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IS THE PALATE AN OPTIMAL SITE FOR MINISCREW PLACEMENT?

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ABSTRACT

To test the hypothesis that palatal bone is able to support miniscrews when subjected to forces generatedduring orthodontic treatment. Finite element method software ANSYS10.0 was used. Tests were done in a state of osseointegration and non osseointegration. Two different palatal regions i.e. one layer of cortical bone and underlying trabecular bone; & two layers of cortical bone with trabecular bone in between were involved. In both cases, for each configuration, two different forces of 240 gfand480 gf were applied to the screws. These load values corresponded to those generated by the application of an orthodontic appliance to the miniscrew. The results showed that miniscrew inserted into the palate can be anchored to bone and loaded within orthodontic force range without bone fracture. The osseointegrated system was characterized by lower level of stress than non osseointegrated but anchorage within the second layer of cortical bone reduced the stress on the trabecular bone, improving stability of the implant. We conclude that miniscrews loaded within the normal orthodontic force range do not exceed stress levels that lead to bone fracture.

KEYWORDS :- osseointegration,nonosseointegration, loading forces, finite element analysis

INTRODUCTION

The quest for absolute anchorage in orthodontic treatment has led to the development of many orthodontic implant designs. One of the most widely tried and trusted sites for insertion of miniscrews is the palate, whose paramedian zone has been found particularly suitable for this purpose as it lacks nerves and blood vessels that could be easily damaged during miniscrew application. Palatal miniscrews are useful adjuncts to a variety of treatment modalities in orthodontics such as distalization, lingual orthodontics etc.

However, despite the numerous studies of these useful appliances, several important points regarding their use still need to be clarified. The first of these is the most advantageous means of their insertion. In fact, miniscrews can be inserted into the palatal bone either involving only the first cortical layer and the underlying trabecular bone, or alternatively penetrating these two strata and continuing through into the second cortical layer. The second important question is how much load a miniscrew can confidently be subjected to. This has been calculated using the finite element method (FEM) for a specific dental implant employed for orthodontic purposes.

This study was devised to establish, using FEM, whether the palatal bone is able to support a miniscrew subjected to the amount of force normally generated during orthodontic treatment. A secondary objective was to determine whether involvement of the inner cortical layer of the palatal bone, together with the outer layer and the trabecular layer in between, has any genuine advantages.

Objectives: To test the hypothesis that palatal bone is able to support miniscrews when subjected to forces generated during orthodontic treatment.

A clinical study by Zachrison reported that carefully performed bonding technique may be of value, particularly on anterior teeth, premolars and mandibular second molars, while the evidence at hand would suggest that first molars are better banded.[4]Another study supported the previous study by showing that lowest failure rates were found with banding on buccal teeth and bonding on anterior teeth. Access, high occlusal forces and moisture contamination was found to be the reasons why author suggested banding the molars.[5]

A comparative study showed that bracket placement and flash removal were found to be much easier with the light-activated composite than with the autopolymerising system.[6] Whereas a longitudinal study done to evaluate and compare the rate of success or failure between a visible light cured bonding material and chemically cured bonding material did not reveal any statistically significant differences between the failure rates of the two systems.[7]

With advances in dental materials and techniques, bonding of orthodontic brackets is easier and more predictable, but recent advances make bonding more efficient and effective.

Table1:Geometric and Mechanical Properties of the Miniscrew

Principal Characteristics	Dimensions
Length of Thread (mm)	8
Diameter of Thread (mm	1.3/1.1
Pitch (mm)	0.8
Core (mm)	0.3
Young's modulus (MPa)	113,800

Materials and Methods:

To fulfill these objectives, the same miniscrew was considered in two different configurations, corresponding to insertion into the anterior and posterior palatal zones. Scenarios of both complete osseointegration and no osseointegration were investigated, and the miniscrew was presented schematically with two different loads, both encountered in normal orthodontic applications.

The results obtained would allow the state of stress generated in the bone to be evaluated and the deflection of implant to be considered, thereby permitting determination of the optimal conditions for an implant of this type.

