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EFFECT OF FACET MATERIAL ON STRESS DISTRIBUTION IN DENTAL IMPLANTS

UTICAJ MATERIJALA LICA KRUNICE NA RASPODELU NAPONA U DENTALNOM IMPLANTU

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Keywords
- stress distribution
- dental implant
- facet material
- connected crowns

Abstract

In this paper, an FEM model is used to analyse the effect of facet material on the load transfer from implant to bone, as one aspect of the broader research, including the effects of a different crown design (connected and separated), a different facet material (porcelain and resin), and different loading (force at one or two points), whereas the focus is on the facet material effect in the connected crown loaded at one point. Results indicate significant reduction of maximum stress if the epoxy resin is used instead of porcelain.

Ključne reči
- raspodela napona
- dentalni implant
- materijal lica krunice
- spojene krunice

Izvod

Analiziran je uticaj materijala lica krunice na prenos opterećenja sa implanta na kost, kao jedan aspekt šireg istraživanja problema, uključujući učinke različitog dizajna krunica (spojenih, odvojenih), tako i različitih materijala (porculan i smola) i različitih opterećenja (sila u jednoj ili u dve tačke), dok je ovde fokusiranost bila uticaj materijala u spojenoj krunici opterećenoj u jednoj tački. Rezultati pokazuju značajno smanjenje maksimalnog napona ako se umesto porculana koristi epoksidna smola.

INTRODUCTION

Development of oral implants significantly contributes to oral rehabilitation of partially or completely toothless patients, /1/. Testing of implant behaviour *in vivo* is practically impossible, so various experimental or numerical methods are used *in vitro* instead. The most commonly used numerical method is the finite element method (FEM), used in dentistry since the early seventies of the XX century. Farah et al. were the first to use FEM for optimisation and design of dental restoration problems, /2/, whereas Weinstein et al. used FEM for solving dental implant problems, /3/. Also, Geng et al. applied FEM for analysis in implant dentistry /4/, while Tatić et al. analysed influence of cavity shape on the stress-strain distribution in dentine and enamel caused by polymerization, /5/. Paunić et al. analysed geometric characteristics of mandible fixation plates, /6/. One can say that FEM enables the testing of shapes and design of fillings, crowns, dental implants, extensions, mobile braces, dentures, as well as interactions between teeth, bone and implants, residual stress testing, testing of masticatory and occlusal forces. Also, FEM can be applied in some other important biomedical problems, as shown in /7-9/.

Anyhow, validity of numerical methods must be verified using experimental methods. Recently, digital image correlation (DIC) was used for this purpose in several problems related to biomaterials /10-11/. In any case, both experimental and numerical methods are applied in order to improve the structural integrity and life of implants, /12-14/. In this paper, the FEM model was used to analyse the effect of facet material on load transfer from implant to bone, as one aspect of a broader research of a problem first analysed in /15-17/ and later on in /1/. In this research the effects of different crown design (connected and separated), different facet material (porcelain and resin), and different loading (force acting at one or two points) is analysed, whereas the focus here was on the facet material effect in the connected crown loaded at one point.

NUMERICAL ANALYSIS BY FEM

Finite element method is based on physical discretization of the considered domain, /18/. Due to the complex geometry of teeth, it is not a simple task to design the appropriate numerical model. However, nowadays optical digital scanners enable realistic numerical models based on a scanned physical model, /1/. In addition, boundary and load conditions of dental implants have to be accurately defined. The FE model is made in SolidWorks® software, with connected crowns, as shown in Fig. 1, /1/. The FE model comprises two teeth and two implants placed in a block simulating the mandible. Implants Titamax GT, Neodent, are placed at locations of the second premolar and the first molar, whereas real teeth are placed as first premolar and second molar /1, 15/.

Numerical stress-strain analysis is performed using FEM in ABAQUS® v6.10 software. All materials are defined as linear elastic, with elasticity modulus and Poisson's ratio given in Table 1. Supports for the block are fixed, whereas the displacement along the upper surface of the block is constrained by the influence of these supports, Fig. 1. Loading is represented as the force of 250 N at a point, on the occlusal surface of the first molar, Fig. 1. The model has of a total of 245,317 TET elements.

Table 1. Values of elasticity modulus and Poisson's ratio.

