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ORIGINAL STUDY

Prevalence and influence of tibial tunnel widening after isolated anterior cruciate ligament reconstruction : a comparative graft analysis – long-term follow-up

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A retrospective study was conducted to evaluate incidence, degree and impact of tibial tunnel widening (TW) after isolated anterior cruciate ligament reconstruction using patella-bone-tendon-bone (PBTB) or semitendinosus tendon (STS) autograft.

Postoperatively mid- and long-term clinical outcome, knee joint stability and prevalence of osteoarthritis (OA) were evaluated. Evaluation was performed clinically using different scores, an arthrometer and radiographically.

On long-term follow-up >75% of patients were graded A or B according to the IKDC-score in both groups. Mean Lysholm score was 90.2 ± 4.8 (PBTB) vs. 88.2 ±3.7 (STS) ; mean Tegner score was 4.9 (PBTB) vs. 4.8 (STS). We found slight differences in the amount of TW in the comparative graft analysis with predominance of the STS subgroup but without clinical impact. There was no statistically significant progression of TW in comparison to the midterm results with slight predominance of TW in the STS group. Radiological evaluation showed degenerative changes of a grade I/II OA in about 60% of patients. Prevalence of a grade III or grade IV OA was found in about 25% in both groups without any significant intergroup difference. Correlation analysis showed no significant relationship between the amount of tibial TW (p>0.05), long-term clinical results, anterior joint laxity or prevalence of OA in both groups.

Tibial TW seems to be a radiological phenomenon most commonly observed within the short to midterm intervals. There is no adverse effect on long-term clinical outcome and stability. Furthermore, it does not constitute for an increasing prevalence of osteoarthritis.

Keywords : anterior cruciate ligament reconstruction ; IKDC-score ; tibial tunnel widening ; graft analysis ; osteoarthritis.

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This study was done in accordance to the Declaration of Helsinki of 1975, as revised in 1983
Informed consent was obtained from all patients.

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INTRODUCTION

Widening of the bony tunnel after anterior cruciate ligament reconstruction (ACLR) represents a well-known phenomenon *(1-4)*. Various mechanical and biological theories have been proposed for the explanation of tibial tunnel widening (TW) as a predominant radiological finding *(5-7)*. Different pathomechanisms are discussed influencing TW such as graft type, motion of the graft within the tunnel, fixation technique or postoperative rehabilitation concepts *(8-11)*. Other studies have shown that biological factors and in particular mechanical factors are associated with TW *(11-13)*. Biological factors represent graft swelling, use of allograft tissue, synovial fluid propagation within the tunnels, and increased cytokine levels *(12,14-17)*. Complete graft-to-tunnel healing is vital to prevent progressive TW *(11,12,18)*. This process at the graft-to-tunnel interface region requires at least 10-12 weeks post reconstruction for the organization of the scar tissue and the development of Sharpey's fibers at the tendon-bone interface *(13,19,20)*. With continuation of the graft maturation remodelling from fibrous tissue to mature bone occurs. The graft-to-tunnel fixation therefore seems to have an initial critical period prior to complete adherence and is influenced by numerous biological and mechanical factors *(13,16,21-24)*. TW the revision setting represents a difficult technical challenge with possible compromise of graft placement, fixation, and graft incorporation *(1,5,6,9)*. This may include the necessity for a staged reconstruction and additional operative procedure with significant cost. Although TW is a well-known phenomen, no study proved it to be of clinical significance on short-, mid-term and especially long-term intervals with respect to laxity, increased failure rates or progression of degenerative changes and does not appear to correlate with poor clinical results, but there is only very few data beyond 3 years *(25-30)*. Therefore main interest of the present study was to evaluate incidence, degree and impact of tibial TW after isolated anterior cruciate ligament reconstruction using two different graft types. Evaluation focussed on long-term clinical outcome, knee joint stability and prevalence of osteoarthritis (OA) after isolated ACLR via PBTB (patella-bone-tendon-bone) or STS (semitendinosus tendon) autograft.

Our study group assumed that in terms of persisting micro-motion within the tunnels and consecutive potential incomplete graft incorporation, TW continues and furthermore provides a significant impact on patient-reported long-term clinical outcome, long-term stability and prevalence of osteoarthritis.

