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ORIGINAL ARTICLE

Comparison between basal disk implants and basal screw implants using finite element analysis method

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Abstract

Background: In recent years, implant dentistry has flourished and has become the most viable treatment for rehabilitation of edentulous jaw. Most of these implants result in post-operative discomfort along with an unpredictable success rate. To overcome these issues, basal implants emerge as a reliable option for the restoration of the edentulous maxilla or mandible.
Aim: The aim of this study was to compare the mechanical properties between basal disk and basal screw type implants.
Materials and Methods: This research deals with a comparison of disk and screw types of basal implants on the basis of medical and mechanical aspects. We carried out finite element analysis of two types of implants. We applied a force of 100N and observed the maximum stress and deformation developed on the basal disk and screw type of implants.
Results: Stress in disk type implant was 360 MPa, while it was observed to be 136 MPa in the screw type. The total deformation of the disk implant was 1.56, while the total deformation in the screw implant was 1.28.
Conclusion: Hence, we find that screw types of basal implants comparatively have lesser stress values and deformation; hence, they have greater structural integrity and have lesser chances of failure.
Clinical Significance: Basal screw implants are significantly more efficient in clinical use than basal disk implants.

Introduction

Dental implants have become a common treatment modality with a high rate of success for tooth, edentulous, and partially edentulous treatment. They provide stable support for artificial teeth as they fuse with jawbone.[5] The term is called osseointegration. Titanium is the most commonly used implant material as it allows integrating with bones without being recognized as a foreign object in our body.[1,2] Implants feel natural than conventional bridges or dentures due to their individual crowns placed over implant. Many limitations are imposed by ordinary bridges such as causing discomfort for sore spots, gagging, or poor ridges. Hence, implants are preferred over them as they also overcome the requirement of adjacent teeth to be prepared or ground down to hold the new replacement tooth in place. Due to technological advancements such as 3D digital imaging and implant surgical planning software, outcomes of dental implant placement have significantly improved with a success rate close to 98%.[1,3]

The conventional type of crestal implants with vertical load transmitting surfaces is inserted into the jaw bone.[4] As they have sufficient vertical bone, the screws are inserted 10–13 mm in length in the anterior segment of the mandible.[4] This is a disadvantage for patients with very less vertical bone availability.[4,5] The healing period for this type of implant is high, bone grafting procedures are essential as the probability of vertical loss of bone, peri-implantitis, crater shaped bone loss, and infections is high for the crestal implants.[4,6,7]

Basal implantology (bicortical implantology/cortical implantology) utilizes the basal cortical portion which excels in quality of the jaw bones for retention of the dental implants. Rules of orthopedic dental surgery are applicable to these implants. These basal implants are also known as lateral implants or disk implants.[4] Basal screw implants can be categorized into (a). Compression screw design (KOS Implant), (b). Bicortical screw design (BCS) (BCS implant), and (c). compression screw + BCS (KOS Plus implant). Basal disk implants can be categorized as: (a). Single piece implant, (b). External threaded connection, and (c). Internal-threaded connection.[7] The main purpose of design of the dental implants is to promote primary stabilization and proper transfer of lead to the surrounding tissue.[14] Stresses generated at different implant levels are dependent on the geometry and shape of the individual components. Primary stability is influenced by the implant macro design which further decides the achievement of osseointegration.[11,15]

There is still a state of ambiguity when questions on implant material and designs are raised for achieving maximum clinical success rate. Risks associated with mechanical design of implants play a major role in implant dentistry, causing an increase in repair cost, unnecessary costs, and loss of time. Many methods involving strain gauges, photoelasticity, and finite element analysis (FEA) are used to create computational, analytical, and experimental models to evaluate the biomechanics of dental implants.[9] The following study deals with the comparison between two types of basal implants, the disk, and the screw type using FEA to evaluate stresses induced by basal implants around the bone and deformation in the implants.[1-3]

Materials and Methods

Preparation of 3D model

Computer-aided design (CAD) – computer-aided three-dimensional interactive application (CATIA) software was used for 3D modeling of implants.

