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Influence of the Platform Switching With a Different Percentages of Platform Switching On Bone And Prosthetic Components: Fea Study

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Abstract

Purpose: This finite element analysis (FEA) study was to evaluate, the stress distribution in peri-implant bone and prosthetic components of implant-supported single crowns with the use of the different percentages of platform-switching (PS) situation with Morse taper implant abutment interface (IAI).

Materials and Methods: FEA models were created to represent, the regular platform group (RP), by connecting 5.0-mm-diameter abutment to the 5.0-mm-diameter implant. The PS group was simulated by connection of a 4.6-mm-diameter abutment (8% PS) and 4.1-mm-diameter abutment (18% PS) to a 5.0-mm-diameter implant. An occlusal load of 100N was applied axially and obliquely on the models using ANSYS software.

Results: PS group presented lower stress values in peri-implant bone and higher stress values in connecting-screw. PS of 18% & 8% reduced von Mises stress in bone by 15.42% & 7.46% respectively. PS increases von Mises stress by 21.43% &12.30% for 18% & 8% of PS, respectively in connecting-screw.

Conclusion: PS had favourable impact on crestal bone by reducing stress on it and the effect of impact becomes more favourable as the percentage of PS increases; however PS had an unfavourable impact on the connecting screw by increasing stress on it and the impact shows more unfavourable results as percentage of PS increases.

Keywords: Connecting-screw, Crestal bone/Peri-implant bone, Morse taper, Platform-switching.

Introduction

The restoration of partial or complete edentulous ridges using dental implants has shown predictable out comes.[1-3] The longevity osseointegrated implants primarily relies on the stability of the bone at the bone implant interface.

Aim of modern implant therapy is not only to achieve osseointegration but also to provide a better esthetics along with the function and stable peri-implant tissue levels that are in harmony with the existing dentition. The crestal bone loss can lead to a collapse of soft tissues and adversely affect the aesthetics of implant-prosthetic elements.

Crestal bone loss was thought to be unavoidable after implant placement. Adell et al[1] were the first to quantify and report marginal bone loss and then later various studies also reported that Implant lose an average of 1.5 mm of bone during the first year in function and less than 0.2 mm annually in subsequent years.[1-3]This is still considered as the clinically acceptable and successful treatment.[2]

The causes of marginal bone loss are complex, which includes a combination of mechanical and biologic factors.[4]The biological factors due to the microgap at the junction of an implant platform and the abutment has been suggested as a main contributor, [5-9] microbial leakage occurs through the microgap, and the degree of leakage is dependent on the type of implant-abutment connection (IAC), the gap size, and the amount of micromovement.[10–12]Microgaps between the implant–abutment interface (IAI) may cause microbial leakage[13, 14] as microorganisms can penetrate through a gap as small as 10 μm.[15]and colonisation through plaque formation at the interface of the implant–abutment complex, [16–18] leading to inflammation in peri-implant soft and hard tissues causing peri-implantitis, bone loss, and eventually, implant failure[16, 17,19.] Biomechanical factor that affect crestal bone resorption is mainly due to occlusal force induced stress and strain within and around the implant prosthesis complex. The amount of stress generated in the bone is directly related to the magnitude and direction of occlusal force applied through the implant supported prosthesis. Only a 20% to 40% of fracture causing strain (i.e. 4,000 microstrains) may trigger cytokine to activate a resorptive response. The interaction of the mechanical and biologic factors in the oral environment is a critical determinant in the development of unfavorable loading conditions that may result in an undesirable bone response and predictable bone loss.[20] This crestal bone loss can further result in increased bacterial accumulation resulting in secondary peri- implantitis which can further result in loss of bone support, which in turn can lead to occlusal overload and further crestal bone loss ultimately resulting in implant failure.[21]

Bone resorption at the implant neck area, however, is not inevitable because some clinical observations have indicated that bone preservation is possible when the narrower diameter of abutment is connected to the implant which is known as platform switching. Platform switching was accidentally established in the 1980s and early 1990s and revealed better preservation of the hard and soft tissues than treatment that use abutments with diameters matched to the implant. Later Lazzara and Porter[22] reported that this occurred because horizontal shifting of the IAJ inward repositioned the inflammatory cell infiltrate and confined it within a 90° area that was not directly adjacent to the crestal bone. Now various Clinical, radiographic, and histological studies have shown reduced peri-implant bone loss with platform switching.[23-29] Studies[30-33] using the finite element method also demonstrated more uniform stress distribution on the peri-implant bone with platform switching than with the traditional technique. Schrotenboer J, et al[34] reported that a 10% reduction in abutment diameter results in a 2.04% and 6.81% decrease in Von-Mises stress under oblique and vertical loading, respectively. A clinical study by Degidi et al [35] reported that when there is zero microgap and no micromovement, platform switching shows no resorption. Studies[36, 37] have also shown that platform switching shifts the area where stress is concentrated away from the cervical bone implant interface, whilst stress increases in the abutment or abutment screw and also may risk the mechanical properties of abutment and connecting screw if horizontal set-off is increased.

Considering the effect of platform switching on crestal/peri-implant bone, on abutment and on abutment screw, the purpose of this study is to assess and compare the effect of various percentages of platformswitched and regular abutments on periimplant bone and prosthetic components.

