IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Effect Of Implant Thread Shapes On Stress Generation In Human Mandible Using Finite Element Analysis

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Abstract: Now a days, implantation is becoming a common phenomenon to maintain oral health. Implants are mainly used to replace broken or spoiled teeth and also to support the denture in case of no teeth on the bone. Since biomaterials (bone is a natural material) can't be replaced, and its decay is related to higher stresses and so there is a need to analyse the effect of thread shapes on the stress generation which is linked to decay of bone. Due to difficulty in application of either theoretical or experimental application to find the stress condition of the bone, in the present work, finite element analysis was carried out to find the stress generation with different thread profiles. 4 types of thread profiles were considered based on the literature of implants used in the dental applications. They are square, V-thread, buttress and Reverse Buttress threads. Literature has ambiguity in finding the best implant thread for better stability of the system which is mainly based on overall deformation and stress conditions. Here geometry is built using Ansys pre-processing module based on standard thread proportions along with meshing. After application of boundary conditions, results were extracted and represented in the tables for 100 N vertical loading. The results shows better stability with square threads compared to other form of threads considering important parameters of structural stability

***Index Terms* -** thread profiles, fea, ansys ,stress concentration.

I. INTRODUCTION

The advent of finite element methods in the numerical analysis, accelerated the process of virtual load testing of components under various types of loads and material conditions. The Finite element process eliminates the need of prototype built up and testing. Also experimental testing procedure will not give deeper perspective of load carrying capacity of the members. Since dental structures are difficult to test experimentally due to the difficulty of setting up of machinery on the live structure and limitation of testing equipment capabilities. The finite element method gives feasible solutions for all type of dental problems with certain limitations like requirement of proper material properties and complete nonlinear behaviour due to bone recovery in time. Thread profiles create stress concentration due to the sharp variations of Geometry and rounding of either at root or crest region. Since geometric variations (figure1) are the main sources of stress concentration, and this stress concentration is the main reason for failure of the bone. This stress concentration creates fatigue and creep failures. Theoretical estimations are very difficult and so finite element analysis can be applied to find the stress nature in the interfaces and the structural members,

Figure 1 Implantation in Dentistry

2 Literature Survey: Implantation is becoming a common thing now a days with the increased life span as well as abnormal food habits. With the change of life style, even the human jaw and teeth structure also not building properly. So possible steps need to be considered for good oral health. Implantation is a requirement in the modern era due to increased comfort requirements. Lot of research has been carried out to find the best thread shape for optimum stress generation in the human jaw structure. Various people have given various conclusions based on their study parameters.

S. Hansson et. al[1] has analyzed retention capacity of various thread profiles which in turn linked to stress generation. Generally lower stress levels indicate higher retention capabilities. They concluded that thread profile has higher effect on decay of the bone and retention capacity. They advised small threads for lesser stress generation. They used 2 dimensional axi-symmetric approach for stress analysis.

J. Jennifer et.al [2], has analysed for stress condition on various types of threads for Osseo-integration and resistance to reverse torque applications. The results show higher reverse torque measurements compared to other thread profiles(V and Reverse Buttress Threads) advising square thread has better results compared to other thread designs.

O.Eraslan et al[3] analysed stress conditions for 4 types of threads (V, Buttress, Reverse Buttress, Square) and concluded that major stresses are developed in the cortical bone and stress spread is up to few starting threads of the implants. They have analysed using Solid works software in cosmos environment. They concluded that even though stresses are same in all the threads, but the stress pattern is changing.

H. S. Ryu et. al[4] has analysed the implants for immediate loading from the available literature and concluded that square and v-thread has better stability compared to other form of threads. .

W.-J. Yu et. al[5] has studied the stress generation during intrusion stage of implant with different thread shape like v, Square, Buttress and reverse buttress. They found the least stress generation with V-Thread and maximum stress generation with square thread. They concluded that v-thread implant is better for easier insertion stresses.

