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Comparison of eccentric and concentric screw placement for hamstring graft fixation in the tibial tunnel

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Abstract Interference screw fixation of four-strand hamstring grafts for ACL reconstruction has recently been introduced. By this method, the interference screw is placed in the tibial and femoral tunnels eccentric (adjacent) to the bundled limbs of the graft. In order to maximize the graft to tunnel contact to promote biological fixation, it is proposed to place the screw concentrically in the tunnel, in the middle of the four limbs of the graft, pressing each limb of the graft into the tunnel wall. This would be difficult to do in the proximal, folded end of the four limb graft situated in the femoral tunnel but can be done easily in the tibial tunnel. The purpose of this study was to evaluate the effect of screw placement on the stiffness, yield load, and ultimate load of hamstring graft fixation in the tibial tunnel. Five pairs of human knees were used for the study. Pull out tests were performed using an MTS system, pulling along the axis of the tibial tunnel. Tibial fixation stiffness was greater using concentric screw placement ($P < 0.05$) although there was no statistical difference in yield load, slippage, or ultimate load.

Key words Anterior cruciate ligament · Graft fixation · Hamstrings · Quadruple semitendinosus-gracilis graft · Tibia

Introduction

Use of hamstring tendon grafts for ACL reconstruction has been increasing with recent improvements in methods for securing the soft-tissue graft into femoral and tibial bone tunnels. One novel method uses a blunt, threaded interference screw to compress the bundled limbs of the graft into the wall of the bone tunnel [6]. The graft is made up of the semitendinosis and gracilis tendons which are folded in half, creating a four-limb graft. The graft is typically sutured on the proximal and distal ends to ensure that the four limbs of the graft remain parallel while the screw is inserted. The folded end of the graft is fixed in the femur, the free ends in the tibia.

The screw is normally placed eccentrically in the tunnel, i.e., adjacent to the bundled graft. Alternatively, in order to maximize contact between the individual limbs of the graft and the tunnel wall the screw can be placed concentrically in the tunnel, inside the graft limbs. The purpose of this study was to compare the tensile stiffness, yield, and ultimate load for a hamstring graft fixed in the tibial tunnel using concentric and eccentric screw placement.

Materials and methods

Five pairs of fresh frozen human cadaver knees were used for this study. The average age was 51 years (range 49–54). The specimens were thawed and semitendinosus and gracilis tendons harvested using a commercially available tendon stripper. The tibia were dissected of all soft tissue and potted in cylinders using low melting point metal. The tendons were cleared of all adherent muscle tissue.

The tendons were folded over a no. 5 suture which subsequently acts as a lead pulling suture. Grafts for eccentric fixation were prepared by bundling the four limbs of the tibial end of the

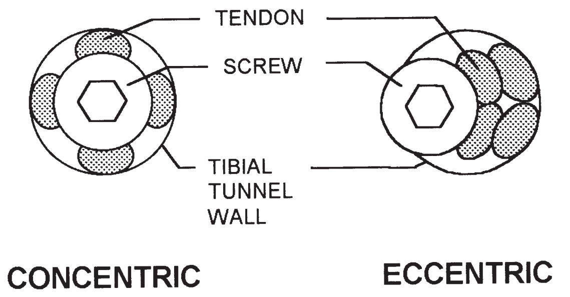

Fig. 1 Schematic of screw position in the tibial tunnel

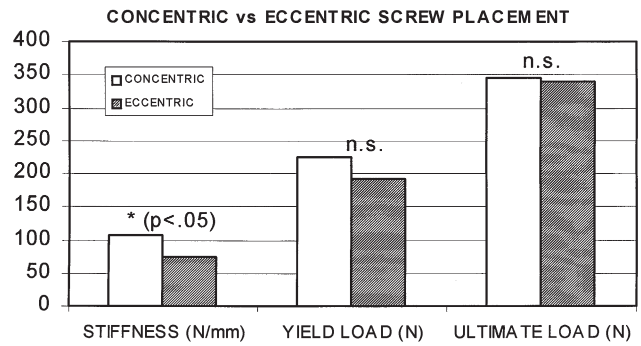

Fig. 2 Stiffness, yield load, and ultimate load for the two screw positions

graft with a modified baseball stitch using no. 1 braided suture. The tibial end of the concentric grafts were prepared using a no. 1 suture in a whip stitch on each limb of the graft. The graft diameter was measured to the nearest 0.5 mm using a tube gage.

