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ORIGINAL STUDY

The lateral tibial tunnel : Does it allow for adequate fixation in ACL surgery ?

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The purpose of this cadaver study about the ACL graft was to compare a "Lateral Tibial Tunnel" (LTT) and a "classic, anteroMedial Tibial Tunnel" (MTT), as to fixation strength and mode of failure. Ten pairs of fresh frozen human proximal tibias were used. In one of both tibias a classic anteromedial tunnel was used, versus a lateral tibial tunnel in the contralateral knee. Autologous doubled semitendinosus and gracilis tendons were fixed in the tunnels. A maximum load to failure test was performed to determine the stiffness and the strength of the graft-tibia complex. Conclusion : for none of the measurements was there any significant difference between both tunnels. The tibial fixation strength of a human autologous doubled hamstring graft in ACL surgery is similar, whether a lateral or an anteromedial tibial tunnel is used. This is the first study investigating fixation strength of an ACL graft in a lateral tibial tunnel.

Keywords : knee ; anterior cruciate ligament ; revision ; lateral tibial tunnel ; biomechanics ; strength.

INTRODUCTION

Anterior cruciate ligament (ACL) surgery has become the treatment of choice for the unstable ACL deficient knee. In spite of this, failure and reoperation rates range from 3 to 27% (*1,2,3,8,20,23*). Although well-described strategies for ACL revision surgery exist, many technical difficulties remain. Indeed, a one-stage or a two-stage revision procedure is often performed, with inferior results compared to primary ACL surgery (*5,6,9,12,21*). Hardware removal, tunnel enlargement and tunnel overlap cause bone-stock deficiency and will negatively affect graft fixation, or will make a one-stage revision surgery even impossible. The authors therefore described a new technique to tackle some of the known problems related to tibial bone stock problems in revision ACL surgery : the "Lateral Tibial Tunnel" (LTT) technique (*22*). This one-stage technique is based on a tibial tunnel drilled from the anterolateral side of the tibia towards the tibial ACL

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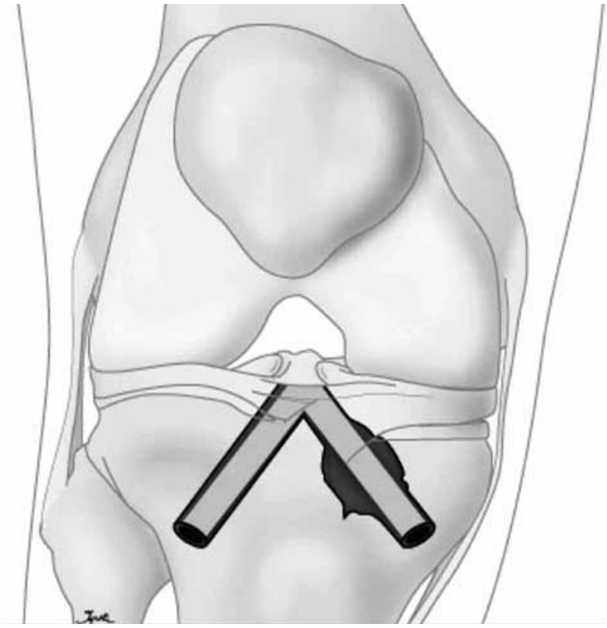

Fig. 1. — The Lateral Tibial Tunnel (LTT) technique in ACL revision surgery : a revision tibial tunnel is drilled from the lateral side of the tibia towards the centre of the tibial ACL footprint. Little tunnel overlap is seen.

footprint (Fig. 1). Only a short tunnel overlap is seen between the primary anteromedial tibial tunnel (MTT) and the revision LTT. Due to this short tunnel overlap, an intact bone tube in the revision LTT will be available, which is as long as the intact bone tube in a primary MTT (22).

The purpose of this cadaver study about the ACL graft was to compare a "Lateral Tibial Tunnel" and a "classic, anteromedial tibial tunnel" (MTT), as to fixation strength and mode of failure. The hypothesis was that pull-out force, stiffness, and failure mode would be similar.

