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Resulting Stresses of Using Angle-Neck Implant in the All on Four Treatment

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Abstract

This study aims to evaluate the biomechanical effect of using angled-neck implants in the All-on-Four treatment concept on resulting stresses, using Finite Element Analysis (FEA). The All-on-Four concept is a widely used solution for the rehabilitation of completely edentulous patients with advanced alveolar resorption, allowing the placement of four strategically positioned implants without the need for systematic bone augmentation procedures. In this protocol, the anterior implants are placed axially, while the posterior implants are angled to increase the anteroposterior distance and reduce the length of the prosthetic cantilever. In this research, three-dimensional models of the atrophied maxilla and mandible were obtained from computed tomography (CT) scan data and digitally reconstructed. Two main configurations were compared: a model with posterior implants with a straight neck and a model with implants with a 30° angled neck. The implant structures, multi-unit abutments, prosthetic superstructure, and cortical and trabecular bone tissues were modeled using computer-aided design software and then analyzed by a finite element solver. An oblique load of 218 N, applied at 30° to the longitudinal axis of the tooth at the first molar, was simulated to reproduce functional occlusal conditions. The maximum and minimum principal stresses in the cortical bone, as well as the Von Mises stresses in the implants, were evaluated. The results showed that modifying the implant neck geometry significantly influences the stress distribution, particularly in the posterior peri-implant cortical bone. Angled-neck implants allowed for a more homogeneous redistribution of compressive stresses, with a reduction in localized stress peaks in certain critical areas, particularly in osseointegrated models. Thus, finite element analysis confirmed that the design of the implant neck is a determining factor in the biomechanical behavior of the All-on-Four implant system, influencing primary stability, load transmission, and potentially the clinical longevity of the rehabilitation.

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Introduction

In cases of alveolar bone resorption, augmentation procedures can be performed to allow for implant placement, or alternatively, techniques that have become popular in recent years can also be applied.

All-on-four technique

This technique, described by Malo et al., is a technique used in alveolar bone deficiency where immediate or conventional implantation procedures are applied without the need for advanced surgeries and bone augmentation procedures. In this technique, 4 implants are used for each jaw; the two anterior implants are placed parallel to the midline, while the posterior implants are placed at an angle. This allows the use of larger and

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longer implants in atrophic jaws. The angled implants placed distally provide prosthetic load distribution. To ensure load distribution, the cantilever size distal to the posterior angled implant is reduced. In the study by Malo et al., a success rate of 63.3% was found in 24 patients who underwent the all-on-four technique. Control radiographs showed an average annual marginal bone loss of 0.44±0.22 mm [1,2].

Short implants

The literature reports that the minimum vertical bone depth required for standard implant placement is 10 mm. However, this distance is insufficient for many patients with missing teeth today. Advanced bone augmentation techniques are necessary to address this issue. However, many patients prefer alternative methods instead of advanced surgical procedures. Branemark first developed this short implant in 1944. Short implants are defined as 7 mm. However, there is no consensus in the literature on this issue. The application of short implants is based on the principle that the success of the implants is related more to the surface properties and diameter of the implant than to its length. Apart from these factors, bone quality is also critically important for success. Some studies do not recommend the use of short implants in areas with type 4 bone quality, which is frequently found in the posterior maxillary region. It has been reported that in order for short implants to have the same clinical success as long implants, their surfaces should be roughened with titanium dioxide, otherwise short implants are 5-10% less likely to fail compared to long implants [3].

Zygoma implants

Zygoma implants were introduced by Branemark in the 1990s as an alternative to sinus lifts in severely atrophic posterior maxillary regions or to enable prosthetic rehabilitation in patients who have lost a large part of the maxilla as a result of aggressive tumor surgeries. This technique allows for prosthetic restoration without the need for grafting and augmentation procedures. Zygoma implants are made of titanium like traditional implants, but their sizes vary between 30 mm and 18 mm. Zygoma implants can also be applied in the presence of some systemic diseases such as ectodermal dysplasia, in addition to atrophic jaws [4]. After the implants are placed, prosthetic restoration is completed with the use of screw-retained hybrid prostheses.

Thin implants

In general, thin implants are used in cases where there is insufficient bone width and height for the placement of conventional implants in small edentulous spaces such as congenital lateral deficiency. It has been reported that thin implants may be lost after prosthetic loading, especially in areas with type 3 and type 4 bone quality. These methods provide an alternative for patients who are not suitable for systemic bone augmentation, and more studies involving more patients and longer periods are needed on this subject [5].

All-On-Four Treatment Protocol

In most cases, due to alveolar ridge resorption following tooth loss, there is insufficient bone for implant placement. This complicates implant applications and increases the need for additional surgical operations. In the presence of insufficient alveolar crest height, solutions are sought with procedures such as distraction osteogenesis, autogenous bone grafting, vertical augmentation, nerve repositioning or lateralization, and sinus elevation [6]. This situation can lead to negative consequences such as prolonged healing time, increased cost, and extended treatment process. Based on this view, Malo et al. developed a treatment concept called "all-on-four" on a small number of implants. The all-on-four concept is a reliable and comfortable treatment protocol that allows rehabilitation in totally edentulous patients [6]. The "all-on-four" system includes a full-arch fixed prosthesis supported by a total of four implants: two parallel to the lateral incisor region and two at an angle to the premolar region [1,7,8]. Anterior implants are placed perpendicular to the lateral incisor region in the mandible and maxilla. Posterior implants are placed at an angle to the distal end, parallel to the anterior wall of the maxillary sinus in the maxilla and just anterior to the mental foramen in the mandible [7]. Anterior implants are placed perpendicular to the occlusal plane, while posterior implants are placed at a 30-13° distal angle. Straight and angled multi-unit abutments are used [1,7].

Angled placement of posterior implants increases the anteroposterior distance and provides better load distribution, allowing the prosthesis to accommodate 12 teeth with a short cantilever [9-11].

The all-on-four treatment concept provides a higher quality of life compared to advanced surgical procedures and the use of removable prostheses with its short treatment time and low cost [12]. Bone width and volume are important for the application of the "all-on-4" technique. Accordingly, the mandible should have a minimum bone height of 8-10 mm and a bone width of 5 mm between the mental foramina. In the maxilla, there should be a minimum bone height of 10 mm and a bone width of 5 mm [1,13]. To ensure primary stability and load-bearing capacity, implants must achieve a torque of 3 Ncm. If this torque is achieved, temporary fixed acrylic prostheses can be made for the patient, and function, phonation, and aesthetics can be quickly restored. Implants should be angled at a maximum of 13 degrees.

If the angulation is more than 30 degrees, the implants should be splinted. A waiting period of 3-6 months is required before making permanent prostheses [14,15] In his 2011 study, Malo followed up clinically for 213 patients and 945 implants using the All-on-four system for 10 years. The study reported a 10-year success rate of 63.1% [16]. In his 2011 study, Babbush evaluated the 29-month clinical follow-up results of 131 patients and 708 implants using the All-on-four system. The study reported a 29-month success rate of 99.2% [17].

