

Effects of wobbling angle on the stability measures of orthodontic mini-implants during insertion and removal procedures

Il-Sik Cho^a; Sang-Ho Baek^b; Young Ho Kim^c

ABSTRACT

Objective: To investigate the effects of wobbling angle on the stability measures of orthodontic mini-implants (OMIs) during insertion and removal procedures in artificial bone blocks.

Materials and Methods: A total of 36 OMIs (self-drilling type, cylindrical shape, 7 mm in length, 1.45 mm in diameter) were allocated into three groups according to the amount of wobbling angle (W-0°, W-2°, and W-4° groups; N=12 per group). The OMIs were installed and subsequently removed from artificial bone blocks (Sawbone) using a driving torque tester with a uniform speed of 28 rpm. Insertion peak time (IPT), maximum insertion torque (MIT), total insertion energy (TIE), near-peak insertion energy (NPIE), maximum removal torque (MRT), and near-peak removal energy (NPRE) were measured.

Results: The W-4° group showed the longest IPT and highest TIE and NPIE, followed by the W-2° and W-0° groups (W-0° < W-2° < W-4°, all $P < .001$). The W-2° and W-4° groups showed significant increase in MIT compared with the W-0° group (W-0° < [W-4°, W-2°]; $P < .001$). Although there was no significant difference in NPPE among the three groups, the W-4° group showed a decrease in MRT compared with the W-0° and W-2° groups (W-4° < [W-2°, W-0°]; $P < .05$). Although the W-4° group showed a 14.5% (2.9 Ncm) increase in MIT compared with the W-0° group, there was only a 6% (1.3 Ncm) decrease in MRT from the W-0° group to the W-4° group.

Conclusion: Slight wobbling during the OMI insertion procedure may be acceptable in terms of the stability measures of OMIs during insertion and removal procedures. (*Angle Orthod.* 2013;83:1009–1014.)

KEY WORDS: Stability measures; Orthodontic mini-implants; Wobbling

INTRODUCTION

The orthodontic mini-implant (OMI), also known as a temporary anchorage device, has been popularized because of its low cost compared with other anchorage devices, relative simplicity of installation and removal, and simplified treatment mechanics, and because it needs no compliance from patients.^{1–4} OMIs can be installed by the manual insertion method using a hand driver or by the motor insertion method using a handpiece.

The motor insertion method has several advantages, including maintenance of a constant drilling speed and force, prevention of excessive insertion torque by the auto-stop or over-limit mechanism during drilling procedure, and easy approach to the palate or the most posterior area of the buccal attached gingiva in the mouth.^{5–7} However, this method requires space for equipment and expensive instruments. Moreover, it is difficult to obtain the proper tactile sensation and to monitor the insertion angle during the insertion procedure.⁷

