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The effect of anterior or posterior tibial tunnel placement of a soft tissue graft with a soft tissue interference screw on fixation biomechanics

Ön çapraz bağ rekonstrüksiyonunda tendon greftinin yumuşak doku interferans vidası ile tibial tünelde öne veya arkaya tespitinin biyomekanik etkisi

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Amaç: Ön çapraz bağ (ÖÇB) rekonstrüksiyonunda kullanılan yumuşak doku tendon greftinin tibial tünelde, yumuşak doku interferans vidası ile öne veya arkaya tespitinin biyomekanik etkileri araştırıldı.

Çalışma planı: On iki adet dana tibiası ve dana ekstansör digitorum süperfisialis tendonu, yumuşak dokulardan temizlenerek altışarlı homojen iki gruba ayrıldı. Hazırlanan tendonlar, tibialarda açılan tünellere 9x30 mm'lik yumuşak doku interferans vidası ile tespit edildi. Tibial tüneldeki tespit, greftin anatomik olmayan (eklemden uzak) pozisyonda önüne (n=6, grup I) veya arkasına (n=6, grup II) uygulandı. Tüm örneklere, Servo-Hidrolik makinede önce 500 defa 50-250 N arasında değişen sinüzoidal kuvvetle 1 Hz frekansta tekrarlı yük verildi, sonra en yüksek dayanma kuvvetinin (load to failure) belirlenmesi için 20 mm/dak hızla gerilme testi uygulandı.

Sonuçlar: Ortalama vida ilerleme torku I. ve II. grupta sırasıyla 8.2±2.4 Nm ve 8.4±2.8 Nm bulundu (p=0.88). Tekrarlayıcı yüklenme testi uygulandıktan sonra, iki grup arasında greftlerde yer değiştirme (1.9±0.8 mm ve 2.3±0.4 mm; p=0.38) ve sertlik (132.7±10.9 N/mm ve 126.4±8.5 N/mm, p=0.98) açısından anlamlı farklılık görülmedi.

Çıkarımlar: Ön çapraz bağ rekonstrüksiyonunda kullanılan yumuşak doku tendon greftinin interferans vidası ile tibial tünelde öne veya arkaya tespitinin biyomekanik açıdan farklı olmadığı sonucuna varıldı.

Anahtar sözcükler: Ön çapraz bağ/yaralanma/cerrahi; biyomekanik; kemik yoğunluğu; kemik vidası; dana; tendon/transplantasyon; tibia/cerrahi.

Objectives: We investigated the biomechanical characteristics of anterior or posterior tibial tunnel placement of the soft tissue graft with a soft tissue interference screw in anterior cruciate ligament (ACL) reconstruction.

Methods: Twelve bovine tibiae and digital extensor tendons were divided into two homogeneously equal groups after they were stripped of all soft tissues. Tibial tunnels were prepared and digital extensor tendons were fixed at nonanatomic (apart from the joint) anterior (n=6, group I) or posterior (n=6, group II) tibial tunnel positions with a soft tissue metal interference screw, 9x30 mm in size. All the specimens were cycled 500 times from 50 to 250 N at 1 Hz frequency in a servo hydraulic test device, after which ultimate load-at-failure testing was performed at a rate of 20 mm/min.

Results: The mean screw insertion torque values were 8.2±2.4 Nm and 8.4±2.8 Nm in groups I and II, respectively (p=0.88). No significant differences were found between the two groups with respect to graft displacement (1.9±0.8 mm *vs* 2.3±0.4 mm; p=0.38) and stiffness (132.7±10.9 N/mm *vs* 126.4±8.5 N/mm, p=0.98) at the end of cyclic loading.

Conclusion: Our results show that the site of nonanatomic soft tissue graft fixation in the tibial tunnel (anterior or posterior) with a soft tissue interference screw do not affect the biomechanical parameters in ACL reconstruction.

Key words: Anterior cruciate ligament/injuries/surgery; biomechanics; bone density; bone screws; cattle; tendons/transplantation; tibia/surgery.

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In the anterior cruciate ligament (ACL) reconstruction surgery, it is important to fix the graft at the most convenient position with an adequate tension and soundness. Due to lack of bone blocks, it is likely that the soft tissue tendon graft may not be always fixed adequately, particularly to the tibial tunnel. It has been reported that the screw-graft fixation is directly associated with the bone mineral density of the tibial proximal and also the screw insertion torque in ACL surgeries performed using the Hamstring tendon.[1] As the bone mineral density in the tibial proximal metaphysis is inferior than in the femoral condyle, the fixation in the tibial tunnel is weaker than in the femoral tunnel.[1,2] Although various methods have been used in order to enhance the strength of the fixation in the tibial tunnel, there is no compromise on an ideal method yet.[3-5]

In the present study, we aimed to compare the effect of anterior or posterior tibial tunnel placement of the graft on the biomechanical parameters. Our hypothesis was that the fixation strength could have been enhanced by posterior placement of the graft.

