EVALUACIÓN DE LOS EFECTOS EN DIENTES MAXILAR Y MANDIBULAR CON TRES CORRECTORES DE CLASE II: UN ANÁLISIS DE ELEMENTOS FINITOS

Jessica Paola Basto Tacuma
Especialista en Ortodoncia y ortopedia maxilar, Unicoc
Paula Alejandra Rojas plaza
Especialista en Ortodoncia y ortopedia maxilar, Unicoc

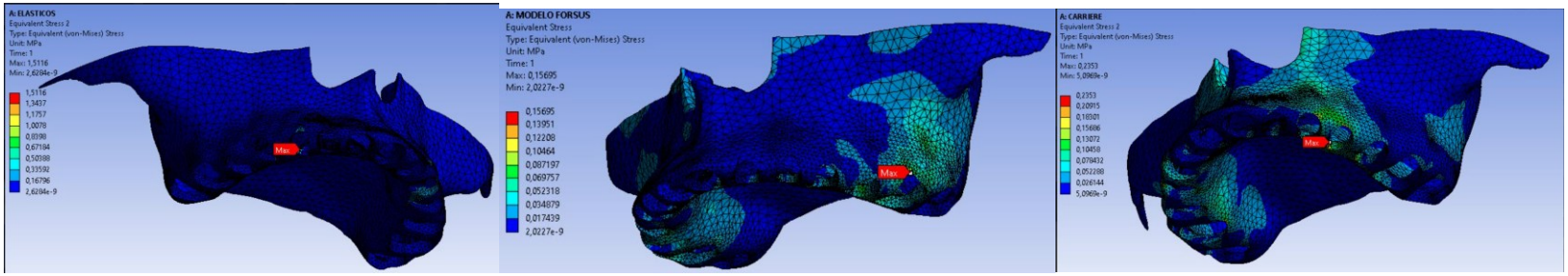
Anexos:
Figuras comparativas tomograficas 3D y Tablas de resultados.

Figuras comparativas

Figure 5. Comparative effects in the Von Misses stress between the FEM models of the 3 appliances on the maxillary.

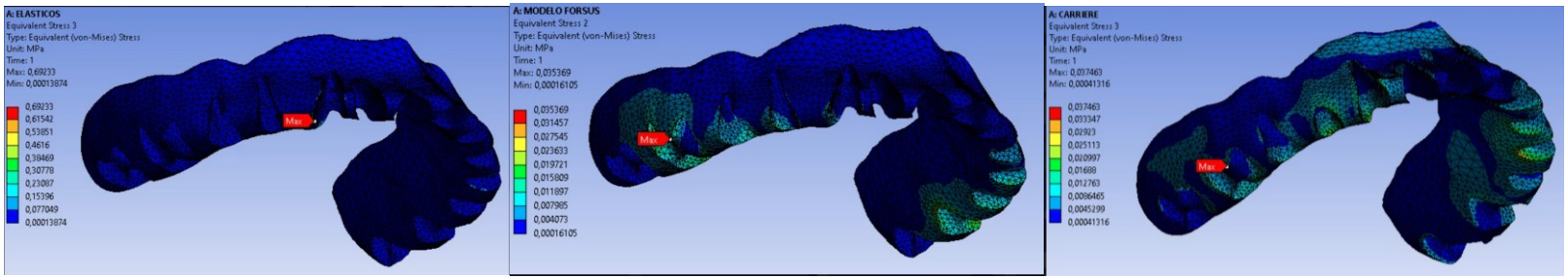
Class II Elastics **Forsus FRD** **CAM**

a. Cortical Bone



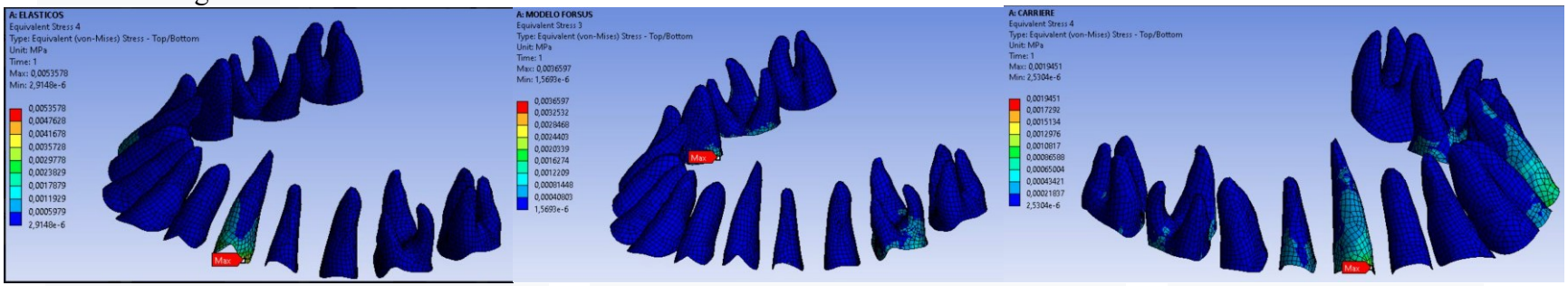
a1. Cortical Bone Class II elastics *a2. Cortical Bone Forsus FRD* *a3. Cortical Bone CMA*

b. Trabecular bone



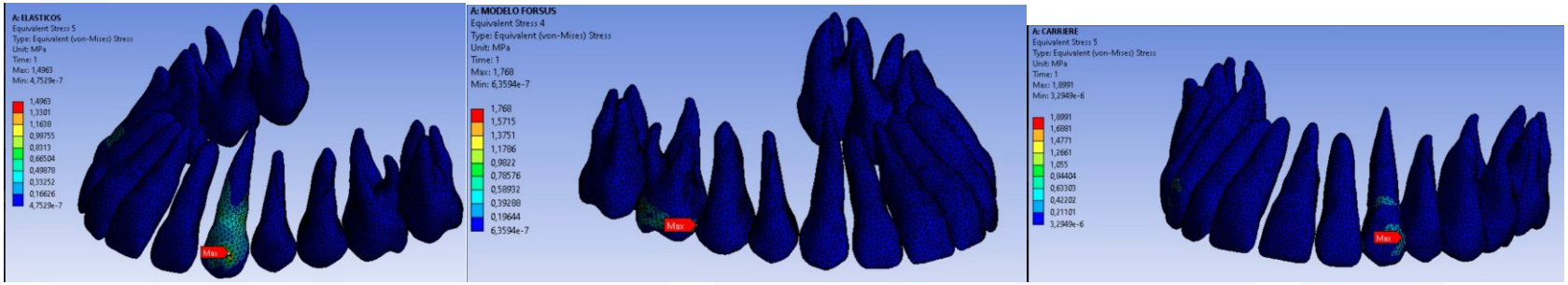
b1. Trabecular bone Class II elastics. *B2. Trabecular bone Forsus FRD* *b3. Trabecular bone CMA*

C. Periodontal ligament



c1. Periodontal ligament Class II eástics . *c2.* Periodontal ligament Forsus FRD *c3.* Periodontal ligament CMA

D. Teeth

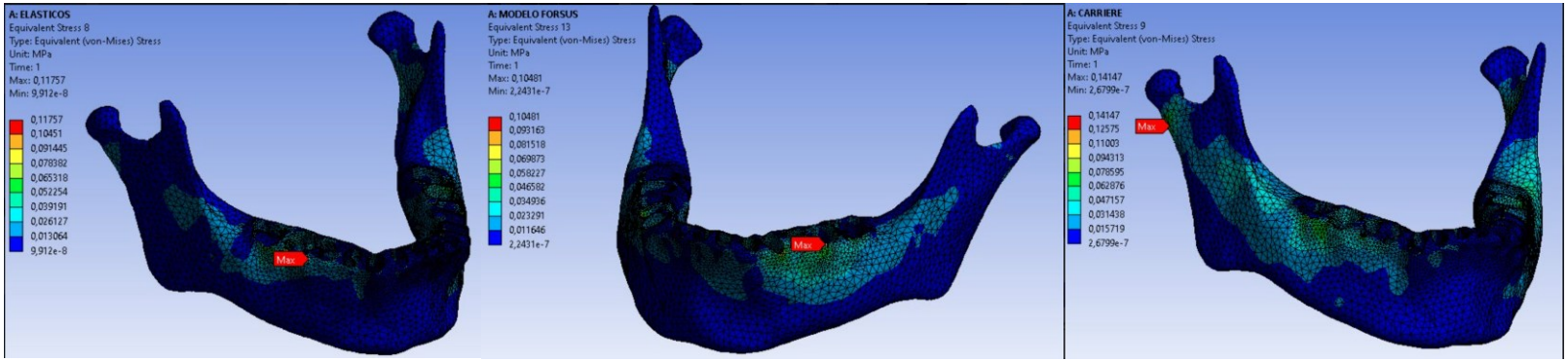


d1. Teeth Class II elastics *d2.* Teeth Forsus FRD *d3.* Teeth CMA

Figure 6. Comparative effects in the Von Misses stress between the FEM models of the 3 appliances in the Mandible.