MATERIALS AND METHODS

Specimens

Twenty paired fresh frozen human knee specimens (age, 21-65 years) were used. Firstly, the gracilis and semitendinosus tendons were harvested and kept in saline. Secondly, all soft tissues around the knee were stripped, the femur was removed and the proximal tibia was cut 20 cm distal to the joint line. The anterior cruciate ligaments were removed at their tibial insertion site. Specimens from subjects older than 65 years were not considered, because they might be osteoporotic. Furthermore specimens with bone disease or previous surgery were excluded.

Surgical technique

The autologous semitendinosus and gracilis tendon grafts were prepared by folding them in the middle over an Ultrabraid (Smith & Nephew, Andover, MA) suture and placing whipstitched sutures in the distal tendon end, starting 60 mm distal from the loop end. The 60 mm loop was intended to replicate 30 mm of tendon in the femoral tunnel and 30 mm of tissue within the joint (4,7,24). The loop was not sutured, to allow a hook to pass when performing the tests (7,14,24). The grafts were sized to the nearest 0.5 mm, after suturing, by passing them through sizing tubes (24). All grafts were sprayed with normal saline during preparation and testing, to prevent desiccation (24).

Each of the 10 pairs of knees was randomized to medial or lateral tunnel placement, resulting in 10 MTT (5 right and 5 left knees) and 10 LTT. A lateral or a medial tibial tunnel was drilled towards the centre of the tibial ACL footprint with a drill-guide angle of 55° referred to the surface of the tibial plateau (22) (Fig. 1). The respective cortical entry points for the MTT and the LTT were situated 2 cm medial and 2 cm lateral to the centre of the tibial tubercle. The appropriate-sized reamer (Smith & Nephew, Andover, MA) was used over a guidewire to ream the tibial tunnel to the same size as the graft. Tunnel dilators (Smith & Nephew, Andover, MA) were used to widen the tunnel by 0.5 mm, if the graft was 0.5 mm larger than the reamer (4,14,24). The prepared grafts were pulled through the tibial tunnel in a retrograde fashion with the looped side pulled from distally to proximally until 60 mm of looped graft was proximal from the tunnel (4,7,24). Tibial cortical aperture fixation was performed with an absorbable, 30 mm, BIORCA-HA (Smith & Nephew, Andover, MA) interference screw which was 1 mm wider than the tunnel (4,11,14,25). A guide-wire was used for screw insertion to prevent screw-graft divergence.

Strength testing

The proximal tibia was securely mounted in a custom-made tissue patch clamp. A preload of 30N was applied to the tendon, prior to the start of the pull (24). The exposed proximal tendon loop was fixed on a test rig and pulled at a fixed angle of exactly 45 degrees inclination referred to the tibial plateau. The pull was performed with a DC motor driven power screw under a controlled speed of 1.5 mm/s, until failure of the fixation occurred (*4,11,14,24*).

During the test, the force and displacement were continuously measured using a standard tension load cell. An HBM Spider (HBM, Darmstadt, Germany) was used with the Catman Easy software (HBM, Darmstadt, Germany) to collect the data. Yield load, displacement at yield load, ultimate load, displacement at failure, stiffness, load applied at 3 mm, 5 mm and 10 mm of graft slippage, and mode of failure were determined. Yield load was determined at the point at which the slope of the force displacement graph began to deviate from linear. The maximal recorded load before failure determined ultimate load. Stiffness was derived from the linear portion of the force-displacement curve.

Statistical methodology

The number of included specimens was not based on a power analysis but on the availability of pairs of intact human cadaver knee specimens under the age of 65 years in the department. A two-sided paired t-test was used to compare the results between LTT and MTT. A 95% confidence interval (CI) was constructed for the difference between LTT and MTT. LTT and MTT measurements were obtained from a paired knee. P-values smaller than 0.05 were considered significant. Analyses were performed using SAS software, version 9.2 of the SAS System for Windows (SAS Institute Inc., Cary, NC, USA).

RESULTS

One pair of knees was excluded from this study due to previous surgery on one of both knees. Eighteen knees from 9 human cadavers remained available for testing : 6 males and 3 females, with a mean age of 45 years (range, 21-65). Demographic data and surgical details are reported in Table I.

