IDR International Dental Research

Original Article

Examination of the stresses of the implants applied to the atrophic edentulous maxilla on the maxillary bone

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Received: 11 March 2021
Accepted: 15 May 2021

Access Online

DOI: 10.5577/intdentres.2021.vol11.suppl1.30

Abstract

Aim: In advanced atrophy of the posterior maxilla, applied zygoma implants increase the success of the surgical procedure by reducing morbidity and procedure time. In our study, using tomographic records, a model with posterior atrophy was obtained in a computer environment, and zygomatic and dental implants in different numbers and localizations were applied to this model. The aim of our study was to choose the most accurate surgical planning according to the stresses arising from the applied forces.

Methodology: In our study, one zygoma implant on the right and left in Group 1, two zygoma implants in Group 2, one zygoma implant in Group 3 and one dental implant in the first premolar tooth area, one zygoma implant in Group 4, and one dental implant in the lateral tooth area and one zygoma implant in Group 5 and one dental implant in the lateral and a first premolar tooth area were applied. 150 N were applied vertically to the prosthetic superstructure from the lateral tooth, 1st premolar tooth, 1st molar tooth, and 2nd molar tooth. As a result of the applied forces, the maximum stress values in the maxilla molar region were examined by finite element stress analysis.

Results: In our study, it was observed that Group 1 had the highest stress value, followed by Group 3. Stress values in Groups 2, 4, and 5 were low, and they were measured close to each other.

Conclusion: As a result of our study, it was seen that zygomatic and dental implants applied in addition to the zygomatic implant reduce stress, and the localization of dental implants affects the stress values.

Keywords: atrophic maxilla, dental implant, finite element stress analysis, zygomatic implant

How to cite this article: Çetindağ A, Gülsün B. Examination of the stresses of the implants applied to the atrophic edentulous maxilla on the maxillary bone. Int Dent Res 2021;11(Suppl.1):210-5. https://doi.org/10.5577/intdentres.2021.vol11.suppl1.30

Introduction

In cases with severe atrophy in the maxilla posterior region, dental implant applications are difficult for many reasons, as the osseointegration time of implants in this region is longer. However, long-term use of removable prostheses in the atrophic maxilla also increases bone resorption (1). Traditional surgical approaches in cases with severe maxillary atrophy use augmentation with block or cancellous bone grafts taken from the autogenous intraoral or extraoral area or alone, combined sinus augmentation applications. Another method is the application of an interpositional corticocancellous iliac block graft after Le Fort I osteotomy (2). However, these methods have disadvantages, such as being complicated, the possibility of morbidity in the recipient area, the need for hospitalization and consequently the increase in cost, the inability to use a temporary prosthesis during the healing phase of the graft, the prolonged treatment period due to grafting, and the high risk of infection, especially in sinus augmentation applications (3,4).

The fact that there are some disadvantages in the reconstruction of the atrophic maxilla posterior region with iliac and Le Fort I surgery has caused researchers to turn to different techniques. In the 1990s, the zygomatic bone was considered the anchorage source for implant application in prosthetic rehabilitation of cases with severe maxilla atrophy (5).

In 1993, Aparicio et al. first studied the possibility of placing dental implants in the zygomatic bone (6). On the other hand, Weischer et al. conducted ongoing studies on the use of the zygomatic bone as an anchorage source in the prosthetic treatment of patients who underwent maxillectomy (5). It was decided in 1993 that the zygomatic bone can be used for support in implant stabilization. (6).

Zygomatic implants are made of titanium and placed in the zygomatic and maxillary bone. Zygomatic implants are designed for treatment of the atrophic posterior maxilla in situations that make it difficult or prevent the placement of conventional implants (7,8). With zygomatic implant application, grafting of the posterior maxilla is avoided, the treatment period is shortened, and the morbidity rate decreases (8-10). Zygomatic implants are used successfully in maxillary atrophy caused by systemic diseases and in maxillectomies performed due to tumors (5,11).

Due to increased interest in biomechanics in recent years, finite element stress analysis has found use in the field of dentistry. The method can be applied in two dimensions and three dimensions (3D). Finite element analysis includes the basic structural properties of the object and the changes that occur with the application of force. It can be examined with mathematical models in small parts of the object, and information about the whole can be obtained (12,13).

The purpose of our study was to examine the stresses on the maxilla alveolar bone caused by vertical forces on the zygomatic and dental implants applied in bilateral atrophic edentulous maxilla in different numbers and localizations with finite element analysis.

