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OPTIMIZATION OF MULTI-CRITERIA DECISION-MAKING FOR DENTAL IMPLANT SELECTION

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Abstract: The long-term biomechanical performance of dental implants is significantly influenced by material composition, anticipated loads, and the geometry of the interface between the implant and the bone. This study applies multi-criteria decision-making methods to select an optimal construction strategy. Through finite element analysis, variables such as implant geometry and stress distribution during loading are integrated into the decision-making process. By processing the results of alternative implants, we ranked these alternatives using an Excel implementation of the VIKOR decision support method commonly used in the literature. Results indicate that the optimal stress distribution depends on the size and shape of the implant. Selecting symmetric fixation points and optimal distances may enhance implant stability and long-term performance.

Keywords: *Multi-criteria decision making, VIKOR method, dental implant*

1. INTRODUCTION

MCDM (Multi-Criteria Decision Making) is a decision-making method that helps reconcile different, often conflicting conditions in the decision-making process. Through the application of MCDM, decision-makers can:

- ***Consider multiple factors:*** MCDM allows decision-makers to simultaneously consider various factors. For instance, in the case of implants, this could include factors such as elastic modulus, antimicrobial properties, support for osteogenesis, etc.
- ***Prioritize:*** MCDM enables the prioritization of different factors in the decision-making process, determining which are the most important or prominent.

- ***Compare alternatives:*** MCDM facilitates the objective comparison of alternatives, taking into account all relevant factors.
- ***Sensitivity analysis:*** MCDM helps assess the sensitivity of results to different factor weightings or alternative selections.

In this case, MCDM assists decision-makers in comprehensively examining the advantages and disadvantages of different models for implants and properly aligning them with given conditions. Through the application of MCDM, decision-makers can better prepare to make optimal decisions among conflicting conditions, considering and weighting different criteria and constraints, such as implant fit, material, fixation, and cost-effectiveness, already in the design process. Consequently, well-founded and balanced decisions can be made for the best fixation construction alternatives in implant design, ensuring the best possible outcomes for patients.

Ideally, optimal fixation construction alternatives should result in minimal stress concentration, evenly distributing external loads onto connected bones. Therefore, the primary goal is to achieve optimal deformation, ensuring compatibility with external loading conditions. Key to this is identifying critical parameters with the greatest impact on implant deformation. We examined mechanical stresses arising in implants and deformations, focusing on three implant alternatives. Finite element analysis of implant mechanical properties was conducted for Ti-6Al-4V material. The Ti-6Al-4V exhibits greater resistance to deformation than surrounding bone. A significant difference in elastic modulus and relative density between the titanium alloy and surrounding bone can cause significant stress transfer effects. Furthermore, the stress stimulation value near the implant in bone is lower than recommended for bone regeneration, leading to absorption of bone tissues around the implant, resulting in implant loosening and ultimately failure.

One potential consequence of such an effect is gradual weakening of the jawbone as the implant assumes a large portion of the load. Evaluation of implant geometric and mechanical properties and their effects is based on loading conditions, associated stresses, and patterns of implant and bone tissue deformation, considering the combined effect of different properties.

2. Materials and methods

Model A: implant with internal octagonal connection and matching platform, and a preformed abutment with screw. Model B: implant with internal hexagon connection and switching platform, and a milling wearable abutment with screw. Model C implant with internal conical-cylindrical connection and switching platform, and a

cementable abutment with screw. The study was carried out using FEM and three study models were built. The parameters used for the construction of the models were as follows: to replicate the geometry of the components of each dental implant system (abutment, screw, and dental implant), preexisting plans were analysed from the implant manufacturing companies. The models were assembled and meshed using finite element software (SolidWorks 2022).
Chewing is a complex biomechanical process that involves the movement of the jaw when food is in the mouth, initiating the chewing cycle. Therefore, dental implants are exposed to a large number of loading cycles during their useful life. This causes mechanical wear of the material (fatigue phenomenon), which reduces its resistance, makes it susceptible to the formation of microcracks, and results in their propagation until failure occurs. The combination of axial and non-axial loading, termed mixed loading, simulates practical conditions where the actual applied force can be inclined with respect to the implant axis. In this finite element study, a frictional coefficient of 0.5 is assumed between the implant, abutment, and screw.