Materials And Method

A finite element study was undertaken to model and analyze the loaded situation. Finite element analysis (FEA) was chosen for this study since it is useful in determining the stress and strain around the dental implant. It provides extensive opportunity for examining the mechanical behaviour of complex biological structures.[38]

Study Model

Models were created as shown in figure 1. A solid implant of 10 mm length and 5.0 mm diameter was modeled and simulated to be placed in the section of bone. Standard abutment of 5.0 mm and abutments simulating platform switching with 4.6mm and 4.1mm, diameter was connected to the implant fixture of standard dimension 5.0 mm diameter by using the connecting screw (figure 2). Length and diameter of the connecting screw were 4.00 m and 1.00 mm respectively. Structural models of the implant, bone, and abutments have been fabricated using Unigraphics NX7.5 software. The numbers of nodes and elements used in the study were 50,000 and 35,000, respectively. All the materials used in the models were considered to be isotropic, homogenous, and linearly elastic. Since there are no universally accepted properties of the biologic materials available in the literature, a mean value of the material properties has been used in the present study are taken by the previously published study (table no 1).[39]

Variables/parameters used in the study

Diameter of the abutment (5.0, 4.6, 4.1mm), direction of load application (axial and oblique). Von Mises stress generated in periimplant bone, on abutment**,** on implant and on abutment screw**.**

Results and discussion

The processed data obtained from finite element analysis was shown in stress maps with a color scale, making it possible to compare the stress distribution in the different structures of the models for both loading situations in peri-implant bone, connecting screw, abutment, and implant were recorded and compared (table no 2, graph no 1 and 2).

Von Mises stresses generated upon force applications through different percentages of PS situation and with regular platform on Periimplant bone, and on prosthetic components were compared and summarized below.

Stress distribution in Peri-implant bone

(Figure no. 3a and 3b, table no.2): In Peri-implant bone cortical bone exhibited higher stress concentration than the trabecular bone. Higher intensity and distribution of stress were observed under oblique loading in comparison to axial loading. It was clearly observed that PS reduced von Mises stress values for the peri-implant bone and as the percentage of horizontal shifting increased the stress values on peri-implant bone reduced more.

Connecting screw

Stress values were higher in the connecting screws than the peri-implant bone, implant and abutment in all models **(Table no 2)**. Among the connecting screws the stress was concentrated threads and neck of the screw **(figure no 4)**. It was clearly observed that PS increased von Mises stress values for the connecting screw and as the percentage of horizontal shifting increased the stress values on connecting screw increased more **(Tables no 2)**.

Implant and abutment

stress values were lower than connecting screw, stress distribution on implant goes on decreases as the percentage of PS increases and on abutment surface goes on increases as the percentage of PS increases (table no 2), and the pattern of stress distribution remains same but concentration of stress values increases (figure no 5 and 6) Both PS groups presented lower stress values in comparison to the RP group, among the PS groups, group with 18% PS presented greater reduction of stress values in comparison to the group with 8% PS for peri-implant bone and implant. In contrast PS presented increased von Mises values on abutment and connecting screw, the stress values on the prosthetic components presented increased von Mises stress values with 18% PS group in comparison to 8% PS group.

The mechanism by which platform switching can contribute to maintain the crestal bone height due to four reasons; [40]

1. Shifting the inflammatory cell infiltrate inward and away from the adjacent crestal bone.
2. Maintenance of biological width and increased distance of IAJ from the crestal bone level.
3. The possible influence of micro-gap on the crestal bone is diminished.
4. Decreased stress levels in the peri-implant bone.

It has also been reported in the literature[20, 21] that crestal bone resorption is related to damage of the supporting interfacial bone. Excessive loading can trigger bone resorption caused by bone microdamage, resulting in craterlike bone defects lateral to the implants.[41] This microdamage to the bone tissue can also be initiated by stress concentrations and stress shielding at the implant neck.[42, 43] .The higher stress values presented by the control group in comparison to the PS models could be attributed to the differences in abutment diameter among the models. Similar results were found by Schrotenboer J et al, [34] and Hsu et al, [44] who evaluated the PS concept using experimental and FEA models and found that PS reduces the strain in crestal bone and various other studies also have demonstrated the advantages of PS. [34, 45, 46, 47]

Conclusion

Within the limitations of the methodology that considered the bone homogenous and isotropic, the results of static load and linear analysis support the following conclusion:

- The model with the non PS abutment had higher values of von Mises stress than the model with the PS abutment.
- There was no difference in the pattern of stress distribution predicted using a PS and non PS abutment but the concentration of stress generated varies with PS.
- From the results of this study it was revealed PS had
- Positive impact on crestal bone **by reducing the crestal bone resorption** by reducing stress on it and the effect of impact increases as the percentage of PS increases.
- Negative impact on the connecting screw and on abutment by increasing stress on it and the impact shows more negative results as the percentage of PS increases.
- Even though the PS revealed negative impact on connecting screw by increasing von Mises stress on it but the stress values were lower than the yield strength of titanium so it can be used without compromising the long-term survivability, but there is need of clinical assessment to know its effect on screw loosening.

