ผลของความยาวหมุดเกลียวขนาดเล็กเหล็กกล้าไร้สนิมต่อเสถียรภาพปฐมภูมิ: การศึกษานอกกาย

Effects of Stainless Steel Miniscrew Length on Primary Stability: An *in vitro* study

ต้นฝน ดามัง[1], คณิช ตรีภูวพฤทธิ์[2], ธีระวัฒน์ โชติกเสถียร[2]
[1]นักศึกษาระดับบัณฑิตศึกษา สาขาวิชาทันตกรรมจัดฟัน คณะทันตแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่
[2]ภาควิชาทันตกรรมจัดฟันและทันตกรรมสำหรับเด็ก คณะทันตแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่
Tonfon Damang[1], Kanich Tripuwabhrut[2], Dhirawat Jotikasthira[2]
[1]Graduate student, Division of Orthodontics Dentistry, Faculty of Dentistry, Chiang Mai University
[2]Department of Orthodontics and Pediatric Dentistry, Faculty of Dentistry, Chiang Mai University

ชม. ทันตสาร 2563; 41(3) : 23-30
CM Dent J 2020; 41(3) : 23-30

Received: 14 January, 2020
Revised: 14 February, 2020
Accepted: 31 March, 2020

บทคัดย่อ

วัตถุประสงค์: เพื่อศึกษาผลของความยาวหมุดเกลียวเหล็กกล้าไร้สนิมขนาดเล็กที่มีต่อแรงบิดในการใส่ที่มากที่สุดและแรงต้านทานการดึงในแนวดิ่ง ณ ตำแหน่งที่มีความหนาแน่นของกระดูกและความหนาของกระดูกทึบต่ำ

วัสดุอุปกรณ์และวิธีการ: หมุดเกลียวเหล็กกล้าไร้สนิมขนาดเล็กจำนวน 36 ตัว ถูกแบ่งเป็น 3 กลุ่ม (กลุ่มละ 12 ตัว) ตามขนาด ได้แก่ 2 มิลลิเมตร x 8 มิลลิเมตร, 2 มิลลิเมตร x 10 มิลลิเมตร และ 2 มิลลิเมตร x 12 มิลลิเมตร หมุดเกลียวขนาดเล็กถูกขันเข้าไปในแท่งกระดูกเทียม ซึ่งกระดูกเทียมถูกสร้างขึ้นมาโดยมี 2 ความหนาแน่น 20 ปอนด์ต่อลูกบาศก์ฟุต และ 10 ปอนด์ต่อลูกบาศก์ฟุต

Abstract

Objective: To determine the effects of different stainless steel miniscrew implant lengths on maximum insertion torque and pull-out strength in a location with relatively low bone density and cortical bone thickness.

Materials and Methods: Thirty-six stainless steel miniscrew implants were evenly assigned to three groups (n=12) according to size: 2 mm x 8 mm, 2 mm x 10 mm, and 2 mm x 12 mm. The implants were wrenched into artificial bone blocks. The artificial bone blocks were made of two different

Corresponding Author:

ธีระวัฒน์ โชติกเสถียร
ศาสตราจารย์ ภาควิชาทันตกรรมจัดฟันและทันตกรรมสำหรับเด็ก
คณะทันตแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่ 50200

Dhirawat Jotikasthira
Professor, Department of Orthodontics and Pediatric Dentistry,
Faculty of Dentistry, Chiang Mai University,
Chiang Mai 50200, Thailand
E-mail: ***dhirawat.j@gmail.com***

เพื่อจำลองกระดูกทึบและกระดูกพรุนบริเวณสันกระดูกโหนกแก้มส่วนใต้ดัดแปรตามลำดับ ทำการทดสอบแรงบิดในการใส่ที่มากที่สุดและแรงต้านทานการดึงในแนวดิ่งถูกวัดโดยเครื่องวัดแรงบิดแบบดิจิทัลและเครื่องทดสอบวัสดุเอนกประสงค์ตามลำดับ ทำการวิเคราะห์ทางสถิติของผลที่ได้โดยวิธีวิเคราะห์ความแปรปรวนทางเดียวและการเปรียบเทียบเชิงซ้อนโดยวิธีทูย์กีที่ระดับนัยสำคัญร้อยละ 5