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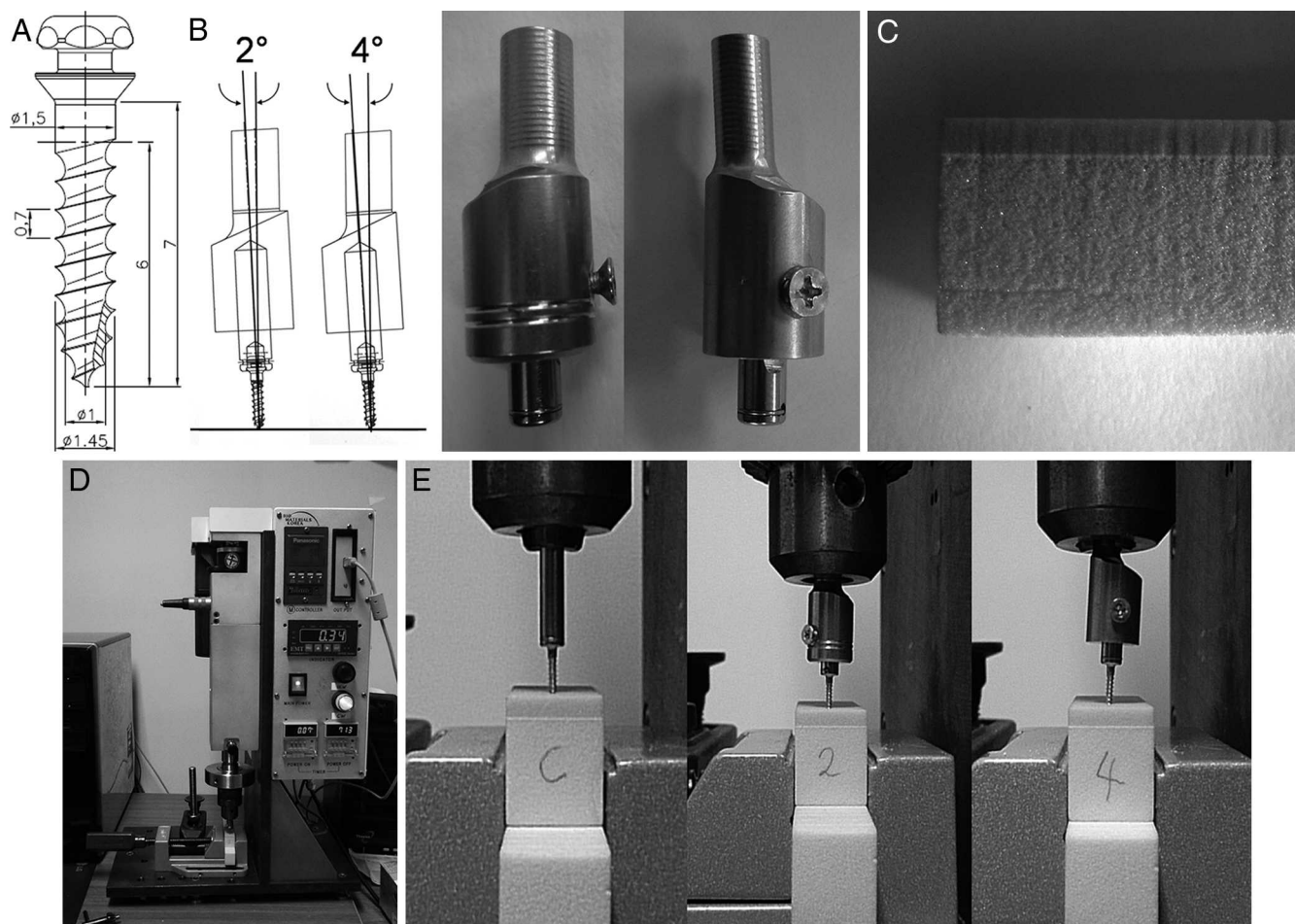


Figure 1. (A) Schematic diagram of the orthodontic mini-implants used in this study (cylindrical shape, 7 mm). (B) Figures and pictures of the wobbling analogs of 2° and 4°. (C) Custom-made polyurethane foam artificial bone block with two layers that simulate the cortical and cancellous bone. (D) The driving torque tester. (E) Insertion of OMIs with the 0° shaft, the 2° wobbling analog, and the 4° wobbling analog.

The manual insertion method is relatively simpler than the motor-driven method. It can also provide better tactile sensation when the OMI tip contacts the alveolar bone, and it also allows for confirmation of the insertion orientation.⁷ However, it is difficult to obtain the appropriate insertion torque, maintain the proper rotational speed, or access the palate or the most posterior area of the buccal attached gingiva in the mouth with a hand driver.⁷

Crismani et al.,⁸ in a systemic review on the success rates of OMI placement, reported an average success rate of 83.6%. Regarding the success rates of manual and motor insertion methods, Kim et al.⁷ reported that the success rate of the motor insertion method was significantly higher than that of the manual insertion method (84.6% vs 69.2%; $P < .001$).

OMI failure factors related to the insertion procedure include inaccurate insertion methods, insufficient irrigation, excessively high drilling speed, inappropriate insertion torque, and slippage of the OMI during placement because of the application of excessive

pressure.^{9–13} Furthermore, lack of experience and improper technique in the manual insertion method may cause the OMI to wobble at the insertion site during the insertion procedure.⁷ Wobbling can increase the amount of reduction of the cortical bone, cause microcrack or damage, and decrease the mechanical retention between the OMI and bone, which will eventually compromise the primary stability of the OMIs. In addition, the secondary stability of OMIs can be affected by bone modeling and remodeling at the OMI–bone interface.^{14–16}

However, to the authors' knowledge, only a few studies have investigated the effects of wobbling angle on the stability measures of OMIs. To produce a specific amount of wobbling during OMI insertion, it is necessary to develop wobbling analogs with certain amounts of angle that can be connected to a driving torque tester. Therefore, the purpose of this in vitro study was to investigate the effects of wobbling angle on the stability measures of OMIs during insertion and removal procedures in artificial bone blocks.