MATERIAL AND METHODS

ACL reconstruction represents a standardized procedure within our institution. Up to 1998 ACL reconstruction was performed via PBTB autograft. Afterwards, due to a switch of the operative technique patients with an isolated ACL rupture were treated via 4 stranded semitendinosus tendon graft reconstruction at our institution. This allows the comparative long-term analysis of ACLR using two different graft types. Inclusion criteria were an isolated primary arthroscopic ACL replacement (no concurrent meniscus or cartilage surgery) ; no previous knee ligament surgery ; a normal contralateral knee. Exclusion criteria were additional ligament injuries, significant articular surface damage or meniscus lesions, evident osteoarthritic lesions or concomitant medial collateral ligament repair at the time of reconstruction as well as osteoarthritic changes (> grade I according to Kellgren-Lawrence). Operative treatment in both groups was performed within 2-3 weeks from injury. The original patient sample in the PBTB group consisted of 166 patients versus (vs.) 112 patients in the STS subgroup. On scheduled midterm follow up (2-3 years post reconstruction) 98 patients in the STS group could be re-evaluated according the functional and radiological scores. Out of this patient sample a total of 52 (46.4%) patients (30 male/22 female) could be re-assessed on long-term follow-up on average 10.2 (8-13y) years after primary reconstruction. The average age was 40.4 years (24-62y). In 32 cases the right knee joint was affected, in 20 times the left knee. With regard to the PBTB group, the study population consisted of 126 patients on midterm follow-up. On long-term follow there were 78 patients, with 73 patients having a complete data record, which accounts for an overall follow-up rate of 44% at 13.5 (range 10-18.5) years after ACLR. The study population on long-term follow up therefore consisted of 46 male and 27 female patients. The mean age was 43 years (range 24-63). In 53 cases the right knee and in 20 cases the left knee was affected.

Operative technique was standardised in all patients.

An autogenous BTB graft from the middle third of the patellar tendon was used for arthroscopic-assisted reconstruction. The central third of the patella (10 mm in width) was harvested and removed with a rectangular bone plug (20-25 mm in length). The exact tibial tunnel placement was performed using the drillguide under arthroscopic view through the posterior part of the middle of the tibial ACL footprint. The exact angle of the tibial guide was determined by the sum of the intertendineous portion of the graft in mm (N) plus 7 according to the N+7 rule *(31)*. The extra-articular portion of the guide was set midway between the apex and the posteromedial border the tibia. To create the femoral tunnel a 5-mm offset guide system was placed transtibially at the posterior margin of the intercondylar notch. The position of the femoral tunnel was determined with the knee in 120º of flexion using the 5 mm offset instrument. Femoral graft fixation was performed by press-fit positioning and by additional joint-distant mini-plate-fixation via a lateral incision. Exact intra-articular graft position of the tibial tunnel was performed with the knee in 90º of flexion, positioned in the footprint of its anatomical insertion. Afterwards tibial graft fixation was performed by press-fit fixation and additional joint distant staple fixation. After femoral fixation the affected knee was cycled for graft fixation and isometry.

In the STS group ACL reconstruction was performed via standard transtibial conventional single-bundle reconstruction (4-stranded semitendinosus tendon graft). The tibial tunnel was drilled using a drill guide under arthroscopic view through the posterior part of the middle of the tibial ACL footprint. A tibial tunnel was created with a cannulated drill with a diameter matched to the width of the prepared graft. To create the femoral tunnel a 5 mm offset guide system was placed transtibially at the posterior margin of the intercondylar notch (1 :30-o'clock or 10 :30-o'clock tunnel position). After passing and flipping the graft EndoButton® fixation (Smith & Nephew Endoscopy, Andover, MA) was performed. Afterwards the knee was cycled for preconditioning of the graft. Tibial-graft fixation was performed by SutureDisc® fixation (Smith & Nephew Endoscopy, Andover, MA).

Postoperative treatment regime did not differ in both groups. Postoperatively, all patients were immobilised in a full-extension orthosis for two days.

Full weight bearing was allowed according to the patient's pain level directly after operation. Afterwards according to our concept of rehabilitation patients were treated with a flexion limiting orthosis (extension/flexion 0°/0°/90°) for 6 weeks. After 6 weeks of rehabilitation there was no additional limitation of the operated knees range of motion. High-demand pivoting sports activities were allowed after six to nine months.