Wakjira et. al [6] has done analysis with 5 types of implant thread profiles and concluded that least stresses were observed with buttress thread and maximum stresses are occurring in the v threads.

Amit Nandi et. al[7] has analysed the stress condition with various types of implant from available literature. They observed that square thread design is the best from outcome of summarized article conclusions.

Dr Susmita Mandal et.. al [8] has carried out analysis for different thread profiles with different bone densities with normal and inclined insertion to find the structural behaviour using finite element analysis. They observed that whatever bone density, normal insertion is better compared to the inclined insertion of the implants. They also observed that D3 bone has more stresses compared to other bone types

3 Thread Profiles: The used thread profiles are as in figure2.

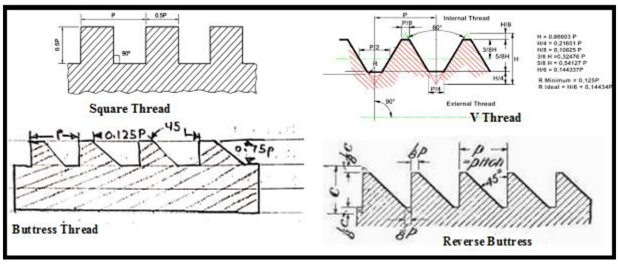


Figure 2 Thread Profiles

4 Methodology: Models are built using Ansys pre-processor as per the dimensions along with cortical bone thickness of 2mm. Using overlap option, the geometries are separated for cortical, cancellous and implant regions. Material properties are attached to various geometries. 4 noded plane42 element option is used for stress analysis. 2-dimensional option is selected due to the mesh size requirement to estimate the effect of root and crest curvature on stress generation. The outer boundary fixed and axial load applied on occulusal surface. Complete bonding is considered between the thread geometry and bone. Analysis is carried out for 100N axial load and results are extracted

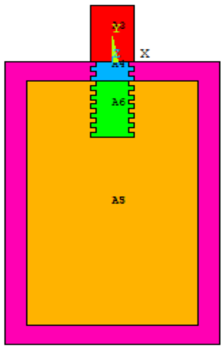
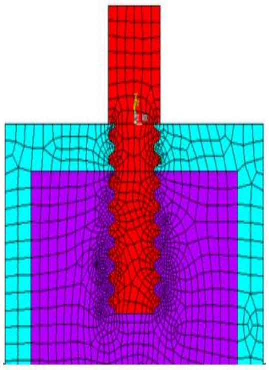
 Plane View of Implant in the Bone	 Magnified view in the implant Region

Figure 3 Square Thread Profile

5 Boundary Conditions: The outer boundary is fixed in all directions and the top surface of implant is subjected to an axial load of 100 N

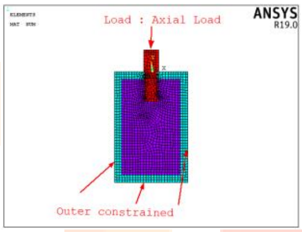


Figure 4 Boundary Conditions

6 Number of elements and nodes

Table 1: Number of elements and nodes

Details	Number of elements	Number of nodes
SquareThread	1501	1558
Vthread	2236	2313
Buttress	1602	1669
Reverse Buttress	1588	1660

Since mesh is the life of finite element analysis, the above said number of elements(Table 1) were used for analysis. Linear elements were considered for analysis under static domain.

7 Material properties

All materials were considered as isotropic and homogenous with the properties shown in the table 2

Details	Young’s Modulus(GPa)	Poison’s ratio
Cortical Bone	13.7	0.3
Cancellous Bone	1.37	0.3
Titanium Implant	110	0.33

Table 2 : Material properties

8 Results: After solving the problems, results were extracted for deformation and vonmises stress distribution and represented in figures from 5 to 9 along with summarisation of the results in table 3. Similarly graphical plots were represented for easier understanding of the results from figure10 to 14.

