CHAPTER 3

PILOT STUDY I

ESTIMATION OF PULLOUT STRENGTH OF MINISCREW IMPLANTS IN FRESH MAXILLARY AND MANDIBULAR DENTOALVEOLAR BONE OF PIGS

3.1) Introduction

Pullout strength testing is a recognized approach to evaluate quantitatively the holding power of screws inserted into bone specimens (An and Draughn, 2000). The evaluation of pullout strength values of screws inserted into the bone specimen allow determination of the optimum screw size, insertion technique, angle of penetration, and screw hole preparation method (Carmouche *et al.*, 2005; Daftari *et al.*, 1994; Huja *et al.*, 2005; Huja *et al.*, 2006). These variables combined with the characteristics of the bone structure, play an important role in the success of screw fixation (Motoyoshi *et al.*, 2007). Although this method is not suitable for direct clinical assessments (it is destructive), the assessment of the force required to pullout a screw from a bone specimen provides valuable information about the bone-screw interface (An and Draughn, 2000).

Therefore, the purposes of this pilot study I were:

1. To assess the maximum pullout values of miniscrews inserted into several sites of the fresh maxillary and mandibular dentoalveolar bone of pigs.
2. To design an appropriate fixation apparatus to grip the bone specimen and miniscrews, thus allowing accurate pullout strength measurements.

3.2) Materials and methods

3.2.1 Experimental animals

Four 3-month-old crossbred swines were used in this pilot study I. The maxillary and mandibular dentoalveolar bones of the pigs were divided into two (buccal and palatal) and one (buccal) areas, respectively as shown in Figure 3.1.

Miniscrew implants were placed in three regions in each group, i.e. anterior, middle and posterior regions.

3.2.2 Miniscrew implants

Seventy two pre-drilling miniscrew implants of 1.6 mm diameter and 8 mm length (Sin®, Sao Paulo, Brazil) were used in this experiment.

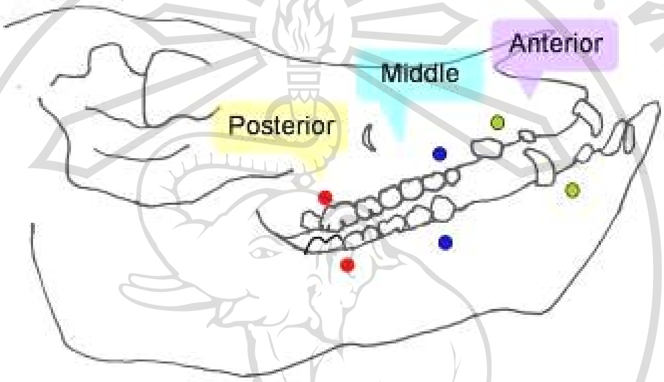

Figure 3.1 Schematic indicating approximate location of miniscrew insertion. *Circles* indicate positions of miniscrew heads. In each region of the maxilla, the miniscrew was placed in both buccal and palatal sites.

3.2.3 Experimental equipment

A holding device and a force gauge (Shimpo FGS-50S, Nidec-Shimpo America Corporation, Kyoto, Japan) were adapted for holding the specimens and measuring the maximum pullout strength, respectively (Figures 3.2 and 3.3). The head of the torque gauge was specially designed with a hook for attachment to the miniscrew implants. Four attempts at designing a rigid attachment were required to sufficiently engage the titanium miniscrew implant. In the first attachment, a .020" stainless steel wire was looped into the hole in the miniscrew neck (Figure 3.4). However, as the pullout force was applied, the head of the screw was broken. A second attachment was designed and developed by using two thin steel plates, as shown in Figure 3.5A. However, these plates were insufficiently rigid to resist the pullout force (Figure 3.5B). Prongs were then designed for the third attachment (Figure 3.6) to connect the screw head to the hook of the torque gauge, but the prongs slipped, thus, preventing the accurate assessment of pullout force. Finally, a fourth attachment composed of a double prong was developed to connect the miniscrew head to the force gauge. This attempt was successful in assessing the pullout forces, as shown in Figure 3.7. Seventy two pre-drilling miniscrew implants of 1.6 mm diameter and 8 mm length (Sin®, Sao Paulo, Brazil) were used in this experiment.

