CHAPTER 4

PILOT STUDY II

THE PULLOUT STRENGTH OF ANGULATED MINISCREW IMPLANTS IN PIG RIBS

4.1) Introduction

The amount of pullout strength of miniscrew implants inserted into the dentoalveolar bone of maxilla and mandible of pigs was estimated in the first experiment. High variation on the maximum pullout strengths (55.3 to 502.2 N) was observed. Because of the high pullout strength of miniscrew implants in pig jaws, a universal testing machine was not use to measure pullout strength. Moreover, a special custom grip was designed and developed to be strong enough to engage the head of the titanium miniscrew implant (shown in Figure 4.1). The internal contours of the jaws of the grip were custom machined and had the same dimensions and profile as the screw head. The custom grip was connected to the actuator of a Universal Testing Machine (Instron Corp, Norwood, MA, USA).

Another important consideration is the control of alignment of the miniscrew implant axis oriented parallel to the pullout force to ensure that no bending moment during the test. In this study the block was prepared in defined angulations and a custom-made holder was specifically designed to stable hold the angulated bone block (Figure 4.2).

The objectives of this pilot study II were:

1. To test the ability of the custom grip to hold the miniscrew head and of the custom holders to hold the bone blocks.
2. To test the control of the axis of the miniscrew implant in the direction of the pullout force during pullout testing.
3. To compare the maximum pullout strength and insertion torque in three specific angulations.

4.2) Materials and methods

4.2.1 Experimental animals

The ribs of a pig were sectioned by a saw to remove unnecessary portions of bone and soft tissue (Figure 4.3 A, B, C). Five specimens were prepared for each angulation tested and embedded in individual bone blocks, using self-curing acrylic, at three angulations (30, 60, 90 degrees) (Figure 4.4). Two implantation sites were marked in each specimen, at least 4 mm apart.

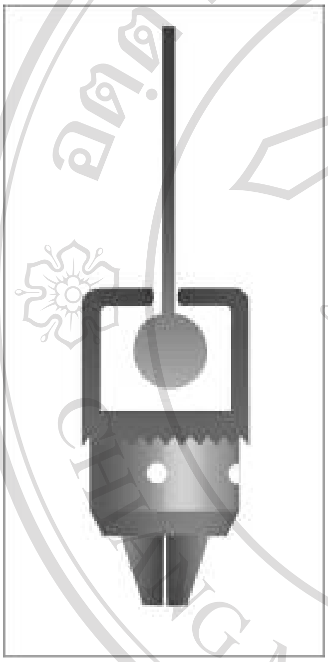

Figure 4.1 A custom grip was specifically designed to hold the head of the titanium miniscrew.

Figure 4.2 Custom-made holder was specifically designed to hold the bone blocks.

