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BIOMECHANICAL ANALYSIS OF AN OPTIMIZED PATIENT-SPECIFIC DENTAL-IMPLANT SCREW IN THE POSTERIOR MANDIBLE

BIOMEHANSKA ANALIZA OPTIMIZACIJE PACIENTOVEGA POSEBNEGA VIJAKA ZOBNEGA VSADKA V ZADNJEM DELU ČELJUSTI

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Implant design developed considerably with the advancement of restorative dentistry. Examining the stress distribution in the cancellous and cortical bones around custom-made implants with different thread-profile models is the study's objective. The newly designed implants were made with a diameter and length of 4.5 mm and 11.5 mm. The implants were designed the same, but had different thread profiles. Model A is designed with a standard V-shape thread design, and it was compared with the remaining three dental implants (models B, C, and D) having different customized thread-profile designs. The biomechanical characteristics of the four implant models were compared with the use of biomechanical profiling to predict the mechanical performance of various dental-screw models, including the influence of physiological factors. The stress distribution in the D4 bone area of implants with different thread-profile designs under a vertical load of 100 N at 0° and an oblique load of 223.6 N at 25° was examined using ANSYS Workbench. The trabecular and cortical bones comprise the structure of the D4 bone area. Deformation and stress (von Mises) findings were found for the dental implants and bone. While implant models C and D showed less stress distribution in the cortical and cancellous bone, they nonetheless produced outcomes superior to those of the conventional model A underloading. According to the findings, the unique dental implant design lessens the stress concentration in the cortical bone's neck area. The suggested model C increases the implant's stability in that region by distributing a low stress over the D4 bone.

Keywords: FEA, cortical bone, trabecular bone, dental implants, thread profiles, stress distribution

Povzetek: razvoj oblikovanja zobnih vsadkov je močno napredoval z novim modernim pristopom k obnovitvenemu zobozdravstvu. Cilj avtorjev pričujoče študije je bilo ugotavljanje porazdelitve napetosti v poroznih in kortikalnih delih kosti (čeljusti) okoli doma izdelanih zobnih vsadkov, ki so imeli različne oblike profilov navojev. Na novo oblikovani vsadki so imeli premer 4,5 mm in višino 11,5 mm ter različen profil navoja. Avtorji raziskave so vsadek A s standardno *V* obliko navoja primerjali s tremi različnimi zobnimi vsadki (z oblikami B, C in D), ki so imeli novo doma razvito obliko navojev. Biomehanske karakteristike vseh štirih izbranih oblik navojev so med seboj primerjali s pomočjo biomehanskega profiliranja za napoved mehanskih lastnosti vključno z učinkom fizioloških faktorjev. Porazdelitev napetosti so simulirali s programskim orodjem na osnovi končnih elelmentov ANSYS Workbench v področju kosti (delu čeljusti) D4 in zobnih vsadkov z različnim profilom navoja pod vertikalno obremenitvijo 100 N pri 0° in obremenitvijo 223,6 N pod kotom 25°. Struktura preseka dela kosti D4 je vsebovala trabekularni (porozni) in kortikalni (površinski) del čeljusti. Avtorji so s pomočjo numeričnih simulacij določili deformacije in von Misesove napetosti v zobnih vsadkih in v kosti. Obliki navojev zobnih vsadkov C in D sta pokazali manjšo porazdelitev napetosti v kortikalnem in trabekularnem delu kosti in nič slabše lastnosti od vsadka s konvencionalno obliko navoja A. V skladu s temi ugotovitvami avtorji ugotavljajo, da so razvili edinstven dizajn zobnih vsadkov z manjšo koncentracijo napetosti v kortikalnem presku kostnega vratu. Predlagana oblika navoja C povečuje stabilnost zobnega vsadka v tem področju s porazdelitvijo nižjih obremenitev preko kosti oziroma izbranega dela čeljusti D4.

Ključne besede: numerična simulacija in analiza na osnovi končnih elementov, kortikalna kost, trabekularna kost, zobni vsadki, profili navoja, porazdelitev napetosti.

1 INTRODUCTION

An artificial tooth root, or a dental implant, is a medical device surgically inserted into the jaw to restore a person's ability to chew and, in certain situations, for cosmetic purposes. The availability of dental implants with incredible long-term results has transformed dental-implant procedures. Ensuring a dental implant's design can endure a range of loading scenarios and safely transfer biting forces to the surrounding region is crucial to the implant's long-term success.[1] Dental implants are surgically inserted into the jawbone to replace the lost teeth. Only after the implants have been inserted into the bone does osseointegration occur due to contact between the implant's surface and the bone around it. Osteointegration is the authentic and systemic connection between the surface of an implant exposed to a functional load and the dwelling and structured bone. Numerous requirements must be satisfied to accomplish osseointegration, such as biocompatible materials, acceptable macro designs, sufficient surfaces, appropriate reconstructive surgery, appropriate implant loading, etc. Cone-Beam Computer Tomography (CBCT), which has replaced time-consuming, expensive, and radiation-in-