Study design

The dimensions of the implant under study were taken. First, a 2D sketch was prepared using the sketcher option. Then, the 2D model was converted into 3D using surface modeling. Thus, an equivalent 3D model of implant was prepared.

Selection of required material and its properties

As the implant material is titanium, the same was selected in ANSYS and all its mechanical properties were specified. The following table illustrates the values specified in the software [Table 1].

Figure 1a shows methodology. Figure 1b shows the material module selected in the FEA software (ANSYS 16.0).

Meshing

As for analysis, the whole element was divided into a number of parts called as nodes. These nodes are joined to each other to form elements. The process of joining these nodes is called meshing. The mesh type selected was tetrahedral and fine meshing was used for titanium implants. This meshing is shown in the following Figure 2a and b.

Fixed constraint

In this, we had fixed the implant potions such as threads in the screw implant and disk in the basal disk implant so that they are static at the time of application of forces which are equivalent to masticatory forces. The following figure shows the fixed part of the implant [Figure 3].

Force constraint

In this, we applied force on the abutment of implant and also defined the direction of the force. Two types of forces applied were tangential and compressive. The amount of force applied was 100N. This is shown in the figure below by red color [Figure 4].

Stress-induced in the implants

Stress is the internal forces per unit area. The stress causes the implant to deform or even break the implant if it exceeds the permissible value. After applying the force, stresses were induced in the implant. The values of stresses were proportional to the forces applied [Figure 5a].

Deformation of the implants

Deformation is the change in size or shape of the component when force is applied on it. In the following study, when 100N force was applied, the following results were obtained [Figure 5b].

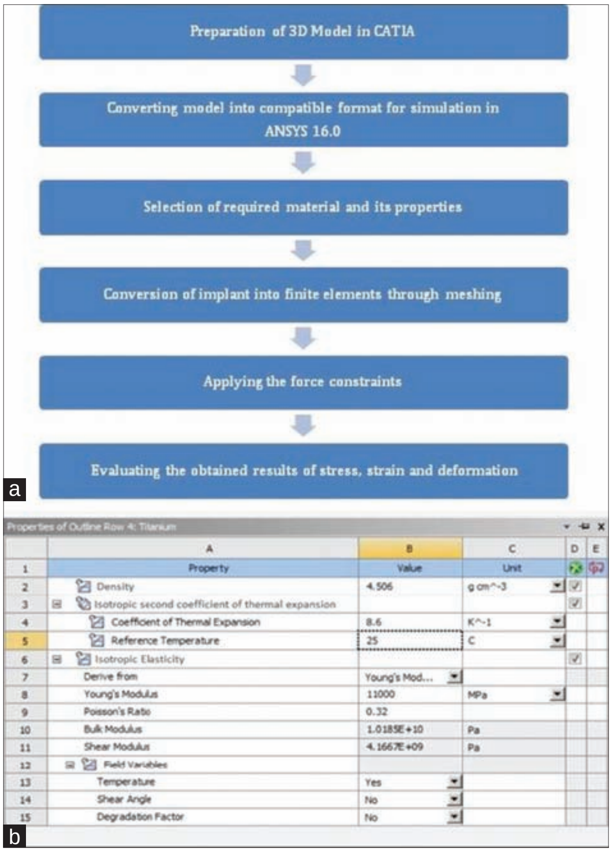
Results

In the following study, the authors have found higher values of stress in the disk implant concentrated at the intersection of implant rod and disk, while stress was comparatively low and well distributed over the entire geometry in the screw type. Deformation was observed to be more in disk implant. Although the design of the screw type of implant was complex, it had high load sustaining hence, had less chances of failure. Moreover, the results obtained from this stress value are shown in table.

The tables represent the obtained values of stress [Table 2] and deformation [Table 3]. Statistical analysis of the stress and deformation developed has been shown Graph 1. A significant amount of stress and deformation can be observed in the basal disk type implants.