Table II summarizes the results of the strength tests. For none of these measurements was there any significant difference between LTT and MTT. Given the small sample size it is more important that the observed differences did not reflect

Table I. — Demography and surgical data

cadaver	side	technique	age (years)	sex	graft size (mm)	tunnel size (mm)	screw diameter (mm)
1	right	MTT	62	male	9	9	10
1	left	LTT	62	male	8	8	9
2	right	LTT	29	male	8	8	9
2	left	MTT	29	male	7,5	7.5	8
3	right	MTT	48	female	7.5	7.5	8
3	left	LTT	48	female	7	7	8
4	right	LTT	65	female	7.5	7.5	8
4	left	MTT	65	female	7	7	8
5	right	LTT	56	male	8	8	9
5	left	MTT	56	male	7	7	8
6	right	MTT	40	male	8	8	9
6	left	LTT	40	male	8	8	9
7	right	LTT	32	female	7	7	8
7	left	MTT	32	female	7	7	8
8	right	MTT	21	male	8	8	9
8	left	LTT	21	male	8	8	9
9	right	LTT	51	male	8	8	9
9	left	MTT	51	male	8	8	9

Table II. — Yield, failure, stiffness, load : no difference MMT/LTT

		Yield	Yield	Failure	Failure	Stiffness	Load at	Load at	Load at
Cadaver	Technique	Yield load	Displ.	Ultim. load	Displ.		3 mm displ.	5 mm displ.	10 mm displ.
		N	mm	N	mm	N/mm	N	N	N
1	MTT	952.6	47.3	952.6	40.9	26.4	17.2	39.9	111.1
1	LTT	427.1	30.8	427.1	26.5	17.4	27.6	53.2	136.2
2	MTT	244.3	32.7	249.9	22.9	8.7	27.4	50.7	115.4
2	LTT	334.3	38.1	334.3	31.1	10.4	23.2	37.0	89.0
3	MTT	179.9	33.5	179.9	25.7	5.8	10.1	21.0	41.3
3	LTT	362.0	30.6	362.0	24.9	13.3	15.1	29.8	87.8
4	MTT	211.3	29.2	211.3	23.5	7.9	14.1	24.0	59.1
4	LTT	292.8	55.6	292.8	47.4	6.2	16.7	30.6	78.8
5	MTT	552.5	44.9	607.9	53.4	15.0	13.2	26.8	76.6
5	LTT	420.9	29.6	605.8	56.8	15.9	21.3	37.6	99.6
6	MTT	316.9	32.6	316.9	26.3	11.1	17.7	36.5	90.9
6	LTT	468.9	43.2	593.5	66.5	11.8	12.8	24.0	67.2
7	MTT	913.7	51.6	913.7	41.6	21.4	14.7	35.7	95.1
7	LTT	785.2	48.4	785.2	44.1	19.7	19.6	36.3	87.1
8	MTT	217.3	27.9	217.9	23.9	9.1	17.3	35.2	71.5
8	LTT	394.4	40.4	477.1	46.4	10.3	20.4	32.1	72.9
9	MTT	426.5	32.8	426.5	29.0	14.8	41.9	77.0	174.2
9	LTT	338.3	46.4	338.3	39.0	9.2	14.2	32.0	79.2
Mean	LTT	425	34.2	469	42.5	12.7	19.0	34.7	88.6
Mean	MTT	446	29.3	453	31.9	13.3	19.3	38.5	92.8
p	LTT vs MTT	0.79	0.30	0.86	0.08	0.69	0.94	0.55	0.77

Displ. = Displacement / Ultim. = ultimate.

superiority of MTT, which was obvious for yield load, maximum load, stiffness, load at 3 mm displacement, load at 5 mm displacement and load at 10 mm displacement, as there was not a systematic tendency in the differences.

The mode of failure was slippage at the screw-tendon interface in all but one case : in the LTT of cadaver 8, pullout of the whole screw-tendon construct occurred. No macroscopic fracture of the tibial plateau could be seen in any specimen.

DISCUSSION

The most important finding was the fact that there was no difference in the fixation strength of an ACL graft between LTT and MTT (Table II). Similar yield load, displacement at yield load, ultimate load, displacement at failure, stiffness, load applied at 3 mm, 5 mm and 10 mm displacement and mode of failure were found between both techniques. This is the first study investigating fixation strength of an ACL graft in a lateral tibial tunnel.

