学 位 論 文 の 要 旨

氏名　青木　陽

学位論文名	Effect of the Positional Relationship Between the Interference Screw and the Tendon Graft in the Bone Tunnel in Ligament Reconstruction
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著者名	Akira Aoki, Shinji Imade, Yuji Uchio

論 文 内 容 の 要 旨

INTRODUCTION

The reconstruction of ligaments using interference screws (ISs) and soft-tissue grafts is considered a standard clinical technique such as in medial patellofemoral ligament reconstruction and anterior talofibular ligament reconstruction. The primary fixation strength of the tendon graft is recognized as an important factor in enabling the early rehabilitation of patients. To the best of our knowledge there have been no reports focusing on the positional relationship between the IS and the tendon graft and the effect of the pull-out direction of the tendon graft. We conducted the present study to determine the precise effects of the positional and length relationships between the IS and the tendon graft in the bone tunnel on the fixation strength in ligament reconstruction.

MATERIAL AND METHODS

Tendon grafts were made from 200 fresh Achilles tendons of male Japanese black cattle. Only 100-mm lengths of the middle third of the Achilles tendon were used. The average dia. of the tendons was 4.7 mm (standard deviation [SD], 0.2). 200 fresh-frozen mature male porcine patellae were prepared at the host site. An all-pass bone tunnel (7.0 mm dia.) was created from the medial to the lateral side of each patella. Cannulated stainless-steel headless screws were prepared as the ISs. The dimensions of the ISs were 5.0 mm in outer dia., 4.1 mm in inner dia., 0.8 mm in pitch, and 10.0 and 20.0 mm in length. The tendon graft (15 mm on the sutured side) was inserted into the bone tunnel of the patella from the medial to the lateral side. (1) The effect of the IS position: the IS was placed on the anterior (the Anterior group) or posterior (the Posterior group) or side (the Side group) of the tendon graft in relation to the pull-out direction. The tendon graft was pulled at 0°, 30°, 60°, and 90° to the bone tunnel, and the maximum pull-out load at each angle was compared among the groups. (2)The relationship between the length of the tendon graft and that of the IS: a 15-mm tendon graft was inserted into the bone tunnel and fixed with a 20-mm IS; in the long-graft group, a 25-mm tendon graft was inserted into the bone tunnel and fixed with a 20-mm IS. The IS position was the same as that in the Anterior group. We compared the maximum pull-out loads at each angle between the short-graft group and the long-graft group, and between the long-graft group and the Anterior group. The Kruskal-Wallis test and a post-hoc test were used in all statistical analyses, and p-values <0.05 were considered significant.

RESULTS AND DISCUSSION

The maximum pull-out loads of the Anterior group were superior to or equal to those of the Posterior and Side groups. At the traction angle of 0°, the maximum pull-out loads were 12.4 N (SD 3.3) in the Anterior group, 12.7 N (SD 3.0) in the Posterior group, and 12.6 N (SD 3.1) in the Side group, with no significant differences among groups (Anterior vs. Posterior, p=0.93; Posterior vs. Side, p=0.96; Anterior vs. Side, p=0.96).At the 30° traction angle, the maximum pull-out loads were 31.9 N (SD 8.3) in the Anterior group, 14.4 N (SD 3.6) in the Posterior group, and 21.5 N (SD 9.0) in the Side group. There were significant differences between the Anterior and Posterior groups (p=0.0005) and the Anterior and Side groups (p=0.039). At the 60° traction angle, the maximum pull-out loads were 46.3 N (SD 9.1) in the Anterior group, 28.5 N (SD 12.0) in the Posterior group, and 27.0 N (SD 8.7) in the Side group. There were significant differences between the Anterior and Posterior groups (p=0.047) and the Anterior and Side groups (p=0.016). At the traction angle of 90°, the maximum pull-out loads were 46.6 N (SD 12.4) in the Anterior group, 41.0 (SD 12.1) in the Posterior group, and 35.2 N (SD 14.5) in the Side group. There were no significant differences among groups for this measure (Anterior vs. Posterior, p=0.54; Posterior vs. Side, p=0.39; Anterior vs. Side, p=0.059).

A tendon graft length longer than the IS provided superior fixation strength compared to a tendon graft length shorter than the IS, and this effect became pronounced as the traction angles increased. The different IS lengths resulted in no significant differences in fixation strength.
The maximum pull-out loads of the short-graft group and long-graft group, respectively, were 8.3 N (SD 2.0) and 18.0 N (SD 8.3) for 0°, 20.6 N (SD 4.5) and 39.8 N (SD 11.0) for 30°, 25.7 N (SD 9.6) and 54.8 N (SD 16.1) for 60°, and 35.5 N (SD 11.8) and 60.1 N (SD 15.8) for 90°,

revealing significant differences for all four traction angles (p=0.007, p=0.009, p=0.002, and p=0.003, respectively). The maximum pull-out loads of the long-graft group tended to be higher than those of the Anterior group for all traction angles, but there were no significant differences between the two groups (0°, p=0.17; 30°, p=0.32; 60°, p=0.46; and 90°, p=0.052).
The differences in the maximum pull-out load between the short-graft and long-graft groups for the 30°, 60°, and 90° traction angles were two-, three-, and 2.7-fold higher than that for 0°, respectively.

We speculate that the horizontal component force of the pullout load may cause torque of the screw, thereby increasing its clamping effect against the bone tunnel. In the Anterior group, this effect was seen at the traction angles of 30° and 60°. There were no significant differences among the groups at the traction angle of 90°, possibly because of the greater frictional force between the tendon graft and the edge of the bone tunnel. If our hypothesis is correct, the effect of the IS position would disappear or lessen when the IS is longer than the tendon graft. To investigate this, we evaluate the relationship between the length of the tendon graft and the length of the IS. Our results revealed that the fixation strength was significantly higher at all traction angles when the IS was shorter than the tendon graft. In addition, our comparison of the short-graft group with the Posterior and Side groups demonstrated that in those three groups the IS theoretically exerts no crimping force on the tendon graft, and there were no significant differences in pull-out load among the groups. These findings support our hypothesis.

On the other hand, the contact area between the IS and the tendon graft of the short-graft group was narrower than that of the long-graft group, and this difference might have had an effect on the fixation strength. The fixation strength of the long-graft group showed a tendency to be stronger than that of the Anterior group, but the difference was not significant. This difference may be the effect of the contact area. However, the Anterior group strongly tended to have a higher fixation strength than the short-graft group for all degrees of traction and a significantly higher strength at 60°, even though the contact area of the Anterior group was narrower than that of the short-graft group. Based on these findings, we speculate that a longer implant length increases the fixation strength, but this effect would be smaller than that of the IS position.

CONCLUSIONS

The positional and length relationships between the IS and the tendon graft in a bone tunnel affect the fixation strength. Based on our present findings, we conclude that the IS should be placed on the same side of the anchorage tunnel on which the tendon graft is loaded, and that the tendon graft should be longer than the IS.