

The Effect of Thread Pitch on the Maximum Insertion Torque of Custom-made Orthodontic Miniscrew Implants

ผลของความถี่เกลียวต่อแรงหมุนสูงสุดบนหลักยึดทางทันตกรรมจัดฟันชั่วคราว

Chalernporn Budsabong (เฉลิมภรณ์ บุษบง)* Dr.Pintu-on Chantarawatit (ดร.พินทุอร จันทรวราทิตย์)**

ABSTRACT

This experiment was designed to evaluate the pure effect of thread pitch on the maximum insertion torque (MIT) of orthodontic miniscrew implants (MIs). Sixty MIs, twelve of each pitch 0.4-mm, 0.6-mm, 0.8-mm, 1.0-mm and 1.2-mm, were specifically designed and manufactured keeping the length, diameter and thread design constant, except for thread pitch. Each MI was placed in the a double-layer synthetic bone block using a digital torque reader screwdriver with a custom holder to control the orientation and to ensure the reproducibility. The insertion torque was report in newton-centimeters (N.cm). The smaller pitch tended to have a greater MIT except for the 1.2-mm pitch, statistically significant ($P<0.05$). It can be concluded that thread pitch influenced MIT of the MIs and thread pitch affected the self-tapping properties of the MIs.

บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อประเมินผลของความถี่เกลียวต่อแรงหมุนสูงสุดบนหลักยึดทางทันตกรรมจัดฟันชั่วคราว หลักยึดทางทันตกรรมจัดฟันชั่วคราวถูกออกแบบและผลิตมาทั้งสิ้น 60 ตัว 12 ตัวในแต่ละกลุ่มความถี่ (0.4 มม., 0.6 มม., 0.8 มม., 1.0 มม. และ 1.2 มม.) โดยมีการควบคุมลักษณะอื่นๆของหลักยึดทางทันตกรรมจัดฟันชั่วคราว ทั้งความยาว, เส้นผ่าศูนย์กลาง และลักษณะของเกลียวให้คงที่ในทุกกลุ่ม ยกเว้นความถี่เกลียวซึ่งเป็นตัวแปรต้น ทำการทดลองในกระดูกจำลองชนิดสองชั้น ไชหลักยึดทางทันตกรรมจัดฟันด้วยไขควงวัดแรงหมุนสูงสุดแบบดิจิทัลในหน่วย นิวตัน-เซนติเมตร โดยใช้ตัวจับกระดูกและไขควงเพื่อควบคุมทิศทางการไขและเพื่อให้เกิดการทำซ้ำได้ การทดลองพบว่า หลักยึดทางทันตกรรมชั่วคราวที่มีความถี่เกลียวที่น้อยจะมีแนวโน้มของแรงหมุนสูงสุดมากขึ้น อย่างมีนัยสำคัญทางสถิติ (กำหนดนัยสำคัญที่ระดับ 0.05) ยกเว้นในกลุ่มที่มีความถี่เกลียว 1.2 มม. ที่มีแรงหมุนสูงสุดลดลง สรุปได้ว่า ความถี่เกลียวมีผลต่อแรงหมุนสูงสุดของหลักยึดทางทันตกรรมจัดฟัน ขณะเดียวกัน ความถี่เกลียวมีผลต่อคุณสมบัติการไขตัวเองที่ทำให้ ต้องใช้แรงบิดมากขึ้นเมื่อมีความถี่เกลียวลดลง

Keywords: Miniscrew implant, Pitch, Maximum insertion torque

คำสำคัญ: หลักยึดทางทันตกรรมจัดฟันชั่วคราว ความถี่เกลียว แรงหมุนสูงสุด

*Student, Higher Graduate Diploma in Clinical Sciences in Orthodontics, Department of Orthodontics, Faculty of Dentistry, Chulalongkorn University

**Assistant Professor, Department of Orthodontics, Faculty of Dentistry, Chulalongkorn University

Introduction

In orthodontic treatment, miniscrew implants (MIs) are now widely used for anchorage control and have expanded the scope of tooth movement because of their various advantages that optimize clinical efficiency and efficacy. Because of its simple placement procedure, this procedure can be performed by orthodontists. However, the clinical uses of MIs include some risk such as mobility, displacement and dislodgement. Mostly, screw mobility and displacement occur during the first week due to their insufficient stability with a failure rate of about 13.5% (Kuroda et al., 2014; Papageorgiou et al., 2012). Therefore, stability is essential to retain the MI in position and to resist orthodontic forces.

