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EFFECT OF CROWN-IMPLANT (C/I) RATIO OF SHORT IMPLANTS ON PERI-IMPLANT STRESS: A FINITE ELEMENT ANALYSIS

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ABSTRACT

Objectives: Purpose of this study was to evaluate the distribution of peri-implant stress with different C/I ratio (1.5:1, 1.75:1, 2:1) according to the von Mises criterion.

Materials and methods: Stress analysis was performed using Invesalius 3.0, Rhinoceros 3D 4.0 software. Three 3D models of the mandibular segment of the bone block were developed:

- model A, a short implant C/I – 1,5:1;
- model B, a short implant C/I -1.75:1;
- model C, a short implant C/I -2:1.

Results: The results of the current study, indicate the increase in crown height showed little difference in load at the crown/implant interface with crown/implant ratios of 1.5:1, 1.75:1 and 2:1.

Conclusions: Study showed that short implantats for prosthetic rehabilitation can be considered favorable and well substantiated, C/I ratio is not so important for the effective functioning of short implants.

INTRODUCTION

Factors that determine the success of implant osseointegration are: implant biocompatibility, implant surface and geometry, implant diameter and length[1-7].

For effective implantation, a sufficient amount of bone tissue is required. To restore the necessary amount of bone tissue, various labor-intensive multi-stage bone-reconstructive operations are used, including autogenous block, distraction method, nerve reposition; these operations are costly, require high professional skills and have a high risk of complications.[8-15]

In order to avoid expensive and time-consuming multi-stage implantation-bone-reconstructive operations in such patients, it is advisable to use a one-stage surgical method using narrow diameter implants or short implants (5 to 6 mm). [16-19]

The use of short implants allows, prevents damage to anatomical structures, reduces time and shows high clinical efficiency. [20-26]

Optimization of macro- and micro-design of short implants by increasing the implant surface, diameter will help to avoid potential risks and ensure long-term stability. [27,28]

The height ratio (C/I) of short implants to the prosthesis structure placed on it can be a risk factor in terms of the distribution of biomechanical stresses associated with overload, and may increase the risk of complications.29 Therefore, it is important to aim for a low C/I ratio, to avoid overstressing the bone. However, some authors argue that treatment with short implants is possible with a C/I ratio greater than 1:1.[30-32]

Predicting the long-term efficacy of short implants requires assessing the effect of length, diameter, and C/I ratio on biological complications.[33-37]

Various in vivo methods have been used to predict the distribution of bone load around the implant, Finite Element Analysis (FEM) is the most successful calculation method [39-41], and can non-invasively depict the stress distribution in a structure. In the scientific literature there are recommendations for a favorable C/I ratios ratio for natural teeth, but recommendations for C/I ratios by implantology have not been established, which may be helpful to determining the prognosis of dental implants.

Purpose of this study was to evaluate the distribution of peri-implant stress with different C/I ratio (1.5:1, 1.75:1, 2:1) according to the von Mises criterion.

MATERIAL AND METHODS

Study included modeling use FEM method. Stress analysis was performed using Invesalius 3.0, Rhinoceros 3D 4.0 software. Three 3D models of the mandibular segment of the bone block were developed: (Fig. 1).

- model A, a short implant C/I – 1,5:1;
- model B, a short implant C/I -1.75:1;
- model C, a short implant C/I -2:1.

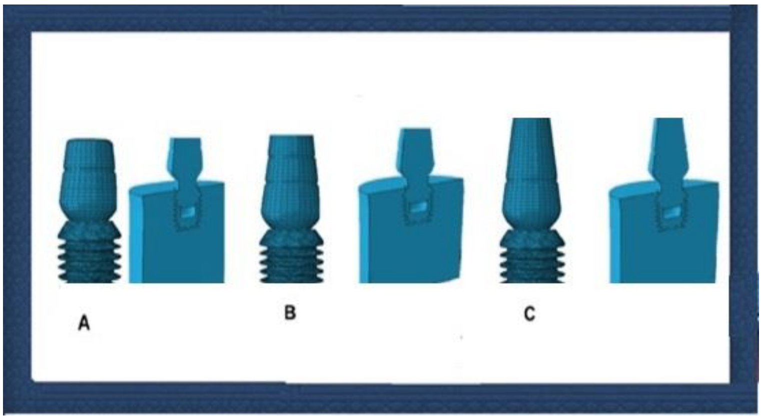

Figure 1 *(Models A, B and C resulting in a C/I ratio.)*

3D computer-aided design software (Solid Works 2010; USA) and Rhinoceros 4.0 CAD were used to calculate the Mises stress distribution. CAD software was used to define the mesh control of the 3D models. The color changes from yellow to blue, where blue represents the maximum stress value expressed in Mega Pascals (MPa).

