Stress Distribution of Maxillary Anterior Retraction Using Miniscrew with Anterior Hook on Continuous Wire (3D Simulation Finite Element Analysis)

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Abstract

To analyze stress distribution on anterior teeth apex, and their surrounding structures during maxillary anterior retraction using continuous archwire with various miniscrew vertical positions and various height of the anterior retraction hook (ARH).

Six 3D maxillary models were constructed from a dry skull and the original objects of brackets, miniscrews, ARH, and archwire. The length of ARH (short / 2 mm, long / 5 mm) and the miniscrew vertical position (3 mm, 5 mm, 8 mm as measured from CEJ) were varied to change the force application direction. Simulations were undertaken using ANSYS 15.0 (ANSYS Inc., USA) by applying 150 gram retraction force. Maximum principle (MaxPS), minimum principle (MinPS) and von Mises (vonMS) stresses were evaluated on each Region of Interest (ROI) visually and numerically.

The stress pattern between short and long ARH were almost similar, except on alveolar bone around the anterior teeth. The difference of ARH length showed statistically significant stress differences on anterior teeth apex and its surroundings. Meanwhile, miniscrew and its surroundings showed opposite results. The highest stress can be observed at the cervical of anterior teeth apex. Equal amount of stress also can be found at the surrounding structures around them.

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Introduction

The miniscrews as an absolute anchorage has gained popularity in clinical orthodontics due to its numerous advantages. It offers many advantages such as easy insertion and removal, immediate loading, the ability to be utilized in various anatomical locations including the alveolar bone surrounding the roots, and economic.[1] Moreover, the miniscrews has been utilized in several clinical applications for example in the retraction of the anterior teeth segment.[2]

In general, the treatment plan for class II malocclusion with a convex face profile and protrusion of the lips includes extracting 2 or 4 premolars followed by the retraction of the anterior segment with maximum anchorage.[2] In this case, the main objectives of the orthodontic treatment are to reduce the proclination of the incisors and enhance the facial profile. Maximum anchorage could be obtained by using additional appliances such as headgears, transpalatal arch, intermaxillary elastics, etc. However, these appliances may require full patient cooperation and some of them might be uncomfortable to use. Therefore, the miniscrew is preferred to achieve absolute anchorage which does not require patient cooperation and considered more comfortable to use.[2]

Furthermore, there exist several studies which focus on anterior teeth segment retraction by using miniscrews to obtain absolute anchorage. These studies provide explanations about the dental, skeletal, and also soft tissues adjustments that occur, the amount of retraction and the duration of the treatment and are mostly clinical. There are numerous case reports that describe the use of the miniscrew as an anchorage for anterior dental segment retraction which also mention the positioning of the miniscrew, its length from the CEJ, and the ideal height of the anterior hook, but then again there

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are not any explanations concerning the reaction and stress distribution of the teeth and the alveolar bone which supports the roots of the teeth.[3]

The reaction of teeth to sliding mechanics is measured by using the Finite Element Analysis (FEA). A 3D computer model is used to simulate various conditions with numerous simulation parameters. Thus, quantitative and qualitative evaluations of the initial reactions of the teeth, the periodontal ligament (PDL), and the alveolar bone can be obtained.[4,5] This study aims to analyze the differences of the stress distribution to the teeth and the alveolar bone supporting the roots of the teeth during the retraction of the anterior teeth segment using continuous wires with different heights of anterior hook retraction and miniscrews.

Materials and methods

The study has been approved by the Ethical Committee of the Faculty of Dentistry, Universitas Indonesia.

Initially, a CBCT (I-CAT 17-19, Pennsylvania) scan of the dry scull was conducted. Afterwards, a 3D solid model of the maxilla was created by assembling each element of the teeth and the alveolar bone of the maxilla. The picture fragments of the CBCT scanning results (DICOM format) were manually divided into segments to obtain a surface model of the first incisive teeth up until the second molar in one quadrant and the alveolar bone of the maxilla using an ITK-Snap software which was kept in a STL format.

