# การเปรียบเทียบความหนาแน่นและปริมาณของกระดูกในกระดูกขากรรไกรล่างด้านหลัง สำหรับการปักหมุดเกลียวขนาดเล็ก: การศึกษาในภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ลำรังสีรูปกรวย

# COMPARISON OF BONE DENSITY AND QUANTITY IN POSTERIOR MANDIBULAR REGION FOR MINISCREW IMPLANT PLACEMENT: A CONE BEAM CT STUDY

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## บทคัดย่อ

ในปัจจุบันหมุดเกลียวขนาดเล็กเป็นเทคนิคทางทันตกรรมจัดฟันที่นิยมใช้เพื่อเป็นหลักยึดกันอย่างแพร่หลาย ปริมาณกระดูก ความหนาแน่นของกระดูก และความหนาของกระดูกทึบที่เพียงพอเป็นปัจจัยหลักที่ทำให้เกิดเสถียรภาพปฐมภูมิ และเพิ่มอัตราความสำเร็จของเทคนิคนี้ ในการศึกษานี้ได้ทำการประเมินความยาวรวมของกระดูก ความหนาแน่นของกระดูก และความหนากระดูกทึบ เพื่อหาตำแหน่งและมุมที่ใช้ปักหมุดเกลียวที่เหมาะสมในบริเวณขากรรไกรล่างส่วนหลัง ทำการศึกษาภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ลำรังสีรูปกรวยในผู้ป่วยจำนวน 75 ราย วัดค่าความหนาของกระดูกทึบ มุมปักหมุดเกลียว ความยาวรวมของกระดูก และความหนาแน่นกระดูก ตั้งแต่ด้านใกล้กลางของฟันกรามซี่ที่ 1 จนถึงด้านไกลกลางของฟันกรามซี่ที่ 2 ที่ระดับ 3-7 มม. ต่ำกว่าสันกระดูกเบ้าฟัน นำมาวิเคราะห์หาความแตกต่างระหว่างกลุ่มโดยใช้การวิเคราะห์ความแปรปรวนทางเดียวและการเปรียบเทียบพหุ พบว่าบริเวณระหว่างฟันกรามซี่ที่ 1 และฟันกรามซี่ที่ 2 มีความหนาของกระดูกทึบมากที่สุด และมีค่าความยาวรวมของกระดูกมากที่สุด ในขณะที่มุมปักหมุดเกลียวในตำแหน่งด้านหลังและห่างจากสันกระดูกเบ้าฟันมีแนวโน้มเพิ่มขึ้น และความหนาแน่นของกระดูกในแต่ละตำแหน่งไม่มีความแตกต่างกัน ซึ่งจากการวิเคราะห์ในภาพรวม ตำแหน่งที่เหมาะสมสำหรับการปักหมุดเกลียวขนาดเล็กคือบริเวณระหว่างฟันกรามซี่ที่ 1 และ 2 กับด้านหลังต่อฟันกรามซี่ที่ 2

**คำสำคัญ**: หลักยึดทางทันตกรรมจัดฟัน, หมุดเกลียวขนาดเล็ก, ความหนาแน่นของกระดูก, ความหนากระดูกทึบ

**Abstract**

Nowadays miniscrew implants are widely used as anchorage in orthodontic treatment. Adequate amount of bone, bone density and cortical thickness are the key factors to obtain primary stability and increase success rate of the miniscrew implants. In this study, total bone length, bone density, and cortical bone thickness were evaluated to find the appropriate site and angulation for miniscrew implant placement. From 75 cone beam CT images, the cortical bone thickness, angulation of insertion, total bone length, and bone density were measured from mesial side of first molar to distal side of second molar at the levels of 3 to 7 mm apical to crestal bone. The data were analyzed using one-way ANOVA and multiple comparisons test. In the interradicular area between first and second molars, maximal cortical bone thickness and total bone length were found. Insertion angulation tended to increase with more posterior and apical positions, whereas bone density in each position was not different. The result showed that the area between first molar and second molar is the most appropriate site for miniscrew insertion, followed by the area distal to second molar.