Material and methods

We used bovine tibia and extensor digitorum superficial (EDS) tendons, which have similar biomechanical characteristics with the human tibia and semitendinosus-gracilis tendons. Twelve pieces of frozen bovine knee were divided into two groups of six. All tibia specimens, which were harvested from healthy animals and kept in plastic bags, were placed in deep freezers within one hour. Tibiae were used within one week after harvesting. Particular attention was paid to thaw the specimens at room temperature (24 °C) 24 hours before assessments.

In order to obtain specimens with a homogenous bone density in the proximal tibial metaphysis in each group, the bone mineral density of specimens was measured by the DEXA screening system (Hologic QDR-4500, Hologic Inc., Waltham, MA, USA) after removal of the soft tissue. The tibiae were kept in 15x25 cm plastic boxes containing physiologic saline solution throughout the measurements. Twelve bovine EDS grafts (70 mm long and 8 mm wide) with double pedicles were debrided of soft tissues, and prepared using the interlocking whipstitch method with an Ethibond No. 2 suture (Ethicon) (Figure 1). A graft table was used to stretch the grafts during the preparation and then to provide a double-pedicle graft as well as using before fixation. Before the fixation, a 3 kg load was applied on the grafts on the table for 15 minutes in order to attenuate its effect on the displacement and stiffness. Then, the tibial tunnel was drilled in a diameter of 7 mm as described by Howell et al.[6] and, dilated with 7.5, 8, 8.5 and 9 mm dilators.

Following the preparation of tunnel, the grafts were placed into the tunnel, and fixed with a soft tissue interference screw (9x30 mm). The screw was placed anteriorly in Group I (n=6, Figure 2a), and posteriorly in Group II (n=6, Figure 2b). In the meantime, the screw insertion torque was measured by a torque meter (P3 Strain Indicator, 4 Channel, Vishay-Measurements Group, USA). Following the fixation, the bovine tibiae cut into similar pieces were embedded in polyester steel plaster; and a worst-case-scenario was established, positioning them with a 45° angle to the fixation table as to transfer the tensile load directly onto the tibial tunnel (Figure 3). The specimens were duly placed into the custom designed Servo-Hydraulic Universal Test Machine (Mechanics Department of Engineering Faculty, ITU - 2003, 200 psi), and made ready for tensile testing. The grafts, which were fixed to the bones were tied to the load cell (ESIT, SPA 300 kg, S/N 223) connected to the servo-hydraulic test machine by inserting a steel needle between the two legs of the free ends. A dynamic stress was applied on the grafts by a repetitive load of 1 Hz frequency, with a sinusoidal force ranging from 50 to 250 Newton (N) for 500 times by the testing machine.

Each specimen was, statically and as initiated from zero N, loaded in a tension test at a speed of 20 mm/min until the damage occurs. During these procedures, changes in the size of grafts were concomitantly and dynamically transferred to the computer by means of a potentiometric displacement transducer (Micro-Epsilon WDS 300 P60 CR P, S/N 4600). The data were directly recorded in the com-

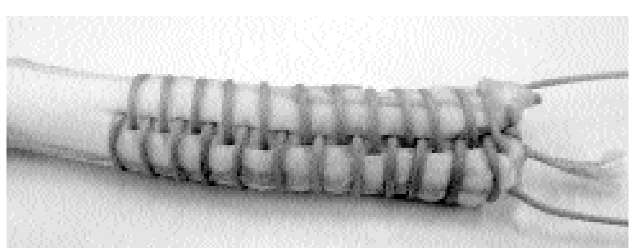

Figure 1. Preparation of the graft.

