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Does miniscrew insertion angulation matter?

Influence of Insertion Angulations of Miniscrew Implant on the Mechanical Retention

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Introduction

The use of insertion angulations during miniscrew implant placement has been recommended as a practical clinical approach, to reduce the risks of damaging the dental roots of adjacent teeth in the dentoalveolar area as the dental roots tend to diverge apically.(1,2)
Moreover, it has been theoretically suggested that the use of such insertion angulations would provide an increase in the surface contact area between the miniscrew and bone, thus improving the mechanical retention of the miniscrew to the bone (3-7).
However, the influence of such insertion angulations on the biomechanical performance of miniscrew implants placed in the dentoalveolar bone has not been extensively investigated.
Therefore, the purpose of this study was to investigate the effects of insertion angulation on the biomechanical performance of the miniscrew implants placed in the dentoalveolar bone of a porcine model.

Material and Methods

Sample
Three hundred and sixty self tapping titanium miniscrew implants with 1.6 mm diameter and 8 mm length (ACR Mini-Implant, BioMaterials Korea. Inc., Guro-gu, Seoul, Korea) were used in this experiment.
Sections of dentoalveolar bone extracted from the maxilla and mandible of ten Gottinger minipigs, 3-4 months of age and with an average body weight of 35 kg were used for the mechanical test. Unnecessary portions of bone were removed and all soft tissues were dissected. According to the site of miniscrew placement, the samples of maxilla and mandible were divided into 3 distinct groups for the analysis; anterior, middle and posterior.

Miniscrew Implant Placement Procedures
In accordance with the experimental design, miniscrew implants were inserted systematically in the dentoalveolar area of the maxilla and mandible with three defined angulations; 30, 60 and 90 degrees to the bone surface. At each selected implant site, a minimum clearance of 3 mm between miniscrew implants was preserved (Figure 1). Custom-made 3-D surgical guides were prepared to assure precise insertion angulations (30, 60 and 90 degrees) to the bone surface during the drilling and miniscrew implant placement (Figure 2).

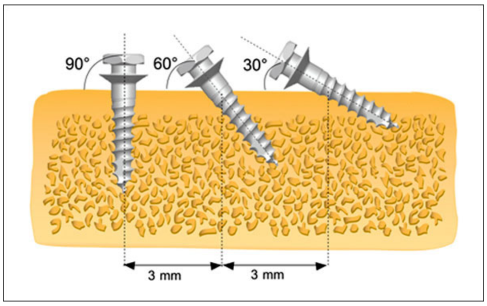

Figure 1

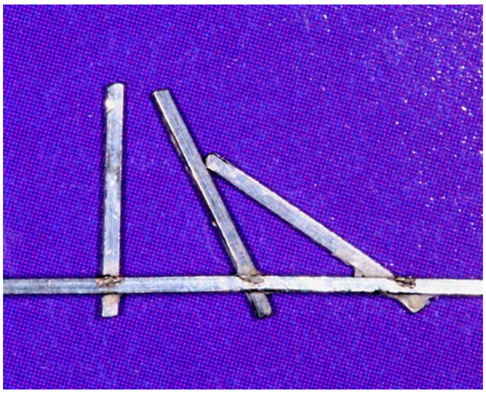

Figure 2

Miniscrew implant placement was carried out using the insertion protocol described by Suzuki and Suzuki (8). A 1.1 mm-diameter spiral drill was used to create the pilot hole into the cortical bone. A slow drill speed (400-500 rpm) was used with normal saline irrigation to avoid excessive heat generation and to remove the bone debris. Miniscrews were inserted into the bone with a manual hand-driver, following the manufacturer's recommendations.

Insertion Torque
For each miniscrew, maximum insertion torque (N cm) was assessed by an Imada torque wrench (Imada Inc., Northbrook, Ill, USA) (Figure 3). Miniscrew implants were inserted in the bone until the head and platform were 1mm from the cortical bone surface (Figure 4). Maximum insertion torque was defined as the peak torque value during miniscrew placement.

Figure 3

Figure 4

Pullout Testing
To examine the pullout strength of a miniscrew inserted at an angle to the axis of the pull, a custom-made grip was designed and machined to grasp the miniscrew head, thus avoiding the bending moment created during the pullout test (Figure 5). The internal contours of the jaws of the grip were custom machined and had the same dimensions and profile as the screw head. A custom-made holding base was specifically designed to hold the specimens (Figure 6). The gripping fixture was connected to the actuator of the Universal Testing Machine (Instron Corp, Canton, Mass., USA). The specimen was attached via the screw head to the grip. A crosshead speed of 0.05 mm per second was applied to pull out the miniscrew implant. The peak load (Fmax) data was recorded by Bluehill software CAT No. 2603-080. Failure was defined as a rapid decline in load following the peak of force.