**Keywords**: Orthodontic Anchorage, Miniscrew Implant, Bone Density, Cortical Bone Thickness

## Introduction

Nowadays the miniscrew implants play an important role in modern orthodontic treatment. The advantages of this technique include an absolute anchorage, small size, easy manipulation, both insertion and removal, possibly immediate loading force and the patient's compliance. This technique has many indications, such as molar distalization, molar uprighting, intrusion, extrusion, expansion, correction of dental midline and correction of canted occlusal plane.

Although miniscrew implants are very useful, their failure rate is quite high with range from 0.0 to 40.8% (Papageorgiou et al., 2012). Many factors contribute to implant's failure including decreased cortical thickness and low bone density. Moreover, miniscrew placement in limited space may cause root contact which leads to implant failure. So complete understanding about the anatomy as well as the bone characteristics in each placement site is necessary to determine the appropriate site and angulation for miniscrew implant placement.

## Objectives and Hypothesis

The objectives of this study were:

1. To evaluate total bone length and cortical bone thickness in the interradicular area of the posterior mandibular regions.
2. To evaluate the density of cortical and cancellous bone in the interradicular area of the posterior mandibular regions.

## Review of Literatures

### Miniscrew Implant

Miniscrew implant or temporary anchorage device (TAD) is one technique of skeletal anchorage. The technique has many advantages, including easy insertion and removal, ability for immediate loading force, ability of placement in various location as well as the good patient's compliance. From the meta-analysis, miniscrew implant placement is more effective than conventional methods, especially as anchorage reinforcement during en-masse retraction (Antoszewska-Smith et al., 2017).

Nowadays there are numerous miniscrew implant systems in the market. They can be divided into many types, according to the implant-bone contact (osseointegrated and non-osseointegrated), the mechanical use (direct anchorage and indirect anchorage), and the insertion method (self-drilling and pre-drilling required) (Alkadhimi and Al-Awadhi, 2018).

### Miniscrew Placement in Posterior Mandible

In the mandible, the common sites for miniscrew implant placement are the interradicular spaces, as well as the mandibular buccal shelf (MBS). Each placement site has the different bone quantity and quality. Poggio et al. used volumetric tomographic images to provide an anatomical map, including the posterior mandibular region, for clinician in interradicular miniscrew placement (Poggio et al. 2006). These interradicular spaces were different in the different dentofacial skeleton patterns (Chaimanee et al., 2011). Liu et al. studied the MBS region and found that the area between the distal root of first molar and the mesial root of second molar should be the first choice for miniscrew implant placement in the MBS area (Liu et al., 2019).

### The Study of Bone Density

The study of jaw bone density is originally and primarily concerned in the implant dentistry field. The bone classifications commonly used are those of Lekholm and Zarb, and Misch.

1. Lekholm and Zarb's Classification

In 1985 Lekholm and Zarb used radiographs to classify bone qualities that were found in the anterior regions of the jawbone into four types. Type 1: homogenous compact bone. Type 2: thick layer of compact bone surrounding dense trabecular bone. Type 3: thin layer of compact bone surrounding dense trabecular bone. Type 4: thin layer of cortical bone surrounding low density trabecular bone (Lekholm and Zarb, 1985).