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tensive medical CT scans, was first used in dentistry a few decades ago. Compared to Multi-Slice Computer Tomography (MSCT), CBCT is less expensive, simpler to acquire, and has fewer metal distortions. Using the Houndsfield Unit Scale (HU), it is regarded as a practical method for determining bone density. Because dental implants expose specific parts of the oral cavity and maxillofacial region to radiation, CBCT is an excellent option. By measuring the distance between the alveolar crest and the mandibular canal to prevent impingement of the inferior alveolar nerve, avoiding perforation of the mandibular posterior lingual undercut, assessing bone density and quality, and assisting in the planning of the oral implant in the maxilla with particular attention to the nasopalatine canal and the maxillary sinus, CBCT scans help with the planning of an implant's placement.

Osseointegration will be conditioned by biomechanical stimuli that directly influence bone-implant contact. The locations of the implant where it meets the surrounding bone are where the load is distributed. Since osseointegration depends on sufficient mechanical stability and a favourable biological environment, dental implants are designed with two main objectives: to favor proper primary stabilization and to encourage appropriate load transfer to the tissues surrounding the implant once secondary or biological stability is attained after osseointegration is achieved.[2] The osseointegration will be conditioned by biomechanical stimuli that directly affect the interface between the implant and the bone. The implant's contact points with the external bone will be capable of dispersing load.[3] The design of dental implants has a couple of goals: to support appropriate primary stabilization and to actively support the proper transition of loads to the tissue surrounding the implant once ancillary or physiological consistency has already been attained after osseointegration. This is because osseointegration depends on achieving sufficient mechanical stability and a favorable biological environment.

The implant's morphological characteristics, the body or core, the threads' form and depth, and the thread's pitch are all aspects of the prosthesis' macro-design. Both the tension that is transferred to the bone supporting the prosthesis and the development of stresses and strains at various levels of the implant are influenced by the shape and geometry of any one of these components.[4] The prosthetic design elements of tapered denture bodies and triangular compression threads increase the main stability. Achieving optimal primary-implant stability requires consideration of the implant macro-design. As soon as the implants are in place, forces must be transmitted, and the prosthesis must propagate stresses and strains on its own in order to employ immediate loading techniques. In Table 1, several studies have analysed how the macro-design of prostheses and the many variables that affect it affect the primary stability of implants and osseointegration as a result.[5] However, dental implants might fail due to insufficient stress distribution. Another crucial element that affects dental implants' success is the stress distribution pattern.[6] The characteristics of the bone supporting the augmentations are a critical factor in primary stability. At the level of the bone where the implants will be placed, there are two forms of bone: cancellous or medullary bone and cortical bone. The macro-design of the implant, the characteristics of the bone that it resides in, the stresses on the implant, and how those loads are distributed will determine the primary stability. The thread-profile designs must be carefully researched and improved to get the optimum outcomes since they are the most significant factor influencing the stress distribution in the surrounding bone region.[7]

Table 1: Determinants of early and late implant failure[8]

Early Failure	Late Failure
Micromovement (lack of primary stability) Short implants Early/immediate loading Narrow implants Low-density bone (osteoporosis)	Bacterial infection One-piece vs two-piece Smoking Neck of the implant History of periodontitis
Surgical trauma Overheating Compression osteonecrosis Infection	Excessive Load Trauma Inadequate restoration Short/narrow implants
Impaired healing Diabetes Age Smoking	

In advance to actual practice, dental implants that use the software can be digitally developed and examined. Potential flaws can be found utilizing the software tools, and any issues can be resolved for a higher success rate in the clinical scenario. The implant surface's noticeably higher taper enables more advantageous implant placement and improved implant stability, simplifying the surgical procedure. Clinical evaluation of the load distribution on the implants and bone brought on by the force applied to dental implants is challenging. Therefore, computational methods like Finite-Element Analysis can assess the loading of dental implants and the underlying bone. FEA has been routinely utilized to forecast the mechanical performance of various dental-implant designs and determine the implant's success.[9]

Metals can be used for dental implants because of their biomechanical characteristics. In addition to these qualities, metals are also simple to work with and have a nice finish. Implants made of metal can also be sterilised using a standard sterilisation method. But as technology has advanced, older metals like cobalt-chromium and stainless steel have become outdated and have been replaced. In recent years, titanium and its alloys, particularly Ti-6Al-4V, have emerged as the metals of choice for dental implants.[10] Titanium has an exemplary proven record of performance when utilized as an implant material, and its biocompatibility is to thank for this success

