MODELING THE STRESS STATE OF HARD TISSUES OF A TOOTH IN THE PROCESS OF RESTORATION OF CLASS I CARIOUS CAVITIES

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To study the stress state of geometrically complex multilayered bio-mechanical system consisting of enamel, dentin and filling, the three-dimensional solid modeling in the SolidWorks software package and mathematical analysis with finite element methods in the ANSYS Workbench program were used in the research. In the mimicking, the tooth is seen as an elastically deformable body under static loading of evenly distributed force. It is found that the inner stress in the hard tissue of intact tooth is maximum (74.2 MPa) in the area of application of the load. The maximum stress (119 MPa) in a restored over the I class carious cavity tooth occurs in the area of enamel contact with the restoration.

Keywords: stress state, tooth, carious cavity, tooth restoration, dentine, enamel, finite elements method.

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Foreword. Longevity of teeth restorations has important clinical and social importance. The development of secondary caries and restoration losses lead to the repeated visits of the patient to the dentist, and new preparation of hard tooth tissues. This can be a starting point for a number of morphological and functional changes not only in the teeth, but in the teeth-jaw system as a whole. This repeated machine treatment leads to thinning of hard tooth tissues, development of cracks and fractures. In the process of preparing and dental restoration, a number of problems, that impair the conditions for holding the restorative material in the carious cavity, can arise and this leads to reduction in the useful life of restorations [1]. One of these problems is secondary caries. Its appearance is possible at damage of marginal adaptation of filings due to the properties of restorative material, polymerization stress, its contraction and elastic modulus [8, 13], as well as the carious cavity configuration factor [11].

Recently, experts have been increasingly focusing on the role of mechanical properties of dental tissues in high quality marginal adaptation of the material. Tooth tissues have a wide range of mechanical properties [10]. Even with high-quality preparation and restoration of cavities during the functional load in the tissues of the tooth own stress takes place, leading to cracks in dentin and enamel, damage of marginal seal, resorption and the loss of material [5]. Stress state of the hard tooth tissues was studied in detail during
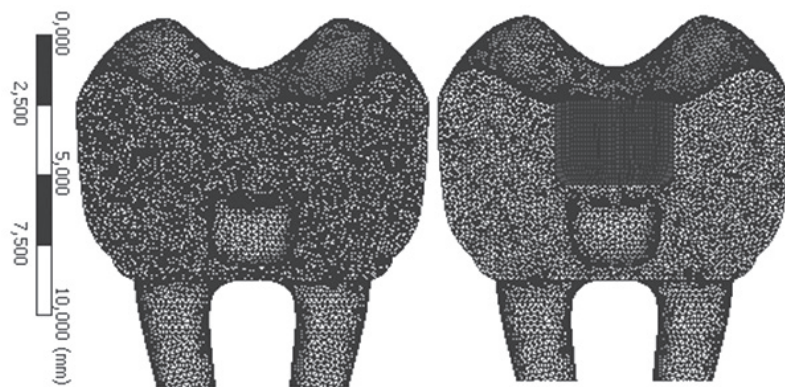
Fig. 1. The finite element model of the intact tooth and the restored one

the endodontic treatment [3], restoration of V-class cavities [7], recovery with artificial crowns [6], occlusal loads [9]. In accessible publications we have not encountered any information on the stress state in the tissues of the tooth, restored over the I class carious lesions.

The objective of our research is to study the stress in the tooth hard tissues using the computer modeling of the restored carious cavities of Class I that are prepared in a classical way.

Methods. A three dimensional model "Enamel – dentine – restoration" has been created on the basis of the X-ray image of the lower molar by means of the SolidWorks program; then it has been exported to the program complex ANSYS Workbench and the final element model has been formed (Fig. 1). The equivalent stress has been calculated by von-Mises upon condition that the root part of a tooth is accurately fixed, all components of the model are isotropic,

a vertical uniaxial charge is according to the tooth center 500 H.

Results. Under the influence of the vertical charge on the model in the intact tooth on the bite surface, the tensions in the enamel correspond topographically to the projection of fissures of molars (Fig. 2a). Several stress fields are identified there; they are spread concentrically from maximum values in the place of action of the charge to minimum values closer to the perimeter of fissures. The first field is formed in the place of action of the vertical charge, the maximum stress is 74.2 MPa. The second field is localized around the first one; it has lower values of the stress up to 50 MPa. The values of the third one decrease to 25-30 MPa. Isolated stress areas up to 35 MPa are determined in the zone of medial and distal edge. The fourth stress field possesses the lowest values – 10-20 MPa.

