THE EFFECT OF PITCH VARIATION ON MECHANICAL PROPERTIES IN THE DESIGN OF TOOTH IMPLANT

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Abstract

This study provides a review of the achievements and advancements in dental technology brought about by computer-aided design and the all powerful finite element method of analysis. The scope of the review covers dental implants, jawbone surrounding the implant and the biomechanical implant and jawbone interaction [1]. The dental implant is desined by SolidWorks and analysed by ANSYS. The main objective of the study was to investigate into the stress and strain variations due to the effect of bone remodelling and healing.In this study, the stresses acting on an abutment and implant types which have three different pitch distance type were inspected. Three types of dental implants, an abutment and a representative cortical bone, cancellous bone and crown were designed. Titanium-Aluminum-Vanadium alloy was chosen for implant and abutment, alumina was chosen for crown, SolidWorks was preferred as program for design and ANSYS for analysis. Deformations, displacement vectors, von Mises stresses, principal stresses on the implant and the abutment were inspected. At the end of the study , the results of the analyses showed that changing the pitch distance affects the analysis results. In this study, our aim was to make an appropriate choice from three different types of implants. An ideal choice should have minimum stresses. According to the results of the analyses, the implant 0,75 mm pitch V-type threaded implant should be chosen.

Keywords: Dental implant; Implant-jawbone interaction; Design

1. Introduction

Dentistry aims at replacing missing teeth since it was first recognized as a profession. For centuries, dental practitioners have relied on their own skills and various artifacts to develop esthetic and functional alternatives to minimize sequelae that occur as a result of edentulism. Partial, complete, fixed, or removable dentures are by far the most commonly used forms of tooth replacement applied. In other words, these devices have been incorporated into the oral cavity anchored on either remaining teeth and/or other anatomical structures. Only scarce archeological reports have demonstrated attempts of incorporating prosthetic devices into the jaws as more natural and functional replacements. However, predictability of these methods was not achieved until recently.

The titanium had apparently bonded irreversibly to living bone tissue, an observation which contradicted contemporary scientific theory. Metal implants in contact with living bone were thought to be embedded in soft tissue, a term known as fibro-osseous integration. This form of metal-to-bone integration was never capable of achieving strong anchorage to bone.

Osseointegration has been described as a direct structural and functional connection between living bone and the surface of a load-bearing implant. This concept was later modified with more advanced imaging techniques. Scanning electromicroscopy revealed that a thin proteogly layer exists between titanium and bone [2].

2. Modelling of Implant

Modelling of the implant involves accurate representation of the implant geometry, taperage , material properties, loading conditions and implant surface structure. Following this , a redesign of the implant geometry can be performed to achieve an optimum stress profile in the surrounding jawbone. Creating an accurate analytical model of a dental implant, using appropriate engineering software, is essential in producing realistic and reliable solutions [1, 9].

2.1. Implant Geometry

Implant design usually refers to the design of the intraosseous “root form” component (the endosseous dental implant). However , the design of the implant-abutment junction and the abutments are extremely important in the prosthodontic management and maintenance and will be dealt with under a separate section. The implant design has a great influence on initial stability and subsequent function in bone. Following are the main design parameters:

2.1.1 Implant Length

Implants are generally available in lengths from about 6 mm to as much as 20 mm. The most common lengths employed are between 8 and 15 mm , which correspond quite closely to normal root lengths. There has been a tendency to use longer implants in systems such as Branemark, compared to , for example , Straumann. The Branemark protocol advocated maximizing implant length where possible to engage bone cortices apically as well as marginally to gain high initial stability.

2.1.2. Implant Diameter

Most implants are approximately 4 mm in diameter. A diameter of at least 3.3 mm is normally recommended to ensure adequate implant strength. Implants of 3 mm diameter are now available and normally recommended for low load situations such as mandibular incisor teeth. Narrow implants may have to be designed as one piece (i.e., incorporating the abutment) as they are too narrow to allow connection via an abutment screw of adequate diameter. Wider diameter implants (5 mm and over) are available, which are considerably stronger, have a much higher surface area, and are often indicated for molar replacement. They may also engage lateral bone cortices to enhance initial stability. However, they may not be so widely used because sufficient bone width is not commonly encountered in most patients' jaws.

