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Analysis of Stress Distribution Around Orthodontic Miniscrew Implant:(A 3-D Finite Element Analysis Study)

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الخلاصة

الاهداف: تهدف الدراسة إلى تقييم الإجهاد في العظم ونزوح الزريعة التقويمية باستخدام الأقطار (١,٣ و ١,٤) ملم المثبتة بزاوية (٩٠°) مع سطح النموذج العظمي المتكون من (١و٢) ملم من سمك العظم القشري. **المواد وطرائق العمل:** تتكون عينة الدراسة من (٢٠(نموذج التي تم تجميعها في أربع مجموعات، كل مجموعة شملت خمسة نماذج. تم تصميم النموذج العظمي من سمك العظم القشري المختلف (١ و٢ ملم) باستخدام برنامج (اوتودسك انفينتر,الإصدار ٢٠١٣) للتصميم والتحليل بطريقة العناصر المحددة ثلاثية الأبعاد. تم إنشاء نماذج الزريعة التقويمية بالأحجام حسب القطر (١,٣ و ١,٤) ملم باستخدام نفس البرنامج وفقا للرسومات التي تم الحصول عليها من شركة (ابسوانكر, دينتوس). ثم غرس الجزء المسنن من الزرعة في كتلة النماذج العظمية عند) ٩٠°) درجة، وبعد تعيين خصائص المواد وتسليط قوة بمقدار (٢(نيوتن, تم تقييم توزيع الإجهاد في العظم ونزوح الزرعات التقويمية في الظروف المختلفة وتحليل النتائج باستخدام الإحصاء الوصفي وتحليل (انوفا و دنكن). **النتائج:** أظهرت الزريعة ذات القطر (١,٤(ملم المغروسة في (٢(ملم في نموذج العظم القشري أدنى إجهاد للعظم وأدنى نزوح للزريعة من البقية. **الاستنتاجات:** كلما زاد سمك العظم القشري وقطر الزريعة سيؤدي لنقصان الاجهاد المتولد في العظم ويقلل من حدوث نزوح الزريعة.

ABSTRACT

Aims: Evaluation of the stress in the bone and miniscrew displacement of 1.3 and 1.4 mm in diameter inserted in two bone models of 1 and 2 mm of cortical bone thickness at 90◦ angulation to the bone. **Materials and Methods:** The sample consisted of 20 models which were grouped into four groups, each group included five models. The bone models of different cortical thickness (1mm,2mm) were designed by a three dimensional Finite Element Analysis Program. The miniscrew models of 1.3 and 1.4 mm in diameter were created by the same program. Then inserting the threaded part of miniscrew in the bone block at 90°, and assigning the material properties and applying of 2N as an orthodontic force. Finally the stress distribution in the bone and miniscrew displacement in the different conditions were evaluated. the results were analyzed by using ANOVA and Duncan analysis. **Results:** The miniscrew diameter 1.4 mm inserted in 2 mm cortical bone thickness demonstrated the lowest bone stress and miniscrew displacement than the others. **Conclusions:** As cortical thickness and miniscrew diameter increased the bone stress reduced and less miniscrew displacement occurs.

Key words: von misses stress, displacement, orthodontic miniscrew, finite element analysis.

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INTRODUCTION

Miniscrews were introduced as absolute anchorage devices recently in orthodontic treatment, can overcome the anchorage loss problems.[1,2,3,4] Furthermore, the excellent results that achieved in various malocclusions.[5,6,7] Miyawaki et al,[8] Cheng et al,[9] Kuroda et al,[10] and Lim et al,[11] reported miniscrew success rates of 84%, 89%, 80% and 83.6%, respectively. Despite the great benefits of using mini screw in providing maximum anchorage control, loosening of mini screw is the biggest problem for the orthodontists, for this reason, numerous researchers[4,6,7] have studied the factors involved in the failure of mini-implants. The success rate related to primary stability that reduces the risk of micromotion and related to the stress-strain field developing in the miniscrew implant itself.[14]

One of the principal factor that influences the stability is stress from loading, fatigue failure of bones can result from damage accumulation.[12] Eva stahal[13] reported that the cortical thickness is a decisive parameter for the stability of these mini-implants, also the miniscrew diameter affecting bone stress as concluded by.[13,15,27]

The authors[16,17,18] disclosed that as increase angulations lead to lessen the stress generated in the bone and the miniscrew displacement demnished. Virtually it is impossible to measure stress accurately around microimplants intraorally. Finite Element Analysis provides an approximate solution for the response of the 3-D structures to the applied external loads under certain boundary conditions(19,24,25).

The aims of this study including the evaluation of the stress that generated in the cortical bone and investigation of the miniscrew displacement using different cortex thicknesses and miniscrew diameters.

