In-Silico approach on Offset placement of implant-supported bridges placed in bone of different density in Orthodontics.

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Abstract - *A dental implant is a titanium post (like a tooth root) that is surgically positioned into the jawbone beneath the gum line that allows your dentist to mount replacement teeth or a bridge into that area. An implant-supported bridge is similar to a regular dental bridge, but it is supported by implants and not by natural teeth. In most cases, when an implant-supported bridge is used, one implant is placed in the jawbone for each missing tooth. Then the crowns are connected to each other to form one piece. An implant-supported bridge is used when more than one tooth is missing. It also may be used when dentist is concerned that the person might put too much pressure on individual implants that are not connected to each other. Primary implant stability and bone density are variables that are considered essential to achieve predictable osseointegration and long-term clinical survival of implants. Information about the influence of bone quality on stress distribution in an implant-supported bridge is limited. In most of the cases implant supported bridges are placed in bone with different density D1, D2, D3 and D4 on both maxilla and mandibular. During clenching or grinding of teeth undergoes, it can put a lot of pressure on individual implant components. This ultimately leads to the loosening of implants fixture from bone. This study focuses on study of stress distribution around implant supported bridges when placed in different bone density. In this study all loading conditions are considered in various cases which acts on implant from normal and oblique loading angle. Also in all cases the material properties for the D1, D2, D3 and D4 bones are considered as transversely isotropic material properties. In most of the cases due to some anatomical restrictions implants are not possible to be inserted in their conventional configuration. Offset placement of implants could be the only solution in relation to the prosthetic unit. This study also focuses analysis on the effect of offset implant placements towards lingual and buccal sides as 0.5mm.*

Key Words: *Finite Element Analysis, Implant-Supported Bridges, Orthodontics, D1-D2-D3-D4 Bone Density.*

1.INTRODUCTION

The application of dental implants for Prosthodontics reconstruction can be traced back to ancient Egypt where sea shells were hammered into human jaw bone to replace missing teeth. Since the late 1960s when the dental implants were introduced for the rehabilitation of completely edentulous patients, an awareness and subsequent demand for this form of therapy has increased. A key factor for the success or failure of a dental implant is the manner in which stresses are transferred to the surrounding bone. This depends on the type of loading, bone–implant interface, the shape and characteristics of the implant surface and the quality and quantity of the surrounding bone. The interrelationship between the bone quality, quantity and the design of the implant play a vital role for clinical success. A compromise in any of these factors will often lead to implant failure. The density of available bone in an edentulous site is the determining factor in treatment planning, and will determine implant design, surgical approach, healing time and if initial progressive bone loading is feasible during prosthetic reconstruction. The various implant designs like the threaded, cylindrical or the tapered design have been shown to have a profound influence on implant biomechanics and stress distribution in the surrounding bone. For osseointegration of endosteal implants to occur, not only is adequate bone quantity (height, width, shape) required, but adequate density is also needed. Zarb and Schmitt stated that bone structure is the most important factor in selecting the most favorable treatment outcome in implant dentistry. Bone quality is a significant factor in determining implant selection, primary stability, and loading time. The classification scheme for bone quality proposed by Lekholm and Zarb has since been accepted by clinicians and investigators as standard in evaluating patients for implant placement. In this system, the sites are categorized into 1 of 4 groups on the basis of jawbone quality. In Type 1 (D1) bone quality, the entire jaw is comprised of homogenous compact bone. In Type 2 (D2) bone quality, a thick layer (2 mm) of compact bone surrounds a core of dense trabecular bone. In Type 3 (D3) bone quality, a thin layer (1 mm) of

