Original Research Paper

Influence of Orthodontic Movement by Bracketless Orthodontic Treatment on Stress Distribution: 3D Finite Element Analysis

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Abstract: The Bracketless Orthodontic Treatment (BOT) is an alternative technique with the concept of installing an orthodontic appliance composed only of wires and composite resin with the aid of 3D technology. However, the biomechanical behavior of this therapeutic modality has yet to be elucidated in the scientific literature. Thus, the objective of this study was to evaluate the stress distribution in tooth movement through 3D Finite Element Analysis (3D FEA) using different displacements (0.15, 0.25 and 0.35 mm) and wire thicknesses (0.012", 0.014" and 0.016") of nickel-titanium wire (NiTi) with BOT. Thus, 3D modeling of a complex structure composed by enamel, dentin, cortical bone, medullary bone, periodontal ligament, composite resin and different orthodontic wire diameters was performed. After modeling, the set was exported to computer-aided engineering software, subdivided into a finite number of elements and a mechanical structural static analysis was subsequently performed. The results were plotted on colorimetric charts for qualitative comparison and the stress peaks on tables for quantitative comparison between the different models. The results showed that orthodontic movement with BOT does not induce damage to the periodontal ligament, dental root or bone tissue, regardless of the simulated orthodontic wire diameter and applied load. The occlusal composite resin and orthodontic wire also presented acceptable stress values during orthodontic activation. Thus, the Bracketless Orthodontic Treatment technique presents a promising biomechanical response during tooth movement with a low risk of damage.

Keywords: Biomechanics, Orthodontics, Finite Element Analysis, Orthodontic Brackets

Introduction

Adolescent and adult patients are more resistant to the use of dental brackets. Many patients claim that even aesthetic (ceramic) brackets do not convey absolute aesthetics. Thus, aligners and lingual orthodontics gain their space with this present demand (da Fonseca Junior *et al*., 2019).

Lingual brackets have considerable advantages, mainly because they are imperceptible as they are bonded to the lingual face of the teeth. On the other hand, the lingual bracket technique leads to initial complaints such as: Hygiene difficulties, altered phonation, tongue discomfort and reduced space. In turn, the aligners are not entirely imperceptible and depend on frequent collaboration regarding its use (Musilli *et al*., 2012).

Most aligner systems recommend a minimum use of 20 h a day and the treatment success is directly linked to regularity and collaboration on the part of the patient (Musilli *et al*., 2012).

The Bracketless Orthodontic Treatment (BOT) is an alternative orthodontic appliance concept composed of only wires and composite resin (Musilli, 2008). This concept arose from the need to stabilize the anterior teeth with fixed retaining, added to the need for little movement and alignment. Thus, it is possible to obtain the desired tooth movement without brackets through the pre-activation of an orthodontic wire (Musilli, 2008; Musilli *et al*., 2012).

Some authors recommend that teeth alignment by BOT should be considered as the first treatment option for cases when aesthetics is considered an important objective, since the appliance is not visible (Mariniello and Cozzolino, 2008). In addition, according to patients, this technique is more comfortable than lingual brackets (Mariniello and Cozzolino, 2008).

According to the literature, orthodontic teeth movements must be achieved using nickel-titanium wires or multi-strand wires applying the commonly used biomechanical principles in conventional orthodontic treatments (Mariniello and Cozzolino, 2008; Musilli *et al*., 2012).

Therefore, the BOT technique includes several advantages such as: (1) Absolute control of protrusion/lingualization by measuring the wires used and previously dimensioned in the prototyped models; (2) Control of the arch shape and the planned expansion; (3) Control of established vertical and anteroposterior movements, also by printed prototypes; (4) It allows the orthodontist to know all the necessary movements established in the planning in advance in degrees and millimeters; (5) It enables previous construction of the arches, minimizing the chair time and establishing a relationship of trust with the patient when all the movements to be performed are demonstrated through a physical model, helping the orthodontist to establish the total treatment time more accurately; (6) It does not interfere in the diction/phonetics of patients and with little interference in hygiene; (7) It is imperceptible (aesthetic) and comfortable; (8) It is fast and efficient; (9) It does not depend on the patient's collaboration because it is a fixed technique; (10) It is a self-ligating technique, straight-wire which allows it to slide when necessary. In addition, it is possible to be used in different clinical cases (da Fonseca *et al*., 2019; Tavares *et al*., 2019).

However, biomechanical evaluation of the effect of this therapeutic modality on posterior teeth has not yet been reported in the literature. It is especially important considering the effect of different tooth movements and that different orthodontic wire diameters and occlusal resin can be used, but have not yet been studied in the BOT, thus justifying the present study.

A methodology which can be used to biomechanically evaluate orthodontic movement is Finite Element Analysis (FEA). FEA is a reliable, economical and fast experimental analysis (when correctly performed). The role of FEA in treatment planning, bone remodeling, determining the center of resistance and rotation and retraction has helped in understanding the biomechanics of tooth movement, thus contributing to advancement of orthodontics treatments (Singh *et al*., 2016). In view of this, the objectives of this study were to evaluate through FEA the following: The stress distribution in a left upper premolar; the stresses in the adhesive interface and in the orthodontic wire, as well as the microstrain generated in the periodontal ligament and alveolar bone during simulated movement and using different displacements and wire thicknesses in the BOT technique.

Methods

A three-dimensional geometric model of the maxilla previously reported in the literature was used for the present study (Tribst *et al*., 2018). The bone tissue showed the periodontal health characteristics and the absence of any anatomical alteration (Fig. 1). Next, the model was imported into computer-aided design software (Rhinoceros version 4.0 SR8; McNeel North America, Seattle, WA). Flat section cuts were used to isolate the element study object, considered the first upper left premolar. The final geometries which composed the 3D model are described as the cortical bone, medullary bone, periodontal ligament, dental root, enamel and dental pulp. Then, all models were verified as volumetric solids and the absence of defective surfaces was manually verified by analyzing the edges used in the modeling protocol.

A model was created taking into account the selected composite resin technique to obtain the geometric models of the resin brackets, respecting the minimum increments and the contact area with the occlusal surface of the premolar based on the ideal occlusion of the modeled dental element (Fig. 2).

Different diameters of orthodontic wires were simulated using a model of a cylindrical, homogeneous and uniform structure created from a reference polyline that was positioned inside the composite resin according to clinical indication (Fig. 3).

Each finished model was exported to computer-aided engineering software (ANSYS 19.2; ANSYS Inc, Houston, TX) in STEP (Standard for the Exchange of Product Data) format for mesh division and analysis using the FEA method (Fig. 4).

After importing the models, a mechanical structural static analysis was used to simulate the orthodontic movement as previously demonstrated in the literature in 0.15, 0.25 and 0.35 mm vestibular displacement. Then, the mechanical properties of each component used in the present study were defined. The required properties were the elastic modulus and the Poisson's ratio of each material, taking into account isotropic, homogeneous and linearly elastic behavior (Table 1).