ผลการศึกษา: หมุดเกลียวขนาดเล็ก 2 มิลลิเมตร x 12 มิลลิเมตร มีแรงบิดในการใส่ที่มากที่สุด (6.03 ± 0.21 นิวตันเซนติเมตร) มากกว่าหมุดเกลียวขนาดเล็ก 2 มิลลิเมตร x 8 มิลลิเมตร (4.91 ± 0.20 นิวตันเซนติเมตร) และ 2 มิลลิเมตร x 10 มิลลิเมตร (4.88 ± 0.18 นิวตันเซนติเมตร) อย่างมีนัยสำคัญ ในขณะเดียวกันไม่พบความแตกต่างอย่างมีนัยสำคัญของแรงบิดในการใส่ที่มากที่สุดระหว่างหมุดเกลียวขนาดเล็ก 2 มิลลิเมตร x 8 มิลลิเมตร และ 2 มิลลิเมตร x 10 มิลลิเมตร แรงต้านทานการดึงในแนวดิ่งของหมุดเกลียวขนาดเล็ก 2 มิลลิเมตร x 8 มิลลิเมตร, 2 มิลลิเมตร x 10 มิลลิเมตร และ 2 มิลลิเมตร x 12 มิลลิเมตร มีค่า 76.49 ± 1.54 นิวตัน 86.22 ± 2.16 นิวตัน และ 108.91 ± 2.88 นิวตัน ตามลำดับ และพบว่าแรงต้านทานการดึงในแนวดิ่งมีปริมาณมากขึ้นอย่างมีนัยสำคัญตามการเพิ่มขึ้นของความยาวหมุดเกลียวขนาดเล็ก

บทสรุป: หมุดเกลียวขนาดเล็กทุกกลุ่มทำให้เกิดแรงบิดในการใส่ที่มากที่สุดที่เหมาะสมในการปักหมุดเกลียวขนาดเล็ก ณ ตำแหน่งที่มีความหนาแน่นของกระดูกและความหนาของกระดูกทึบต่ำ

คำสำคัญ: หมุดเกลียวขนาดเล็ก เสถียรภาพปฐมภูมิ แรงบิดในการใส่ แรงต้านทานการดึงในแนวดิ่ง

densities, 20 pounds per cubic foot (pcf) and 10 pcf, to replicate the cortical and cancellous bone on the modified infrazygomatic crest area, respectively. The maximum insertion torque and pull-out strength were measured using a digital torque gauge and universal testing machine, respectively. One-way analysis of variance (ANOVA) and Tukey's multiple comparison test were performed. The significance level was determined at 5%.

Results: The 2 mm x 12 mm miniscrew implants had significantly greater maximum insertion torque (6.03 ± 0.21 Ncm) than the 2 mm x 8 mm (4.91 ± 0.20 Ncm) and 2 mm x 10 mm (4.88 ± 0.18 Ncm) implants, whereas there was no significant difference between the 2 mm x 8 mm and the 2 mm x 10 mm implants. The pull-out strength of the 2 mm x 8 mm, 2 mm x 10 mm and 2 mm x 12 mm miniscrew implants were 76.49 ± 1.54 N, 86.22 ± 2.16 N and 108.91 ± 2.88 N, respectively. The pull-out strength significantly increased in a length-dependent manner.

Conclusions: All groups provide appropriate maximum insertion torque for miniscrew implant placement in a location with relatively low bone density and cortical bone thickness.

Keywords: miniscrew implant, primary stability, insertion torque, pull-out strength

Introduction

Currently, miniscrew implants have been widely incorporated in orthodontic practice, owing to skeletal anchorage needs and few patient compliance requirements.(1) Orthodontic treatment with miniscrew implants as anchorage is indicated in various circumstances, including molar distalization, anterior en-masse retraction, and molar intrusion for anterior open bite correction.(2) In the maxilla, the modified infrazygomatic crest is commonly used sites for miniscrew implant placement in contemporary orthodontic treatment.(3) In this area, stainless steel miniscrew implants are usually preferred to titanium implants.(3) The cortical bone thickness at the modified infrazygomatic crest is 1.18 - 1.31 mm(4), which is relatively low, when compared to other placement sites, including the palatal area in the maxilla and the buccal shelf area in the mandible.(5)

The stability of miniscrew implants is a crucial factor in determining the success rate of orthodontic treatment.(6) The stability of miniscrew implants can be categorized into two types: primary and secondary stability.(6,7) Primary stability is the initial strength of the mechanical interlock between the threads of miniscrew implants and surrounding bone(8), whereas secondary stability is derived from the biological osseointegration between the implants and bone.(7) Typically, orthodontic force is applied to implants either immediately or after a delay to allow healing after the implant placement.(9) Therefore, primary stability is the most important key for providing stationary anchorage during orthodontic treatment.