2.2. Implant Shape

Implants come in a very wide variety of shapes with many of the design features shared between systems and others limited to systems, especially where patents exist. The shape and screw design of the implant together with the recommended site preparation does have an effect on the surgical performance and stability of the implant that may guide operator preference. Most implants are parallel cylindrical or tapered cylindrical threaded designs. The tapered design will normally require more torque to insert as the wider part gradually engages the prepared site. The apical design may also be parallel or more commonly tapered to allow easier insertion , and may be smooth or have cutting faces to achieve self-tapping of the bone. The thread design and pitch vary considerably. A common thread pitch is 0.6 mm. The thread design may be more rounded or sharp and contribute to stability of the implant on insertion. The coronal end of the implant may be parallel sided or flared to provide a larger head or platform to connect to the abutment. The outer surface profile of the coronal end may have the same thread profile as the body of the implant, a finer microthread or a smooth profile. The surface characteristics may be the same as the body of the implant or smoother. The abutment connection to the implant may be within the implant (internal connection) or sit on top of the implant (external connection)

2.3. Material Properties of Implant

The biomechanical properties of an implant are very different to the original tissue. The design and manufacture of artificial materials that are aimed at being used within the human body, is becoming increasingly challenging. Titanium and bio-ceramic materials, such as hydroxyapatite are extensively used as fabrication materials for dental implant due to their high compatibility with hard tissue and living bone.Titanium has reasonable stiffness and strength while hydroxyapatite has low stiffness , low strength and high ability to reach full integration with living bone. A number of material properties have been adopted for titanium in previous analysis. The Young's modulus of titanium has been taken from 102.2GPa to 113.8 GPa, and the Poisson's ratio, between 0.29 and 0.35, based on different material testing [1, 8].

2.3.1. Material Selection

Dental implants are constructed from a range of materials such as titanium, stainless steel, titanium alloy and zirconium. Zirconium implants are one of the newest forms of implants and are promoted for their aesthetic qualities, biocompatibility and mechanical structure. As regards osseointegration, zirconium implants appear to offer the same success rates as titanium implants although there is no long data available to support this view. Some dental professionals view them as less stable and liable to fracture than the standard titanium implant.

Zirconium implants are pure white and have an obvious aesthetic advantage in that they are indistinguishable from natural teeth. Titanium and other types of implants are usually silver or black in color and can sometimes be viewed through the gum. However, the all white zirconium implant blends in well with the other teeth. The majority of implants are constructed from titanium is available in four grades, depending on the levels of iron and carbon within. Titanium alloy implants contain a mixture of aluminum and vanadium alloy and are promoted as being of greater strength and durability than the all titanium variety. The surface of an implant may be anodised, etched, sandblasted or plasma sprayed to aid with osseointegration. One of the main issues with implants is that of biocompatibility. They need to be able to integrate with human tissue and bone without any risk of an immunological response. Titanium is safe and readily accepted by the human body and is unlikely to cause an allergic reaction or toxicity [4, 7].

2.4. Loading Conditions

When applying FEA to dental implants, it is important to consider not only axial forces and horizontal forces (moment-causing loads), but also a combined load (oblique bite force), since these are more realistic bite directions and for a given force will cause the highest localized stress in cortical bone. İnvestigated the influence of axial and non-axial occlusal loads on the bone remodelling around implants in a dog mandible simulated with FEA. Strong correlation between the calculated stress distributions in the surrounding bone tissue and the remodelling phenomena in the comparative animal model was observed. They concluded that the highest bone remodelling events coincide with the regions of highest equivalent stress and that the major remodelling differences between axial and non-axial loading are largely determined by the horizontal stress component of the engendered stresses. The importance of avoiding or minimizing horizontal loads should be emphasized. In summary, both static and dynamic loading of implants have been modelled with FEA. In static load studies, it is necessary to include oblique bite forces to achieve more realistic modelling. Most studies concluded that excessive horizontal force should be avoided. The effects of dynamic loading requires further investigation [2, 7].

3. Parts of Dental Implants

3.1. Crown

An artificial replacement that restores the missing tooth structure by surrounding part or all of the remaining structure with a material such as cast metal, porcelain or a combination of materials such as metal and porcelain. It is the top most part of the restoration, which is visible to us in the mouth. These crowns help in aesthetics, in mastication, in balancing the occlusion and they are hand made by the dental technicians. These are usually made of metal or porcelain or a mixture of both [3, 8].

3.2. Abutment

It is a part of the implant which resembles a prepared tooth, and which is screwed to the body of the implant. It is the part which provides support to the artificial crown, and lies between the crown and the implant body. The abutment provides retention to the prosthesis [3].

3.3. Implant Body

This is the part of the implant which is placed during the first stage of the implant surgery, and which provides the anchor or foundation for the restoration. This part is fixed in the jaw bone, and on this the abutment is screwed in the next stage of the surgery. The implant body can be threaded or non-threaded. When the natural teeth are lost, the bone loss is common. But when the fixture is placed, the bone tissue tends to grow around it and thus the jaw bone is strengthened again. The commercially available implant bodies are made of either commercially pure titanium or the titanium alloys and depending on the need, they may or may not be coated with hydroxyapatite [3].