Each of the surface model was made into a solid model with the aid of the Geomagic software and saved in an IGES format. Additionally, the periodontal ligament solid model was constructed based on the anatomy of the roots of each tooth using the same software. Moreover, solid models of the miniscrews, bracket, force module and continuous wires (Stainless Steel SS 0.019 x 0.025) with anterior hooks were constructed according to the original by using the Autodesk Inventor software.

Subsequently 2 solid models of 3D maxilla which consisted of 1 solid model of a 3D maxilla with continuous wire and 2 mm anterior hook, and 1 solid model of a 3D maxilla with continuous wire and 5 mm anterior hook were constructed. Furthermore 6 work models of the 3D maxilla with different heights of anterior hooks and miniscrews were prepared.

Linear FEA simulations to measure the distribution of stress to the teeth and alveolar bone surrounding the roots when exposed to 150 grams of retraction force were further conducted using the ANSYS software (MaxPS, MinPS, and VonMS scores were analyzed).

The results were analyzed through descriptive and analytical approaches with the aid of the SPSS software and the parametric test was completed by using independent t-test for one group of hooks and in between groups of hooks.

Results

The results of the maxillary model simulation within the anterior teeth apex Region of Interest (ROI) confirmed that the highest MaxPS score was located in the the cervico-palatal of the lateral incisive in all groups. While the highest MinPS score and VonMS score were located in the cervico-labial of the lateral incisive in all groups. The simulation results within the bone surrounding the anterior teeth ROI of the 2 mm hook maxillary model with a height of 3,5,8 mm confirmed that the highest MaxPS, MinPS and VonMS scores were respectively located in the cervico-palatal of the central incisive, the distal of the canine, and the palate of the central incisive. Similar to the 2 mm hook group, the highest MinPS score in the 5 mm hook group was also found in the distal of the canine. Whereas the highest MaxPS scores in the 5 mm hook was found in the cervical of the lateral incisive, and the highest VonMS score in the 5 mm hook group when the miniscrew was located at 8 mm height were found in the cervical of the lateral incisive and the distal of the canine.

The normality test which was conducted using the Kolmogorov-Smirnov data normality test confirmed that each group had normal data distribution with $P>0.05$. The mean graphic in Figure 1 showed that the stress distribution scores of the anterior teeth apex and the bone surrounding the anterior teeth decreased as the height of the miniscrew increased either on the *Von Misses Stress* (VonMS), the *Maximum Principle Stress* (MaxPS), or the *Minimum Principle Stress* (MinPS) scores.

The hypothesis testing was conducted using the independent t test. The independent t test was conducted twice, the first independent t test was conducted to compare two types of hooks towards the height locations of the miniscrew during the anterior maxillary segment retraction simulation within all of ROI (Table 1-2). The second independent t test was conducted to compare the height locations of the miniscrew towards 2 types of hooks on the anterior maxilla within all of ROI (Table 3-4).

The significance within the bone around the anterior teeth apex ROI was found in every stress scores of each height comparisons of the miniscrew (Table 1), while the significance within the anterior teeth apex ROI were only found in the MaxPS scores of the 2 mm hook when the miniscrew was located at 3 mm height compared to 5 mm, and 3 mm compared to 8 mm (Tabel 2). Moreover, the MaxPS scores for the 5 mm hook when the miniscrew was located at a height of 5 mm compared to 8 mm, and 3 mm compared to 8 mm were significant.

Afterwards, independent t test was conducted to compare the height locations of the miniscrew towards 2 types of hooks on the anterior maxilla within the anterior teeth apex and bone surrounding it. The stress scores of the anterior teeth apex and the bone surrounding it showed significant differences (Tables 3-4). The $p<0.05$ significance indicated some differences in the stress distribution of the bone around the anterior teeth and of the anterior teeth apex when located at a height of 3 mm from the CEJ during the anterior maxillary segment retraction using continuous wire with a 2 mm anterior hook compared to a 5 mm one with 150 grams of retraction force. This was similar to the independent t test within the bone around the anterior teeth and anterior teeth apex ROI when the miniscrew was located at a height of 5 mm which also demonstrated $P<0.05$. Similar to the independent t test within the bone around the anterior teeth and the anterior teeth apex ROI when the miniscrew was located at a height of 3 mm and 5 mm, at 8 mm $P<0.05$ had also been observed.

