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The effect of miniscrew length and bone density on anchorage resistance: An in vitro study

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Keywords
Bone density
Miniscrew length
Stability

Summary

Introduction > With conventional anchorage, it is usually hard to accomplish a satisfactory result with an absolute anchorage, and this limitation could be resolved by the usage of mini-screw. The successful rate of miniscrew usage depends on its stability, which was determined by its length, bone density, cortical bone thickness, the insertion technique, the insertion angle, and the applied loads.
Objective > To observe the effect of miniscrew length and bone density on anchorage resistance.
Material and methods > Thirty pieces of miniscrew with 1.6 mm in diameter were divided into three groups based on its length ($n = 10$): 10 mm (L), 8 mm (M), and 6 mm (S). Each group was further divided into 2 sub-groups: to be planted in optimal density bovine ribs (L1, M1, S1) and to be planted in low-density bovine ribs (L2, M2, S2). The density of bovine ribs was measured by CBCT. After the insertion of miniscrews based on respective groups, tensile test was done by means of Autograf Univerval Testing Machine to measure its stability. The data recorded was analysed using the Least Significant Difference (LSD) Fisher's test.
Results > The results of this study showed that L1 provided the greatest stability than other groups. On the other hand, the least stability was found in S2.
Conclusion > The length of miniscrew and the density of bone affect the stability of miniscrew. In bone with optimum density, 10 mm and 8 mm miniscrew equipped good anchorage resistance while in bone with low-density only 10 mm miniscrew provided favourable anchorage resistance.

Mots clés
Densité osseuse
Longueur des mini-vis
Stabilité

Résumé

Effets de la longueur des mini-vis et de la densité osseuse sur la résistance d'ancrage : une étude in vitro

Introduction > *Il est en pratique difficile d'obtenir un ancrage absolu satisfaisant avec un ancrage conventionnel et cet obstacle pourrait être surmonté en utilisant des mini-vis. Le taux de réussite de l'utilisation d'une mini-vis dépend de sa stabilité qui a été déterminée par sa longueur, la*

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densité osseuse, l'épaisseur de l'os cortical, la technique d'insertion, l'angle d'insertion et les charges appliquées.

Objectif > *Observer l'effet de la longueur des mini-vis et de la densité osseuse sur la résistance de l'ancrage.*

Matériels et méthodes > *Trente mini-vis de 1,6 mm de diamètre ont été divisées en trois groupes selon leur longueur (n = 10) : 10 mm (L), 8 mm (M) et 6 mm (S). Chaque groupe a été divisé en deux sous-groupes : les mini-vis à implanter dans des côtes bovines de densité optimale (L1, M1, S1) et les mini-vis à implanter dans des côtes bovines de faible densité (L2, M2, S2). La densité des côtes bovines a été mesurée au moyen de tomodensitométrie CBCT. Une fois les mini-vis insérées en fonction des groupes respectifs, elles ont été testées en traction pour mesurer leur stabilité par une machine d'essai Universal Autograf. Les données enregistrées ont été analysées à l'aide du test post hoc de différence significative minimale (LSD) de Fisher.*

Résultats > *Les résultats de cette étude ont montré que L1 offrait une plus grande stabilité que les autres groupes. En revanche, c'est avec S2 que la stabilité était la plus faible.*

Conclusion > *La longueur de la mini-vis et la densité osseuse affectent la stabilité de la mini-vis. Dans les os à densité optimale, les mini-vis de 10 mm et 8 mm ont une bonne résistance d'ancrage, alors que dans les os à faible densité, seule une mini-vis de 10 mm offre une résistance d'ancrage favorable.*

Introduction

In orthodontic tooth movement, anchorage is required to prevent undesirable tooth movement in order to achieve a successful treatment, thus control of anchorage is essential during orthodontic treatment [1]. Conventional anchorage could be classified as extra-oral anchorage, which could be done by using headgear or facemask, and intra oral anchorage, which could be done with transpalatal arch, Nance, or lingual arch. Unfortunately, a satisfactory anchorage result is difficult to be achieved by conventional anchorage as it has a limitation, which could be overcome by the usage of miniscrew [2].