cortical bone surrounds a core of dense trabecular bone of favorable strength. In Type 4 (D4) bone quality, a thin layer (1 mm) of cortical bone surrounds a core of low-density trabecular bone. Jaffin and Berman reported that 55% of all failures occurred in D4 bone, with an overall 35% failure. To gain insight into the biomechanics of oral implants, it is crucial to understand the behavior of bone around implants. The mechanical distribution of stress occurs primarily where bone is in contact with the implant. The density of bone is directly related to the amount of implant-to bone contact. The percentage of bone contact is significantly greater in cortical bone than in trabecular bone. The initial bone density not only provides mechanical immobilization during healing but also permits better distribution and transmission of stresses from the implant-bone interface., Increased clinical failure rates in poor quality, porous bone, as compared to more dense bone, have been well documented. To decrease stress, the clinician may elect to increase the number of implants or use an implant design with greater surface area.
Three-D FE analysis has been widely used for the quantitative evaluation of stresses on the implant and its surrounding bone. Some investigators studied the influence of the implant design on stress concentration in the bone during loading and indicated that the implant design was a significant factor influencing the stress created in the bone. Others studied the influence of the bone-implant interface on stress concentration. These authors demonstrated that when maximum stress concentration occurs in cortical bone, it is located in the area of contact with the implant, and when the maximum stress concentration occurs in trabecular bone, it occurs around the apex of the implant. FE analysis was used in the present study to examine the effect of the bone quality on stress distribution for an implant-supported crown.

2. METHODOLOGY

Table -1: Material Properties

Material Properties	Modulus of elasticity (Gpa)	Poisson's ratio
Porcelain	82.8	0.35
D1	9.5	0.3
D2	5.5	0.3
D3	1.6	0.3
D4	0.69	0.3
Cortical bone	14.8	0.3
Titanium	110	0.35

2.1 Geometric modeling

A Three unit S-T (Straight-Tilted) bridge condition is being taken for the analysis. Several conditions like S-T (Straight-Tilted), S-S (Straight-Straight), S-S-T (Straight-Straight-Tilted), T-S-T (Tilted-Straight-Tilted) and S-S-S (Straight-Straight-Straight) are also being used now a days. In this we are using S-T condition. Bone model both cortical and cancellous bones were created on SolidWorks 14.0 according to the standard dimensions obtained from the Dental science. The cancellous bone is further divided into two density combinations (D1/D3 & D2/D4). Five CAD models are needed for the current study as depicted in the figure below. A segment of mandible (one half) is taken for the study. Three implants, one at first premolar, other at second premolar and third one at first molar region are placed. Implants in the molar region are tilted distally and premolars are kept straight. Test model being zero degree offset in distally tilted molar.

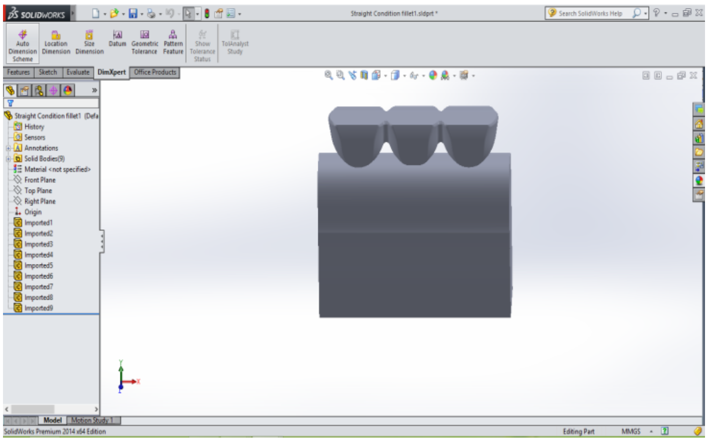

Fig-1: Implant model

The complete CAD model of implant were modelled with particular dimensional details of inner diameter of 3.6 mm, outer diameter 4.2 mm, pitch 2x1.2 mm and length 10 mm are taken. Abutment used are angulated (30 degrees). The complete CAD model was then saved in Parasolid format(.x_t).
Three conditions were created Straight condition, Buccal offset 0.5mm, Lingual offset 0.5mm.