3.4. Healing Screw

This is a part of the implant which isn't permanently placed, but is used during the healing phase when the soft tissue over the implant body is being healed. The healing screw facilitates the suturing of the soft tissue, and it also prevents the growth of tissue over the edge of the implant [3].

3.5. Healing Caps

These are the dome shaped caps placed over the healing screws to project through the soft tissue into the oral cavity, and they range from 2-10 mm in length. They prevent the overgrowth of the tissues over the implant body, and even guide for the placement of the permanent restoration after the second stage of the surgery. The dental implant bodies are usually made of titanium alloys, as Titanium is one of those components which help in the process of osseointegration, where the jaw bone and the implant screw integrate with one another and the jaw bone tend to grow and fix around the bone.

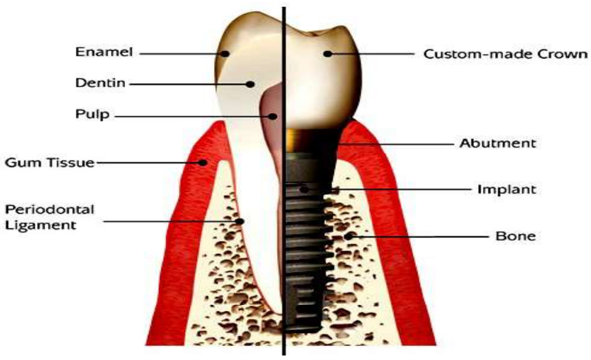

Fig. 1. Parts of the Implant

4. Design and Analysis

4.1.Implant Design

For desinging of parts Solidworks 2010 was prefered as design programme. Before the design different implant and abutment catologes were searched to get types , shapes and dimensions. All parts were chosen according to standarts. For abutment and implant Ti-6Al-4V was selected for the material.

The design was repeated for 0.4 , 0.5 and 0.75 mm pitch V-type threaded implant as it can be seen I only changed the pitch of the implant. Fig.2. and Fig.3. implant designs can be seen. The implant was chosen from Nucleoss catolog page 12 , type T3 implant diameter and height and code was T3 5010 [5].

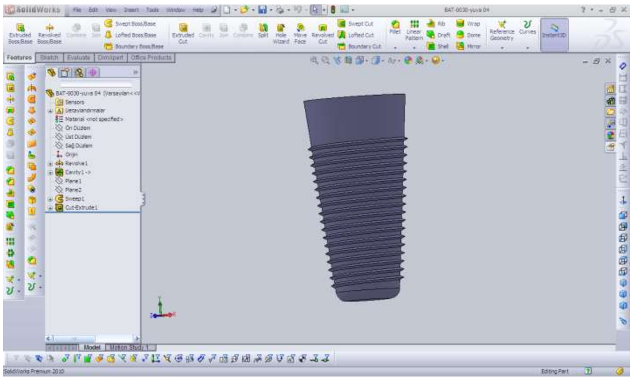

Fig. 2. 0.4 mm pitch V-type treaded implant solid model

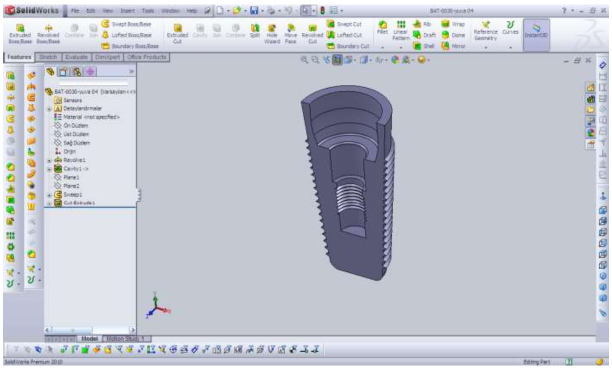

Fig.3. 0.4 mm pitch V-type threaded implant section view

4.2. Abutment Design

The abutment was chosen from Nova catolog , page 13 and the type was BAT0030 [6].

4.3.Crown Design

Crown was designed in the Solidworks and added 99.5% Alumino material.

4.4.Assembly

Assembly of abutment, implant and crown is shown below.