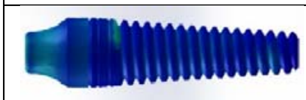
Table 1

Materials and mechanical properties

Material	**Young's Modulus (MPa)**	**Poisson's Ratio**	**Yield Strength (MPa)**
Cortical Bone	13.700	0.3	150
Cancellous Bone	1.370	0.3	130
Ti-6Al-4V	110.000	0.3	870

Table 2

Maximum von Mises stress and in all three study models

IMPLANT MODEL	**Maximum von Mises Stress (MPa)**		**Displacement (mm)**	
A	**Bone**	**Implant**	**Bone**	**Implant**
	40.5	135	0.010	0.1010
B	**Bone**	**Implant**	**Bone**	**Implant**
	51.49	187.2	0.00858	0.01
C	**Bone**	**Implant**	**Bone**	**Implant**
	59.45	293.3	0.01977	0.02668

A 3D solid-type mesh with tetrahedral elements based on curvature was used, which provided greater precision in the analysis of results due to its automatic creation of more elements in areas of greater curvature adapted to the circumferential shapes of the implants.
The Young's modulus, Poisson's rate and yield stress are shown in Table 1. The stress distribution was assessed using the von Mises stress through the comparison of normal, principal, and equivalent stresses.

3. Results

Axial load was applied on the surface of the abutment to analyse the stress distribution and determine the maximum stress values; the stress distribution was evaluated using von Mises stress. After applying an axial load, Model A showed a maximum von Mises stress value of 135 MPa (Table 2). Models B and C showed maximum von Mises stress values of 187.2 MPa and 293.3 MPa (Table 2); this stress was concentrated on the implant neck in all models (Figure 1-3).