MIs stability is a consequence of both primary stability and secondary stability (Kim, 2014; Ure et al., 2011). Primary stability depends on mechanical retention of the MIs, and secondary stability depends on primary stability and the healing process, including osseointegration. However, MIs do not need to osseointegrate in order to obtain clinical success (Kim, 2014). Therefore, primary stability is an important factor because it affects secondary stability. Also, in their clinical application, MIs are sometimes loaded immediately.

Factors associated with MI primary stability are insertion technique (R. Reynders et al., 2009), insertion site anatomy and design (Park et al., 2006; R. Reynders et al., 2009). which include length, diameter, fluting, surface treatment, shaft design, thread shape, thread depth and thread pitch (Papageorgiou et al., 2012; Park et al., 2006; R. Reynders et al., 2009). Concerning thread pitch, thread pitch is the distance between the threads of the MI (Figure 1) and the role of thread pitch is to control the MIs advancement distance in one turn. Also, variation in thread pitch can increase or decrease the bone-to-implant surface area. Therefore, variation in thread pitch affects the primary stability of the MIs. However, few scientific evidences are available on the influence of thread pitch on MIT properties of MIs. Furthermore, most previous studies used commercial MIs which compromised the control factors (Brinley et al., 2009; Marco Migliorati et al., 2012; M. Migliorati et al., 2011).

Maximum insertion torque has been commonly used to analyze the primary stability of MIs designs (Kim, 2014). The Higher MIT, the lower in mobility and failure of MIs were found. However, the high MIT also creates an excessive stress and causes microdamage in alveolar bone which leads to reduce the MIs stability. At present, there is insufficient evidence of optimum MIT to obtain higher success of MIs (R.A.M. Reynders et al., 2012).

Objectives of the study

This experiment was designed to

- explore the effect of pitch on the MIT of orthodontic MIs
- provide an optimum pitch of 1.5 x 8 mm MIs

Materials and methods

Miniscrew implants design and manufacture

Miniscrew implants were specifically designed in Solid Work program (Dassault Systèmes, Waltham, MA) keeping the length, diameter and thread design constant, except for the pitch (Figure 1). The length was 8-mm long with a sharp and taper end point. The threads of MSIs were a buttress reverse thread shape with 45-degree leading and 90-degree trailing angle. The major and minor diameter were 1.5 mm and 1 mm, respectively. The MIs, made of 316 medical grade stainless steel, were manufactured by a Computer Numerical Control (CNC) (C.C. Autopart Co Ltd, Chachoengsao, Thailand).

