CHAPTER 4

Results

A FE model was constructed and meshed into several small elements. The teeth, PDL and alveolar bone had tetrahedron elements. The brackets and arch wire had hexahedron elements. The mesh model contained 792,987 nodes and 3,312,844 elements. The pattern of von Mises stress distribution in the PDL and the displacement of the six maxillary anterior teeth were investigated.

4.1 The pattern of von Mises stress distribution in the PDL

Von Mises stress (Mega Pascal or MPa) was calculated, which represented the distribution of stress in color-coded map. Red color represented the area with maximum stress and dark blue color represented the area with minimal stress. The distribution of von Mises stress indicated a displacement of teeth. Even level of stress distribution along the PDL represent the bodily movement of tooth. A tipping tooth have greater stress in some area than the others.

The stress distribution pattern on the PDL of the teeth when an intruding force of 60 g was applied in anchorage design 1 is shown in Figure 4.1. The stress was greater on the central incisors than lateral incisors or canines. The greatest stress value was at the cervix of the labial side of the PDL of the right central incisor ($+1.184 \times 10^{-2}$ MPa). The least stress value was at the cervical-middle third of the palatal side of the PDL of the right canine ($+5.803 \times 10^{-6}$ MPa).

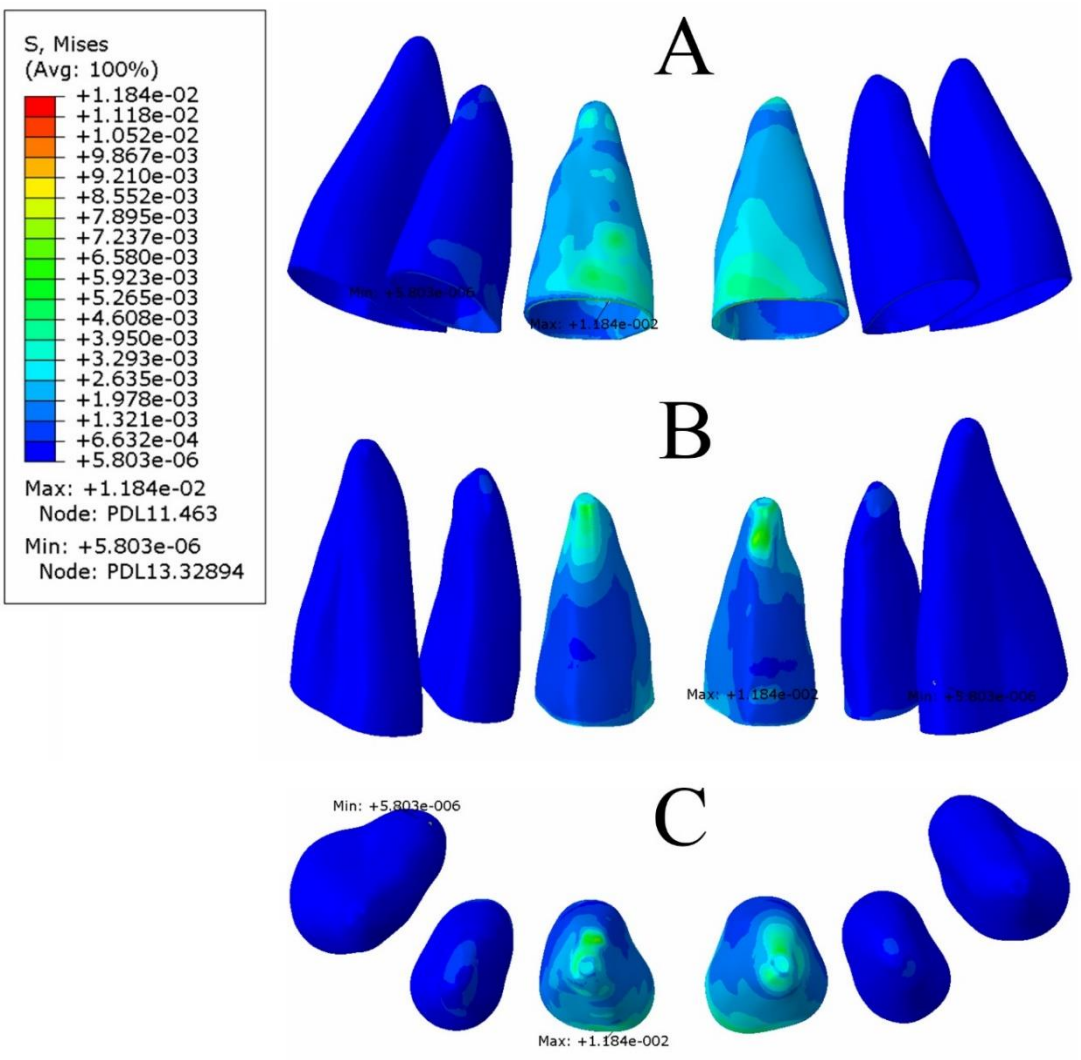

Figure 4.1 Anchorage design 1 (one-mini-screw design). The color-coded map shows the distribution of von Mises stress of 60 g force: A) Labial, B) Palatal, and C) Apical views.

The stress distribution pattern on the central incisors were greater on the labial side than on the palatal side, mesial and distal side had rather equal stress. On the labial side, the stress was greater at the cervix and decrease toward the apex. On the palatal side, the stress was greater at the apex than the other area. The greatest stress was at the cervix of the labial side of the PDL. (Figure 4.2 and 4.3)

On the lateral incisors, the labial side had more stress than the palatal side and the mesial side had more stress than the distal side. On the labial and side, the stress distribution was rather equal along the PDL. On the palatal side, the stress was greater at the cervix and apex than the middle of the PDL. The greatest stress was at the cervix of the PDL. (Figure 4.4 and 4.5)

On the canines, the labial had slightly more stress than the palatal side at the cervical third. The mesial side had slightly more stress than the distal side at the middle third. On the labial side the stress was greater at the cervical third than the other areas. On the palatal side, the stress distribution was rather equal along the PDL. The greatest stress was at the cervix of the PDL. (Figure 4.6 and 4.7)

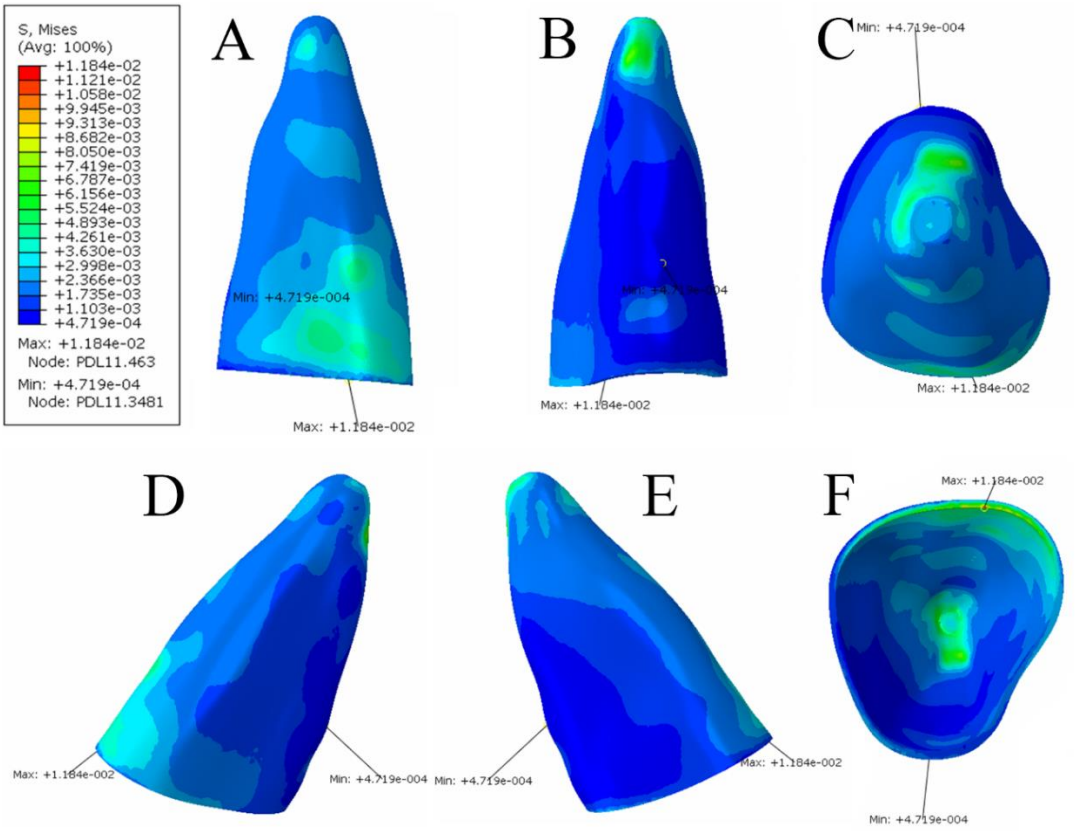

Figure 4.2 Anchorage design 1 (one mini-screw design). The color-coded map showed the distribution of von Mises stress of 60 g force on the right central incisor: A) Labial, B) Palatal, C) Apical, D) Mesial, E) Distal, and F) Occlusal views.