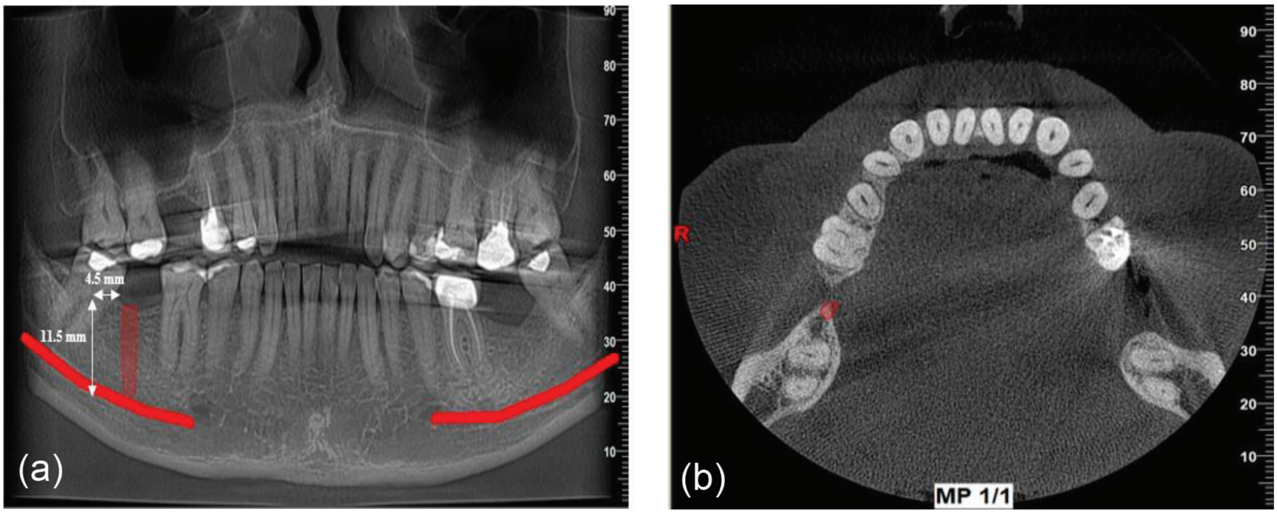

Figure 1: CBCT scan of a patient with a missing tooth in D4 bone

with titanium implants. However, titanium has an aesthetic problem because of its grey tone. This problem is more apparent when the soft tissue condition is not ideal, and the implant's dark tint is seen through the thin mucosa.[11] There are three different types of titanium alloys: alpha, beta, and $\alpha - \beta$. The additional substances function as phase condition stabilizers when pure titanium is heated with Al, Va under certain circumstances and then cooled. Aluminium enhances the strength and stabilizes the alpha-phase conditions. As a stabilizer of the beta phase, we have vanadium. The alpha-beta variant is present in the majority of alloys. The most popular implant has 6 % Al and 4 % V.[12]

The maximum stress values in the surrounding bone area must be minimized throughout the design phase to maximize the implant's stability. In this investigation, the implant is loaded vertically and obliquely to measure the stress distribution in the area of the bone around it. This FEA investigation's primary objective is to investigate how different implant designs affect the stress-strain distribution to the dental implant and the supporting bone.

2 MATERIALS AND METHODS

2.1 Computer-Aided Design (CAD) Modelling

The CBCT scan obtained from a patient aged 53, depicted the need for a dental implant of length 11.5mm and diameter 4.5mm (**Figure 1**).

Four unique implant types were developed, each with a similar diameter (4.5 mm) and length (11.5 mm), and they all have the same surface and material characteristics. Comparable to the other three implant models, Model A of the four implants shares a common thread.

A typical implant featuring a cylindrical body and "V"-shaped threads. (Model A, Figure a).

A proposed implant model B with a ridge-shaped thread design and a cavity between the threads (Model B, Figure b).

A proposed implant model C with a ridge-shaped thread design (Model C, Figure c).

A proposed implant model D with a cavity between the threads (Model D, Figure d).

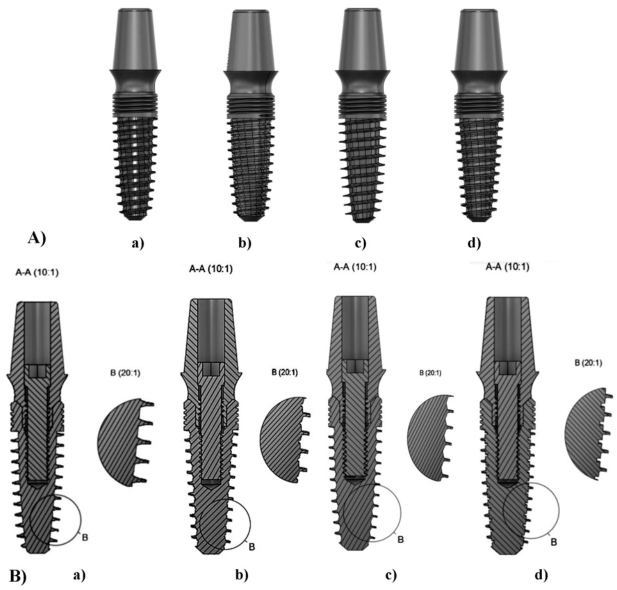

Figure 2: Thread-profile design of implant model for D4 bone: A) Solid model, B) Cross-sectional model