Discussion

Finite Element Analysis (FEA) is a modern tool for numeric stress analysis with advantage for it is applicable on solid form with irregular geometry that contains heterogeneous properties materials.[4,5] The objective of FEA application is to minimize various calculative procedures to obtain absolute solution for biomechanical system.[4] FEA is applicable in linear and non-linear on solid and liquid structures and every problem can be described into simpler parts. FEA is non-invasive technique to simulate every stage of biological condition: pre, intra, and post-surgery in order to obtain more accurate and trusted result.[4] It is very difficult to observe dental biomechanical movement through experimental approach due to limited mechanical index measurement, inaccurate parameter control, and varied samples. Therefore, FEA provides a more flexible and alterable approach for dental movement biomechanical evaluation compared to experimental approach.[6,7] However, to modelize human structure is a very laborious work to do due to its complexity of anatomical structure and lack of mechanical behaviours knowledge. As the result, inaccurate data, information, and interpretation will lead to wrong output.[4]

This study describes how stress distribution to anterior teeth apex and alveolar bone surrounding it on maxillary anterior teeth segment using miniscrew installed at 3mm, 5mm, and 8mm height from CEJ; 2mm and 5mm anterior hook with 150 g retraction force. Strong force during retraction will caused external resorption from apical. Upadhyay et al and Kim et al write that force can be given during retraction using miniscrew is approximately 150-200 g.[1,8] Liou et al discovered that significant movement happens when miniscrew is given force as much as 400 g. Therefore, this study gives 150 g force during retraction with miniscrew.[9]

This study utilizes maxilla part of dry skull scanned with CBCT, then 3D model along with bracket, wire, hook, miniscrew, and periodontal ligament, and jawbone were produced. Nevertheless, this study has limitation and certain assumption made to simplify the model making process and problem solving. The entire anatomical structure is regarded homogenous, isotropic, and linear, and they possess elastic material behaviour characterized by two materials, namely Modulus Young and Poisson ratio.

3D model is designed to imitate normal dental structure with 110° incisive inclination. We use 1.6 mm miniscrews with 8 mm length (Dual Top Anchor System, Jeil Medical Corporation) installed at 90° insertion angle against bone.

Jasmine et al studied the amount of stress on miniscrews and surrounding bone on three different angulations, 30°, 60° and 90°. Result of the study showed the bigger the miniscrew insertion angulations against bone leads to less stress occurrence. Hence, the placement of miniscrew at 90^0 against bone will reduce stress concentration and enhance its stability.[10] Miniscrew should be installed on alveolar bone without damaging adjacent dental root. Positioning miniscrew more apical in between dental root reduces damage possibility in adjacent dental root. However, miniscrew will touch free gingiva which will lead to soft tissue complication because the difficulties to clean the area.[9] Liou et al state safety limit for positioning miniscrew is 2 mm from the root.[9] At buccal maxilla area, the most amount of inter-radiculer bone located at second premolar and first molar, 5-8 mm from the alveolar crest.[11,12]

Lu et al (2015) state bigger miniscrew has better stability. However, bigger miniscrew will lead to higher possibility of dental root trauma.[13] Gracco et al reported on finite study element that failure of miniscrew installation happens to miniscrew of 14 mm length with optimal screw length 9 mm.[14] FEA reliability depends on mesh model. On this study, the nodes and elements of maxilla model with 2 mm hook respectively 613031 and 344131, whereas nodes and elements of maxilla model with 5 mm hook respectively 611788 an 344331. Nodes and elements on this study are of greater number compared to previous studies which several of them possess almost similar model to this study have nodes and elements around 48429-399320 nodes and 107446-319803 elements.[15-17] The more nodes on the model, more accurate the biggest stress position will be.

Rudolph et al applied FEA method to study five types of orthodontic force lead to highest stress to root apex. Those types are intrusion, extrusion, rotation, bodily movement and tipping. The method exhibits intrusion, extrusion and rotation forces concentrated at apical root; tipping concentrated at alveolar apex; bodily movement stress distributed throughout periodontal ligament, but concentrated at alveolar apex. Rudolph et al. is in accordance with this study. The outcome of maxilla model simulation bone ROI around dental root indicate the highest stress value located on the apex of central and lateral incisive alveolar teeth.[18] The outcome of maxilla model simulation on dental root indicates the highest stress occurs on cervical dental incisive which area close to alveolar apex.