	Model part	Material	Elasticity modulus (MPa)	Poisson's ratio
Natural teeth	first premolar and second molar	dentin	18,600	0.31
	first premolar and second molar	enamel	84,100	0.2
Artificial teeth	first premolar and second molar facet	porcelain	69,000	0.3
		acrylate resin	2,979	0.4
	first premolar and second molar body/skeleton	Ni-Cr-Ti	218,000	0.33
	first premolar and second molar implant	Ti	110,000	0.35
Bone	body	epoxy resin	210	0.42
Supports	1 & 2	steel	200,000	0.3

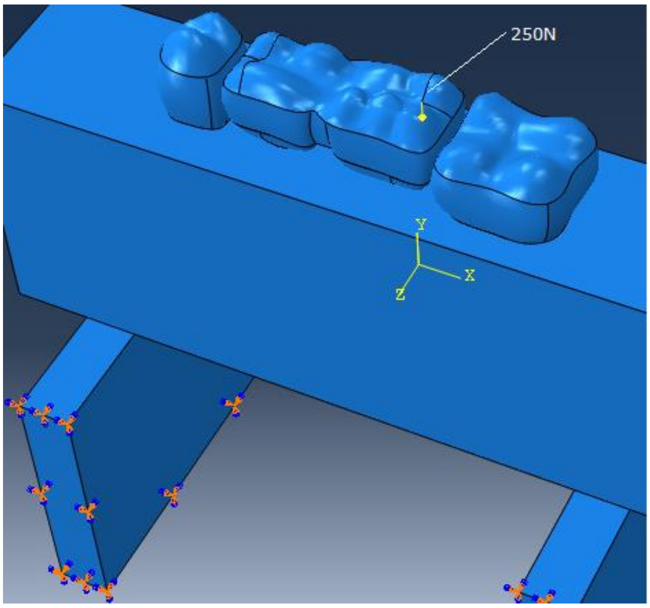


Figure 1. Connected crowns and loading at one point: a) SolidWorks® model; b) testing assembly.

Table 2. Maximum von Mises stresses (MPa).

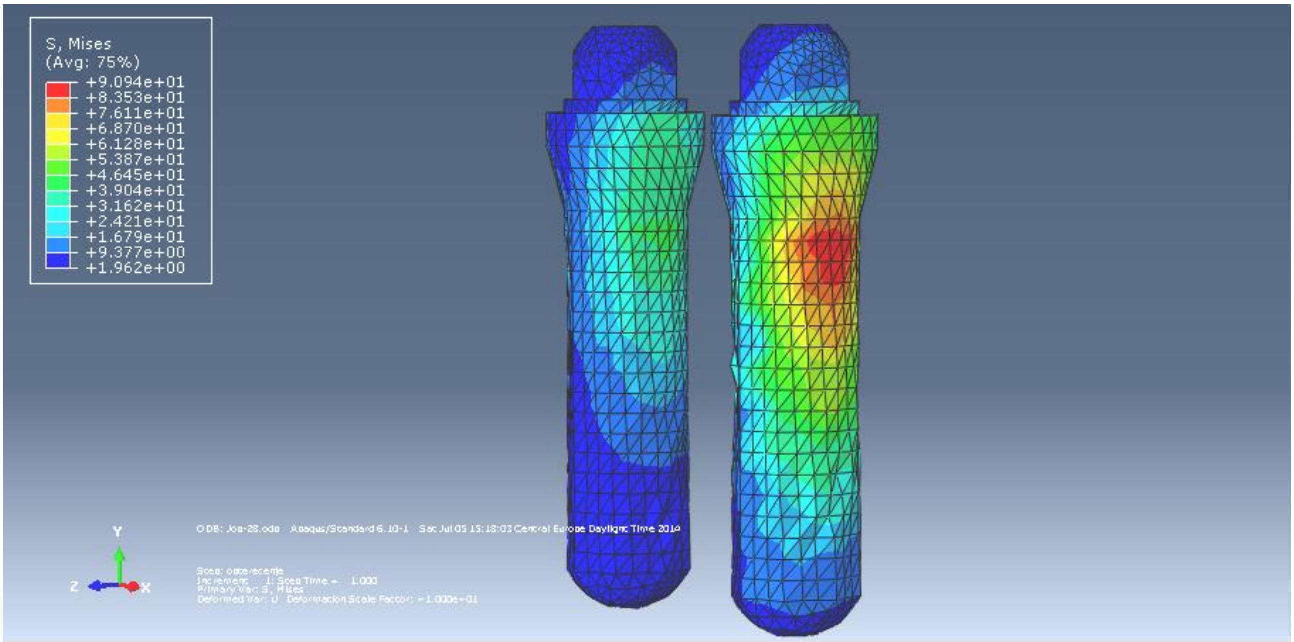
MODEL	Bone	Implant	Load Region
CCP1x250	12.6, Fig. 2c	94.7, Fig. 2a	503.2 Fig. 2b
CCR1x250	11.3, Fig. 3b	102	411.9 Fig. 3a

RESULTS AND DISCUSSION

Von Mises stress distribution in the implant, the whole model and in bone are shown in Fig. 2 for the case of porcelain facet, whereas its distribution in the whole model and bone are shown in Fig. 3, for the case of epoxy resin facet. Table 2 summarizes results for maximal von Mises stresses.