Comparison of our results with other studies investigating fixation strength of doubled hamstrings grafts with an interference screw in a classic anteromedial tibial tunnel showed in general higher ultimate loads in these studies compared to our study (*7,10,11,13*). However, most of these studies were performed on bovine or porcine tibiae (*7,10, 13,15*). Although the bone mineral density of these last specimens is comparable to the BMD of young human bone, caution should be used in extrapolating the results from animal studies : one cannot assume that the structural properties of fixation devices determined in animal tissue predict their performance in human knees (*7*). Comparison with similar studies performed on human cadaver tibiae showed equal results regarding ultimate load and yield load (*4,19,24*). Yield load and ultimate load compared favourably with the forces exerted on the cruciate ligaments *in vivo*, more specifically in relation to normal walking, as calculated by Morrison (*17,18*). This proves that all these MTT and LTT constructions are able to resist normal forces during level walking.

When comparing the results of this study with similar human cadaver studies regarding displacement at yield load, displacement at ultimate load and stiffness, larger displacements and lower elasticity were seen in the current study (*4,24*). However, without any difference between LTT and MTT. Differences in strain rate, differences in load applied during pre-tensioning and differences in the direction of the pull between various studies might be responsible for some of the divergent results. For instance, the pre-tensioning loads vary from 10N during several seconds to 100N during 5 minutes (*7,11*).

All graft-screw-bone complexes failed due to slippage of the graft between the screw and the bone. This is the same mode of failure as reported in other studies (*15,16*). A primary concern of the LTT is the possibility of a fracture of the tibial surface or rupture of the ACL graft. In order to avoid the risk of such bony fracture or tendon rupture, the pull was not performed in line with the tibial tunnel (worst-case scenario) as done in most other studies (*4,14*). A more physiological angle of 45° between the intra-articular course of the graft and the tibial plateau was used. But neither fracture of the tibial plateau nor tearing of the graft was seen in any specimen.

Limitations

This study had several weaknesses. Firstly, the number of tested specimens was too low to detect statistically significant differences between both groups. Indeed, the number of included specimens was not based on a power analysis but on the availability of paired human cadaver knees from subjects under age 65. A post hoc power analysis showed that a sample size of 250 specimens would have been necessary to detect a 10% difference for yield load. Not only the small sample size but also the large standard deviation of the mean difference between the yield load of both techniques was responsible for the lack of power. On the other hand, the load necessary to obtain a graft slippage of 3 mm, 5 mm and 10 mm revealed a much higher power to detect a difference between both techniques for these parameters, because a smaller standard deviation of the mean difference between results of both groups was seen.

Secondly, bone mineral density was not measured prior to surgery, to exclude patients with osteoporotic bone. Of course, only specimens from subjects under 65 were used, in order to reduce the risk (*24*). Moreover, this variable was controlled by using pairs of knees, so that comparison became possible. Last but not least, these specimens from older people would have consisted in a worst case scenario, as the fixation strength would probably be less than in young athletes.

Thirdly, no cyclic loading was performed prior to the test. Some other investigators do this before loading to failure (*16*). Possible slippage during cyclic loading in these studies can explain the lesser displacement at yield load and at load to failure.

Fourthly, this study evaluated the fixation strength of a *primary* ACL repair (with either an LTT or an MTT), in spite of the fact that the LTT technique was developed for ACL *revision surgery*. However, there are 3 reasons to mitigate this statement : a. we know from previous work that an LTT is significantly longer than an MTT (*22*) ; b. furthermore we discovered that the intact bone tube of a revision LTT has the same length as the intact bone tube of the primary MTT in the same knee (*22*) ; therefore screws of at least 30 mm can be used in a revision LTT, whereas a substantial tunnel widening is present in the proximal part of the primary MTT ; c. additional back up cortical fixation can be performed as proposed in many studies to enhance the fixation strength : indeed, at the end of an LTT procedure, the anterior tibial muscle can be reattached to cover those fixation devices, which is not possible with a classic MTT technique.

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