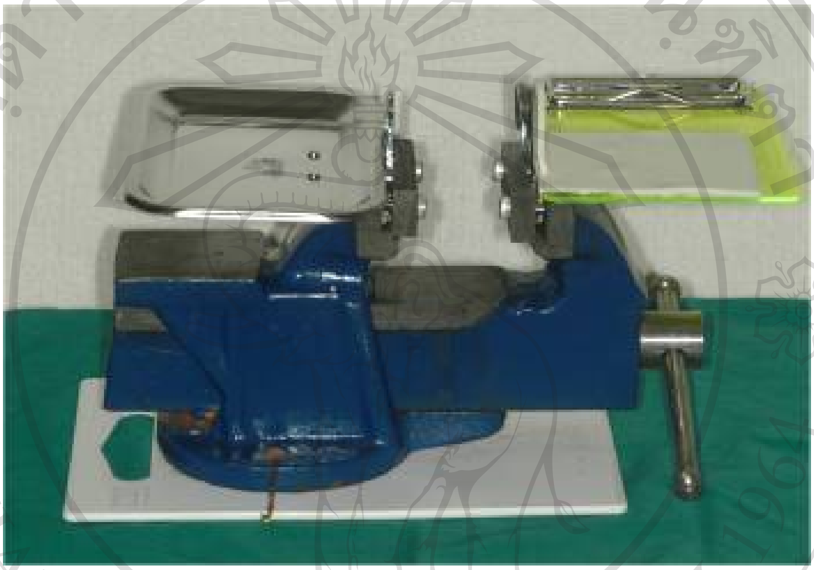

Figure 3.2 The holding device

Figure 3.3 The force gauge

Figure 3.4 The first miniscrew implant attachment design
Left: Prepared attachment, Right: Broken neck of miniscrew

Figure 3.5 The second miniscrew implant attachment design
Left: Prepared attachment, Right: Broken attachment

Figure 3.6 The third miniscrew implant attachment design

Figure 3.7 The fourth miniscrew implant attachment design

3.2.4 Procedure

Miniscrew implant placement was carried out following the insertion protocol proposed by Suzuki and Buranastidporn (2005). A 1.3mm-diameter spiral drill was used to create a pilot hole directly through the mucosa without a prior incision into the maxillary and mandibular dentoalveolar bone. A slow drill speed (400-500 rpm) and manual driller (Figure 3.8A, B) were used with normal saline irrigation to avoid heat generation. The direction of miniscrew implant insertion was oriented perpendicular to the soft tissue surface. The miniscrew implants with attachments were inserted by a custom manual screwdriver (Figure 3.9) into the pilot hole (Figure 3.10). The specimen with the inserted miniscrew implant was carried on the holding device (Figure 3.11). The attachment was connected to the hook of the torque gauge (Figure 3.12) and the miniscrew implant was pulled out by a custom pullout device.

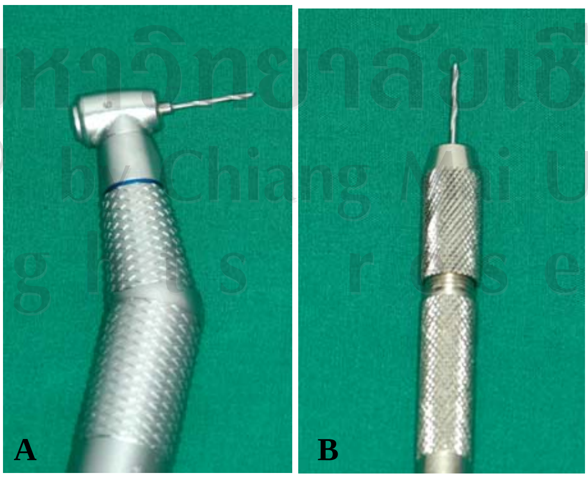

Figure 3.8 The screw driller A: Slow speed drille, B: manual driller

Figure 3.9 Three types of manual screwdriver

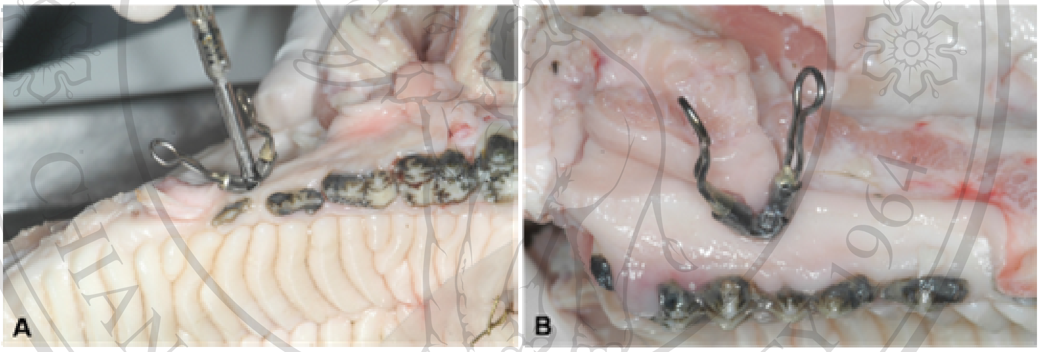

Figure 3.10 A: The screw with the fourth attachment was placed in the buccal side of the middle region of the maxilla by manual screw driver., B: The fourth attachment with miniscrew implant in the posterior region of the maxilla

Figure 3.11 The maxilla and torque gauge were placed on the holding device.