MATERIALS AND METHODS

The sample consisted of 20 models grouped into four groups, each one included five models. The first two groups comprised of two bone models of 1 mm cortical thickness had implanted with 1.3 and 1.4 mm minscrews, and the second two groups of two bone models of 2 mm cortical thickness had implanted with 1.3 and 1.4 mm minscrews. A Proffessional Autodesk Inventor version (2013, USA) used as a Software for modeling and stress analysis and for statistical analysis used SPSS (version 19.5) .

The methods: the first step begin with preparation of the Finite Element Model geometry, the creation of two miniscrew models of 1.3 and 1.4 mm diameter according to Sketches of Absanchor orthodontic miniscrew (Dentos, Korea) that has implanted length of 8 mm and the thread pitch of 0.5 mm, which inserted at 90° to bone model, that designed of cortical 1 and 2mm thickness and cancellous bone of 15*15*10 (width, depth and height). The second step include assigning of the material properties for each model components. The miniscrew assumed to be titanium alloy with a Young's modulus of 114 GPa and a Poisson's ratio of 0.34,(23) the Young's modulus of the cortical and cancellous bones were 13.7GPa(20,21,24) and 1.3 GPa(21,24) respectively of 0.3(22) Poisson's ratios for both of them. The third step which was the transformation of the domain bone miniscrew model into Finite Element structure by method called "meshing". The forth step which was include constrain of the external surfaces except the top then the application of 2N to the miniscrew head in mesiodistally direction simulating the loading condition as in Figure (1).

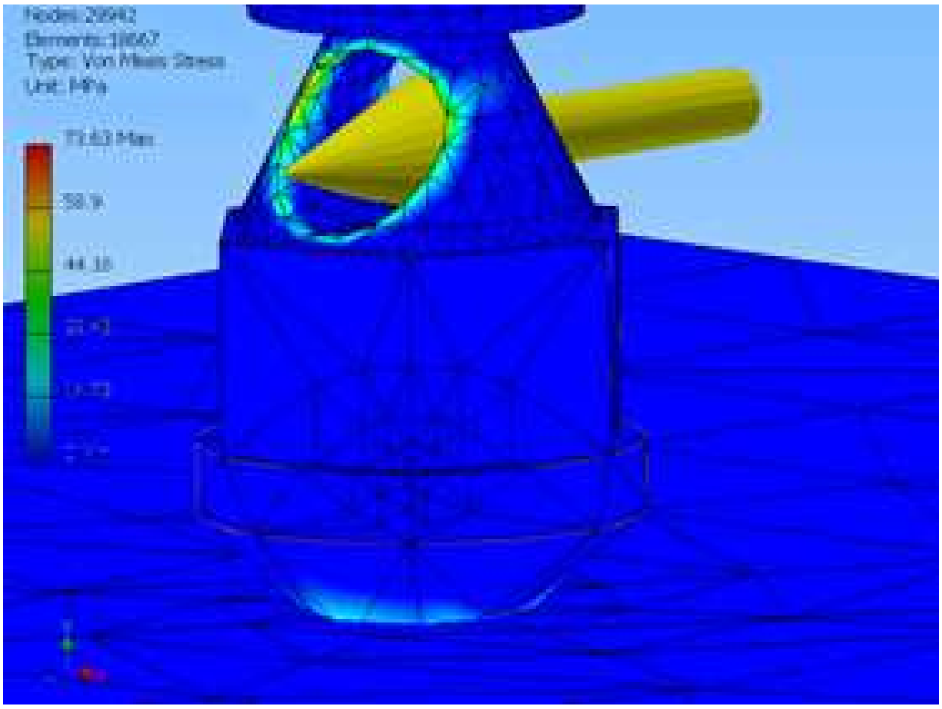

Figure (1): Finite Element Miniscrew Bone Model.

RESULTS

The Table (1) and Figure (2), showed the Descriptive Analysis and ANOVA with Duncan Multiple Analysis Range Test, the miniscrew diameters of 1.3 and 1.4 mm that implanted in the bone block of 1 and 2 mm cortical bone thickness (CBT) revealed a significant differences among them, except in 2mm (CBT). Whereas the miniscrew displacement appeared that there were a significant differences among them (Figure (3)).

Table (1) : Descriptive Analysis and ANOVA with post hoc Duncan Multiple Analysis Range Test for the Bone stress (unit MPa)and Miniscrew Displacement using diameter of 1.3 and 1.4 mm Implanted in Bone Models of 1 and 2mm Cortical Thickness(CBT).