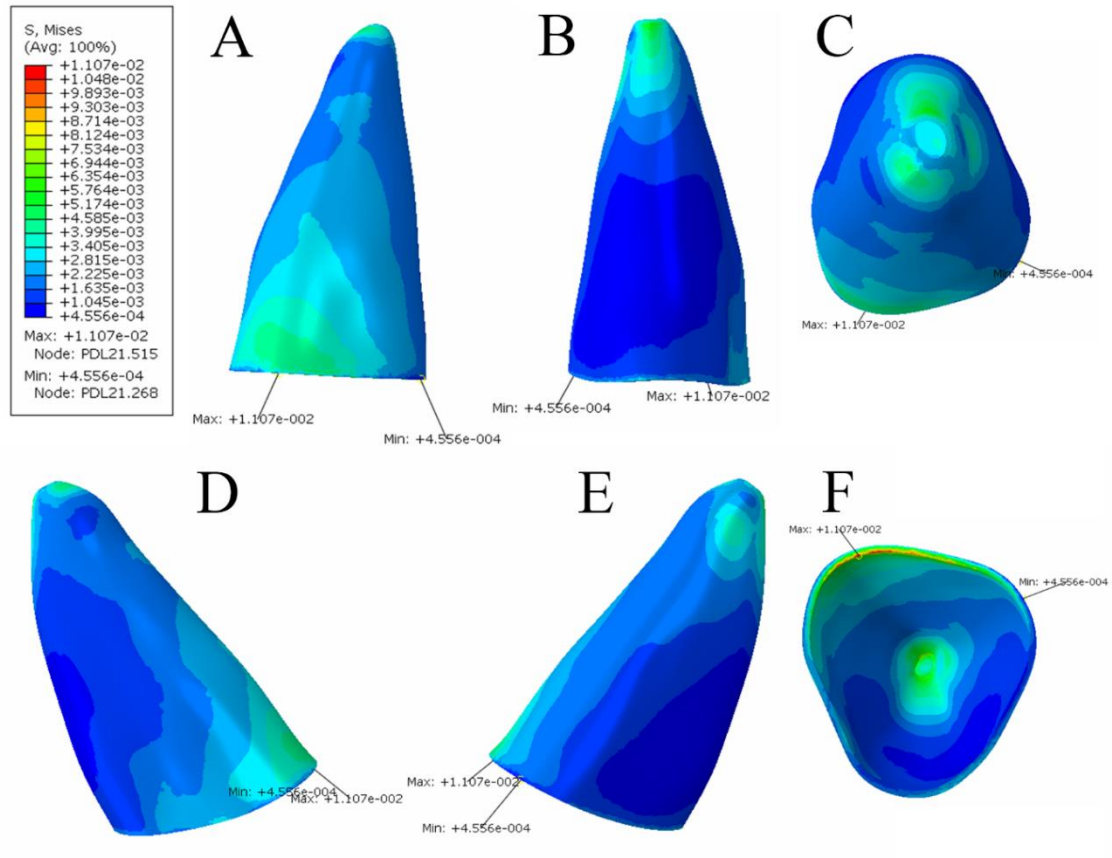

Figure 4.3 Anchorage design 1 (one mini-screw design). The color-coded map showed the distribution of von Mises stress of 60 g force on the left central incisor: A) Labial, B) Palatal, C) Apical, D) Mesial, E) Distal, and F) Occlusal views.

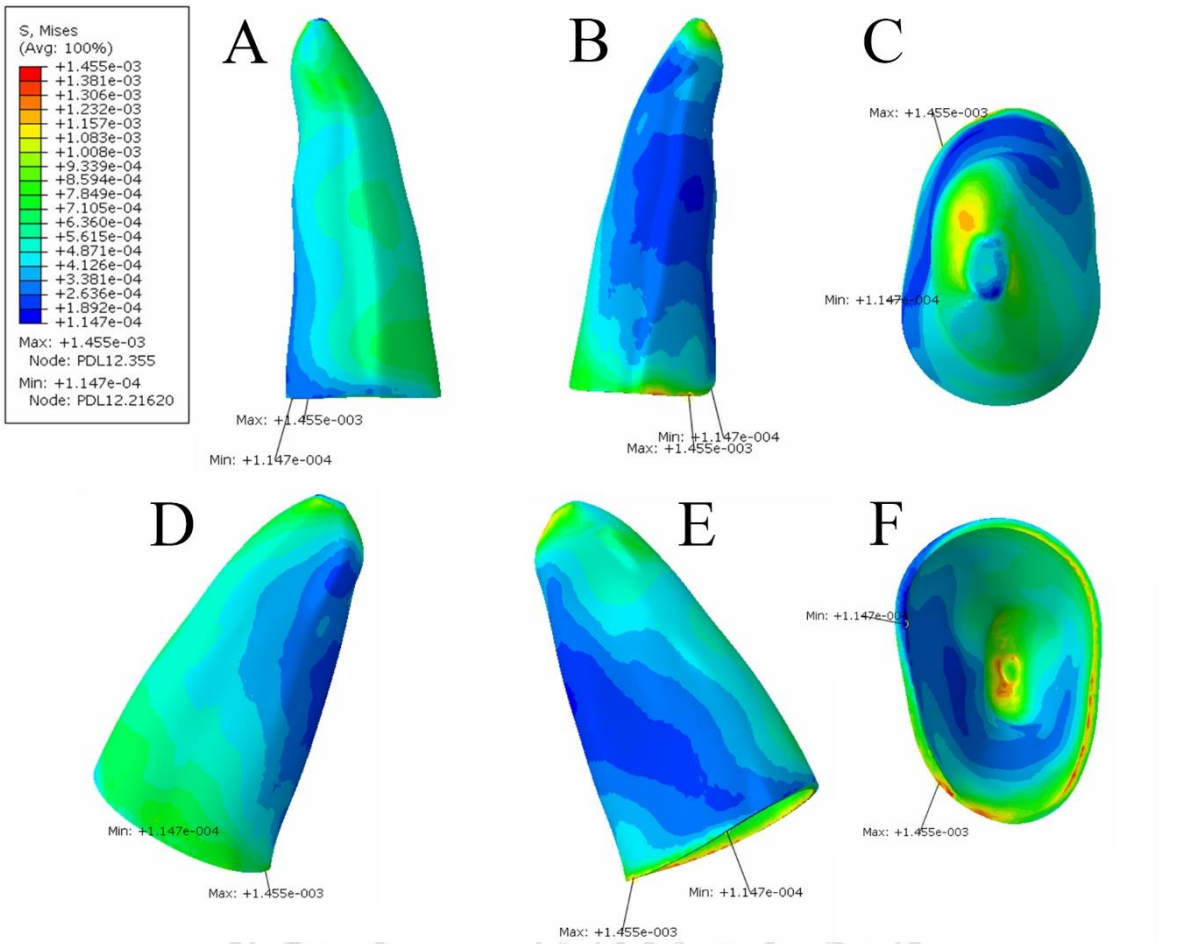

Figure 4.4 Anchorage design 1 (one mini-screw design). The color-coded map showed the distribution of von Mises stress of 60 g force on the right lateral incisor: A) Labial, B) Palatal, C) Apical, D) Mesial, E) Distal, and F) Occlusal views.

