Aleksandar Sedmak[1], Ivana Petrović[1], Miloš Milošević[2], Calin Dascau[3], Tamara Golubović[2], Radun Vulović[4]*

EFFECT OF DENTAL IMPLANTS LOADING AND DESIGN ON STRESS DISTRIBUTION IN A MANDIBLE BONE

UTICAJ OPTEREĆENJA I DIZAJNA SA ZUBNIH IMPLANATA NA RASPODELU NAPONA U VILIČNOJ KOSTI

Originalni naučni rad / Original scientific paper
Rad primljen / Paper received: 2.12.2025
https://doi.org/10.69644/ivk-2025-03-0521

Adresa autora / Author's address:
[1)] University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia A. Sedmak https://orcid.org/0000-0002-5438-1895 ; *email: aleksandarsedmak@gmail.com
[2)] Innovation Centre of the Faculty of Mechanical Engineering, Belgrade, Serbia M. Milošević https://orcid.org/0000-0002-2418-1032 ; T. Golubović https://orcid.org/0000-0001-8283-1104
[3)] 'Victor Babeș' University of Medicine and Pharmacy, Dept. of Internal Medicine, Timișoara, Romania
[4)] Institute for Information Technologies, Kragujevac, Serbia R. Vulović https://orcid.org/0000-0002-5545-9965

Keywords
- finite element method
- stress distribution
- dental implants
- mandible bone

Ključne reči
- metoda konačnih elemenata
- raspodela napona
- zubni implanti
- vilična kost

Abstract

The effect of dental implants loading and design on stress distribution in a mandible bone is analysed using the finite element method. Loading is modelled as a single force or as two equal halves. Implants are either separated or connected by a crown. In this way four different cases are presented and analysed in respect to stress distribution in mandible bone. It is concluded that the highest stress appears in separated implants, loaded in a single point, whereas the lowest stress is obtained in connected implants loaded in two points.

Izvod

Uticaj opterećenja i dizajna zubnih implantata na raspodelu napona u viličnoj kosti analiziran je primenom metode konačnih elemenata. Opterećenje je modelirano kao jedna sila ili kao dve jednake polovine sile. Implantati su ili razdvojeni ili spojeni krunicom. Na ovaj način su predstavljena i analizirana četiri različita slučaja u pogledu raspodele napona u viličnoj kosti. Zaključeno je da se najveći napon javlja kod razdvojenih implantata, opterećenih u jednoj tački, dok je najmanji napon kod spojenih implantata opterećenih u dve tačke.

INTRODUCTION

Finite element method (FEM) is nowadays commonly used to determine stress distribution in any loaded structure, including implants and surrounding mandible, /1-5/. The FEM is used since it can provide detailed insight into different effects, such as splinting and interproximal contact tightness on load transfer by implant restorations, /6/, choice of crown design on load transfer from implant to the bone, /7/, facet material on stress distribution in dental implants, /8/, superstructure, implant length, and mandible height on stress distribution around dental implants, /9/, and implant design and loading simulation on implant stresses, /10/.

FINITE ELEMENT MODELLING

Physical models of the connected and separated implants are shown in Fig. 1. Both models consist of a block into which the first premolar, second molar, whereas two implants with crowns are inserted at the second premolar and the first molar positions. Assembly of the model with separated implants is presented in 6 stages: 1. first premolar, 2. second molar, 3. implants, 4. crown for the second premolar, 5. crown for the first molar, and 6. final assembly. The tooth model is constructed in two steps. The first step involves the creation of dentin, followed by the construction of enamel in the second step. Other details are given in /10/.

a)

b)

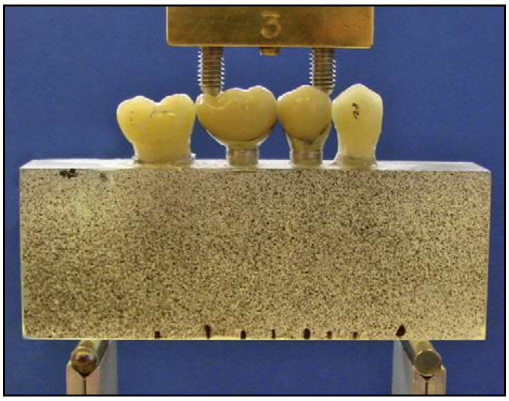

Figure 1. Physical model: a) coupled; b) separated abutments, /10/.

