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# DEVELOPMENT OF THE PRECISION DEVICE FOR TARGETED DELIVERY OF MEDICATION AND CREATION OF ISOLATED RESERVOIRS IN THE WEDGE-SHAPED LESION

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**Svetlana Gazhva[1], Roman Gorbatov[2], Elena Yakubova[1]✉, Ruslan Kasumov[1], Natalia Krasnokutskaya[1]**

[1] *Department of Dentistry, Faculty of Doctors' Advanced Training, Privolzhsky Research Medical University, Nizhny Novgorod*
[2] *Department of Traumatology, Orthopedics and Neurosurgery, M.V. Kolokoltsev Privolzhsky Research Medical University, Nizhny Novgorod, Russia*

✉ *ilina.ramaeva@mail.ru*

**ABSTRACT** — This study proves the necessity of using new minimum intervention tooth-preserving technologies and their implementation methods in hard dental tissue pathology treatment, in particular, wedge-shaped defects within enamel. Personalized approach to choosing the treatment method for this type of pathology is updated. The study prioritizes the pathogenetic mechanisms of this process, taking into account morphofunctional changes in enamel. Changes in architectonics of tooth enamel and its elemental composition are studied and discussed. A method of delivering the medication directly into the lesion is suggested.
The objective of this study was to develop a precision device for targeted delivery of medication and creation of isolated reservoirs in the wedge-shaped lesion. Materials: slices of teeth removed due to orthodontic indications. Methods: experimental, analytical, statistical, sociological, electron microscopy.
The scientific basis and principles of the research concept are based on the data on microstructural transformations, changes in the elemental composition of the tooth with a wedge-shaped defect. It is proved that oxygenation increases in a wedge-shaped lesion while the amount of fluorine and carbon compounds decreases, leading to the presence of such non-specific microelements as sulfur. The results obtained are the basis for the application of a targeted and personalized algorithm for treating this pathology, using additive technologies and 3D printing.

## INTRODUCTION

The global scientific community has proved in theory, and dentists have confirmed it in practice that the incidence of hard dental tissue disease, both before and after tooth eruption, tends to increase [1, 3]. Based on the data from foreign scientists, carious lesions of hard dental tissue are diagnosed in 98% of the world population [2], while the incidence of non-carious lesions forming after tooth eruption has increased significantly and has reached 60% in some of the Russian regions and 82% in the world [3, 4, 5]. At the same time, this pathology is becoming more prevalent in younger people [3, 6, 7], with 53.6% of people being diagnosed with this pathology at the age of 21 to 35 years old [3] which makes it not only a medical, but also a socio-economic issue [1, 2, 4].

The diagnostic difficulty and the low efficiency of treatment at earlier stages are caused by the lack of consensus regarding the etiology, pathogenic mechanisms [4] and the treatment strategy, and depend on the intensity of destructive changes in the enamel structure, as well as the oral cavity conditions [5]. Most of the existing treatment methods do not provide the necessary long-term effect and require follow-up visits and additional treatment courses, as the disease state worsens and complications appear [3, 4,5, 6]. Moreover, the application of such methods leads to discomfort in the oral cavity of patients, as well as aesthetic defects on the enamel surface [3, 5, 7]. In order to solve this problem, it is necessary to find new minimum intervention tooth-preserving technologies and methods, and to develop a personalized approach to choosing the treatment method in each specific clinical situation [4, 5].

## OBJECTIVE

Development of the precision device for targeted delivery of medication and creation of isolated reservoirs in the wedge-shaped lesion at initial stages.

## MATERIALS AND METHODS

We have carried out a controlled, guided, experimental in vitro study, aimed at studying enamel architectonics, and its elemental composition in a wedge-shaped lesion, and subsequently analyzing e-copies of the enamel structure. We focused on the initial symptoms of a wedge-shaped defect because it determines the choice of non-invasive technologies. The study was conducted at a laboratory for electron microscopy and small-angle X-ray diffractometry using a Quanta 200i

3D FEI scanning electron microscope (USA) with a energy dispersive spectroscopy system (Fig. 1).

***Fig. 1.*** *A Quanta 200i 3D FEI scanning electron microscope*

The study materials were slices of teeth removed in vitro due to orthodontic indications with a HM 450 microtome and having a wedge-shaped defect on their surface. We analyzed the results of e-copies of teeth slices, registered changes in enamel architectonics (represented by fissures along the enamel columns) and pores in the lesions (Fig. 2), and visualized the enamel lesion demineralization area (Fig. 3)

The enamel elemental composition in a wedge-shaped lesion (Fig. 4) showed an increase in oxygenation, decrease in the amount of fluorine, presence of sulfur (which most likely proves a change in the crystal structure of hydroxyapatite) as well as decrease in the amount of carbon compounds. The calcium-phosphorus ratio was 1:0.7 which indicates a demineralization process.

The obtained results were subjected to statistical processing which showed statistical confidence ($p < 0.05$, confidence coefficient — 95%).

The obtained results were used to develop a method for mathematical modelling-based transfer of lesion parameters to a 3D model using mathematical formulas, to determine the amount of damaged tissues, to calculate the optimal amount and size of cavities required to deposit the medication in the hard dental tissue lesion, to develop a technology for computer modelling of a personalized 3D tooth lesion model, to develop a method for creating pores of any complexity, shape and size on the 3D model prototype of a personalized mouth guard for high-precision delivery and deposition of medication, and to develop a technology for SLA 3D printing of a jaw model with a medication reservoir prototype.