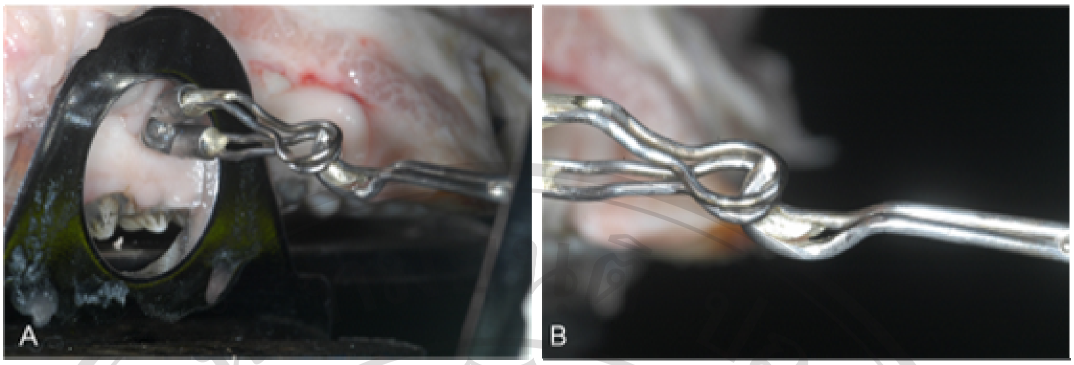

Figure 3.12 A: The fourth attachment was inserted through the holding device for attachment to the torque gauge., B: The connection between the arm of the fourth attachment and the hook of the Imada torque gauge

3.2.5 Statistical analysis

Statistical tests were carried out with the statistics software SPSS 10.0 (SPSS Inc., Chicago, IL, USA). The mean values of the individual measurements were tested for significance using the Mann-Whitney U and the Kruskal-Wallis tests for nonparametric samples. Maximum error was limited to $p < 0.05$.

3.3) Results

Seventy two specimens were successfully recorded for pullout tests with the fourth miniscrew implant attachment. Maximum pullout strength values ranged from 55.3 to 502.2 N. Miniscrew implants that were bent during pullout testing are shown in Figure 3.13.

Significant differences ($p < 0.05$) in maximum pullout strengths were detected among the locations examined (Table 3.1). In the maxilla, the anterior area had lower maximum pullout strength than the middle and posterior areas ($p < 0.05$). In the mandible, there were significant differences ($p < 0.05$) between all groups (Figure 3.14).

In the comparison of drilling methods, there were no significant differences ($p = 0.05$) between the slow speed drill and the manual drill (Table 3.2).

Figure 3.13 Bent miniscrew implants

Table 3.1 Comparison of maximum pullout strength (N) between areas

Area	MxB		MxP		Md	
	Median	Interquatile range	Median	Interquatile range	Median	Interquatile range
Anterior	192.60	30.23	145.10	155.70	68.75	14.30
Middle	235.10	159.78	389.85	89.80	256.55	112.48
Posterior	396.35	128.95	363.25	30.73	356.35	96.43
Kruskal-Wallis test	$p < 0.05$		$p < 0.05$		$p < 0.05$	

MxB, buccal maxilla; MxP, palatal maxilla; Md, Mandible

Table 3.2 Comparison of maximum pullout strength (N) between drilling method

Procedure	MxB		MxP		Md	
	Median	Interquatile range	Median	Interquatile range	Median	Interquatile range
Slow speed	207.95	179.78	326.75	281.63	243.05	233.78
Manual	278.25	186.58	363.75	106.73	313.05	317.53
Mann-Whitney U	*NS*		*NS*		*NS*	