Table 1. Physical Properties of the Polyurethane Foam Used in the Artificial Bone Block^a

	Density		Compressive		Tensile	
	pcf	g/cc	Strength, MPa	Modulus, MPa	Strength, MPa	Modulus, MPa
Cortical layer	50	0.80	58	1400	32	2000
Cancellous layer	30	0.48	19	520	12	427

^a The data in this table were adopted from Cho and Baek.²⁵

MATERIALS AND METHODS

OMIs and Allocation of Groups

A total of 36 OMIs (self-drilling type, cylindrical shape, 7 mm in length, 1.45 mm in diameter; Biomaterials Korea Inc, Seoul, Korea, Figure 1A) were allocated into three groups according to the amount of wobbling angle (control [0°], 2°, and 4°; Figure 1B): W-0°, W-2°, and W-4° groups (N = 12 per group).

Artificial Bone Block

Custom-made polyurethane foam artificial bone blocks with two layers that simulate the cortical and cancellous bone (180 mm long, 15 mm wide, and 18 mm high; the upper layer with a density of 0.80 g/cc [50 pcf] and a height of 3 mm; the lower layer with a density of 0.48 g/cc [30 pcf] and a height of 15 mm; Sawbone, Pacific Research Laboratories, Inc, Vashon, Wash; Table 1; Figure 1C) were fixed with a metal clamp.

Insertion and Removal of OMIs

The OMIs were installed and subsequently removed from artificial bone blocks using a driving torque tester with a uniform speed of 28 rpm (Biomaterials Korea

Inc, Figure 1D). A 500-g weight was added to the tester’s rotational axis during the insertion procedure and was removed during the removal procedure to mimic the presence and absence of perpendicular pressure in the clinical situation, respectively.

After the shafts of the control (0°), the 2° wobbling analog, or the 4° wobbling analog were attached to the chuck of the torque tester’s rotational axis, the OMIs were installed at a distance of 10 mm to prevent possible crack in the artificial bone block.

Measurements of the Insertion and Removal Variables

During the insertion and removal procedures, insertion peak time (IPT), maximum insertion torque (MIT), total insertion energy (TIE), near-peak insertion energy (NPIE), maximum removal torque (MRT), and near-peak removal energy (NPRE) were measured. These insertion and removal variables are defined in Figures 2 and 3.^{17,18}

Statistical Analysis of the Insertion and Removal Variables

The sample-size determination was performed by a power analysis using the Sample Size Determination Program, version 2.0.1 (Seoul National University Dental Hospital, 2007-01-122-004453, Seoul, Korea). Because the normality and equality of variance

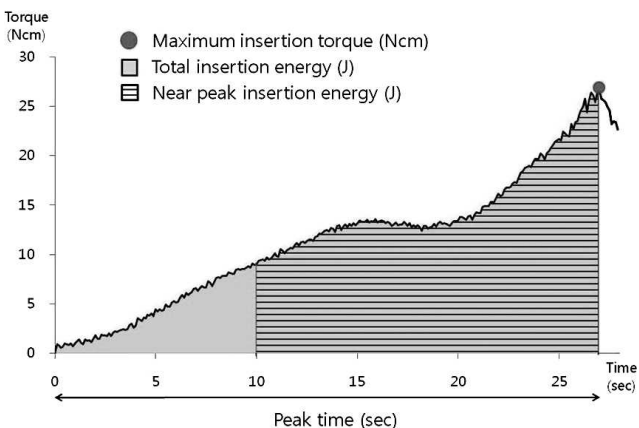


Figure 2. Definitions of the insertion variables. Insertion peak time (seconds) is the time from the beginning to the maximum insertion torque during OMI insertion. Maximum insertion torque (Ncm) is the maximum torque value during OMI insertion. Total insertion energy (J) is calculated by the area under the graph from the beginning of insertion to the maximum insertion torque during OMI insertion. Near-peak insertion energy (J) is the energy measured from the point of maximum insertion torque to eight rotations before that point.