Primary stability of miniscrew implants depends on various factors, including cortical bone thickness and miniscrew implant design.(8) It has been demonstrated that the greater the cortical bone thickness, the greater is the primary stability of miniscrew implants.(10,11) Maximum insertion torque and pull-out strength are commonly used methods for measuring the stability of miniscrew implant *in vitro*.(12,13) Previous *in vitro* studies have shown that maximum insertion torque is significantly increased with increased miniscrew implant length.(10,14) Furthermore, it has been reported that an increase in miniscrew implant length increases pull-out strength.(10) A retrospective clinical study found that longer miniscrew implants provided significantly higher success rates than did the shorter implants.(15) However, an *in vitro* study has contrarily reported that the length of miniscrew implants has no effect on maximum insertion torque.(16) Furthermore, a few clinical studies have reported that different miniscrew implant lengths had no effect on success rate.(17,18)

According to previous studies,(10,14-18) the effects of miniscrew implant length on primary stability are still inconclusive and no experimental studies in relatively low-density bone, comparable to that of the modified infrazygomatic crest area, have been conducted. The aim of this study was to determine the effects of different stainless steel miniscrew implant lengths on maximum insertion torque and pull-out strength, representing miniscrew implant primary stability in a location with relatively low bone density and cortical bone thickness.

Materials and Methods

Thirty-six stainless steel miniscrew implants (PW Plus Orthodontic Screw, PW Plus Co., Ltd., Nakhon Pathom, Thailand) were evenly assigned to three groups (n=12) according to size: 2 mm x 8 mm, 2 mm x 10 mm, and 2 mm x 12 mm.

Thirty-six artificial bone blocks (Sawbones, Pacific Research Laboratories, Vashon, Washington, USA), sized 14 mm x 14 mm x 20 mm, were made of two different types of solid rigid polyurethane foam, to replicate the bone of the modified infrazygomatic crest. Polyurethane foam with the densities of 20 pounds per cubic foot (pcf), corresponding to 0.32 g/ cm^3 with 1.2 mm thickness, and 10 pcf, corresponding to 0.16 g/ cm^3 with 18.8 mm thickness, was used to represent cortical and cancellous bone, respectively.

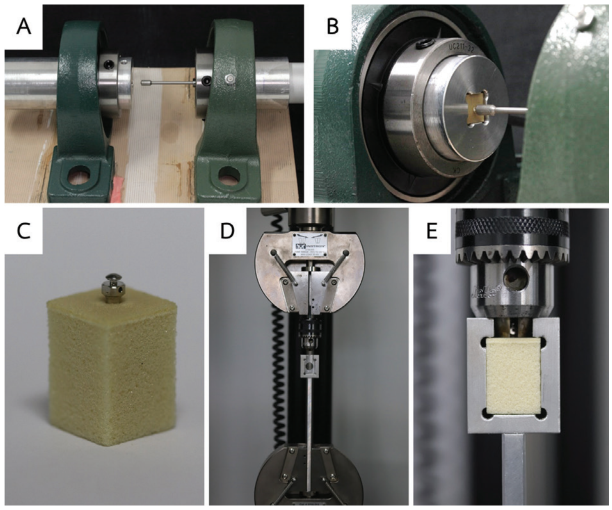
Insertion torque test

The miniscrew implant placement angulation was controlled, perpendicular to the artificial bone block surface, by the bearing device for the artificial bone block holder and the bearing device for the digital torque gauge holder (Figure 1A). The implant was wrenched into the artificial bone block with a constant speed of twelve rotations per minute. Meanwhile, the insertion torque was recorded by the digital torque gauge (digital torque gauge, model HTGS-2N, IMADA Inc, Northbrook, Illinois, USA). The implant was wrenched until the entire thread of the implant was placed in the artificial bone (Figure 1B). The greatest torque during miniscrew implant insertion was recorded as the maximum insertion torque. The artificial bone block with the implant was then ready for the pull-out test (Figure 1C).