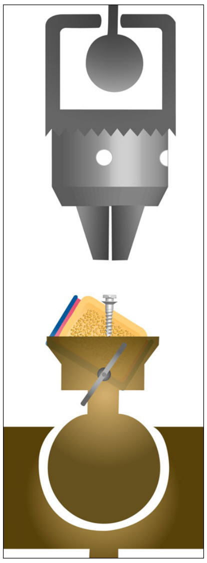

Figure 5

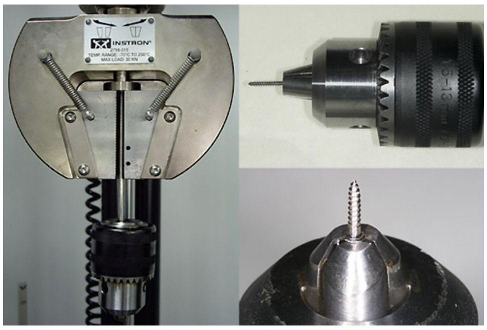

Figure 6

Statistical Analysis
Descriptive statistics and multiple comparisons between groups were performed using one-way ANOVA and post-hoc analyses by the Tukey-Kramer method to detect any difference between pullout characteristics. The differences in maximum pullout strength and maximum insertion torque between maxilla and mandible were analyzed using a Student t-test. Pearson correlation coefficients were used to study the relationship between pullout strength and insertion torque. The results were considered significant when $P<0.05$. All calculations were performed through the use of SPSS version 10.0 for windows.

Results

Maximum pullout force and insertion torque were assessed and analyzed for miniscrew implants inserted in three different orientations relative to the cortical bone surface of the dentoalveolar area. Relatively high correlation was observed between maximum pullout force and insertion torque ($r = 0.81$, $P < 0.01$).
Results of maximum pullout strength and maximum insertion torque measurements of miniscrews inserted in the dentoalveolar bone of maxilla and mandible are shown in the Figures 7 to 11.
In general, miniscrews inserted in the mandibular bone exhibited significantly ($P < 0.05$) higher values for the maximum pullout strength and maximum insertion torque than did the miniscrews inserted in the maxilla.

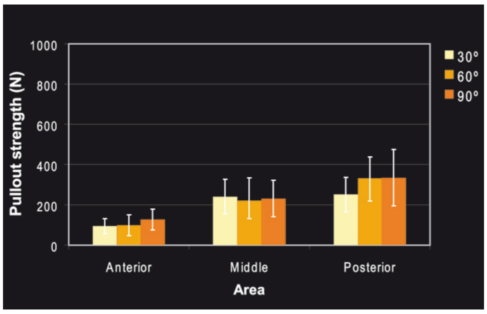

Figure 7

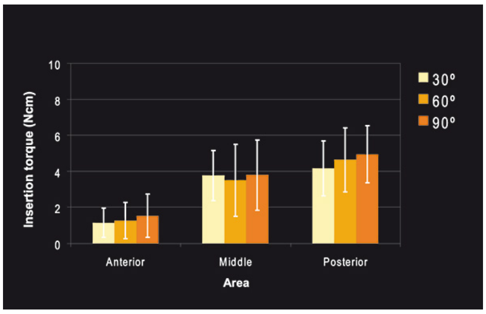

Figure 8

In the dentoalveolar bone of the maxilla, no significant differences between the maximum pullout strength and insertion torque of miniscrews inserted with 30, 60 or 90 degrees to the bone surface were observed. The anterior area of the maxilla exhibited significantly lower maximum pullout and insertion torque values than did either the middle ($P < 0.001$) or posterior areas ($P < 0.001$). No significant difference was observed between the maximum insertion torque values of miniscrews inserted in the middle and posterior areas of the maxilla (Figures 7 and 8).

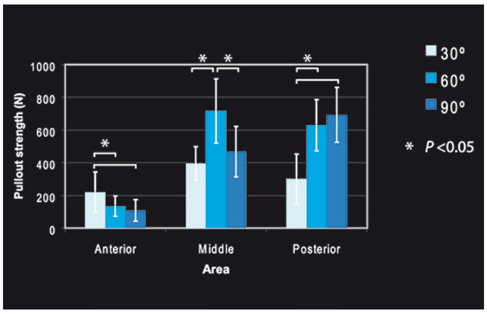

Figure 9

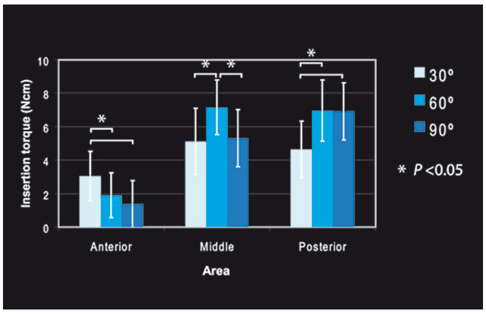

Figure 10

In the dentoalveolar bone of the mandible, the use of insertion angulation demonstrated a significant ($P < 0.01$) effect on the maximum pullout and insertion torque values. However, these changes did not follow a unique pattern for the various areas of the mandible (anterior, middle and posterior). (Figures 9 and 10).

Conclusions

Insertion angulation did not improve the mechanical performance of miniscrews implanted in the maxillary dentoalveolar bone. Reduced insertion angulation (30 degrees) was effective in only the anterior portion of the mandible.
This study was our first attempt to assess the effects of the insertion angulation on the mechanical performance of the miniscrew implants. Further studies are necessary to evaluate the mechanism of miniscrew retention in the maxilla and mandible of cadavers.

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