VonMS may be applied to predict material failure, e.g metal. Experts state material failure can occur when VonMS exceeds yield strength during tension. However, for fragile material (e.g. bone) MaxPs is more widely applied than VonMS value. Experts state that material failure occurs when MaxPS reaches ultimate tensile strength or ultimate comprehensive strength.[19] Ultimate comprehensive strength is maximum tension a material can endure when it is being stretched and compressed before it is broken. According to MaxPS theory, excessive tension on cortical bone is assumed happens as the apex of MaxPS reaches 100-130 MPa ultimate tensile strength or when the apex of MinPS reaches 170-190 MPa ultimate tensile strength.[19] The value of MaxPS and MinPS in this study does not exceed 0.1 MPa that means maximum value of ROI bone surrounding anterior teeth apex and anterior teeth apex do not exceed 8 MPa, which is maximum value on bone ROI around miniscrew. MaxPS and MinPS value of this study is much lower than ultimate tensile strength and ultimate comprehensive strength. Therefore, we can conclude that if 150gr retraction tension connected from 2 mm hook or 5 mm to miniscrew installed at the heights of 3 mm, 5 mm, and 8 mm shall not cause any damage to tissue nor root resorption.

Panedo et al (2010) stated that dental root surface has to be exposed to stress lower than stress caused by blood to capillary vessel as much as 0.0026 MPa to avoid periodontal tissue damage. Average value of VonMS and MaxPS at dental root indicates value higher than 0.0026 MPa.[20] It is evident that 150 g force given for maxilla anterior segment retraction sufficient to move the teeth. Unpaired *t* test towards two types of hooks against miniscrew height maxilla anterior segment retraction for ROI bone surrounding dental signifies distinction. Therefore, we can conclude height difference of miniscrew and hook significantly affects stress on bone surrounding dental root. Value of MinPS, however, does not indicate significant differences towards two types of hooks against miniscrew height. Contrary, hook intergroup-paired *t* test demonstrated significant differences at overall stress value tested. To conclude, miniscrew height does not affect stress value occurs on dental root, but the height difference of hook with the height of similar miniscrew affects stress occurs on dental root.

Unpaired t test at miniscrew height against 2 types of hook at maxilla anterior for ROI bone around dental root and dental root showed significant results at overall stress value. In conclusion, hook height greatly affects stress distribution at bone around dental root and the root as well. Figure 2 shows different hook height towards the height of similar miniscrew leads to different vector result. After comparison, there is no difference of hook to miniscrew distance for 2 mm and 5 mm hook. Distinguishing factor is course of the force leads to different height of force arm. Force arm will affect force moment in which greater force arm will lead to greater value of force moment.

Significance of value of intergroup hook differs one to another. Significance of value of a hook group on miniscrew ROI and bone around miniscrew does not form a particular pattern. This concludes that stress distribution hook group similar to ROI miniscrew and its surrounding bone is affected by difference height of miniscrew.

Conclusions

Finite element analysis is beneficial method to analyze stress occurs on and around dental root and it's response to orthodontic force. FEA helps researchers to observe invisible, such as stress distribution in a complex geometry as found on teeth and tissue. FEA simplifies complex matters and providing accurate and trusted results. This study concludes that stress occurs on miniscrew ROI, surrounding bone, bone surrounding dental root, and dental root on maxillary anterior segment with 150 gram force on hook and miniscrew height difference does not damage the tissue and cause any material failure. This study concludes the highest stress occurs on miniscrew neck at miniscrew ROI, cortical bone around miniscrew neck, cervical root at dental root ROI, and cervical or bone margin at bone ROI around dental root.

Declaration of Interest

The authors report no conflict of interest and the article is not funded or supported by any research grant.