von Mises stress **Displacement**

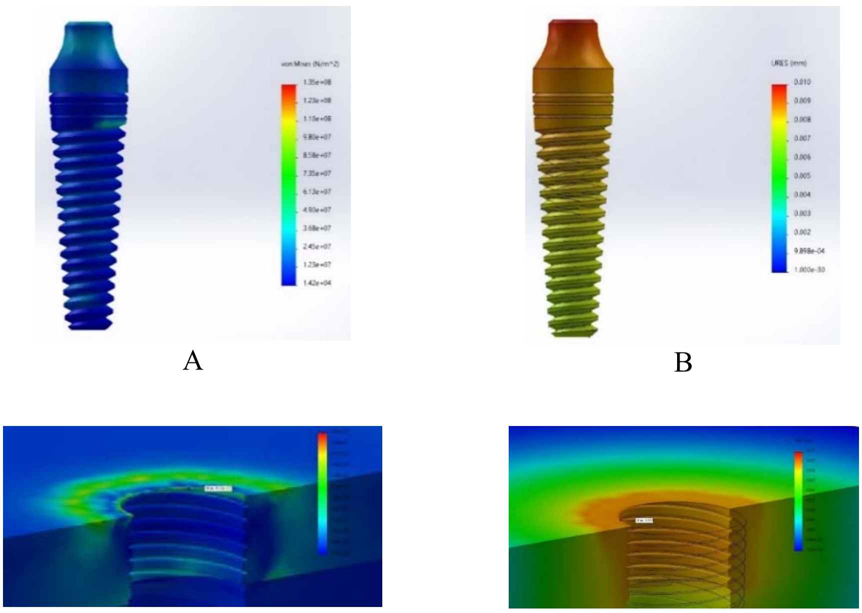


Figure 1. *Model A subjected to a 300 N axial load*

von Mises stress **Displacement**

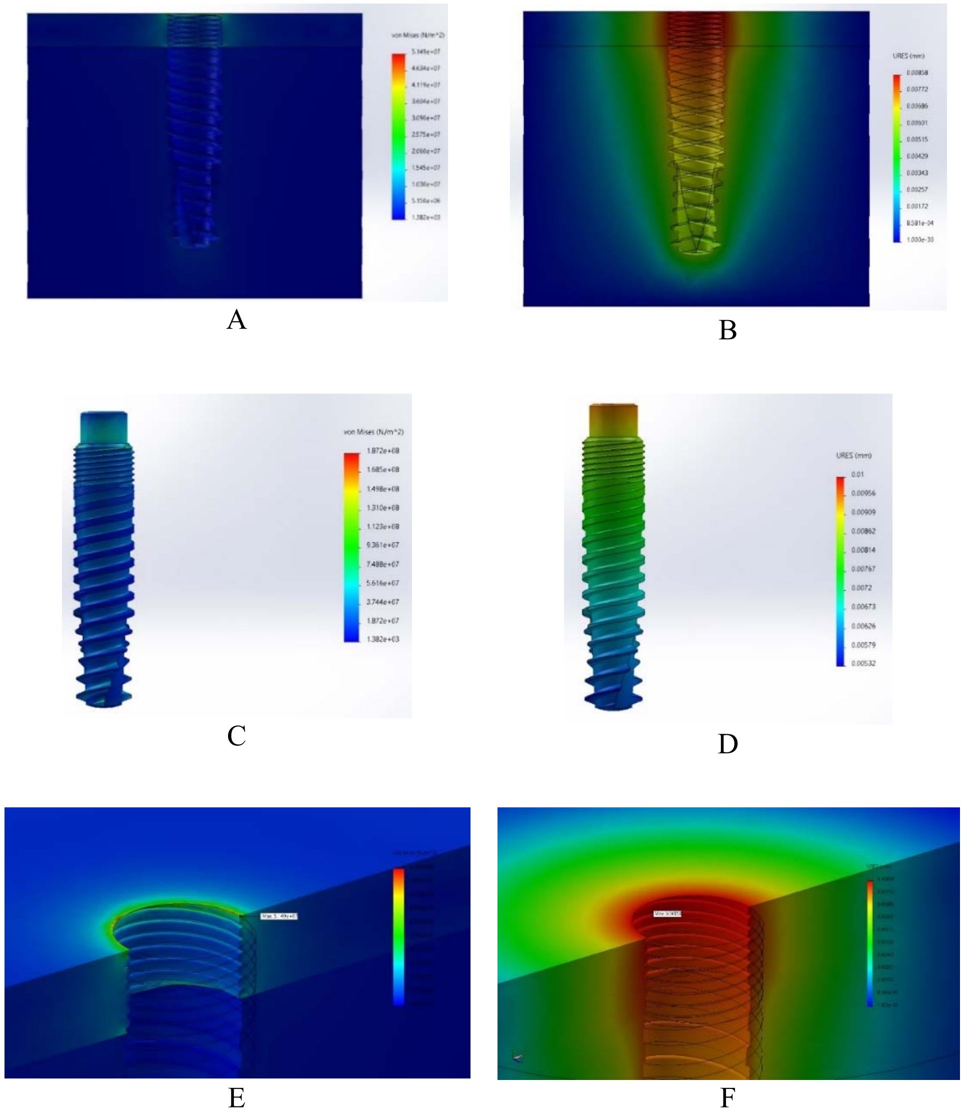


Figure 2. *Model B subjected to a 300 N axial load*

von Mises stress **Displacement**

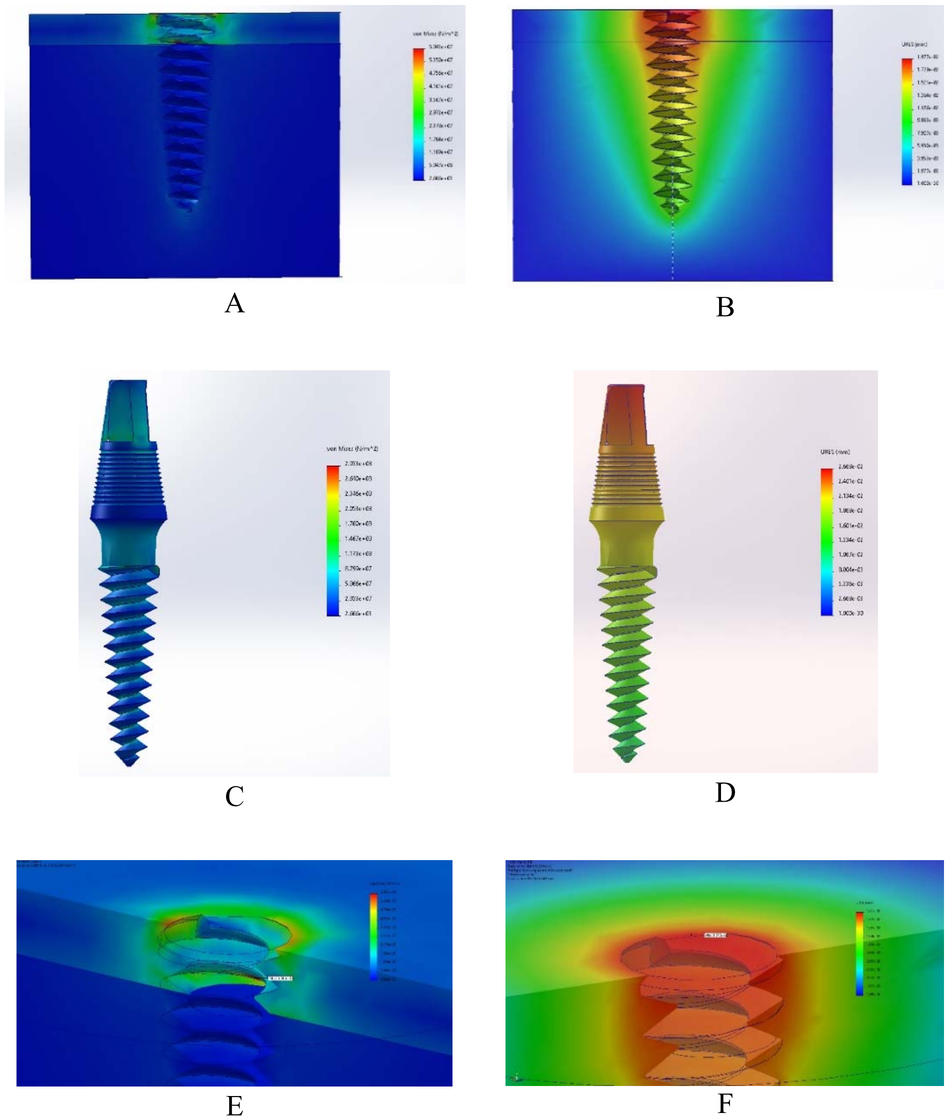


Figure 3. *Model C subjected to a 300 N axial load*

In dentistry, platform switching is a method used to preserve alveolar bone levels around dental implants, is whenever an abutment is used that is smaller in diameter than the implant platform. Platform switching can help prevent crestal bone loss, which is fundamental for the implant's long-term success and stability. The implant-abutment connection plays a crucial role in stress distribution. The reduction of stress at the implant-abutment connection may avoid some mechanical complications, such as abutment fracture, screw fracture, screw loosening, and augmented leakage at the implant-abutment connection.

We found that implants with conical connections showed lower stress than implants with internal hexagonal connections. The internal conical connection generated greater resistance to deformation and fracture. The stress concentration on the abutments is higher than on the implant. The highest stress values were formed on the abutment and on the upper part of the implant.

4. VIKOR METHOD IN DECISION SUPPORT

