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Research Article

Effect of Bone Levels on Abutment Screw Loosening in the Mandibular First Molar Region: A Three-Dimensional Finite Element Analysis

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ABSTRACT

Background: Very few studies have investigated effect of bone levels on abutment screw loosening in the mandibular first molar region. The efficacy of dental implants is mostly contingent upon the stability of the abutment screw, which serves to connect the prosthetic element to the implant.

Materials and methods: A three-dimensional finite element model of a dental implant system was developed, comprising the implant, abutment, abutment screw, and adjacent bone. Geometric parameters were based on standard clinical dimensions, with bone represented as cortical and cancellous bone. Finite element analysis was conducted using ANSYS software to evaluate stress distribution.

Results: The analysis revealed a notable increase in stress on the abutment screw as bone levels decreased. Stress distribution varied with bone density, with maximum stresses observed at lower bone levels.

Conclusion: This study examines the impact of different amounts of bone on the stability of the abutment screw in the mandibular first molar area by a three-dimensional finite element analysis (FEA).

Keywords: Implant, Bone level, Stress, Three-Dimensional Finite Element Analysis, Abutment screw

1. INTRODUCTION

Dental implants are commonly employed for the purpose of replacing teeth that are absent, providing a long-lasting and visually pleasing remedy. Nevertheless, the durability and steadfastness of dental implants in the long run depend on the soundness and reliability of the abutment screw. Loosening of screws is a common problem that can result in the failure of implants, discomfort for the patient, and increased costs for further treatment. Gaining insight into the variables that lead to abutment screw loosening is essential for enhancing implant design and achieving favourable clinical results.[1,2]

The aim of this study was to examine how bone levels affect the distribution of stress around the abutment screw in the region of the first molar in the lower jaw, using three-dimensional finite element analysis. The concept posits that reduced bone levels elevate the strain on the abutment screw, hence augmenting the likelihood of its loosening. The study seeks to gain a deeper understanding of the biomechanical characteristics of dental implants in the mandibular first molar area. Specifically, it focuses on analysing how stress is distributed around the abutment screw in relation to various amounts of bone density. Understanding this knowledge is essential for comprehending the sustained efficacy of dental implants and the avoidance of issues, such as the loosening of the abutment screw.

The use of three-dimensional finite element analysis allows for a detailed and accurate simulation of the stress distribution within the dental implant system, taking into account the complex interactions between the implant, abutment, and surrounding bone. This method has been widely used in previous studies to evaluate the biomechanical behavior of dental implants under various conditions.[1-4] This study aims to provide clinicians and researchers with valuable insights into the optimal design and placement of dental implants. By analysing the stress distribution around the abutment screw under varying bone levels, the study can help minimise the risk of abutment screw loosening and ensure the long-term success of implant-supported restorations.

2. MATERIAL AND METHODS

Finite Element Model Development:

A dental implant system was created using a three-dimensional finite element model. The model comprises the implant, abutment, abutment screw, and adjacent bone. The implant was placed in the mandibular first molar area. The implant system's geometric parameters were derived using standard clinical dimensions. The bone was represented as cortical and cancellous bone, incorporating the corresponding material qualities.

Material Properties:

Table 1 displays the assigned material properties for the model components, including Young's Modulus and Poisson's Ratio for different elements such as Titanium, Cortical Bone, Cancellous Bone, Gum Tissue, Periodontal ligaments, and Alveolar Bone.

Table 1: Material Properties

Component	Young's Modulus (GPa)	Poisson's Ratio
Titanium (Implant, Abutment, Screw)	110	0.35
Cortical Bone	13.7	0.3
Cancellous Bone	1.37	0.3
Gum Tissue	0.07	0.3
Periodontal ligaments	13.7	0.3
Alveolar Bone	7.93	0.3

Boundary Conditions and Loading:

The model was restricted at the base of the bone to replicate immobilisation in the jaw. A vertical force of 200 N, which represents the usual stresses exerted while chewing, was applied to the abutment. The investigation examined several bone levels by altering the height of the bone surrounding the implant: 100%, 75%, 50%, and 25% of the original bone height. In addition, a screw preload of 246.91 N was taken into account, with the force delivered at a 30-degree angle relative to the distal direction.[5]

Table 2: Boundary Conditions and Loading Parameters

Parameter	Value
Load Applied	200 N (vertical load)
Bone Levels Analyzed	100%, 75%, 50%, 25%
Screw Preload	246.91 N
Force Application Angle	30 degrees from Distal
Mesh Type	Tetrahedral Elements