To carry out the finite element analysis of the palatal bone–miniscrew system, a three-dimensional geometric model of an implant (DENTICON Company, Mumbai, India) with thread length 8mm was created using the computer-aided design software ANSYS 10.0. with help of geometric and mechanical properties which were available from manufacturers **(Table I and Table II)** and *(***Fig.1A and Fig. 1B)**. The characteristics of this self-threading miniscrew are reported in Table .I and Figure. 1A & 1B. In the three dimensional model used for study, the threads were represented as helicoidal rather than circular to get exact accuracy.

The bone was made up of two different materials, namely cortical and trabecular bone. As previously mentioned, two configurations corresponding to two different sites were constructed. The first, Configuration 1, featured a layer of trabecular bone between two cortical layers and represented the thinner posterior portion of the palate **(Fig.2A).** The second ,Configuration 2, represented an anterior portion of the palate (about 4 mm from the incisive foramen) made up of a layer of trabecular bone underlying a layer of cortical bone (**Fig. 2B**).

The principal characteristics of the two configurations are reported in Table 2. The dimensions of the different components of the palatal bone were evaluated from previous study by Fengshan Chen et al[4].

With ANSYS Multiphysics 10.0, the two miniscrew–palatal bone configurations were considered in both a state of total osseointegration between screw and bone and in a state of no osseointegration. In both cases, for each configuration, calculations were made with two different forces applied to the screw: 240 gram force(gf) and 480 gram force (gf). These load values corresponded to those generated by the application of an orthodontic appliance to the miniscrews **(Fig. 2A and Fig. 2B).**

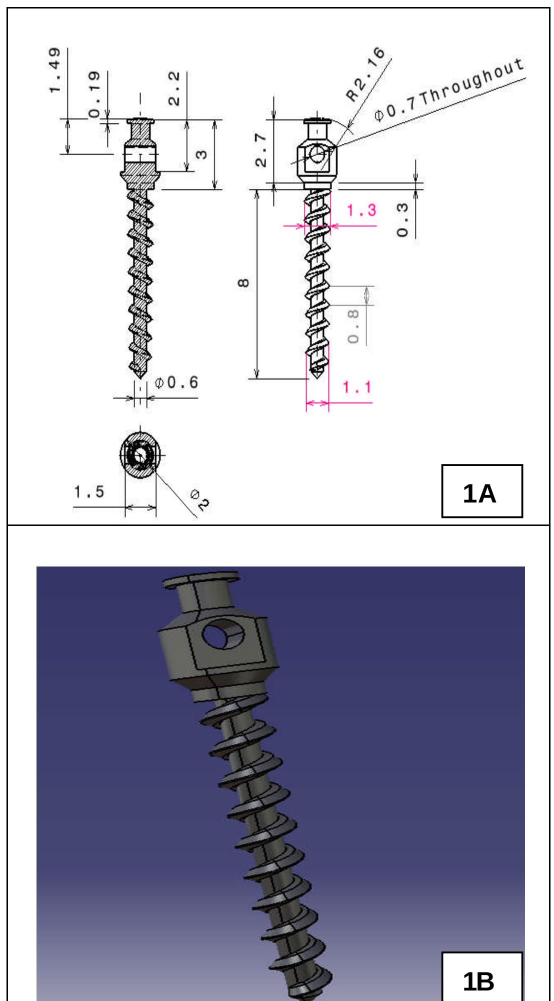

Fig.1A and 1B: Characteristics of self threading mini screw

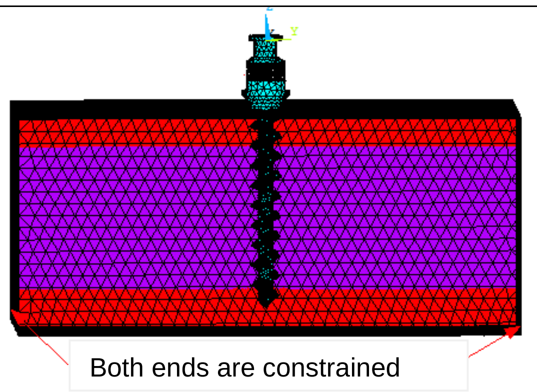

Fig. 2A. Configuration 1 featuring a layer of trabecular bone between two cortical bone layers