2. Misch's Bone Density Classification

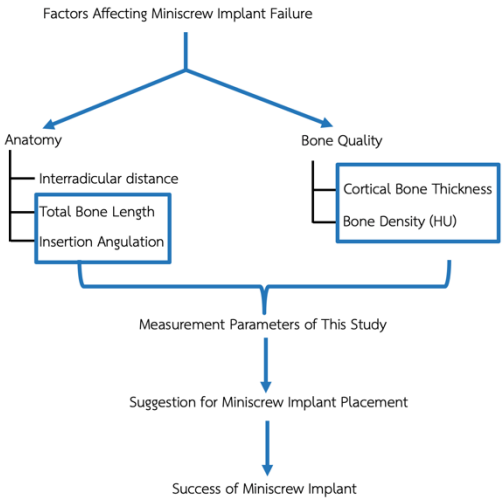
Bone has an internal structure described in term of density that reflects the strength of the bone. Carl E. Misch classified bone density that was found in all regions of the maxilla and mandible into four types based on macroscopic trabecular and cortical bone (Misch & Judy, 1987). D1 is the hardest bone which displays dense cortical bone with less trabecular bone that lead to the highest primary stability of implant. More contact surface between implant and bone is achieved. D2 is a high bone density with a porous thick cortical and coarse trabecular bone, lead to adequate for primary stability of implant. D3 is a low bone density that has a thin porous cortical bone with fine trabecular bone. D4 is a very low bone density due to a very thin cortical bone and fine trabecular bone within.

Base on tactile sense can be classified into 4 types. D1 bone is similar to drilling into oak or maple wood, D2 bone tactile sense like a white pine or spruce, D3 bone is similar to drilling into a balsa wood, and D4 bone is similar to drilling into Styrofoam.

Base on Computed tomography (CT) can be classified into 5 types. D1 bone density greater than 1250 Hounsfield units (HU), D2 bone density within 850-1250 HU, D3 bone density within 350-850 HU, D4 bone density within 150-350 HU, and D5 less than 150 HU.

In miniscrew implant field, there were some studies about the effects of bone density on the miniscrew success/failure. In the insertion torque study, the 6-8 mm miniscrews were inserted into the synthetic bones with various densities and natural bones. The sufficient mechanical stability of miniscrew implant needed at least 1-2 mm of cortical bone thickness with cancellous bone, then the cancellous bone influenced to improve the implant stability (Fernandes et al., 2015). The results conformed to the micro CT study which found that cancellous bone was important for primary stability of miniscrew implants (Marquezan et al., 2013).

**Conceptual Framework**




**Research Methodology**

Volumetric tomographic images of 75 mandibles retrieved from the records of patients receiving orthodontic treatment at BTU Orthodontic Clinic since 1 December 2016 to 30 November 2019 (age range was 20 to 45 years old). The patients with systemic diseases or medications affecting bone metabolism, periodontal bone loss, tooth missing and history of mandibular fracture were excluded.

Setting of the reference planes and measurement techniques were modified from the described standard method (Poggio et al. 2006). Points of measurements in antero-posterior direction were 1) between second premolar and first molar, 2) mid-buccal of first molar, 3) between first and second molars, 4) mid-buccal of second molar and 5) distal to second molar, whereas the points in vertical direction were 3, 5 and 7 mm apical to the crestal bone level (Fig. 1).

The measured parameters include 1) cortical bone thickness, 2) insertion angulation, 3) total bone length, and 4) bone density (in HU). All parameters were measured in bucco-lingual direction which conformed to clinically miniscrew implant placement direction (Fig. 2). The research protocol was approved by BTU Ethics Committee (Approval Number 4/2562).