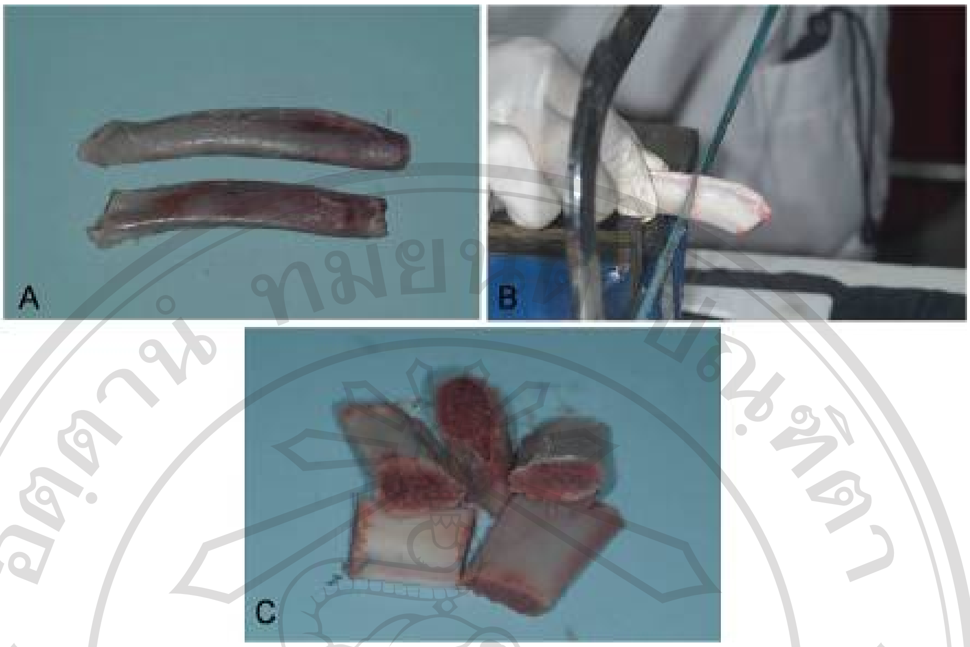

Figure 4.3 Bone preparation A: Rib bone, B: Bone being cut, C: Cut rib bone

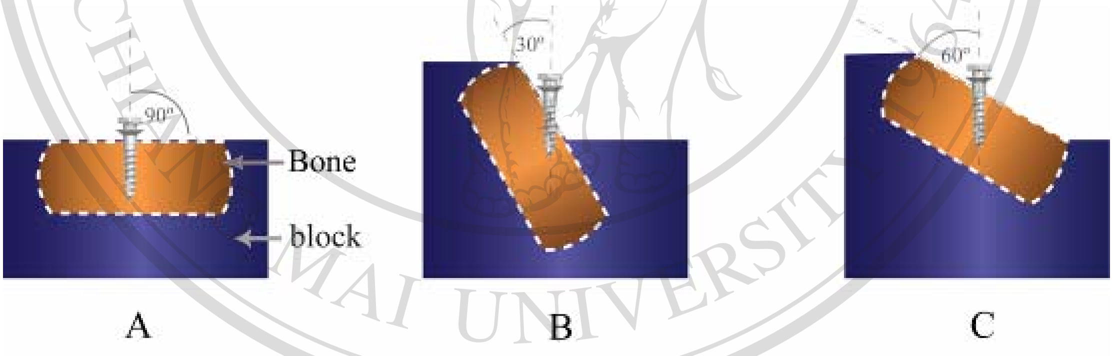

Figure 4.4 Diagram of alignment of miniscrew implant into bone block

4.2.2 Miniscrew implants

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

4.2.3 Procedure

4.2.3.1 Preparation of bone block

Plastic tubes, 1.5” diameter, were cut at 30, 60 and 90 degrees to their long axes at one end, and 90 degrees at the other end to form the basis of the bone blocks.

Fifteen pieces of pig rib were randomly selected into three groups, five for each angled bone block. The plastic tubes were placed with the 90-degree ends on a glass slab. The rib pieces were lowered into the plastic tubes and fixed using the flat surface of a metal ruler to align the superior bone surfaces with the angled surfaces of the plastic tubes. Initially, a self-curing dental acrylic resin was mixed and poured into plastic tubes around the ruler to fix the bone in the tubes. After the acrylic resin set, the ruler was removed and additional acrylic resin was poured to cover the junction between the bone and the original resin. The acrylic plastic tubes were placed into a water bath at room temperature and the resin was allowed to set for 10 to 15 minutes. This helped to dispel the exothermic setting reaction of the resin (Figure 4.4).

4.2.3.2 Miniscrew implant insertion and insertion torque measurement

Miniscrew implant placement was carried out using the insertion protocol proposed by Suzuki and Buranastidporn (2005). A 1.3 mm diameter spiral drill was used to create a pilot hole into the cortical bone, with normal saline irrigation to avoid excessive heat. It was necessary to align the axis of the driller vertically to create the defined angulations. The miniscrew implants were inserted into the prepared pilot holes using a custom manual screwdriver as far as the last tread of the screw (Figures 4.5 A, B, C). Finally, the Imada torque wrench was used until the platform was placed 1 mm from bone surface (Figure 4.5D). The torque value was recorded in Newton centimeters (Ncm).

4.2.3.3 Preparation of pullout measurement

For pullout testing, a custom-made grip and holder was specifically designed to grasp the screw head and hold the bone block, respectively (Figure 4.6A). The screw grip was connected to the grip of the Universal Testing Machine (Instron Corp, Norwood, MA, USA). The 30- 60- and 90- degree bone block were placed in the holder shown in Figure 4.6B, C, D, respectively. The bone blocks were attached via the screw head to the grip. The long axis of miniscrew implants was aligned with the axis of the testing machine to ensure that no bending moment was produced during the pullout test and only axial pullout strength was recorded. A crosshead speed of

0.05mm per second (Baker *et al.*, 1999; Huja *et al.*, 2005) was applied to extract the screw. The peak load-at-break data (Fmax or maximum force) were recorded by Bluehill software CAT No. 2603-080 (Instron, Norwood, MA, USA).