Table 1: Parameters and values

S. No.	Parameter	Value
1	Material	Titanium
2	Composition	6% Al, 4% V, 0.25% Fe, 0.2% O_2, remainder Ti
3	Form and condition	Cast and Machined
4	Yield strength	880 MPa
5	Hardness	334 BHN
6	Young's modulus	11000 MPa
7	Poisson's ratio	0.32



Properties of Outline Row 4: Titanium

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	4.506	g cm^-3		
3	Isotropic second coefficient of thermal expansion				
4	Coefficient of Thermal Expansion	8.6	K^-1		
5	Reference Temperature	25	C		
6	Isotropic Elasticity				
7	Derive from	Young's Mod...			
8	Young's Modulus	11000	MPa		
9	Poisson's Ratio	0.32			
10	Bulk Modulus	1.0185E+10	Pa		
11	Shear Modulus	4.1667E+09	Pa		
12	Field Variables				
13	Temperature	Yes			
14	Shear Angle	No			
15	Degradation Factor	No			

Figure 1: (a) Flowchart of methodology, (b) Material specification module in ANSYS 16.0

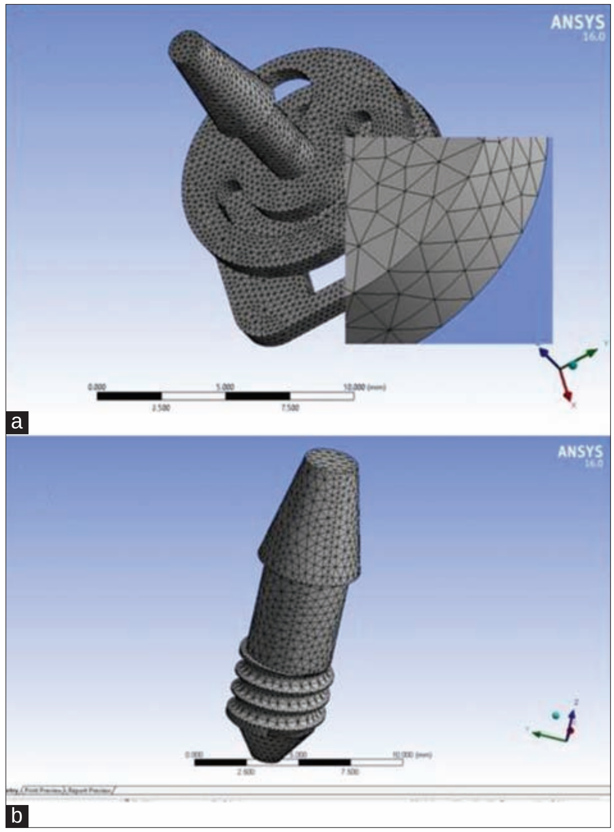


Figure 2: (a) Meshing of disc implant, (b) Meshing of screw implant

Table 2: Stress value results

Parameter	Value
Maximum stress of material	800 MPa
Maximum stress developed	360 MPa
Factor of safety	1.5

Table 3: Deformation value results

Parameter	Value (in mm)
Total deformation of disc implant	1.56
Total deformation of screw implant	1.28

Discussion

In case of severely atrophic jaws, implant placement becomes very challenging due to the poor quality of the implant bed. Various bone augmentation procedures such as ridge augmentation, sinus lift, calvarial bone graft, and displacement of mental nerves can be used to overcome these unfavorable conditions. However, these procedures are subjected to an unpredictable degree of morbidity and sometime patients are also reluctant to such expensive surgical procedures. To overcome these issues basal implants can be a viable treatment option. Basal implants (lateral implants), also known as disk implants, are used in atrophic jaw bones.[2-4]