Miniscrew usage could accomplish various orthodontic tooth movement, such as anterior and posterior intrusion, molar distalisation, and en-masse retraction or protraction, which previously infeasible with conventional anchorage [3]. It also could safely produce a successful space closure after extraction and intrude overerupted maxillary and mandibular incisive, without affecting posterior teeth and the vertical dimension [4].

Miniscrew stability determined by the insertion technique, the insertion angle, its length, the applied loads, bone density, and cortical bone thickness [5]. Previous study done by Petrey et al. [6] stated that there is a correlation between miniscrew length and its loading ability in producing primary stability, which is essential in order to be able to receive load in absolute anchorage. The length of anchorage extends its surface contact with cortical bone, which is optimizing its stability while the orthodontic force is given. In opposition to the statement, other studies conducted by Kuroda et al. [7] argued that there is no correlation between miniscrew length and its stability. An increase on miniscrew length could cause alveolar bone damage and resulting in its mobility [8].

In addition, bone density is one of the factors influencing mini screw insertion failure besides the presence of bone inflammation in miniscrew location insertion, the age and the characteristic of bone. Therefore, bone density is an important factor to be considered in determining the successful of orthodontic treatment [9].

The difference in research findings of mini-screw length correlation with its stability encouraged a further experiment to determine the effect of miniscrew length and bone density on anchorage resistance.

Material and methods

Experimental design

All experimental procedures were approved by the Board for Animal Experiments, Faculty of Dental Medicine, Universitas Airlangga, No. 030/HRECC.FODM/III/2017. The experimental research involved post-test only control group design using four fresh ribs bovine. To determine bone density, each bovine was scanned by Cone Beam Computed Tomography (CBCT) unit (Orthopantomograph OP300, Wisconsin, USA). The result of bone density measurement was presented in HU (*hounsfield units*). The optimum density range of bone was 500–850 HU, while it was considered low density if less than 500 HU. After the measurement, the samples immersed in PZ solution (NaCl 0,9%) for 1 × 24 hours and stored in room temperature prior the treatment.

Thirty self-drilling orthodontic miniscrews (diameter 1.6 mm; Biokey, Taoyuan, Taiwan) were divided into three groups based on its length (n = 10): 10 mm (L), 8 mm (M), and 6 mm (S). Each group was further divided into 2 sub-groups: to be inserted in optimal density bovine ribs (L1, M1, S1) and to be inserted in