Materials and Methods

In this study, tomography of a fully edentulous adult patient was taken to create a geometric model of the upper jaw (Fig. 1). The jawbone was scanned using conical beam ray tomography. Six hundred and one sections were obtained in the scan. The volumetric data were then reconstructed with a slice thickness of 0.2 mm. The sections obtained from the reconstruction were imported into 3D-Doctor software in DICOM 3.0 format (Fig. 2). The bone tissues on the sections were separated in the 3D-Doctor software. The decomposed sections were turned into a 3D model. The 3D model obtained was turned into a smooth surface consisting of elements with uniform proportions in the 3D-Doctor software, and the modeling process of the upper jawbone was completed. Zygomatic implants with the same size and diameter and dental implants with the same size and diameter were applied to the virtual model created in five different procedures.

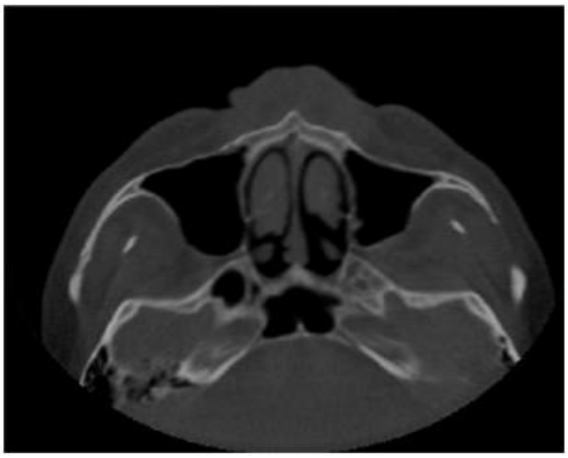

Figure 1. Tomography image of an edentulous adult patient

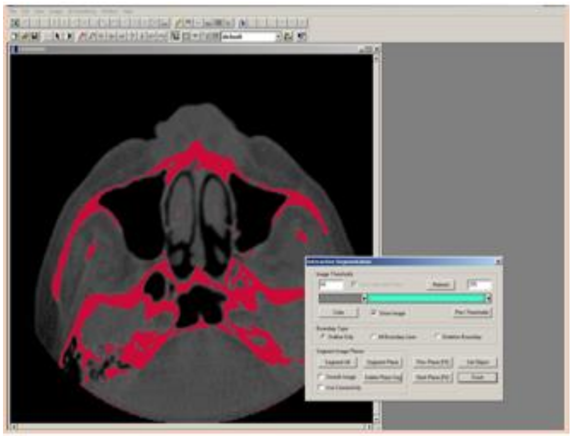

Figure 2. Transferring tomography images to 3D-Doctor Software

In our study, one zygoma implant on the right and left in Group 1, two zygoma implants in Group 2, one zygoma implant in Group 3 and one dental implant in the first premolar tooth area, one zygoma implant in Group 4, and one dental implant in the lateral tooth area and one zygoma implant in Group 5 and one dental implant in the lateral and a first premolar tooth area were applied (Fig. 3-7).

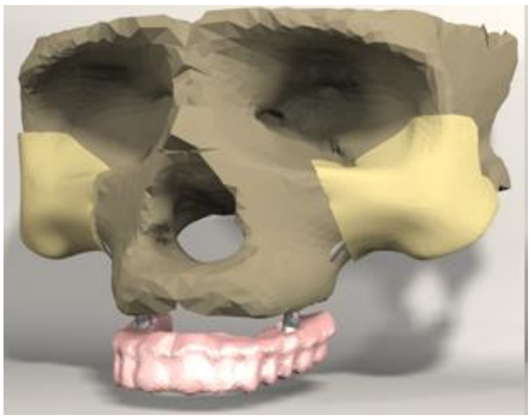

Figure 3. The model in which zygomatic implant is applied with prosthetic superstructure in Group 1