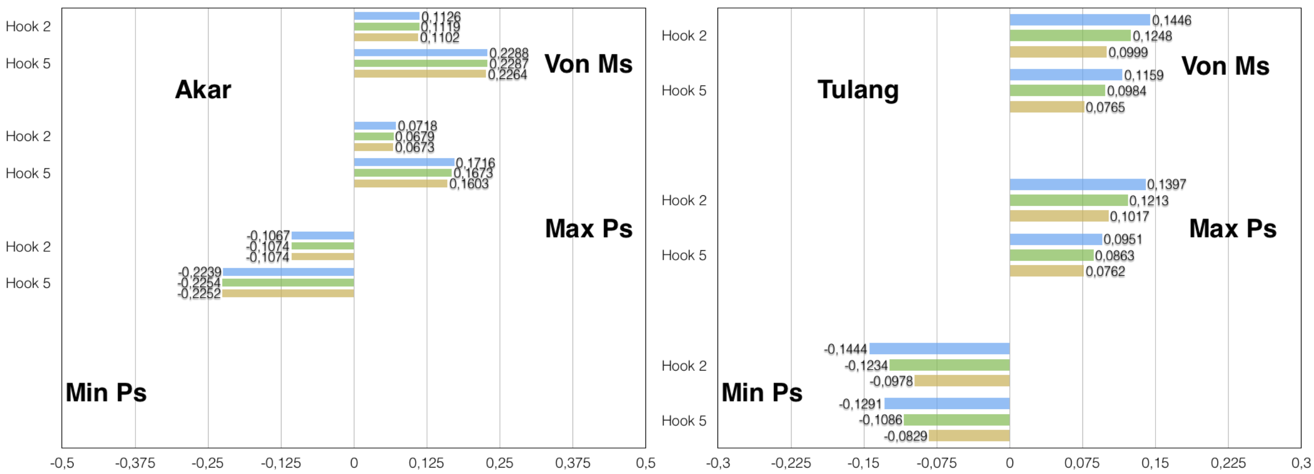

Figure 1. Graphic mean of stress value generated after simulation of maxillary anterior retraction using different hooks with different miniscrews vertical height. (blue = 3 mm; green = 5 mm; orange = 8 mm).

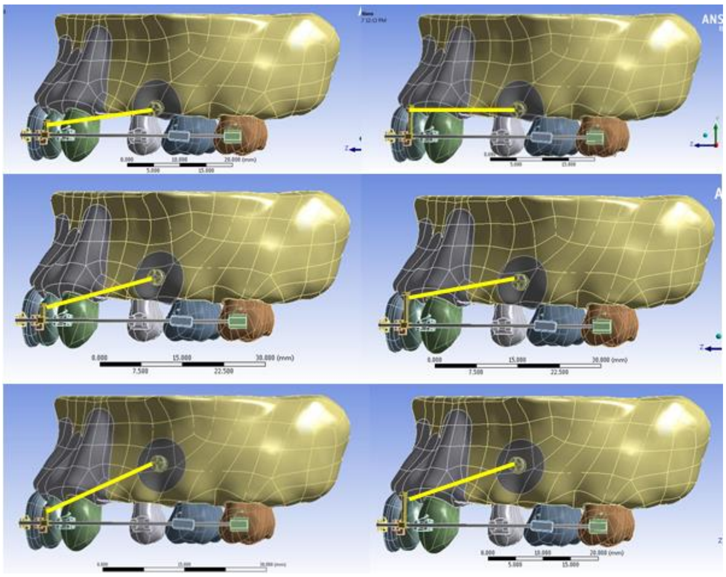

Figure 2. Force Vector on 3D Maxillary Model with Different Height of Hook and Miniscrews.