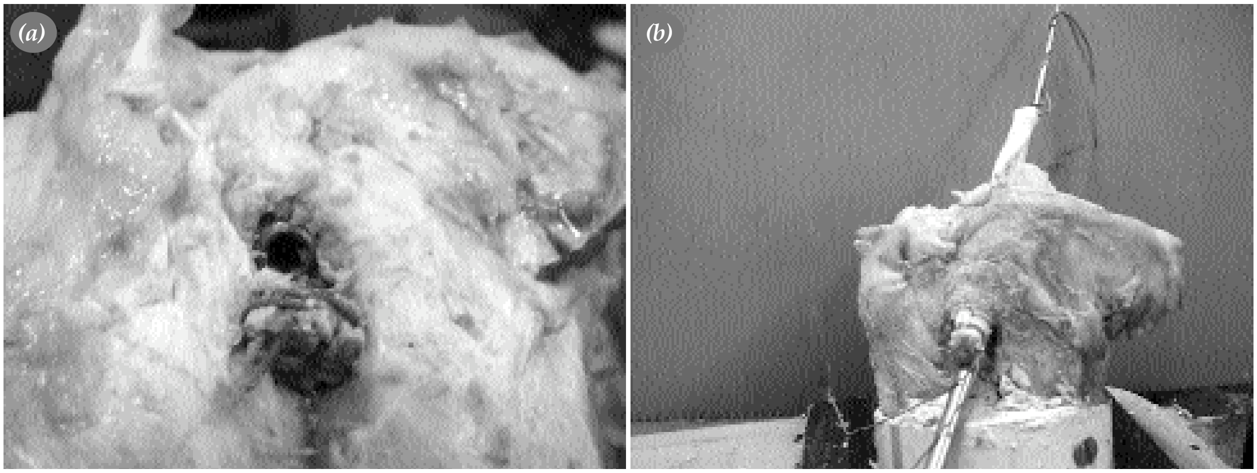

Figure 2. (a) Anterior, and (b) posterior placement of the soft tissue interference screw.

puter by a data collection system called "ESAM Traveller" (Type 1032-S, S/N 0060502; ESA Messtechnik, GmbH, Olching, Germany) at a speed of 100 Hz/sec. As biomechanical parameters, the insertion torque (described as the strength confronted while the screw advances within the tunnel), the stiffness (described as the resistance the individual length of the graft shows against the deforming strength) and the maximum load to failure (described as the strength immediately before the damage in the fixation area against the load applied) were evaluated.

Statistical analyses were performed using the Mann-Whitney U-test, and SPSS for Windows version 11.0 software program; $p<0.05$ was considered significant.

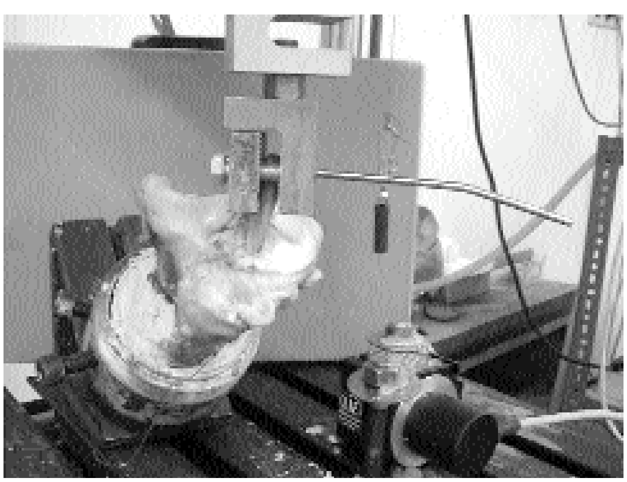

Figure 3. Loading test in the servo-hydraulic machine.

Results

The mean bone mineral density was similar in both groups (0.90±0.22 g/cm2 for Group I, and 0.88±0.20 gr/cm2 for Group II, p=0.94). The mean screw insertion torque values were 8.2±2.4 Nm and 8.4±2.8 Nm in groups I and II, respectively (p=0.88). No damage was observed in any of the specimens during the cycling load test. The mean graft displacement was 1.9±0.8 mm in Group I, and 2.3±0.4 mm in Group II at the end of the cycling load (p=0.38). For stiffness, both groups had similar mean values (132.7±10.9 N/mm and 126.4±8.5 N/mm, respectively p=0.98). In Group I, two grafts (450 N and 375 N), and in Group II one graft (310 N) reached the maximum load to failure strength, leaving the screw inside the tunnel. All the remaining specimens reached the maximum load to failure strength when the screw lacerated the graft. Therefore, the graft-screw-tunnel complex fixation strength was not measured (Table 1).