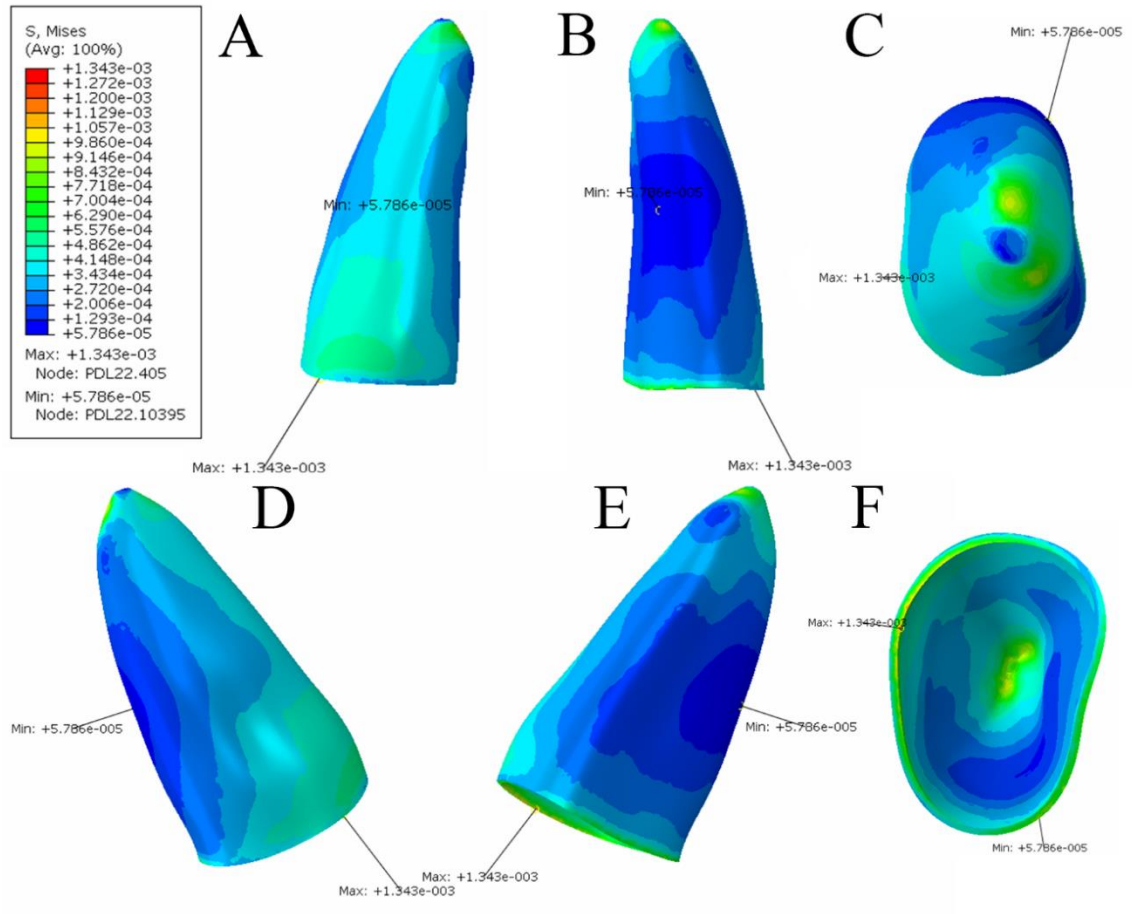

Figure 4.5 Anchorage design 1 (one mini-screw design). The color-coded map showed the distribution of von Mises stress of 60 g force on the left lateral incisor: A) Labial, B) Palatal, C) Apical, D) Mesial, E) Distal, and F) Occlusal views.

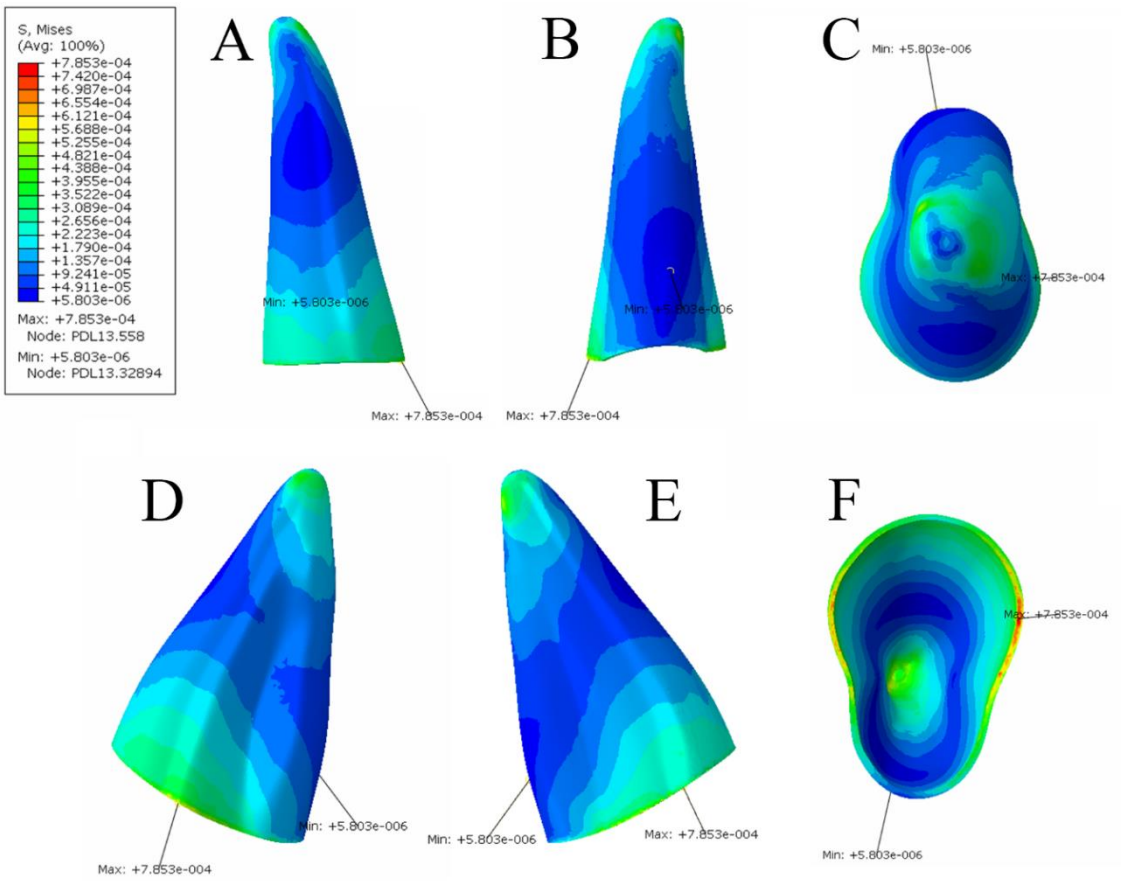

Figure 4.6 Anchorage design 1 (one-mini-screw design). The color-coded map showed the distribution of von Mises stress of 60 g force on the right canine: A) Labial, B) Palatal, C) Apical, D) Mesial, E) Distal, and F) Occlusal views.

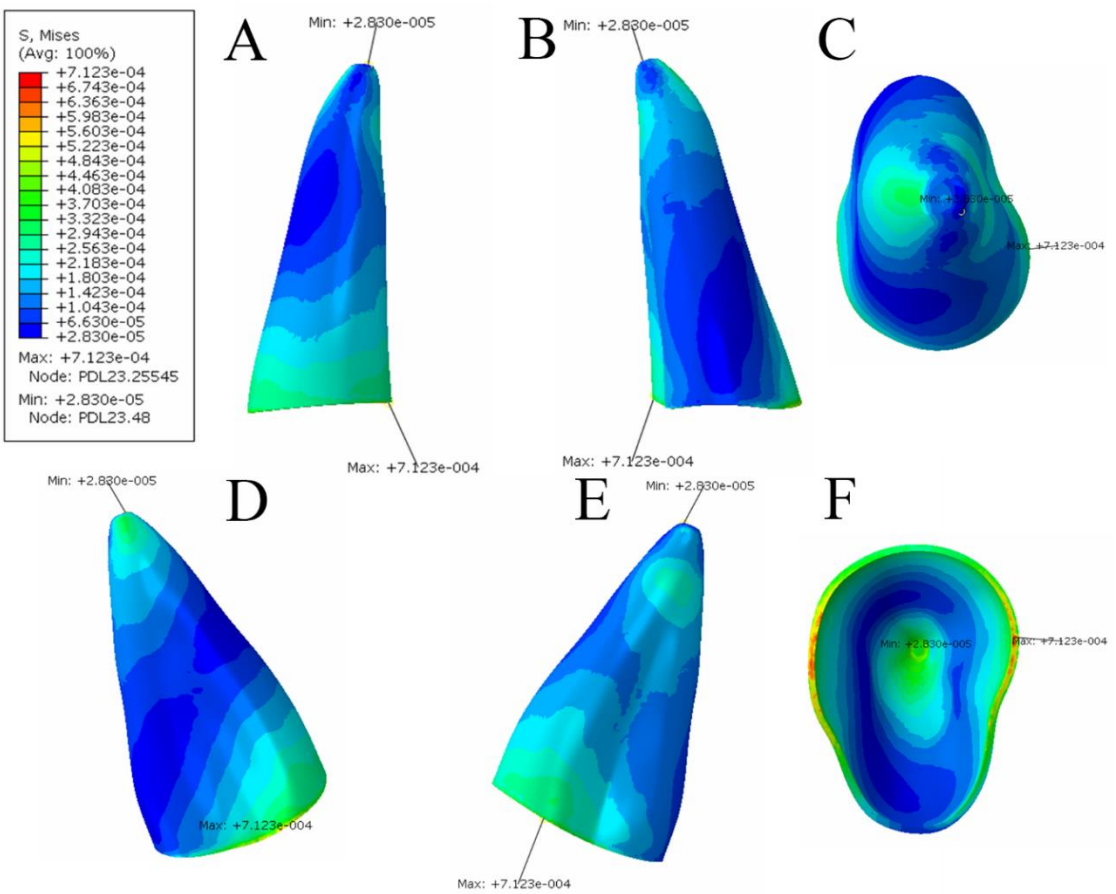

Figure 4.7 Anchorage design 1 (one-mini-screw design). The color-coded map showed the distribution of von Mises stress of 60 g force on the left canine: A) Labial, B) Palatal, C) Apical, D) Mesial, E) Distal, and F) Occlusal views.