Next, the contacts were manually defined between each structure, being considered ideal among the simulated human tissues and frictional between orthodontic wire and the composite resin. The system fixation was defined at the bone tissue base in the interaction region with the rest of the maxilla.

The models' subdivision into a finite number of nodes and elements was defined after the mesh convergence test with 10% linearity. The loading was based on the orthodontic wire displacement during controlled movement at three different levels (Gomez *et al*., 2015; Saga *et al*., 2016).

The required results were: The displacement tendency based on the point of the tooth's fulcrum during orthodontic movement (Knop *et al*., 2015), microstrain in bone tissue (Frost 1994), minimum and maximum principal stress for the periodontal ligament (de Paula *et al*., 2018; da Rocha *et al*., 2021), minimum and maximum principal stress for the dental root (Dal Piva *et al*., 2018), von-Mises stress for the orthodontic wire (Buyuk *et al*., 2019) and maximum principal stress for the adhesive interface of the composite resin bracket (Tribst *et al*., 2019). In addition to the colorimetric maps of stress distribution, the peaks of each analysis criterion were plotted for quantitative comparison. Reaction strength in bone tissue was also calculated as a function of applying the load exerted on the orthodontic wire (Melsen, 1999).

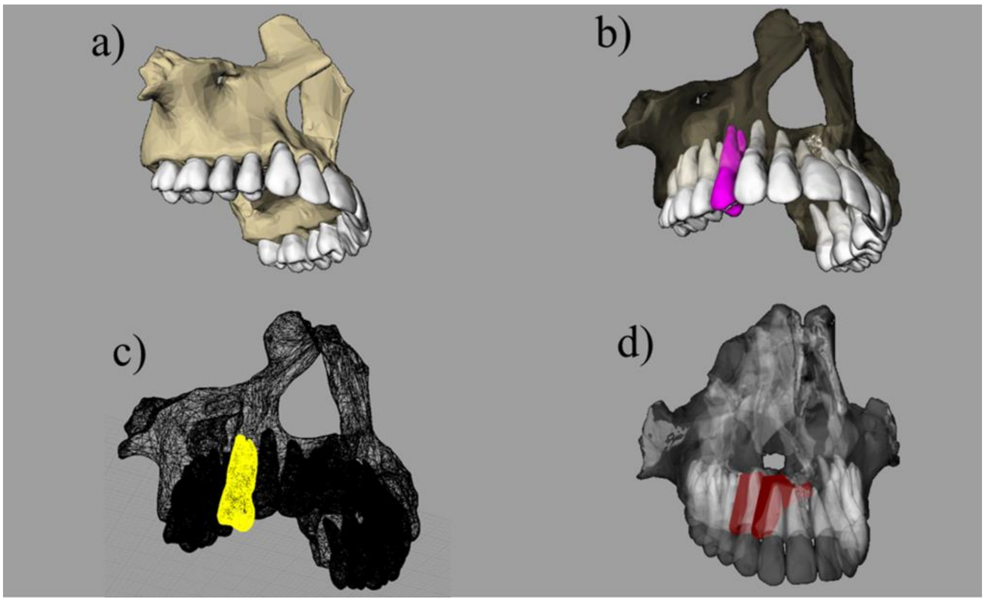

Fig. 1: Perspective view of: (a) Three-dimensional maxilla dental model; (b) tooth study object selected for export in STL; (c) Stereolithography model formed by point cloud; and (d) Maxillary bone section to create the volumetric bone model around the premolar

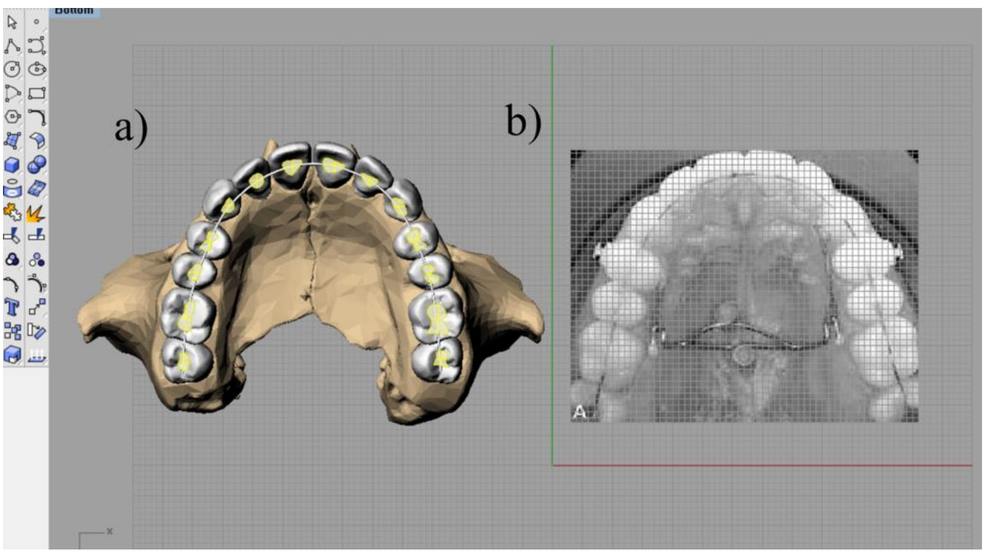

Fig. 2: Occlusal view of (a) 3D model based on (b) oral photograph for accurate representation of the orthodontic wire's spatial position

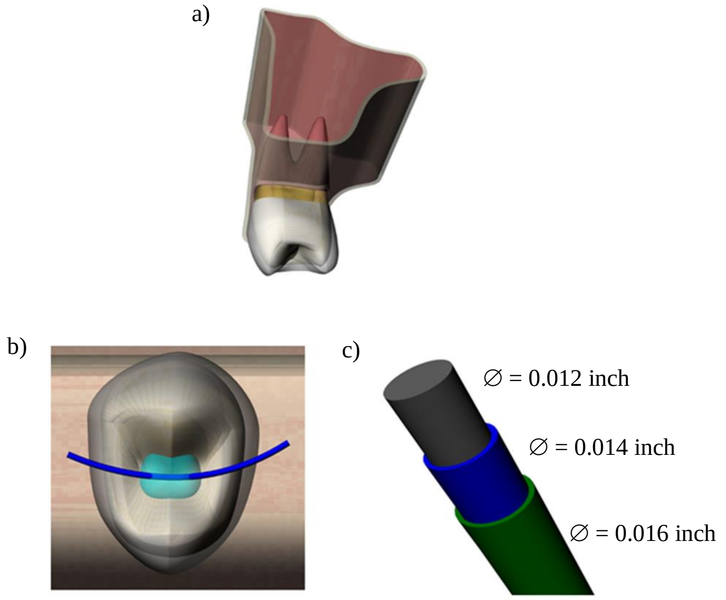

Fig. 3: Layout of three-dimensional models. (a) Structures configured in volumetric solids after configuring the surfaces; (b) occlusal representation of the appliance fixed with composite resin; and (c) difference in the orthodontic wire diameters simulated in the present study: 0.012”, 0.014” and 0.016” wires