ASSESSMENTS

Clinical evaluation on midterm and long-term follow-up intervals was performed using the IKDC standard evaluation form and the scores of Tegner and Lysholm. Furthermore, the pre-operative status was documented. Assessment of the anterior laxity was carried out with the KT-1000® arthrometer (Medmetric, San Diego, CA) according to the IKDC graduation (degree of differential instrumental laxity in side comparison). Radiological evaluation of the tibial tunnel was performed on antero-posterior (AP) and strict lateral (L) views under establishment of 4 degrees of tibial TW. Based on conventional radiographs with an additional small standardised metal ball (25 mm) in 3 planes, the study group firstly calculated the actual tunnel diameters in mm measuring the sclerotic margins of the inserted tunnels on 3 different points (T1-T3) under assistance of a radiologist. The diameter of the tibial tunnel was measured 1 cm distal to the ACL insertion at proximal (T1), middle (T2), and distal (T3) location (Fig.1). Afterwards to provide a better quantification and statistical analysis of the TW the

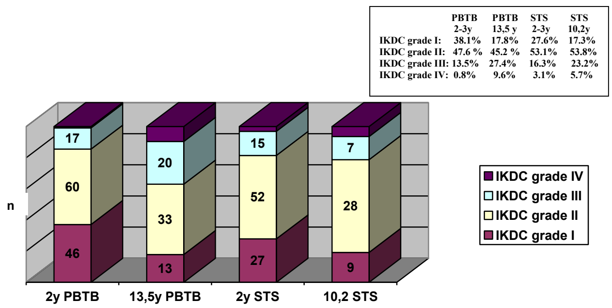

Fig. 1. — Evaluation according to the IKDC-score in both groups.
Abbreviations : IKCD, International Knee Documentation Committee ; PTBT, patella-bone-tendon-bone ; STS, semitendinosus tendon.

study group determined 4 degrees of tunnel widening with conversion of the absolute values in mm into a 4 staged ratio based on the comparison to the results of the initial drill-width and direct postoperative x-ray with regard to the actual measured values. Maximum diameter on each location (T1-T3) was used to define the ratio as tunnels might be of different shapes. The establishment of a 4 staged ranking systems as well as the use of the metal ball should assure a minimization of radiographic errors to due projection the diameter of the tibial tunnel. Grade I TW was defined as a ratio of 1.0-1.1 of the diameters of the tibial tunnel between the T1-T3 locations. Grade II was defined as a ratio of 1.1-1.2, grade III as a ratio of 1.3-1.4 and grade IV should constitute for a ratio of >1.5. The tunnels were furthermore classified as cone, linear or cavitatory according to Peyrache et al. *(32)*. The degree of degenerative changes of radiographic tibio-femoral and patello-femoral knee OA was determined via application of the radiological scale of Kellgren and Lawrence on all follow-ups *(33)*. Radiological evaluation of the pre-trauma status supplemented the overall radiological assessment.

Statistical analysis was performed by using the software SPSS 20.0. version for windows.

Correlations were regarded as significant at $p < 0.05$ concerning the Pearson-Chi square test and the Kruskal-Wallis test.

RESULTS

Clinical evaluation showed deterioration according to the IKDC questionnaire on long-term course in comparison to the midterm results (Fig.1).

Criteria for a deterioration of the clinical results on long-term follow-up consisted e.g. of pain and progressive swelling of the knee joint at strong load or symptoms of graft withdrawal within the subjective IKDC questionnaire. Additionally, patients reported of having to quit certain sports. Furthermore, an extension deficit, intermittent intra-articular effusion formation or a striking differential laxity on assessment with the KT-1000® arthrometer accounted for worse results within the objective IKDC evaluation.

Clinical assessment showed a deterioration of the average values within long-term course (Table I). During the entire follow-up period there was also a decrease in the activity level. Practice of pivot/shift and contact sports decreased from about 75-80% to 45% in both graft groups. Furthermore, competitive involvement decreased from 65% to 18.5%. In contrast, the rate of 76% and 71% of patients (55 of 73 in the PBTB group/37 of 52 in the STS group) still participating in recreational sports at final follow-up was very high.

Table I. — Knee function and activity level according to the Lysholm scoring scale and the Tegner activity scale

	Knee function: Lysholm Scale				Activity level: Tegner activity score			
	PBTB group		STS group		PBTB group		STS group	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Pre-trauma	95.7	65-100	96.3	64-100	5.8	2-10	5.7	3-10
Midterm	92.4	35-100	92.4	41-100	5.4	2-10	5.2	2-10
Long-term	90.2	25-100	88.2	25-100	4.9	1-10	4.8	2-9

Abbreviations : PTBT, patella-bone-tendon-bone ; STS, semitendinosus tendon.

