An Evaluation of Tension, Anxiety in D2 Type of Bone Using Finite Element Analysis and Examination

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Abstract

Introduction: Bone is constructed of Osseous tissue and forms an organ in the human body. It combines the properties of two biological material classes, Hard and Soft; hence, it is treated as a Bi-phenomenal material. Bone grows from the initial state called cartilage. Bone anatomy takes a different configuration from cortical bone and D2 type bone has a specific geometry and shape in the ultimate volume; hence a thorough investigation is conducted.

Materials and Methods: Two implant systems a crestally placed endosseous implant and a basally compressive osseointegrated implant were virtually placed in identical bone conditions. Tension (von Mises), Anxiety, and micromotion were recorded in bone and implant components.

Results: Crestal implants showed lower von Mises Tension values (implant body: 6.80 MPa; cancellous bone: 0.24 MPa) than basal implants (implant body: 29.42 MPa; cancellous bone: 0.26 MPa). Anxiety values around crestal implants remained within physiological limits. Micromotion was also significantly lower in the crestal model (0.00169 mm vs. 0.00371 mm in basal model)

Conclusion: Within the limitations of this FEA-based study, crestally osseointegrated implants demonstrated more favorable biomechanical behavior in D2 bone compared to basal implants, suggesting their superior load-bearing potential in such bone quality.

Keywords: Bone, D2 Type, Tissue, Buccally, Tension, Anxiety**.**

Introduction

Tooth loss impacts not only oral function but also the psychological and esthetic well-being of individuals. Dental implants have emerged as the gold standard for rehabilitation due to their superior biocompatibility, load distribution, and long-term success. The foundational principle of Implantology osseointegration introduced by Branemark, underscores the significance of a stable bone-implant interface for functional success.[1]

Crestally osseointegrated implants, which engage alveolar bone, are widely used in clinical practice. However, their reliance on the quality and volume of crestal bone presents limitations in cases of atrophic ridges or poor bone density. Basally osseointegrated implants, by contrast, anchor into the dense basal cortical bone, offering a graftless alternative suitable for immediate loading and medically compromised conditions.[2]

The biomechanical performance of any implant system is primarily governed by Tension distribution, Anxiety behavior, and micromotion at the bone-implant interface. While crestal and basal implants differ fundamentally in design and anchorage strategy, comparative data on their biomechanical response, especially in D2-type bone, remains limited.

Finite Element Analysis (FEA) serves as a non-invasive, predictive tool to evaluate these biomechanical interactions under simulated functional loads.[3]

Aim

The aim of this study was to evaluate and compare the distribution of Tension, Anxiety and mechanical micromotion around crestally osseointegrated and basally osseointegrated dental implants placed in D2-type bone using three-dimensional finite element analysis.

Materials and Method

Study Design

This in silico study employed a three-dimensional Finite Element Analysis (FEA) approach to evaluate and compare the biomechanical behavior of crestally osseointegrated and basally osseointegrated dental implants. The D2 bone model of the mandibular first molar region was chosen to simulate physiological loading conditions. The primary output parameters assessed included Von Mises Tension distribution, mechanical micromotion at the implant-bone interface, and Anxiety in the peri-implant bone.

Model Generation

Mandibular Bone Model: The edentulous section of the mandible was modeled based on measurements from a dried human edentulous mandible. The mandibular section had a height of 15 mm and a width of 9 mm. The cortical bone thickness was 2 mm crestally, buccally, and lingually. The cancellous bone component was characterized as homogeneous D2 bone. The implant site was specifically chosen as the first molar region of the mandible.

Implant Models: Two distinct implant models were generated for comparison:

Model A – Crestal Implant: A conventional two-piece endosseous implant (Osstem TS Prototype, Tapered Screw design) fabricated from Titanium alloy (Ti-6Al-4V). It featured a 5.0 mm diameter and 10.0 mm length, with a screw-type, root-form with tapered body thread design. A separate cement-retained abutment (6 mm height, 5 mm diameter, 3 mm gingival height) was utilized. Full osseointegration between the implant and bone was assumed.