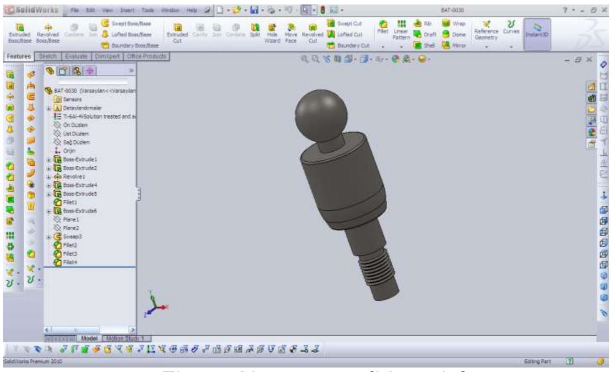

Fig. 4. Abutment solid model

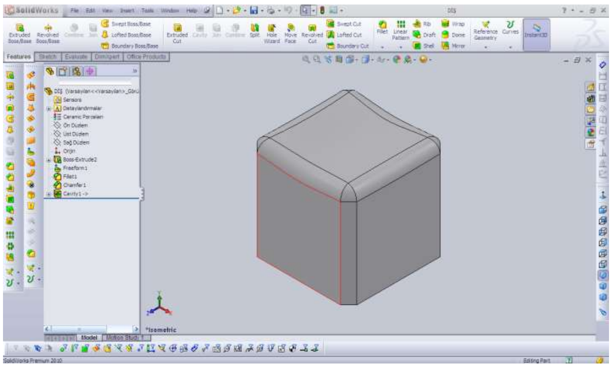

Fig. 5. Tooth

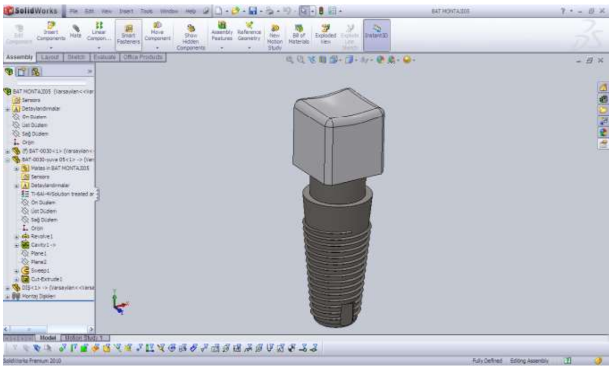

Fig. 6. Assembly

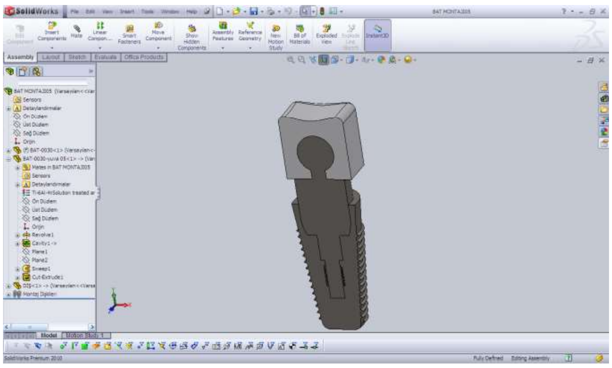

Fig. 7. Section view of assembly

The hole was drilled for each pitch distance in the mandibula and the assembly was designed for 0.4, 0.5, 0.75 mm pitch V-type threaded implant so, analysis was done for each of them.

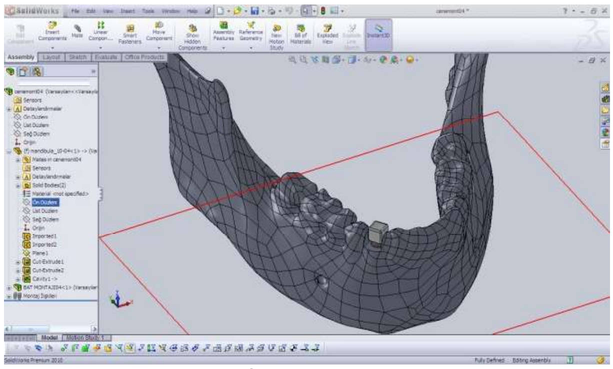

Fig. 8. Assembly of implant , abutment ,crown and mandibula

4.4.Analysis

The structure which is designed in three different parameters (0.4 , 0.5 ,0.75 mm pitch) that analysed in ANSYS-v12. As it can be seen in the Fig.9. the structure was meshed by automatically in the programme.