Computational model for connected implants consists of 245317 tetrahedral elements, whereas the model with separated implants has 370669 tetrahedral elements.

Material properties are shown in /7/ for all materials used in this analysis (natural teeth, implants - stainless steel, bone - epoxy resin, support - steel).

RESULTS AND DISCUSSION

Figures 2-5 show von Mises stress distribution in the bones for these two models and two different force presentations, acting in one or in two points. In case of the model with separate implants, stress is higher in the area of the bone around the second molar root. In addition, higher stresses are located around the implant neck at the tip of the bone. As expected, high stresses occur in the bone area next to the implant top, as well. Since the load is transferred only by implants located at the first molar, stresses also appear in the bone between the implants, contrary to the model with connected implants, providing more uniform stress distribution. Anyhow, von Misses stress distribution in the implants is similar in both models, although stress values differ. Stress concentration occurs on the implant outer side in contact with the bone, particularly on the implant located at the first molar. This is expected, since the load point is applied on the molar crown.

One should notice also the quantitative differences between four presented maximal stresses. The highest maximal stress is obtained for the model with separated implants and force presented in one point (49.2 MPa), while the lowest stress (6.5 MPa) is obtained for the connected implants and force in two points. In between are maximal stresses for connected implants with force in one point (11.4 MPa) and separated implants with forces in two points (29.0 MPa).