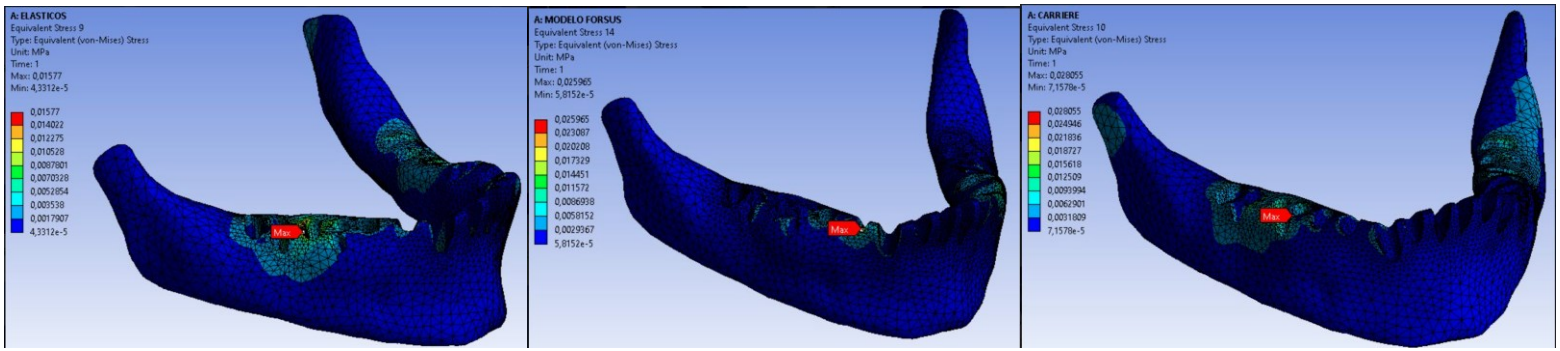
Class II Elastics **Forsus FRD** **CAM**

a. Cortical Bone



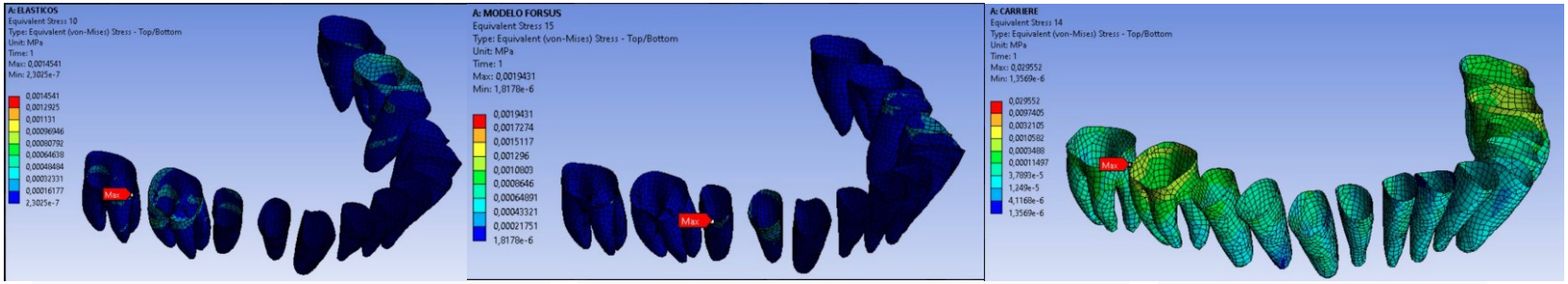
a1. Cortical Bone Class II elastics *a2. Cortical Bone Forsus FRD* *a3. Cortical Bone CMA*

b. Trabecular bone



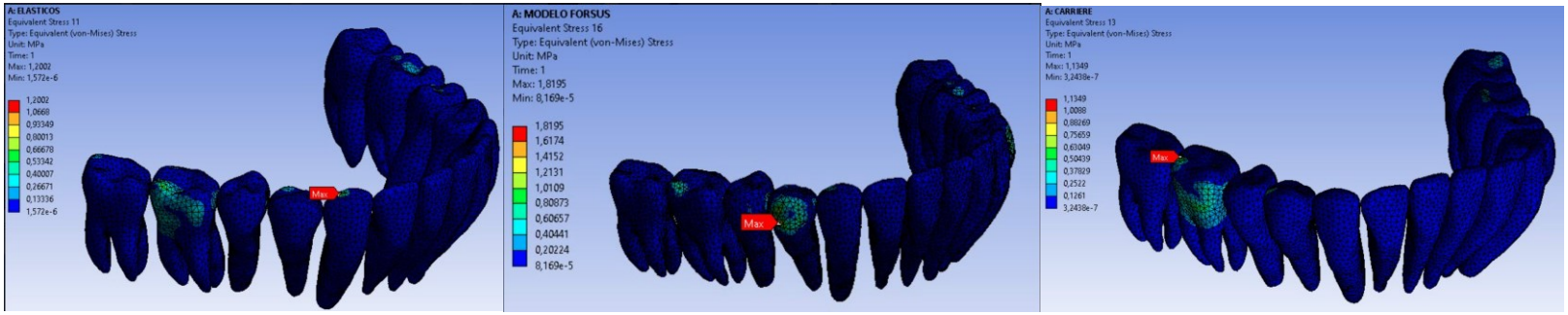
b1. Trabecular bone Class II elastics. *B2. Trabecular bone Forsus FRD* *b3. Trabecular bone CMA*

c. Periodontal ligament



c. Periodontal ligament Class II eástics *c.* Periodontal ligament Forsus FRD *c.* Periodontal ligament CMA

d. Teeth

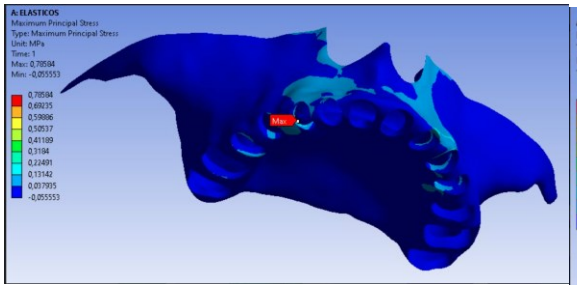


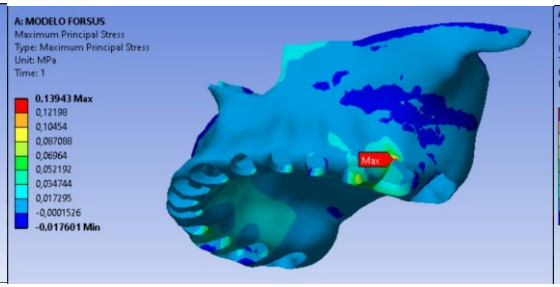
d1. Teeth Class II elastics *d2.* Teeth Forsus FRD *d3.* Teeth CMA

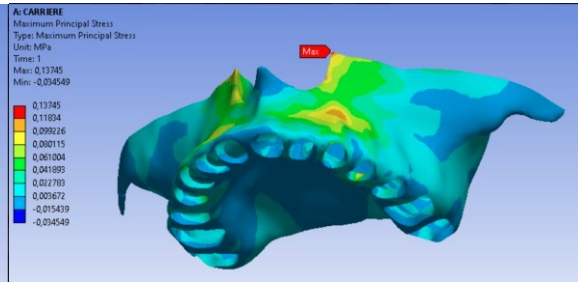
Figure 7. Comparative effects in the Maximum principal stress between the FEM models of the 3 appliances in the maxillary.

Class II Elastics **Forsus FRD** **CAM**

a. *Cortical Bone*

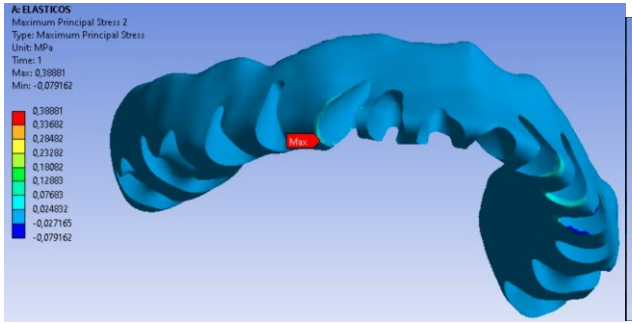


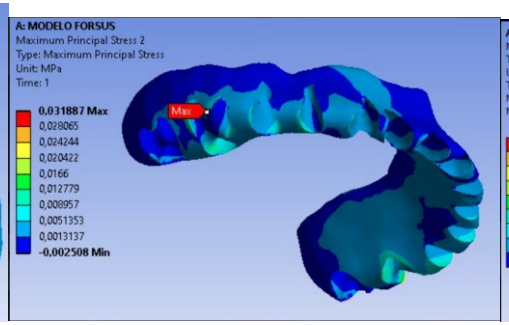


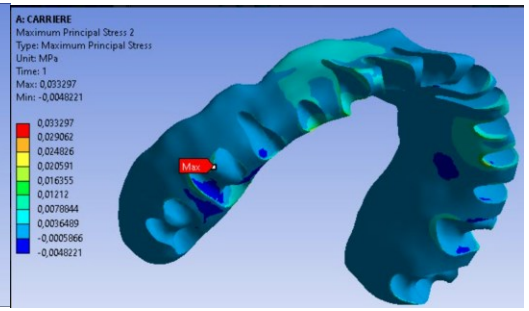


a1. Cortical Bone Class II elastics *a2. Cortical Bone Forsus FRD* *a3. Cortical Bone CMA*