Pull-out test

The pull-out test was performed using a universal testing machine (Instron 5566, Instron Limited, Norwood, Massachusetts, USA). The pulling apparatus was connected to the superior clamp. The artificial bone block holder for the pull-out test was fixed to the inferior clamp. The cross head was adjusted up or down until the pulling apparatus closed to the superior edge of artificial bone block holder for the pull-out test (Figure 1D). The artificial bone block with miniscrew implant was placed in the artificial bone block holder for the pull-out test. The implant was grasped by the pulling apparatus (Figure 1E). The universal testing machine was run with a load cell of 500 N and a speed of 10 mm/minute. Each test lasted 30 seconds. The pull-out force from the start until the end of the test was recorded. The maximum force, as the implant began to loosen, was recorded as the pull-out strength.

The data were described as means and standard deviations and were processed using SPSS version 17.0 (IBM, Armonk, New York, USA). The Shapiro-Wilk test was performed to verify the normal distribution of the data. Levene's test was applied to assess the equality of variances. One-way analysis of variance (ANOVA) was performed to test differences in means between groups. Tukey's multiple



รูปที่ 1 *A: มุมการปักหมุดเกลียวขนาดเล็กถูกควบคุมโดยตลับลูกปืนสองชิ้น*
B: หมุดเกลียวขนาดเล็กถูกไขเข้าไปในกระดูกเทียมซึ่งอยู่ในตัวยึดกระดูกเทียม
C: กระดูกเทียมถูกเตรียมสำหรับนำไปทำการทดสอบแรงต้านทานการดึงในแนวดิ่ง
D: การจัดเตรียมการทดสอบแรงต้านทานการดึงในแนวดิ่ง
E: หมุดเกลียวขนาดเล็กถูกจับโดยส่วนยื่นสำหรับการดึง

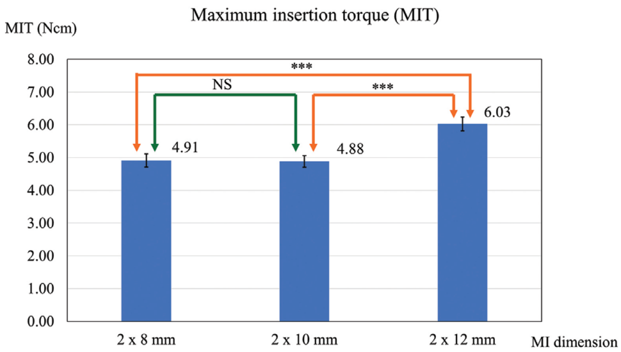
Figure 1 *A: The miniscrew implant placement angulation was controlled by two bearing devices.*
B: The miniscrew implant was wrenched into the artificial bone block in the artificial bone block holder.
C: The artificial bone block with the miniscrew implant was prepared for the pull-out test.
D: Pull-out test set-up
E: The miniscrew implant was grasped by the pulling apparatus.

comparison test was used to identify which pairs of means were different. The significance level was determined at 5%.

Results

1. Maximum insertion torque

The maximum insertion torque of the 2 mm x 8 mm, 2 mm x 10 mm and 2 mm x 12 mm miniscrew implants was 4.91 ± 0.20 Ncm, 4.88 ± 0.18 Ncm and 6.03 ± 0.21 Ncm, respectively. The Shapiro-Wilk test and Levene's test verified the normal distribution and equality of variances of the maximum insertion torque. ANOVA showed significant differences in mean maximum insertion torque among the three groups ($p \leq 0.001$). Tukey's multiple comparison test was performed to compare the means of maximum insertion torque. The results are displayed in Figure 2. No significant difference in the maximum insertion torque was found between the 2 mm x 8 mm miniscrew implants and the 2 mm x 10 mm implants. On the other hand, the 2 mm x 12 mm implants had significantly greater maximum insertion torque than did the 2 mm x 8 mm ($p \leq 0.001$) and the 2 mm x 10 mm implants ($p \leq 0.001$).