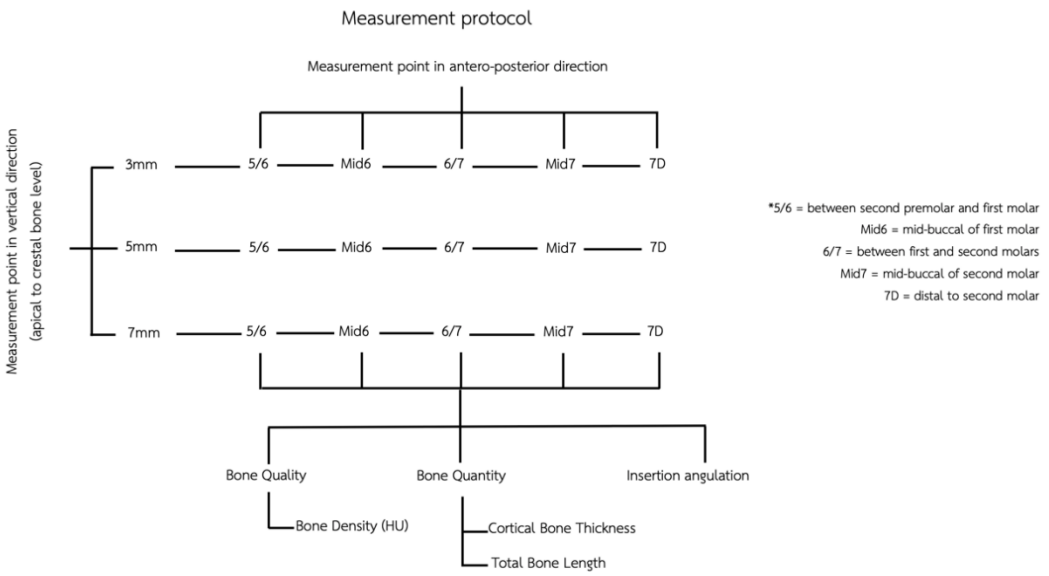



Fig.1 Measurement point, including bone quality, bone quantity, and insertion angulation, in different areas

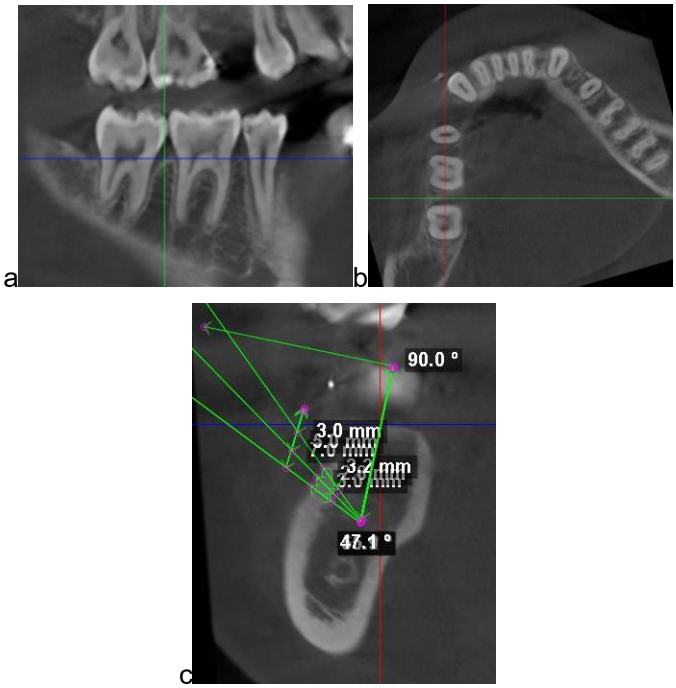



Fig.2 a) average of crestal bone level was set as shown in blue line, b) average long axis of posterior teeth was set as reference in red line, c) long axis of tooth was set in $90^{\circ}$ as reference angulation, 3mm-5mm-7mm below from crestal bone level in vertical direction were set as different point of insertion, all parameters were measure following these lines.

**Research Results**

For cortical thickness, at 3 mm apical to crestal bone level, means of the thickness ranged from 3.20 to 3.92 mm. The thickest area was interradicular area between first and second molars (3.92 mm) which differed from the area between second premolar and first molar, and mid-buccal areas of first and second molars ($p$<0.05). The second highest thickness was found distal to second molar (3.80 mm). At 5 and 7 mm, cortical bone thickness tended to increase with more posterior positions (Fig. 3). For insertion angulation, the means of angle ranged from 42.2 to 76.5 degrees. Insertion angulation tended to increase with more posterior and apical positions (Fig. 4).