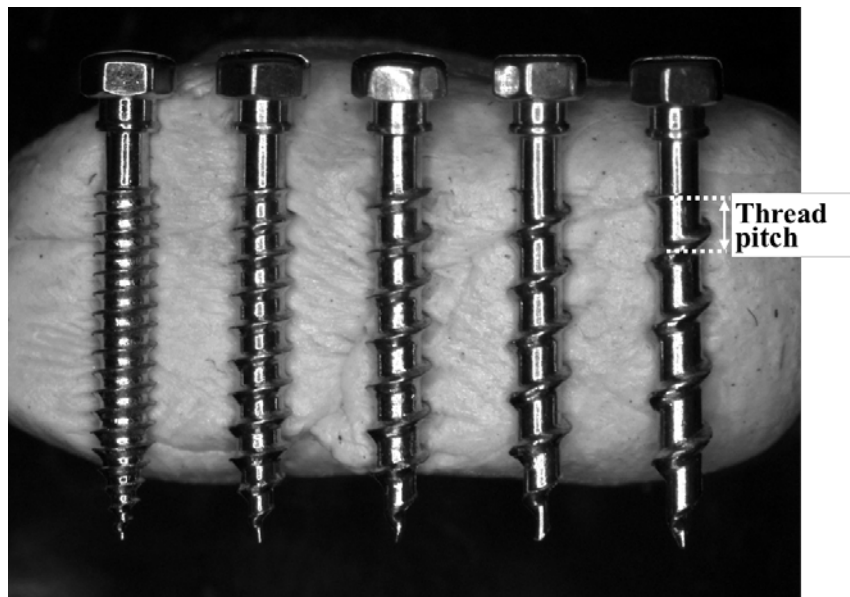


Figure 1 Custom-made 1.5 x 8 mm miniscrew implants with five different pitch: from left to right, 0.4-mm thread pitch; 0.6-mm thread pitch; 0.8-mm thread pitch; 1.0-mm thread pitch; 1.2-mm thread pitch.

Maximum insetion torque testing

Each miniscrew implant was placed in the a double-layer synthetic bone block (solid foam 1522-03 laminated with 2-mm solid foam 1522-16; Sawbone®, Vashon, WA). The double-layer synthetics bone blocks were made of polyurethane of density 0.64 g/cm³ and epoxy glass of density 0.32 g/cm³ to replicate the cortical layer and the trabecular layer, respectively. Each bone block was marked and inserted at the center. The MIT was measured with a torque reader screwdriver (MXITA; Zhejiang, China) (Figure 3) with a speed of 360 degree per second, constantly. The MIT reported in newton-centimeters (N.cm) at a precision of 0.1 N.cm

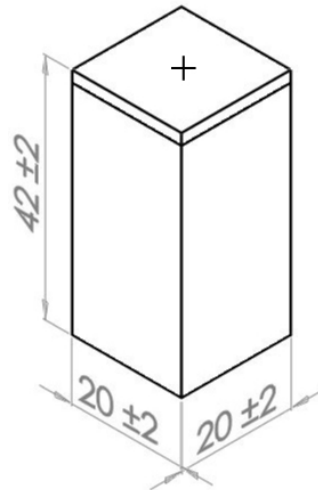


Figure 2 A double-layer synthetic bone block with a mark on the center

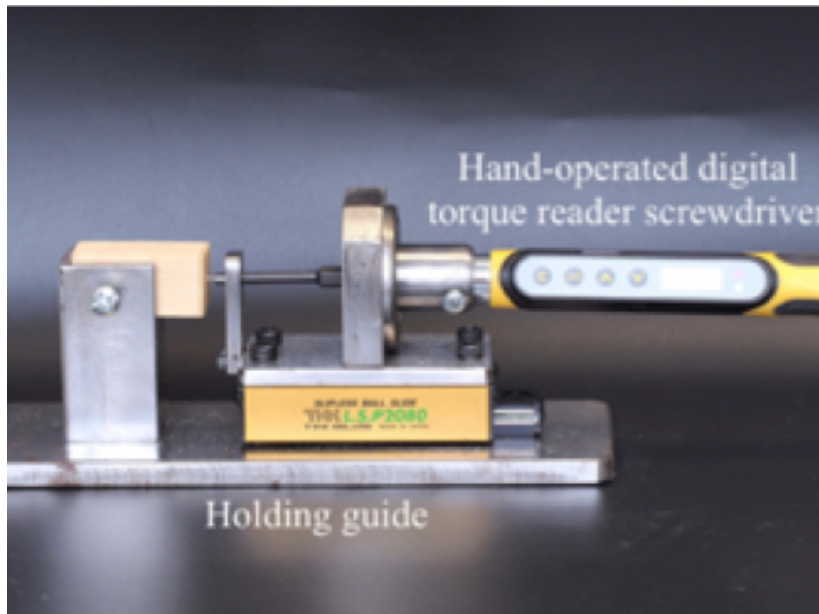


Figure 3 Testing apparatus: a digital torque reader screwdriver with a holding guide