Further studies are required to evaluate the stress/strain values with more variables such as bone density, the internal wall thickness of an implant, connection depth and the degree of taper and interface conditions. Finite Element Analysis is based on mathematical calculations, while living tissues are beyond the confines of set parameters and values since biology is not a computable entity. Therefore, Finite Element Analysis should not be considered as a sole means of understanding the behavior of a geometrical structure in a given environment. Actual experimental techniques and clinical trials should follow Finite Element Analysis to establish the true nature of the biologic system. Clinical implications: **chances of screw**

loosening and fracture are more with the PS implant abutment connecting so while planning clinical application of PS concept it better to use the connecting screw which is made up of high strength **and the wider diameter so** the strength of connecti**ng screw is increased.**

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Legends Table and Figure

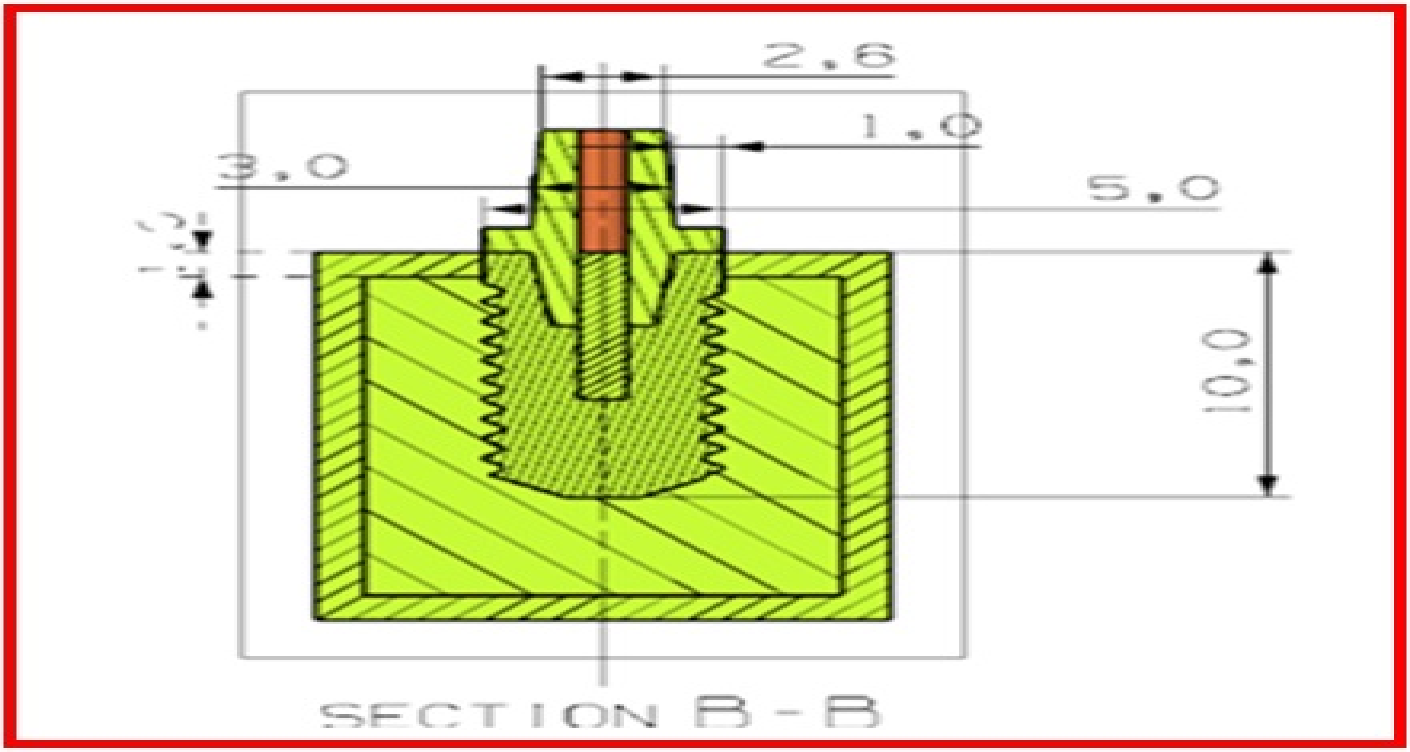


Figure 1: Model representing bone, implant, and abutment and connecting screw

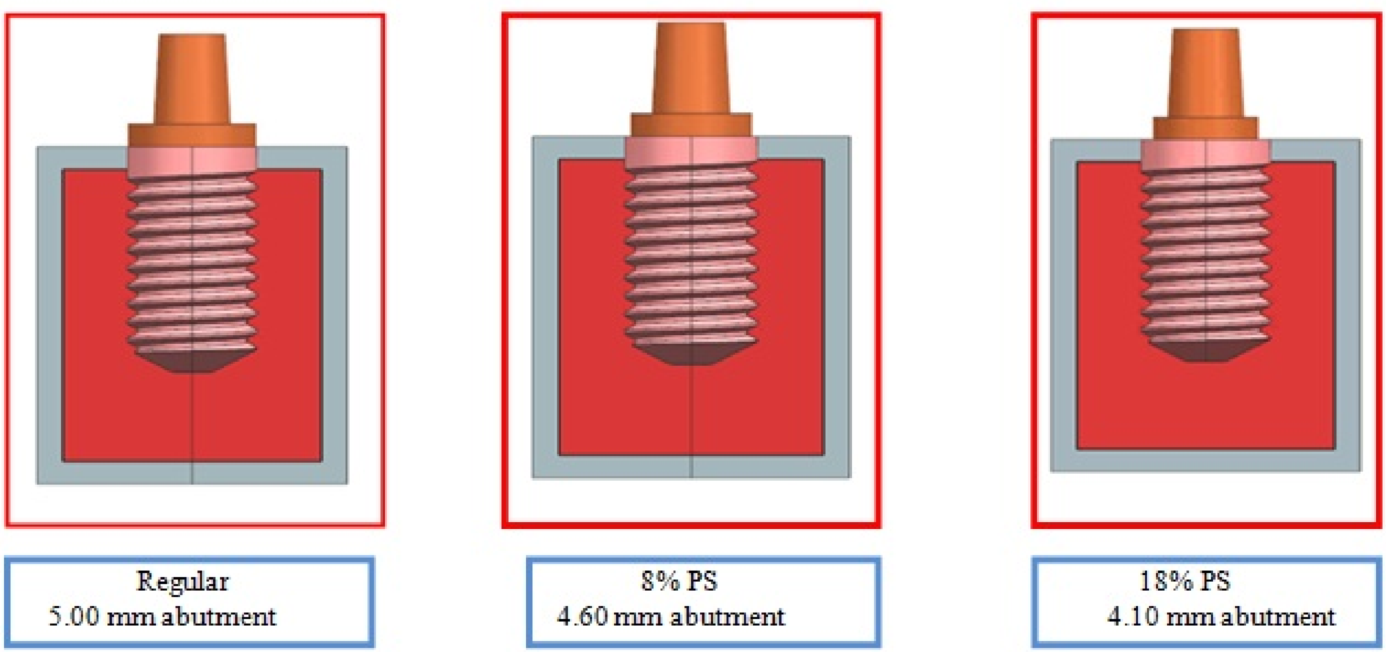
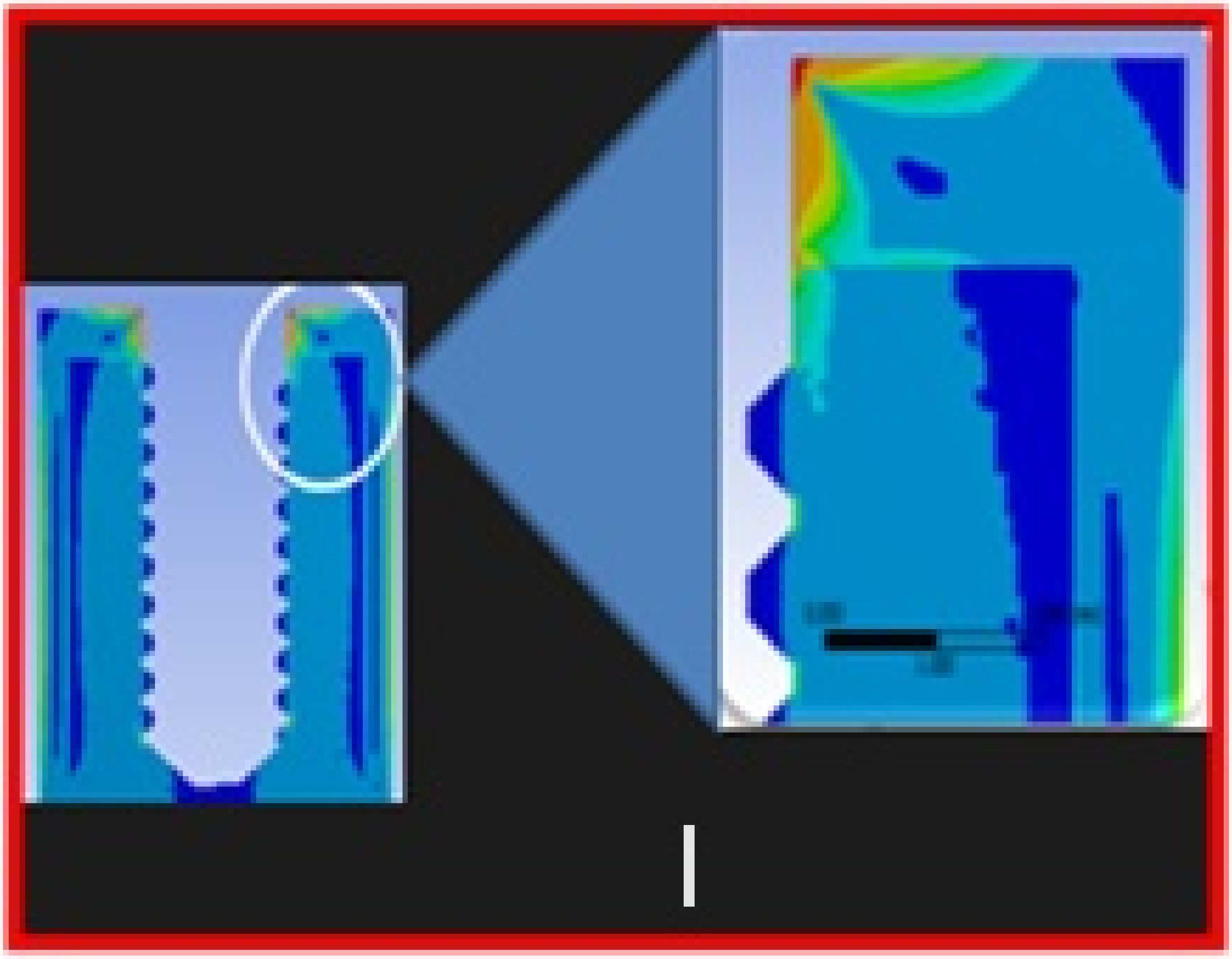