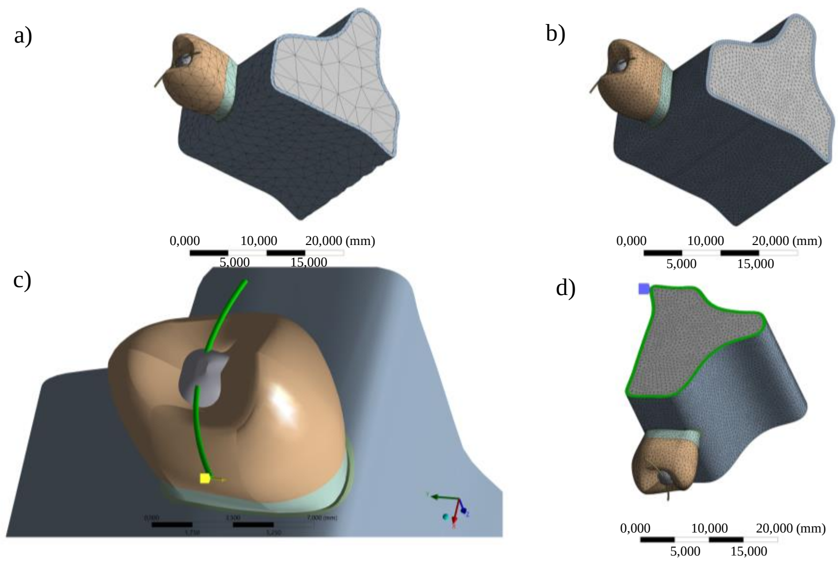

Fig. 4: Layout of three-dimensional models. (a) View of the automatic mesh formed by computer-aided engineering software with obsolete definitions for mechanical structural static analysis; (b) View of the refined mesh after the convergence test with adequate definitions for the mechanical structural static analysis; (c) Contour condition with activation direction indicated by the yellow arrow on the orthodontic wire; and (d) Cortical bone fixation as a support for the analysis

Table 1: Mechanical properties used for computational simulation

Material	Elastic modulus (MPa)	Poisson’s ratio
Enamel	84100	0.30
Dentin	18600	0.30
Periodontal ligament	50	0.45
Cortical bone	13700	0.33
Medullary bone	1400	0.31
Filtek Bulk Fill resin	13460	0.18
NiTi orthodontic wire	30000	0.30

Table 2: Alveolar bone reaction force in the periodontal ligament (in N) according to different displacements and orthodontic wire diameters

Displacement	NiTi orthodontic wire diameter (In)	Reaction force (Newtons)
0.15	0.012	0.030
	0.014	0.033
	0.016	0.035
0.25	0.012	0.050
	0.014	0.055
	0.016	0.058
0.35	0.012	0.072
	0.014	0.077
	0.016	0.079

An analysis of tooth displacement to verify the tooth movement tendency in the different models is shown in the following figures

Results

An analysis of the alveolar bone reaction force in the periodontal ligament of the premolar comparatively quantified the load distributed over each alveolus, as shown in Table 2.

It is observed in the models that there is a similar sense of vestibular movement between them, with greater coronary displacement due to the increase in the applied orthodontic wire diameter (Fig. 5 and 6). The tooth movement increased in both the root apex and in the clinical crown region with the increase in the occlusal orthodontic wire diameter, obtaining an approximate resistance center with the individual arch and magnitude proportional to the load applied to the wire. The maximum movement values in mm are plotted in Table 3.

A strain analysis of the periodontal ligament on the alveolar bone shows a comparison of the force variation impact on the orthodontic movement tendency in the simulated models. Figure 7 shows the results for the periodontal ligament according to the compression strain criterion; and (Fig. 8) shows the results for the periodontal ligament according to the tensile strain criterion. It is possible to notice a greater magnitude for the compressed region than for the dental ligament of the tractioned palatal root, with higher values when larger diameter wires receive greater load. The peaks are plotted in Table 4 for quantitative comparison.

An increase in the compressive zones could be verified in the alveolar bone tissue analysis in proportion to the periodontal ligament strain (Fig. 9). For the color map of the hard lamella region, the tooth movement with the occlusal bracket leads to wider compressive stress concentration areas when greater forces are used, with little visible difference for the different diameters of simulated wires.

Quantitative analyzes were also performed and revealed the same pattern as the qualitative data. In a study presented by Frost (1994), Wolff's law and the behavior of bone structures in relation to different stimuli were reviewed. In this study, bone microstrain values are assumed to be able to modify the bone remodeling behavior and apposition and were used as safety parameters. Thus, values above 1500 με tend to activate lamellar bone remodeling, leading to reformulation and reinforcement, while values above 3000 με induce remodeling disorganization which generates irreversible micro damage to the bone. Thus, models that received 0.35 mm orthodontic wire activation are more likely to favorably remodel the supporting periodontal tissue without causing unwanted bone resorption (Table 5).

An analysis of the root dentin pressure on the alveolar bone was performed to compare the impact of bone variation on the orthodontic movement tendency in the models. The contour graphs for stress distribution in the dental root are illustrated in (Fig. 10) (compression) and 11 (tensile).

The red color shows higher stress concentration areas. The greatest compression areas throughout the simulation were located on the premolar cervical region, regardless of the model, being concentrated in the vestibular region (Fig. 10). The dental root tensile was concentrated on the dental element palate with greater magnitude in the models with greater applied displacement (Fig. 11). Considering that the median tensile strength varies from 44.4 MPa in the internal dentin near the pulp to 97.8 MPa near the dentin-enamel junction (Staninec *et al.*, 2002), none of the models would have the capacity to damage the dental tissue or promote fractures with the simulated loads and wires (Table 6).

The von-Mises criterion was used (Cai, 2020) to analyze the mechanical response, as well as the moment generated associated with the orthodontic wire strain. However, none of the models present plastic strain during loading applied for tooth movement based on the proportionality limit of the metallic alloy of the orthodontic wire close to 2000 MPa (Table 7). Even so, larger diameter wires have a greater capacity to resist applied strain and exhibit lower stress values in their structure when compared to thinner wires (Fig. 12).

As the success of orthodontic treatment is related to keeping the wire in position to properly apply force, the composite resin adhesive area was also investigated to assess the possibility of detachment (Fig. 13).