b. Trabecular bone

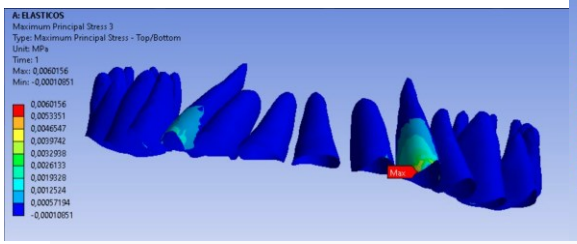


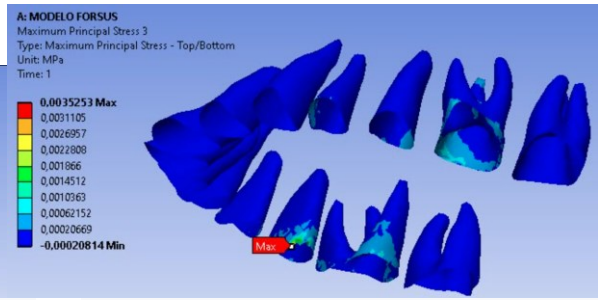


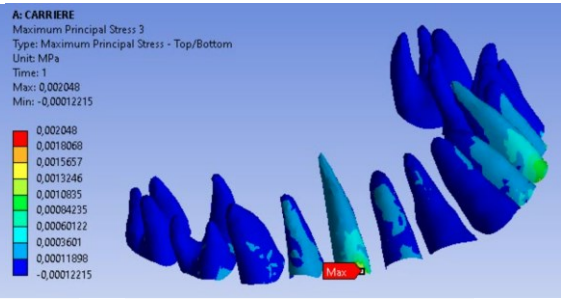


b1. Trabecular bone Class II elastics. *B2. Trabecular bone Forsus FRD* *b3. Trabecular bone CMA*

C. Periodontal ligament

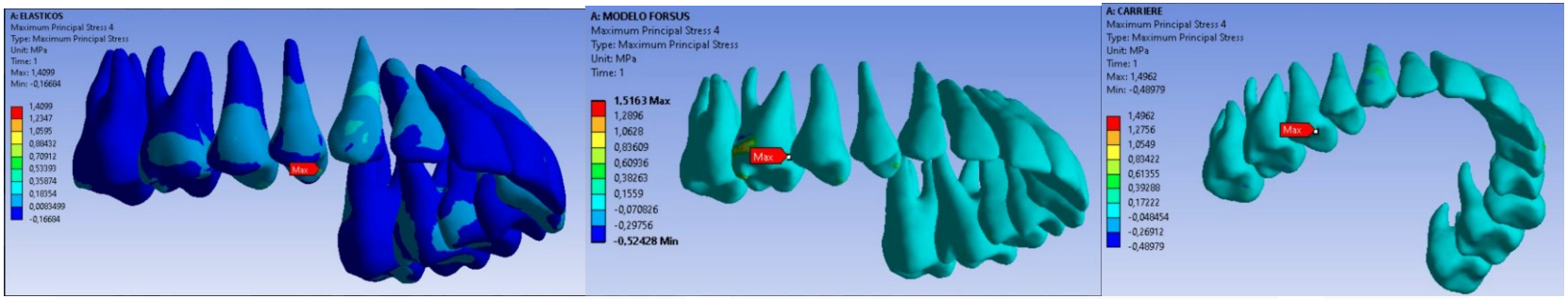






c1. Periodontal ligament Class II eástics *c2.* Periodontal ligament Forsus FRD *c3.* Periodontal ligament CMA

D. Teeth

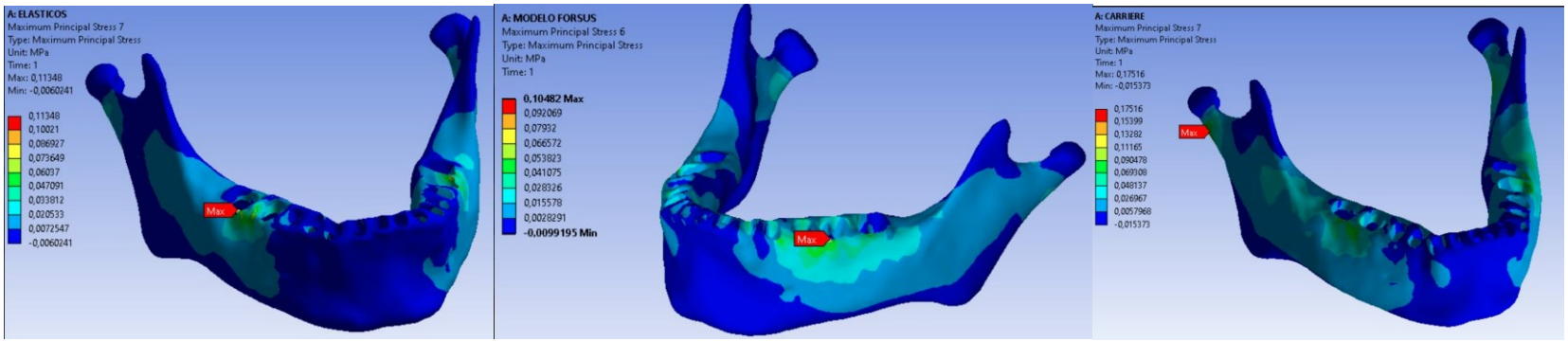


D1. Teeth Class II elastics *d2.* Teeth Forsus FRD *d3.* Teeth CMA

Figure 8. Comparative effects in the Maximum principal stress between the FEM models of the 3 appliances in the mandible.

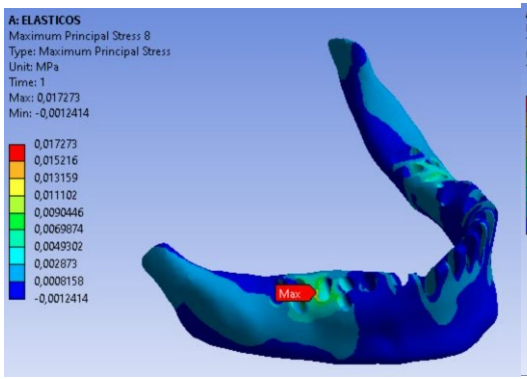
Class II Elastics **Forsus FRD** **CAM**

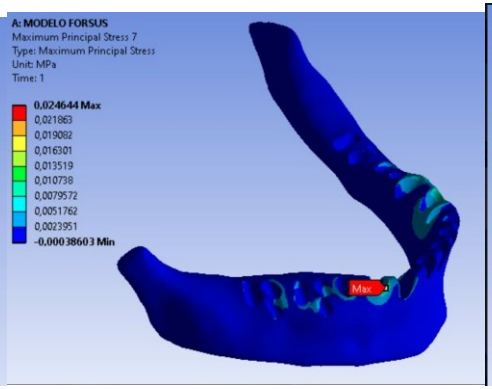
a. Cortical Bone

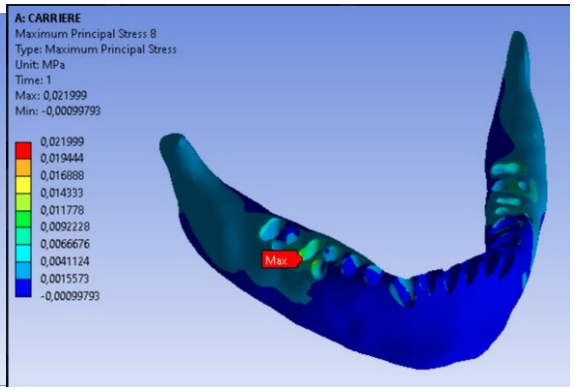


a1. Cortical Bone Class II elastics *a2. Cortical Bone Forsus FRD* *a3. Cortical Bone CMA*

b. Trabecular bone

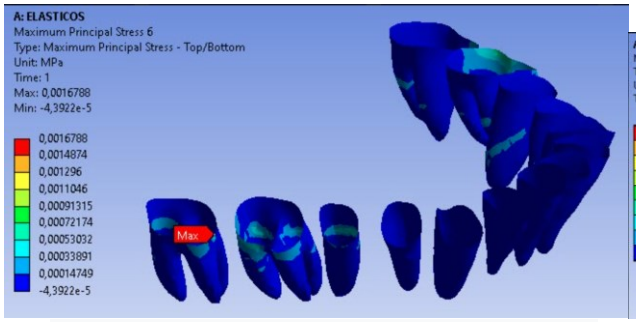


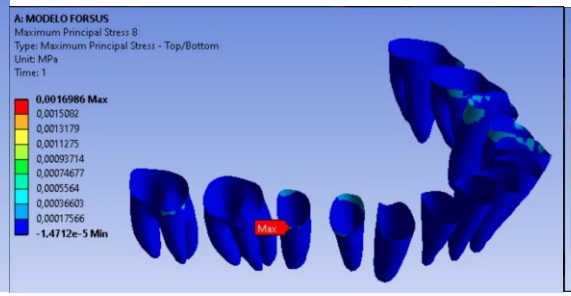


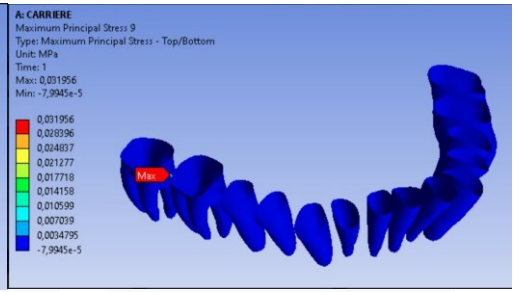


b1. Trabecular bone Class II elastics. *B2. Trabecular bone Forsus FRD* *b3. Trabecular bone CMA*