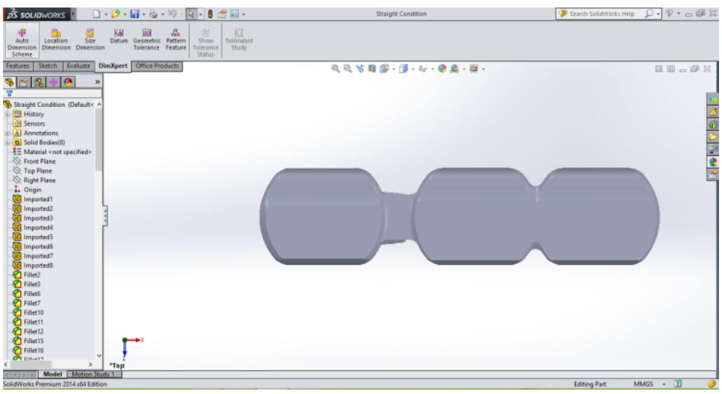

Fig -2: Straight condition

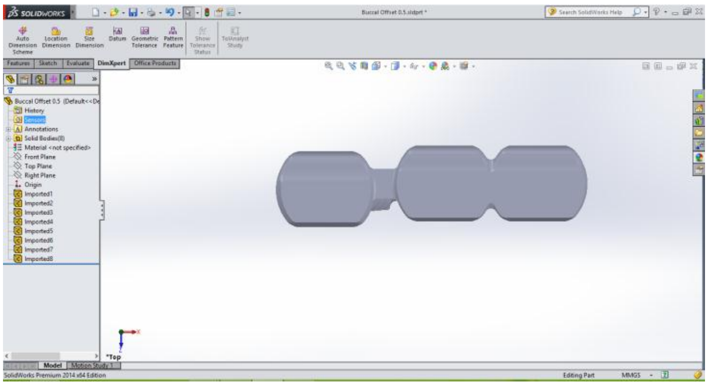

Fig -3: Bucccal offset 0.5mm

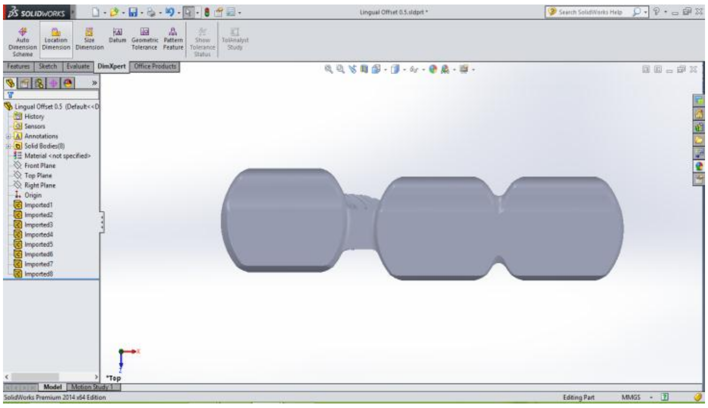

Fig -4: Lingual offset 0.5mm

2.2 Analysis

For the analysis and execution of the programme and interpretation of the results, material properties of the cortical and the cancellous bone of all the models were applied as transversely isotropic and linearly elastic while the materials of implant and prosthetic crown were assumed to be isotropic, and linearly elastic.

The cancellous bone is equally divided into two parts for assigning the two density combinations. For this another plane was created through the exact centre of the cancellous bone and slicing has been done because each half should be assigned with two different density values.

Next comes the mesh generation part. For meshing the CAD model was first imported into the analysis environment using the Parasolid format (.x_t)The three dimensional finite element model corresponding to the geometric model was meshed using Ansys Pre- processor (ANSYS version 17.0 software). Here we used fine meshing with default element size and a relevance of 100 for accurate solution.

Boundary conditions are applied. Constraints were applied on the distal end of the model in all the three axes and omitting support at the bottom permitted bending of model. These aspects make the model a more realistic representation of the clinical situation. Fixed support is being provided at the bottom of the model and symmetry was provided at both sides.

Load is applied after fixing all the boundary conditions. The magnitude of applied loads were within physiologic limits and direction of application of loads simulated the clinical situations. Here we considered two type of loads one vertical loading and another oblique loading acting at an angle of 45 Degree.

After setting up the all the required condition for FE analysis we set the solver conditions and solved the complete model. The solver conditions set as linear solving condition. After solving the results were generated such as total deformation, Von-mises stress distribution to know the area of maximum stress, Minimum principle Stress and Maximum Principle Stress to know where compressive and tension stresses acting in the whole model according to the given loading condition. Comparison of each results based on the bone densities, areas of implant failure, effects of offset conditions on the stress distribution over the implant, stress distribution for normal and oblique conditions are being done and major reasons for implant failure can be interpreted.