As can be seen from Figs. 2 and 3, as well as from Table 2, the highest stress occurs in the region where the loading point is located. For connected crowns, the load is transferred to the connected skeletons and through both implants to the bone, thus the bone is subjected to lower maximum load since it is of a more uniform distribution, /1, 19/. On the other hand, in case of the model with separate crowns, the load is entirely transferred to the skeleton of the first molar and then to the implant places instead of the first molar, as shown in /1/, so it can be concluded again that higher stresses are present in the model with separate crowns, /1, 19/. Due to the load being transferred only by the implant located next to the first molar, stresses appear in the bone between the implants.

a)



b)

c)

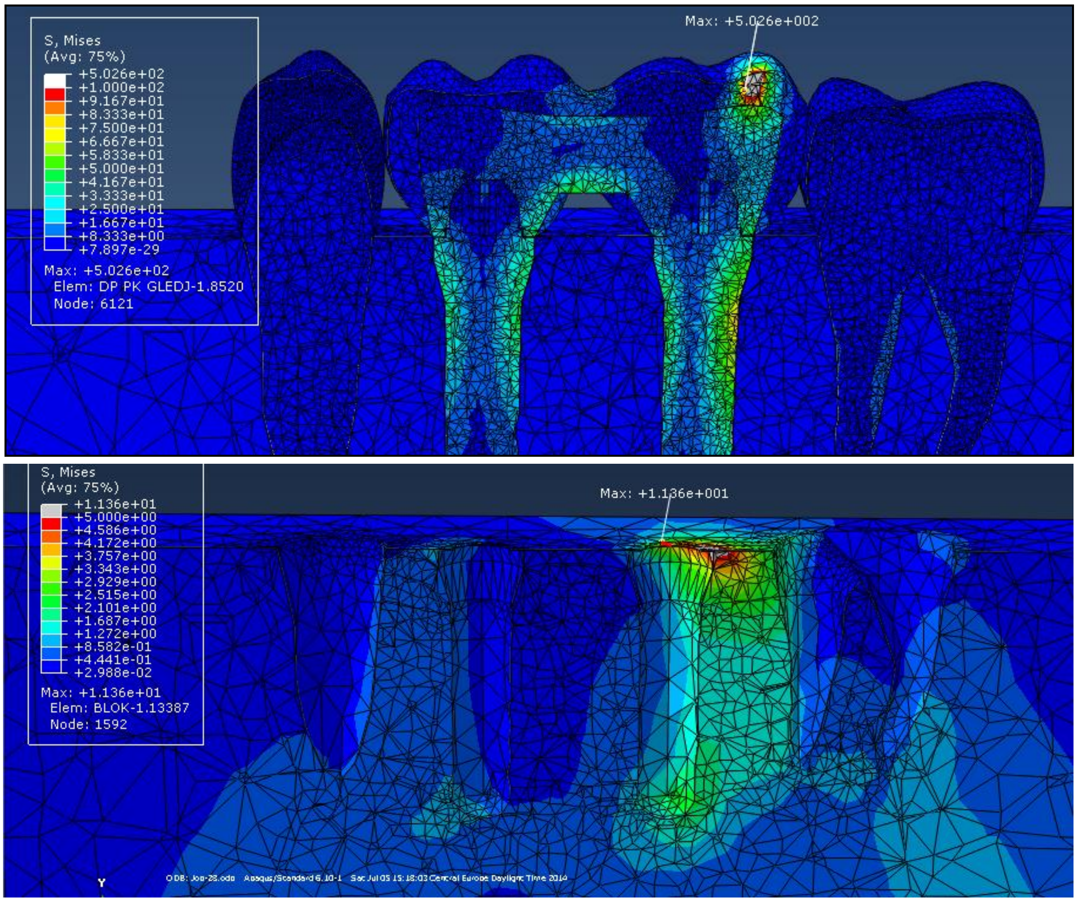


Figure 2. Von Mises stress distribution in porcelain facet: a) implant; b) crown; c) bone.

a)

b)