Stress	Hook	Heights of miniscrew	N	Mean	SD	95% CI of the Difference		p
						Lower	Upper	
VonMS	Hook 2	3 mm	69	0.1446	0.01859	0.0143	0.0253	0.000*
		5 mm	69	0.1248	0.01352			
		5 mm	69	0.1248	0.01352	0.0204	0.0294	0.000*
		8 mm	69	0.0999	0.01325			
		3 mm	69	0.1446	0.01859	0.0393	0.0501	0.000*
		8 mm	69	0.0999	0.01325			
	Hook 5	3 mm	69	0.1159	0.01925	0.0119	0.0229	0.000*
		5 mm	69	0.0984	0.01261			
		5 mm	69	0.0984	0.01261	0.0186	0.0253	0.000*
		8 mm	69	0.0765	0.00646			
		3 mm	69	0.1159	0.01925	0.0345	0.0442	0.000*
		8 mm	69	0.0765	0.00646			
MaxPS	Hook 2	3 mm	58	0.1397	0.01754	0.0125	0.0243	0.000*
		5 mm	58	0.1213	0.01425			
		5 mm	58	0.1213	0.01425	0.0149	0.0244	0.000*
		8 mm	58	0.1017	0.01120			
		3 mm	58	0.1397	0.01754	0.0326	0.0435	0.000*
		8 mm	58	0.1017	0.01120			
	Hook 5	3 mm	58	0.0951	0.01430	0.0043	0.0133	0.000*
		5 mm	58	0.0863	0.00972			
		5 mm	58	0.0863	0.00972	0.0068	0.0133	0.000*
		8 mm	58	0.0762	0.00798			
		3 mm	58	0.0951	0.01430	0.0146	0.0232	0.000*
		8 mm	58	0.0762	0.00798			
MinPS	Hook 2	3 mm	75	-0.1444	0.01721	-0.0259	-0.0161	0.000*
		5 mm	75	-0.1234	0.01313			
		5 mm	75	-0.1234	0.01313	-0.0291	-0.0219	0.000*
		8 mm	75	-0.0978	0.00893			
		3 mm	75	-0.1444	0.01721	-0.0509	-0.0421	0.000*
		8 mm	75	-0.0978	0.00893			
	Hook 5	3 mm	75	-0.1291	0.01732	-0.0254	-0.0157	0.000*
		5 mm	75	-0.1086	0.01231			
		5 mm	75	-0.1086	0.01231	-0.0291	-0.0223	0.000*
		8 mm	75	-0.0829	0.00831			
		3 mm	75	-0.1291	0.01732	-0.0507	-0.0419	0.000*
		8 mm	75	-0.0829	0.00831			

Table 1. Independent t-test Result of 2 Types of Hooks (2 mm or 5 mm) to Miniscrew Vertical Height on Simulation of Maxillary Anterior Retraction for ROI Bone Surrounding Anterior Teeth.

Stress	Hook	Heights of miniscrews	N	Mean	SD	95% CI of the Difference		p
						Lower	Upper	
VonMS	Hook 2	3 mm 5 mm	67 67	0.1126 0.1119	0.01285 0.01141	-0.0034	0.0049	0.729
		5 mm 8 mm	67 67	0.1119 0.1102	0.01141 0.01151	-0.0023	0.0055	0.416
		3 mm 8 mm	67 67	0.1126 0.1102	0.01285 0.01151	-0.0018	0.0065	0.268
	Hook 5	3 mm 5 mm	67 67	0.2288 0.2287	0.03422 0.03134	-0.0112	0.0113	0.994
		5 mm 8 mm	67 67	0.2287 0.2264	0.03134 0.02732	-0.0078	0.0123	0.653
		3 mm 8 mm	67 67	0.2288 0.2264	0.03422 0.02732	-0.0083	0.0129	0.664
MaxPS	Hook 2	3 mm 5 mm	83 83	0.0718 0.0679	0.00854 0.00514	0.0017	0.0061	0.001*
		5 mm 8 mm	83 83	0.0679 0.0673	0.00514 0.00457	-0.0009	0.0021	0.434
		3 mm 8 mm	83 83	0.0718 0.0673	0.00854 0.00457	0.0024	0.0066	0.000*
	Hook 5	3 mm 5 mm	83 83	0.1716 0.1673	0.02287 0.01822	-0.0020	0.0107	0.181
		5 mm 8 mm	83 83	0.1673 0.1603	0.01822 0.01345	0.0021	0.0119	0.005*
		3 mm 8 mm	83 83	0.1716 0.1603	0.02287 0.01345	0.0056	0.0171	0.000*
MinPS	Hook 2	3 mm 5 mm	67 67	-0.1067 -0.1074	0.01583 0.01364	-0.0043	0.0058	0.769
		5 mm 8 mm	67 67	-0.1074 -0.1074	0.01364 0.01307	-0.0046	0.0046	0.997
		3 mm 8 mm	67 67	-0.1067 -0.1074	0.01583 0.01307	-0.0042	0.0057	0.762
	Hook 5	3 mm 5 mm	67 67	-0.2239 -0.2254	0.04158 0.03794	-0.0122	0.0151	0.833
		5 mm 8 mm	67 67	-0.2254 -0.2252	0.03794 0.03268	-0.0123	0.0119	0.975
		3 mm 8 mm	67 67	-0.2239 -0.2252	0.04158 0.03268	-0.0115	0.0140	0.846

