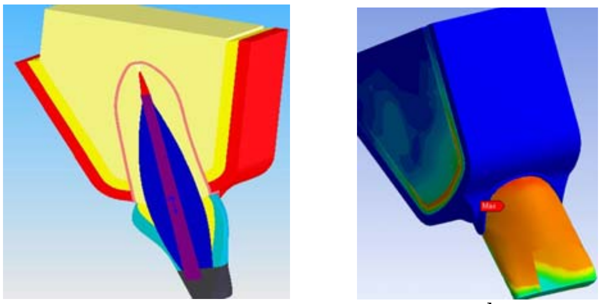
FEM ANALYSIS IN MODERN DENTISTRY

[1]Geramy A., [2]Kizilova N.

[1]TehranUniversity of Medical Sciences, Iran
[2]V.N.Karazin Kharkov National University, Ukraine

Finite element (FEM) analysis is a very efficient tool for development of patient-specific geometrical and mechanical models of tooth restoration with dental implants and fillings, complex systems of maxillary and mandibular teeth for individual planning of dental prosthetic design, dental braces and microscrews for orthodontic tooth movement [1].

FEM analysis of a single tooth is not useful without a proper modeling of the neighboring teeth which are in contact. The main interest for dentists is calculation of the strain-stress state of the tooth after restoration with/without root implants. The forces can be modeled as pressure fields distributed over the upper surface which is in contact with opposite tooth/teeth or food. When the material paratemers for the cement and implants are varied, the stress concentration regions can be visualized and the risk of fracture can be estimated. A series of surprising results on optimal combinations of the elastic, viscous and thermal properties of the materials for the restoration have been obtained. It was shown the titanium dental implants is not the best solution because they lead to stress concentration at the implant-cement interface, while the glass and resin implants could give more uniform stress distributions [2]. An example of complete restoration of the tip of incisor with root implant is presented in fig.1a,b.



a b

Fig.1. (a) - a model of tooth with root implant (in the center) and cement (at the tip); (b) - the equivalent (von Mises) stress distribution in the model.

Individual planning of the orthodontic tooth movement can be done on the complex system consisted of the cortical and spongy bone of the skull/jaw, tooth, titanium miniscrew and springs which are in contact with the tooth crowns and miniscrews, and periodontal ligament (PDL). In some studies the PDL is modelled as a set of spontaneously distributed beam finite elements located by their ends onto the root and the bone surfaces accordingly. A simplier approach based on rotation of a virtual tap producing the elongated elements (fig.2a) by simple rotation procedure in SolidWorks or other CAD software has been proposed in [3]. The interface between the implant, gum (1) and bone (2) (fig.2b) could be assigned according to healthy/parodontosis state of the patient (the gum to bone level). The statical stress tests reveal high critical stresses at the implant-bone interface that could gradually lead to the bone demineralization and remodelling, weakening the PDL and loosening the fixation [1,2]. Some computation results for the stress distribution in the tooth+microscrew+jaw model are presented in fig.2c.

More complex systems of teeth together with bone tissues are used for planning the orthodontic tooth movement by different metal and elastic sptings attached to the tooth crown brackets. A thorough quantitative estimantion of distributions of the vectorial displacement fields along the tooth crown and root helps in individual planning of the orthodontic procedure that will provide needed shift, rotation, torquing or tipping of the tooth/teeth. The concepts of the centre of rotation, centre of resistance, point/area of application of the force and centre of gravity (for computations of the moments of inertia) are of big importance for any quantitative estimation. It is important, the simplified mechanical models based on the net force and moment of force laws gives a rough but fast estimation of the stress-strain state of the complex mechanical systems of teeth with dental braces [4,5].

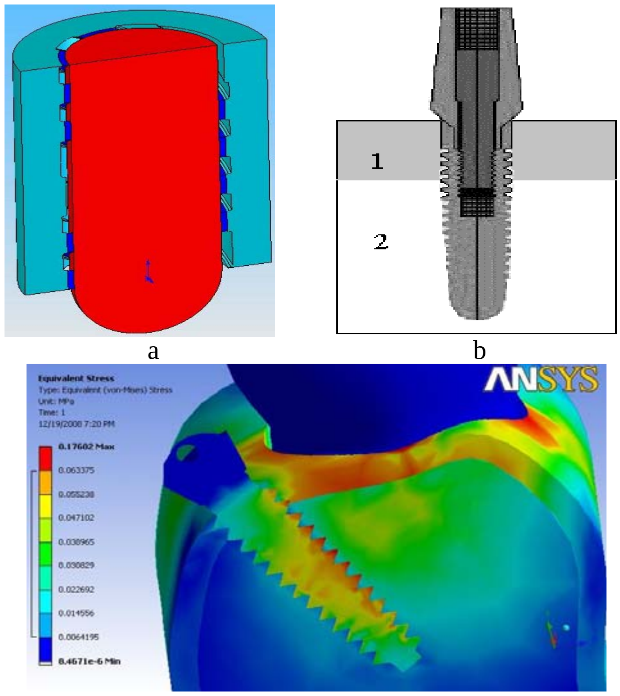


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Fig.2. (a) – the model of PDL; (b) the implant with structured PDL in the gum (1) and bone (2) tissures; (c) the equivalent stress distribution in the model.

The FEM analysis of the individual CT-based cases will be even more important with further development of fast numerical methods and visualization tools.

LITERATURE

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