The stress distribution pattern on the PDL of the teeth when an intruding force of 60 g was applied in anchorage design 2 is shown in Figure 4.8. The stress was greater on the central and lateral incisors than canines. The greatest stress value was at the apex of the PDL of left central incisor ($+1.775x10^{-3}$ MPa). The least stress value was at the apex of the PDL of left canine ($+1.178x10^{-5}$ MPa).

On the central incisors, the stress value was rather equal on every sides of the PDL. The greatest stress was at the apex of the PDL. (Figure 4.9 and 4.10)

On the lateral incisors, the labial side had slightly more stress than the palatal side. The mesial and distal side had rather equal stress. The greatest stress loaded on the apex. (Figure 4.11 and 4.12)

On the canines, the labial side had slightly more stress than the palatal side. The mesial and distal side had rather equal stress. In the right canine, the greatest stress was at the apex of the PDL. In the left canine, the greatest stress was at the cervix of the PDL. (Figure 4.13 and 4.14)

The stress values of the intrusion of six maxillary anterior teeth were compared between anchorage design 1 and 2. The greatest stress values of anchorage design 1 ($+1.184x10^{-2}$ MPa) was greater than that in anchorage design 2 ($+1.775x10^{-3}$ MPa). In anchorage design 1 there was much greater von Mises stress on the central incisors than on the lateral incisors or canines, whereas the stress distribution in anchorage design 2 was rather equal on the central and lateral incisors and more than on the canines. In addition, anchorage design 1 had different stress distribution between the labial and palatal and between the mesial and distal sides of each tooth, whereas in anchorage design 2, the stress distribution between each side of each tooth was almost equal.

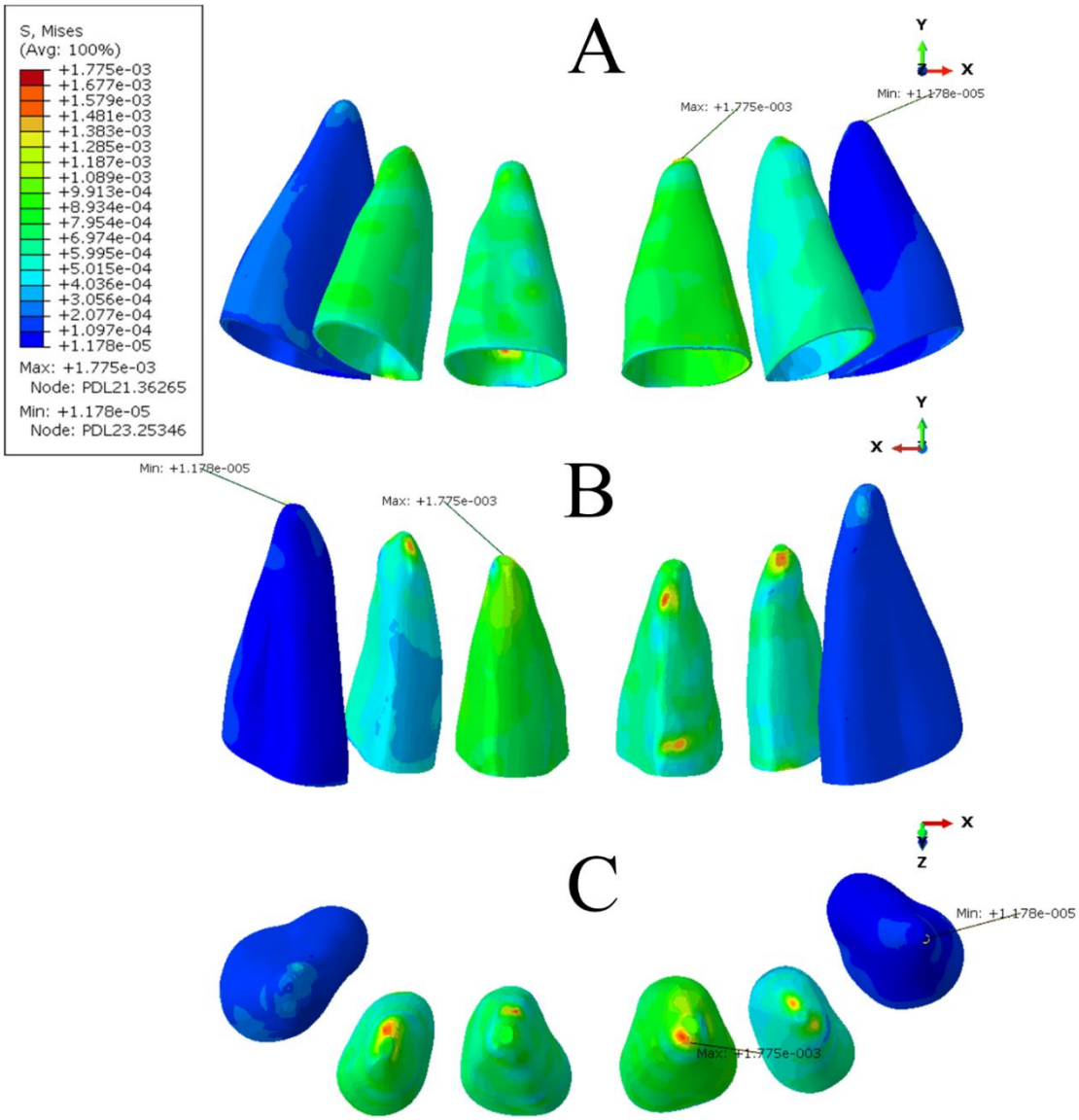

Figure 4.8 Anchorage design 2 (two-mini-screw design). The color-coded map shows the distribution of von Mises stress of 60 g force: A) Labial, B) Palatal, and C) Apical views.