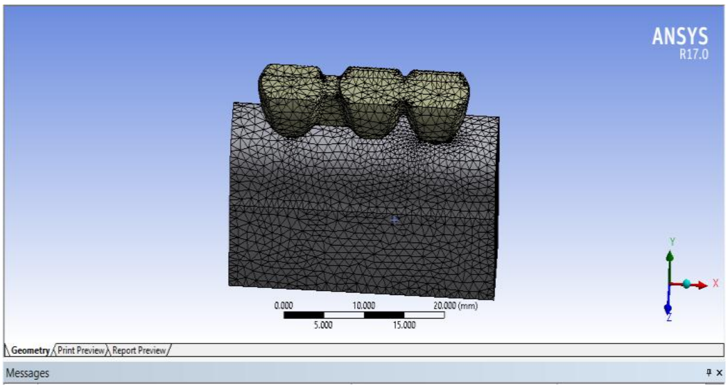

Fig -5: Meshed model

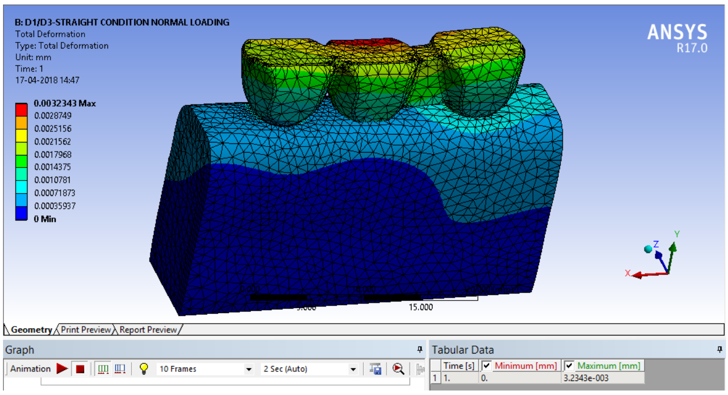

Fig -6: Total deformation

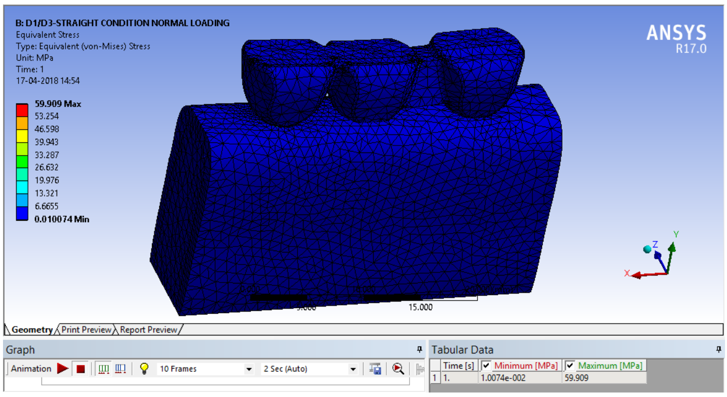

Fig -7: Equivalent stress

2.3 Results

From all the analysis it is been observed that maximum stress were observed on the inclined abutment whereas the maximum deformation was on the crown in all the cases and on both normal as well as oblique loading.