Table 2: Standard dimension of dental implant features

S. No.	Feature	Dimensions, mm
1.	Platform diameter	3.5
2.	Bevel diameter	4.5
3.	Implant height	11.5
4.	Pitch	0.8
5.	Abutment post height	5.5
6.	Abutment cuff height	2
7.	Implant screw thread	1.8 × 0.35 (Diameter × Pitch)
8.	Fixture internal hex	2.3

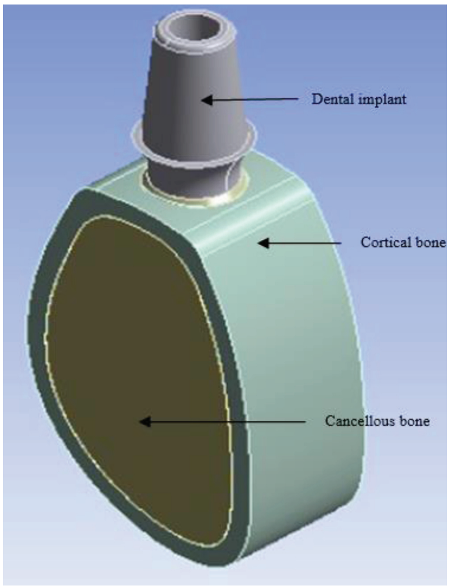

Figure 3: The implant, cortical bone, and cancellous bone are included

The other implant variants have different thread-profile designs than the conventional implant, which has a typical V-shaped thread design. The same standard dimension is used to create all four dental implants. **Table 2** includes a list of the dental implant sizes.

The 3D computer-aided design models were made with Autodesk Fusion 360. These geometries were input using ANSYS Workbench 2021 R2, a finite-element analysis tool, to create meshes and perform the finite-element analysis. A bone block model made of a cancellous bone core, also known as a trabecular bone core, encircled by 1-mm cortical bone was produced based on a cross-sectional scan of the mandibular area that measured 17 mm in height and 12 mm in breadth.[13] The bone model, shown in **Figure 3**, describes the cortical and cancellous bones.

2.2 Material Properties

All the materials are homogeneous, linearly elastic, and isotropic. Bone from the cortical and cancellous regions and titanium alloy (Ti-6Al-4V) are the materials employed in the finite-element analysis model. **Table 3** provides the material parameters used in the FE model, which are obtained from the literature and include the density, Poisson's ratio, and modulus of elasticity.[14]

Table 3: Mechanical properties of bone and implant

S.No.	Particulars	Youngs Modulus, GPa	Poisson Ratio	Density, kg/m^3
1.	Cortical Bone	14.7	0.30	1850
2.	Cancellous Bone	1.470	0.30	900
3.	Titanium alloy (Ti-6Al-4V)	110	0.35	4500

2.3 Finite-Element Analysis

To simplify the model, one or more characteristics are ignored in the current investigation. The simplifications do not impact the final analysis results. The interface between the bone and implant was expected to simulate osseointegration completely. As a result, a "fixed connection" scenario is created between implant-cortical bone and implant-cancellous bone. The same "fixed bond" is also established between the cortical and cancellous bones.[15]

The FEA model of standard implant model A consists of 51,136 nodes and 28,640 elements, implant model B consists of 1,07,497 nodes and 62,014 elements, and model C consists of 57,734 nodes and 32,577 elements. The FEA model of implant model D consists of 76,009 nodes and 43,033 elements. The implant model's boundary conditions were entirely limited in all directions, preventing the cortical or cancellous bone from moving in any direction.[16,17]

2.4. Loading Conditions

Axial or non-axial loading is possible. An axial force is applied downward to the implant's long axis. The tensile stress is transmitted by non-axial pressures or horizontal loading forces and attempts to separate the components by inducing a destructive bending movement. Mixed loading–a combination of axial and non-axial loads–simulates real-world situations where the actual force exerted can be angled relative to the implant axis. These oblique pressures have a higher degree of clinical realism. All four dental implant types had their long axes exposed to static vertical loads of 100 N at 0° and an oblique load of 223.6 N at 25° (composed of a vertical force of 100 N and a horizontal force of 200 N). The mesh size was programmed to adapt to the specific characteristics of the implant models automatically.[18]

2.4.1 FEA Data Collection

The stress distribution is obtained by setting the von Mises stress (equivalent stress) as the output variable in the ANSYS Workbench 2021 R2. The maximum stress values on the cortical bone and the stress distribution at the cancellous bone were determined using the von Mises stresses.[19]