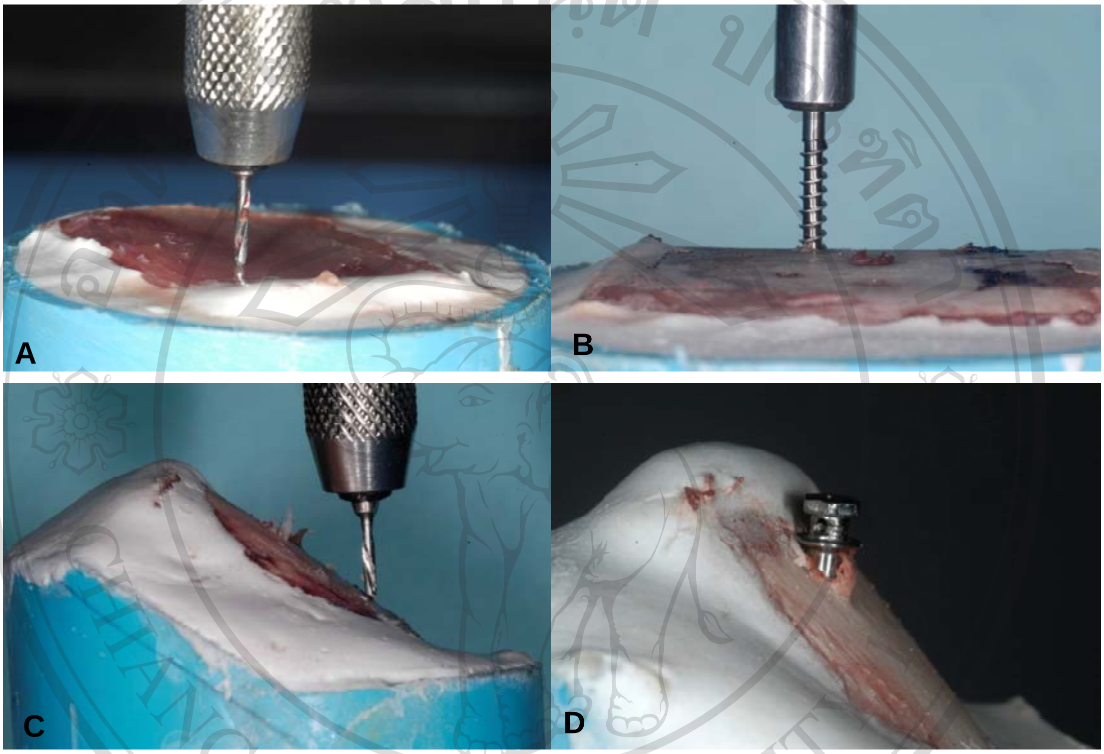

Figure 4.5 A: Long axis of driller perpendicular to bone surface., B: Long axis of screw perpendicular to bone surface., C: Long axis of driller aligned vertically to the 60-degree bone block., D: Platform placed 1 mm from bone surface.

4.2.3.4 Statistical analysis

Multiple comparisons between groups were performed using one-way ANOVA and post-hoc analyses used the Tukey's test. The results were considered significant when $p < 0.05$. All calculations were performed through the use of SPSS version 10.0 for windows (SPSS Inc., Chicago, IL, USA).