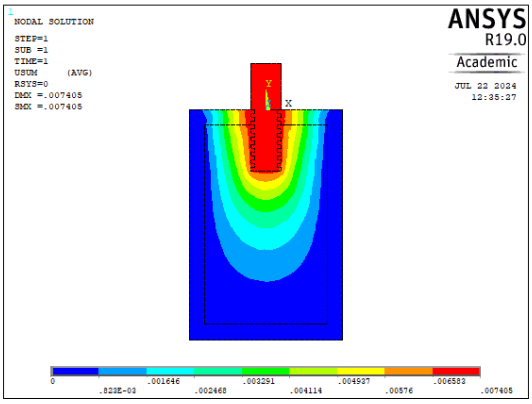


Figure 5: Deformation Model for square thread model(maximum deformation : 0.007405mm)

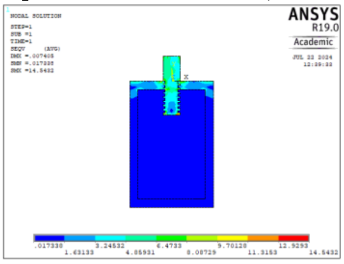


Figure 6 Overall Stress plot (Maximum stress:14.5432MPa)

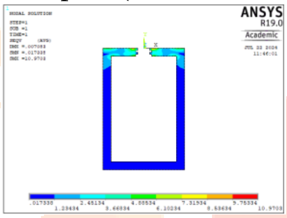


Figure7:Cortical Stress (Maximum stress: 10.9703MPa)

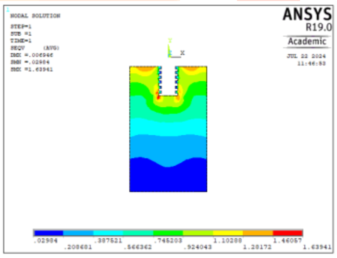


Figure8: Cancellous Stress Plot(Maximum stress: 1.63941MPa)

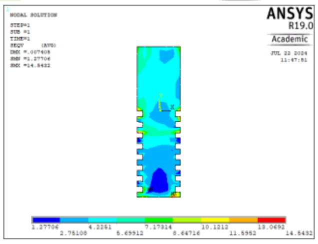


Figure9 :Implant Stress (Maximum Stress: 14.5432MPa Similarly, results are obtained for other thread profiles and results are summarized as follows.

Table 3: Results table for axial load

Details	Square Thread	V thread	Buttress	Reverse Buttress
Deformation (mm)	0.007405	0.007346	0.007394	0.007359
Overall Stress (MPa)	14.5432	17.947	19.4309	20.2911
Cortical Stress (MPa)	10.9703	12.7115	11.2944	16.4107
Cancellous Stress (MPa)	1.63941	2.23502	1.4542	1.5568
Implant Stress (MPa)	14.5432	17.947	19.4309	20.2911

The results were graphically plotted as follows.