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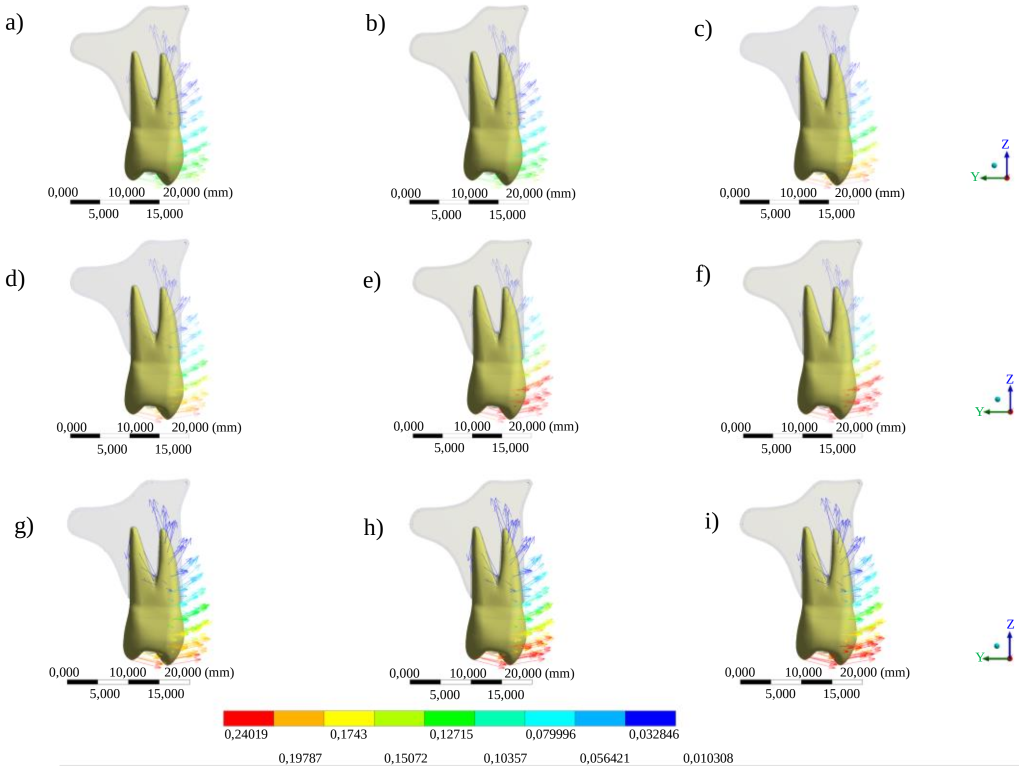

Fig. 5: Movement trends of the models. The arrows indicate the direction of tooth displacement and its intensity (red for greater displacement; green for less displacement). (a) 0.012" wire with 0.15 mm activation, (b) 0.012" wire with 0.25 mm activation, (c) 0.012" wire with 0.35 mm activation, (d) 0.014" wire with 0.15 mm activation, (e) 0.014" wire with 0.25 mm activation, (f) 0.014" wire with 0.35 mm activation, (g) 0.016" wire with 0.15 mm activation, (h) 0.016" wire with 0.25 mm activation, (i) 0.016" wire with 0.35 mm activation

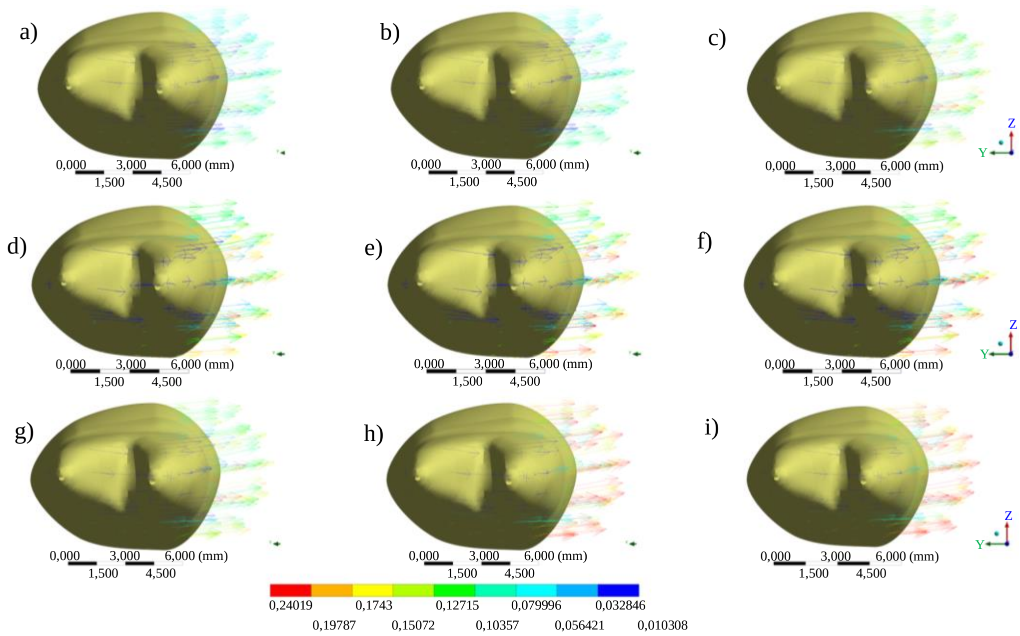

Fig. 6: Radicular portion movement trend of the models. The arrows indicate the direction of tooth displacement and its intensity (red for greater displacement; green for less displacement). (a) 0.012" wire with 0.15 mm activation, (b) 0.012" wire with 0.25 mm activation, (c) 0.012" wire with 0.35 mm activation, (d) 0.014" wire with 0.15 mm activation, (e) 0.014" wire with 0.25 mm activation, (f) 0.014" wire with 0.35 mm activation, (g) 0.016" wire with 0.15 mm activation, (h) 0.016" wire with 0.25 mm activation, (i) 0.016" wire with 0.35 mm activation