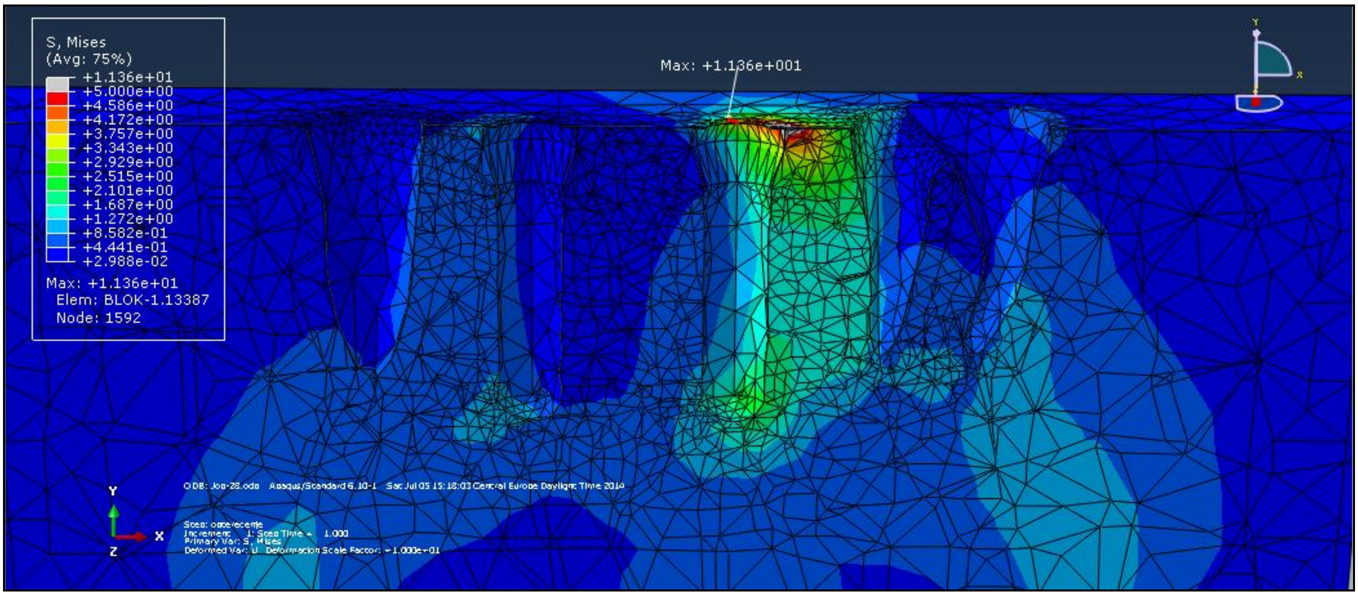

Figure 2. Von Mises stress distribution for connected implants and force in one point.

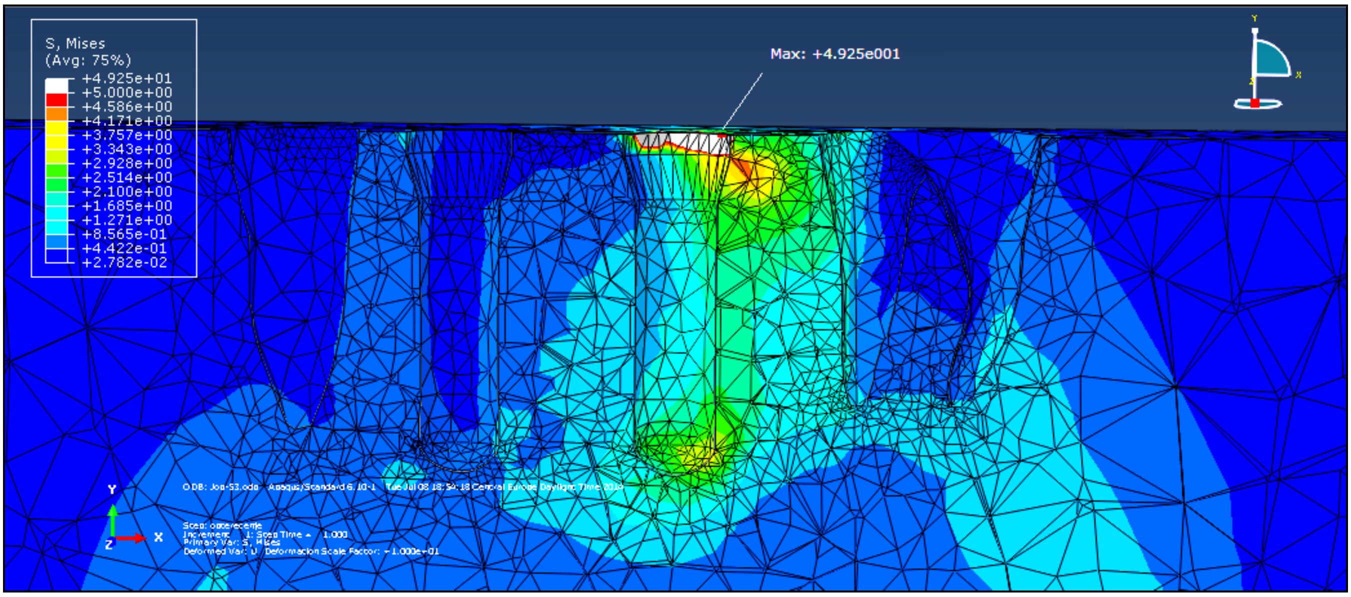

Figure 3. Von Mises stress distribution for separated implants and force in one point.