*The following equipment was used for the study:*

An SLA 3D printer — Formlabs Form 2 (USA) (Fig. 5), a 3D scanner — Shining 3D (Fig. 6)

***Fig. 2.*** *Enamel surface in the wedge-shaped lesion area, fissures and pores in the lesion area; SEM, 3000x magnification*

***Fig. 3.*** *Enamel demineralization in the wedge-shaped lesion, SEM, 3000x magnification*

| Element | Wt% | At% |
|---|---|---|
| CK | 22.27 | 32.57 |
| NK | 07.92 | 09.94 |
| OK | 38.22 | 41.96 |
| NaK | 00.62 | 00.47 |
| MgK | 00.52 | 00.37 |
| SiK | 00.10 | 00.06 |
| PK | 10.09 | 05.72 |
| SK | 00.11 | 00.06 |
| ClK | 00.26 | 00.13 |
| CaK | 19.88 | 08.71 |
| Matrix | Correction | ZAF |

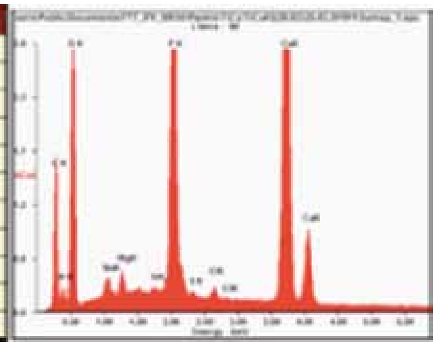

***Fig. 4.*** *Enamel elemental composition of a tooth with a wedge-shaped defect*

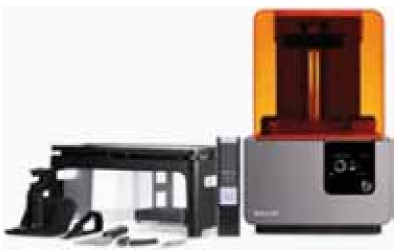

***Fig. 5.*** *An SLA 3D Printer – Formlabs Form 2 (USA)*


***Fig. 6.*** *A 3D Scanner – Shining 3D*

The technological process consists of the following stages:

***Stage 1:*** taking the impressions of the upper and lower jaw, using silicone material on plastic impression trays, and model casting (Fig. 7). ***Stage 2:*** 3D scanning of the stone jaw model and obtaining a virtual 3D prototype of such model (Fig. 8). ***Stage 3:*** loading the virtual prototype into the Autodesk Meshmixer software (USA) and hybrid parametric modelling of the pathological lesion on the 3D model of a patient's damaged tooth (Fig. 9). ***Stage 4:*** modelling the microspheres for local retention of the medication. Performing a boolean operation, in order to combine the area of the pathological lesion and the reservoir precisely filled with one layer of microspheres (Fig. 10). ***Stage 5:*** exporting the jaw models created using the software in .stl format so that they could be printed using photopolymer material on a SLA 3D printer (Fig. 11). ***Stage 6:*** using the vacuum forming method, in order to produce an individual device using elastomeric thermoplastic polyurethane (Fig. 12), which is then grinded, polished and treated with an antiseptic solution. In order to assess the precision of jaw models produced using the newly developed technology, a study was conducted which included 38 patients. A randomization method (random number generator) was used to divide them into 2 groups: 1 — models made using the newly-developed algorithm (n=19), 2 — models made using the traditional method (n=19). The study provided statistically significant proof ($p < 0.05$) that the localization parameters of reference points for targeted medication delivery on jaw models were most precise in group 1. Thus, the developed technology allows to ensure precise planned parameters of non-invasive treatment of a tooth with a wedge-shaped defect within enamel.

## CONCLUSION

The personalized non-invasive approach to choosing the treatment method for a wedge-shaped defect within enamel will allow to use an individual device for minimum intervention tooth-preserving treatment, designed for targeted delivery of medication to the lesion.

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***Fig. 7.*** *An impression of the lower jaw and a cast stone model*

***Fig. 8.*** *3D scanning of a jaw stone model using a Shining 3D scanner*

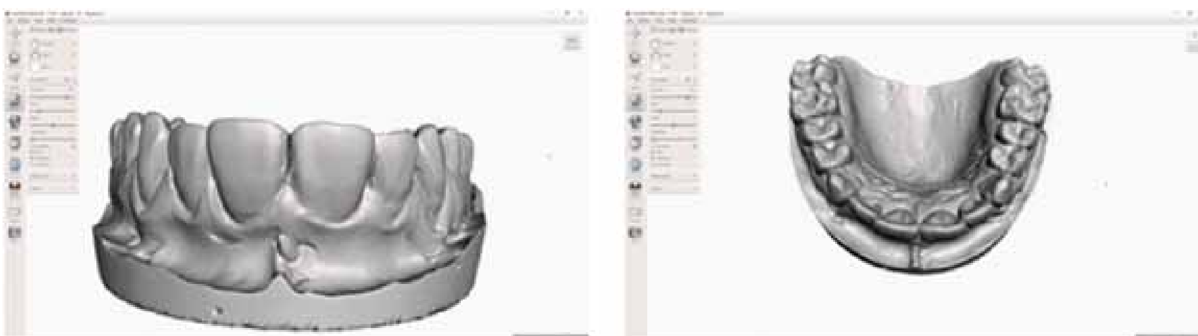

***Fig. 9.*** *Hybrid parametric modelling of the pathological lesion, "Autodesk Meshmixer" (USA)*

***Fig. 10.*** *Modelling the microspheres in the pathological lesion area*

***Fig. 11.*** *Printed models of the upper and lower jaws, made using the newly developed technology*

***Fig. 12.*** *A ready individual device made of elastomeric thermoplastic polyurethane (DURAN®, Scheu Dental, Germany)*

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