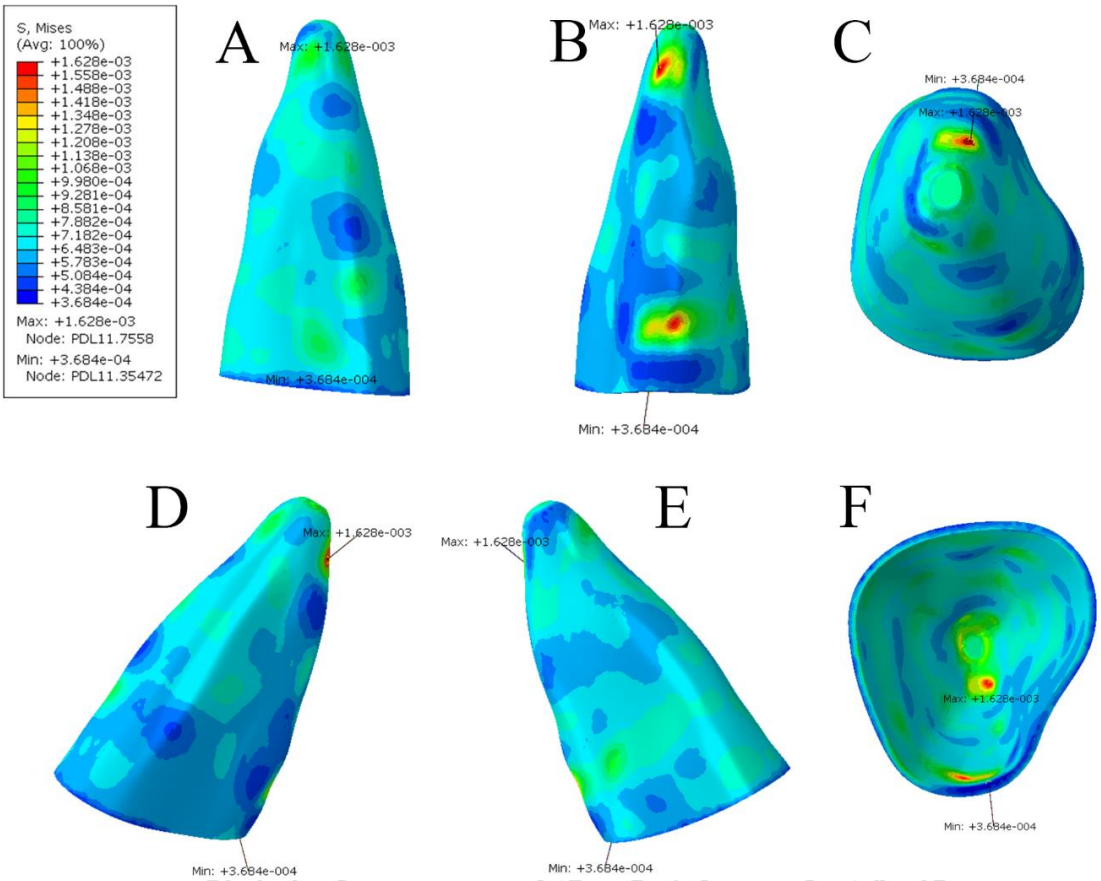

Figure 4.9 Anchorage design 2 (two-mini-screw design). The color-coded map showed the distribution of von Mises stress of 60 g force on the right central incisor: A) Labial, B) Palatal, C) Apical, D) Mesial, E) Distal, and F) Occlusal views.

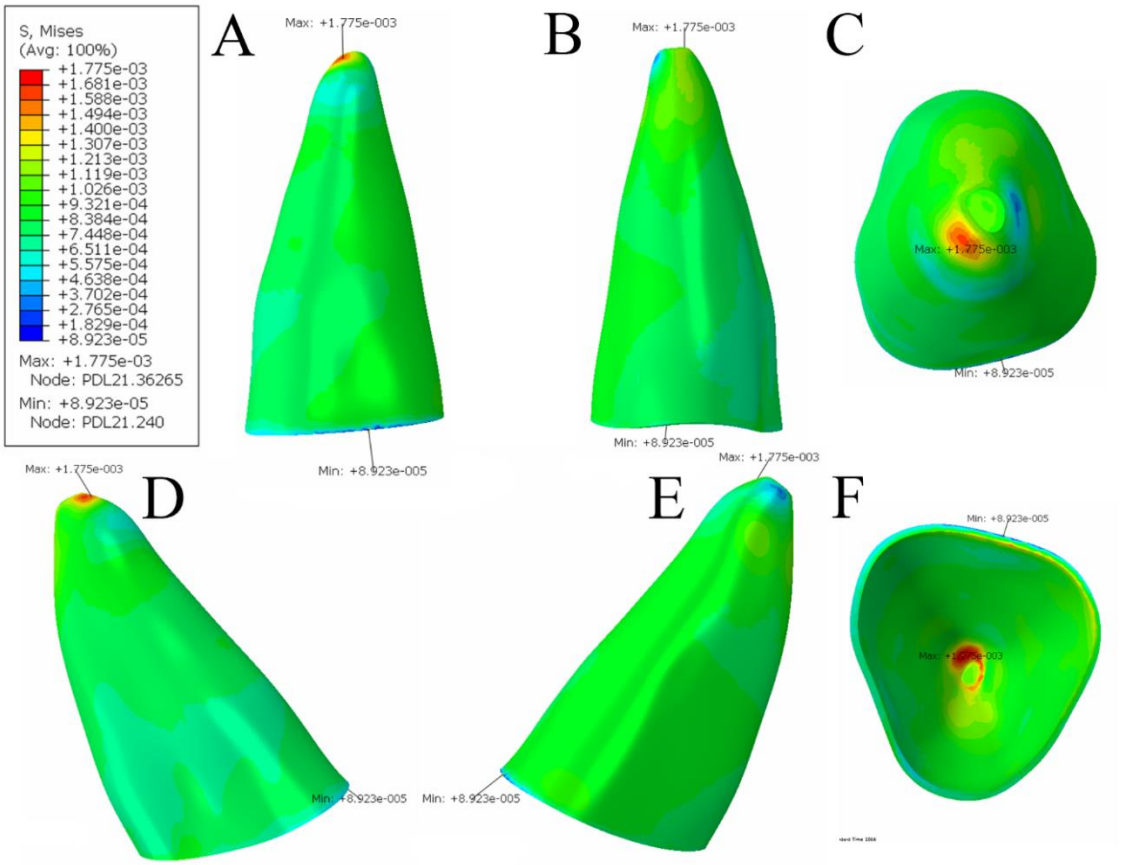

Figure 4.10 Anchorage design 2 (two-mini-screw design). The color-coded map showed the distribution of von Mises stress of 60 g force on the left central incisor: A) Labial, B) Palatal, C) Apical, D) Mesial, E) Distal, and F) Occlusal views.

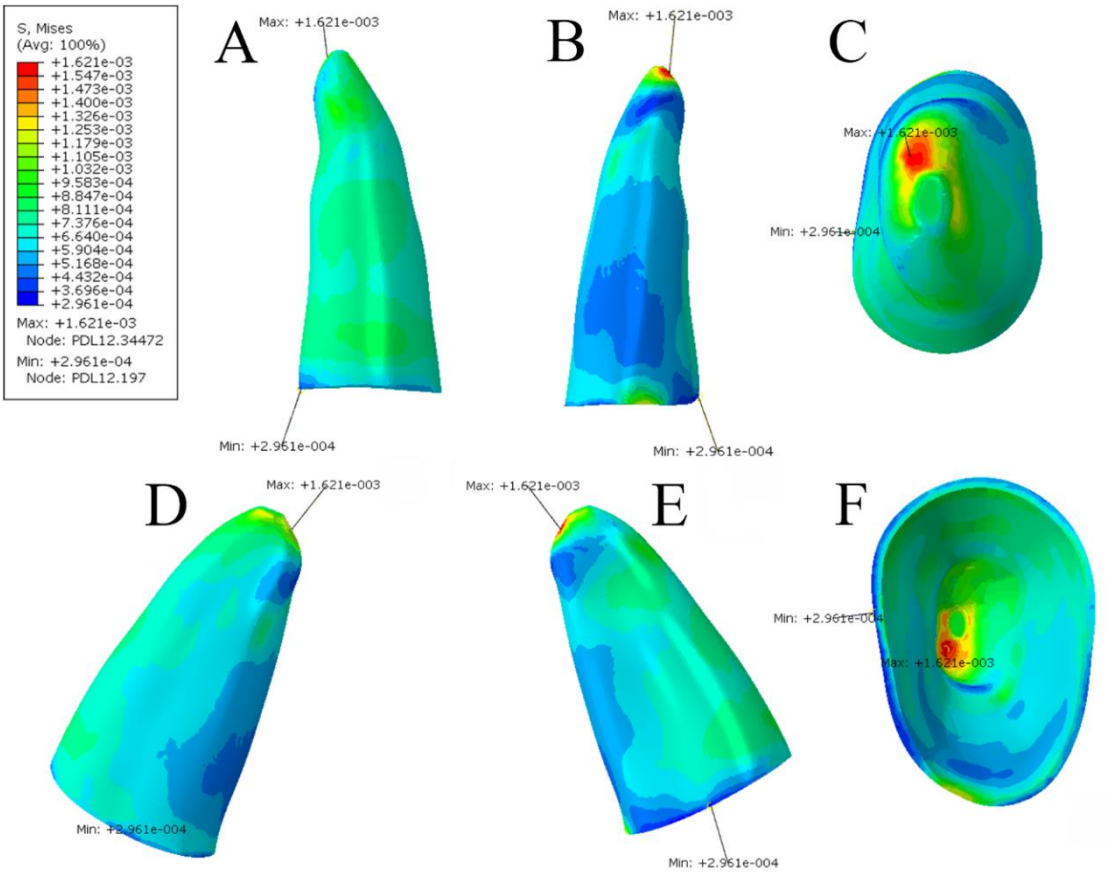

Figure 4.11 Anchorage design 2 (two-mini-screw design). The color-coded map showed the distribution of von Mises stress of 60 g force on the right lateral incisor: A) Labial, B) Palatal, C) Apical, D) Mesial, E) Distal, and F) Occlusal views.