Basal implants are the singular element implants with abutment being an integral part of the implant body.[4] It was developed by French and German scientists in a number of stages, but the first single-piece implant was technologically modified by Dr. Jean Marc Julliet in 1972. Dr. Stefan Ihde developed the lateral disk implants in 1997, while the screwable designs were developed in 2005.[12] The drawback of interface problem in conventional two or three-piece implants is overcome by the basal implant. This implant type has a polished surface which prevents the adhesion of bacteria or plaque to the neck or body of the implant.[4] The wide thread turns on the implant body, enhances the vascularity around the implant, and increases the bone-implant contact.[4] Neck of this implant has abutment with a gradually convergent section with a degree of inclination of 12–25 degrees.[4]

In the following study, FEA has been used to perform a mechanical comparison between basal disk and screw type of implants. CAD is a computer technology which is used to design a product and aids in the documentation of the process. CAD is used to produce detailed engineering designs of physical parts of manufactured products. It is also used to create a conceptual design, product layout, strength, and dynamic analysis of assembly and the manufacturing processes. Various CAD modeling software are available such as AutoCAD, CATIA, and SOLIDWORKS. For this research, we used CATIA for

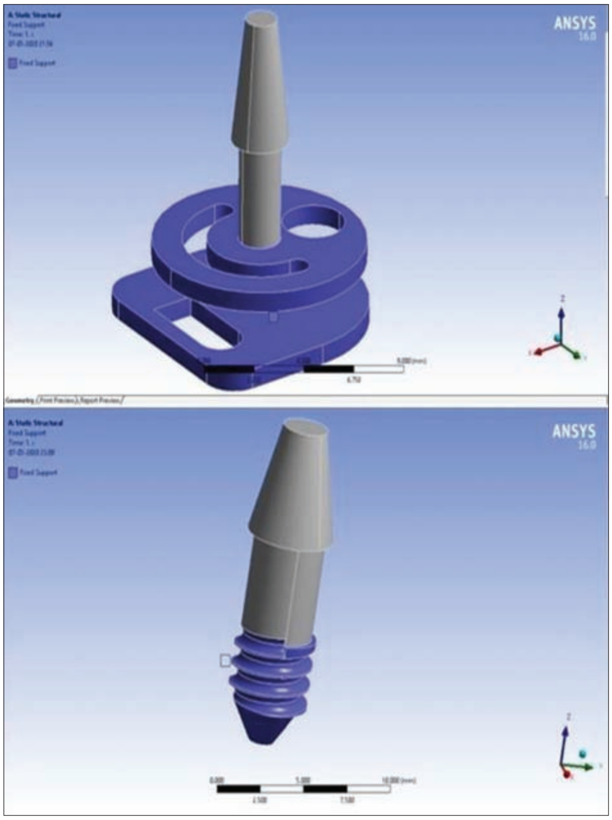


Figure 3 : Supporting the surfaces of implants

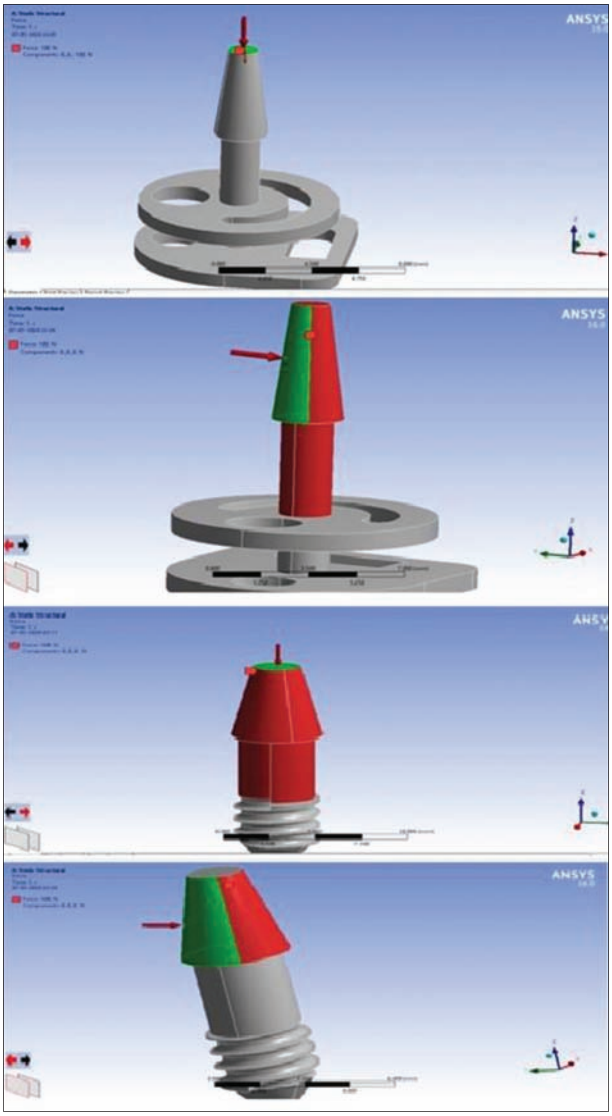


Figure 4: Application of forces on selected surfaces

3D modeling of implant. Through simulation of various types of forces applied on implant such as compressive or tangential, various stress distribution diagrams can be plotted. These stress distribution diagrams with various stress values provide an accurate representation of mechanical stability and effectiveness of their design. Deformation of implants and their respective values can also be obtained through FEA.