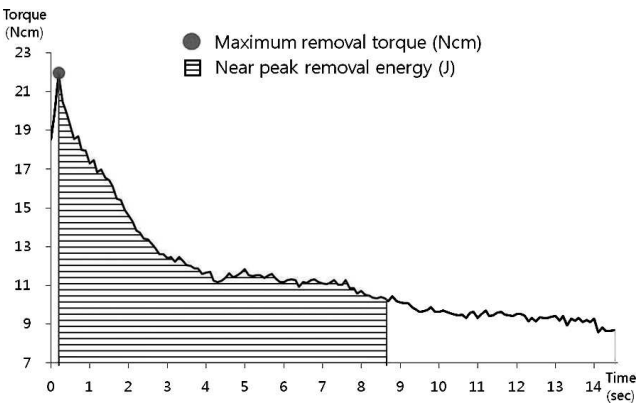


Figure 3. Definitions of the removal variables. Maximum removal torque (Ncm) is the maximum torque recorded during the removal procedure. Near-peak removal energy (J) is the energy measured from the point of the maximum removal torque to four rotations after that point.

Table 2. Comparison of the Insertion and Removal Variables Among Control, 2° Wobbling Angle, and 4° Wobbling Angle Groups^a

	Angle of wobbling (mean $\pm$ SD; N=12 per group)			Significance	Multiple Comparison
	Control (0°)	2°	4°		
Insertion peak time (seconds)	24.88 $\pm$ 0.98	25.95 $\pm$ 0.86	28.85 $\pm$ 1.66	$P < .001^{***}$	C < 2° < 4°
Maximum insertion torque (Ncm)	23.99 $\pm$ 1.10	26.90 $\pm$ 0.84	26.63 $\pm$ 0.99	$P < .001^{***}$	C < (4°, 2°)
Total insertion energy (J)	7.46 $\pm$ 0.31	7.98 $\pm$ 0.30	8.98 $\pm$ 0.47	$P < .001^{***}$	C < 2° < 4°
Near peak insertion energy (J)	6.73 $\pm$ 0.26	7.00 $\pm$ 0.23	7.31 $\pm$ 0.15	$P < .001^{***}$	C < 2° < 4°
Maximum removal torque (Ncm)	21.91 $\pm$ 1.44	21.85 $\pm$ 1.20	20.59 $\pm$ 1.40	$P = .0369^*$	4° < (2°, C)
Near peak removal energy (J)	3.25 $\pm$ 0.10	3.30 $\pm$ 0.09	3.22 $\pm$ 0.09	$P = .1630$	—

^a One-way analysis of variance and Duncan's multiple comparison test were performed. C represents control; * $P < .05$; *** $P < .001$.

assumption were not violated in the data set, one-way analysis of variance and Duncan's multiple comparison tests were performed for statistical analyses. The level of significance for all the tests was set at $P < .05$.

RESULTS

Insertion Variables

IPT variables. The W-4° group showed the longest IPT, followed by the W-2° and W-0° groups (W-0° [24.9 seconds] < W-2° [26.0 seconds] < W-4° [28.9 seconds]; $P < .001$; Table 2, Figure 4A). The differences in IPT between the W-0° and W-2° groups and between the W-0° and W-4° groups were

1.1 second (0.5 turn of OMI at 28 rpm) and 4 seconds (1.8 turn of OMI at 28 rpm), respectively (Table 2).

MIT and insertion torque-time graph. The W-4° and W-2° groups showed 13% (2.6 Ncm) and 14.5% (2.9 Ncm) increases in MIT, respectively, compared with the W-0° group (W-0° [24.0 Ncm] < [W-4° {26.6 Ncm}, W-2° {26.9 Ncm}]; $P < .001$; Table 2, Figure 4A). The fluctuation pattern of insertion torque, especially from the early to middle part of insertion procedure, was more definite in the W-4° group than in the W-2° and W-0° groups (Figure 4A).