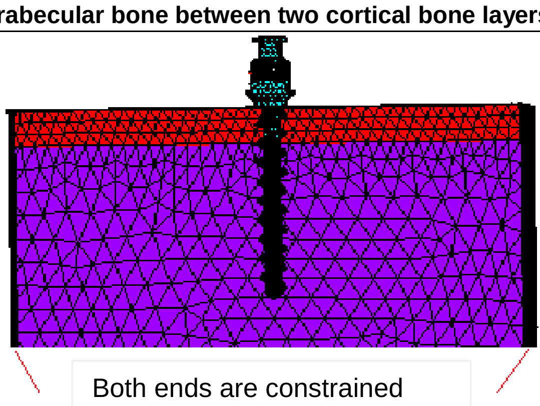

Fig.2B. Configuration 2 featuring a layer of trabecular bone underlying a layer of cortical bone.

The geometric model described previously was rendered into discrete elements using 10-node nonlinear tetrahedral elements (SOLID92), resulting in approximately 1,00,616 nodes. In this operation, the symmetry of the problem was considered, and thus only half of the domain was actually distinguished and analyzed. The mesh at the interface between the bone and screw was refined to increase the accuracy of the results in this area.

In the nonosseointegrated situations, auxiliary "friction" elements (CONTA170 and TARGE174) were used in the contact surfaces between miniscrew and bone. All materials were considered linearly elastic and isotropic.

The external surfaces of the modeled bone, except for that at the site of miniscrew insertion, were considered fixed because they form part of the palate and are thus not subjected to movement. Furthermore, the load employed to simulate the actual state of tension was applied as a concentrated force applied at the level of hole made for wire engagement. **(Fig.3).**

Results

First, the configurations with non osseointegration were analyzed, and then those with osseointegration were analyzed. The results of both analyses were subsequently compared to determine the advantages and disadvantages of each. The two levels of load, 240 gf and 480 gf were studied. The results of the FEM allowed evaluations of the stress and displacement. The maximum stress values obtained were at the implant bone interface and only those were considered for comparison.

Non Osseointegrated Configurations (Table 3)

The results of the simulations of the non osseointegrated configurations at the level of 240gf load are represented in figure 4 and figure 5.

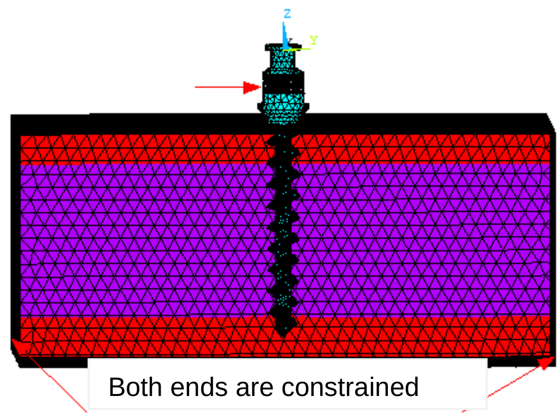

Fig.3. Application of load to model

The plots obtained for overall Von Misses stress (including miniscrew stress) and Displacement as well as cortical& trabecular plots are given separately **(a,b,c,d,e,f in Fig. 4 and Fig.5).**

In both configurations the stress was distributed in the same manner, with its more value at trabecular layer and lesser in cortical layer. Less overall stress values were observed in Configuration1 and more in Configuration 2. Individual values of stress for cortical and cancellous bones also were less in configuration 1 as compare to configuration2.

Displacements also were taken in consideration. The resulting strain also differed between the two configurations. The strain or deflection in Configuration.2 was more than in Configuration.1 and it was most apparent in the trabecular layer.

The results on 480gf load application on the same configurations are summarized in **Table IV**. The values obtained are in similar pattern i.e. more stress and deflection in Configuration2 and less in Configuration1. (**Fig. 4 and Fig.5**)

Table 2: **Geometric Characteristics and Mechanical Properties of the Bone in Configurations 1 and 2.**

Principal Characteristics	Cortical (1)	Trabecular (1)	Cortical (2)	Trabecular (2)
Thickness (mm)	1.5	5.75	1.5	7.25
Length (mm)	20	20	20	20
Width (mm)	10	10	10	10
Young's modulus (MP	13700	1370	13700	1370
Poisson's ratio	0.26	0.30	0.26	0.30
Frictional coefficient	0.2	0.2	0.2	0.2

Table 3 :The Displacement and Von Mises Stress values obtained on 240g and 480g loads --Non Osseointegrated Configurations.