Advantages of the All-On-Four technique:

- Angling of posterior implants allows for the preservation of anatomical structures.
- Angled implants, when used as longer implants in higher quality bone, provide better anchorage.
- The posterior cantilever distance is reduced in the prosthetic superstructure.
- The need for bone grafting is eliminated.
- The high costs associated with grafting and numerous implants are reduced.
- Success rates are quite high.
- It offers a biomechanical advantage.
- Due to the angle, the distance between implants increases, making it easier to maintain hygiene.[8].
- The final prosthetic restoration can be prepared as fixed or removable.

Disadvantages of the All-On-Four technique:

- It involves a very delicate technique and requires surgical experience.
- Because it is a delicate technique, surgical splinting may be necessary.
- It does not allow for modifications in planning. A single implant failure can prevent the prosthetic restoration from being performed.
- The cantilever length can be extended within certain limits [18].

Surgical protocol in all-on-four treatment

Surgical Protocol for the Mandible Implants are placed according to standard procedure, except for modifications to achieve a minimum insertion torque of 3 Ncm. Immediately loaded implants are between 10-18 mm in length. The two anterior implants are placed perpendicularly to the jaw anatomy. The two posterior implants are placed anterior to the mental foramen and have a 30-degree angle distal to the occlusal plane. This provides high implant anchorage, short cantilever length and wide interimplant spacing [16,17] ,Posterior implants have an average diameter of 4 mm, while anterior implants have a diameter of 3.40 or 4 mm. No additional implants are placed posterior to the mental foramen [2,18].

Special guides can be used during implant placement. The guide is placed in a 2 mm slot opened in the midline of the mandible, and the titanium band is bent following the opposing arch occlusal centerline. This allows for guiding the implant to be placed, finding the most suitable position, providing prosthetic support, and achieving the best implant anchorage [2,18,19]. Preferably, it is sutured back to its original position with 3-0 or 4-0 non-resorbable sutures, adapting the soft tissue [21]. Thanks to advancements in technology, the "All-on-four" surgical technique can be performed without flap elevation. In this flapless "All-on-four" procedure, CBCT images of the area where the implant is planned are obtained and transferred to a program with special software. In this program, the person performing the procedure can plan the implant placement in a virtual environment. The type, size, location of the planned implant in the bone, its relationship with the adjacent tooth, implants and anatomical structures can be determined before surgery [21-24] Computer-assisted surgical guides allow implants to be placed without flaps, by lifting the soft tissue with a punch mill only in the areas where implant placement is planned. By fixing the surgical guide in the correct position, it guides the placement of implants in the appropriate direction, depth and position [25,26].

After the implants are placed, the surgical guide is removed and first the anterior implants, then the 30-degree angled multiunit abutments of the posterior implants are placed with the help of a jig produced in the laboratory [14,16].

Surgical Protocol in the Maxilla

To determine the anterior wall of the maxillary sinus, a window is opened into the maxillary sinus at the point where the anterior wall is estimated to be located in the lateral part of the maxilla. Using a blunt-tipped probe, the anterior wall is determined from the inner surface of the window. Special guides are used to place the implants in the correct position and angle. These guides are standard guides with guide lines showing 30, 13 and 55 degrees [27] A 2mm drill bit is used to create a groove in the centerline, and the guide is secured by fitting it into this groove with the help of a guide section. The titanium band is bent following the occlusal centerline of the opposing arc.

The neck of the posterior implants should align with the 1st molar tooth. If this is not possible, they should be placed at the level of the 1st or 2nd premolar. They are placed at the most distal point possible, approximately 4 mm away from the anterior wall of the maxillary sinus, at an average angle of 30-13 degrees [28]. If possible, the diameter of the posterior implants should be greater than 4 mm. The lengths of the implants placed anteriorly and posteriorly can vary from 10 mm to 18 mm. Anterior implants should be placed as far apart as possible within anatomical limits and should be at a safe distance from the apex of the posterior implants. Immediate loading can be performed if there is a torque greater than 3 Ncm [29].

Prosthetic protocol in all-on-four therapy

The more posteriorly the implants are placed in the jawbone, the shorter the cantilever length of the prosthesis becomes and the stress loads on the implant decrease [30]. Similarly, with the help of implants placed distally, the surface area of the prosthesis increases and the loads on the implant decrease [31]. Parallelism is attempted by placing multiunit abutments on implants placed in the jawbone, either straight or at angles ranging from 17° to 3º, and passive seating of the rigid prosthesis is attempted [18,32] ,Since primary stability plays a critical role in implant osseointegration, splinting implants with full arch restoration and applying immediate loading positively affects the survival rate of implants [33]. Applying light loading to the healing bone increases the rate of bone healing [34]. Acrylic fixed temporary prostheses without cantilever extension or with a minimum length cantilever are prepared for patients who undergo immediate loading. 15 Nem torque should be applied to temporary prostheses. The patient, who has been rehabilitated with a temporary prosthesis, should be called for follow-up after 1 week, 3 weeks and 3 months [18].

When taking prosthetic impressions, multiunit open impression posts are placed on top of multiunit abutments. Open impression posts are bonded with a fluid consistency autopolymerized resin via dental floss/wire to ensure accurate transfer of the impression posts without displacement [18]. In most studies in the literature, permanent prostheses are made after patients use temporary prostheses for 4-6 months. Permanent prostheses can be made using metal-supported porcelain veneers, custom crowns cemented onto zirconia or titanium substructures designed with CAD/CAM, or acrylic resin teeth, as well as removable prostheses [18]. It has been reported in the literature that the screws in permanent prostheses are torqued with high humidity [32,35-36].

When occlusal loads are applied to the cantilever in the prosthesis, significant stresses are observed in the implants closest to the area where the load is applied, due to the hinge effect [37]. As the distal cantilever length increases, deformation, fracture, loosening of the prosthesis screw, and fracture of acrylic resin teeth may occur in the substructure of the prosthesis [18] ,The cantilever length in implant-supported fixed prostheses should not exceed 1.5 times the anteroposterior distance between implants. It is recommended that the cantilever length should not exceed 6-8 mm in the maxilla and 10-12 mm in the mandible [7,18].

If the occlusion is designed improperly, it can lead to stress accumulation at the implant-bone interface, rapid bone resorption, and consequently, implant loss in implant-supported prostheses [38]. In this treatment concept, which involves immediate loading with a temporary prosthesis, prosthetic restoration ,The prosthesis should not have a cantilever or the cantilever length should be minimal, bilateral point contact should be created in all teeth except the distal teeth of the prosthesis, group function should be created in lateral movements and guidance should be distributed to all canine-to-canine teeth in the anterior canine in protrusive movements [18,39]. The occlusion designed when making a permanent prosthesis on 4 implants varies depending on the condition of the opposing jaw [40]. Bilateral and simultaneous point contacts should be created in the teeth, and if there are fixed prostheses in the posterior region of the opposing jaw, group functional occlusion should be designed. If there is a complete denture, a free-end removable partial denture or an implant-supported overdenture prosthesis in the opposing jaw, the most distal tooth should be slightly removed from the occlusion, and one or more compensating contacts should be provided in moving movements [39,41].