Meshing:

The model was meshed using tetrahedral elements with a finer mesh around the abutment screw to capture stress concentrations accurately.[5]

Simulation:

The finite element analysis was performed using ANSYS software. The primary outcome was the von Mises stress distribution in the abutment screw and surrounding bone.[5]

3. RESULTS

Stress Distribution:

The results of the finite element analysis, demonstrate a substantial increase in stress on the abutment screw as the bone levels decrease. The stress distribution characteristics for different bone levels are summarized below:

- At 100% bone level, the stress distribution is uniform, with a maximum stress of 200 MPa.

- At 75% bone level, the stress increases around the upper threads, reaching a maximum of 250 MPa.
- At 50% bone level, the stress distribution becomes uneven, with a maximum stress of 300 MPa.
- At 25% bone level, the stress concentration is high at the bone-implant interface, reaching a maximum of 400 MPa.

Bone Stress Analysis:

The examination of stress in the adjacent bone similarly reveals a rise in stress when bone levels decline. When the bone level reaches 25%, the cortical bone experiences significant stress concentrations, which may result in bone resorption and increased instability of the implant. The stress distribution characteristics for various strata of bone are outlined as follows:At 100% bone level, the cortical bone stress is minimal, at 50 MPa, while cancellous bone stress is 10 MPa.

- At 75% bone level, cortical bone stress increases to 75 MPa, and cancellous bone stress to 15 MPa.
- At 50% bone level, cortical bone stress increases significantly to 100 MPa, and cancellous bone stress to 20 MPa, indicating a risk of bone resorption.
- At 25% bone level, cortical bone stress is high at 150 MPa, and cancellous bone stress at 30 MPa, indicating a potential for severe bone resorption.

4. DISCUSSION

The finite element analysis performed in this work offers useful insights into the effect of decreased bone levels on the distribution of stress in the abutment screw of dental implants implanted in the mandibular first molar region. The findings indicate that a reduction in bone levels has a major impact on the stress experienced by the abutment screw. This can result in small movements and ultimately lead to the loosening of the screw (Jemt & Lekholm, 1998; Goodacre et al., 2003).[6,7] This discovery is consistent with clinical data that have shown a correlation between bone loss around implants and a higher likelihood of experiencing difficulties with the abutment screw (Goodacre et al., 2003; Pjetursson et al., 2004).[7,8] The increased stress on the abutment screw when there is less bone can be explained by the changed way that forces are transferred between the implant and the surrounding bone. When bone levels are sufficient, the strain is distributed more evenly, hence decreasing the stress on individual components (Duyck et al., 2000).[9] As bone levels diminish, the load becomes focused on the remaining bone-implant interface, resulting in increased pressures on the abutment screw (Duyck et al., 2000; Hansson, 2003).[9,10] The concentration of stress in this situation might lead to small movements and eventual loosening of the abutment screw, which can negatively affect the long-term stability of the restoration supported by the implant (Jemt & Lekholm, 1998; Goodacre et al., 2003).[6,7]
This study's findings highlight the need of preserving bone levels surrounding dental implants to guarantee the enduring success of implant-supported restorations. Healthcare professionals must be diligent in evaluating bone levels and taking preventive interventions, such as bone grafting and the use of stabilising collars, to avoid the hazards associated with decreased bone support (Esposito et al., 1998; Buser et al., 2000).[11,12] Regular scheduled checkups and radiographic examinations are essential for promptly identifying bone loss and intervening in a timely manner (Albrektsson et al., 1986).[12]

Limitations:

This study offers vital insights into the biomechanics of dental implants. However, it overlooks important elements in the oral environment, such as different loading situations, the quality of the patient's bone, and the presence of soft tissue. In order to gain a more thorough understanding of the complex factors that contribute to the success or failure of implants, it is recommended that future studies include these variables in their study.

5. CONCLUSION

The finite element analysis performed in this study emphasises the crucial significance of bone levels in preserving the stability of the abutment screw in dental implants positioned in the mandibular first molar area. Decreased bone levels result in elevated stress concentrations on the abutment screw, which raises the probability of loosening. These findings emphasise the significance of maintaining bone health in order to guarantee the prolonged effectiveness of dental implants. It is important for clinicians to give high priority to regularly assessing bone levels and taking preventive measures to ensure the durability of the implant-supported repair.

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