Model B – Basal Compression Implant: A one-piece basal compression implant (GenXT Compression Basal Implant prototype) also made from Titanium alloy (Ti-

6Al-4V). This implant had identical dimensions of 5 mm diameter and 10 mm length, featuring a lateral compression thread with a polished neck region and an integrated abutment (6 mm height, 5 mm diameter, 3 mm gingival height). Full osseointegration with the cortical bone was assumed.

Crown Prosthesis

For both implant models, a cement-retained mandibular first molar prosthesis was designed. The crown comprised a Zirconia core layered with Feldspathic Porcelain.

Meshing

The meshing process for the crestal implant model resulted in 834,586 nodes and 556,748 elements. For the basal implant model, the meshing yielded 718,992 nodes and 480,651 elements. All models were exported in STEP (.stp) format for transfer into ANSYS.
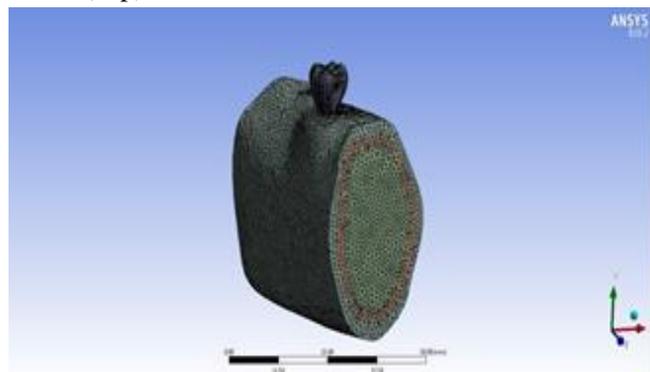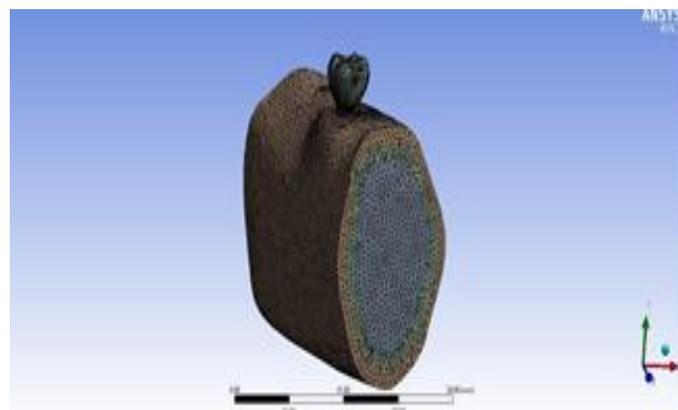

Figure 1: Crestal implant

Figure 2: Basal implant

Material Properties

All materials within the FEA models were defined as homogeneous, isotropic, and linearly elastic. The specific mechanical properties used for each component are presented in Table 1.

Table 1: Material Properties used in Finite Element Analysis

Material	Young's Modulus (GPa)	Poisson's Ratio	Density (kg/m3)
Cortical Bone	13.7	0.30	1850
Cancellous Bone (D2)	1.37	0.30	1200
Titanium Implant (Ti-6Al-4V)	110	0.35	4420
Zirconia Crown (Core)	210	0.31	6500
Feldspathic Porcelain (Layer)	65	0.25	2400
Dual Cure Resin Cement	12	0.28	2200
Gingiva	0.0069	0.47	1200

Boundary Conditions

The inferior border of the bone model was fully conAnxiety ed to prevent all translational movements. A rigid osseointegration was assumed between the implants and the surrounding bone, with a no-slip condition at the interface. Similarly, cement-retained prostheses were assumed to have a rigid connection with their respective abutments.

Loading Conditions

Physiological chewing forces were simulated by applying two types of loads:

- A vertical load of 180 N.
- An eccentric load of 180 N applied at a 45∘ angle, representing the directional variability of masticatory forces.