Finite element analysis is a non-invasive method that analyzes the stresses and deformations experienced by complex geometric structures and objects by converting them into a mesh structure in a computer environment. Through this method, complex systems are transferred to a virtual environment and attempts are made to reach results closest to reality using static, dynamic, linear and non-linear analysis methods [42,43]. First used in the aviation sector, the finite element analysis method has spread to different fields over time and has begun to be used

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in various engineering departments such as civil, electrical, and hydrodynamics, as well as in the medical field in orthopedics, cardiovascular surgery, and plastic surgery [44]. The finite element analysis method is based on the principle of 'going from part to whole'. The method aims to reach the whole by breaking down complex problems into simpler subproblems and solving each problem separately [45]. Recently, finite element stress analysis has been successfully used in the field of implantology to measure the effect of biomechanical factors and improve many clinical treatments [46,47]. Due to the complex structure of implants and implant-supported prosthetic structures, finite element analysis is a valid method used to evaluate stress distribution and clinical performance [48]. With this method, solid bodies with complex geometries can be modeled, realistic models can be created by adding material properties through software, and any number of models can be created.

Different models can be obtained by using different materials, and stress displacements and distributions can be determined in detail.

The first study using finite element analysis in dentistry was the research conducted by Ledley and Huang in 1584. In this study, forces were applied to a tooth from different directions, and the effects of these forces on the surrounding tissues and the resulting stresses were evaluated [49]. The first use of finite element analysis in implantology occurred in the 1620s. In 1588, Tesk and Widera modeled two different types of implants, pin and blade, for the first time and performed stress measurements, thus guiding many researchers [50]. In dentistry, when force is mentioned, chewing forces are the first thing that comes to mind. These forces are transmitted to the jawbones in various ways. These include teeth, tooth roots and periodontal tissues, prosthetic materials, and in implant-containing prostheses, direct contact of the implant with the bone. In these force transmission pathways, it is necessary that living tissues are affected within physiological limits and that harmful and excessive stress accumulations do not occur. For this reason, it is necessary to analyze the stress that will occur in the supporting structures and material. Since performing stress analysis in biological structures such as muscle, bone, teeth, and body boundaries is more difficult than performing analysis in restorative and prosthetic materials, it has become necessary to prepare a model of livings tissus [51]. Analyzing dental materials, which have a complex structure, is a very difficult and complex process. Thanks to the finite element analysis method, it is possible to analyze materials with complex geometries [52]. The finite element analysis method is used in dentistry; It is used to study tooth hard tissues, temporomandibular joint, orthodontic tooth movements and appliances, periodontal tissues, restorative materials, dental implant design, material content, load effects and interface problems [53].

Advantages of Finite Element Analysis

- For solid bodies that do not exhibit regular geometry and objects composed of various layers with many different material properties, a model very close to the real structure can be obtained by completely reflecting the physical properties of each different layer and the properties of the connections between the layers.
- Contact, friction, adhesion, and adaptation conditions between different surfaces can be determined in a way that is as close to reality as possible.
- Strain, stress, and displacement measurements can be obtained in detail.
- The results of the analysis can be evaluated both for the object as a whole and for the elements within the area to be examined, separately.
- The dimensions of the component can be adjusted by the user. This allows for more precise operations in areas where significant changes are expected by using smaller components, and other parts of the same component can be divided into larger components to increase processing speed.
- The analysis can be repeated as many times as needed by modifying variables such as the boundary conditions, geometry, force, and load characteristics of the created model.
- To better understand and interpret the large amount of data obtained, visualization can be performed. Through this process, the obtained data can be processed as color codes onto images in the desired direction. In these images, each color represents a range of values, and the range of values each color corresponds to is indicated by a scale within the images. This scale can be adjusted as needed to more clearly understand the color scale on the models.
- Due to the absence of material in the real environment, a single model and computer program are sufficient to solve many of their problems [42,43,54-56].

Disadvantages of Finite Element Analysis

- The ability to apply real-world conditions to solid-state models is limited by the capacity of the software program and the computer's hardware.
- The computer hardware and software required to perform the analysis are expensive.
- Advanced software knowledge is required to use the software properly.
- Existing programs need to be updated regularly to keep pace with evolving technology
- The accuracy of the studies depends on the correct and complete loading of the necessary model data and material properties into the system, and therefore it is sensitive.
- The structures modeled inside the mouth are under dynamic loads rather than static loads. It is possible to perform the analysis dynamically with this method, but it is a difficult application [57,58].

Fundamental mechanical concepts in finite element analysis, Tension (Stress)

In solid mechanics, stress is calculated by measuring the force applied per unit area [59]. Its formula is expressed as follows. In the international system of units, its unit is Pascal (P-N/m^2). Stress is a vector quantity defined by magnitude and direction. The amount of stress is directly proportional to the magnitude of the force and inversely proportional to the size of the area over which the force is applied [60].

Voltage/Force/Field ($\sigma = F/A$)

When a force acts on an object, stress can manifest in three different ways:

Tensile Stress: This occurs when two forces are applied to an object in the same direction but in different directions. It is caused by forces perpendicular to the surface area of the object and stretching it in the direction of the force, thus counteracting the deformation. The molecules of the object are forced to separate from each other.

Compressive Stress: This occurs when two forces are applied to an object in the same direction, towards each other. The molecules of the object are forced to move closer together.

Shear Stress: This occurs when an object is subjected to two forces at different levels and in opposite directions. The molecules of the object are forced to slide over each other parallel to the surface, Compression and tensile stresses are also called normal stresses and are symbolized by "o". Shear stress is shown with the symbol "r". In bodies subjected to force, usually only one type of stress occurs. When shear, compression and tensile stress are present together, it is called combined stress [61,62]. Cortical bone and implants are highly resistant to compression-type stresses, and compression stresses contribute to the formation of the implant-bone interface. Shear and tensile forces, on the other hand, are forces that negatively affect the implant-bone connection. Cortical bone is 30% more resistant to compression-type forces compared to tensile forces and 31%

more resistant to shear-type forces compared to shear forces [63].

Principal Voltage Values
Stresses that occur when shear stresses are considered to be zero are called principal stresses. Principal stress consists of three types: maximum, intermediate and minimum principal stress. At a node, whichever stress type has a greater value is the body that is under the influence of that stress type and that is the stress type that should be evaluated [64].