Table 2. Independent t-test result of 2 types of hooks (2 mm or 5 mm) to miniscrew vertical height on simulation of maxillary anterior retraction for ROI anterior teeth apex.

Stress	Heights of miniscrews	Hook	N	Mean	SD	95% CI of the Difference		p
						Lower	Upper	
VonMS	3 mm	Hook 2 Hook 5	69 69	0.1446 0.1159	0.01859 0.01925	0.0224	0.0352	0.000*
	5 mm	Hook 2 Hook 5	69 69	0.1248 0.0984	0.01352 0.01261	0.0220	0.0308	0.000*
	8 mm	Hook 2 Hook 5	69 69	0.0999 0.0765	0.01325 0.00646	0.0199	0.0269	0.000*
MaxPS	3 mm	Hook 2 Hook 5	58 58	0.1397 0.0951	0.01754 0.01430	0.0387	0.0505	0.000*
	5 mm	Hook 2 Hook 5	58 58	0.1213 0.0863	0.01425 0.00972	0.0306	0.0396	0.000*
	8 mm	Hook 2 Hook 5	58 58	0.1017 0.0762	0.01120 0.00798	0.0219	0.0291	0.000*
MinPS	3 mm	Hook 2 Hook 5	75 75	-0.1444 -0.1291	0.01721 0.01732	-0.0208	-0.0097	0.000*
	5 mm	Hook 2 Hook 5	75 75	-0.1234 -0.1086	0.01313 0.01231	-0.0189	-0.0107	0.000*
	8 mm	Hook 2 Hook 5	75 75	-0.0978 -0.0829	0.00893 0.00831	-0.0178	-0.0122	0.000*

Table 3. Independent t-test result of various heights of miniscrews (3 mm, 5 mm, and 8 mm) to 2 types of hooks (2 mm or 5 mm) on simulation of maxillary anterior retraction for ROI bone surrounding anterior teeth.

Stress	Heights of miniscrews	Hook	N	Mean	SD	95% CI of the Difference		p
						Lower	Upper	
VonMS	3 mm	Hook 2	67	0.1126	0.01285	-0.1250	-0.1073	0.000*
		Hook 5	67	0.2288	0.03422			
	5 mm	Hook 2	67	0.1119	0.01141	-0.1249	-0.1088	0.000*
		Hook 5	67	0.2287	0.03134			
	8 mm	Hook 2	67	0.1102	0.01151	-0.1234	-0.1090	0.000*
		Hook 5	67	0.2264	0.02732			
MaxPS	3 mm	Hook 2	83	0.0718	0.00854	-0.1051	-0.0946	0.000*
		Hook 5	83	0.1716	0.02287			
	5 mm	Hook 2	83	0.0679	0.00514	-0.1035	-0.0953	0.000*
		Hook 5	83	0.1673	0.01822			
	8 mm	Hook 2	83	0.0673	0.00457	-0.0961	-0.0899	0.000*
		Hook 5	83	0.1603	0.01345			
MinPS	3 mm	Hook 2	67	-0.1067	0.01583	0.1065	0.1280	0.000*
		Hook 5	67	-0.2239	0.04158			
	5 mm	Hook 2	67	-0.1074	0.01364	0.1082	0.1277	0.000*
		Hook 5	67	-0.2254	0.03794			
	8 mm	Hook 2	67	-0.1074	0.01307	0.1092	0.1262	0.000*
		Hook 5	67	-0.2252	0.03268			

Table 4. Independent t-test result of various heights of miniscrews (3 mm, 5 mm, and 8 mm) to 2 types of hooks (2 mm or 5 mm) on simulation of maxillary anterior retraction for ROI anterior teeth apex.

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