion in the wedge-shaped defect's cavity determined in the images remains under the restoration thus increasing the risks of recurrence or development of the carious processes under the filling. This bears a major clinical significance since the incomplete treatment of the tissue can lead to increased risks of recurrence or development of the carious processes under the filling thus worsening the condition of the hard tissues.

The qualitative and quantitative analysis of the chemical composition of the tooth enamel in the site of restoration with Estelite Asteria (Tokuyama Dental) is the following: C- 27.7±5.7; O — 32±2 Na — 0.5±0.05; Si- 22.6±1.2; Cl – 0.44±0.06; S - 0.17±0.059; P - 12.3±1.7; Ca - 25.9±3.8; Zr - 8.85±0.045 (fig. 10).

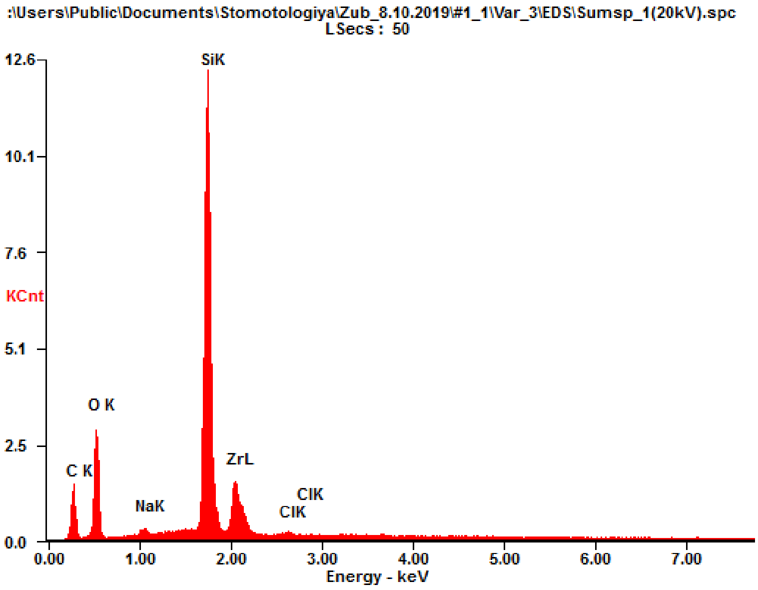

Fig. 10. The qualitative and quantitative analysis of the chemical composition in the site of restoration.

The presence of enamel demineralization is also confirmed by the calcium-phosphorous ratio of 1:0.8, which leads to weakening the process of remineralization and does not result in stabilization. Findings of silicon and zirconium in the enamel layer confirm the presence of the main components of the composite material Estelite Asteria (Tokuyama Dental).

Differences between the first and the second, the first and the third groups are statistically significant ($p < 0.05$, confidence interval 95%) while the obtained values between the second and third groups are not statistically significant. This is due to the increased calcium loss from the hard tissues of the tooth. The same pattern is observed with respect to phosphorus (group I - 1.07 ± 0.11 mmol/L; II - 1.57 ± 0.08 mmol/L; III - 1.47 ± 0.1 mmol/L) in thin sections with a wedge-shaped defect and after application of minimally invasive techniques.

Obtained results confirm that minimally invasive technique can be the treatment of choice in the wedge-shaped defect within the enamel infiltrating the demineralized zone and preventing the further development of the pathological process. At the same time it is important to take into consideration the fact that the enamel defect is not restored which in turn might lead to the disease progression.
Conclusion:

The results of our study give evidence that the structural changes in the enamel depend on the nature of the pathological process, its depth and the nosological form of the disease. In this case the microstructure of the enamel in the affected area is characterized by the presence of pores, deep cracks in the enamel rods, demineralization areas, linear chaotic defects with clear borders, which are confirmed by the optic images made with the help of the scanning electronic microscope.

This study shows the necessity of the further investigation of this problem using the scientific research aiming at theoretical rationale and clinical judgement of using minimally invasive technologies in the enamel structure for restoring the wedge-shaped defects.

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