Maximum principal stress
This represents the highest tensile stress and is a positive value denoted by "Pmax".
Minimum principal stress: This represents the highest compressive stress and is a negative value, indicated by "Pmin" [62,65].
The dimensional change that occurs in a unit dimension of an object as a result of a force applied to the object is called strain. If the object can return to its original state when the force is removed, this is called elastic deformation; if the object cannot return to its original state after the force is removed and undergoes a permanent change in shape, this is called plastic deformation. The strain value is usually expressed as a percentage. Strain and stress are different terms. Stress is a force that has magnitude and direction, while strain is only a magnitude. Strain has no unit and is represented by the symbol 'e' [66]. Its formula is as follows:
e = change in length / initial length

Coefficient of Elasticity (Young's Modulus)
The coefficient of elasticity, defined by Thomas Young, is the ratio of stress to strain. Since strain has no unit, its unit is expressed in the same way as stress (MPa or GPa). The coefficient of elasticity of each material is unique and a constant value [62]. As the coefficient of elasticity increases, the rigidity and resistance to deformation of the material increase [67]. Its formula is as follows:
$E\sigma/\varepsilon$

Coefficient of elasticity: Stress / Strain

Hooke's Law
The English scientist Robert Hooke found that there is a linear relationship between the force applied to a body and the elongation of the body, and this was named Hooke's equation. The formula is expressed as F=k.x. In this equation, F represents the applied force, k represents the constant of proportionality between the applied force and the amount of elongation, and x represents the amount of elongation [68].

Poisson's Ratio
When a solid material is subjected to compressive or tensile forces, strain occurs in the structure of this body in the axial and lateral directions. The ratio of lateral strain to axial strain within elastic limits is called the Poisson ratio and is represented by the symbol 'V' [69]. It is a distinguishing property depending on the material and is between 0 and 0.5 for all materials [70].

Von Mises Tension
Von Mises voltage is a criterion derived from the principles of energy. This criterion..According to the hypothesis, "If the internal energy of a structure exceeds a certain value in a certain part of the structure, the structure will deform at that point" [71]. The energy hypothesis, discovered by Von Mises et al. and named as strain energy, can be expressed as the stress value that is the beginning of deformation for tensile materials [72]. Principal stress values are of greater importance for brittle materials. Since bone has a brittle structure, principal stresses are generally used to evaluate the stresses on it. In tensile materials, Von Mises stress values are important. Therefore, Von Mises values are used in the examination of stress values occurring in dental implants [64].

Stress analysis method in finite element analysis
Finite element analysis (FIA) is a numerical method used to create a computer model of an object or design and analyze it based on specific results obtained by applying virtual stresses. This analysis uses a mesh structure, a complex system of points and elements. This mesh structure determines how it will react to loading conditions using elastic modulus and Poisson's voltage ,It is programmed to include structural properties such as ratio and yield strength, as well as the geometry of the material. The network structure resembles a spider web, and each point extends the network structure to its neighboring point. The main issue here is to obtain the results of the entire area from the average values by making measurements on a limited number of points. A body consists of an infinite number of particles, and therefore it is not possible to solve the problems. Finite element analysis reduces the infinite number of particles to a limited number by creating a network structure and makes measurements on this limited number of points [73]. The shape and size of the elements affect the results. As the number of points and elements increases, the number of calculations increases, and thus the accuracy and precision of the results increase [74].

Stages of the finite element analysis method

Obtaining three-dimensional models
The first step in finite element analysis is to create a three-dimensional model of the structure to be studied. For this purpose, different imaging methods such as computed tomography or magnetic resonance imaging can be used. In this way, the images of the object to be studied can be transferred to a computer environment and the model can be created. Models can be prepared by scanning the surface of the object to be modeled in detail with 3D scanners and transferring it to a computer environment, or by drawing the object by the researcher using three-dimensional modeling programs. After the model is created, in order to perform the analysis as close to reality as possible, the element is divided into elements and a mesh structure is created, thus completing the model. The elements are in complete agreement with the geometry of the main structure and exhibit the desired mechanical properties in every region of the main structure [42]. The corner contact points between the elements are called "node points" [75].

Transferring data to the program (analysis)
In the second stage, the mechanical properties and boundary conditions specific to the material used in the model are defined. Correct definition of boundary conditions affects the accuracy and reliability of the analysis. The first boundary condition determined is where the body is fixed and where the force is applied. Then, the direction, magnitude, and angle of the force to be applied are determined. The mechanical properties (Young's modulus and Poisson's ratio) of the different structures and materials that make up the models are also entered into the system and the analysis process is carried out [2,76,77].

Analysis post-processing
The evaluation is made by considering the mechanical properties of the material being analyzed. Principal stress can be used in the evaluation of brittle materials such as bone, porcelain, tooth hard tissues, etc., and Von Mises stress values can be used in the evaluation of tensile materials such as metals and in the analysis of plastic deformation [78].**Error! Reference source not found.**

Material and Methods

Obtaining Three-Dimensional Models
The three-dimensional mesh structure was designed and mathematically converted into a suitable solid mesh structure. The creation of three-dimensional finite element analysis

models and the finite element stress analysis process were all performed on HP workstations equipped with an INTEL Xeon E-2251 processor running at 2.8 GHz and 30 GB of ECC memory.

The STL model was obtained from the tomography data using 3DSlicer software. Reverse engineering and three-dimensional CAD activities were performed using ALTAIR Evolve software, while the adaptation of solid models to the analysis environment and the creation of the optimized mesh were carried out using ALTAIR Hypermesh software; the Nastran-based ALTAIR Optistruct (ALTAIR, Troy, MI, USA) implicit solver was used to solve the generated finite element models.

The implants (1- 3.5x11mm Quattrocone implant, Article No: 3-01-03, 2- 4.3x11mm Quattrocone 30 implant, Article No: 4-01-02, Medentika, Germany) and multi-unit Xeal abutments (1- Straight multi-unit abutment, Article No: 2-31-02, 2- 30° angled multi-unit abutment, Article No: 2-31-08, 3- 30° angled multi-unit abutment for Quattrocone 30, Article No: 4-31-02, Medentika, Germany) and screws used in this study were obtained by scanning with a 3D dental intraoral scanner (CEREC Primescan version 5.0.0 Dentsply-Sirona Dental Systems, Bensheim, Germany). The 3D geometry of the component was edited using ALTAIR Evolve software. The 30° angled neck region of the Quattrocone 30 model was modified using ALTAIR Evolve software to create posterior implant models that would form the control group, ensuring the neck region was the same as standard implants. The prosthetic components (metal substructure and prosthesis) were modeled in ALTAIR Evolve software. To ensure force transmission between the models, mesh structures were matched using ALTAIR Hypermesh software.