Results	Studied Variables		Descriptive			Duncans Groups*
	MS Diam. (mm)	CBT (mm)	Sample N.	Mean	SD.D	
Bone Stress (MPa)	1.3	1mm	5	14.51	1.82	A
		2mm	5	10.17	0.66	C
	1.4	1mm	5	12.32	1.20	B
		2mm	5	9.90	0.99	C
Miniscrew Displ. (mm)	1.3	1mm	5	0.0041	0.00	A
		2mm	5	0.0035	0.00	B
	1.4	1mm	5	0.0032	0.00	C
		2mm	5	0.0028	0.00	D

* Different letters means significant difference.
MS Diam. : Miniscrew Diameter, CBT: Cortical Bone Thickness
Sample N. : Number of the samle, SD.D: Slandered Deviation.

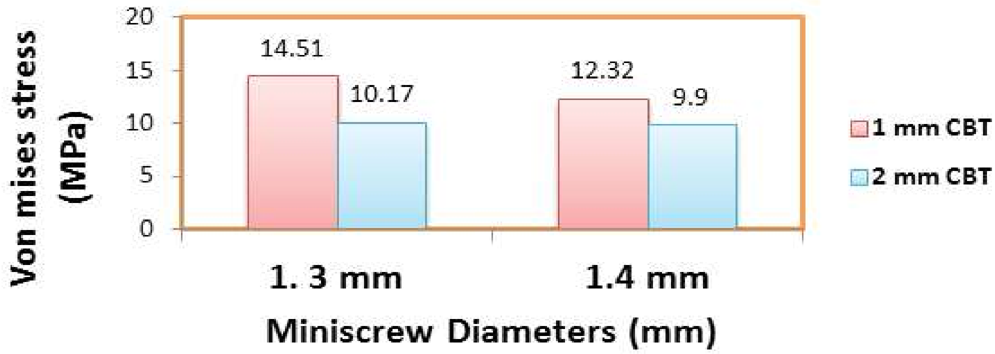

Figure (2): Mean Value of Von misses Stress of The Bone.

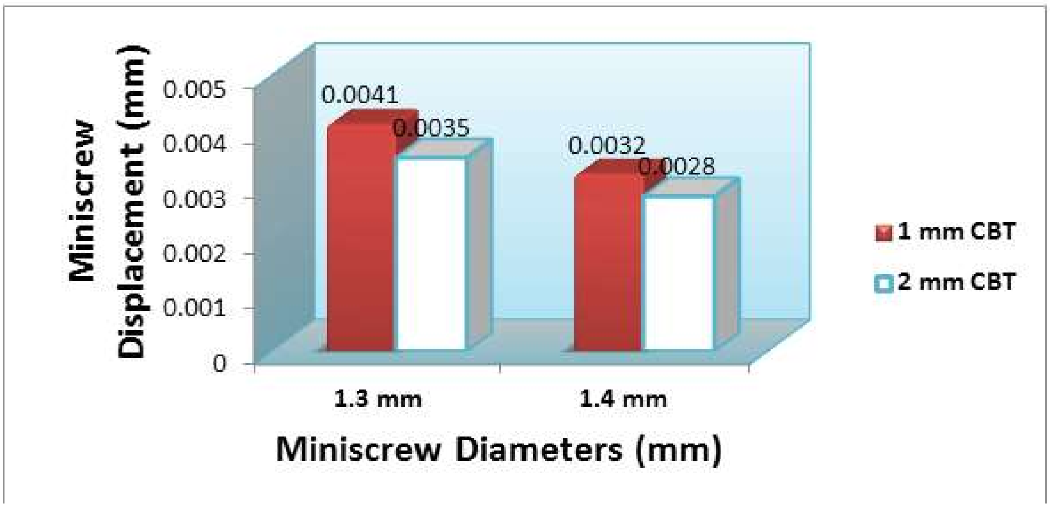

Figure (3): Mean Value of Miniscrew Displacement.

DISCUSSIONS

Bone stress of cortical bone: The statically significant difference between von mises stress mean value of the bone for the miniscrew diameter of 1.3 and 1.4 mm at 1mm cortex thickness, this could be due to different diameter. The mean von mises value of 1.3 mm miniscrew diameter of this study was (14.5 MPa) which was very close to Jasmine´s[20] finding (12.5 MPa) and disagree with Stahal's[13] result (26 MPa). Whereas the bone von mises stress mean value of 1.4 mm miniscrew diameter of this study was (12.32 MPa) which was very close to what reported by Duaibis[21]whose value was (10.36 MPa) while more than Zhang's[22] result (0.56 MPa) and this is could be due to that Zhang[22] was used larger diameter. Miniscrew displacement: There was statically significant difference between Miniscrew displacementat mean value for miniscrew diameter of 1.3 and 1.4 mm at different cortical bone thickness (CBT), This can be explained to the different miniscrew diameter similar conclusion was reported by Duaibis et al[21].

Conclusions

The cortical bone thickness has an essential effect on the bone stress, reduced bone stress as increase in the cortical bone width. The miniscrew diameter can be regarded as determanent variable, the displacement minimized as increase minscrew diameter.

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