Figure 2: Models representing implant connected with abutment of different diameter

Table no 1. Material properties

Materials	Youngs's modulus (GPa)[39]	Poisson ratio[39]
Cortical bone	13,700	0.30
Trabecular bone	1,370	0.30
Titanium (Ti-6Al-4V)	103,4000	0.35



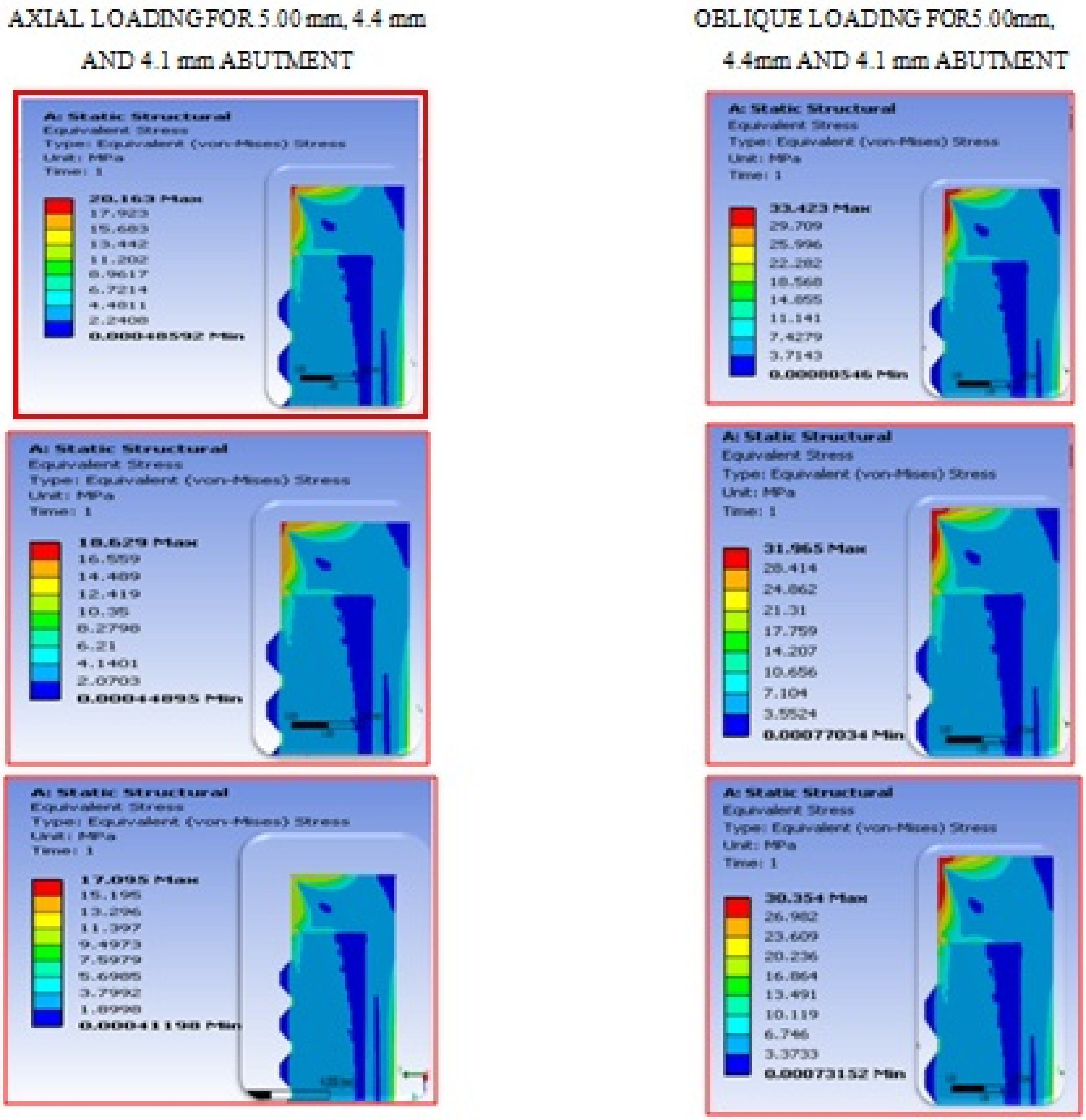


Figure 3 area of interest in study on bone

	Location of the Von Mises Stress	RP Group Abutment Diameter 5.00 mm		PS Group Abutment Diameter 4.6 mm (8% PS)		PS Group Abutment Diameter 4.1 mm (18% PS)	
		axial	oblique	axial	oblique	Axial	oblique
1	Bone	20.1	33.4	18.6	31.96	17.09	30.35
2	Implant	41.5	80.4	37.7	73.49	34.1	64.85
3	Connecting screw	82.1	173.14	92.0	187.3	99.7	202.73
4	Abutment	60.59	82.18	64.85	98.62	72.2	112.16

Table no 2. Effects of Von Mises stress (in MPa) in the models under axial and oblique loading of 100N with different diameter of the abutment on bone, implant, connecting screw and on abutment

Figure: 4. Von Mises stress analysis for Morse taper IAI with different percentage of PS on connecting screw under axial & oblique (15 degree) loading