During the development process, we ranked different alternative solutions and the process of selecting the most suitable option: based on 7 criteria, we ranked the 3 alternatives with the VIKOR method. The models of the produced alternatives and the results of the finite element load simulations performed on them were collected and processed, and the alternatives were ranked using the VIKOR method applied in Excel. The results of the evaluation process are shown in Table 4.

Table 3

Criteria taken into account during the process of comparing alternatives and their priorities

Criteria	Importance
C1 cost	6
C2 deformation in bone	7
C3 deformation in implant	8
C4 maximum stress in bone	10
C5 operational lifespan	6
C6 maximum stress in implant	9
C7 repair request	5

Table 4

Determination of the ranking of the alternatives

Implant model	**Criteria**						
	C1	C2	C3	C4	C5	C6	C7
Model A	10	0.010	0.1010	40.5	100	135	100
Model B	7	0.00858	0.01	51.49	100	187.2	100
Model C	8	0.01977	0.02668	59.45	100	293.3	100
	0.0612	0.1836	0.1632	0.2040	0.1224	0.1836	0.0816
Ranking: Model A Model B Model C							

5. Summary

Models with switching platforms with an internal hexagon or conical-cylindrical connection generate lower maximum stress values, the major areas of stress were concentrated on the implant-abutment interface and the surrounding cortical bone. The results of the simulations on different alternatives and the application of the VIKOR method, which establishes a ranking based on the evaluation criterion system, can be concluded that it effectively supports the development processes of dental implants.

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