THE INFLUENCE OF CRESTAL BONE LOSS AND BONE GRAFT REPLACEMENT ON THE STRESS DISTRIBUTION AROUND DENTAL IMPLANTS: A FINITE ELEMENT ANALYSIS

THE EUROPEAN ASSOCIATION FOR OSSEOINTEGRATION
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Abstract

Background:
The prosthesis supported by osseointegrated implants has become a basic part of restorative therapy for both completely and partially edentulous patients. Various studies have shown that the stability of implant is related to the biomechanical properties of the bone surrounding. Time-dependent marginal bone loss around implants is still unavoidable and could jeopardize the stability of implant and the supported prosthesis. Because the finite element method is an effective analysis tool, it has been used in a variety of biomechanical studies regarding dental implantation.

Aim:
The aim of this study was to investigate the biomechanical effects of grafts and stresses distribution in the bone surrounding an implant placed in mandible premolar region based on the finite element method.

Methods:
A 3-dimensional finite element model of a mandible premolar section of bone was used in this study. The standard threaded implant, anatomy of the crestal cortical bone and cancellous bone with the vestibule bone defects around dental implants were represented in the 3-dimensional finite element models. A dental implant of 4.1 mm diameter and 10 mm length and for the defects around implant neck depth of 2 mm, 4 mm and 6 mm were chosen. Axially 300N and laterally 100N of forces were considered and the stresses developed in the supporting structures were analyzed.

Results:
According to our results the stress was highest in the cortical bone, lower in the grafted bone, and lowest in the cancellous bone which is a parallel outcome with the literature. Stresses produced with off-axial loads were higher in the cortical and grafted bones and lower in the cancellous bone compared with axial loads.

Conclusions and clinical implications:
Findings in our study suggest that the type of loading affects the load distribution more than the variations in bone, and native bone is the primary supporting structure.
Methods and Materials
The 3-D FEA is considered an appropriate method for investigation of the stress throughout a 3-D structure, and therefore this method was selected for bone and implants stress evaluation in this study. The software SOLIDWORKS (Yenasoft, Ataşehir, İstanbul) was used for preprocessing, finite element analysis, and ANSYS 14.0 for postprocessing in the study. A main 3-D model of a box shaped mandibula premolar region was designed for testing and analysis.

The model consisted of 2 mm cortical bone with cancellous bone inside. By this model 3 bony defects with 1 mm width were formed, first one was with 2 mm height, second one was with 4 mm height and the last one was with 6 mm height. In the superstructure the Dental Implant KA had a diameter of 4.1 mm, length of 10 mm and H2 abutment were chosen for the analysis. Otogenous (G1) and bioglass 45S5 (G2) synthetic graft materials were applied into the defects formed before. All materials used in the models were considered to be isotropic, homogeneous and linearly elastic.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Elastic Modulus (MPa)</th>
<th>Poisson Ratio</th>
<th>Density (kg/m^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>14,000</td>
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<td>0.0018</td>
</tr>
<tr>
<td>G2</td>
<td>35,000</td>
<td>0.3</td>
<td>0.0027</td>
</tr>
<tr>
<td>Titanium</td>
<td>110,000</td>
<td>0.3</td>
<td>0.0045</td>
</tr>
<tr>
<td>Cortical bone</td>
<td>14,000</td>
<td>0.3</td>
<td>0.0022</td>
</tr>
<tr>
<td>Cancellous bone</td>
<td>3,000</td>
<td>0.3</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Table 1: Material properties

The implant, the abutment, the bone and graft materials are assumed to be bounded and the mesh was generated (Figure 1). Forces of 300 N and 100 N were separately applied axially (AX) and buccolingually (BL), respectively, to the center of the abutment of totally 6 different FE model and the von Mises stresses (equivalent [EQV] stresses) in the structure were calculated (Figure 2).

Results
In all of the six models maximum von Misses stresses occurred on the side where the horizontal force applied on the abutment and the implant neck. While G1 and G2 showed similar stress values with the bone, G2 showed higher values comparing G1 (Table 2). Stress values showed an increase while defect depth increased.

Moreover, since defect depth increased, the area of the stresses occurred on the implant and abutment expanded, however the intensity of the stresses showed a decrease (Figure 3, 4).
According to our results, the stress was highest in the cortical bone, lower in the grafted bone and lowest in the cancellous bone. As we expected, G2 bioglass showed higher stress values while G1 otogenous bone graft showed similar values with the bone. Stresses produced with off-axial loads were higher in the cortical and grafted bones and lower in the cancellous bone compared with axial loads.

Conclusions

We can figure out that the type of loading affects the load distribution more than the variations in bone, and native bone is the primary supporting structure. But as bone resorption progresses, the increasing stresses of the cancellous bone and implant under lateral load may raise the risk of failure. While deciding the type of the grafting procedure, this comparison of otogenous graft and bioglass may highlight the importance of otogenous bone grafts.

References