3 RESULTS AND DISCUSSION

The conventional model A and additional suggested models B, C, and D all have maximum values for the stress distribution (von Mises) reported in Table 4. The suggested implant type A, B, C, and D's stress distribution in the cortical bone (bone 1) and cancellous bone (bone 2) is shown in Figures 4 and 5. In all FEA models, the maximum stresses were found in the cortical bone surrounding the implant and in the implant neck area un-

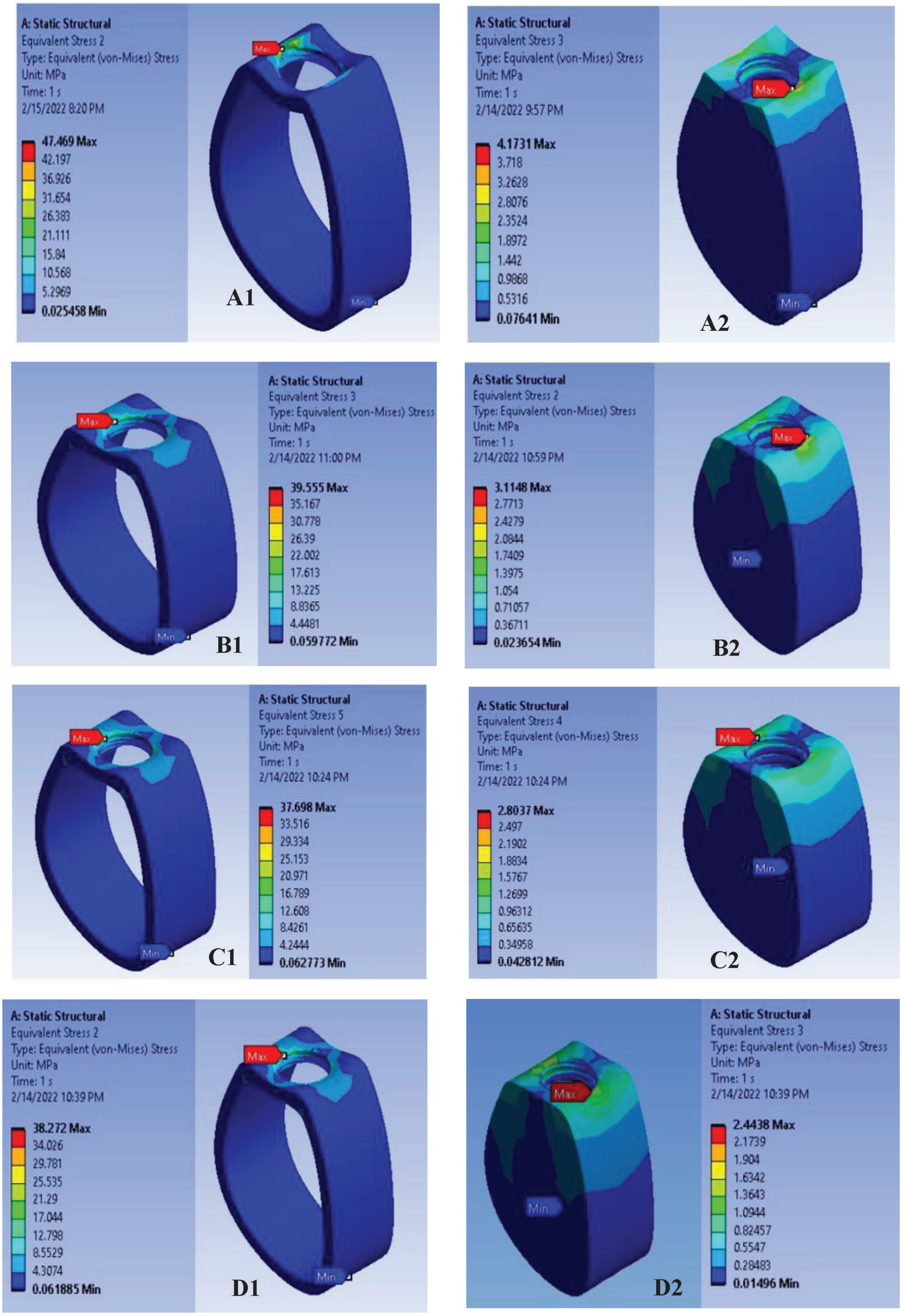

Figure 4: FEA of stress distribution under 100 N vertical load of dental models

der 100 N at 0° and an oblique loading of 223.6 N at an angle of 25°.

The highest von Mises stress in the cortical bone for model A under a loading of 100 N at 0° was 47.439 MPa, whereas the stresses in the cortical bones for models B, C, and D were 39.555 MPa, 37.698 MPa, and 38.272 MPa, respectively. Model A showed a maximum von Mises stress of 47.439 MPa in the cortical bone with a loading of 223.6N at 25°, whereas Model B, Model C, and Model D had stresses of 39.555 MPa, 37.698 MPa, and 38.272 MPa, respectively.