To control the perpendicular orientation and to ensure the reproducibility, the MIT was measured using a custom-made holding guide (Figure 3). The holding guide was designed and manufactured with two components, a holder for a bone block and a holder for a digital torque reader screwdriver. A bone block was placed at the holder and locked to prevent the displacement and ensure the accuracy of the placement procedure. The screwdriver was placed in a roller and locked, allowing its rotation movement and its precise angulation. The insertion torque was measured while the miniscrew implant was inserted, the MIT was recorded when the last thread was inserted.

Statistical analysis

Sample size was calculated from a previous study (Marco Migliorati et al., 2012). With power of 90% and $\alpha = 0.05$, a minimum of 12 MIs was required for each pitch. Confirming the normality of distribution and the equality of variances with Shapiro-Wilk's test and Levene's test were used. One-way analysis of variance (ANOVA) and Tukey post-hoc tests were used to compare the results obtained from each pitch. Statistical analyses were performed by using the SPSS software (SPSS for Mac, version 22.0; IBM, Chicago, IL). The level of significance was set at 0.05.

Results

The means and the standard deviations of MIT are shown in Table 1. The MIT mean ranged from 7.89 ± 0.69 N.cm (1.0-mm pitch) to 13.2 ± 0.60 N.cm. (0.4-mm pitch) with a statistically significant difference between the pitches ($F=124.5$; $p=0.000$). The MIT between every pitch was statistically significant with $p=0.000$, $p=0.000$, $p=0.015$ and $p=0.000$ between 0.4-mm pitch and 0.6-mm pitch, 0.6-mm pitch and 0.8-mm pitch, 0.8-mm pitch and 1.0-mm pitch, and 1.0-mm pitch and 1.2-mm pitch, respectively (Figure 4) The smaller pitch tended to have a greater MIT except for the 1.2-mm pitch which has higher MIT than 0.8-mm and 1.0-mm pitch.

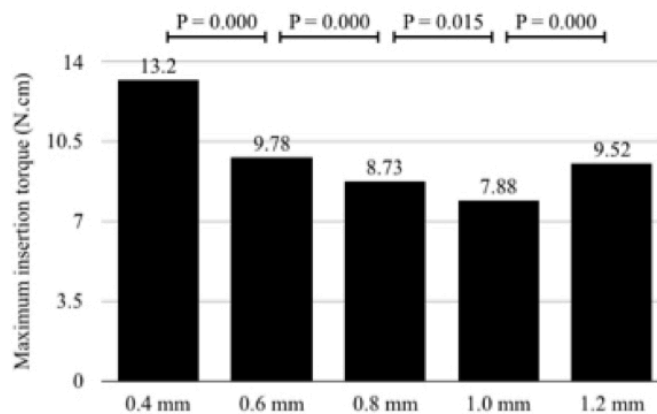


Figure 4 The effects of MI pitch on MIT

Table 1 Means, standard deviations and coefficient of variation values of MIT

Pitch (mm)	MAXIMUM INSERTION TORQUE		
	Mean (N.cm)	SD (N.cm)	CoV (%)
0.4	13.2	0.60	4.56
0.6	9.78	0.61	6.21
0.8	8.73	0.56	6.45
1.0	7.88	0.69	8.70
1.2	9.52	0.65	6.82

Discussions

Besides the patient's anatomy and the placement procedure, the design of miniscrew implants is essential in order to optimize its success. MIs designs could vary in its length, diameter, shaft design, surface treatment and thread design. Many of these factors have been well documented (Chen et al., 2010; Holm et al., 2012; Lim et al., 2008; Wiechmann et al., 2007). To minimize the failure, MIs were designed based on those studies. The diameter and length (1.5 mm x 8 mm, respectively) of the MIs were chosen because of their optimum usage, i.e., to be able to be used in multiple areas such as interdental, infrazygomatic, palatal or buccal shelf areas. From a finite element, a 1.0-mm minor diameter was chosen because the study suggested that the minor diameter should be 0.68 of the major diameter (Chang et al., 2012). The buttress reverse thread shape thread design was chosen because this design had the greatest pullout strength among other designs (Gracco et al., 2012). The MI was designed with a sharp and tapered end point, therefore the MI had both self-drilling and self-tapping properties. All the MIs were successfully placed by a hand-operated screwdriver without a predrilled hole. The synthetic bone density were chosen by a previous study (Song et al., 2007).