รูปที่ 2 *แผนภาพแสดงความแตกต่างค่าเฉลี่ยของแรงบิดในการใส่ที่มากที่สุดระหว่างกลุ่มตัวอย่าง 3 กลุ่ม แกนตั้งแสดงค่าเฉลี่ยของแรงบิดในการใส่ที่มากที่สุด แกนนอนแสดงขนาดของหมุดเกลียวขนาดเล็ก NS: $p > 0.05$ และ ***$p \leq 0.001$*

Figure 2 *Graph demonstrates the differences in mean maximum insertion torque among the three sample groups. The Y-axis displays the means of the maximum insertion torque. The X-axis displays miniscrew implant dimension. NS: $p > 0.05$ and *** $p \leq 0.001$*

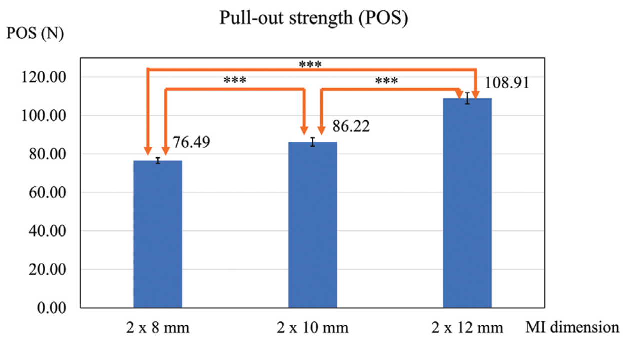
2. Pull-out strength

The means and standard deviations of the pull-out strength of the 2 mm x 8 mm, 2 mm x 10 mm and 2 mm x 12 mm miniscrew implants were 76.49 ± 1.54 N, 86.22 ± 2.16 N and 108.91 ± 2.88 N, respectively. The Shapiro-Wilk test and Levene's test verified the normal distribution and equality of variances of the pull-out strength. ANOVA showed significant differences in mean pull-out strength among the three groups ($p \leq 0.001$). Tukey's multiple comparison test revealed significant differences in pull-out strength among all groups ($p \leq 0.001$). The results are shown in Figure 3. The pull-out strength of the 2 mm x 12 mm implants was significantly greater than that of the 2 mm x 10 mm ($p \leq 0.001$) and the 2 mm x 8 mm implants ($p \leq 0.001$). In addition, the pull-out strength of the 2 mm x 10 mm implants was significantly greater than that of the 2 mm x 8 mm implants ($p \leq 0.001$).

Discussion

The study demonstrated that the miniscrew implant length influenced maximum insertion torque and pull-out strength of stainless steel miniscrew implants. The maximum insertion torque of the 2 mm x 12 mm implants was significantly greater than that of the 2 mm x 8 mm and 2 mm x 10 mm implants, whereas there was no significant difference between the 2 mm x 8 mm and 2 mm x 10 mm implants. The pull-out strength significantly increased in a length-dependent manner.

Maximum insertion torque is the standard measurement for assessing miniscrew implant



รูปที่ 3 *แผนภาพแสดงความแตกต่างค่าเฉลี่ยของแรงต้านทานการดึงระหว่างกลุ่มตัวอย่าง 3 กลุ่ม แกนตั้งแสดงค่าเฉลี่ยของแรงต้านทานการดึงในแนวดิ่ง แกนนอนแสดงขนาดของหมุดเกลียวขนาดเล็ก NS: $p > 0.05$ และ *** $p \leq 0.001$*

Figure 3 *Graph demonstrates the differences in mean pull-out strength among the three sample groups. The Y-axis displays means of the pull-out strength. The X-axis displays miniscrew implant dimension. NS: $p > 0.05$ and ***$p \leq 0.001$*

stability.[19] The optimum maximum insertion torque may be different, depending on the placement methods and types of miniscrew implant. It has been generally accepted that the recommended maximum insertion torque is 5 - 10 Ncm.[20] However, one study reported that insertion of miniscrew implants with maximum insertion torque less than 5 Ncm provided better stability, than with maximum insertion torque above 5 Ncm.[21] The excessive maximum insertion torque may result in ischemia or necrosis of bone around miniscrew implants.[22]