C. Periodontal ligament

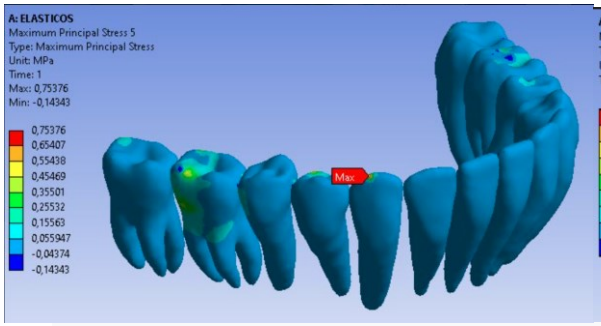




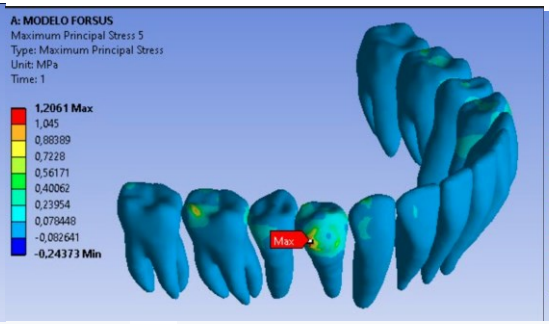


c1. Periodontal ligament Class II eástics *c2.* Periodontal ligament Forsus FRD *c3.* Periodontal ligament CMA

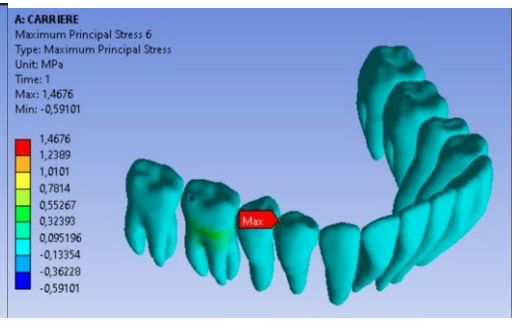
D. Teeth



d1. Teeth Class II elastics



d2. Teeth Forsus FRD

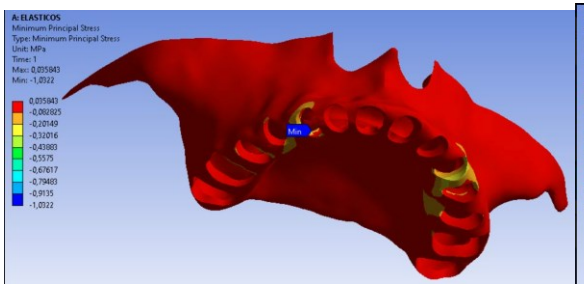


d3. Teeth CMA

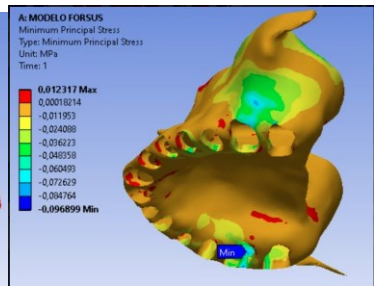
Figure 9. Comparative effects in the Minimum principal stress between the FEM models of the 3 appliances.in the Maxillary

Class II Elastics **Forsus FRD** **CAM**

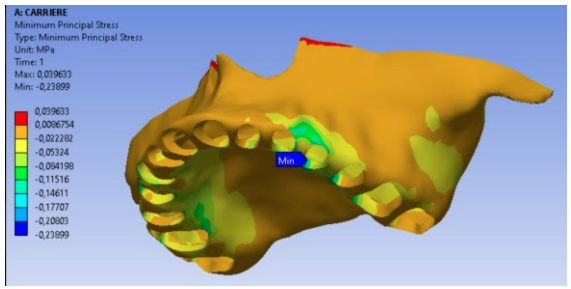
a. Cortical Bone



a1. Cortical Bone Class II elastics

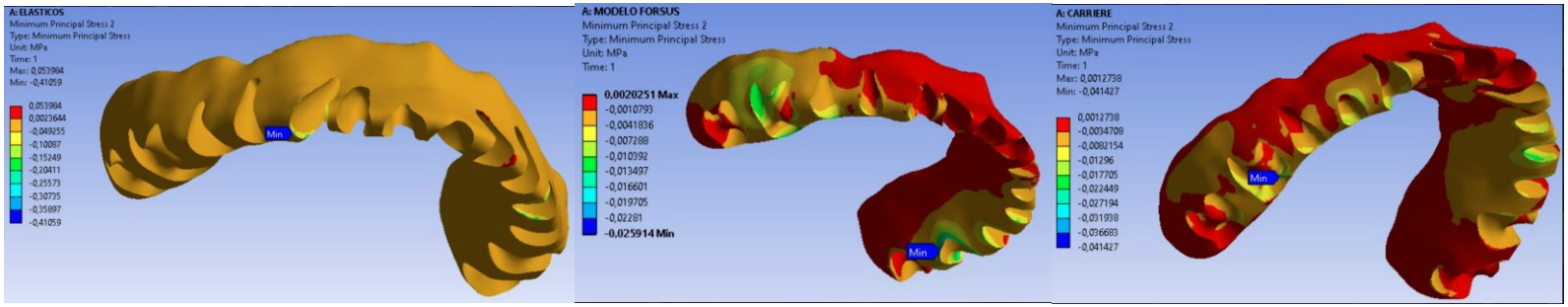


a2. Cortical Bone Forsus FRD



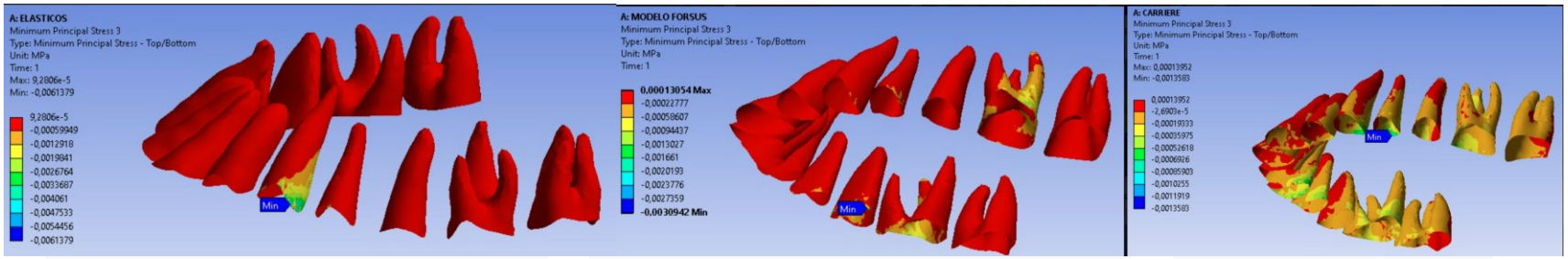
a3. Cortical Bone CMA

b. Trabecular bone



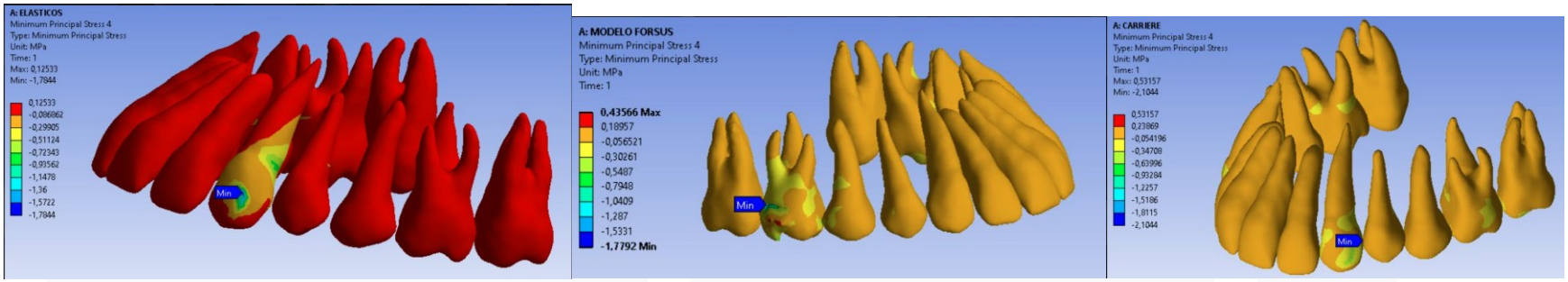
b1. Trabecular bone Class II elastics. *B2. Trabecular bone Forsus FRD* *b3. Trabecular bone CMA*