Table 1. The maximum load to failure strength values (N) measured following the cycling loading test

Specimens	Group 1	Group II
1	450	800
2	725	760
3	645	630
4	375	310
5	790	725
6	740	680

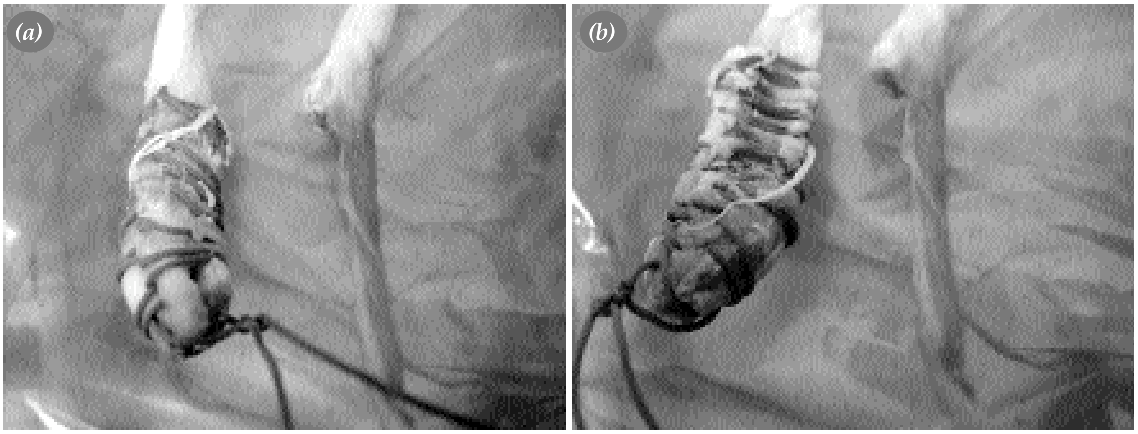

Figure 4. (a, b) Appearance of the graft lacerated by the soft tissue interference screw.

Discussion

The fixation in the ACL surgery must have abundant strength and stiffness in order to be able to achieve knee stability in the postoperative three months and prevent any slippage of the graft.[7] An early advancing rehabilitation following the surgery is as much important as the surgery. If the fixation is inadequate after the anterior cruciate ligament reconstruction, the surgeon can prevent early mobilization and weight-bearing of the patient during rehabilitation, which results in decreased bone mineral density in the proximal tibial metaphysis, and in cortical bone loss. The reduction is particularly observed in and around the tibial tunnel the graft is fixed with.[8,9] Because of the inter-triggering characteristics of these two factors which have negative effect on the cruciate ligament reconstruction, the primary goal should be to start advancing early rehabilitation program for the patient, enhancing the graft fixation strength.

In a study on the calf tibia, Weiler et al.[10] found that the bone mineral density decreased from the cortical bone toward the central in specimens harvested from the same depth. Based on this outcome, the bone mineral density is different in the anterior and posterior walls where the screw would contact. Due to the graft laceration by screw, we couldn't prove our hypothesis, which was based on the idea that when the graft was placed posteriorly, the graft would be in contact with the anterior wall, which has more mineral density while the threads of the screw would fit well into the spongious bone and the fixation strength would be enhanced. We couldn't find any study in the literature screening, which evaluated the anterior and posterior placement of the graft and the fixation behavior in cycling load and tensile tests.

We used bovine knees in our study as it biomechanically resembles the human tibia[11] and it is more easily available.[12,13] Similarly, we used bovine EDS as grafts since they are easily available, and they have similar stiffness and viscoelastic behavior against the high load applied on the human semitendinosus and gracilis tendons. The length of the graft was adjusted as 40 mm after the fixation level of the tibia because the length of the free graft remaining between the two fixation levels in the ACL surgeries is approximately 40 mm. Thus, we tried to increase the standardization of the study by attenuating the effect of additional factors on the outcome.

We observed that even tough their threads were not sharp, the soft tissue interference screws could have lacerated the soft tissue tendon graft. In all specimens with graft laceration, the screw lacerated the graft from the contact point of the tip (Figure 4a, b). The lacerated region evokes two mechanisms: the first one is that the graft was weakened and lacerated as a result of extreme loading at the ultimate point of the screw tip where the bone and soft tissue interference screw are tightly contacted before it gets thinner; and the second one is that the worst-case-scenario could only be used partly and the pulling strength was not completely in parallel to the tunnel during the study. In that case, although they should be parallel to each other, the screw and the graft were positioned across each other. We believe that both mechanisms may have played a role in the laceration of the graft; but their crosswise position exacerbated the first mechanism.

In conclusion, we found that anterior or posterior tibial tunnel placement of the graft had no effect on the biomechanical parameters following the cycling load tests. As the cycling load test used in our study was similar to the load used during the rehabilitation following a normal ACL reconstruction, we believe that the same rehabilitation protocol can be used following a reconstruction where the screw is placed on both sites, and this allows the surgeon to employ the technique he/she is used to do during surgery.

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