To evaluate MI stability influenced by thread pitch variation, two important factors affected the results, the MIs design and the bone model (Brinley et al., 2009; Marco Migliorati et al., 2012; M. Migliorati et al., 2011). However, those factors were not completely controlled. Two of the studies determined the stability of MI pitch from different manufacturers which had variation in the MI design, not just the pitch variation alone (Marco Migliorati et al., 2012; M. Migliorati et al., 2011). Therefore, it was impossible to determine the pure effect of the thread pitch on the MIT. Only one study had a specifically manufactured the MI to evaluate the effect of the thread pitch alone (Brinley et al., 2009), but the MI was tested on the non-corticated synthetic bone blocks which is not a good model for human bone. In this study, the double-layer bone blocks were chosen to represent both cortical bone and trabecular layer human bone, also, to ensure the uniformity and reproducibility properties. By which, this study could isolate the effect of the thread pitch of the MIs on the MIT.

Maximum insertion torque is a standard measurement to evaluate miniscrew implants stability. To achieve the proper primary stability and clinical success, the clinician should choose an optimum MIT. Many studies have evaluated the optimum MIT, but the recommendations are variable (Mitsuru Motoyoshi et al., 2006; M. Motoyoshi et al., 2007; R.A.M. Reynders et al., 2012; Suzuki et al., 2011). In those studies, the MIT ranged from 5 – 25 N.cm, and in the present study, MIT ranged from 6.90 – 14.0 N.cm. Too low MIT affects the retention, whereas too high MIT causes microdamage to the bone, followed by bone necrosis and eventual miniscrew failure. A clinical study, using 1.6-mm dia x 8-mm long MIs, recommended an optimum range of MIT of 5-10 N.cm (Mitsuru Motoyoshi et al., 2006). In the present study, the optimum MIT was found in 0.8-mm pitch and 1.0-mm pitch (8.73 ± 0.56 N.cm and 7.88 ± 0.69 N.cm, respectively).

Because thread pitch is the distance between the threads of the MIs, a fine pitch needs more turns to insert the MIs when compared with a coarse pitch. Furthermore, the finer the pitch, the more bone-to-

implants surface which should lead to a higher MIT. Therefore, the results of the present study showed that the finer the pitch creates greater the MIT, which was statistically significant for all pitches except for the 1.2-mm pitch which had significantly higher MIT than 0.8-mm and 1.0-mm pitch. A previous study showed the same tendency, even though the result was not statistically significant (Brinley et al., 2009). For the reverse tendency of 1.2 mm pitch, thread pitch might affect the self-drilling and self-tapping properties of the MIs. Therefore, too much distance between the threads of MIs could influence the MIT.

Conclusions

Under the laboratory condition, using double-layer synthetic bone blocks and 1.5 mm dia x 8 mm long, the maximum insertion torque increased with increasing pitch.

Acknowledgements

This study was supported by the Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand.