The character of the stress in the
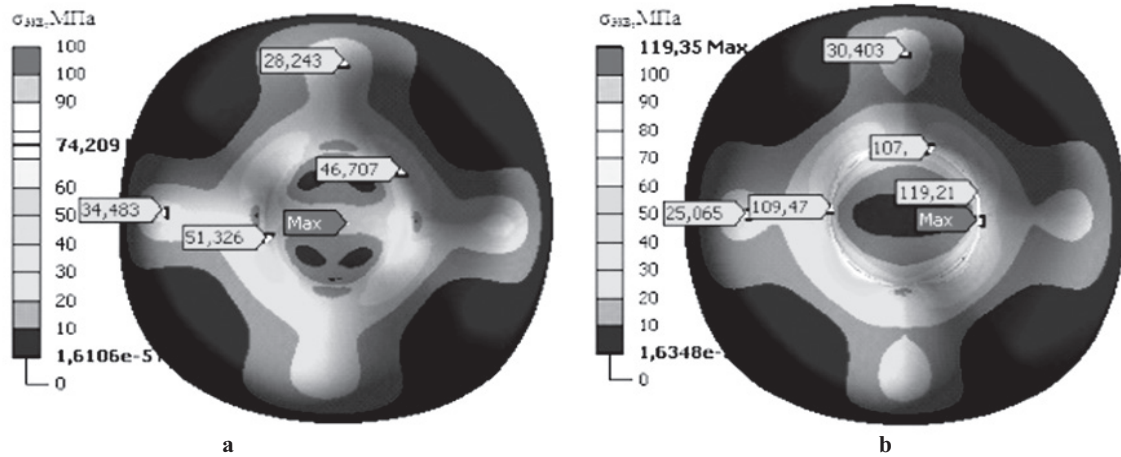
Fig. 2. Areas of stress in the enamel on the occlusal surface: intact tooth (a), restored one (b).

enamel in a restored tooth is the same as in the intact tooth (Fig. 2b). But the first field starts around the filling; the maximum stress value in the enamel is 119 MPa that is 60 % higher than in the intact tooth. The second stress field is about 100 MPa (100% higher than the intact one).

In the sagittal section of the intact tooth in the place of the charge the stress of the whole thickness of the enamel is 52-55 MPa, it reaches its maximum (74 MPa) in the area of enamel and dentine border. The values in the dentine decrease to 10 MPa. The same stress force is also determined in the neck area of the enamel and dentine **(Fig. 3a)**.

In the restored tooth in the upper layers of the filling the stress created is same like in the enamel of the intact one (52-55 MPa). Moreover, in the area of the direct contact of the filling with the enamel, it is increasing almost up to 120 MPa. The stress force of hard tissues is decreasing to 10-15 MPa in the thickness of the cover dentine as well as in the neck area (Fig. 3b).

Discussion. Thus, the stress in the solid tissues of intact and restored teeth has different meanings. In the study we examined the components of the model "enamel-dentine-filling" as isotropic materials, but the physical properties of the tooth are uniform. Anisotropy of dentin ensures the availability of a tubular unit in its structure, and in enamel - prismatic structure [6]. The renewing material also has anisotropy due to non-organic filler. Thus, each component of the model "enamel-dentine-seal" has its own physical characteristics, especially elastic modulus. If this module in each component is different, the stress is distributing unevenly both upward and downward in them. Great tension arises in the element of the model, the elastic modulus of which is higher [2]. In our study it is shown that stress is much higher in the enamel, which is directly in contact with the filling material. It may be a risk factor for deformation in the enamel with the gradual weakening of its structure and development of micro-

cracks and defects leading to damage of marginal adaptation of restoration. Given this fact, it is necessary to use a recovery material which has an elastic modulus similar or close to the tooth - to strengthen their structure [12]. It is also necessary to carry out further research on methods used to optimize the formation of carious cavities, especially treatment of enamel margin.

Stress increasing in the enamel of the intact tooth on the enamel-dentine border can be explained by the peculiarities of the role of hard tissue with functional load and also higher elastic modulus in the enamel. Mechanical role of the enamel is to protect the dentine because of its high wear, and mechanical role of dentine is to absorb the power load because of its high strength resistance [4].

Stress state of a cervical part of intact and restored teeth is resulting from the transfer of reactive power from the surface of the load through the enamel-cementum junction to the root, and then
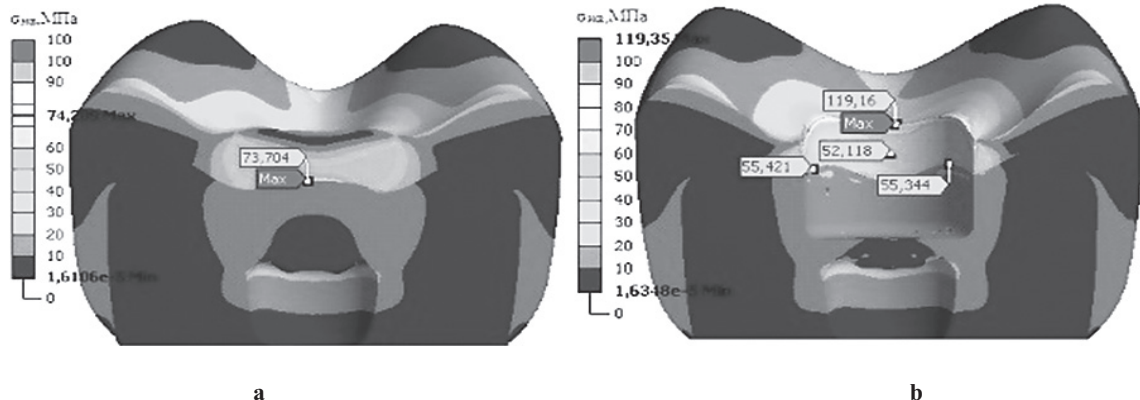
Fig. 3. Zones of stress of tooth tissues in the sagital area: intact tooth (a), restored one (b).

in the alveolar bone. These forces can cause stress in remote areas from the standpoint of force application [7].

Conclusions. The stress in hard tissues of the intact and restored teeth has different values. Under the vertical uniaxial charge on the restored tooth, with decay of Class I of the molar of the lower jaw, the maximum stress appears on the border of the direct contact with the restoration.

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