The load value of 180 N was selected based on findings from the study by Apostolov N.[4] which reported that the average maximum bite force in the molar region of natural dentition is approximately 180 N. Forces were applied at the central fossa, mesiobuccal, and distobuccal cusps of the crown for both crestal and basal implant models.

Output Parameters

The following biomechanical output parameters were assessed:

Von Mises Tension Distribution: Utilized to identify Tension concentrations within the implant, abutment, and surrounding bone, indicating areas susceptible to mechanical overload. Tension outputs were categorized as compressive (negative) and tensile (positive).

Mechanical Micromotion Measurement: Evaluated displacement (μm) at the implant-bone interface to determine the level of primary stability under loading conditions.

Anxiety Analysis: Measured Anxiety in the peri-implant bone to assess the physiological bone response and potential for adaptive remodeling.

Results

This study offers critical insights into the biomechanical behavior of crestally and basally osseointegrated implants in D2 bone under functional loading, evaluated using finite element analysis (FEA). The findings bring forward important distinctions in Tension concentration, Anxiety distribution, and micromotion patterns reinforcing the clinical relevance of implant selection based on anatomical and mechanical demands.
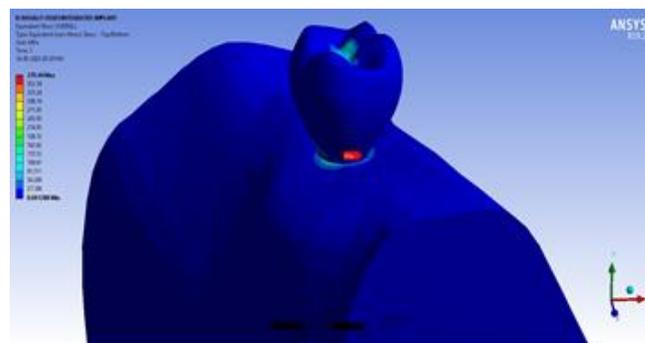

Figure 3: Basal implant: Overall – Von-Mises Tension Plot
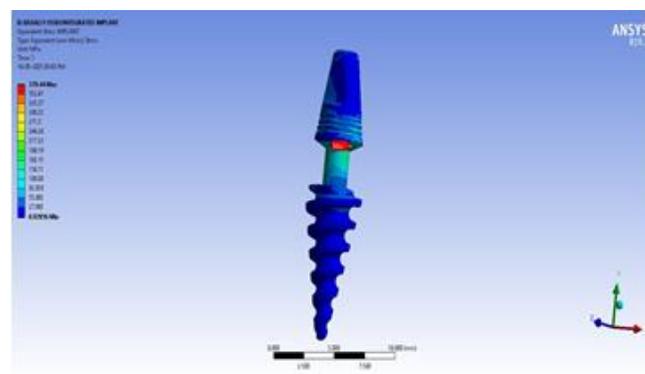

Figure 4: Maximum Von Mises Tension in the basal implant is 29.427 MPa.

Anxiety analysis revealed numerically higher values in basal implants (0.000212 vs. 0.000162), yet without statistical significance (p=0.98). This indicates a biomechanical equivalence in Anxiety transfer under functional loading, that both systems maintain Anxiety