TIE and NPIE. The W-4° group showed the highest TIE and NPIE, followed by the W-2° and W-0° groups (W-0° < W-2° < W-4°; TIE, 7.5 J < 8.0 J < 9.0 J; NPIE, 6.7 J < 7.0 J < 7.3 J; all $P < .001$; Table 2; Figure 4A). Increases in TIE and NPIE from the W-0° group to the W-4° group were 20% (1.5 J) and 9% (0.6 J), respectively.

Removal Variables

NPRE variables. There was no significant difference in NPRE between the three groups (Table 2; Figure 4B).

MRT and removal torque-time graph. The W-4° group showed a decrease in MRT compared with the W-0° and W-2° groups (W-4° [20.6 Ncm] < [W-2° {21.9 Ncm}, W-0° {21.9 Ncm}]; $P < .05$; Table 2; Figure 4B). However, the decrease in MRT from the W-0° group to the W-4° group was only 6% (1.3 Ncm).

The W-4° and W-2° groups showed a more noticeable fluctuation pattern of removal torque from the middle to the last part compared with the early part of the removal procedure, although the degree of fluctuation was less than that of the insertion torque-time graph (Figure 4B).

DISCUSSION

Numerous studies have examined the effects of design, length, surface treatment, and installation angle on the success rate and stability of the OMIs.^{18–25} However, wobbling, which is considered to be one of the important contributing factors for the success rate of the manual insertion of OMIs, has not

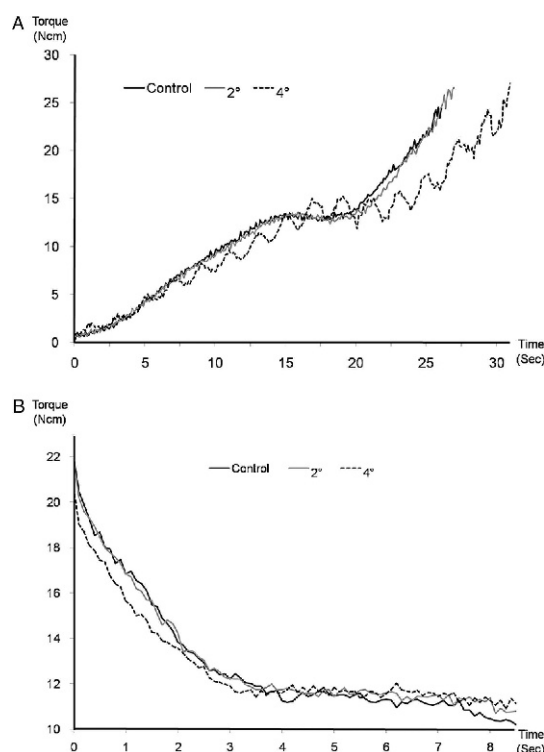


Figure 4. (A) Superimposition of the time-insertion torque graph among the control, 2° wobble angle, and 4° wobble angle. (B) Superimposition of the time-removal torque graph among the control, 2° wobble angle, and 4° wobble angle.

been investigated. Therefore, in this study, wobbling analogs were invented to mimic the clinical situations encountered during manual insertion method using a hand driver.

The reason why artificial bone block with 3 mm of cortical bone was used in this study was to simulate the clinical situation of OMI installation in the mandibular molar area, where the cortical bone thickness of the alveolar bone is known to be thicker than other areas.²⁶ In this area, the possibility of slippage and/or wobbling is known to be increased.⁷

The finding that the W-4° group showed the longest IPT, followed by the W-2° and W-0° groups ($W-0^\circ < W-2^\circ < W-4^\circ$; $P < .001$; Table 2) indicates that a greater wobbling angle takes time to make a hole due to an increased amount of bone reduction in the artificial cortical bone area during the insertion procedure. However, the 4 seconds (1.8 turn of OMI at 28 rpm; Table 2) difference in IPT between the W-0° and W-4° groups may not be clinically important.