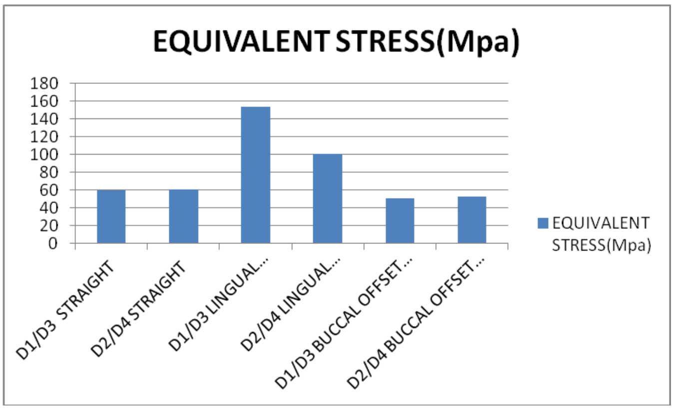

Chart -1: Equivalent stress normal loading

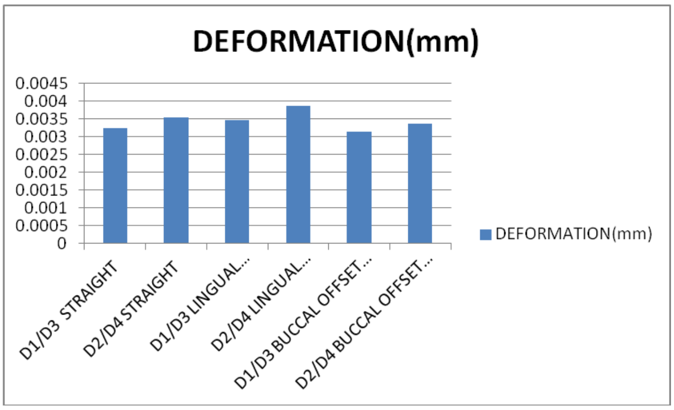

Chart -2: Total deformation normal loading

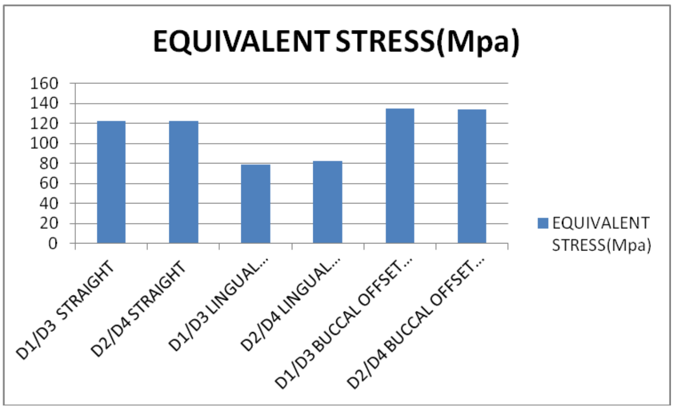

Chart -3: Equivalent stress oblique loading

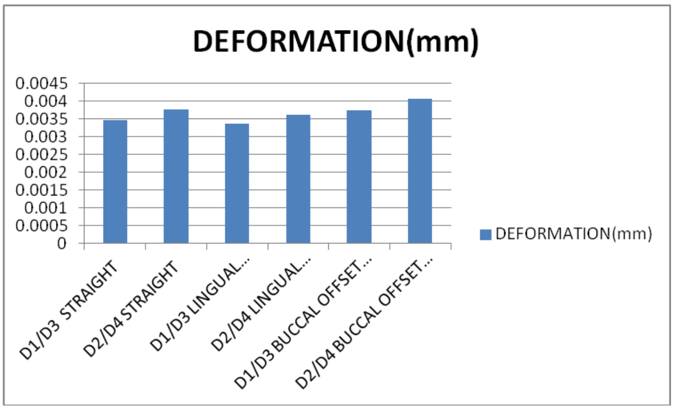

Chart -4: Total deformation oblique loading

3. CONCLUSIONS

For normal loading the maximum stress distribution was observed for D1/D3 lingual 0.5mm offset condition followed by the D2/D4 lingual 0.5mm offset condition, whereas minimum stress was observed on D1/D3 buccal 0.5mm offset condition. In case of total deformation maximum deformation was observed for D2/D4 lingual 0.5mm offset condition and minimum was on D1/D3 buccal offset 0.5mm condition.

For oblique loading maximum stress was observed on the D1/D3 buccal 0.5 offset condition and D2/D4 buccal 0.5mm condition, whereas minimum was observed for both lingual offset conditions. Total deformation was observed maximum in case of D2/D4 buccal 0.5mm condition and minimum on D1/D3 lingual 0.5mm condition.

From the study on the effects of offset placement of the implant on various bone densities under normal and oblique loading conditions its been found out that in all the cases the maximum equivalent stress distribution was found on the inclined abutment followed by the straight abutment whereas the maximum total deformation was observed on the crown followed by the abutments. This will be due to the chewing action of the teeth, hence a compressive force will be developed which in turn causes the failure of the implant. It can be concluded that the implant failure can be eliminated to a far extend by making necessary changes in the design of the implant mainly of the abutment and implant.

For Lingually offset conditions the maximum stress and total deformation was observed during the normal loading.

For Buccally offset conditions maximum stress and total deformation was observed for oblique loading.

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