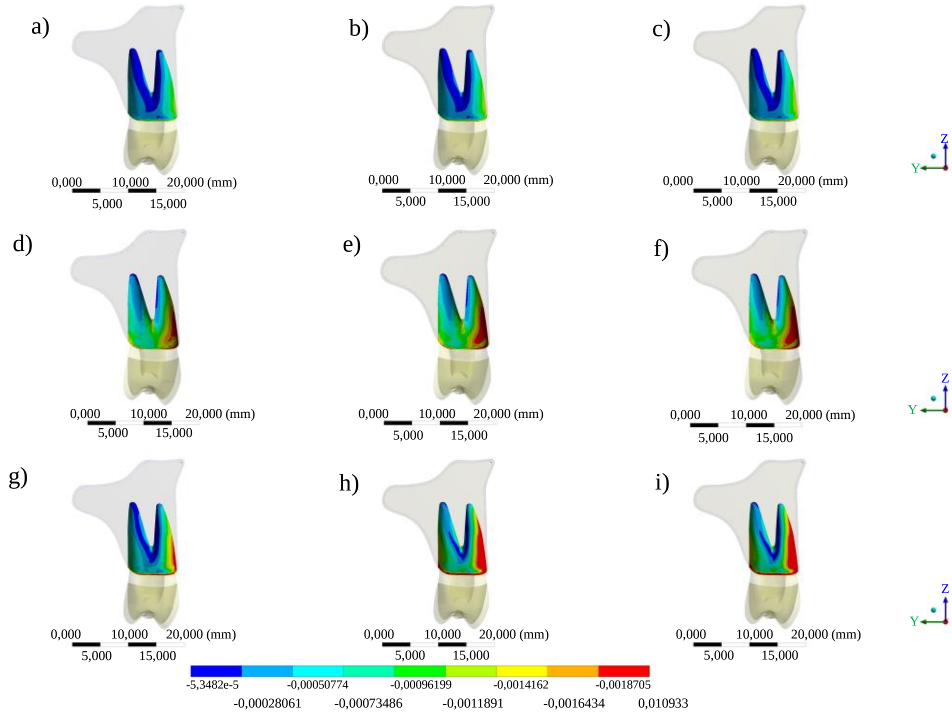

Fig. 7: Minimal principal strain in the periodontal ligament. (a) 0.012” wire with 0.15 mm activation, (b) 0.012” wire with 0.25 mm activation, (c) 0.012” wire with 0.35 mm activation, (d) 0.014” wire with 0.15 mm activation, (e) 0.014” wire with 0.25 mm activation, f) 0.014” wire with 0.35 mm activation, (g) 0.016” wire with 0.15 mm activation, (h) 0.016” wire with 0.25 mm activation, (i) 0.016” wire with 0.35 mm activation

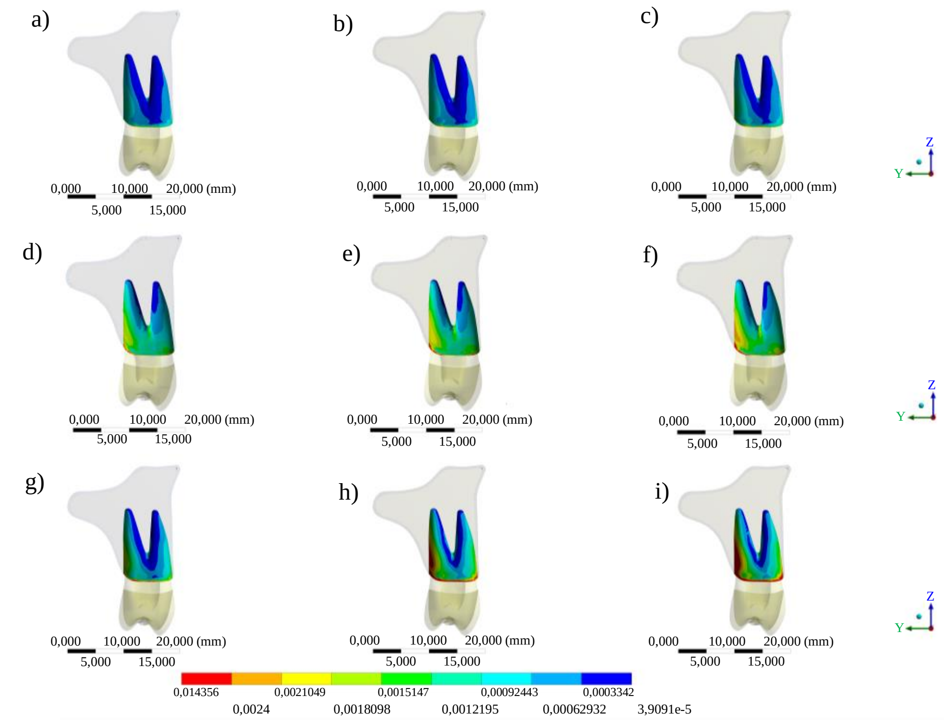

Fig. 8: Maximum principal strain in the periodontal ligament. (a) 0.012” wire with 0.15 mm activation, (b) 0.012” wire with 0.25 mm activation, (c) 0.012” wire with 0.35 mm activation, (d) 0.014” wire with 0.15 mm activation, (e) 0.014” wire with 0.25 mm activation, (f) 0.014” wire with 0.35 mm activation, (g) 0.016” wire with 0.15 mm activation, (h) 0.016” wire with 0.25 mm activation, (i) 0.016” wire with 0.35 mm activation

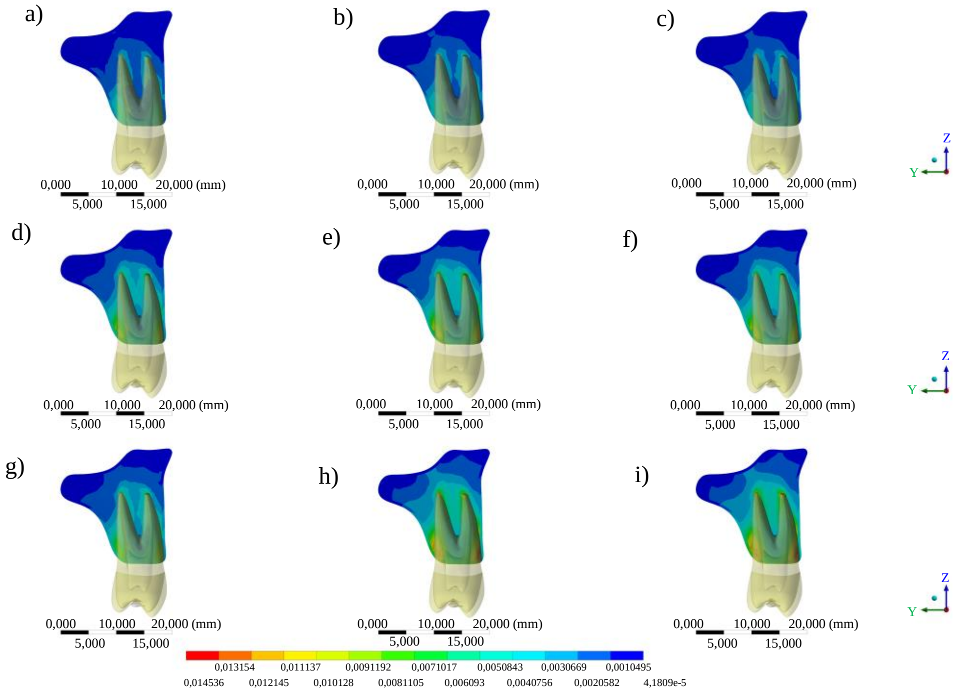

Fig. 9: Minimal principal strain in the periodontal ligament. (a) 0.012" wire with 0.15 mm activation, (b) 0.012" wire with 0.25 mm activation, (c) 0.012" wire with 0.35 mm activation, (d) 0.014" wire with 0.15 mm activation, (e) 0.014" wire with 0.25 mm activation, (f) 0.014" wire with 0.35 mm activation, (g) 0.016" wire with 0.15 mm activation, (h) 0.016" wire with 0.25 mm activation, (i) 0.016" wire with 0.35 mm activation