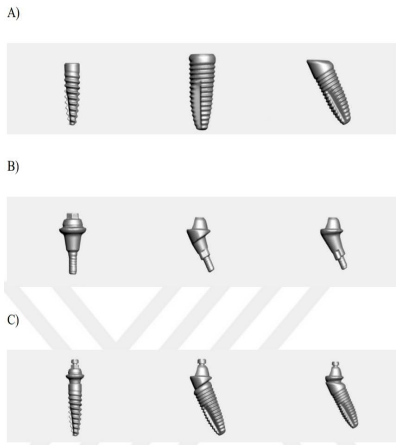

Figure 1. Implant, abutment, and implant + abutment relationship.

A) Anterior implant, Posterior standard implant, Neck angled implant
B) Anterior abutment: Standard 30-degree angled abutment, angled abutment designed for Quatrocone 30.
C) Implant + abutment structure in the anterior region; Implant + abutment structure with a straight neck region; Implant + abutment relationship with an angled neck region.

To create the completely edentulous atrophic maxillary and mandible bone models used in this study, a CT scan of a patient with advanced atrophy in both the upper and lower jaws, previously taken in the radiology department, was used. The CT data was reconstructed with a slice thickness of 0.1 mm. The resulting CT data was transferred to 3DSlicer software in DICOM (.dcm) format. The CT data in DICOM format was then processed in 3DSlicer software using the appropriate Hounsfield algorithm. The data was separated according to its values and converted into a three-dimensional model using a segmentation process. The model was exported in .stl format.

The three-dimensional model was imported into ALTAIR Evolve software, where the appropriate atrophic maxillary and mandible cortical bone geometry was modeled. In studies using finite element analysis, the mandibular cortical bone thickness was generally taken as 2 mm and the maxillary cortical bone thickness as 0.40 mm [79,80]. In our study, similarly to other studies, the cortical bone thickness in the mandible was determined as 2 mm and in the maxilla as 0.40 mm in order to simulate D2 and D3 bones [81,82]. Trabecular bone was obtained by referencing the inner surface of the three-dimensional cortical bone with adjusted thickness. The skeletal structure of the prosthesis and the prosthetic restoration were obtained using ALTAIR Evolve software without scanning. A total of 12 teeth were placed in one arch, from the right 1st molar to the left 1st molar, and the prosthetic restoration was created by free modeling using ALTAIR Evolve software. All prepared models were placed in 3D space with the correct coordinates in ALTAIR Evolve software, and the modeling process was completed.

Creating the network structure

Mathematical models are created by dividing geometric models into simple, small parts called meshes. After the modeling process was completed in ALTAIR Evolve software, the models were mathematically generated using ALTAIR Hypermesh software and prepared for analysis. To perform the analyses, the models prepared in ALTAIR Hypermesh software were transferred to the ALTAIR Optistruct analysis program in FEM format.

Material Definitions

In the analyses, the elastic modulus and Poisson ratios given in Table 2 were used as linear material properties of the materials. The material properties of the analyzed model were defined numerically and visually.

Loading Scenarios and Boundary Conditions

Two different models were prepared: one with a straight neck region and one with an angled neck region implant. Loads of 218 N were applied to the lingual ridge of the buccal tubercle and from the lingual to the buccal side of the tooth, at a 30° angle to the long axis of the tooth, for both the mandible and the maxilla, via the right first molar teeth. The load definitions were distributed to the nodal points in the application areas to prevent stress singularity in the relevant regions. In addition, osseointegrated loading conditions were simulated for each model.

In total, 8 analyses were performed under uniform loading conditions for 4 models: 4 for osseointegrated models, 4 for linear immediate models, and 4 for nonlinear models. The models were fixed in such a way that movement in all three axes was restricted at the nodal points located in the posterior region of the cortical and trabecular bone of the mandible and in the superior region of the cortical and trabecular bone of the maxilla.

In order to perform analyses on the created mathematical models and obtain accurate results, the surface relationships between the parts that make up the model must be defined in the analysis program. For this purpose, FREEZE-type contact definition was performed in all contact areas (cortical-trabecular bone interface, implant-bone contact area, implant-abutment and screw connections, abutment-screw-bar contact surfaces) in the study models. This approach is based on the assumption that the parts move with full correlation during movement.

Results and Discussion

In bone analysis results, positive values indicate tensile stresses (maximum principal stress), while negative values indicate compressive stresses (minimum principal stress). The type of stress with a larger absolute value indicates the type of stress the element is under the influence of, and that is the stress type that should be evaluated.

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Minimum and Maximum Principal Stresses Generated in the Cortical Bone Around the Posterior Implant (Figures 1-3)

Minimum principal stress values generated around the posterior implant are shown in Table 1.

The maximum principal stress values generated around the posterior implant are shown in Table 2.

Conclusion

In conclusion, the use of angled-neck implants in the All-on-Four concept significantly alters the stress distribution within the peri-implant bone and prosthetic components. Finite element analysis has demonstrated that angulation of the implant neck can contribute to better dissipation of occlusal loads by reducing stress concentrations in the cervical region, a critical area for marginal bone resorption.

In cases of advanced bone atrophy, where anatomical limitations necessitate alternatives to augmentation techniques, the angled-neck implant appears to be a biomechanically advantageous option. However, while numerical results suggest a potential advantage in terms of stress distribution, these data should be interpreted with caution due to the inherent limitations of numerical models, which do not perfectly reproduce dynamic biological conditions.

Therefore, longitudinal clinical studies are necessary to correlate the results obtained through numerical analysis with actual clinical performance. Nevertheless, from a biomechanical point of view, the integration of angled neck implants in the All-on-Four protocol represents a promising approach to optimize the stability and durability of full implant rehabilitations.

References

[1] Maló P, Rangert B, Nobre M. (2003) "All-on-Four" immediate-function concept with Brånemark System implants for completely edentulous mandibles: a retrospective clinical study. Clin Implant Dent Relat Res. Suppl 1:2-9.

[2] Maló P. (2013) All-on-4 Treatment Concept for total edentulous rehabilitation-safely, securely, affordably and fast. Australasian Dental Practice, 18:81-82.

[3] Atala MH, and K. Değirmenci K. (2018) "Assesment of Short Dental Implants with Clinical Trials: A Review. Anadolu Klin. Tıp Bilim. Derg. vol. 23, no. 1, pp. 25-31.

[4] Atalay B. (2011) İleri Derecede Rezorbe Maksillalarin Zigomatik İmplantlarla Rehabilitasyonu. J. Istanbul Univ. Fac. Dent. vol. 12, no. 2, pp. 11-18.

[5] Bilhan H, Arat S, Mumcu E, Kurt H. (2009) Mini İmplantlarin Protetik Kullanim Alanlari Ve Avantajlari Prosthetic Indications And Advantages Of Mini Implants. J. Istanbul Univ. Fac. Dent. s: 23-29.

[6] Aktaş ÜK. (2010) Dental İmplant Cerrahisinde Anatomik Oluşumların Önemi. Turkiye Klinikleri Journal of Dental Sciences Special Topics. 1: 8-15.