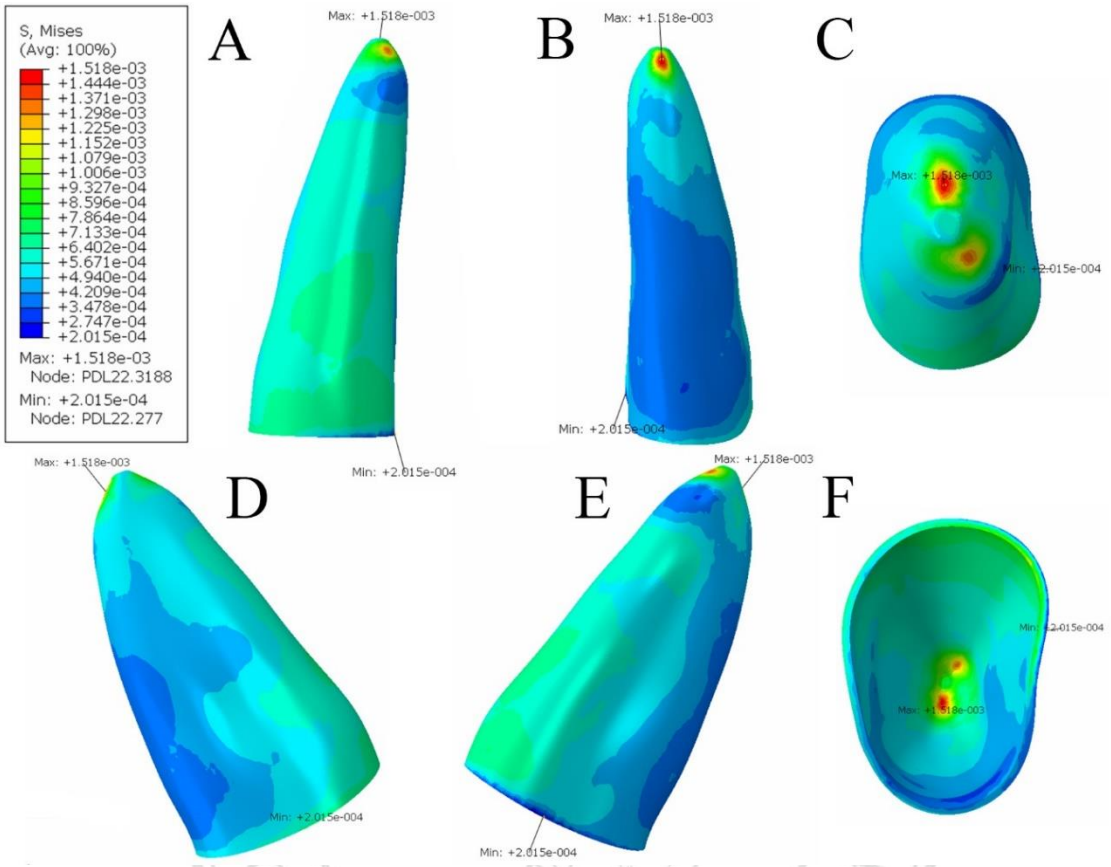

Figure 4.12 Anchorage design 2 (two-mini-screw design). The color-coded map showed the distribution of von Mises stress of 60 g force on the left lateral incisor: A) Labial, B) Palatal, C) Apical, D) Mesial, E) Distal, and F) Occlusal views.

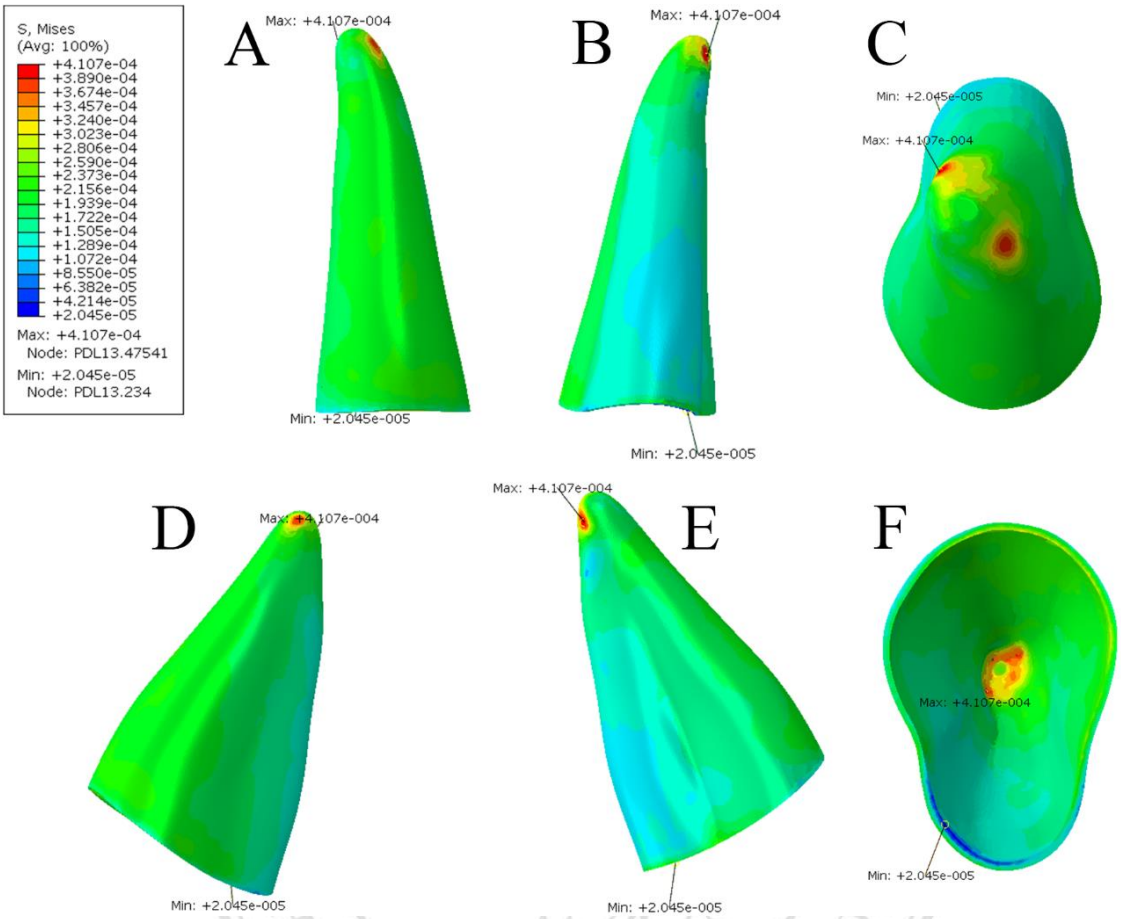

Figure 4.13 Anchorage design 2 (two-mini-screw design). The color-coded map showed the distribution of von Mises stress of 60 g force on the right canine: A) Labial, B) Palatal, C) Apical, D) Mesial, E) Distal, and F) Occlusal views.