An axial force of 100 N was applied to the occlusal surface of the crown. Bone density were modeled by changing the elastic modulus of tissue with elastic moduli of 13,7 GPa, the titanium implant component alloy with an elastic modulus of 112 GPa and the superstructure feldspathic Ceramic of the model was designed as a restoration with an elastic modulus of 82,8 GPa.20.

The abutment and implant body were treated as a single unit, which prevented the potential effect of micromotion between the components. images of implants and abutments were reconstructed using CT pro 2.0 software (Metrics, Belgium).The bone model represented a mandibular bone block in the region of the second molar of quality type II bone in the center of the trabecular bone surrounding 1 mm of cortical bone. The surrounding bone around each implant was modeled as a cylinder 15 mm in diameter and 18 mm high. Bone block information was obtained using a CT database of implants and abutment geometries.

After wards, modeling solids geometries have been exported to FEA pre- and post-processing software (FEMAP 11.2, Siemens PLM) to get the grids tetrahedral parabolic solid elements.

3D computer-aided design software (Solid Works 2010; USA) and Rhinoceros 4.0 CAD were used to calculate the Mises stress distribution. CAD software was used to define the mesh control of the 3D models. The color changes from yellow to blue, where blue represents the maximum stress value expressed in megapascals (MPa). The stress analysis was performed under the following conditions: the model contained an implant preloaded to 35 N, an abutment, and a cemented crown. An axial force of 100 N was applied to the occlusal surface of the crown. Bone density were modeled by changing the elastic modulus of tissue with elastic moduli of 13,7 GPa, the titanium implant component alloy with an elastic modulus of 112 GPa, and the superstructure feldspathic Ceramic of the model was designed as a restoration with an elastic modulus of 82,8 GPa.20. All materials modeled in this study are presented in Table 1.

Table 1 *(Mechanical properties of the simulated materials.)*

Simulated materials	Young Modulus (GPa)	Poisson ratio (ν)
Trabecular bone tissue	1.37	0.30
Cortical bone tissue	13.7	0.30
Titanium (implant)	112.0	0.35
Cement	22.4	0.35
Feldspathic Ceramic	87.8	0.35

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS. P values <0.05 were considered statistically significant using Student's t-test.

RESULTS

Under axial load, the highest stresses were concentrated at the abutment/implant junctions, the highest stresses were 67.94 MPa C/I -1.5:1, 68.09 MPa C/I -1.75:1 and 68.24 MPa C/ I -2:1, respectively (Figure 2).

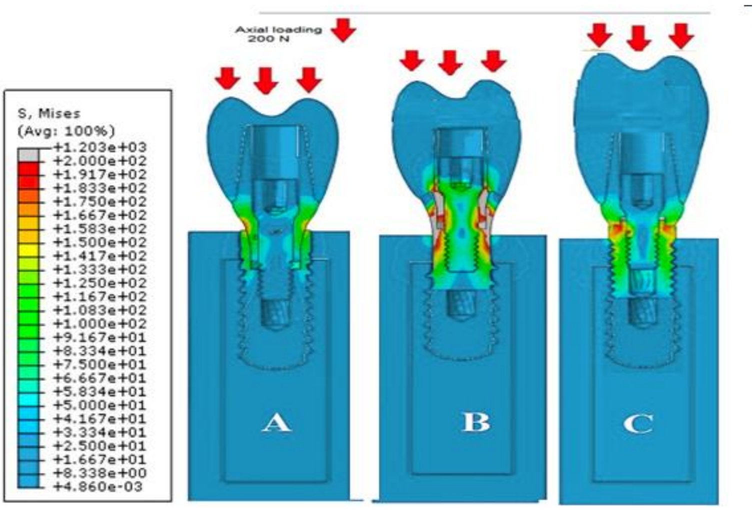

Figure 2 *(von Mises stress distribution on implant/crown set — axial loading. (A) C/I -1.5:1 (B) C/I 1.75:1 (C) C/I-2:1 in type II bone with 100N axial load.)*

The increase in crown height showed little difference in load at the crown/implant interface with crown/implant ratios of 1.5:1, 1.75:1, and 2:1 respectively (Figure 3).