C. Periodontal ligament



c1. Periodontal ligament Class II eástics *c2.* Periodontal ligament Forsus FRD *c3.* Periodontal ligament CMA

D. Teeth

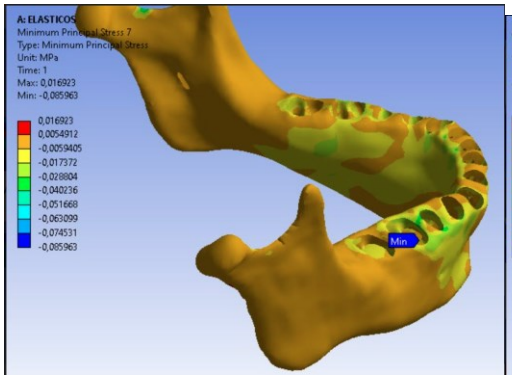


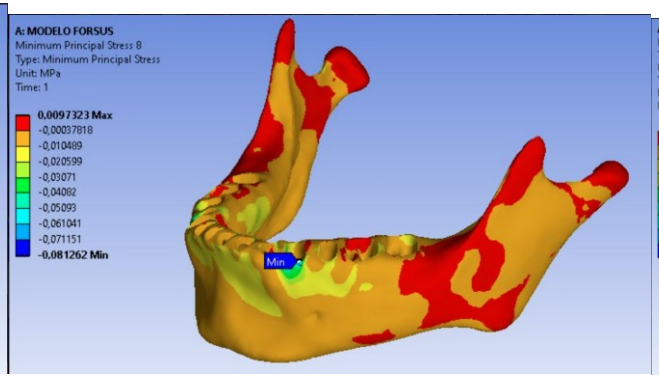
d1. Teeth Class II elastics *d2.* Teeth Forsus FRD *d3.* Teeth CMA

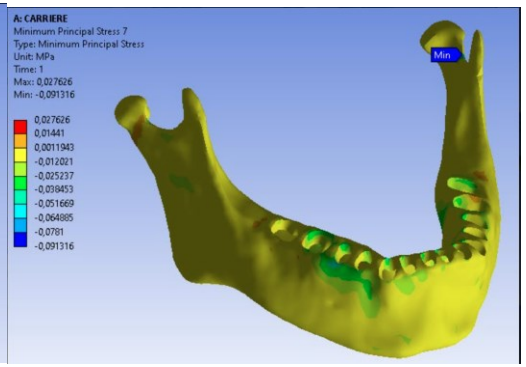
Figure 10. Comparative effects in the Minimum principal stress between the FEM models of the 3 appliances in the mandible.

Class II Elastics **Forsus FRD** **CAM**

a. Cortical Bone

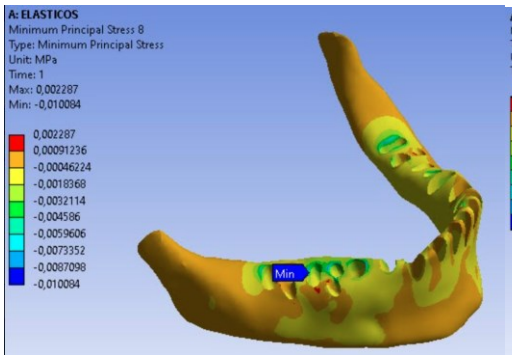


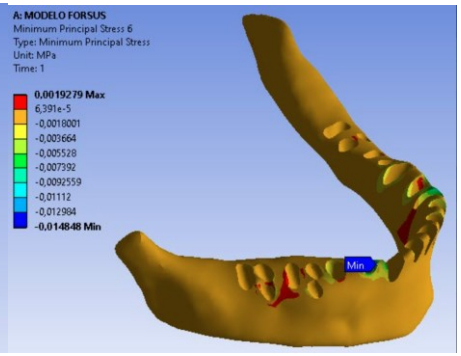


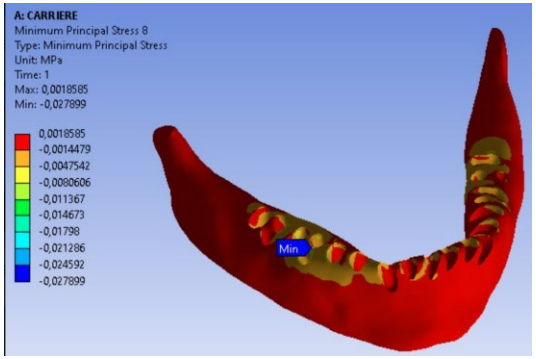


a1. Cortical Bone Class II elastics *a2. Cortical Bone Forsus FRD* *a3. Cortical Bone CMA*

b. Trabecular bone

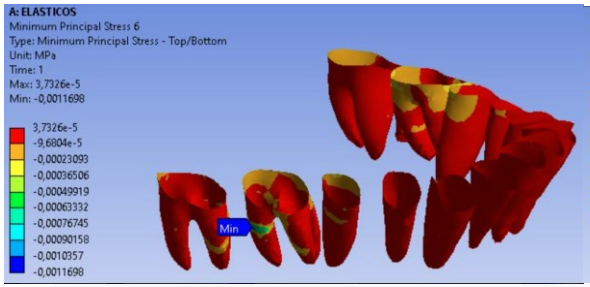


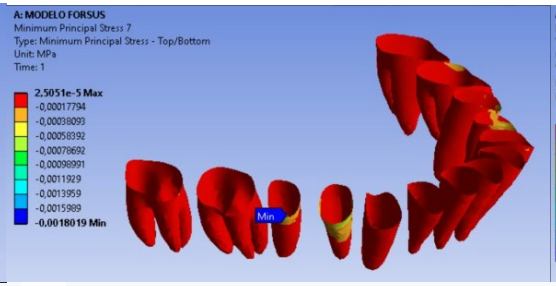


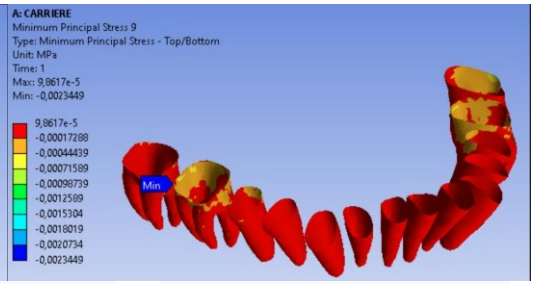


b1. Trabecular bone Class II elastics. *B2. Trabecular bone Forsus FRD* *b3. Trabecular bone CMA*

C. Periodontal ligament

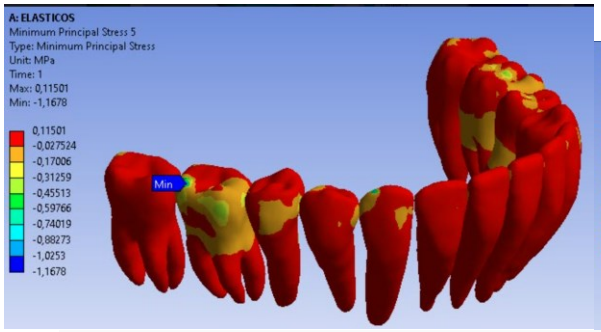


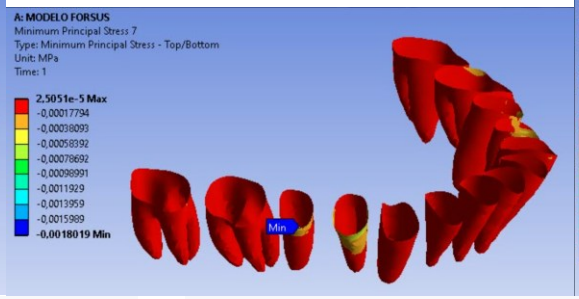


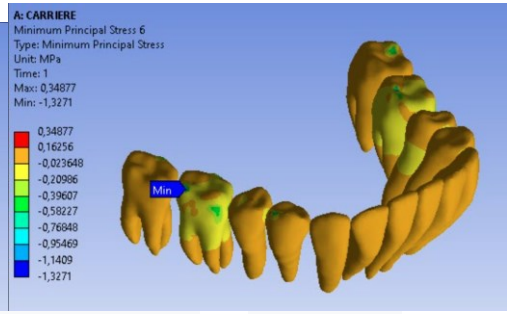


c1. Periodontal ligament Class II eástics *c2.* Periodontal ligament Forsus FRD *c3.* Periodontal ligament CMA