The maximum von Mises stress in the cancellous bone for model A under loading of 100 N at 0° was 4.1731 MPa, while the maximum von Mises stress in the cancellous bone for models B, C, and D was 3.1148 MPa, 2.8037 MPa, and 2.4438 MPa, respectively. Model A had a maximum von Mises stress in the cancellous bone of 6.3885 MPa under loading 223.6N at 25°. In contrast, model B had a maximum von Mises stress in the cancellous bone of 5.6167 MPa, model C had a maximum von Mises stress in the cancellous bone of 4.8639 MPa, and model D had a maximum von Mises stress in the cortical bone of 3.895 MPa.

When compared to the stress distribution in the cortical and cancellous bones of Model A, B, and C, respectively, Model C and Model D had the lowest stress distribution.

Table 4: Stress distribution in proposed models

Models	Component	Equivalent (Von Mises) stress (MPa) 100 N, 0° Angle		Equivalent (Von Mises) stress (MPa) 223.6 N, 25° Angle	
		Static Loading	Dynamic Loading	Static Loading	Dynamic Loading
Model A	Cortical Bone	47.439	49.531	80.199	81.856
	Cancellous Bone	4.1731	5.923	6.3885	6.514
Model B	Cortical Bone	36.555	41.321	65.149	67.025
	Cancellous Bone	3.114	5.181	5.616	5.826
Model C	Cortical Bone	37.698	39.723	59.739	61.786
	Cancellous Bone	2.803	3.018	4.863	4.996
Model D	Cortical Bone	38.272	41.025	60.542	61.778
	Cancellous Bone	2.443	3.987	3.895	4.096

Various design components, including fixture form, thread shape, pitch, screw type, and fixture connection type, are used to create dental implants. The literature has extensively covered the design aspect.[20,21] However, the results cannot be applied when several changes are made to the thread profile design. In implant dentistry, FEA is utilized to examine and predict variations brought on by modifications to thread profile design. To evaluate the mechanical behavior of dental implant models with the same diameter and length in response to variations in thread profile design, this work employed a FEA.[22] According to the results of this investigation, the implant neck was the area under the most stress. The distribution of stress in the implant's neck area must thus be considered more when designing dental implants. Some studies suggest that altering the thread-profile design may impact on the stress level on the peri-implant cortical bone, avoiding the loss of that bone.[23]

The crestal bone near an implant in an oblique contact angle with the crestal bone to the implant neck rather than a perpendicular angle with the implant neck exhibits lower peak stresses.[24] Stress is distributed more evenly by the divergent implant collar than by the straight form.[25] To resolve the disputed question of whether implant geometry is optimal for preserving crestal bone and has a lesser stress distribution, new implant models were designed and analyzed in this work. The tapering root analogue morphology of the new implant body mimics the form of natural roots. Because a tapered implant body minimizes the cortical and trabecular bone stress, it is a characteristic of all the implant designs. According to earlier research, the fixture's tapering body design may reduce the peak stress in both the trabecular and cortical bone.[26] Using three-dimensional finite-element analysis techniques, a stress analysis of various implants was performed.[27] When compared to three cylindrical implants with and without a "V" thread, two stepped implants with and without a "V" thread, and a tapered body implant with thread, the authors discovered that the tapered body implant with thread showed a 32 percent decrease in stress in the cortical bone and a 17 percent decrease in stress in the trabecular bone. Additionally investigated was the effect of implant body profile design on stress distribution.[28]

The authors claim that lowering the implant taper results in tension in the bone around the implant's neck area, while increasing implant taper generates stress in the bone surrounding the implant's body. Using a three-dimensional FEA, it was determined how different implant thread-profile designs affected how much stress was placed on the nearby bones.[29] The researchers used four implant designs with the same diameter and length. In terms of stress distribution in the nearby bone area, tapered implants had the most advantageous stress design when compared to cylindrical implants. A study also showed the effect of implant design on stress distribution in the cortical and trabecular bone.[29] In particular, in low-density bone, the authors hypothesised that tapered implants would perform better than cylindrical implants. Additional studies have investigated the impact of primary implant stability on implant profile design.[30] The implant will be more stable and simpler if the implant body and thread profile are tapered, simplifying the surgical procedure.[31]

In some therapeutic situations, when greater implant durability is needed, tapered implants offer some benefits. These circumstances include immediate loading procedures, post-extraction implants, and implant implantation in low-density bone.[32] In examining the suggested design models on the cortical and trabecular bone, implant models C and D indicated lower stress in the sur-