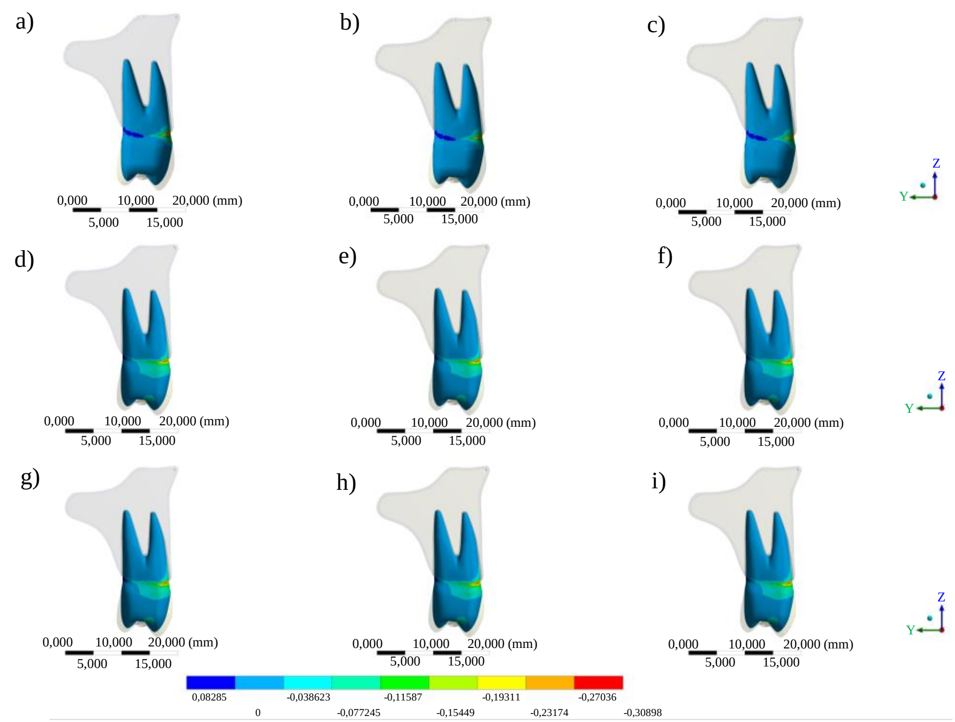

Fig. 10: Minimum principal stress on the dental root. (a) 0.012" wire with 0.15 mm activation, (b) 0.012" wire with 0.25 mm activation, (c) 0.012" wire with 0.35 mm activation, (d) 0.014" wire with 0.15 mm activation, (e) 0.014" wire with 0.25 mm activation, (f) 0.014" wire with 0.35 mm activation, (g) 0.016" wire with 0.15 mm activation, (h) 0.016" wire with 0.25 mm activation, (i) 0.016" wire with 0.35 mm activation

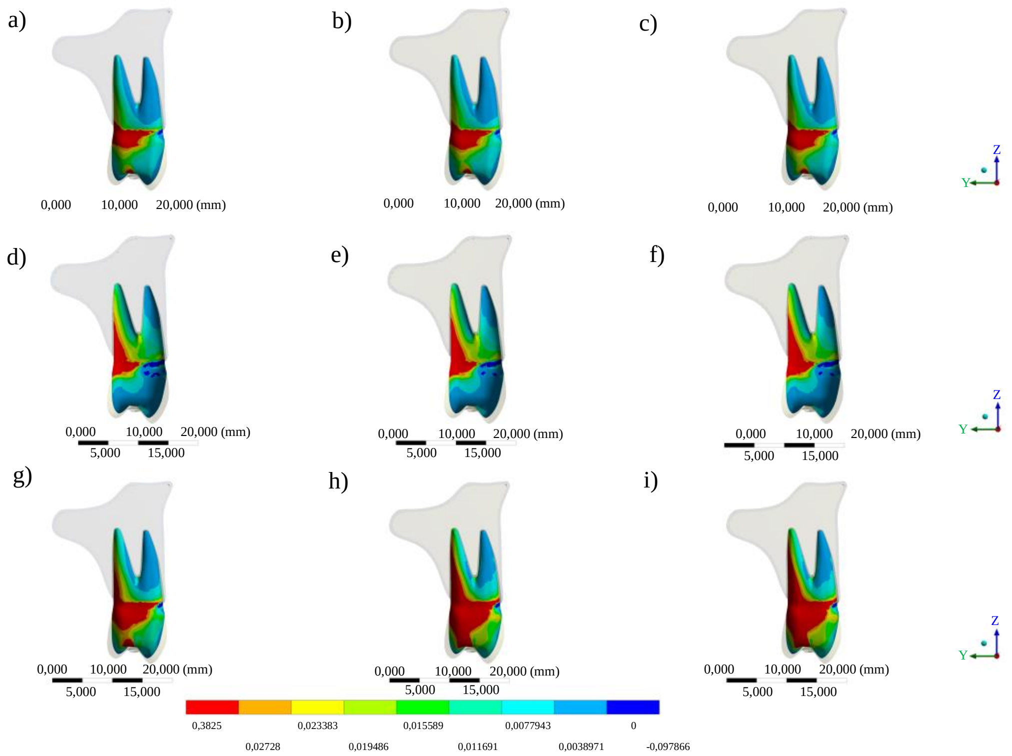

Fig. 11: Maximum principal stress on the dental root. (a) 0.012” wire with 0.15 mm activation, (b) 0.012” wire with 0.25 mm activation, (c) 0.012” wire with 0.35 mm activation, (d) 0.014” wire with 0.15 mm activation, (e) 0.014” wire with 0.25 mm activation, (f) 0.014” wire with 0.35 mm activation, (g) 0.016” wire with 0.15 mm activation, (h) 0.016” wire with 0.25 mm activation, (i) 0.016” wire with 0.35 mm activation