MxB, buccal maxilla; MxP, palatal maxilla; Md, Mandible

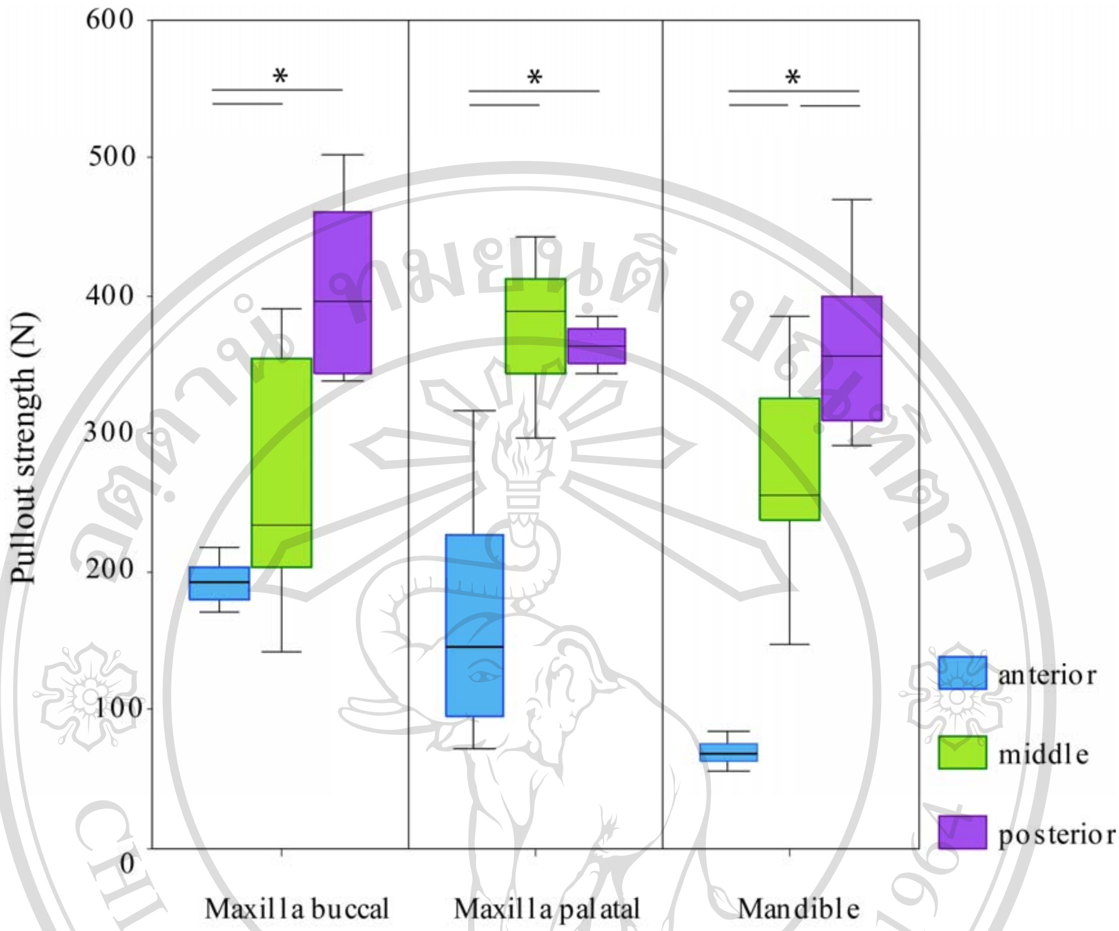

Figure 3.14 Maximum pullout strength by location. * $p < 0.05$ (Mann-Whitney U test)

3.4) Discussion

One purpose of this study was to quantify pullout strengths of miniscrews placed in various locations in the maxilla and the mandible. A range of maximum pullout strengths (55.3-502.2 N) was afforded by the bone-supporting miniscrews in the different regions of the pig jaws. Because of the high pullout strengths of the miniscrew implants in the pig jaws, four attempts in designing a rigid attachment were required to sufficiently engage the titanium miniscrew implant. Although the fourth attachment was the strongest and was successful in removing the miniscrew, it could not control the axis of the miniscrew in the axis of the pullout force, resulting in a bending moment being produced during the pullout test and in the miniscrew being bent. Bending moment of a screw during the pullout strength assessment is not desirable because it would not allow the correct assessment of the axial holding power of the miniscrews. The bending moments would, instead generate a combination of indeterminate moments and axial forces that would not allow the accurate assessment of the holding power of the miniscrew to the bone (An and Draughn, 2000).

A limitation of this pilot study was the use of a conventional pullout gauge with no pullout speed control. Moreover, the force measurement of the torque gauge was limited to 500 N, consequently being unable to assess pullout values that exceed this value. The machine for pullout testing should ensure that the long axis of miniscrew implants was aligned with the axis of the testing machine, so that no bending moment was produced during the pullout test.

A universal testing machine would provide more accurate assessments of the pullout strengths with advantage of controlling the crosshead speed. However, by that time, the Faculty of Dentistry had not purchased a universal testing machine.

Another aim of this study was to examine the difference in pullout strength at various sites where the miniscrews were placed. The results showed that there were differences in pullout strengths in different locations of the maxilla and the mandible. This finding is in agreement with Huja *et al.* (2005), who assessed the primary stability of miniscrew implants placed in various locations in the jaws of dogs after they were sacrificed through pullout testing. They also found that the primary stability of these miniscrew implants was correlated to the thickness of the cortical bone.

In this study, no significant difference between different protocols for miniscrew implant placement using hand and slow speed mechanical drillers was observed. The results are in agreement with the observations made by Gillis *et al*. (1992), who studied the holding power of cortical screws after power tapping and hand tapping in paired equine third metacarpal bones.

3.5) Conclusions

Maximum pullout strength of miniscrew implants ranged widely and there were differences of pullout strength values in different locations of fresh maxillary and mandibular dentoalveolar bone in pigs**.**