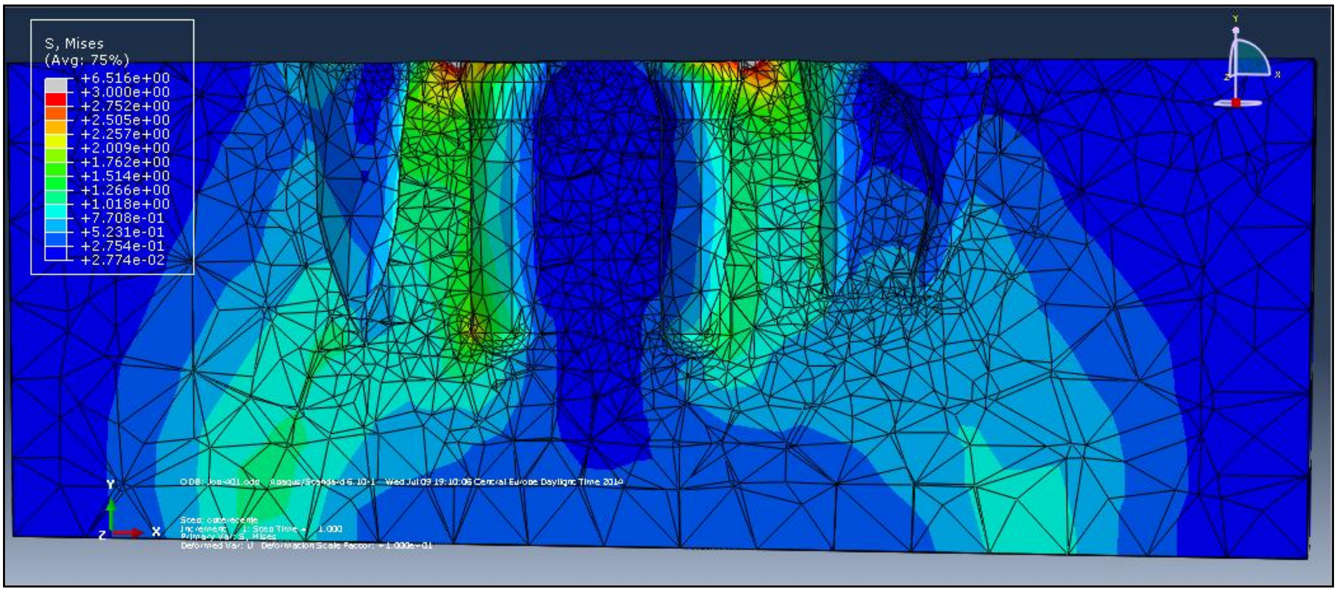

Figure 4. Von Mises stress distribution for connected implants and forces in two points.