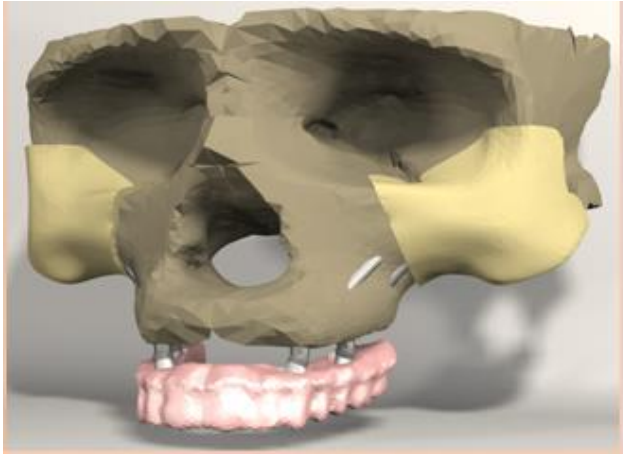

Figure 4. The model in which zygomatic implant is applied with prosthetic superstructure in Group 2

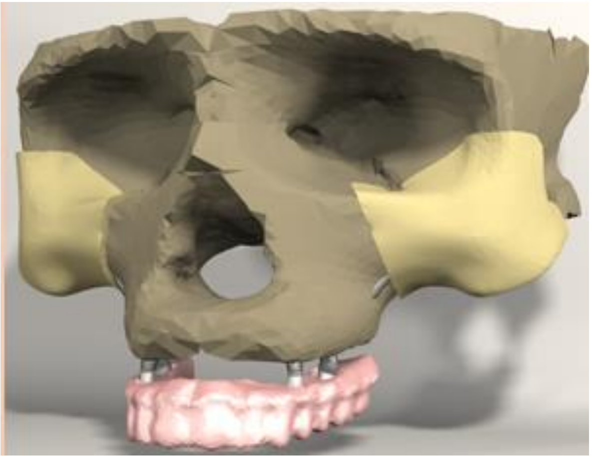

Figure 5. The model with zygomatic implant is applied with prosthetic superstructure in Group 3

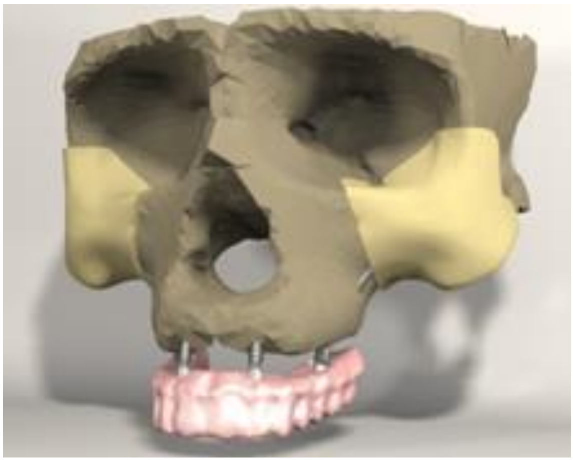

Figure 6. The model in which zygomatic implant is applied with prosthetic superstructure in Group 4

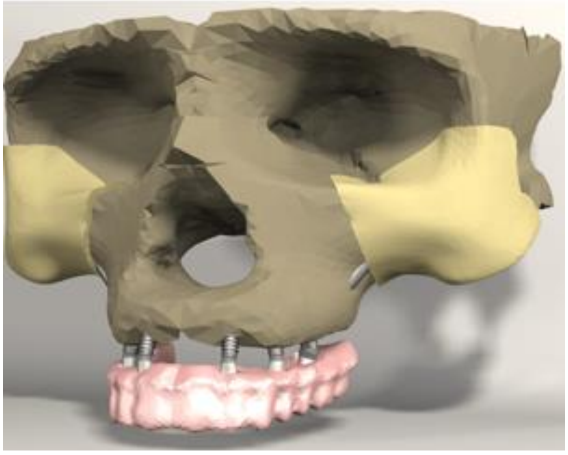

Figure 7. The model in which zygomatic implant is applied with prosthetic superstructure in Group 5

The zygoma implants (Nobel Biocare® AB, Goteborg, Sweden) used in the study were 4 mm in diameter and 35 mm long, and dental implants (Nobel Biocare® AB, Goteborg, Sweden) were 3.5 mm in diameter and 10 mm in length. The zygoma implants were placed by the extrasinus method, and 150 N forces were applied vertically in the prosthetic superstructure from 2-4-6-7 teeth (Fig. 8).