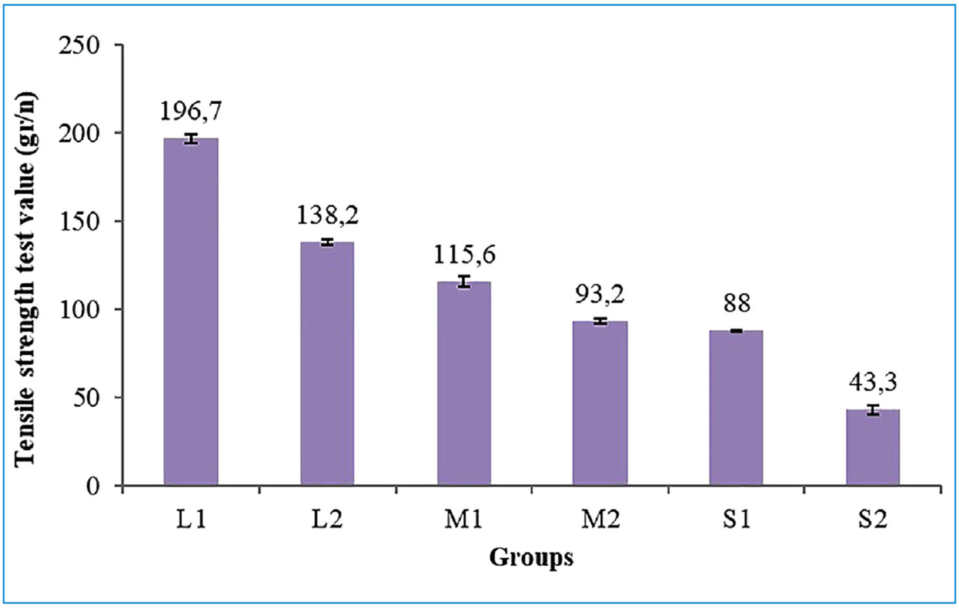

FIGURE 1

Bar graph of the tensile strength test mean value of 1.6 mm in diameter miniscrew insertion in the low and optimum bone densities

low-density bovine ribs (L2, M2, S2). The placement of all miniscrews was done by a single operator using screwdriver (3 M, St. Paul, USA) according to the manufacturer with 45° of insertion angle. All samples with miniscrew inserted were bonded with ligature wire (RMO, Colorado, USA) in order to be able to be held with autograf. Tensile strength test was done perpendicularly to miniscrew insertion angle by means of Universal Testing Machine jenis Autograf (Shimadzu E10, Kyoto, Japan) until the miniscrew was pulled out. The value of required force to pull out the miniscrew was recorded and then analysed to determine the most stable miniscrew based in its length.

Statistical analysis

All data were tested for normal distribution by means of Kolmogorov-Smirnov test. One Way ANOVA and Least Significant Difference (LSD) test ($P > 0.05$) were performed to determine the influence of different miniscrew length and bone density to the stability of miniscrew using statistical software program SPPS version 20 (IBM, New York, USA).

Results

Bone density measurement was done to four different cow ribs prior the treatment and the result was: A bovine ribs aged < one-year old has 298.5 hounsfield units (HU) in bone density, B bovine ribs aged < one-year old has 320.8 HU, C bovine ribs aged 1.5–2 years old has 592.5 HU, and the D bovine ribs aged 1.5–2 years old has 785.7 HU. A and B bovine ribs were considered having an optimum bone density, while C and D bovine ribs were considered having a low bone density.

LSD test used for the tensile strength test data was done to find the difference of miniscrew stability between 6 mm, 8 mm, and 10 mm in length to the optimal bone density of bovine ribs (L1, M1, S1) and low-density bovine ribs (L2, M2, S2) (*figure 1*). The results confirmed that there is a significant difference between each group ($P = 0.00 < 0.05$). L1 group has the highest tensile strength result (196.7 g/n), while the lowest strength was found in S2 group (43.3 g/n).

Discussion

Bone density is one of the possible factors to cause the failure of miniscrew placement besides the presence of bone inflammation in the location of miniscrew insertion, the characteristic and age of the skeletal. Therefore, bone density is one of the key factors to determine the success of orthodontic treatment [9]. Mandible has a statistically higher density value in basal cortical bone compared to alveolar bone. The result of this study showed that the thickness and the density of bone vary with the distance from alveolar crest in the interradicular area. The success of miniscrew as an orthodontic anchorage could be achieved if it was placed in an area with 6 mm bone density from apical to the alveolar crest [10].

In general, there is a progressive increase of bone density from anterior area with lower bone density to posterior area with higher bone density in mandible. Several studies found that there was a higher bone density in cortical area compared to the cancellous area. Therefore, it is necessary for miniscrew to be inserted in an oblique angle to the long axis of the tooth in order to obtain a boarder surface contact between miniscrew and cortical bone [11].

Alveolar bone density test could be done using cone beam computed tomography (CBCT) radiograph photography. Alveolar bone density values of the posterior of mandible and anterior of maxilla are 500–850 HU, while those of the anterior of mandible and the posterior of maxilla are less than 0–500 HU and more than 850 HU [12].