D. Teeth





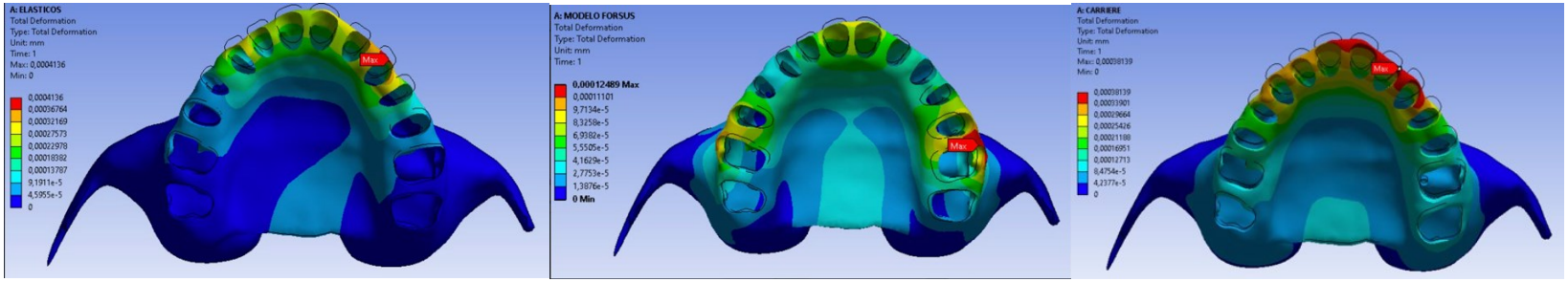


D1. Teeth Class II elastics *d2.* Teeth Forsus FRD *d3.* Teeth CMA

Figure 11. Comparative effects in the total deformation between the FEM models of the 3 appliances in the Maxillary with a deformation scale of 2.2 X 10^4

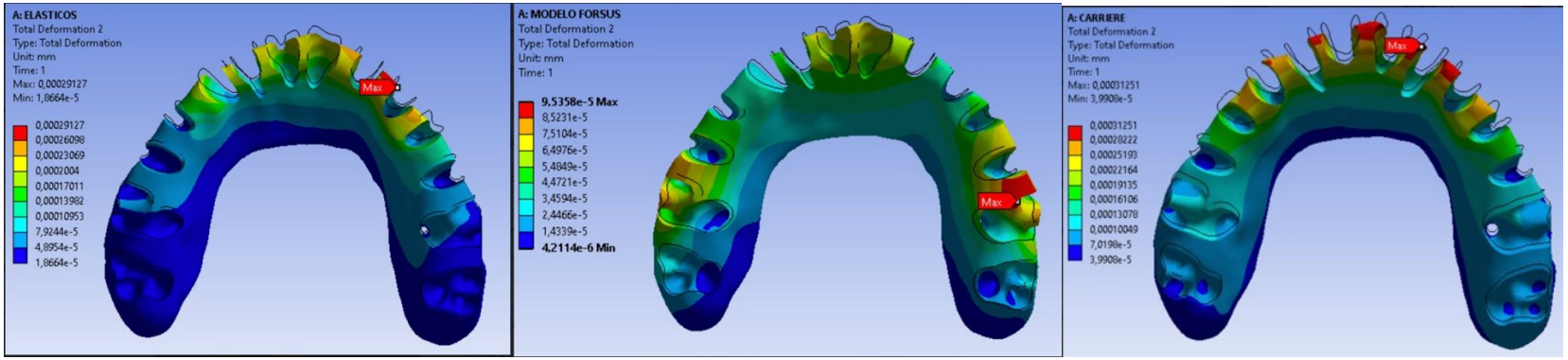
Class II Elastics **Forsus FRD** **CAM**

a. Cortical Bone



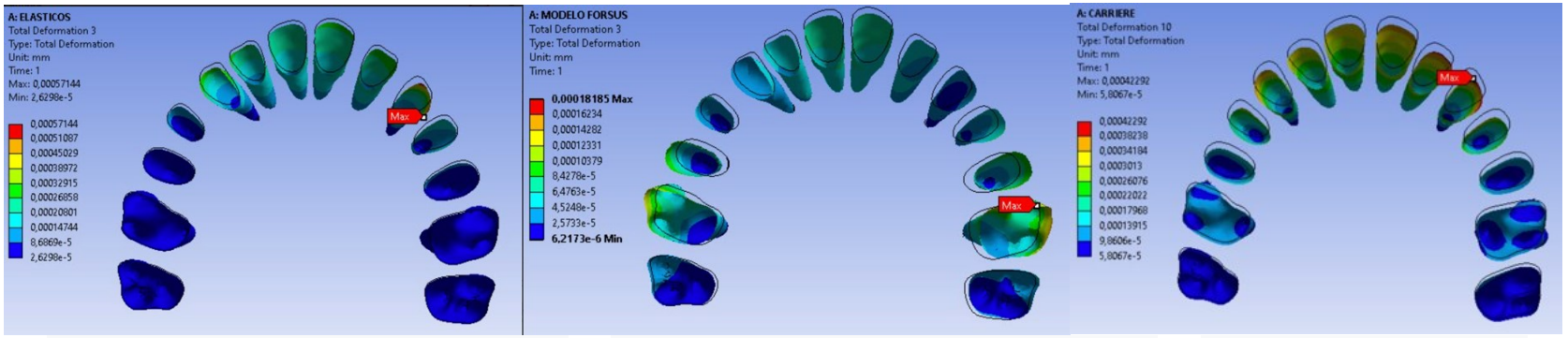
a1. Cortical Bone Class II elastics *a2. Cortical Bone Forsus FRD* *a3. Cortical Bone CMA*

b. Trabecular bone



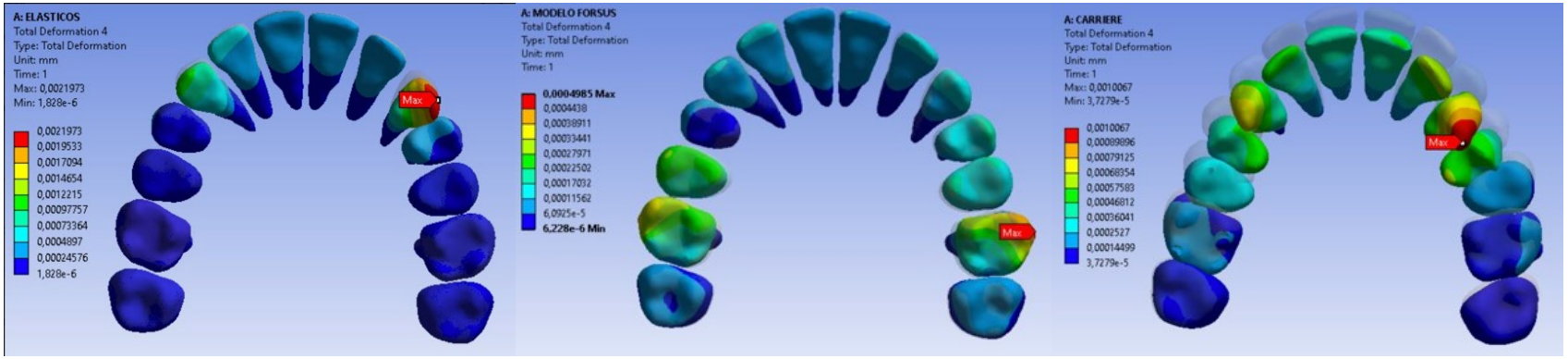
b1. Trabecular bone Class II elastics. *B2. Trabecular bone Forsus FRD* *b3. Trabecular bone CMA*

C. Periodontal ligament



c1. Periodontal ligament Class II elastics *c2.* Periodontal ligament Forsus FRD *c3.* Periodontal ligament CMA

D. Teeth

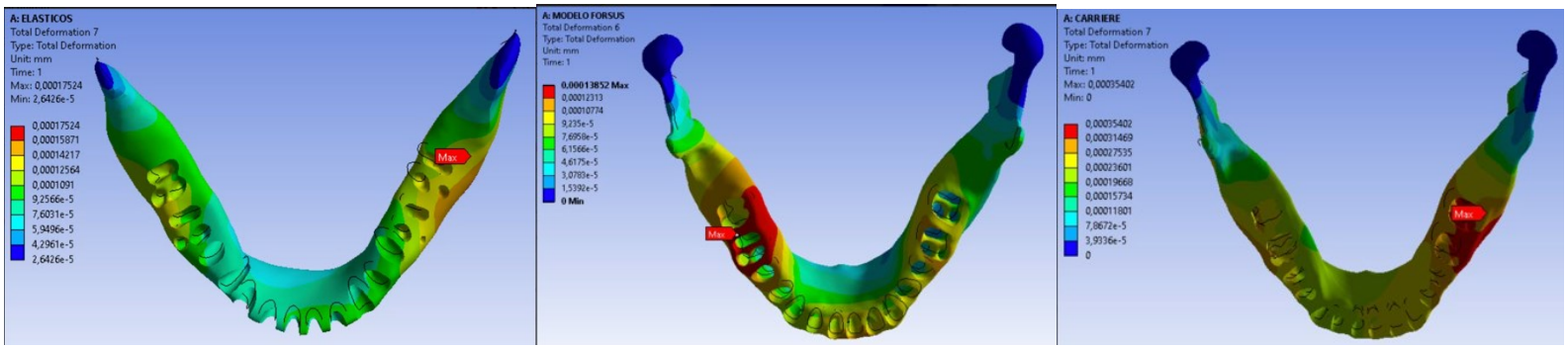


d1. Teeth Class II elastics *d2.* Teeth Forsus FRD *d3.* Teeth CMA

Figure 12. Comparative effects in the total deformation between the FEM models of the 3 appliances in the Mandible with a deformation scale of 2.2 X 10^4