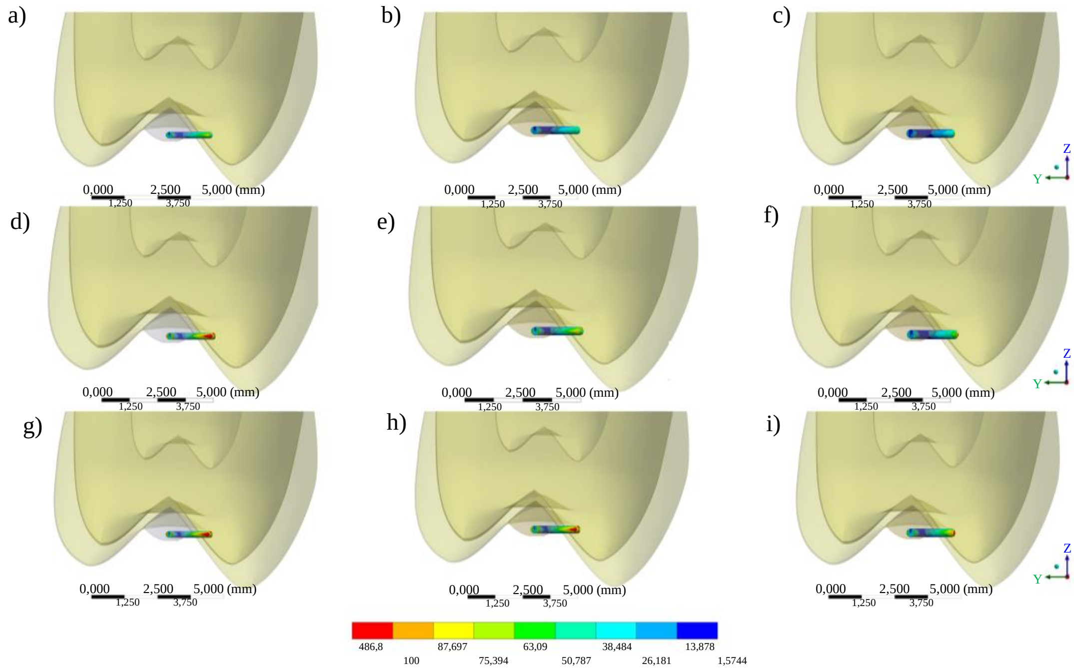

Fig. 12: Von-Mises stress in the orthodontic wire. (a) 0.012” wire with 0.15 mm activation, (b) 0.012” wire with 0.25 mm activation, (c) 0.012” wire with 0.35 mm activation, (d) 0.014” wire with 0.15 mm activation, (e) 0.014” wire with 0.25 mm activation, (f) 0.014” wire with 0.35 mm activation, (g) 0.016” wire with 0.15 mm activation, (h) 0.016” wire with 0.25 mm of activation, (i) 0.016” wire with 0.35 mm activation

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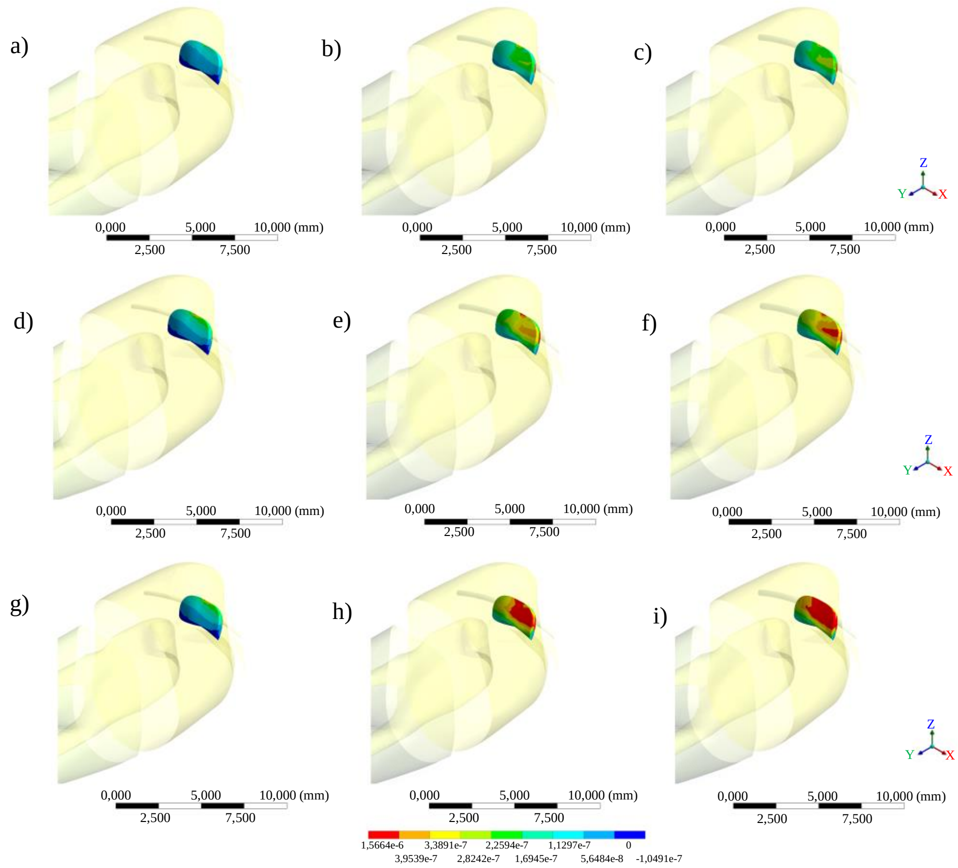

Fig. 13: Maximum principal stress in the occlusal composite resin. (a) 0.012” wire with 0.15 mm activation, (b) 0.012” wire with 0.25 mm activation, (c) 0.012” wire with 0.35 mm activation, (d) 0.014” wire with 0.15 mm activation, (e) 0.014” wire with 0.25 mm activation, (f) 0.014” wire with 0.35 mm activation, (g) 0.016” wire with 0.15 mm activation, (h) 0.016” wire with 0.25 mm activation, (i) 0.016” wire with 0.35 mm activation

Table 3: Tooth movement (mm) according to different displacements (mm) and orthodontic wire diameters (In)

Displacement	Orthodontic wire diameter	Tooth movement tendency
0.15	0.012	0.13287
	0.014	0.14025
	0.016	0.14411
0.25	0.012	0.19243
	0.014	0.20751
	0.016	0.21113
0.35	0.012	0.22145
	0.014	0.32726
	0.016	0.33626

Table 4: Tensile and compression microstrain peaks of the periodontal ligament (mm/mm) according to different displacements (mm) and orthodontic wire diameters (In)

Displacement	Orthodontic wire diameter	Compression strain	Tensile strain
0.15	0.012	-5.891 e-003	2.1108 e-005
	0.014	-6.3906 e-003	2.2845 e-005
	0.016	-6.5598 e-003	2.3455 e-005
0.25	0.012	-6.9128 e-003	2.9756 e-005
	0.014	-7.3543 e-003	2.991 e-005
	0.016	-7.9834 e-003	3.131 e-005
0.35	0.012	-9.8184 e-003	3.518 e-005
	0.014	-1.4911 e-002	4.321 e-005
	0.016	-1.5306 e-002	5.472 e-005

Table 5: Microstrain peaks (mm/mm) in the alveolar bone according to different displacements and orthodontic wire diameters (In)

Displacement during the movement	Orthodontic wire diameter	Von-Mises microstrain in the bone
0.15	0.012	810
	0.014	849
	0.016	879
0.25	0.012	921
	0.014	993
	0.016	1102
0.35	0.012	1301
	0.014	1982
	0.016	2035

Table 6: Stress peaks in the root dentin (MPa) according to different displacements (mm) and orthodontic wire diameters (In)

Displacement	Orthodontic wire diameter	Compressive stress	Tensile stress
0.15	0.012	-1.6678	2.0584
	0.014	-1.8059	2.1361
	0.016	-1.8539	2.2950
0.25	0.012	-1.9131	3.0126
	0.014	-1.9982	3.1644
	0.016	-2.1242	3.2341
0.35	0.012	-2.7796	4.8307
	0.014	-4.2138	5.2175
	0.016	-4.3257	5.3551