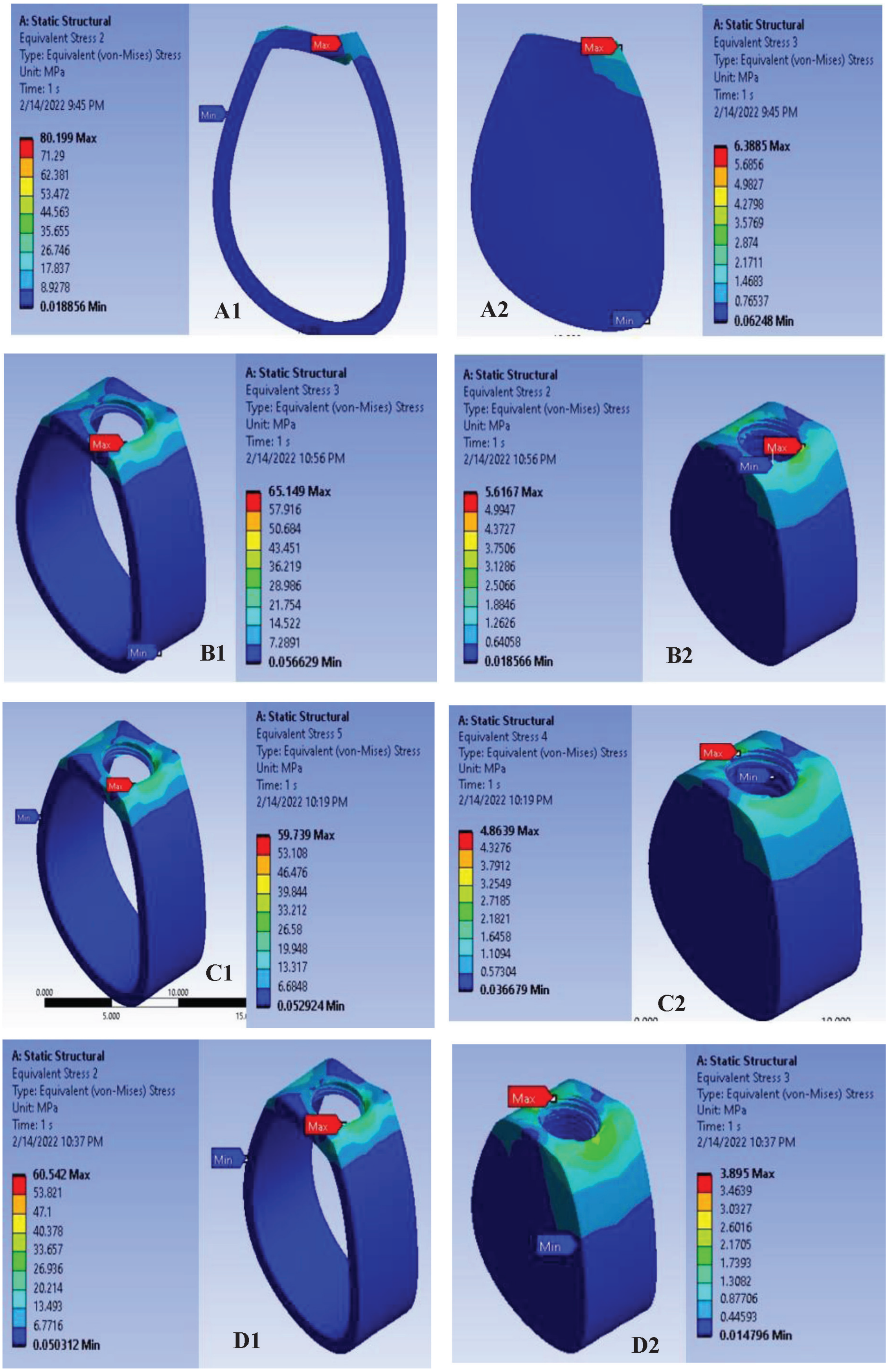

Figure 5: FEA of stress distribution under 223.6 N oblique load at an angle of 25° of dental models

rounding bone region. The stress reduction in models C and D might be attributed to the biomechanical impact of the thread-profile design with an improved interfacial area for bone-implant contact. According to in-vitro and in-vivo research, micro-threads in dental implants' profile designs may positively impact on how the stress is distributed in the cortical and trabecular bone.[33] FEA is used to examine the impact of micro-threads on the stress distribution implant in the peri-implant bone. Researchers evaluated 17 implants with and without micro-threads on the thread profile design, and they discovered that the latter had reduced marginal bone loss after three years of functional loading. Thread geometry is another critical factor affecting dental implant stability.[34]