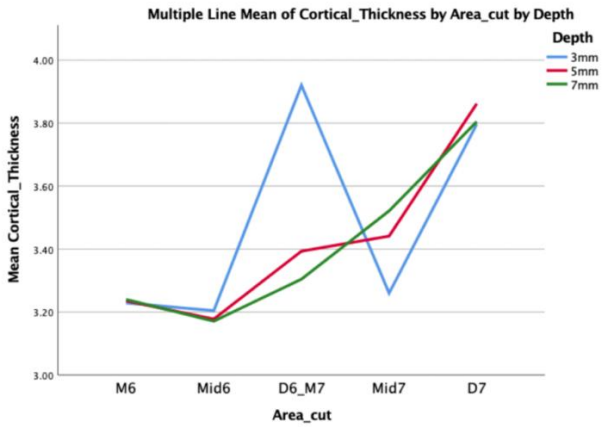



Fig. 3 The mean cortical thickness, at 3, 5 and 7 mm from crestal bone level. At 3 mm below crestal bone level between the first molar and second molars, the most cortical bone thickness was revealed, whereas at 5 and 7 mm below crestal bone, cortical bone thickness tended to increase in posterior regions.

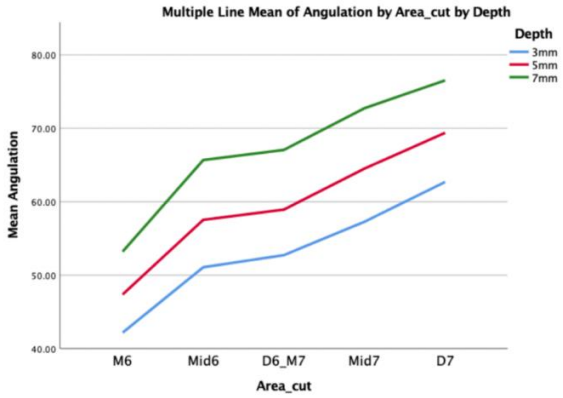



Fig. 4 The angulation of insertion, at 3, 5 and 7 mm from crestal bone level. Insertion angulation tended to increase with more posterior and apical positions.

For the total bone length study, the distances in the interradicular areas tended to be greater than those of mid-buccal areas. In the more apical positions, total bone lengths tended to decrease (Fig. 5). For the bone density analysis, in the more apical

position, bone density tended to decrease, and the density gradually increased from anterior to posterior respectively, but there was no statistical difference (Fig. 6).

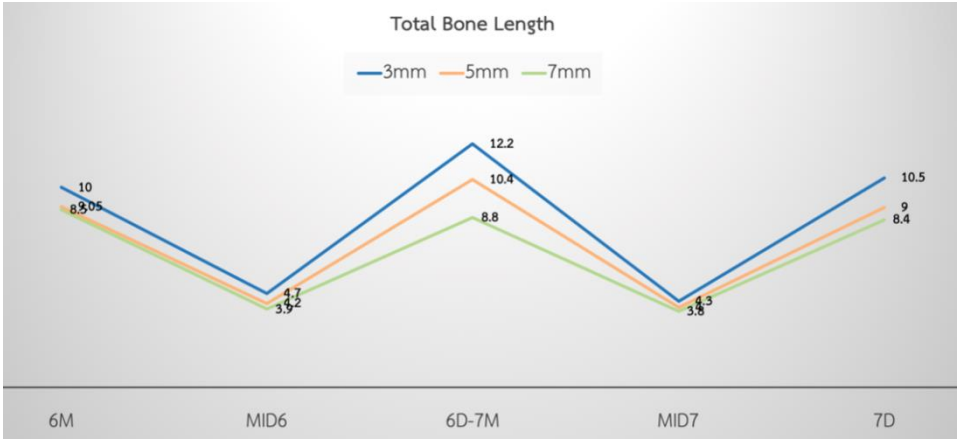



Fig. 5 The total bone lengths in different position and depth. Interradicular area had significantly greater insertion length than mid-buccal area of the teeth