FEA is a programmed method used to predict the reaction of a product to real-world forces, vibrations, and other physical effects. It is basically a numerical model for analyzing stresses and distortions in any form of geometry.[8] FEA provides an approximate prediction of how the component under study will behave in real-world circumstances. For FEA, the component is divided into small sizes known as "finite elements" coupled through nodes. Every single element is studied, calculations are carried out, and individual results are obtained. The individual results are combined to obtain the final result of the structure. The type, planning, and total number of elements used for the study are the deciding factors for the accuracy of the result.[1-3]

Stress distribution in finite element method studies is generally interpreted as von Mises stress, which is estimated in three planes - x-axis, y-axis, and z-axis using a formula.[8] Rubo *et al.* observed that the stresses were clustered at the loading point. A stiffer framework may allow better stress distribution.[3] In the following study, the authors observed stress to be concentrated at the implant-abutment interface. There were higher values of stress on the disk type implants than the screw type. This caused a greater amount of deformation seen on the disk type of implant.[10] The structural integrity of the screw type implant was much better than the disk type.

Studies show what peak Von Mises stress occurs at the upper part of the contact area between bone and the vertical shaft of the implant. Peak stresses were found at the base of the implant only in extreme soft contact definitions.[13] In the following study, the authors found that equivalent stress was more near the crestal plate of the basal disk implant and above the first turn in the screw type of basal implant.

In our knowledge, not many studies have been conducted to compare the mechanical properties between basal disk type and screw type of implant. Hence, using FEA in this study, the authors could conclude superiority between the basal disk and