	Non-Osseointegrated	Displacement (mm)	Stress (MPa)
Configuration-1 240 grams load	Overall	0.020372	166.882
	Cortical	0.001378	23.285
	Cancellous	.007494	4.352
Configuration-1 480grams load	Overall	.040744	333.764
	Cortical	.002756	46.57
	Cancellous	.014988	8.705
Configuration-2 240 grams load	Overall	0.020645	188.09
	Cortical	0.0026	26.209
	Cancellous	.00098	11.656
Configuration-2 480 grams load	Overall	0.041291	377.8
	Cortical	0.0052	52.418
	Cancellous	0.00196	23.312

Table 4: The Displacement and Von Mises Stress values obtained on 240g and 480g loads Osseointegrated configurations.

	Osseointegrated	Displacement (mm)	Stress (MPa)
Configuration-1 240 grams load	Overall	0.015207	157.142
	Cortical	0.001364	16.144
	Cancellous	0.000646	2.018
Configuration-1 480grams load	Overall	0.030413	314.235
	Cortical	0.002728	32.288
	Cancellous	0.0001292	4.036
Configuration-2 240 grams load	Overall	0.0158	162.86
	Cortical	0.0022	23.285
	Cancellous	0.000842	8.705
Configuration-2 480 grams load	Overall	0.0314	325.72
	Cortical	0.0044	46.57
	Cancellous	0.000168	16.14