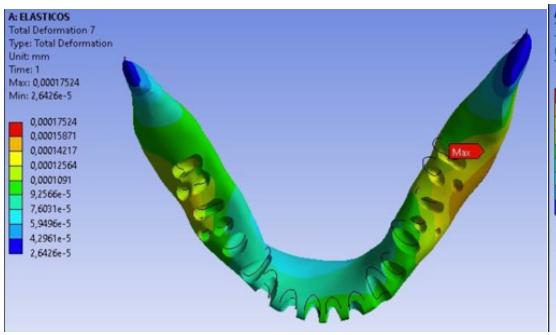
Class II Elastics **Forsus FRD** **CAM**

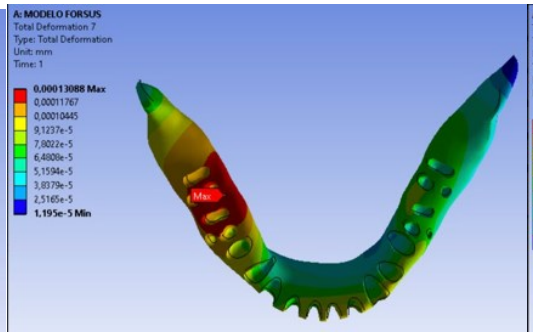
a. Cortical Bone

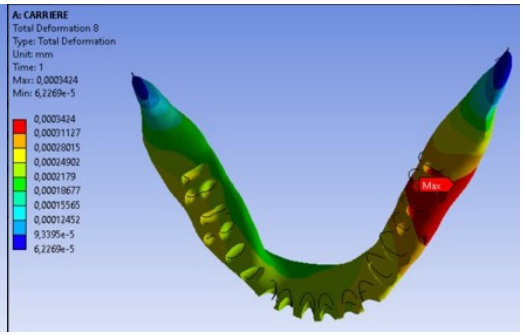


a1. Cortical Bone Class II elastics *a2. Cortical Bone Forsus FRD* *a3. Cortical Bone CMA*

b. Trabecular bone

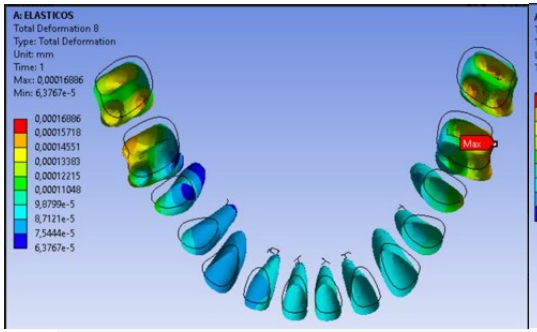


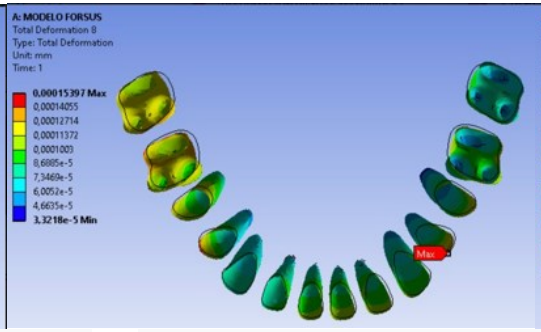


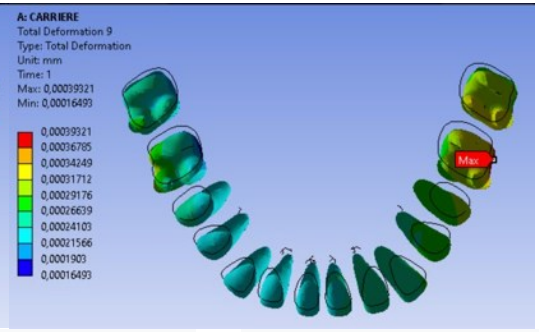


b1. Trabecular bone Class II elastics. *B2. Trabecular bone Forsus FRD* *b3. Trabecular bone CMA*

C. Periodontal ligament

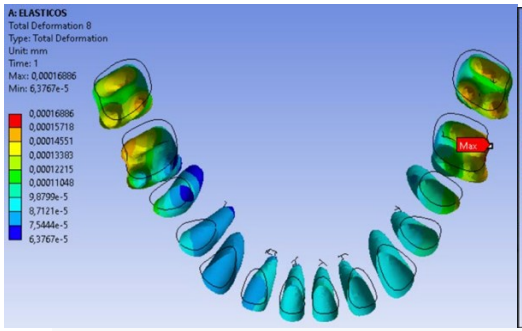




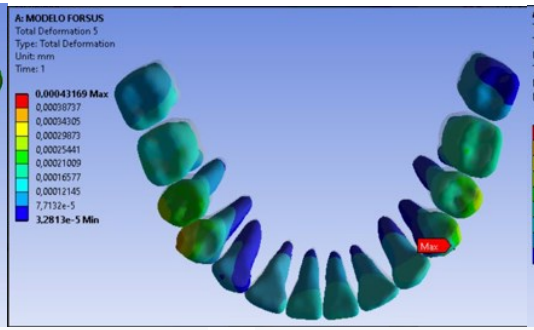


C1. Periodontal ligament Class II elastics *c2.* Periodontal ligament Forsus FRD *c3.* Periodontal ligament CMA

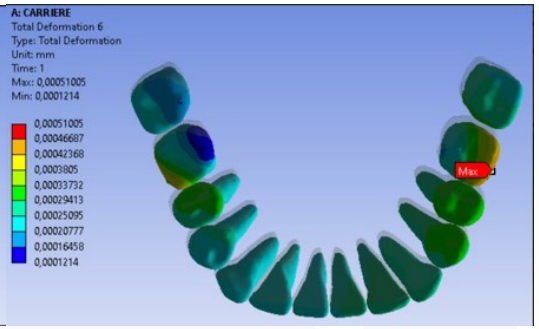
D. Teeth



d1. Teeth Class II elastics



d2. Teeth Forsus FRD



d3. Teeth CMA

Table 1 Constants for the Mooney-Rivlin equation

Constant	Value (MPa)
C10	-0.2055
C01	0.42
C11	4.24

Table 2. 1 Material properties of anatomic structures and materials in de FEM model.

Structure	*Young's modulus* N/mm^2	*Poisson's ratio*	*Element type*	*Material Type*
Teeth(1)	20.300	0.30	Tetrahedron /quad	Isotropic homogenous elastic
Enamel(2)	84.120	0.33	Tetrahedron /quad	Isotropic homogenous elastic
Dentine(2)	18.600	0.31	Tetrahedron /quad	Isotropic homogenous elastic
Cement(1)	18.600	0.31	Tetrahedron /quad	Isotropic homogenous elastic
Periodontal ligament(1)	69.000	0.45	Tetrahedron /quad	Nonlinear viscoelastic
Bone(1)	140.000	0.30	Tetrahedron	Isotropic homogenous elastic
Cancellous bone(1)	13.700	0.38	Tetrahedron	Isotropic homogenous elastic
Cortical Bone(1)	34.000	0.26	Tetrahedron	Isotropic homogenous elastic
Clear aligner(3)	1000	0.40	Shell	Isotropic homogenous elastic
Stainless steel(4)	210000	0.3	Prismatic/quad	Isotropic homogenous elastic

Table 3. Maxillary von Mises Stress results

FEM models of Appliances			
	Class II elastics	**FRD**	**CAM**
# Nodes	1.207.182	1.280.801	933.279
#Elements	748.983	771.350	5.99.868
STRUCTURES	**von Mises Stress (MPa)**	**von Mises Stress (MPa)**	**von Mises Stress (MPa)**
Cortical Bone Place of maximum value	Palatal center of cervical area of upper canine	Buccal center of cervical area of upper first molar	Buccal center of cervical area of upper second premolar
Maximum value	1.5116	0.15695	0.2353
Minimum value	2.684e-9	2.0227e-9	5.0969e-9
Trabecular Bone Place of maximum value	Distal- palatal cervical area of upper canine	Buccal center of cervical area of upper first molar	Buccal center of cervical area of upper first molar
Maximum value	0.69233	0.0355369	0.037463
Minimum value	0.00013874	0.00016105	0.00041316
PDL Place of maximum value	Distal cervical area of upper canine	Palatal cervical area of upper second premolar	Buccal mesial cervical area of upper canine
Maximum value	0.00533578	0.0036597	0.0019451
Minimum value	2.9148e6	1.5693e-6	2.5304e-6
Teeth Place of maximum value	Buccal center of the crown of upper canine	Buccal distal area of the crown of upper second premolar	Buccal Mesial area of the crown of upper canine
Maximum value	1.4963	1.768	1.8991
Minimum value	4.7529e-7	6.3594e-7	3.2949e-6