Bovine ribs were used as the insertion media of the miniscrew and prior bone density measurement was done. This measurement was done to prove that bovine ribs have a similar density with human mandible bone, which showed a similar characteristic with the presence of cortical and cancellous bone [13]. This study used bovine ribs with different age as mature bovine aged 1.5–2 years old has higher density compared to bovine aged less than a year old [14]. The result showed that the low bone density ribs have the value of 320.8 HU and 298.5 HU, while the optimum bone density ribs have the values of 692.5 HU and 785.7 HU. This was in accordance with a study conducted by Lagravère [12], which stated that alveolar bone density values range was 500–850 HU and low bone density value was less than 500 HU.

The result of tensile strength test was used to observe the required force value to pull out the mini-screw in order to find the most stable miniscrew based on its length. The higher the required force, the stable the miniscrew is. The tensile strength test of miniscrew in low bone density showed that 10 mm miniscrew required the highest force with 138.2 g/n compared to 8 mm and 6 mm miniscrew, which consecutively were 93.2 and 43.3 g/n. Besides, the result of tensile strength test in optimum bone density showed that 10 mm mini-screw required 196.70 g/n, while 8 mm and 6 mm required 115.64 and 87.99 g/n, respectively. It showed a significant difference of the required force resulted from different miniscrew lengths and bone densities, which was in accordance with several studies. A study conducted by Petrey et al. [6] confirmed that miniscrew length has an effect to its stability in alveolar bone by increasing the contact surface area with cortical bone and resulted in a better stability when orthodontic force was given.

Sarul et al. [15] also stated that the length of miniscrew might be an important factor that determine the long-term success rate in the mandible of 20- to 29-year-old women, which was showed by a higher stability found in 8-mm miniscrew that in 6 mm miniscrew. Moreover, study conducted by Nienkemper et al. [16] proved that 11 mm miniscrew provide greater stability than 9 mm miniscrew when inserted in the midpalatal region and Chatzigianni et al. [13] reported that 9 mm miniscrew displaced significantly less than 7 mm miniscrew when a high force loaded. The bigger diameter and the longer miniscrew will gain greater stability and lower level of stress and displacement [17].

On the other hand, Cheng et al. [18] and Park et al. [19] reported that the length of miniscrews had no effect on implant survival and their clinical success.

Anterior en mass retraction in orthodontic movement required 115–140 g/n of force value [5,20]. Based on the mean of required value, 8 mm and 10 mm miniscrew in optimum bone density have the most optimum value for en mass movement, while in low bone density, 10 mm mini-screw has the most optimum value.

The longer the miniscrew, the broader its contact surface with the cortical bone and generally its increased stability. Histomorphometrical and biomechanical analysis could prove that miniscrew length affects its stability. The length of miniscrew determines the stability as it was retained to some cortical boned and the ratio of cortical bone to cancellous bone was known to have an important role to the stability of miniscrew. Axial force resulted could increase the retention of miniscrew with bone osseointegration [5]. Miniscrew length affects the primary stability. With adequate primary stability (without any movement of the implant), bone will stimulate the remodelling process around the implant [21]. Excellent miniscrew stability is necessary while en masse teeth retraction is done. By replacing the 6 mm mini-screw with the 10 mm will increase the surface contact between cortical bone and miniscrew. Miniscrew with 10 mm in length, which inserted in 45°-insertion degree, will increase the surface contact by 1.5-fold [22].

The placement of miniscrew with 8–10 mm will increase the surface contact and improve the mechanic retention of miniscrew to the cortical bone [23]. By inserting the 10 mm miniscrew with 10–45° insertion angles to cortical bone, it will prevent the destruction of tooth apex in the interradicular area. This insertion angle will minimise the contact with tooth apex as appropriate space is relatively available, the contact surface between miniscrew and cortical bone will increase, and the stability will improve [24]. Insertion of 10 mm miniscrew will improve its stability and increase the clinical accuracy, as the part of miniscrew implanted in cortical bone is wider [25].`

Conclusion

The length of mini-screw and the density of bone affect the stability of miniscrew. In bone with optimum density, 10 mm and 8 mm miniscrew equipped good anchorage resistance while in bone with low-density only 10 mm mini-screw provided favourable anchorage resistance.

Disclosure of interest: the authors declare that they have no competing interest.

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