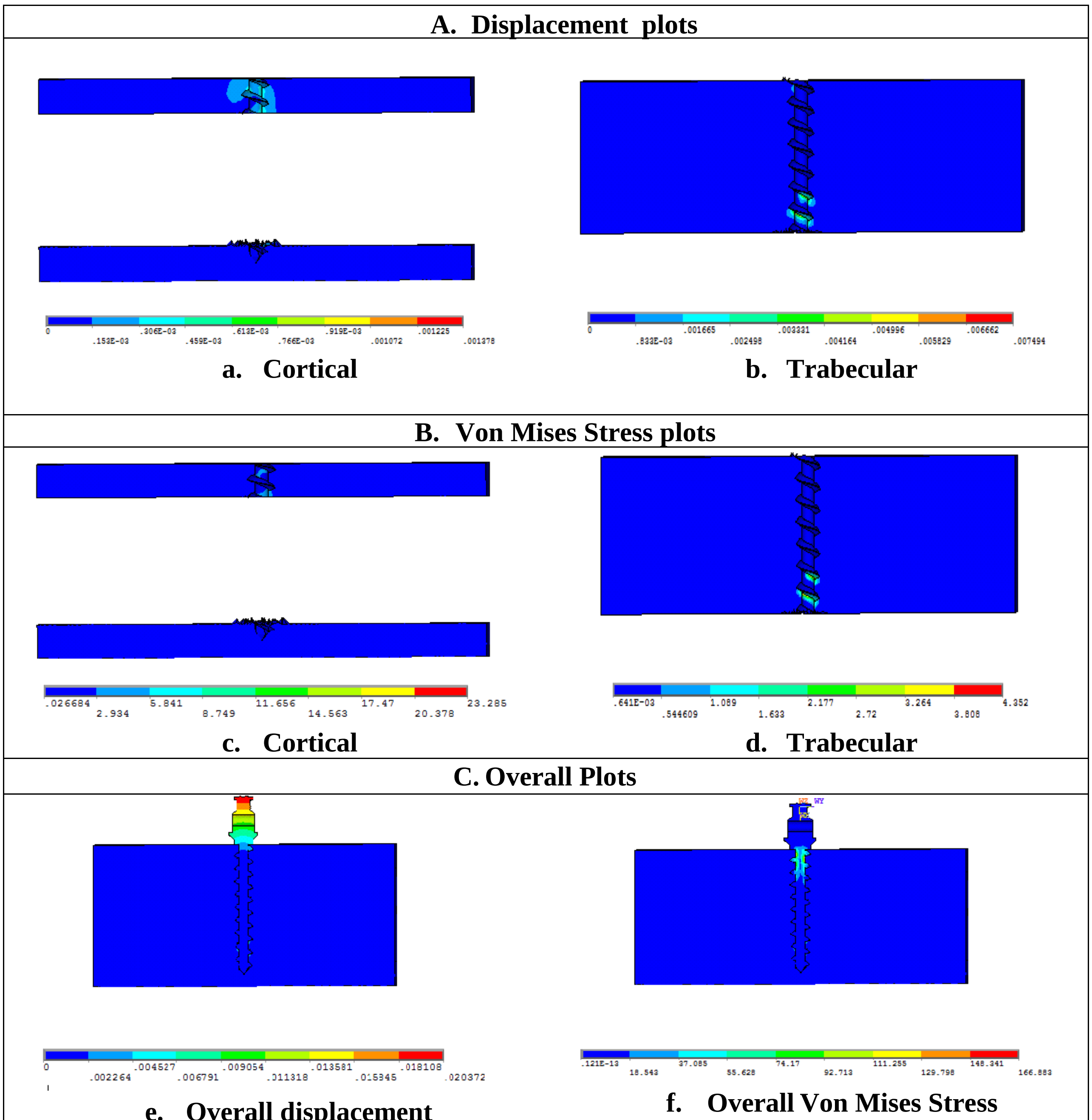

Fig.4. Double cortical layer non osseointegrated configuration (Configuration 1 with 240g load)

Configurations With Osseointegration-(Table 4.)

The results obtained with these configurations are simulated in figure 6and figure 7. The values obtained are summarized in **Table 5.**

In the configurations without osseointegration the results were in the same manner. The considerable difference was observed in values of stress and deflection. Both the stresses and deflections were more as compared respectively to the Osseointegrated configurations (**Fig. 6 and Fig.7**).

Discussion:

Similar studies of this type of system allow a qualitative comparison of the results. Luca Lombardo etal[1] usedsimilar configurations for the study. In the implant model threads were represented circular and more importance was given to stress generated in bone values only. In the present study the threads were represented helicoidal, as well as the head of implant model prepared with the hole for the orthodontic wire engagement making the model more similar to the actual implant.Also, importance is given to stress generated in bone as well as deflection of implant. In the present study similar thickness of bone in both configurations were used for comparison.