References

- Brinley CL, Behrents R, Kim KB, Condoor S, Kyung H.-M, Buschang PH. Pitch and longitudinal fluting effects on the primary stability of miniscrew implants. *The Angle Orthodontist* 2009; 79(6): 1156-61.
- Chang JZ-C, Chen Y-J, Tung Y-Y, Chiang Y-Y, Lai EH-H, Chen W-P, Lin C-P. Effects of thread depth, taper shape, and taper length on the mechanical properties of mini-implants. *The American Journal of Orthodontics and Dentofacial Orthopedics* 2012; 141(3): 279-88.
- Chen Y, Kyung HM, Gao L, Yu W-J, Bae E-J, Kim S-M. Mechanical properties of self-drilling orthodontic micro-implants with different diameters. *Angle Orthod* 2010; 80(5): 821-27.
- Gracco A, Giagnorio C, Parenti SI, Bonetti GA, Siciliani G. Effects of thread shape on the pullout strength of miniscrews. *Am J Orthod Dentofacial Orthop* 2012; 142(2): 186-90.
- Holm L, Cunningham SJ, Petrie A, Cousley RR. An in vitro study of factors affecting the primary stability of orthodontic mini-implants. *The Angle Orthodontist* 2012; 82(6): 1022-28.
- Kim KB. *Temporary Skeletal Anchorage Devices: A Guide to Design and Evidence-Based Solution*. Switzerland: Springer; 2014.
- Kuroda S, Tanaka E. Risks and complications of miniscrew anchorage in clinical orthodontics. *The Japanese Dental Science Review* 2014; 50(4): 79-85.
- Lim S-A, Cha J-Y, Hwang C-J. Insertion torque of orthodontic miniscrews according to changes in shape, diameter and length. *The Angle Orthodontist* 2008; 78(2): 234-40.

- Migliorati M, Benedicenti S, Signori A, Drago S, Barberis F, Tournier H, Silvestrini-Biavati A. Miniscrew design and bone characteristics: an experimental study of primary stability. *The American Journal of Orthodontics and Dentofacial Orthopedics* 2012; 142(2): 228-34.
- Migliorati M, Signori A, Biavati AS. Temporary anchorage device stability: an evaluation of thread shape factor. *European Journal of Orthodontics* 2011; 34(5): 582-86.
- Motoyoshi M, Hirabayashi M, Uemura M, Shimizu N. Recommended placement torque when tightening an orthodontic mini-implant. *Clinical Oral Implants Research* 2006; 17(1): 109-14.
- Motoyoshi M, Matsuoka M, Shimizu, N. Application of orthodontic mini-implants in adolescents. *The International Journal of Oral and Maxillofacial Surgery* 2007; 36(8): 695-99.
- Papageorgiou SN, Zogakis IP, Papadopoulos MA. Failure rates and associated risk factors of orthodontic miniscrew implants: a meta-analysis. *The American Journal of Orthodontics and Dentofacial Orthopedics* 2012; 142(5): 577-95.
- Park H-S, Jeong S-H, Kwon O-W. Factors affecting the clinical success of screw implants used as orthodontic anchorage. *The American Journal of Orthodontics and Dentofacial Orthopedics* 2006; 130(1): 18-25.
- Reynders R, Ronchi L, Bipat S. Mini-implants in orthodontics: a systematic review of the literature. *The American Journal of Orthodontics and Dentofacial Orthopedics* 2009; 135(5): 564-5.
- Reynders RAM, Ronchi L, Ladu L, van Etten-Jamaludin F, Bipat S. Insertion torque and success of orthodontic mini-implants: a systematic review. *The American Journal of Orthodontics and Dentofacial Orthopedics* 2012; 142(5): 596-614.
- Song Y-Y, Cha J-Y, Hwang C-J. Mechanical characteristics of various orthodontic mini-screws in relation to artificial cortical bone thickness. *The Angle Orthodontist* 2007; 77(6): 979-85.
- Suzuki EY, Suzuki B. Placement and removal torque values of orthodontic miniscrew implants. *The American Journal of Orthodontics and Dentofacial Orthopedics* 2011; 139(5): 669-78.
- Ure DS, Oliver DR, Kim KB, Melo AC, Buschang PH. Stability changes of miniscrew implants over time: a pilot resonance frequency analysis. *The Angle Orthodontist* 2011; 81(6): 994-1000.
- Wiechmann D, Meyer U, Büchter A. Success rate of mini-and micro-implants used for orthodontic anchorage: a prospective clinical study. *Clinical Oral Implants Research* 2007; 18(2): 263-67.