Table 4. Mandibular von Mises Stress results

FEM models of Appliances			
	Class II elastics	**FRD**	**CAM**
# Nodes	1.207.182	1.280.801	933.279
#Elements	748.983	771.350	5.99.868
STRUCTURES	**Von Misses Stress (MPa)**	**Von Misses Stress (MPa)**	**Von Misses Stress (MPa)**
Cortical Bone Place of maximum value	Mesial of the lower first molar	Mesial of the lower first molar	Buccal mesial cervical area of the lower second molar
Maximum value	0.11757	0.10481	0.14147
Minimum value	9.912e8	2.2431e-7	2.6799e-7
Trabecular Bone Place of maximum value	Mesial of the lower first molar	Mesial of the lower first premolar	Mesial of the lower first premolar
Maximum value	0.01577	0.025965	0.028055
Minimum value	4.3312e-5	5.8152e-5	7.1578e-5
PDL Place of maximum value	Mesial cervical area of lower second molar	Vestibular cervical area of lower second premolar	Distal-cervical area of the lower first molar
Maximum value	0.0014541	0.0019431	0.02955
Minimum value	2.3025e-7	1.8178e-6	1.3569e6
Teeth Place of maximum value	Distal slope of lower canine	Center of the crown of the lower first premolar	Occlusal on the distobuccal groove of the first lower molar
Maximum value	1.2002	1.8195	1.1349
Minimum value	1.572e-6	8.169e-5	3.2438e-7

Table 5. Maxillary Maximum and Minimum principal stress results

FEM models of Appliances						
	Class II elastics		**FRD**		**CAM**	
# Nodes	1.207.182		1.280.801		933.279	
#Elements	748.983		771.350		5.99.868	
STRUCTURES	**Maximum principal stress**	**Minimum principal stress**	**Maximum principal stress**	**Minimum principal stress**	**Maximum principal stress**	**Minimum principal stress**
Cortical Bone Place of maximum value	Distal cervical area of upper canine	Disto palatal cervical area of upper canine	Buccal center of cervical area of upper first molar	Palatal center of cervical area of upper first molar	Buccal apical area of the upper canine	Palatal center of cervical area of upper first premolar
Maximum value	0.78584	0.035843	0.13943	0.012317	0.13745	0.039633
Minimum value	-0.055553	-1.0322	-0.017601	-0.096899	-0.034549	-0.23899
Trabecular Bone Place of maximum value	Distal cervical area of upper canine	Distal cervical area of upper canine	Buccal center of cervical area of upper first molar	Disto palatal cervical area of upper second molar	Buccal center of cervical area of upper first molar	Palatal center of cervical area of upper first molar
Maximum value	0.38881	0.053984	0.031887	0.0020251	0.033297	0.0012738
Minimum value	-0.079162	-0.41059	-0,002508	-0.025914	-0.0048221	-0.041427
PDL Place of maximum value	Mesial cervical area of upper canine	Distal cervical area of upper canine	Palatal center of cervical area of upper second premolar	Palatal distal area of upper second premolar	Buccal cervical area of upper canine	Palatal center of cervical area of upper first premolar
Maximum value	0.0060156	9.286e-5	0.0035253	0.00013054	0.002048	0.00013952
Minimum value	-0.00010851	-0.0061379	-0.00020814	-0.0030942	-0.00012215	-0.0013583
Teeth Place of maximum value	Distal slope of palatal cusp of the upper first premolar	Buccal center of the crown of upper canine	Mesial center of the crown of upper first molar	Buccal distal area of the crown of upper first molar	Mesial slope of bucal cusp of the upper second premolar	Mesial center of the crown of upper first premolar
Maximum value	1.4099	0.12533	1.5163	0.43566	1.4962	0.053157
Minimum value	-0.16684	-1.7844	-0.52428	-1.7792	-0.48979	-2.1044

Table 6. Mandibular Maximum and Minimum principal stress results

FEM models of Appliances						
	Class II elastics		**FRD**		**CAM**	
# Nodes	1.207.182		1.280.801		933.279	
#Elements	748.983		771.350		5.99.868	
STRUCTURES	**Maximum principal stress**	**Minimum principal stress**	**Maximum principal stress**	**Minimum principal stress**	**Maximum principal stress**	**Minimum principal stress**
Cortical Bone Place of maximum value	Buccal cervical area of the lower second molar	Mesial buccal cervical area of the lower first molar	Buccal cervical area of the lower first molar	Palatal center cervical area of the lower first premolar	Buccal interproximal area of lower first and second molar	Lingual cervical area of the lower first molar
Maximum value	0.11348	0.016923	0.10482	0.0097323	0.17516	0.027626
Minimum value	-0.006024	-0.085963	-0.0028291	-0.081262	-0.015373	-0.091316
Trabecular Bone Place of maximum value	Distal cervical area of the distal root of the lower first molar	Lingual cervical area of the distal root of the lower first molar	Mesial cervical area of the lower first premolar	Disto Palatal cervical area of first lower molar	Buccal Mesial cervical area of the lower first molar	Buccal Mesial cervical area of the lower first molar
Maximum value	0.017273	0.002287	0.0019279	0.0020251	0.021999	0.0018585
Minimum value	-0.0012414	-0.010084	-0.014848	-0.02591	-0.00099793	-0.027899
PDL Place of maximum value	Mesial cervical area of the lower second molar	Second third of the distal root of the lower first molar	Buccal cervical area of the lower second premolar	Buccal cervical area of the lower second premolar	Distal-cervical area of the lower first molar	Mesial- vestibular cervical area of lower first molar
Maximum value	0.0016788	3.7326e-5	0.0016986	2.5051e-5	0.031956	9.8617e-5
Minimum value	-4.3922e-5	-0.0011698	-1.4712e-5	-0.0018019	-7.9945e-5	-0.0023449
Teeth Place of maximum value	Distal slope of lower canine	Occlusal on the distobuccal groove of the first lower molar	Ditobucal center of the crown of the lower first premolar	Center of the crown of the lower first premolar	Occlusal on the distobuccal groove of the second lower first molar	Occlusal on the distobuccal groove of the first lower molar
Maximum value	0.75376	0.11501	1.2061	0.14016	1.4676	0.34877
Minimum value	-0.143443	-1.1678	-0.24373	-2.0897	-0.59101	-1.3271

Table 7. Total deformation Maxillary

FEM models of Appliances			
	Class II elastics	**FRD**	**CAM**
# Nodes	1.207.182	1.280.801	933.279
#Elements	748.983	771.350	5.99.868
STRUCTURES			
Cortical Bone Place of maximum value	Buccal cervical area of upper canine	Mesialbucal cervical area of the of upper first molar	Distobuccal cervical area of upper lateral incisor
Maximum value	0.0004136	0.00011101	0.00038139
Minimum value	0	0	0
Trabecular Bone Place of maximum value	Mesialbucal cervical area of upper canine	Mesial cervical area of the of upper first molar	Mesialbuccal cervical area of upper lateral incisor
Maximum value	0.00029127	9,5358e-5	0.00031251
Minimum value	1.8664e-5	4.211e-6	3,9908e-5
PDL Place of maximum value	Distal cervical area of upper canine	Mesial cervical area of the of upper first molar	Distobuccal cervical area of upper canine
Maximum value	0.00057144	0.00018185	0.00042292
Minimum value	2,6298e-5	6,2173e-6	5.8067e-5
Teeth Place of maximum value	Cusp tip of upper canine	Distobuccal of the crown of lower first molar	Distal slope of upper canine
Maximum value	0.0021973	0.0004985	0.0010067
Minimum value	1.828e-6	6.228e-6	3.7279e-5

Table 8. Total deformation Mandibular

FEM models of Appliances			
	Class II elastics	**FRD**	**CAM**
# Nodes	1.207.182	1.280.801	933.279
#Elements	748.983	771.350	5.99.868
STRUCTURES			
Cortical Bone Place of maximum value	Buccal distal area of the lower second molar	Distobuccal cervical area of lower first molar	Buccal cervical area of lower second molar
Maximum value	0.00017524	0.00013852	0.00035402
Minimum value	2.6426e-5	0	0
Trabecular Bone Place of maximum value	Buccal distal area of the lower second molar	Mesiolingual cervical area of lower second molar	Distobuccal cervical area of lower lateral incisor
Maximum value	0.00017524	0.00013088	0.0003424
Minimum value	2.6426e-5	1.195e-5	6.2269e-5
PDL Place of maximum value	Buccal cervical area of lower first molar	Buccal cervical area of lower canine	Buccal cervical area of lower first molar
Maximum value	0.00016886	0.00015397	0.00039321
Minimum value	6.3767e-5	3.3218e-5	0.00016493
Teeth Place of maximum value	Buccal cervical area of lower first molar	Buccal center of crown of the lower canine	Buccal center of crown of lower first molar
Maximum value	0.00016886	0.00043169	0.00051005
Minimum value	6.3767e-5	3.2813e-5	0.0001214