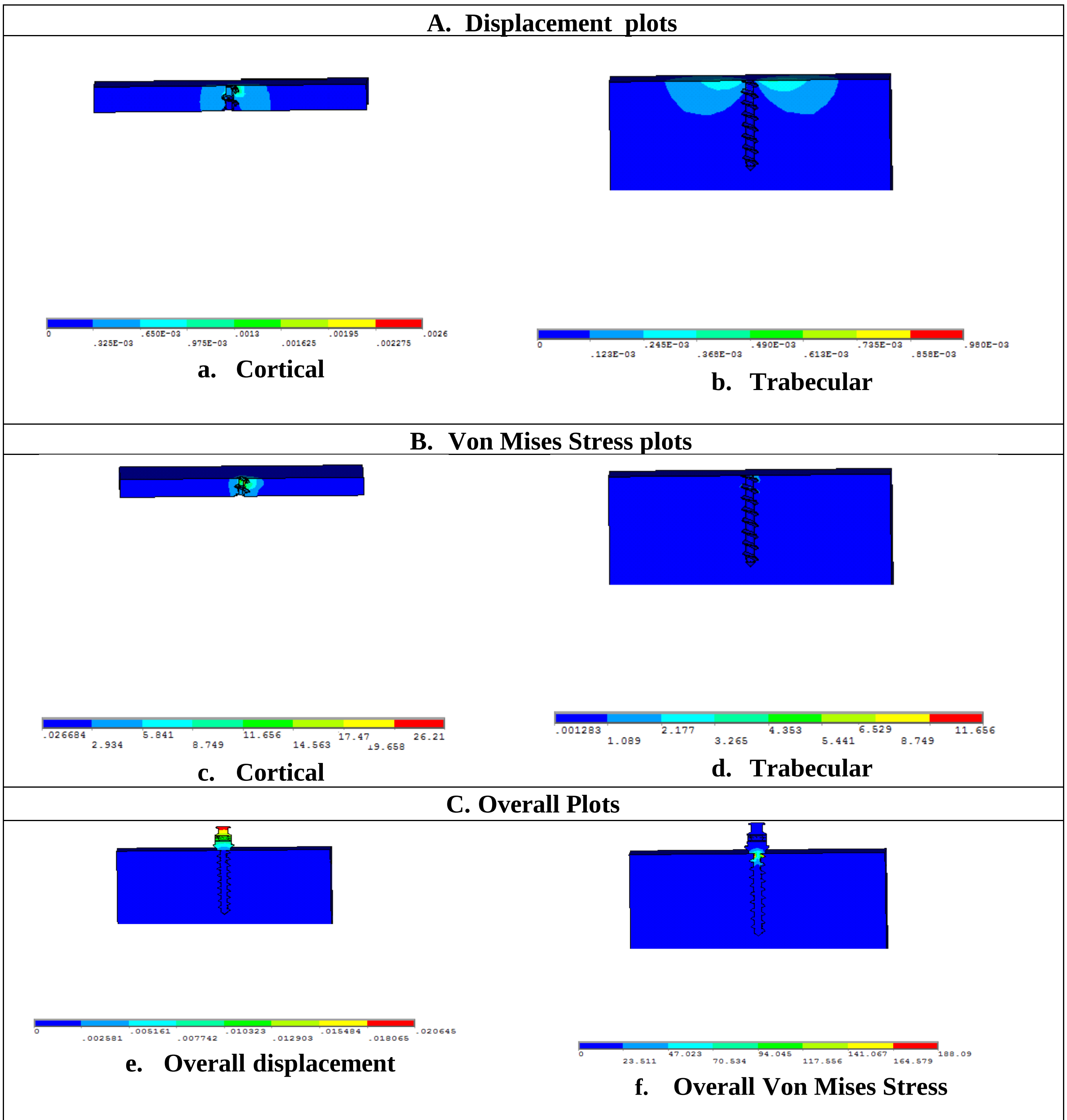

Fig.5. Single cortical layer non osseointegrated configuration (Configuration 2 with 240g load)

Dalstra et al[5] used a miniscrew of similar geometry as that examined here to evaluate the stress distribution in bone. Likewise, the FEM simulations in the present study showed that the cortical layer has a determining influence on the state of stress of the miniscrew-bone system. In fact, in all the configurations considered, the presence of a second cortical layer reduces the stress in the trabecular layer, which, being weaker is the more critical zone.

The results obtained show that, for all the configurations examined, the maximum Von Misses stress did not exceed the strength of either the cortical or the trabecular bone. Suitable strength values for palatal trabecular and cortical bone are 50 MPa and 170 MPa respectively, as reported in a study by Kaplan et al[7] Although these values are averages, and therefore subject to individual variations in bone density, in none of the cases considered in the present study were these critical values exceeded, except