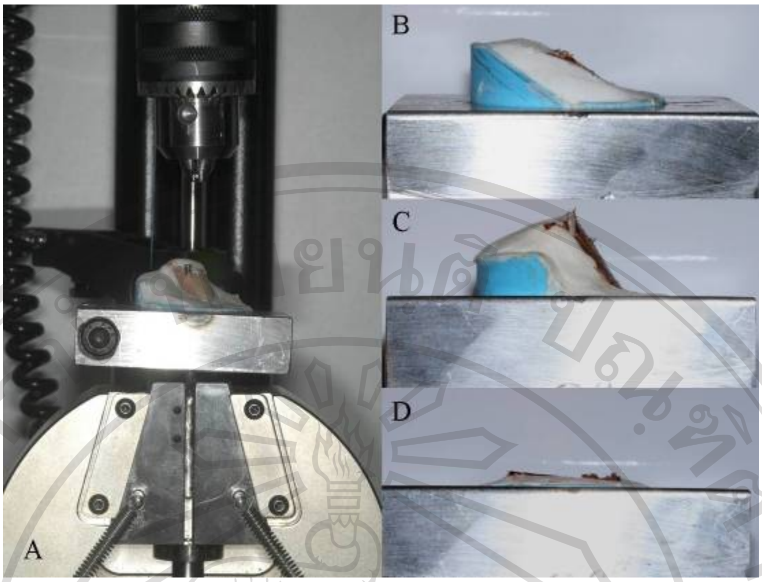

Figure 4.6 A: Holder, B: 30-degree bone block, C: 60-degree bone block, D: 90-degree bone block

4.3 Results

The insertion torque and pullout strength of thirty miniscrew implants were successfully recorded. The results are shown in Table 4.1. This experiment showed that there was no bent screw found.

Significant differences ($p < 0.05$) in maximum pullout strengths were detected among the angulations examined. The 30-degree angulation had the highest pullout strength, followed, in decreasing order, by 60- and 90-degree angulations (Figure 4.7). There were significant differences ($p < 0.05$) in insertion torque between the 30-degree and 90-degree angulations (Figure 4.8).

Table 4.1 Maximum pullout strength (N) and insertion torque (Ncm) correlated with degrees of insertion angulation

Angulations	Maximum pullout strength		Insertion torque	
	Mean	SD	Mean	SD
30º	163.13	29.95	3.08	0.974
60º	126.48	53.61	1.93	1.18
90º	107.91	38.31	3.97	1.37

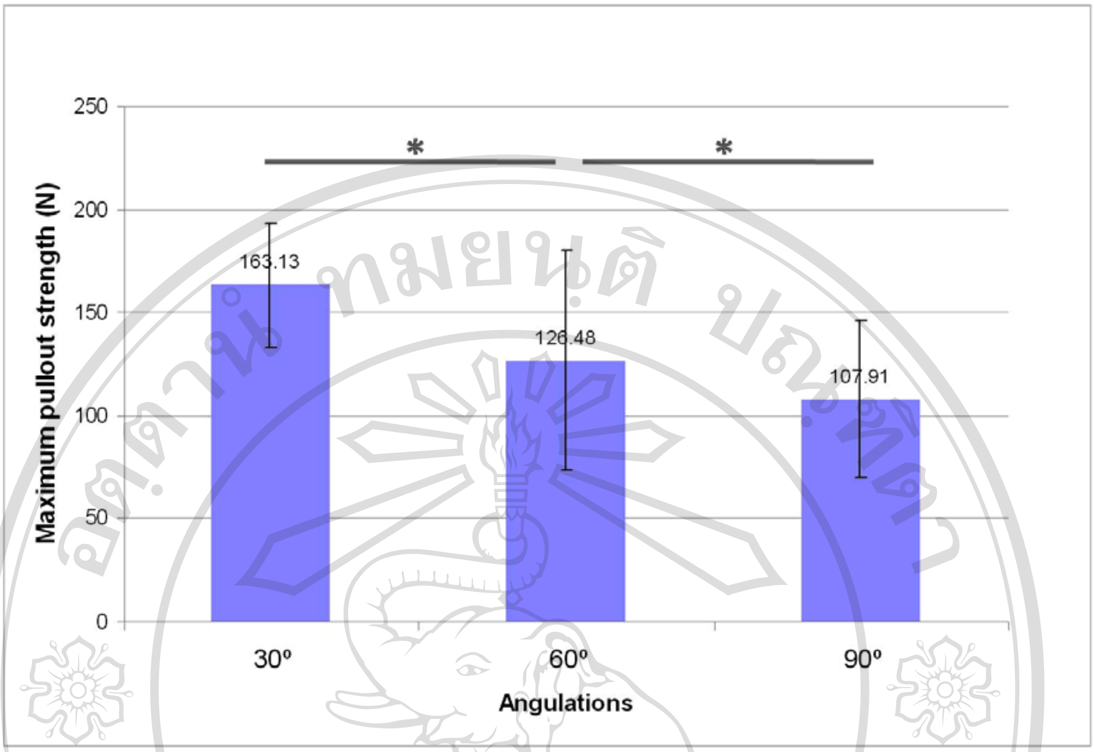

Figure 4.7 Maximum pullout strength correlated with insertion angulations. (*$p < 0.05$)

