Tension Degradation of Anterior Cruciate Ligament Grafts With Dynamic Flexion-Extension Loading: A Biomechanical Model in Porcine Knees

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Purpose: This study investigates the influence of various femoral anterior cruciate ligament graft fixation methods on the amount of tension degradation and the initial fixation strength after cyclic flexion-extension loading in a porcine knee model. **Methods:** One hundred twenty porcine digital extensor tendons, used as 4-stranded free tendon grafts, were fixated within porcine femoral bone tunnels by use of extracortical button, cross-pin, or interference screw fixation. One hundred twenty porcine patellar tendon–bone grafts were fixated by use of cross-pin, interference screw, or press-fit fixation. Each femur-graft complex was submitted to cyclic flexion-extension loading for 1,000 cycles throughout different loading ranges, and the total loss of tension was determined. After cyclic testing, the grafts were loaded to failure, and the data were compared with a pullout series without cyclic loading. **Results:** Tension degradation after 1,000 cycles of flexion-extension loading averaged 62.6% ± 10.0% in free tendon grafts and 48.9% ± 13.35% in patellar tendon–bone grafts. There was no influence of the loading range on the total amount of tension degradation. The total amount of tension degradation was the highest with interference screw fixation of free tendon and patellar tendon–bone grafts. Despite excessive loss of tension, the initial fixation strength of the femur-graft complex was not reduced. **Conclusions:** The method of femoral graft fixation significantly influenced tension degradation during dynamic flexion-extension loading. Femoral graft fixation methods that secure the graft close to the tunnel entrance and that displace the graft substance from the center of the bone tunnel show the largest amount of tension degradation during cyclic flexion-extension loading. The graft substance, not the fixation site, was the weakest link of the graft complex within this investigation. **Clinical Relevance:** We believe that the graft fixation method should be considered when aiming to improve the precision of femoral graft placement in anterior cruciate ligament reconstruction. **Key Words:** Knee—Anterior cruciate ligament reconstruction—Hamstring graft—Patellar tendon—Cyclic testing—Graft tension.

Surgical reconstruction of the anterior cruciate ligament (ACL) primarily aims to prevent recurrent instability and to restore normal laxity to an ACL-deficient knee. Because postoperative knee laxity is directly correlated with graft tension, the initial tension applied to the graft at the time of surgery and the amount of tension degradation throughout the early postoperative period are major factors influencing the stability of the knee.[1-5] To date, there is no consensus on the amount of tension that should be applied to the graft at the time of surgery, and studies thus far have failed to prove a significant influence of initial graft tension on the long-term functional outcome of an ACL-reconstructed knee.[5-8] Moreover, experimental studies suggest that the tension applied to the graft at the time of surgery has decreased over time, so differences in the initial graft tension have diminished throughout the early postoperative period.[1,5,6]

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In accordance, investigations in human ACL-reconstructed cadaveric knee specimens proved that patellar tendon or hamstring tendon grafts lose approximately 50% of their initial tension when being loaded in dynamic flexion-extension cycles.[2,3] These studies have shown that the loss of graft tension correlates well with an increase in anterior tibial translation. This in turn may cause functional instability of the ACL-reconstructed knee.[2,3] Factors that might affect the postoperative course of graft tension include bone tunnel placement,[9-11] graft type,[12] initial graft tension,[1-5] knee angle at the time of fixation,[9,13] biologic graft remodeling,[14,15] and graft slippage at the site of fixation.[16] In addition, the position of the graft within the femoral tunnel, as determined by the method of femoral graft fixation, may be an unrecognized factor contributing to tension degradation with the onset of postoperative knee motion. This is assumed because artificial fixation of a patellar tendon–bone or hamstring tendon graft within the bone tunnel does not imitate the insertion geometry of the native ACL.[17] Furthermore, several femoral graft fixation devices likely displace the graft substance away from the center of the bone tunnel, which the surgeon previously had considered the optimal position for graft placement in an individual knee. Consequently, it is proposed that the course of tension is influenced when submitting the graft to cyclic flexion-extension loading and depends on the method of femoral graft fixation. Furthermore, it is proposed that cyclic flexion-extension loading more accurately mimics the dynamic loading character of ACL grafts in vivo when compared with uniaxial polycyclic loading protocols.[18-20] The purposes of this study were (1) to introduce a dynamic flexion-extension loading protocol for ACL grafts, (2) to determine the influence of the femoral graft fixation method on the initial course of graft tension under dynamic loading conditions, and (3) to investigate whether the graft fixation strength was reduced after dynamic flexion-extension loading. It was hypothesized that (1) graft fixation methods that secured the graft close to the bone tunnel entrance or that displaced the graft substance from the center of the bone tunnel would display the greatest amount of tension degradation with dynamic flexion-extension loading and that (2) dynamic flexion-extension loading would not significantly reduce the initial graft fixation strength.

METHODS

Experimental Model

We used 240 porcine knees to investigate the biomechanical properties and graft loading characteristics of 6 different femoral graft fixation methods (Fig 1). Porcine specimens, rather than human cadaveric knees, were used to account for the large variability in bone quality and the limited number of human donors available. All fresh porcine knee specimens (mean age, 12 months) were obtained from the local slaughterhouse and were stored at −20°C in sealed plastic bags. Twelve hours before testing, the specimens were thawed at room temperature, and they were kept moist with physiologic saline solution throughout the preparation and testing procedure. The knee joint was disarticulated and surrounding soft tissues removed from the femur. The femoral shaft was cut 15 cm from the joint line, and a transverse 12-mm drill hole was placed within its proximal end perpendicular to the axis of the femur to create a rigid fixation of the femur

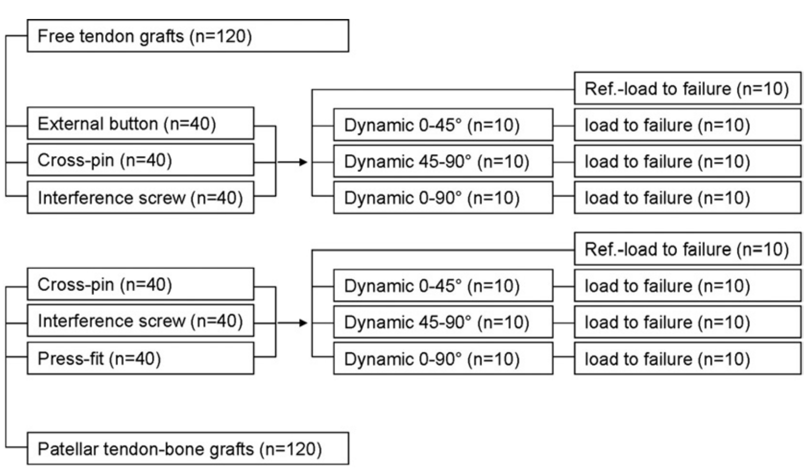

FIGURE 1. Testing sequence.