AXIAL LOADING FOR 5.00 mm, 4.4 mm AND 4.1 mm ABUTMENT

OBLIQUE LOADING FOR 5.00 mm, 4.4mm AND 4.1 mm ABUTMENT

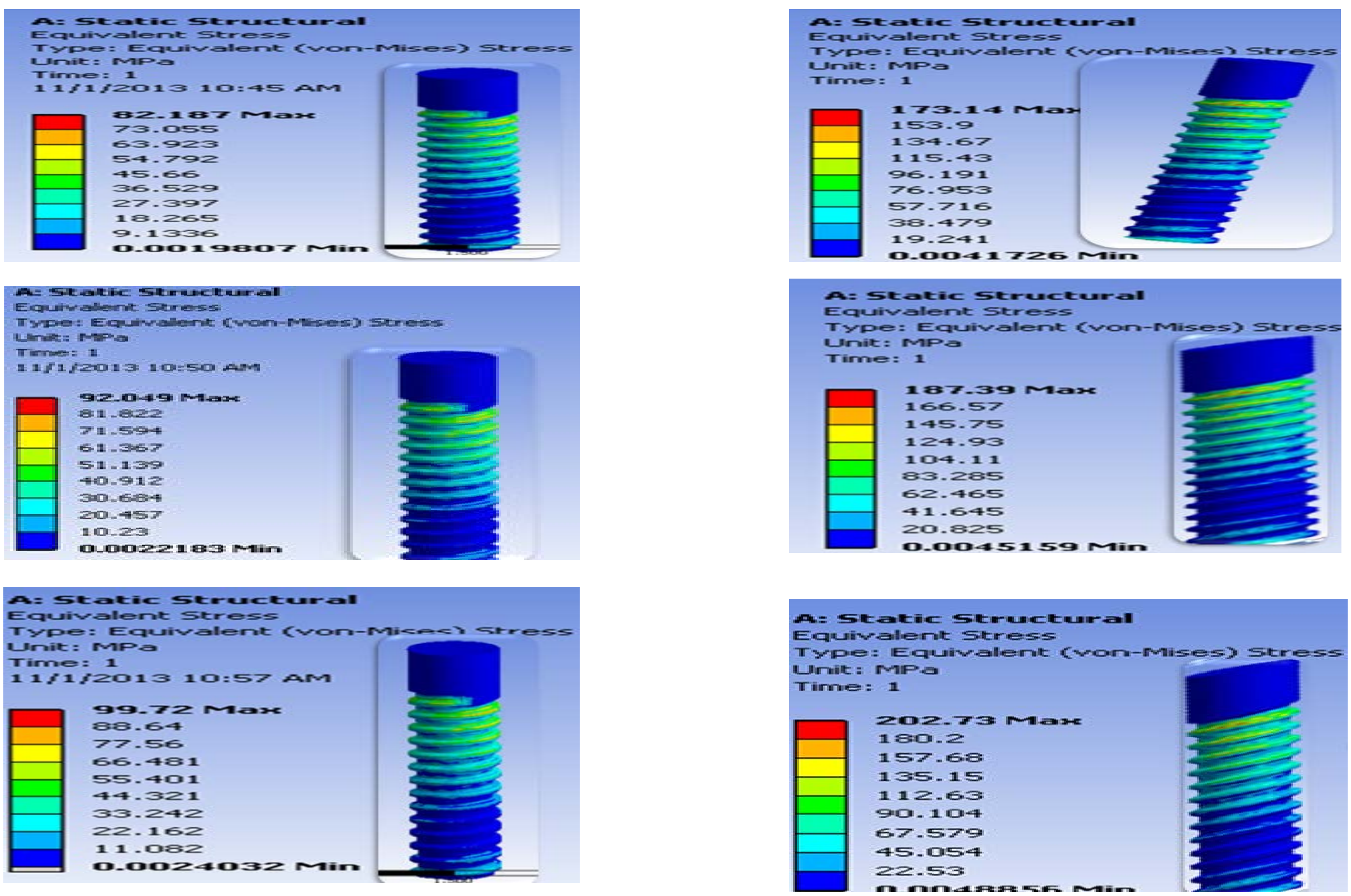
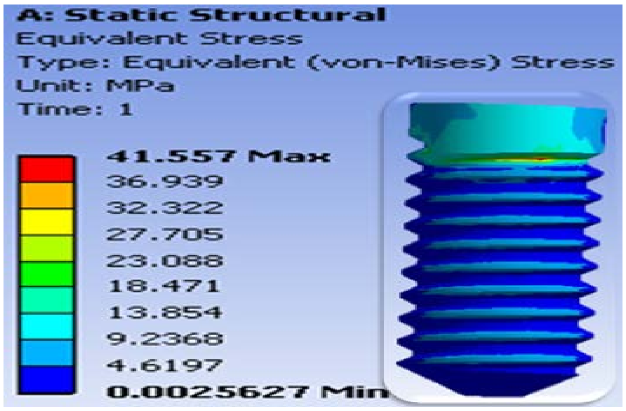
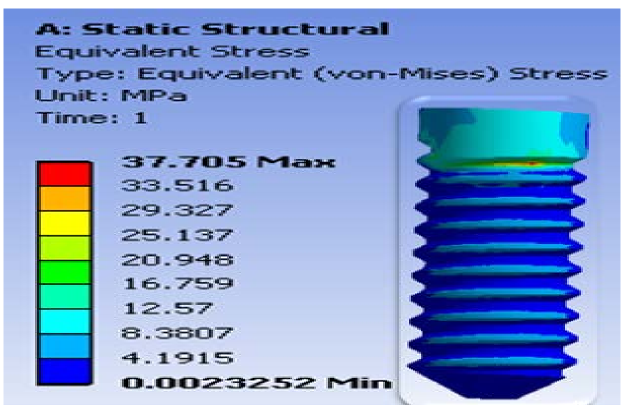
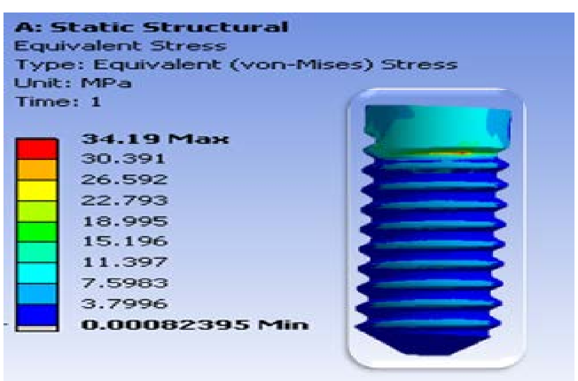