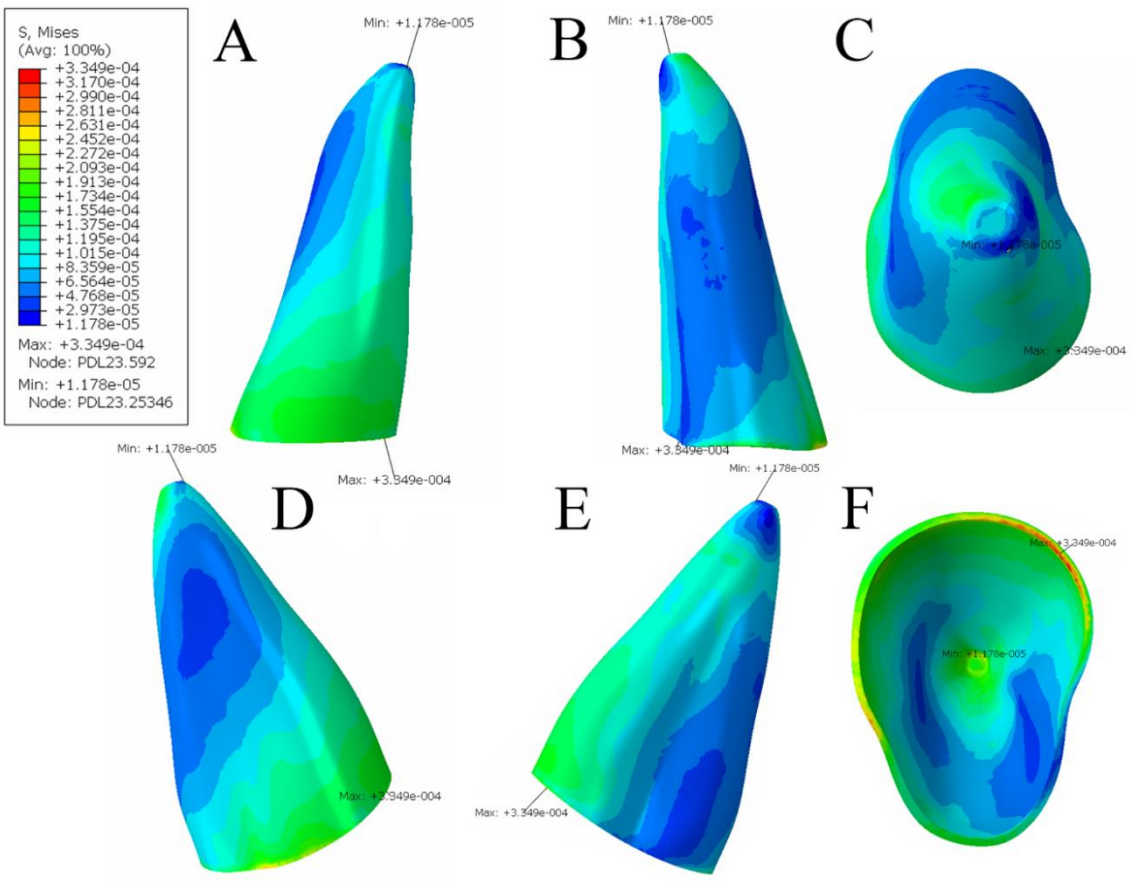

Figure 4.14 Anchorage design 2 (two-mini-screw design). The color-coded map showed the distribution of von Mises stress of 60 g force on the left canine: A) Labial, B) Palatal, C) Apical, D) Mesial, E) Distal, and F) Occlusal views.

4.2 The displacement of the six maxillary anterior teeth

Displacement of the crowns and roots of the six maxillary anterior teeth in anchorage design 1 is shown in Table 4.1 and Figure 4.15. In the x-axis, the mesio-distal direction, the crowns of the six maxillary teeth moved mesially and the root apices moved distally. In the y-axis, the vertical direction, the crowns and root apices of all teeth were intruded, except that the root apices of the canines were slightly extruded. In the z-axis, the labio-palatal direction, the crowns of all teeth moved labially, and the root apices of all teeth moved palatally. The central incisors moved farther than the lateral incisors or canines.

Table 4.1 The displacement of each tooth in anchorage design 1.

Tooth	Part	Displacement (mm)		
		ΔX	ΔY	ΔZ
Right central incisor	Crown	2.06E-3	8.40E-3	6.98E-3
	Root	-1.51E-3	1.20E-3	-5.68E-3
Right lateral incisor	Crown	1.77E-3	1.24E-3	2.35E-3
	Root	-0.47E-3	0.30E-3	-1.59E-3
Right canine	Crown	1.02E-3	0.21E-3	1.20E-3
	Root	-0.41E-3	-6.97E-5	-0.44E-3
Left central incisor	Crown	-2.51E-3	8.22E-3	7.60E-3
	Root	1.64E-3	1.01E-3	-6.12E-3
Left lateral incisor	Crown	-1.26E-3	1.22E-3	1.70E-3
	Root	0.39E-3	0.18E-3	-1.07E-3
Left canine	Crown	-1.06E-3	4.30E-5	1.13E-3
	Root	0.48E-3	-0.25E-3	-0.28E-3

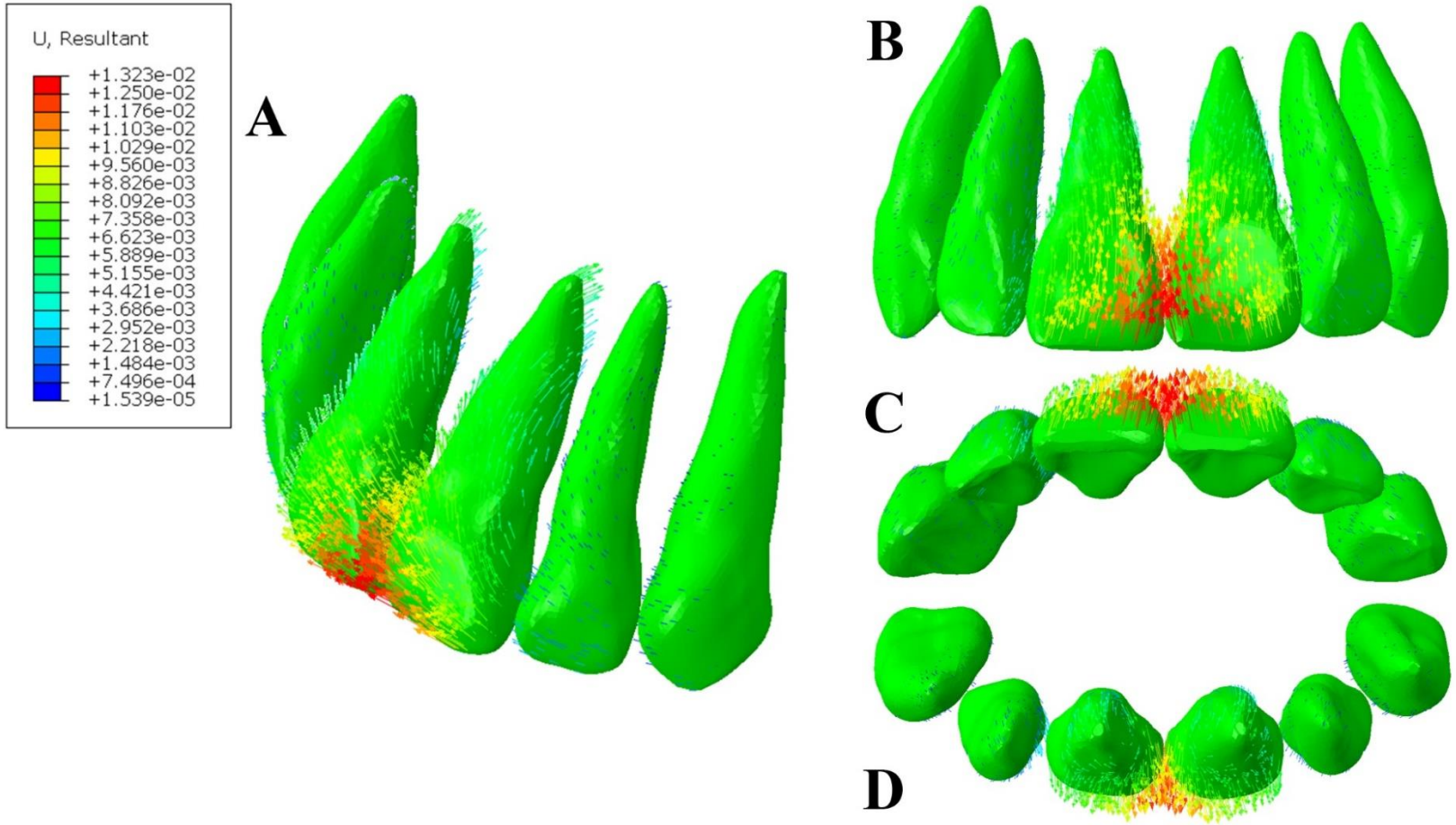

Figure 4.15 Overall displacement of the six maxillary anterior teeth in anchorage design 1. The direction of the arrows represents the direction of the movement of the teeth. The length and color of the arrows represent the distance of the movement of the teeth.

Displacement of the crowns and roots of the six maxillary anterior teeth in anchorage design 2 is shown in Table 4.2 and Figure 4.16. In the x-axis, the mesio-distal direction, the crowns of the six maxillary teeth moved distally and the root apices moved mesially. In the y-axis, the vertical direction, the crowns and root apices of all teeth were intruded. In the z-axis, the labio-palatal direction, the crowns of the central incisors moved palatally, whereas the crowns of the lateral incisors and canines moved labially. The root apices of all teeth moved palatally. The central and lateral incisors moved a similar distance to each other, but a greater distance than the canines.

Table 4.2 The displacement of each tooth in anchorage design 2.