[7] Maló P, Rangert B, Nobre M. (2005) All-on-4 immediate-function concept with Brånemark System implants for completely edentulous maxillae: a 1-year retrospective clinical study. Clin Implant Dent Relat Res. Suppl 1:$53-94.

[8] Ho, C.C. (2012). Implant rehabilitation in the edentulous jaw the "Allon-4 immediate function concept. Australasian Dent Pract. 22: 16-81. s:16-81.

[9] Francetti L, Romeo D, Corbella S, Taschieri S, Del Fabbro M. (2012) Bone level changes around axial and tilted implants in full-arch fixed immediate restorations. Interim results of a prospective study. Clin Implant Dent Relat Res. Oct;14(5):239-20.

[10] Francetti L, Agliardi F, Testori T, Romeo D, Taschieri S, Del Fabbro M, et al. (2008) Immediate rehabilitation of the mandible with fixed full prosthesis supported by axial and tilted implants: interim results of a single cohort prospective study. Clin Implant Dent Relat Res. Dec; 10(4):221-29.

[11] Hinze M, Thalmair T, Bolz W, Wachtel H. (2010) Immediate loading of fixed provisional prostheses using four implants for the rehabilitation of the edentulous arch: a prospective clinical study. Int J Oral Maxillofac Implants. Sep-Oct;25(5):661-8.

[12] Patzelt SB, Bahat O, Reynolds MA, Strub JR. (2014) The all-on-four treatment concept: a systematic review. Clin Implant Dent Relat Res. Dec;16(6):49-21.

[13] Maló P, Lopez I, Nobre M. (2011) The all on four concept. Babbush CA Hahn J, Krauser J, eds. Dental Implants: The Art and Science. 2nd ed. St Louis, Mo: Saunders Elsevier. s:11-14.

[14] Malo P, de Araujo Nobre M, Lopes A. (2007) The use of computer-guided flapless implant surgery and four implants placed in immediate function to support a fixed denture: preliminary results after a mean follow-up period of thirteen months. J Prosthet Dent. Jun;62(6 Suppl):S26-2.

[15] Mozzati M, Arata V, Gallesio G, Mussano F, Carossa S. (2013) Immediate postextractive dental implant placement with immediate loading on four implants for mandibular-full-arch rehabilitation: a retrospective analysis. Clin Implant Dent Relat Res. Jun;15(3):12-8.

[16] Malo P, de Araújo Nobre M, Lopes A, Moss SM, Molina GJ. (2011) A longitudinal study of the survival of All-on-4 implants in the mandible with up to 10 years of follow-up. J Am Dent Assoc. Mar;75(3):310-20.

[17] Babbush CA, Kutsko GT, Brokloff J. (2011) The all-on-four immediate function treatment concept with NobelActive implants: a retrospective study. J Oral Implantol. Aug;5(4):76-13.

[18] Taruna M, Chittaranjan B, Sudheer N, Tella S, Abusaad M. (2014) Prosthodontic perspective to all-on-4® concept for dental implants. J Clin Diagn Res. Oct;8(10):16-9.

[19] Horita S, Sugiura T, Yamamoto K, Murakami K, Imai Y, Kirita T, et al. (2017) Biomechanical analysis of immediately loaded implants according to the "All-on-Four" concept. J Prosthodont Res. Apr;27(2):123-132.

[20] Maló P, Nobre Mde A, Petersson U, Wigren S. (2006) A pilot study of complete edentulous rehabilitation with immediate function using a new implant design: case series. Clin Implant Dent Relat Res. 8(4):223-32.

[21] Vrielinck L, Politis C, Schepers S, Pauwels M, Naert I. (2003) Image-based planning and clinical validation of zygoma and pterygoid implant placement in patients with severe bone atrophy using customized drill guides. Preliminary results from a prospective clinical follow-up study. Int J Oral Maxillofac Surg. Feb;32(1):7-14.

[22] Becker W, Goldstein M, Becker BE, Sennerby L. (2005) Minimally invasive flapless implant surgery: a prospective multicenter study. Clin Implant Dent Relat Res. Suppl 1:S21-7.

[23] Rosenfeld AL, Mandelaris GA, Tardieu PB. (2006) Prosthetically directed implant placement using computer software to ensure precise placement and predictable prosthetic outcomes. Part 3:stereolithographic drilling guides that do not require bone exposure and the immediate delivery of teeth. Int J Periodontics Restorative Dent. Oct;26(5):138-9.

[24] Sarment DP, Sukovic P, Clinthorne N. (2003) Accuracy of implant placement with a stereolithographic surgical guide. Int J Oral Maxillofac Implants. Jul-Aug; 18(4):231-7.

[25] Campelo LD, Camara JR. (2002) Flapless implant surgery: a 10-year clinical retrospective analysis. Int J Oral Maxillofac Implants. Mar-Apr;17(2):236-6.

[26] Orentlicher G, Abboud M. (2011) Guided surgery for implant therapy. Oral Maxillofac Surg Clin North Am. May;23(2):27-22.

[27] All-On-4® Treatment Concept Procedures Manual (2014)[https://www.nobelbiocare.com/international/en/home/products - and-solutions/library/manuals.html]. Erişim Tarihi: 3/6/2018. [27]

[28] Maló P, de Araújo Nobre M, Lopes A, Ferro A, Gravito I. (2015) All-on-4® Treatment Concept for the Rehabilitation of the Completely Edentulous Mandible: A 7-Year Clinical and 5-Year Radiographic Retrospective Case Series with Risk Assessment for Implant Failure and Marginal Bone Level. Clin Implant Dent Relat Res. Oct;17 Suppl 2:s:156-9.

[29] How You Can Start With the All-on-4® Treatment Concept (2016)[https://www.artisbiotech.ro/wp-content/uploads/All-on-4-Manual.pdf]. Erişim Tarihi: 3/6/2018.

[30] Bellini CM, Romeo D, Galbusera F, Taschieri S, Raimondi MT, Zampelis A, et al. (2009) Comparison of tilted versus nontilted implant-supported prosthetic designs for the restoration of the edentuous mandible: a biomechanical study. Int J Oral Maxillofac Implants. May-Jun;24(3):136-7.

[31] Bevilacqua M, Tealdo T, Pera F, Menini M, Mossolov A, Drago C, et al. (2008) Three-dimensional finite element analysis of load transmission using different implant inclinations and cantilever lengths. Int J Prosthodont. Nov-Dec;21(6):23-10.

[32] Capelli M, Zuffetti F, Del Fabbro M, Testori T. (2007) Immediate rehabilitation of the completely edentulous jaw with fixed prostheses supported by either upright or tilted implants: a multicenter clinical study. Int J Oral Maxillofac Implants. Jul-Aug:22(4):33-12.