Figure-: 5. Von Mises stress analysis for Morse taper IAI with different percentage of PS on Implant under axial & oblique (15 degree) loading

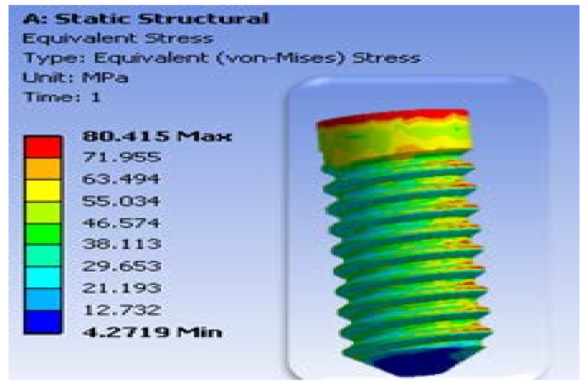
AXIAL LOADING FOR 5.00 mm, 4.4 mm AND 4.1 mm ABUTMENT

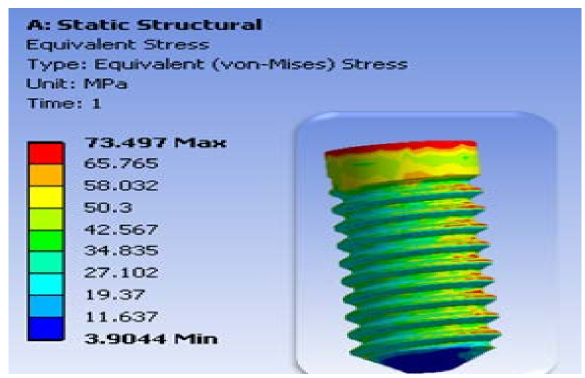


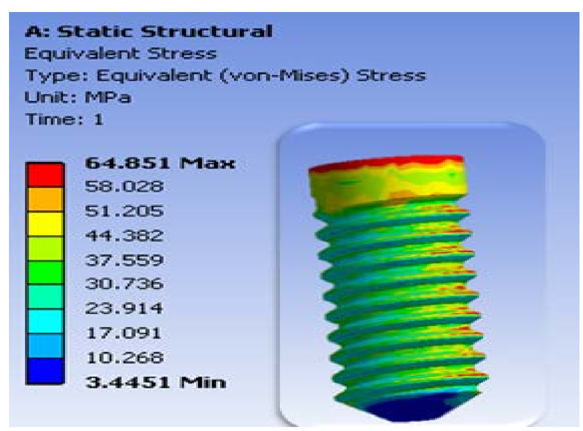


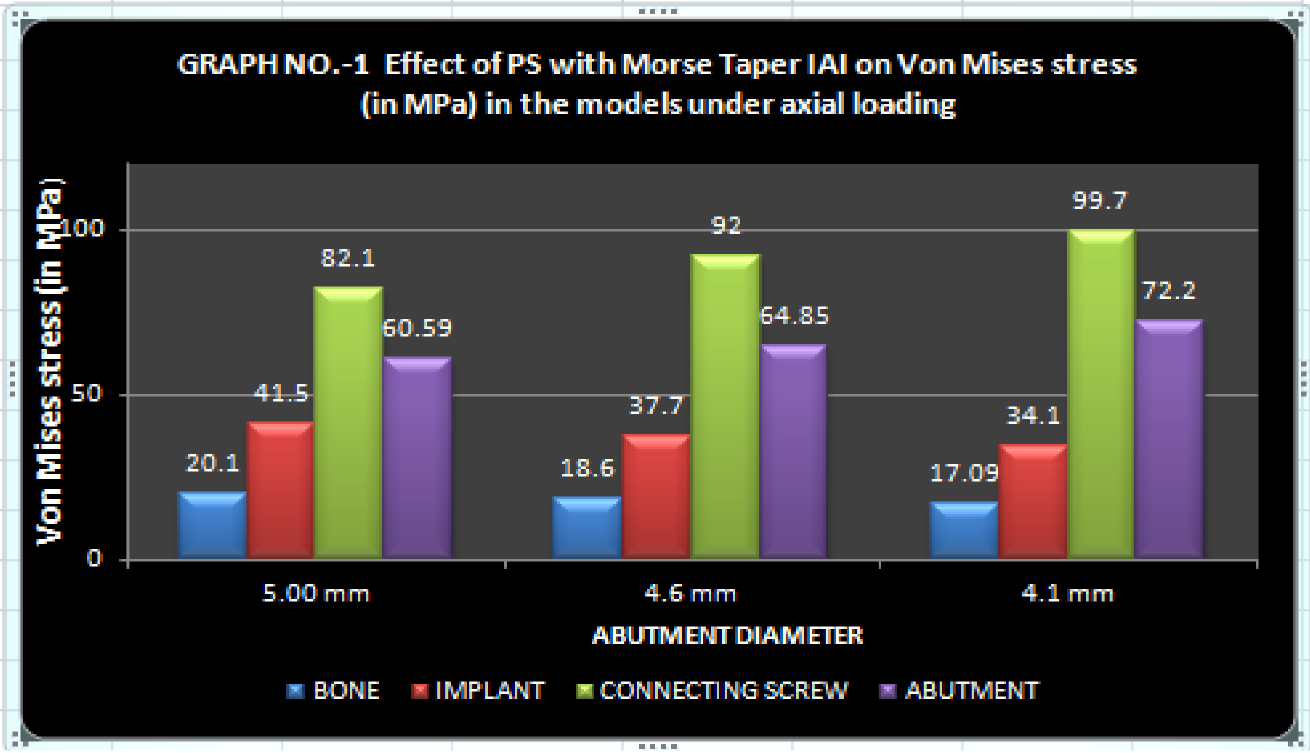


OBLIQUE LOADING FOR 5.00 mm, 4.4mm AND 4.1 mm ABUTMENT