In this study, the maximum insertion torque of 12-mm-length miniscrew implants was significantly greater than that of 8-mm- and 10-mm-length implants. The maximum insertion torque of 8-mm-, 10-mm- or 12-mm-length implants, ranging from 4.88 to 6.03 Ncm, was approximate to the recommended maximum insertion torque. Despite the implant lengths having significantly influenced maximum insertion torque in this study, the 8-mm-, 10-mm- or 12-mm-length implants provided optimal maximum insertion torque, based on previous studies.[21,22]

The pull-out strength has been described as holding power and is directly related to primary stability of miniscrew implants.[11] In this study, the pull-out strength was significantly increased in a length-dependent manner, ranging between 76.49 N and 108.91 N. In clinical practice, orthodontic and dentofacial orthopedics traction force is usually applied in the lateral direction with ranges of force 0.29 - 3.92 N and 4.9 - 9.8 N, respectively.[10] In this study, the miniscrew implants were pulled out perpendicular to the artificial bone, so as to compare the results with those of previous study.[10] It should be pointed out that the pull-out strength in this study does not directly reflect the resistance of miniscrew implants from the clinical orthodontic and dentofacial orthopedic force.

It has been suggested that maximum insertion torque and pull-out strength should be simultaneously investigated.[10] The appropriate miniscrew implant should minimize maximum insertion torque in order to decrease osseous damage and maximize pull-out strength in order to increase holding power.[10] In our study, miniscrew implant length does not affect maximum insertion torque and pull-out strength equally. A 50% increase in miniscrew implant length (8-mm to 12-mm) increased insertion torque and pull-out strength 22.81% and 42.38%, respectively. This finding shows that increased implant length leads to two times increased pull-out strength rather than increased maximum insertion torque.

It has been recommended that miniscrew implants placed in the modified infrazygomatic crest should be tilted by 55º - 70º to the maxillary occlusal plane after initial penetration.[3] Tilting the placement angulation in the apical direction reduces the risk of root damage because the implant is placed in an area of increased interradicular distance.[23] One previous study showed that the increased angulation between miniscrew implant and bone surface produced greater maximum insertion torque and pull-out strength.(11) In our study, miniscrew implants were inserted perpendicular to the artificial bone surfaces, the same as in the previous studies, so that the results can be compared with those of the other studies.(10,14) In addition, miniscrew implant insertion perpendicular to the artificial bone surface resulted in reproducibility of tests. Because of the difference in insertion angle between our study and clinical practice, the effects of insertion angle should be considered before applying the results of this study in clinical situations.

Further study should be performed to test the effects of different miniscrew implant lengths and insertion angles on insertion torque, pull-out strength and resistance to lateral force loading.

Conclusions

The 2 mm x 12 mm miniscrew implants had significantly greater maximum insertion torque than the 2 mm x 8 mm and 2 mm x 10 mm implants. The pull-out strength significantly increased in a length-dependent manner. The 2-mm-diameter miniscrew implant with 8 mm, 10 mm and 12 mm length provide sufficient maximum insertion torque in a location with relatively low cortical bone thickness and bone density.

Acknowledgements

The authors are grateful to the Faculty of Dentistry, Chiang Mai University for grant support. The authors would like to express our recognition to Dr. Thanapat Sastraruji, Faculty of Dentistry, Chiang Mai University for statistical consultation and Dr. M. Kevin O Carroll, Professor Emeritus of the University of Mississippi School of Dentistry, USA and Faculty Consultant at Chiang Mai University Faculty of Dentistry, Thailand, for his assistance in the preparation of the manuscript.

References

1. Uesugi S, Kokai S, Kanno Z, Ono T. Prognosis of primary and secondary insertions of orthodontic miniscrews: What we have learned from 500 implants. *Am J Orthod Dentofacial Orthop* 2017; 152(2): 224-231.
2. Papadopoulos MA, Tarawneh F. The use of miniscrew implants for temporary skeletal anchorage in orthodontics: a comprehensive review. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007; 103(5): e6-15.
3. Lin JJ. *Creative orthodontics blending the damon system & TADs to manage difficult malocclusions.* Taipei: Yong Chieh Co.; 2010: 149-208.
4. Lohalertkit C, Janhom A, Patanaporn V, Jotikasthira D. Comparison of infrazygomatic crest thicknesses between Thai patients with Class I and Class II skeletal pattern using cone beam computed tomography. *OJ Thai Assoc Orthod* 2018; 8: 4-12.
5. Deguchi T, Nasu M, Murakami K, Yabuuchi T, Kamioka H, Takano-Yamamoto T. Quantitative evaluation of cortical bone thickness with computed tomographic scanning for orthodontic implants. *Am J Orthod Dentofacial Orthop* 2006; 129(6): 721 e7-12.
6. Tseng YC, Pan CY, Liu PH, Yang YH, Chang HP, Chen CM. Resonance frequency analysis of miniscrew implant stability. *J Oral Sci* 2018; 60(1): 64-69.
7. Buschang PH, Kim KB. Considerations for optimizing the use of miniscrew implants in orthodontic practice. In: Kim KB, ed: *Temporary Skeletal Anchorage Devices*, Heidelberg: Springer; 2014: 1-27.