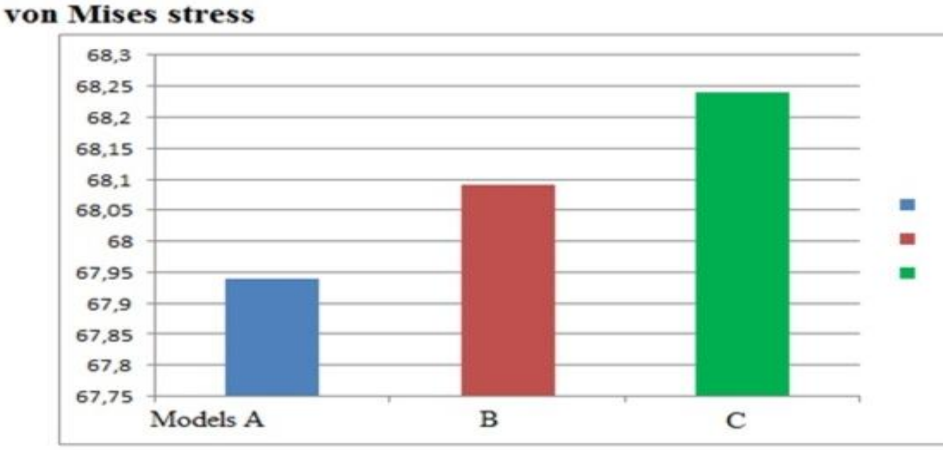

Figure 3 *(Model C showed little difference in load at the with crown/implant 2/1 ratios.)*

DISCUSSION

Dental implants are widely used for prosthetic rehabilitation in patients with various forms of adentia.42 In recent years, short implants have become a predictable alternative for patients with vertical bone resorption (≤ 8 mm in length).[43–45]

Crown-to-implant ratio (C/I) is an important factor in successful oral restoration with short implants. Analysis of the occlusal load force at the bone-implant interface is important for the success or failure of an implant. One of the factors contributing to bone resorption around the implant body is overload which can lead to bone resorption and complications[46].

Various in vivo methods are used to assess bone stress around an implant.

FEM is widely used to study biomechanics in various industries including mechanical engineering, civil engineering and aircraft industry[47].

Computerized Finite Element Analysis (FEM) is widely used in implantology to study the nature of the load on the bone around the implant and to predict the success of implantation in the clinical setting48-[50].

The results of Finite Element Analysis (FEM) by some authors indicate that the C/I ratio is not so important for the effective functioning of short implants and does not affect the loss of alveolar bone around the implant.[51-53]

Tawil G et al in his research has shown that short implants are clinically successful regardless of the crown C/I ratio.[54]

Schulte et al. compared the survival of single implants with different C/I crown-to-implant ratios and compared it to the crown-root ratio for natural teeth. The implant survival rate was 98.2% suggesting that the guideline used for natural teeth should not be applied to implant-supported restorations.[55]

Long-term in vivo and in vitro studies are needed to objectively assess the effect of C/I ratio of short implants success.

In this study, we performed a biomechanical test on short implants using 3D finite element analysis to elucidate the distribution of bone stresses around implants with crowns of different heights (crown/implant ratios 1.5:1, 1.75:1 and 2:1 respectively) according to the von Mises stress distribution. The bone area around the implant was used to compare stress distribution between models. Maximum underlying stress criteria have been used to evaluate cortical and trabecular bone (brittle materials), these criteria make it possible to distinguish between tensile and compressive stresses. The unit of measurement in this study was the Mega Pascal (MPa).

The results of the current study, are consistent with the results of our previous clinical study; short implants in the resorbed jaw segment is a reliable treatment method.56-59

CONCLUSION

Study showed that short implantats for prosthetic rehabilitation can be considered favorable and well substantiated, C/I ratio is not so important for the effective functioning of short implants.

Competing Interest

The author declares that he has no competing Interest. None of the authors have relevant financial relations with a commercial interest.

Funding

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Ethical Approval and Consent to participate"

The study was reviewed and approved by University Ethical Committee (Approval number N12, Date 17.11.2021) and in accordance with those of the World Medical Association and the Helsinki Declaration.

Consent for publication

Patients were informed verbally and in writing about the study and gave written informed consent.

Availability of data and materials

All data generated or analysed during this study are included in this published article.

Authors' contributions"

Naira Ghambaryan : Conceptualization, Methodology, Investigation, Validation, Funding acquisition, Writing – original draft, Writing – review & editing.
Curd Bollen, Seda Geghamyan:Data curation, Validation, Writing – review & editing
Gagik Hakobyan: Conceptualization, Methodology, Supervision, Validation, Writing – review & editing.

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