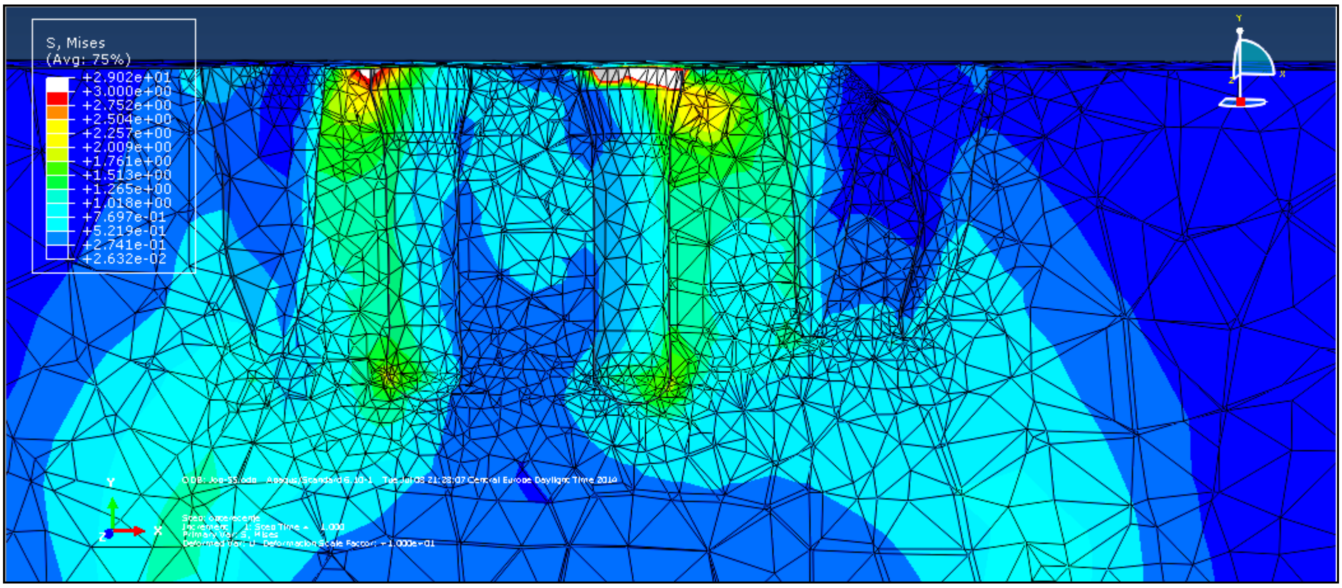

Figure 3. Von Mises stress distribution for separated implants and forces in two points.

CONCLUSIONS

Based on the results presented in this study, it can be concluded that connecting implants and applying forces at two points significantly reduces maximum stress values in comparison with separated implants and force in one point.

ACKNOWLEDGEMENTS

The authors would like to thank the support from the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia, under contract No. 451-03-136/2025-03/200213 (from February 4, 2025).

REFERENCES

1. Cicciù, M., Cervino, G., Bramanti, E., et al. (2015), *FEM analysis of mandibular prosthetic overdenture supported by dental implants: Evaluation of different retention methods*, Comput. Math. Methods Med. Article ID 943839. doi: 10.1155/2015/943839
2. Omori, M., Sato, Y., Kitagawa, N. et al. (2015), *A biomechanical investigation of mandibular molar implants: reproducibility and validity of a finite element analysis model*, Int. J Implant Dent. 1: 10. doi: 10.1186/s40729-015-0011-5
3. Tiossi, R., Vasco, M.A.A., Lin, L., et al. (2013), *Validation of finite element models for strain analysis of implant-supported prostheses using digital image correlation*, Dent. Mater. 29(7): 788-796. doi: 10.1016/j.dental.2013.04.010
4. Geng, J.P., Tan, K.B., Liu, G.R. (2001), *Application of finite element analysis in implant dentistry: a review of the literature*, J Prosthet. Dent. 85(6): 585-598. doi: 10.1067/mpr.2001.115251
5. Čolić, K., Sedmak, A., Vučetić, N., et al. (2024), *Finite element stress state analysis of mini dental implants*, Struct. Integr. Life, 24(1), 29-32. doi: 10.69644/ivk-2024-01-0029
6. Guichet, D.L., Yoshinobu, D., Caputo, A.A. (2002), *Effect of splinting and interproximal contact tightness on load transfer by implant restorations*, J Prosthet. Dent. 87(5): 528-535. doi: 10.1067/mpr.2002.124589
7. Petrović, I., Sedmak, S., Tatić, U., et al. (2014), *Influence of choice of crown design on load transfer from implant to the*

bone, J Manuf. Industr. Eng. 13(3-4): 1-3. doi: 10.12776/mie.v13i3-4.414
8. Sedmak, A., Milošević, M., Čolić, K., Petrović, I. (2023), *Effect of facet material on stress distribution in dental implants*, Struct. Integr. Life, 23(3): 363-366.
9. Meijer, H.J.A., Kuiper, J.H., Starmans, F.J.M., Bosman, F. (1992), *Stress distribution around dental implants: influence of superstructure, length of implants, and height of mandible*, J Prosthet. Dent. 68(1): 96-102. doi: 10.1016/0022-3913(92)90293-j
10. Sedmak, A., Petrović, I., Milošević, M., et al. (2025), *Digital twin-based numerical simulation of stress distribution in the mandible with dental implants*, Struct. Integr. Life, 25(2): 161-167. doi: 10.69644/ivk-2025-02-0161