Tooth	Part	Displacement (mm)		
		ΔX	ΔY	ΔZ
Right central incisor	Crown	-0.33E-3	1.61E-3	-0.64E-3
	Root	0.43E-3	1.34E-3	-1.08E-3
Right lateral incisor	Crown	-7.76E-5	1.92E-3	0.41E-3
	Root	0.24E-3	1.26E-3	-1.41E-3
Right canine	Crown	-0.19E-3	0.61E-3	0.26E-3
	Root	0.20E-3	0.33E-3	-0.38E-3
Left central incisor	Crown	0.91E-3	1.91E-3	-0.85E-3
	Root	-0.61E-3	1.73E-3	-1.28E-3
Left lateral incisor	Crown	0.49E-3	1.69E-3	0.41E-3
	Root	-0.44E-3	0.88E-3	-1.13E-3
Left canine	Crown	0.60E-3	0.30E-3	2.89E-5
	Root	-0.27E-3	7.53E-5	-0.18E-3

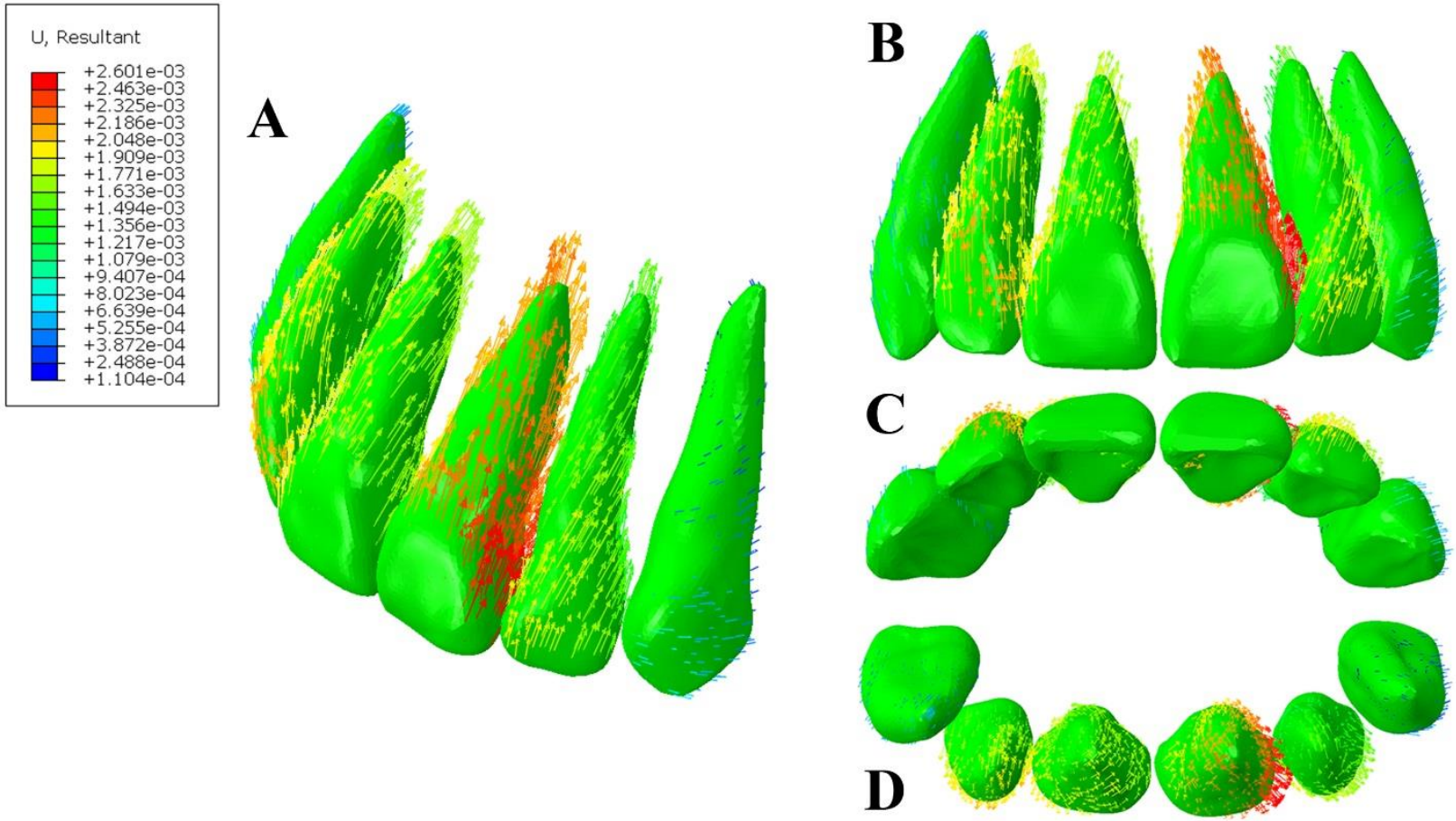

Figure 4.16 Overall displacement of the six maxillary anterior teeth in anchorage design 2. The direction of the arrows represents the direction of the movement of the teeth. The length and color of the arrows represent the distance of the movement of the teeth.

The displacement of the six-intruded maxillary anterior teeth was compared between anchorage designs 1 and 2. The central incisors in anchorage design 1 were intruded more than those in anchorage design 2, whereas the lateral incisors and canines in anchorage design 1 were intruded slightly lesser than those in anchorage design 2. However, the teeth in anchorage design 1 were proclined and rotated, the central incisors in anchorage design 2 were intruded along the long axis with no proclination, and the lateral incisors and canines were slightly proclined and rotated. The displacement of each tooth is shown in Figure 4.17.

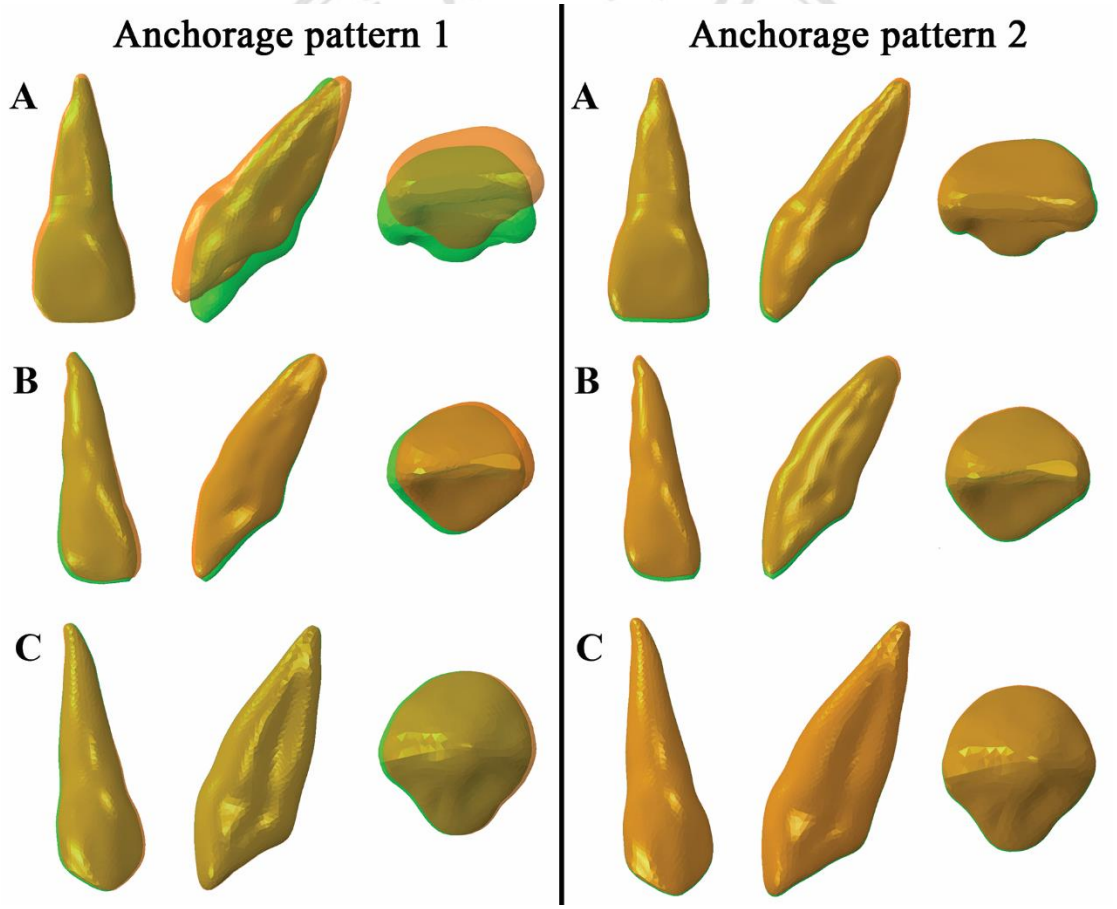

Figure 4.17 Displacement of teeth indicated by superimposition of before (green) and after (orange) loads of the teeth (Magnified differentiation). Each set of pictures consists of the labial, mesial and occlusal views, respectively. A) Right central incisor. B) Right lateral incisor. C) Right Canine.