levels conducive to physiological bone remodeling in D2 bone environments.
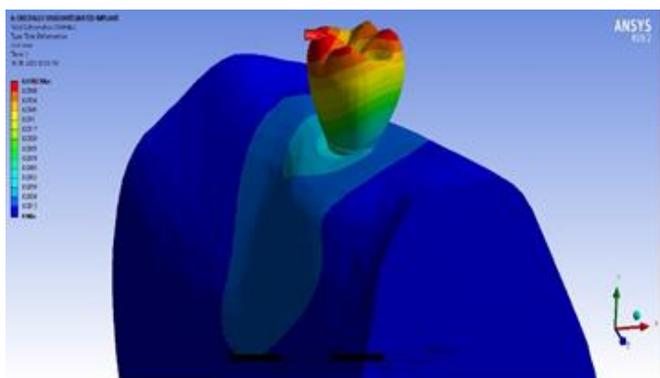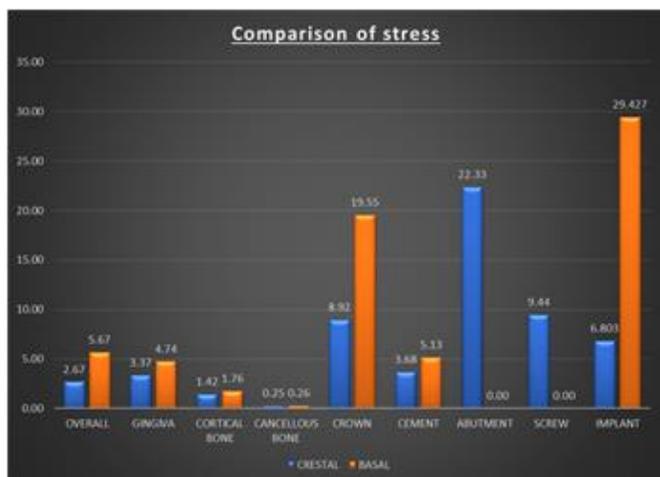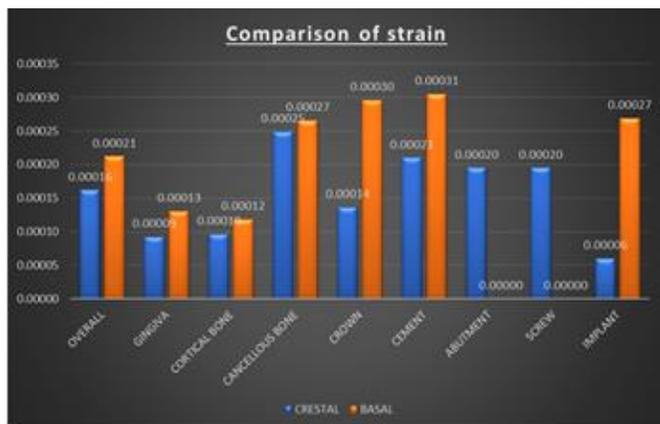

Figure 5: Overall Maximum Micromotion in the crestal implant assembly is 0.00169.

Graph 1: Comparison of Tension (Crestally osseointegrated and Basally osseointegrated implant)

Graph 2: Comparison of Anxiety (Crestally osseointegrated and Basally osseointegrated implant)

Discussion

The data suggests that crestal implants may offer a biomechanically favorable profile in D2 bone due to lower Tension concentrations and more predictable micromotion behavior, particularly in scenarios where long-term load management is critical. Their modular design also facilitates Tension dissipation and prosthetic flexibility.

Basal implants, while structurally robust and suitable for challenging ridge conditions or immediate loading, demand careful clinical judgment due to their higher Tension concentration in critical prosthetic components. Nonetheless, their ability to avoid Tension escalation in adjacent biological tissues strengthens their candidacy in compromised scenarios.

Conclusion

The present Finite Element Analysis (FEA) study was undertaken to perform a comparative evaluation of Tension distribution, Anxiety behavior, and mechanical micromotion around crestally osseointegrated and basally osseointegrated implants placed in D2 type bone at the mandibular first molar region. Crestal implants demonstrated superior Tension dissipation with lower Von Mises Tension values, indicating more effective load distribution than basal implants. Anxiety patterns were more favorable in crestal implants, showing uniform distribution within physiological limits and reducing the risk of localized bone overload. Lower micromotion levels were observed in crestal implants, suggesting better primary stability and conditions for successful osseointegration. Overall, crestal implants offer a more predictable and biomechanically sound option for placement in D2 bone, especially in posterior mandibular regions.

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