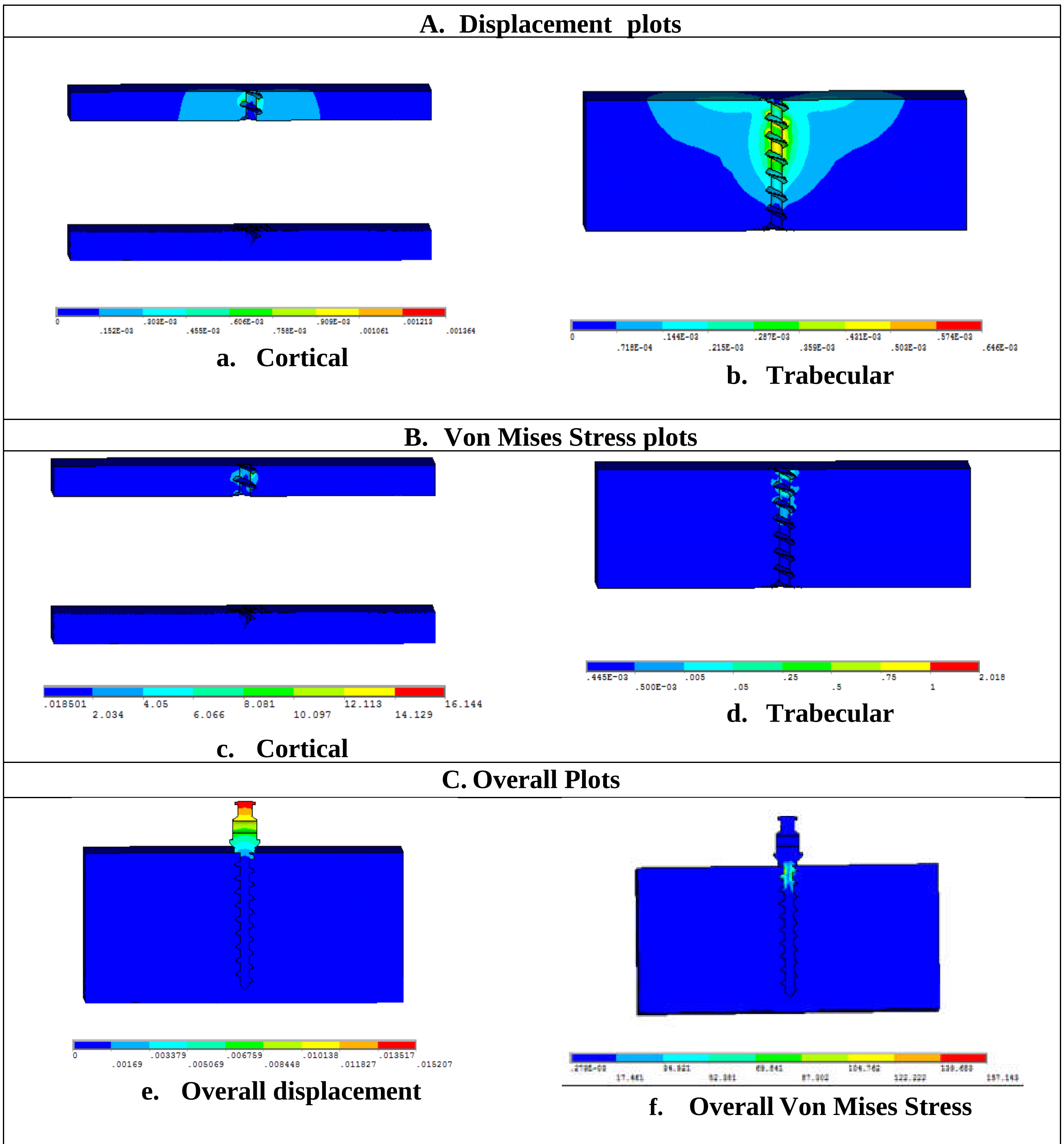

Fig.6. Double cortical layer osseointegrated configuration (Configuration 1 with 240g load)

non osseointegratedsingle cortical layer configuration. Therefore, in agreement with Dalstraet al[5], we can say that, in the presence of bone of good quality and adequate thickness, miniscrews do not cause fracture of bone.

The most interesting aspect of the results obtained in this study is related to the stress distribution in the configurations in which the miniscrew contacts both layers of cortical bone in addition to the trabecular bone. When this occurs, in both the presence and absence of osseointegration, the load in both the cortical and trabecular layers is reduced. This is particularly important when larger forces (480 gf) are exerted on nonosseointegratedminiscrews, as this configuration is such, that the cortical layers share most of the stress and hence excessive loading of the trabecular bone is prevented.

On the basis of this FEM simulation we can conclude that, from a mechanical point of view, bicortical palatal anchorage is advantageous in clinical practice, especially