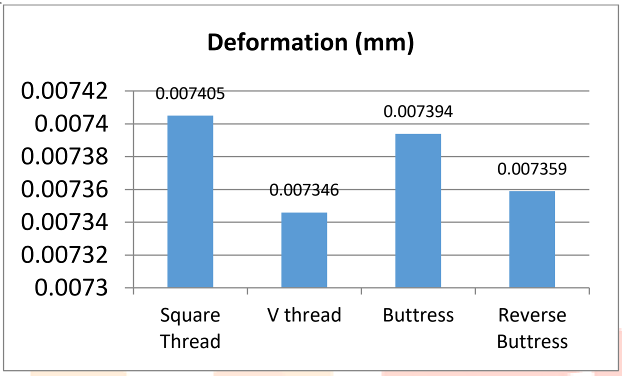


Figure10: Variation of deformation with Thread profiles

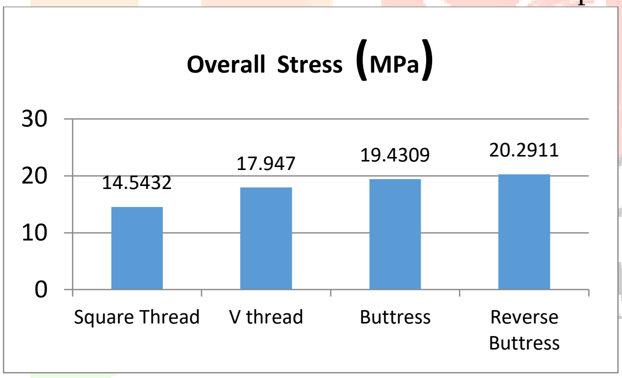


Figure11: Variation of Overall stress with Thread profiles

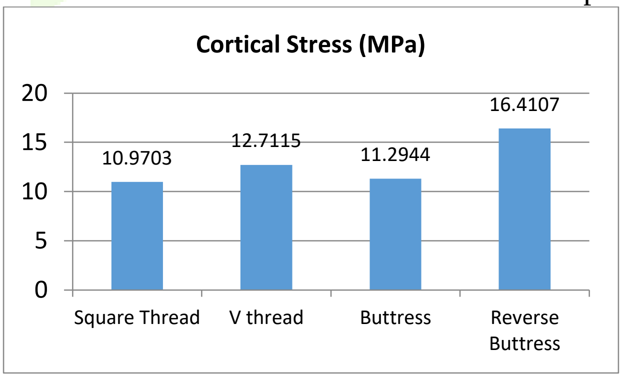


Figure12: Variation of Cortical stress with Thread profiles

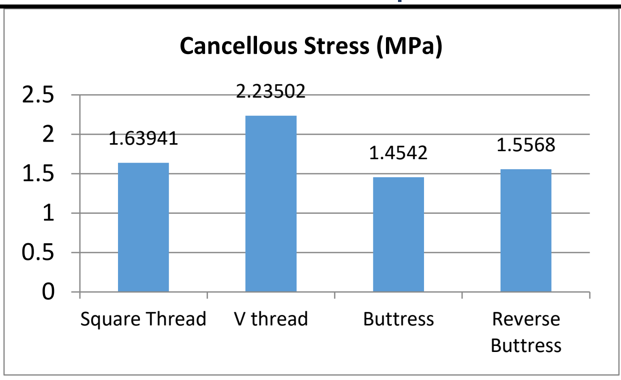


Figure13: Variation of Cancellous stress with Thread profiles

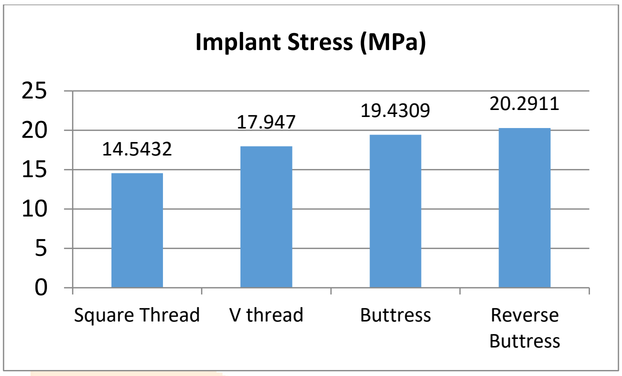


Figure14: Variation of Implant stress with Thread profiles

9 Conclusions: The results show least deformation for V-Thread and least stresses for square threads. Least cancellous stress for buttress thread. Lesser implant stress is observed for Square thread. By consideration of more parameters like overall stress and implant stress, square threads give the best performance for dental structures. Their retention capacity will be better with lower stress generation under given loading considerations. Also this design is much simpler to manufacture compared to other design shapes. The Stress reduction can be attributed to least stress concentration with square threads.

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