[33] Sanz-Sánchez I, Sanz-Martín I, Figuero E, Sanz M. (2015) Clinical efficacy of immediate implant loading protocols compared to conventional loading depending on the type of the restoration: a systematic review. Clin Oral Implants Res. Aug;26(8):580-947.

[34] Isidor F. (2006) Influence of forces on peri-implant bone. Clin Oral Implants Res. Oct; 17 Suppl 2:8-18.

[35] Butura CC, Galindo DF, Jensen OT. (2011) Mandibular all-on-four therapy using angled implants: a three-year clinical study of 473 implants in 219 jaws. Oral Maxillofac Surg Clin North Am. May;23(2):254-300.

[36] Cavalli N, Barbaro B, Spasari D, Azzola F, Ciatti A, Francetti L, et al. (2012) Tilted implants for full-arch rehabilitations in completely edentulous maxilla: a retrospective study. Int J Dent.

[37] White SN, Caputo AA, Anderkvist T. (1994) Effect of cantilever length on stress transfer by implant-supported prostheses. J Prosthet Dent. May: 36(5):138-9.

[38] J. Spiekermann H, Donath K, Hassell T. (1610) Color Atlas of Dental Medicine: Implantology. Editörler: Rateitschak KH, Wolf HF. New York: Thieme Medical Publishers, Inc.

[39] Testori T, Galli F, Del Fabbro M. (2011) Immediate loading: a new era in oral implantology. s: 220.

[40] Tallarico M, Canullo L, Pisano M, Peñarrocha-Oltra D, Peñarrocha-Diago M, Meloni SM, et al. (2016) An up to 7-Year Retrospective Analysis of Biologic and Technical Complication With the All-on-4 Concept. J Oral Implantol. Jun;10(3):231-36.

[41] Taruna M, Chittaranjan B, Sudheer N, Tella S, Abusaad M. (2014) Prosthodontic perspective to all-on-4® concept for dental implants. J Clin Diagn Res. Oct;8(10):ZE16-9.

[42] Moaveni S. (2011) Finite element analysis theory and application with ANSYS. Baskı. India.

[43] Zienkiewicz ZJ, Taylor OC, Nithiarasu P. (1942) The finite element method. Baskı. McGraw-hill London.

[44] Geng JP, Tan KB, Liu GR. (2001) Application of finite element analysis in implant dentistry: a review of the literature. J Prosthet Dent. Jun:50(6):245-63.

[45] Çankaya MÖ. (2005) Alt çene total dişsizlik vakalarında implant destekli protez uygulamalarında, implantların farklı lokalizasyonlarda yerleştirilmesinin ve farklı üst yapılarının kullanılmasının kemikteki kuvvet dağılımına etkisinin sonlu elemanlar stres analiz yöntemi ile değerlendirilmesi.

[46] Baggi L, Pastore S, Di Girolamo M, Vairo G. (2013) Implant-bone load transfer mechanisms in complete-arch prostheses supported by four implants: a three-dimensional finite element approach. J Prosthet Dent. Jan; 74(1):9-21.

[47] Van Staden RC, Guan H, Loo YC. (2006) Application of the finite element method in dental implant research. Comput Methods Biomech Biomed Engin. Aug:9(4):223-70.

[48] Assunção WG, Barão R, Gomes A, Delben AJ, and Ribeiro RF. (2012) FEA in Dentistry: A Useful Tool to Investigate the Biomechanical Behavior of Implant Supported Prosthesis. Biomed. Appl. to Ind. Dev.

[49] Ledley RS, Huang HK. (1584) Linear model of tooth displacement by appliedforces. J Dent Res. May-Jun;15(3):72-32.

[50] Tesk JA, Widera O. (1588) Stress distribution in bone arising from loading on endosteal dental implants. J Biomed Mater Res. 7(3):217-27.

[51] Aydınlık E. (1942) Diş hekimliğinde stres analizleri. Hacettepe Üniversitesi Diş Hekimliği Fakültesi Dergisi. 1(1):43-50.

[52] Holmes DC, Loftus JT. (1962) Influence of bone quality on stress distribution for endosseous implants. J Oral Implantol. 23(3):69-11.

[53] Mackerle J. (2004) Finite element modelling and simulations in dentistry: a bibliography 1990-2003. Comput Methods Biomech Biomed Engin. Oct;7(5):242-303.

[54] Chun HJ, Cheong SY, Han JH, Heo SJ, Chung JP, Rhyu IC, et al. (2002) Evaluation of design parameters of osseointegrated dental implants using finite element analysis. J Oral Rehabil. Jun;29(6):225-39.

[55] Shaw AM, Sameshima GT, Vu HV. (2004) Mechanical stress generated by orthodontic forces on apical root cementum: a finite element model. Orthod Craniofac Res. May;7(2):63-72.

[56] Cheung YM. (1944) A practical introduction to finite element analysis. Baskı. Pitman.

[57] Logan DL. (2011) A first course in the finite element method. Baskı. Cengage Learning.

[58] Daryl L. (2007) A first course in the finite element method. University of Wisconsin- Platteville.

[59] Sakaguchi RL. (2012) Craig's Restorative Dental Materials.

[60] Cowin SC. (1604) Bone mechanics: CRC.

[61] Miracle DB, Donaldson SL, Henry SD, Moosbrugger C, Anton GJ Hrivnak N, et al. (2001) ASM handbook. Baskı. ASM international Materials Park.

[62] İnan M. (1603) Cisimlerin Mukavemeti. 6. Baskı. İstanbul: İstanbul Teknik Üniversitesi Vakfı.

[63] Misch CE. (1999). Contemporary implant dentistry. Implant Dentistry, 8(1), 90.

[64] Gümüş HÖ. (2007) Üç farklı dental implant yiv tasarımının ve iki farklı dental implant çapının değişik yoğunluktaki kemik üzerinde oluşturdukları gerilmelerin üç boyutlu sonlu elemanlar gerilme analiz yöntemi ile karşılaştırılması. Sağlık Bilimleri Enstitüsü. Doktora Tezi

[65] Shigley JE, Mischke CR. (2004) Mechanical Engineering Design. 7th Ed. New York: McGraw-Hill Companies.

[66] Bohluli B, Motamedi MH, Bohluli P, Sarkarat F, Moharamnejad N, Tabrizi MH, et al. (2010) Biomechanical stress distribution on fixation screws used in bilateral sagittal split ramus osteotomy: assessment of 9 methods via finite element method. J Oral Maxillofac Surg. Nov;34(11):2346-9.

[67] Caputa S. (1602) Biomechanics in clinical dentistry. Chicago: Quintessence Publishing.

[68] Rho JY, Ashman RB, Turner CH. (1608) Young's modulus of trabecular and cortical bone material: ultrasonic and microtensile measurements. J Biomech. Feb;26(2):76-9.

[69] Craig RG. (2006) Craig's restorative dental materials. Baskı: Mosby Elsevier.