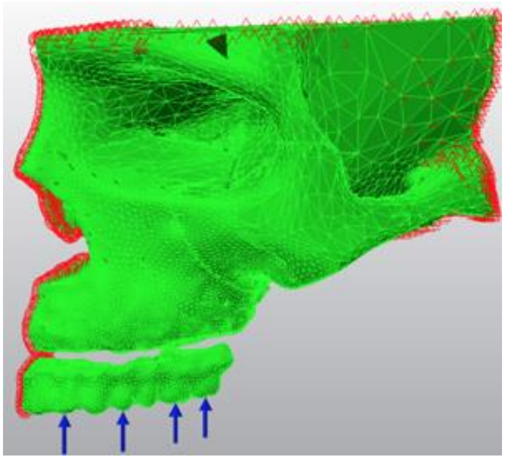

Figure 8. 150 N force applied vertically to teeth

The maximum stress values in the alveolar bone of the maxillary molar region as a result of the applied forces in the study were examined by finite element stress analysis. The stresses occurring in the alveolar bone around the implants were measured in megapascals (MPa) (N/mm^2). In the analysis, the regions with intense stress are shown in red, while the regions with low stress are shown in blue.

Results

As a result of loading, the maximum stress values in alveolar bone were measured as 184.447 MPa in Group 1, 18.1964 MPa in Group 2, 49.5588 MPa in Group 3, 28.8771 MPa in Group 4, 27.0335 MPa in Group 5 (Fig. 9-13).

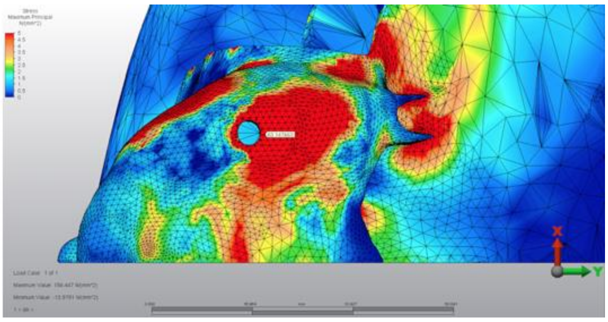

Figure 9. Maximum stress value in alveolar bone against vertical force in group 1

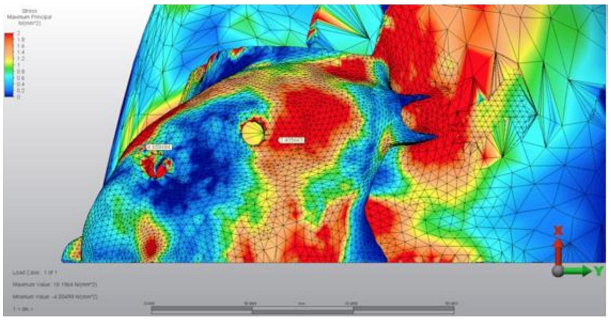

Figure 10. Maximum stress value in alveolar bone against vertical force in group 2

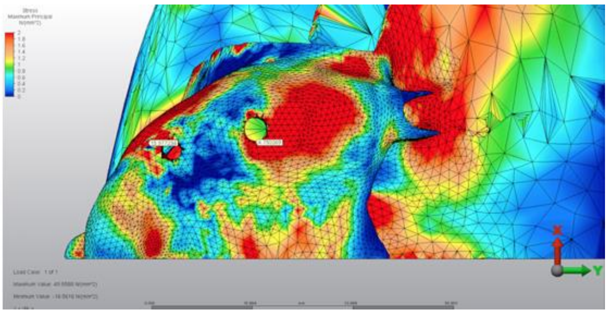

Figure 11. Maximum stress value in alveolar bone against vertical force in group 3

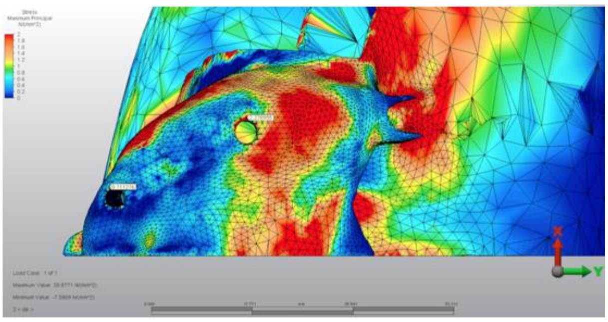

Figure 12. Maximum stress value in alveolar bone against vertical force in group 4

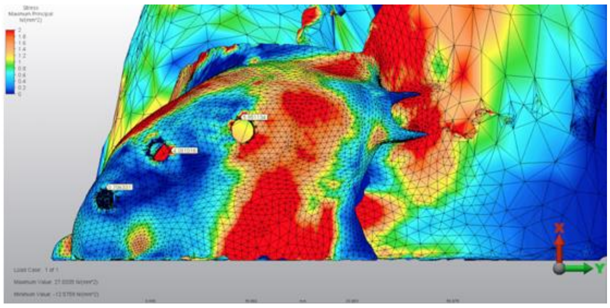

Figure 13. Maximum stress value in alveolar bone against vertical force in group 5