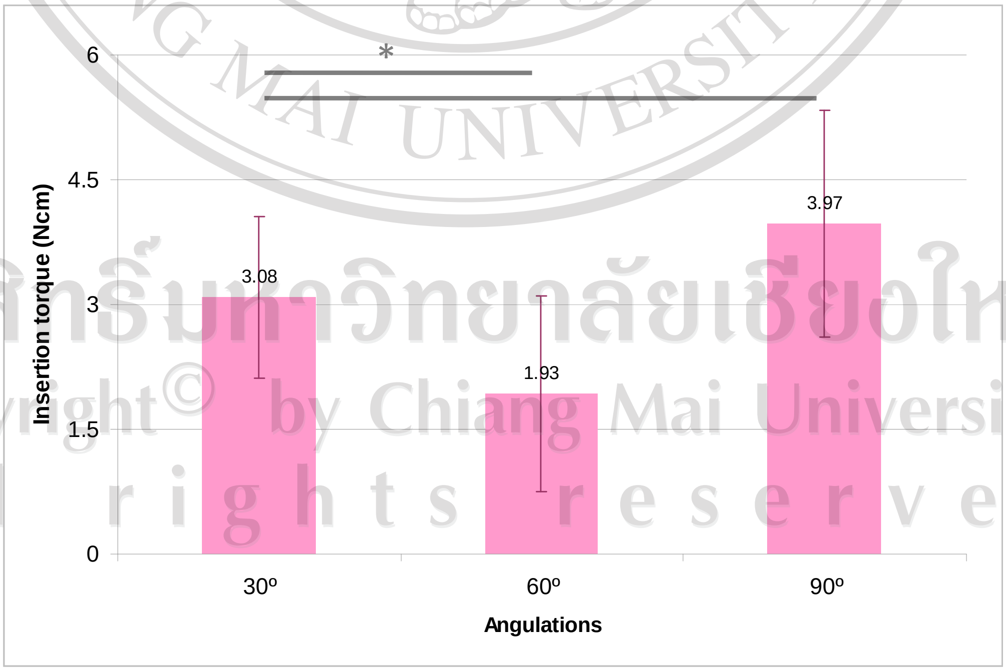

Figure 4.8 Maximum insertion torque correlated with insertion angulations. (*$p < 0.05$)

4.4) Discussion

The custom grip and holders were able to hold the head of the screw and the bone blocks, respectively. The developed holder is shown in Figure 4.6A. This holder was designed to lock firmly the bone block. In order to allow the assessment of miniscrews inserted at angulations in the bone, bone block were carefully inserted at the planned angulations into the acrylic block. This experiment showed that no screws were bent because the long axis of the screw was aligned with the axis of the pullout force.

Pullout testing showed that the 30-degree miniscrew angulation had the highest pullout strength followed by the 60- and 90-degree angulations. The explanation is that the purchase afforded by the cortical bone thickness is different. Deguchi *et al*.(2006) quantitatively analyzed the differences in relative cortical bone thickness produced by different miniscrew angulations in the maxilla and the mandible using 3D-CT scan. They found that there was a significant difference in the thickness of cortical bone at 30-, 60- and 90-degrees. The smaller the angulations, the more cortical bone contact there was with the miniscrew in both jaws. The relative cortical bone thickness is an important factor related to the mechanical retention of miniscrew implant. The relevance of cortical bone thickness is supported by Huja *et al*.(2005), who assessed the mechanical retention of miniscrew implants by pullout testing. Miniscrew implants were placed in various locations in the jaws of dogs, after they were sacrificed, where cortical bone thicknesses were different. They concluded that the primary stability of these miniscrew implants was correlated with the thickness of the cortical bone.

4.5) Conclusions

Reduced angulation (30 degrees) provided the highest pullout strength followed by 60 and 90 degrees.

No screws were bent during pullout testing.