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学位論文名　Proximal Half Angle of the Screw Thread Is a Critical Design Variable Affecting the Pull-out Strength of Cancellous Bone Screws

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論文内容の要旨

INTRODUCTION

Most fracture fixation techniques rely on sufficient screw anchorage, and the increasing number of cancellous bone fractures demands a better-designed cancellous screw. Regarding the shape of the threads, most commercial screws have almost vertically edged threads with a minimal proximal half angle. However, few studies have examined the shape of screw threads or the proximal half angle by determining the actual pull out strength from cancellous bone.

Although the bone screw is an ideal device for fragile bone fixation because of the effect of osteointegration, no study has reported on the design of bone screws. In this study, we examined the pull-out strength of threads with different proximal half angles from cancellous bone and compared the outcomes using metal and bone screws.

MATERIAL AND METHODS

Metal screws were made of stainless steel using a computerized, numerically controlled lathe. Three fragments of cortical bone were collected from each shaft of the tibias of 6-month-old male Cambrough pigs (body mass, 110–120 kg). Bone screws were made in the same manner as metal screws. As a model recipient, cancellous bone was taken longitudinally from the patellar groove of the femur of the same animals. Inserting screws, using an appropriate tap of an identical shape to the screws, the screws were inserted with an electronic screwdriver at a compression pressure. The pull out strength was recorded at the maximum value observed immediately before screw pullout. Microcomputed tomography was performed on bone screws before and after the pullout test. The volumetric bone mineral density of cancellous bone was measured for ten recipient models of porcine femurs and cortical bone of ten porcine tibias. The relationships of the proximal half angle and screw materials were analyzed using two-factor factorial analysis of variance (ANOVA) and the Tukey-Kramer post hoc test. The correlation between pull out strength and displacement was evaluated using Pearson's test.

RESULTS AND DISCUSSION

The pull out strength was significantly influenced by the proximal half angle ($P < 0.01$), but not by the material ($P = 0.87$). There was a significant interaction between the angle and the material ($P < 0.01$). The pull out strength was maximal at 30° for both metal and bone screws, and there was no significant difference between the two. However, the metal screws were stronger at 0° (109% of bone screws, $P < 0.05$) and weaker at 60° (72%

of bone screws, $P < 0.01$). In the 0° threaded screws, some intact trabecular structures of cancellous bone were preserved in the valleys of the screws. By contrast, in the 30° threaded screws, only damaged cancellous bone was seen. The weight of cancellous bone attached to the screws was significantly influenced by both the proximal half angle ($P < 0.01$) and the material ($P < 0.01$). There was a significant interaction between the angle and material ($P < 0.01$). The weight was smaller at 60° than at 0° and 30° ($P < 0.01$). When the proximal half angle changed from 0° to 30°, the pull out strength of metal screws increased by 16% and that of bone screws by 17%. In this study, the pull out strength of the screws was maximal at 30°; 348.8 (44.1) N with metal and 326.6 (39.4) N with bone. It was intermediate at 0°; 301.9 (35.9) N with metal and 278.2 (30.6) N with bone. It was minimal at 60°; 126.5 (39.0) N with metal and 174.8 (29.7) N with bone. Cancellous bone was damaged between the threads at 30°, while intact cancellous bone was preserved between the threads at 0°.

CONCLUSION

The pull out strength of the screws was maximal at 30°. Commercial cancellous bone screws can be improved by changing their thread shape, which will minimize the damage to recipient bone.