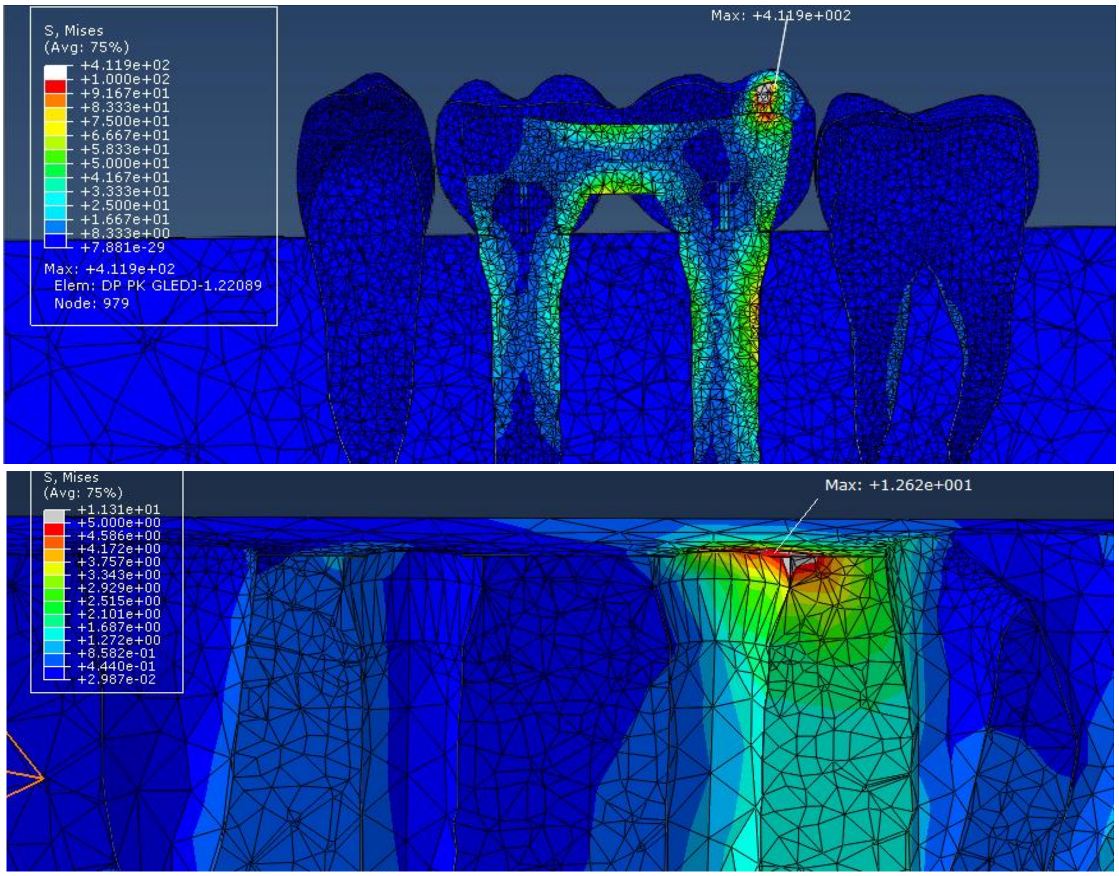


Figure 3. Von Mises stress distribution, acrylate resin facet: a) crown; b) bone.

Stress concentration in the implant occurs on the outer side, which is in contact with the bone, particularly on the implant located at the first molar, as expected, since the point where the load is applied is on the crown of this molar, Fig. 3a. For the model with connected crowns, the maximal stress in implant with acrylate epoxy is 94.7 MPa, slightly lower than 102 MPa, which corresponds to porcelain facet.

Once results obtained in this study are taken into consideration, it can be concluded that the difference in load transfer, as well as the values of maximum Misses stresses is evident. Same results are obtained in studies, shown in /15-17/. Maximum Misses stresses occur in the region at the bone top, near the implant neck, regardless of the number of loading points.

Facet material has a significant effect on maximum Von Mises stress, being reduced cca. 20 % if epoxy resin is used instead of porcelain (411.9 MPa vs. 502.3 MPa). In the bone and implant, this effect is much less expressed, being less than 10 % (bone 11.3 MPa vs. 12.6 MPa; implant 94.7 MPa vs. 102 MPa, Table 2). One should also notice that these differences are not as significant as in the case of connected vs. separated crown design (min. 40 %), and force acting at one vs. two points (min. 60 % in bone and implant, but also cca. 20 % in load region), as shown in /1/.

CONCLUSIONS

The restoration of a partially or completely toothless jaw is of great importance. Based on the results presented here, it can be concluded that acrylate resin is a better option as a material for the crown facet. Nevertheless, differences are not significant, contrary to the case of connected vs. separated crown design, and force acting at one or two points.

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