Although Meursing Reynders et al.²⁷ reported that there was currently no evidence of an association between the specific level or range of the MIT and a higher OMI success rate, several MIT ranges have been recommended from the OMI systems and manufacturers, such as 5 to 10 Ncm by Motoyoshi et al.,²⁸ 20 Ncm by Kim et al.,⁷ and 20 to 40 Ncm by Baumgaertel et al.²⁹ Because the presence of a wobbling angle increases the amount of reduction of the artificial cortical bone during the insertion procedure, MIT increased approximately 2.6 to 2.9 Ncm (13% to 14.5%) in the W-4° and W-2° groups ($W-0^\circ < [W-4^\circ, W-2^\circ]$; $P < .001$; Table 2). In addition, the wobbling OMI may push the artificial bone adjacent to the OMI outward, and thereby contribute to increase in MIT. Therefore, further in vivo study will be necessary to confirm that the same findings occur in real bone.

The higher TIE in the W-4° group, followed by the W-2° and W-0° groups ($W-0^\circ < W-2^\circ < W-4^\circ$; $P < .001$; Table 2), is likely due to the increases in MIT and IPT with increasing wobbling angle. Comparison of NPIEs revealed that the amount of energy required for the last eight turns of the OMI insertion procedure was proportional to the increases in wobbling angle and MIT ($W-0^\circ < W-2^\circ < W-4^\circ$; $P < .001$; Table 2). Because the amount of increase in TIE from the W-0° group to the W-4° group (20%) was larger than the increase in NPIE (9%), TIE might be more clinically meaningful than NPIE.

Because an increase in wobbling angle can increase the amount of reduction of the artificial bone adjacent to the OMI during the insertion procedure, MRT in the W-4° group decreased, which was expected ($W-4^\circ < [W-2^\circ, W-0^\circ]$; $P < .05$; Table 2). However, the decrease in MRT of only 6% (1.3 Ncm) from the W-0°

group to the W-4° group may not be clinically significant. In addition, the amount of energy required for the first four turns of the OMI removal procedure (NPRe) was the same among the three groups (Table 2). Because the amount of gap between the diameter of the upper part of the hole and the OMI may explain the difference in the mechanical retention at the OMI-artificial bone interface, further in vivo studies are needed to compare the amount of gap between the OMI and hole in the bone.

The clearer fluctuation pattern of insertion torque and removal torque in the W-4° group compared with the W-2° and W-0° groups (Figures 4A,B) may be due to the degree of wobbling. These fluctuation patterns appear to be maximized at the start of the OMI insertion and at the end of the OMI removal process.

In conclusion, although the W-4° group showed a 14.5% (2.9 Ncm) increase in MIT compared with the W-0° group, there was only a 6% (1.3 Ncm) decrease in MRT from the W-0° group to the W-4° group. These findings indicate that 4° of wobbling did not significantly affect the amount of MRT compared with 0° of wobbling.

As described by Kim et al.,⁷ wobbling can be prevented in a number of ways. First, the clinician should check that the shaft is securely connected to the driver holder. Second, low pressure and low drilling speed are recommended to minimize OMI slippage and bone overheating and to maintain proper tactile sensation and insertion orientation of the OMI. Third, when long OMI is used, the motor insertion method using an engine driver can decrease wobbling. And last, because a high cortical bone density can increase the possibility of wobbling during the initial stage of placement, predrilling is recommended in areas with high cortical bone density.^{25,30,31}

In the manual insertion method, the protocol to minimize wobbling can be summarized as follows. The clinician establishes the initial insertion path in the cortical bone (the first 2 to 3 mm) using a palm grip with perpendicular pressure to the hand driver. Then, the clinician changes the palm grip to a pencil grip, thus avoiding perpendicular pressure to the hand driver, and follows the established insertion path into the cancellous bone.

Because this study is an in vitro experiment performed in artificial bone blocks, it has some limitations with regard to understanding the biologic responses as well as how the short-term and long-term success rates of the OMIs are affected.²⁵ Therefore, further in vivo studies using animal models and clinical studies will be needed to investigate the effects of wobbling angle on stability measures, bone-implant contact, microdamage, and primary and secondary stability. However, standardization of clinicians' skill,

insertion-site preparation, cortical bone thickness, and amount of wobbling angle will be necessary.

CONCLUSIONS

- Although an increase in wobbling angle during the OMI insertion procedure can damage adjacent bone and contribute to negative effects on the primary and/or secondary stability of OMIs, slight wobbling during the OMI insertion procedure may be acceptable in terms of the stability measures of OMIs during insertion and removal procedures.
- It will be necessary to perform an in vivo study to corroborate that the same findings will occur in the real bone.

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