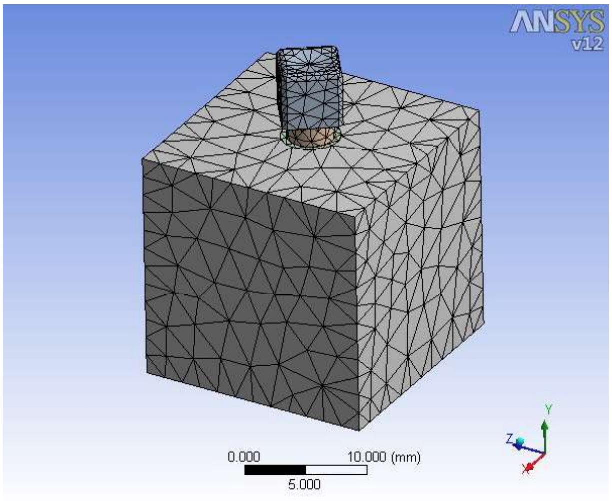

Fig. 9. Mesh of structure

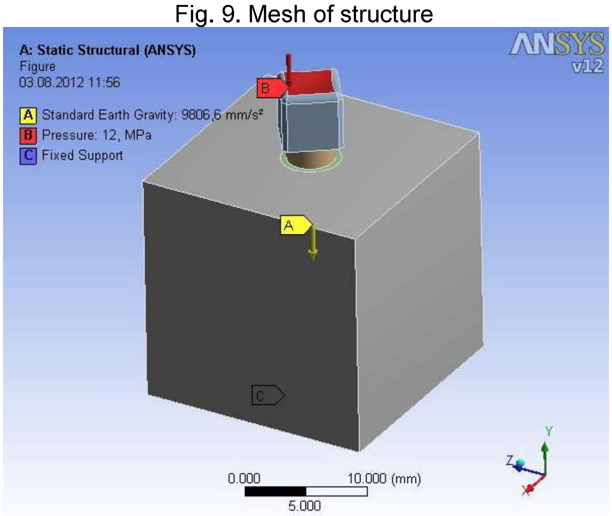

Fig. 10. Static Structural

In the structure it was applied standard earth gravity, 300 N force was effected on the tooth which had 25 mm^2 surface area that equal 12 MPa and bottom surface of the mandibula was selected as fixed support. For the analysis results; 1) Total deformation 2) Equivalent (von-Misses) elastic strain 3) Equivalent von-Misses stress 4) Maximum principal elastic strain, are chosen. These are done for each of design.

5. Results

Just below 0.75mm pitch V-type treaded implants analysis of the results is given.

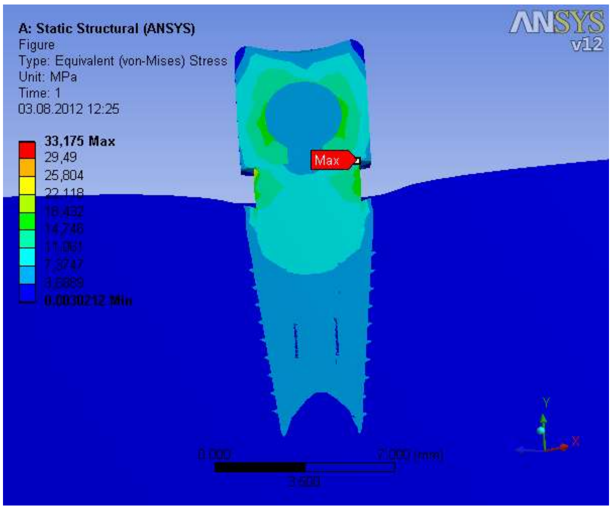

Fig. 11. Equivalent (Von-Misses) stress for 0.75 mm pitch

The contact surface between mandibula and implant teeth the stress is 3.6889 MPa value is measured. The stress is increase through the center of the implant. The maximum stress is seen between tooth and neck of the abutment which is 33.175 MPa.

The stress, on the contact surface between mandibula and implant teeth , is measured minimum for 0.4 mm pitch V-type threaded implant. Because of the number of teeth are 18 so, the contact surface is the highest. The contact surface between mandibula and implant teeth the stress is measured maximum for 0.5 mm pitch V-type threaded implant. It has 15 teeth because of this it has smaller cantact surface area than 0,4 mm pitch implant so it has higher stress. The contact surface between mandibula and implant teeth the stress is measured for 0.75 mm pitch V-type threaded , between 0.4 mm pitch and 0.5 mm pitch V-type threaded implant. It has 10 teeth which smaller than others. But compared to others, the slope of helix is increased so stress gets decrease. The maximum stresses are not seen on the contact surface between mandibula and implant teeth so, is the useful design for dentistry application. Because of the sponge structure of the bone, it is better way to use 0.75 mm pitch implant rather than 0.4 mm pitch, not to damage the cancelleous bone.

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