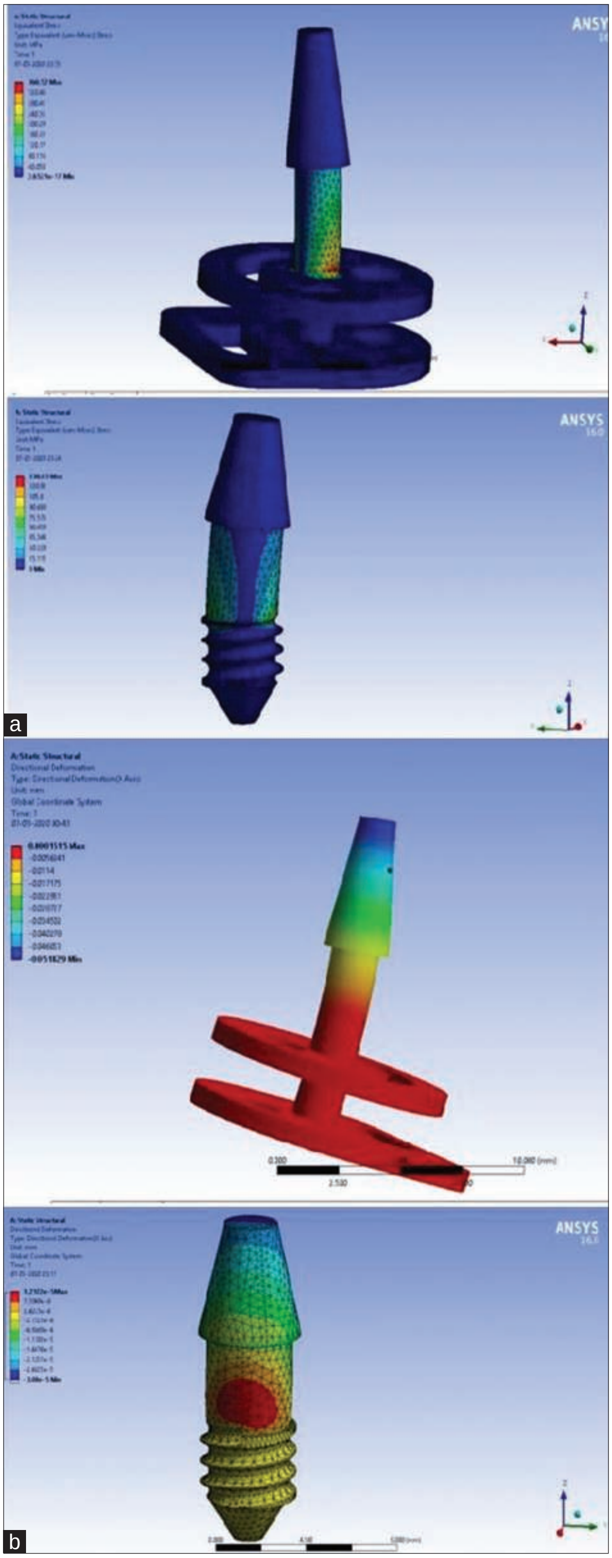
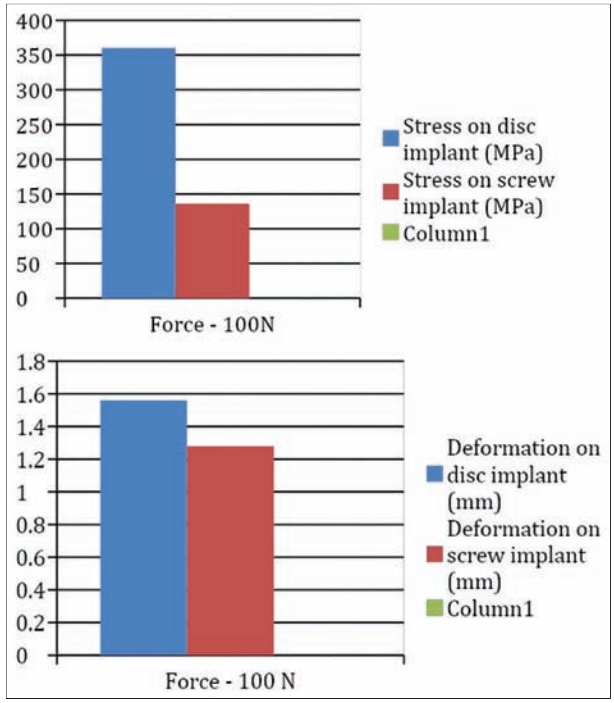


Figure 5: (a) Stress values and its distribution, (b) Deformation of implant (Simulation)



Graph 1: Graph showing amount of stress and deformation on disc and screw type of dental implant

screw type of implants in terms of mechanical properties such as stress and deformation.

Conclusion

Within the limitations of this study, we can conclude that it is possible to predict the mechanical properties of implants using FEA. Using the analysis, we can conclude that basal screw implants have better structural integrity and less chances of failure when compared to basal disk implants.

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