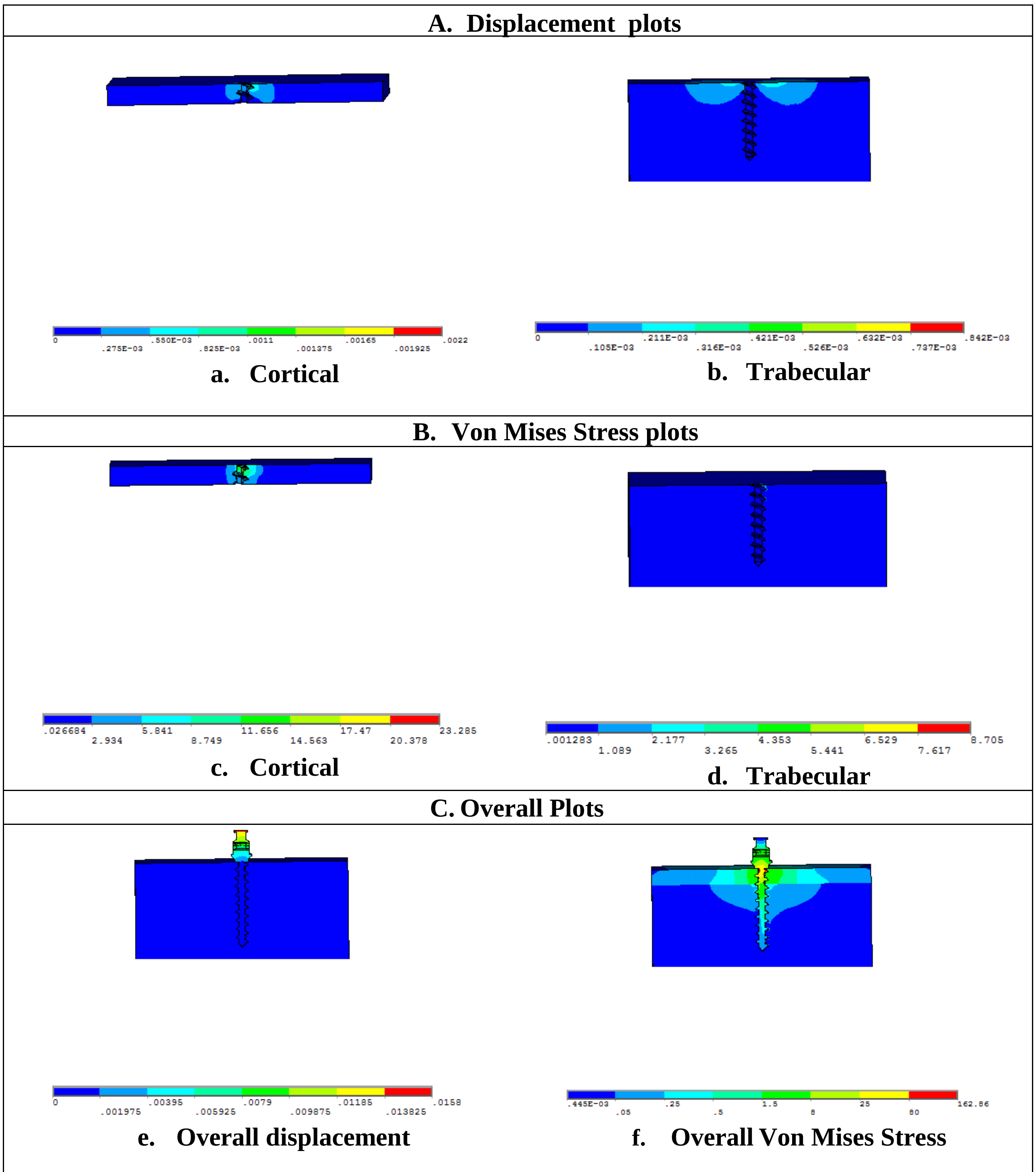

Fig.7. Single cortical layer osseointegrated configuration (Configuration 2 with 240g load)

in the absence of osseointegration, as it reduces the risk of microfractures in the trabecular bone layer. The sole reason for not employing bicortical anchorage in the palate could be the risk of perforation of the nasal cavity floor. However, it has previously been demonstrated that a perforation of the nasal cavity or maxillary sinus of less than 2 mm in diameter heals spontaneously, without complications, and does not compromise primary stability.

CONCLUSION:

A miniscrew of Thread diameter 1.3/1.11 mm and thread length 8 mm inserted into the palate is able to withstand loads between 240gf and 480 gf, without causing fracture to bone, in the presence of osseointegration.

Placement of the screw into both cortical layers markedly reduces the load at the trabecular bone and increases the stability of the implant.

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