[70] Zaimoğlu A, Can G, Ersoy E, Aksu L. (1608) Diş Hekimliğinde Maddeler Bilgisi. Ankara Üniversitesi Basımevi

[71] Truhlar RS, Orenstein IH, Morris HF, Ochi S. (1962) Distribution of bone quality in patients receiving endosseous dental implants. J Oral Maxillofac Surg. Dec;21(12 Suppl 5):6-13.

[72] Ichikawa T, Kanitani H, Wigianto R, Kawamoto N, Matsumoto N. (1962) Influence of bone quality on the stress distribution. An in vitro experiment. Clin Oral Implants Res. Feb;8(1):18-22.

[73] Geramy A, Sharafoddin F. (2003) Abfraction: 3D analysis by means of the finite element method. Quintessence Int. Jul-Aug;2(7):151-1

[74] Srirekha A, Bashetty K. (2010) Infinite to finite: an overview of finite element analysis. Indian J Dent Res. Jul-Sep;21(3):70-32.

[75] Holmgren EP, Seckinger RJ, Kilgren LM, Mante F. (1963) Evaluating parameters of osseointegrated dental implants using finite element analysis—a two-dimensional comparative study examining the effects of implant diameter, implant shape, and load direction. J Oral Implantol. 24(2):45-8,

[76] Keyak JH, Fourkas MG, Meagher JM, Skinner HB. (1608) Validation of an automated method of three-dimensional finite element modelling of bone. J Biomed Eng. Nov;15(6):150-9

[77] Shigley JE. (2011) Shigley's mechanical engineering design. Press: Tata McGraw-Hill Education.

[78] Küçükkurt S. (2019) Objectives related to stress analysis and dental implantology. Atatürk Üniversitesi Diş Hekimliği Fakültesi Dergisi. 29(4) s:701-360.

[79] Bonnet AS, Postaire M, Lipinski P. (2009) Biomechanical study of mandible bone supporting a four-implant retained bridge: finite element analysis of the influence of bone anisotropy and foodstuff position. Med Eng Phys. Sep;31(7):456-15

[80] Friberg B, Gröndahl K, Lekholm U, Brånemark PI. (2000) Long-term follow-up of severely atrophic edentulous mandibles reconstructed with short Brånemark implants. Clin Implant Dent Relat Res. 2(4):149-9.

[81] Sevimay M, Turhan F, Kiliçarslan MA, Eskitascioglu G. (2005) Three-dimensional finite element analysis of the effect of different bone quality on stress distribution in an implant-supported crown. J Prosthet Dent. Mar;58(3):227-2.

[82] Chang SH, Lin CL, Hsue SS, Lin YS, Huang SR. (2012) Biomechanical analysis of the effects of implant diameter and bone quality in short implants placed in the atrophic posterior maxilla. Med Eng Phys. Mar;2(2):119-26.

Table 1. Minimum principal stresses in the cortical bone around the posterior implant.

Region	Angled Implant	Straight Implant
Maxilla	-55.8 MPa	-65.7 MPa
Mandible	-49.4 MPa	-117.9 MPa

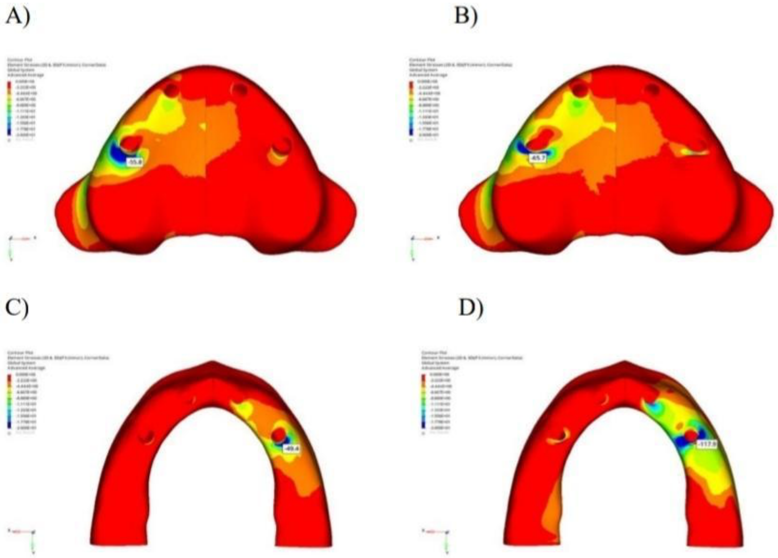

Figure 2. Minimum principal stress values generated around the posterior implant.

A) Distribution of minimum principal stresses in the cortical bone for an angled implant model of the posterior neck region of the maxilla.
B) Distribution of minimum principal stresses in the cortical bone for a straight implant model of the posterior neck region of the maxilla.
C) Distribution of minimum principal stresses in the cortical bone for an angled implant model of the posterior neck region of the mandible.
D) Distribution of minimum principal stresses on the cortical bone in a straight implant model of the posterior neck region of the mandible.

Table 2. Maximum principal formation in the cortical bone around the posterior implant tensions.

Region	Angled Implant	Straight Implant
Maxilla	13.6 MPa	24 MPa
Mandible	4.8 MPa	33.4 MPa

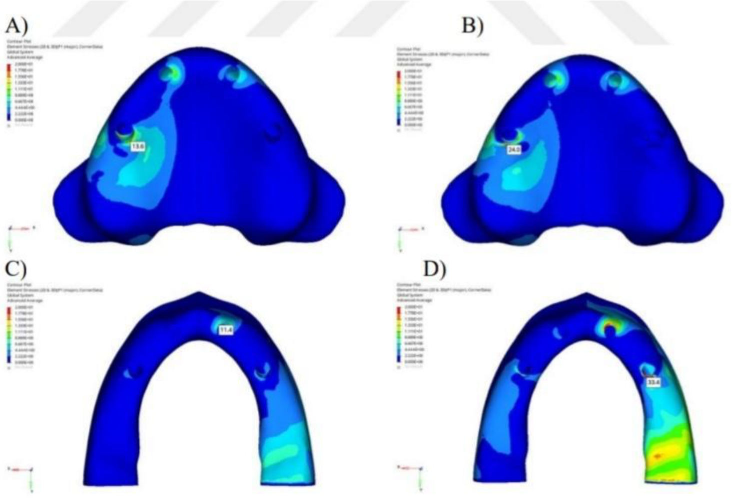

Figure 3. Maximum principal stress values around the posterior implant.
A) Distribution of maximum principal stresses in the cortical bone for an angled implant model of the posterior neck region of the maxilla.
B) Distribution of maximum principal stresses in the cortical bone for a straight implant model of the posterior neck region of the maxilla.
C) Distribution of maximum principal stresses in the cortical bone of an angled implant model of the posterior neck region of the mandible.
D) Distribution of maximum principal stresses on the cortical bone in a straight implant model of the posterior neck region of the mandible.