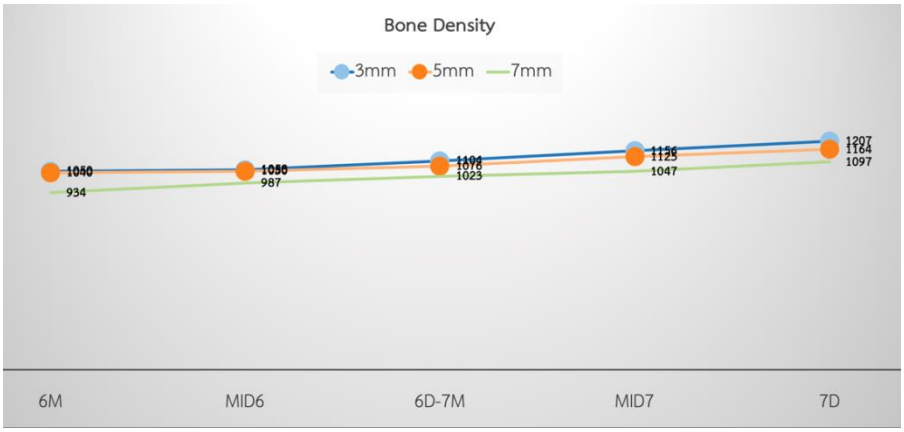



Fig. 6 The bone density in Hounsfield Units (HU). The density gradually increased from anterior to posterior respectively, but there was no statistical difference.

**Conclusions, Discussion and Recommendations**

Throughly understanding of the bone anatomy and bone quality is necessary for clinician to place the miniscrew implant successfully. From literature review, implant failure rate is higher in the cases with decreased cortical thickness and decreased bone density. Placement of miniscrew implant may cause root contact which leads to root damage and implant failure. However, most of previous studies focused on finding the “safe zone” for

miniscrew implant placement (Poggio et al., 2006; Chaimanee et al., 2011; Liu et al., 2019).

For cortical thickness study, at 3 mm apical to crestal bone level, means of the thickness ranged from 3.20-3.92 mm. The thickest area was interradicular area between first and second molars (3.92 mm). At 5 and 7 mm, cortical bone thickness tended to increase with more posterior positions. This trend was similar to the results from the study of Liu et al. which found that the buccal cortical thickness increased from the premolar to molar regions. However, Liu et al. found that the cortical increased from crestal to the apical areas, which differed from our findings, and the mean of thickness in Liu et al.'s study ranged from 1.02 to 7.61 mm, whereas our study found the range from 3.20 to 3.92 mm. These differences may be caused by the angle of measurement, the more oblique placement, the more cortical bone thickness measured. The means of angulation of insertion of our study ranged from 42.2 to 76.5 degrees which correlated to the clinical practice, so our cortical thickness results should be useful.

For total bone length study, we measured both interradicular and mid-buccal regions and found that the distances in the interradicular areas tended to be greater than those of mid-buccal areas. In the more apical positions, total bone lengths tended to decrease. The mean total bone length in the interradicular areas ranged from 8.4 to 12.2 mm. Compared to the study of Poggio et al., the mean total bone lengths ranged from 8.9 to 13.4 mm and tended to increase in more apical position (Poggio et al., 2006). However, degree of difference was minimal and it may not affect the clinical implication.

Although some studies indicated the effects of bone density on the success/failure of miniscrew implants, there was no previous study about the bone density in the interradicular implant placement from our review. The mean of bone density from our study ranged from 934 to 1156 HU, which was categorized as D2 (850-1250 HU) in the Misch's Classification. The D2 bone can withstand stress well and it serves as a good bone type for osseointegrated implant, so the bone quality in posterior mandible from our study was good for miniscrew implant placement.

For conclusions. the area between first molar and second molar is the most appropriate site for miniscrew insertion, followed by the area distal to second molar, because of good cortical bone thickness and total bone length. The angulation of insertion is in the acceptable range, whereas the average bone density in the posterior is in the D2 group.

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