8. Araghbidikashani M, Golshah A, Nikkerdar N, Rezaei M. *In-vitro* impact of insertion angle on primary stability of miniscrews. *Am J Orthod Dentofacial Orthop* 2016; 150(3): 436-443.
9. Migliorati M, Drago S, Gallo F, et al. Immediate versus delayed loading: comparison of primary stability loss after miniscrew placement in orthodontic patients—a single-centre blinded randomized clinical trial. *Eur J Orthod* 2016; 38(6): 652-659.
10. Shah AH, Behrents RG, Kim KB, Kyung HM, Buschang PH. Effects of screw and host factors on insertion torque and pullout strength. *Angle Orthod* 2012; 82(4): 603-610.
11. Meira TM, Tanaka OM, Ronsani MM, *et al.* Insertion torque, pull-out strength and cortical bone thickness in contact with orthodontic mini-implants at different insertion angles. *Eur J Orthod* 2013; 35(6): 766-771.
12. Migliorati M, Benedicenti S, Signori A, *et al.* Miniscrew design and bone characteristics: an experimental study of primary stability. *Am J Orthod Dentofacial Orthop* 2012; 142(2): 228-234.
13. Baumgaertel S. Predrilling of the implant site: Is it necessary for orthodontic mini-implants?. *Am J Orthod Dentofacial Orthop* 2010; 137(6): 825-829.
14. Lim SA, Cha JY, Hwang CJ. Insertion torque of orthodontic miniscrews according to changes in shape, diameter and length. *Angle Orthod* 2008; 78(2): 234-240.
15. Lin SY, Mimi Y, Tak CM, Chiong FKW, Chew WH. A study of success rate of miniscrew implants as temporary anchorage devices in Singapore. *Int J Dent* 2015; 2015: 1-10.
16. Holm L, Cunningham SJ, Petrie A, Cousley RR. An *in vitro* study of factors affecting the primary stability of orthodontic mini-implants. *Angle Orthod* 2012; 82(6): 1022-1028.
17. Lim HJ, Choi YJ, Evans CA, Hwang HS. Predictors of initial stability of orthodontic miniscrew implants. *Eur J Orthod* 2011; 33(5): 528-532.
18. Lai TT, Chen MH. Factors affecting the clinical success of orthodontic anchorage: Experience with 266 temporary anchorage devices. *J Dent Sci* 2014; 9(1): 49-55.
19. Suzuki EY, Suzuki B, Aramrattana A, Harnsiriwattanakit K, Kowanich N. Assessment of miniscrew implant stability by resonance frequency analysis: a study in human cadavers. *J Oral Maxillofac Surg* 2010; 68(11): 2682-2689.
20. Reynders RAM, Ronchi L, Ladu L, Etten-Jamaludin FV, Bipat S. Insertion torque and success of orthodontic mini-implants: a systematic review. *Am J Orthod Dentofacial Orthop* 2012; 142(5): 596-614.
21. Suzuki M, Deguchi T, Watanabe H, et al. Evaluation of optimal length and insertion torque for miniscrews. *Am J Orthod Dentofacial Orthop* 2013; 144(2): 251-259.
22. Motoyoshi M, Hirabayashi M, Uemura M, Shimizu N. Recommended placement torque when tightening an orthodontic mini-implant. *Clin Oral Implants Res* 2006; 17(1): 109-114.
23. Laursen MG, Melsen B, Cattaneo PM. An evaluation of insertion sites for mini-implants: a micro - CT study of human autopsy material. *Angle Orthod* 2013; 83(2): 222-229.