Based on the thread arrangement, including shape and size, stresses in the bone-implant region have been reported.[35] The first implant to be presented was the "V"-shaped implant. Because it offers a superior initial mechanical interlock, a "V"-shaped design is frequently used in mechanical engineering to increase the stability of metal parts when they are brought together. Thanks to excellent knowledge of stress patterns, several thread geometry-related concepts have been investigated. Buttress threads combine the advantages of both "V"-shaped and rectangular thread designs, transferring force more equally than "V"-shaped threads.[36] Shear stress is the primary harmful force during bone-implant contact. Implant threads should provide for increased stability and implant surface to lessen the number of adverse stresses. A photo elastic stress analysis technique was used to record the force on the bone-implant interface, and it was connected to the thread's facial angle. It has been demonstrated that reverse buttress and rectangular threads produce less shear stress than V-shaped threads. Additionally, V-shaped buttress threads can exert stresses that could form flaws.[37]

Conversely, V-shaped thread profiles and reverse buttress threads transmit force via tensile, compressive, and shear stresses. Buttress and rectangular thread implantation primarily distribute axial loads by compressive strength.[38] According to results from FEA research connected to bone-implant contact, published in a literature review, the rectangular thread offers the best surface area for transmitting compressive stress. The results show that rectangular-shaped threads transfer less compressive and cutting-type stresses to the surrounding tissues than V-shaped profiles and reverse-angled-shaped threads. The rectangular thread implants exhibited the highest torque when the removal values of osseointegrated implants with V-shaped, rectangular, and reverse-angled threads were evaluated.[39] In the current study, the stress distribution in the cortical and cancellous bone of implant models B, C, and D was compared to the typical implant model A. The cortical and trabecular bone is less stressed by implant models C with a ridge-shaped thread profile and implant model D with a hollow than by implant model A with a V-shaped thread.[40] The thread profile shape in implants C and D can increase the stress distribution in the nearby bone area due to the aforementioned considerations. One factor that causes bone loss surrounding a dental implant is unfavorable stress distribution. Other factors include surgical trauma, implant-abutment micro-gaps, and bacterial infiltration. Marginal bone loss has been connected to surface characterization and implant thread profile design.[41]

The primary objective of the ongoing FEA studies is to look at the load-dependent biomechanical conditions in the tissues around implants. The geometry of the implant-bone contact at the crest level characterizes the zones of concentrated stress. According to the research, implant model C in the current study had a lower maximum equivalent stress in the cortical bone. The cortical bone experiences stress of 37.698 MPa and 38.272 MPa when 100 N of force is applied vertically along the vertical axis of the implant, respectively. These stresses are lower than those experienced by implants A and B, which share 47.439 MPa and 80.1999 MPa, respectively. The stress in the cortical bone is 59.739 MPa and 60.524 MPa, respectively, when 223.6N force is applied at an angle of 25° to the implant's axis. This stress is lower than that of another implant, which has values of 80.1999 MPa and 65.149 MPa. Implant models C and D also show reduced stress in the cancellous bone than implant models A and B. It is challenging to compare the findings of this investigation to those of previous studies since, as far as the authors are aware, no FEA data on the approximate threshold value at which marginal bone resorption may occur has been reported in the literature. We were able to demonstrate, however, that models C and D are preferable to models A (standard) and B in terms of decreasing the stress in the peri-implant cortical bone region since the stress is lower in equivalent lengths and diameters, based on the data acquired in this study. Some issues with the present FEA research prevent it from correctly simulating clinical trials.

First, the force that the tongue exerts while chewing and the impact of different loading circumstances cannot be considered by FEA. Second, despite this not often being the case in practice, the jawbone was meant to be isotropic and homogenous, with a bonded contact between the implant and cortical/cancellous bone and between the cortical and cancellous bone. Third, occlusal pressures were delivered to the implant rather than the crown under clinical circumstances. The current study cannot provide absolute and effective stress compared to a genuine model, even though such simplifications are allowed in the experimental test. The results revealed must thus be compared to those acquired from in-vivo studies.

4 CONCLUSIONS

In the current investigation, the link between the loading force and stress on the bone surrounding four dental implant models with identical diameter and length (4.5 × 11.5 mm) and various thread-profile designs was examined. We could draw the conclusion that implant design appears to have an impact on how strain and stress are distributed in bone and implants based on the results of this FEA study and within its limitations. According on the results of the FEA analysis,

- Compared to the traditional model's A, B, and D, the novel implant model C showed reduced maximum von Mises stresses in the peri-implant cortical bone area.
- The implant model C showed a reduced stress concentration in the compact bone region, which was transferred to the cancellous bone region during axial and oblique load.
- The implant model C also showed a strain in the cortical bone region and lower stress concentration in the cancellous bone than the model's A, B, and D.
- In any situation, the load distribution may be acceptable, given the resistance of the nearby bone.

Within the limitations of the current experiment, it is conceivable to conclude that the novel implant design 'C' can contribute to a proper stress distribution on the surrounding bone, which impacts the implant's long-term endurance. An upcoming investigation ought to attempt to correlate results with clinical findings. In doing so, it enhances the validity of the models. In addition, simulate the consequence of saliva, infection and fatigue failure under repetitive, realistic, and cyclic loading conditions must be evaluated.

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