BIOMECHANICAL ANALYSIS OF EARLY HEALING AT GRAFT-TUNNEL INTERFACE IN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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INTRODUCTION:
In the anterior cruciate ligament (ACL) reconstruction, with soft-tissue graft such as a hamstring tendon graft, delayed incorporation of the graft within the bone tunnel has been pointed out to be one of the potential shortcomings. Failure to achieve sound graft-bone healing may lead to less optimal outcome such as bone tunnel enlargement and non-anatomical insertion formation (1). In order for the reconstructed ACL to reproduce the function of the native ligament, restoration of mechanical properties of the insertion site as well as those of the graft substance is important. Nevertheless, the conventional mechanical test deals with a bone-ligament construct as a whole and the mechanical behavior of the graft inside the bone tunnel has not been well investigated. Radiographic dimension analysis using metal markers has been developed to evaluate the graft-tunnel motion under applied tension, and the results of the in-vivo experiment have been reported (2). Based on the results of the preceding investigation, this study was undertaken to investigate the time-dependant change in mechanical behavior of the graft-bone interface in an in-vivo ACL reconstruction model.

MATERIALS AND METHODS:
ACL reconstruction model: Fifteen skeletally mature male Beagles were used in this study. The ACL reconstruction was performed using a patellar tendon graft. To obtain the soft-tissue graft, proximal end of the patellar tendon was cut at the insertion and only the tibial end bone plug was taken. Then, 4-mm diameter bone tunnels were drilled both in the femur and the tibia. After the tibial end bone plug of graft was fixed proximally, patellar tendon graft was fixed to the tibia by tying the suture to the fixation post. At surgery, metallic radiographic markers (0.5 mm in diameter) were embedded at the following locations: 1) at the edge of the articular outlet of tibial bone tunnel (reference marker), and 2) within the graft substance inside the tibial bone tunnel 5 mm distal to the reference marker (graft marker) (Fig 1).

Biomechanical Analysis: The tibia-graft complex was harvested at 0, 2, and 4 weeks after surgery (5 samples at each time period), and mounted on the specially designed loading device with the tibial end bone plug of the graft and the tibia clumped. Then, stepwise tensile loads were applied in line with the tibial tunnel from 0 to 30 N with 5 N increments. An anterior-posterior micro-radiographs was taken at each load. The radiograph was digitized, and the distance between the graft marker and the reference marker was measured using image analyzing software (NIH Image). Increase in displacement of the graft marker from the reference marker under each tensile loading was calculated, and denoted as the graft tunnel motion (GTM). Furthermore, a slope of the load-GTM curve (N/mm) was measured and used as an additional parameter to express the stiffness property of the graft-bone tunnel interface. Then, these two parameters were compared among the three groups (0, 2, and 4 weeks) using One-Factor ANOVA test. Significance was set at p<0.05.

RESULTS:
There were no signs of infection and graft failures with gross inspection at specimen harvest. In the mechanical analysis, a failure of the specimen was not observed up to a 30 N tension. The GTM increased linearly with stepwise application of tensile loading in all groups. Comparison of the GTM with a 30 N load showed significant differences between each of the three time periods (Fig 2). The measured stiffness values were 14, 39 and 118 N/mm at 0, 2 and 4 weeks after surgery respectively (Fig 3). Analysis of the stiffness of the graft-bone tunnel interface demonstrated significant increase at 4 weeks comparing with those at 0 and 2 weeks.

DISCUSSION:
Detailed biomechanical analysis of the graft-bone tunnel interface in the time course after the ACL reconstruction has yet to be reported. In this in-vivo investigation, a significant reduction in the GTM and an increase in the stiffness of the graft-bone interface could be detected during the initial 4 weeks after the surgery. Although the initial fixation afforded by the fixation post technique was poor as revealed by substantial GTM, significant improvement in the mechanical properties of the interface was observed in an early period after surgery. However, if the insertion of the reconstructed ACL is to be anatomically reestablished at the bony surface, there should be no GTM. Moreover, in the clinical setting, whether the new interface in the healing process can withstand the load applied in the current early aggressive rehabilitation is still not known. Further studies to enhance healing of the graft-bone interface are required. For the future experiment to examine the effect of the new interventions for healing enhancement at the ACL graft insertion site, the analytical method adopted in this study would also be applicable.

REFERENCE:

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