Tibial tunnels were drilled using a drill guide and guide wire. The tunnel was directed so as to exit the tibial plateau centrally in the ACL tibial attachment footprint. Final tunnel sizing was accomplished using a compacting router with the same diameter of the graft (0.5 mm increment). Graft diameter ranged from 6.5 to 8.5 mm. The grafts were passed through the tibial tunnel and fixed using a titanium screw: 9 mm outside thread diameter, 25 mm long (9 × 25 SIS, Smith & Nephew). Eccentric and concentric screw placement was used in tibia from paired knees, randomly assigning eccentric fixation to either the left or right knee and using concentric fixation in the other. Figure 1 is a schematic representation of the two screw placements in the tibial tunnel.

The specimen was mounted to allow tensile testing along the axis of the tibial tunnel. The proximal, looped end of the graft was gripped by a simple clamp. A 10-N tensile preload was applied to the graft to remove slack prior to tensile testing. All tensile tests were performed at 1.0 in./s (25.4 mm/s). The load was measured by a calibrated transducer and digitally recorded at a sampling rate of 100 Hz. The yield load was taken from the load/displacement graph where it departed from linear behavior. The stiffness was calculated from the linear part of the curve. The ultimate load was taken as the maximum recorded load. Slippage was taken as the tensile tester crosshead displacement at the yield load. The two-tailed Student's t test for paired data was performed to determine whether statistically significant differences existed for the stiffness, slippage, yield, and ultimate loads using eccentric and concentric screw placement.

Table 1 Stiffness, yield load, slippage, and ultimate load for the two screw positions

	Concentric	Eccentric	
Stiffness (N/mm)	105.6 ± 34.1	74.2 ± 23.6	$P < 0.05$
Yield load (N)	224.0 ± 53.8	190.8 ± 62.6	n.s.
Slippage (mm)	2.2 ± 0.8	2.5 ± 0.7	n.s.
Ultimate load (N)	344.4 ± 129.5	340.0 ± 83.5	n.s.

Results

The stiffness, yield load and ultimate load for the two screw positions are shown in Fig. 2. The results are summarized in Table 1.

Discussion

A number of new methods for fixing the hamstring have recently been introduced; most of these are for proximal graft fixation in the femoral tunnel. Distal graft fixation to the tibia is typically carried out on the front surface of the tibia, external to the tibial tunnel. If the graft is not long enough, sutures are used to bridge the gap between the graft and external fixation. Since the sutures are less stiff than the tendons, this configuration reduces the overall stiffness of the graft construct [8]. External fixation effectively lengthens the graft, which also reduces its stiffness [3]. An additional drawback of external tibial fixation is lack of soft tissue over the hardware, which can lead to irritation and sometimes necessitate hardware removal.

When the limbs of the graft are bundled, one or more limbs of the graft may be compressed between the screw and another limb of the graft. Ensuring that all limbs are in contact with the tunnel wall can maximize the frictional force, preventing the graft from being pulled out of the tunnel. This may be the reason for the increased stiffness seen in the concentric configuration. Two recent studies confirm the healing response of a hamstring graft fixed using eccentric screw placement [4, 5], although the effect of concentric screw placement on the biological healing remains to be evaluated.

A pull-out study recently published by Simonian et al. [7] showed no difference in stiffness (approximately 30 N/mm) or maximum pullout force (approximately 250 N) for the eccentric and concentric screw placements. A number of factors may contribute to the higher stiffness and maximum load that we observed. Most importantly, Simonian, et al. used a 10-mm diameter hole drilled in a polyurethane foam block used to model the tibial tunnel. The diameter of the graft was not reported. Using a constant tunnel diameter of 10 mm, the fixation strength decreases as the graft diameter decreases since the strength of the fixation comes from the friction between the graft and tunnel wall. Therefore it is crucial to have a tight fit between the graft and tunnel so the screw insertion produces the pressure needed for secure fixation. Also, a 2.5 cm^3 cube was used to simulate the tibia, resulting in a 2.5-cm-long tunnel. This is the same length as the 9×25 absorbable screw used in the testing. Considering this configuration, it is possible that the pressure between the graft and tunnel wall was relieved where the graft exited the tunnel, possibly reducing the fixation strength and stiffness.

It should be noted that the cadaver specimens used in this study were older and of marginal bone quality. Although no bone density measurements were made, one can assume that the absolute pull out strength and stiffness in young tibia would be higher than the values reported here [1, 2].

Internal fixation of the hamstring graft using an interference screw can address some of the problems related to external fixation. Although current techniques call for eccentric screw placement in the tibial tunnel, placing the screw concentrically in the tunnel can maximize graft-tunnel contact. Concentric screw placement may also facilitate biological healing of all four limbs of the soft tissue graft to the bone. In vivo testing is required to evaluate the effect on healing.

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