Table 7: Von-mises stress peaks in the orthodontic wire (MPa) according to different displacements (mm) and orthodontic wire diameters (In)

Displacement	Orthodontic wire diameter	Tensile stress
0.15	0.012	44.86
	0.014	30.837
	0.016	22.388
0.25	0.012	74.767
	0.014	51.395
	0.016	37.314
0.35	0.012	74.767
	0.014	71.953
	0.016	52.239

Table 8: Peak of tensile stress on occlusal composite resin (MPa) according to different displacements (mm) and orthodontic wire diameters (In)

Displacement	Orthodontic wire diameter	Tensile stress
0.15	0.012	0.5109
	0.014	0.8172
	0.016	0.9998
0.25	0.012	1.0208
	0.014	1.2267
	0.016	1.3283
0.35	0.012	1.8762
	0.014	2.0735
	0.016	2.1972

Assuming that the minimum adhesive resistance value in enamel is about 22.4 MPa (Andrade *et al*., 2010), it is possible to assume that this resinous bracket model does not represent a detachment risk by the simple activation of the orthodontic wire with values that do not exceed 2.2 MPa (10% of the average bond strength), as plotted in Table 8.

Discussion

The use of alternative orthodontic techniques enables obtaining particular results according to the desired movements. The present study demonstrated that the Bracketless Orthodontic Treatment (BOT) promotes a promising biomechanical response in tooth movement, regardless of the orthodontic wire diameter and simulated displacements.

It is important to note that the BOT in the occlusal posterior teeth is an alternative technique for resolving desired tooth movements (Tavares *et al*., 2019; da Fonseca Junior *et al*., 2019). However, adequate isolation of fluids and great collaboration from patients are required from the bonding procedure until each reactivation of the device (Mariniello and Cozzolino 2008).

As a disadvantage, this technique requires a longer clinical time (over 30 min.) and the need for an occlusal lift. Even so, the occlusal lift helps in several cases and can be an advantage so that the contacts between the cusps of the upper and lower teeth are released, facilitating the initial orthodontic movements. The fact of not having orthodontic accessories and facilitating hygiene constitutes an excellent tool for tooth movement (Nunes *et al*., 2020).

Knowing the stress concentration in the periodontium helps to predict the pain and potential damage which can occur even under functional bite force (Da Rocha *et al*., 2021). Thus, when there is higher compression stress concentration, there will be a stimulus for bone tissue degeneration, which means a possible increase in progressive insertion loss (Da Rocha *et al*., 2021). Basically, the strains and stresses in the periodontal ligament are responsible for activating a cascade of biological events and oxytocins which induce alveolar bone remodeling; however, at the same time they can make the teeth which are moved more susceptible to orthodontically-induced inflammatory root resorption (Roscoe *et al.*, 2015). However, no model simulated in the present study appears to be able of generating root resorption with reaction forces of less than 0.1 N on the medullar bone region and strain levels below 43 KPa.

Regarding the mechanical bone tissue stimulation, the results obtained in the load applications during orthodontic movement did not exceed the maximum physiological limit to induce severe bone resorption (Frost 1994). On the contrary, models with 0.35 mm wire displacement will tend to activate lamellar bone remodeling.

The von-Mises distortion criterion considers that the flow of a ductile material begins when the concentrated stress magnitude vector reaches a critical value (Wang *et al*., 2021). This part of the plasticity theory is best applied to ductile materials, such as orthodontic wires with linear elastic behavior (Cai, 2020). However, the calculated stress value in the present study is minimal and suggests that there will be no damage to the orthodontic wire structure at the expense of the applied load. In short, the treatment will not be compromised and the desired function can be achieved regardless of the wire diameter (0.012”, 0.014” or 0.016”).

Several aspects must be considered with regard to the bond strength and adhesion durability of composite resin to mineralized dental tissues such as: The dental structure heterogeneity, the exposed adhesive surface hydrophilicity, the dental substrate characteristics and the adhesive and composite resin characteristics, as well as its physicochemical properties (Cardoso *et al.*, 2011). Thus, tensile stress represents one of the main results for bond strength and adhesive failure of dental restorations (Ausiello *et al*., 2020); in turn, it is of interest to the dental surgeon to understand the clinical variables which can affect the magnitude of the tensile stress generated at the adhesive interface between composite and tooth. In this sense, the present study investigated how the orthodontic wire diameter can facilitate detachment of the composite resin over different activation levels. However, the values did not exceed 10% of the critical stress value for adhesive failures between composite resin and enamel (Andrade *et al*., 2010). Thus, it can be indicated that the use of BOT is safe in terms of maintaining the orthodontic wire in position, as well as the resin brackets. However, different results may be observed in teeth with severe occlusal wear and dentin exposure, restored with other direct and indirect synthetic materials, with unbalanced parafunction and occlusion, which may affect the efficiency of this treatment modality.

It is important to note that the BOT technique has already been discussed in the literature with reports of more than 9 years of follow-up (Musilli, 2008), being considered a technique for devices capable of ensuring good control of tooth and root movement. The present study corroborates this statement, demonstrating a minimal risk for the component structures of the periodontium and the tooth submitted to orthodontic movement by this technique. However, force control, adequate orthodontic planning, correct modeling preparation of the wire and composite resin are essential, as well as the occlusal considerations of each case for clinical success and a safe dental movement protocol (Yu *et al*., 2013).

Most research protocols, including FEA, have methodological limitations; so that numerical computational studies cannot replace clinical studies (Trivedi, 2014). FEA is a widely used numerical analysis which has been applied successfully in many areas of engineering and bioengineering since the 1950s. This numerical analysis can be considered the most comprehensive method currently available to calculate stress distributions in complex conditions (Yue *et al*., 2009). Other advantages of this method compared to other research methodologies are the reduced laboratory costs, reduced time to perform the investigation and the provision of information which cannot be obtained by in vitro or even clinical studies (Trived, 2014).

Conclusion

The Bracketless Orthodontic Treatment presents different stress magnitudes and strain concentration proportional to the orthodontic wire diameter and the force applied for tooth movement. However, under properly controlled conditions, the induced biomechanical response is favorable to tooth movement with low risk for damage to oral tissues and the composite resin debonding.

Author’s Contributions

Guaracy Lyra da Fonseca Junior: Study conception and design; Analysis and interpretation of data; Drafting of manuscript; Critical revision.

Ney Tavares Lima Neto: Study conception and design; Drafting of manuscript; Critical revision.

Evelyne Pedroza de Andrade: Study conception; Drafting of manuscript; Critical revision.

João Paulo Mendes Tribst: Modelling; Acquisition of data; Critical revision.

Cristina Harrop: Study conception; Supervision; Critical revision.

Juliana Cama Ramacciato: Study conception; Supervision; Critical revision.

Ethics

The corresponding author confirms that all author have read and agree to the publish version of the manuscript. This article is original and contains unpublished material and no ethical issues involved.

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