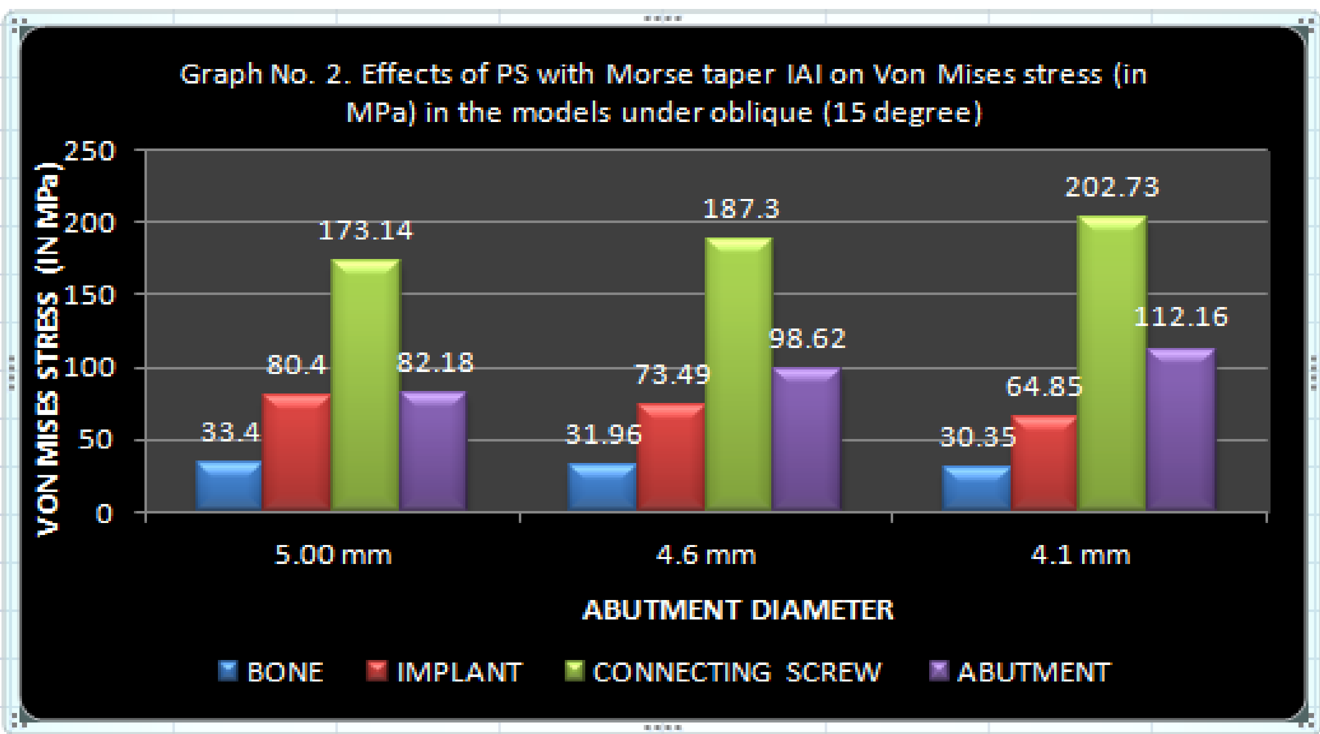








Graph no 1. **Von Mises stress (in MPa) generated in the models under axial an loading with different diameter of the abutment in bone, implant, connecting screw, abutment.**



Graph no 2. **Von Mises stress (in MPa) generated in the models under oblique loading with different diameter of the abutment in bone, implant, connecting screw, abutment.**