According to the results of the study, the maximum stress values occurring in the alveolar bone of the molar region against the vertical force, from highest to lowest, respectively; Group 1, Group 3, Group 4, Group 5, and Group 2. When these results are interpreted, the most ideal planning according to the maximum stress values in the alveolar bone against vertical forces is Group 2, where two zygomatic. This was followed by Group 4 and Group 5. It was observed that Group 3, in which dental implants were applied to one premolar area in addition to one zygoma implant, also gave similar results. In Group 1, where one zygomatic implant was applied, the maximum stress values were observed at the highest value.

Discussion

In 2012, Ishak et al. in their finite element stress analysis studies, they applied a vertical force of 150 N to the metal substructure at the level of the central tooth, 1st premolar tooth, 1st molar tooth and 2nd molar tooth. They examined the stress distribution in occlusal loads of zygoma implants applied with different surgical methods in the treatment of atrophic maxilla (14).

In 2015, Romeed et al. applied 150 N force in lateral and vertical directions to 4 zygomatic implants applied with the extrasinus technique in patients who underwent maxillectomy as a result of head and neck cancer and compared their stress levels. The reason why the amount of force is chosen vertically as 150 N is that the maximum bite force is at this value in adult patients using implant-supported removable prostheses (15-18).

In 2010, Miyamoto et al. obtained a three-dimensional solid model in a computer environment using the CT of a patient who had hemimaxillectomy. They applied two zygoma implants to the maxillectomy side and 2 and 3 conventional dental implants to the unaffected side. They reported that the application of zygomatic implants to the affected side reduces the stresses on the prosthetic superstructure and that the forces are evenly distributed (19).

In 2014, Ishak and Aisyah compared the effects of different numbers of conventional implants on the stability of the zygoma implant in their finite element stress analysis study. They applied only one zygoma implant to one side in the first group, one zygoma implant and one conventional implant in the second group, one zygoma implant and two conventional implants in the third group. According to the results of the study, they found that conventional implants used in addition to the zygoma implant positively affect the stability (20).

In their finite element stress analysis studies conducted in 2014, Wen et al. applied different numbers of zygomatic implants with Brånemark technique, extrasinus, and extramaxillary techniques, and conventional dental implants with different numbers and localizations. In this way, they obtained a total of 9 different models. Vertical and lateral forces were applied to these models, and stress values were compared. In the study, they applied the forces as 150 N vertically and 50 N laterally. According to the results of the study, they reported that they achieved the lowest stress in the group which a double-sided zygoma implant applied with the extrasinus technique and a double-sided lateral tooth implant (21).

In our study, based on literature support, we applied zygomatic implants and dental implants in different localizations to a 3D model of a patient with bilateral posterior maxilla atrophy. We used finite element stress analysis to examine the amount of stress and stress areas that occur in surrounding tissues as a result of masticatory forces. In the 5 different models we planned, a force of 150 N was applied vertically from the lateral tooth, 1st premolar tooth, 1st molar tooth, and 2nd molar tooth region, and the answer to the most accurate surgical planning was tried to be found.

Conclusions

If zygomatic implants are used for implant-supported prosthetic rehabilitation in patients with bilateral atrophic maxilla, according to the stress values we obtained, it was concluded that one of the Group 2, Group 4, and Group 5 surgical plans should be preferred. In the study, the highest stress value was seen in the Group 1 model, which we obtained by applying double-sided one zygomatic implant, and it was thought to be the last group to be applied as planning.

In addition, it has been observed that the localization of dental implants applied in addition to the zygomatic implant is important, and the lateral tooth area meets the forces more balanced.

Acknowledgments: This study was presented as a full-text oral presentation at the 1st International Dental Research and Health Sciences Congress held between 20-22 May 2021.

Peer-review: Externally peer-reviewed.

Author Contributions: Conception – A.Ç.; Design –B.G.; Supervision – A.Ç.; Materials – B.G.; Data Collection and/or Processing –A.Ç.; Analysis and/or Interpretation - B.G.; Literature Review – A.Ç.; Writer – B.G.; Critical Review – A.Ç.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study has received no financial support.

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