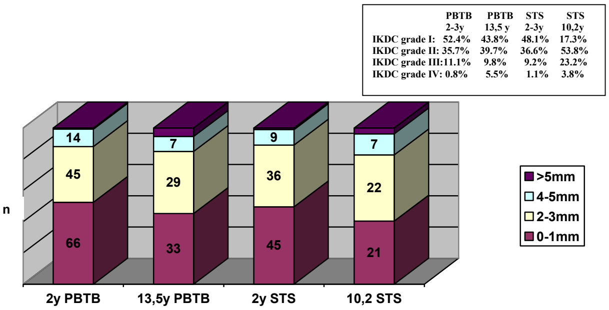

Fig. 2. — Evaluation of the anterior laxity with the KT-1000 arthrometer in both groups
Abbreviations : IKCD, International Knee Documentation Committee ; PTBT, patella-bone-tendon-bone ; STS, semitendinosus tendon

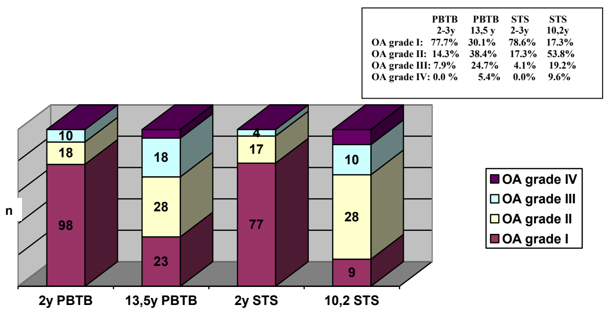

Fig. 3. — Prevalence of osteoarthritis according to the Kellgren Lawrence score in both groups.
Abbreviations : OA, osteoarthritis ; PTBT, patella-bone-tendon-bone ; STS, semitendinosus tendon.

Assessment of the anterior translation with the KT-1000® arthrometer according to the IKDC graduation showed a slight deterioration on long-term follow-up in comparison to the results at two-year follow-up in both groups. We did not find any significant intergroup difference with regard to different used graft types or fixation techniques. However, overall long-term knee joint stability remained satisfactory to excellent after ACLR on long-term interval (Fig. 2).

Radiological assessment according to Kellgren and Lawrence revealed no signs of degenerative changes on pre-trauma assessment. On two-year follow up as well as on long-term follow-up an increase of degenerative changes was detected on radiological evaluation in both groups. Again, we did not find any significant intergroup difference with regard to different used graft types or fixation techniques. (Fig. 3)

The margins of the tunnels on the tibial side were well detected and easily identified on both antero-posterior and lateral views at 2 year and long-term follow-up. In contrast, especially in the PBTB group, directly postoperatively tunnel diameter, length and position could not reliably be determined. Therefore, initial tunnel diameter was calculated from the width of the drill to create the tunnels during reconstruction. In order to minimize miscalculation of the tunnel size based on potential oblique and eccentric guide wire position, potentially leading to a larger tunnel diameter than the initial drill size, we standardised intra-operative tunnel placement and drill guide positioning and repeatedly controlled guide wire positioning via intra-operative x-ray imaging. On the femoral side the tunnel diameters were difficult to identify, in particular on long-term follow-up in the PBTB group due to total incorporation. Therefore, reliable measurements in particular in comparison to the STS group could not be made. Radiological assessment of the tibial tunnels and potential TW on two-year follow-up showed in 46.8% a grade I, in 22.3% a grade II, in 16.7% a grade III and in additional 14.3% a grade IV TW of the tibial tunnel in the PBTB group.

In the STS group radiological evaluation showed in 36.7% a grade I, in 19.4% a grade II, in 26.5% a grade III and in additional 17.4% a grade IV TW of

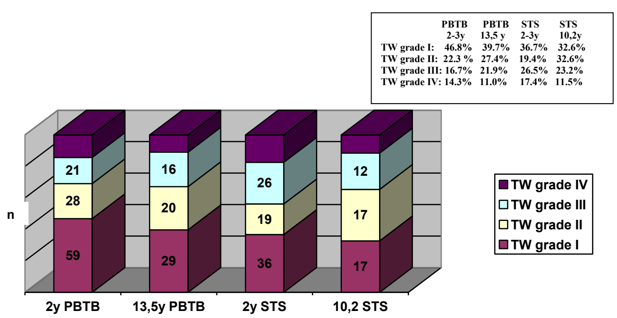

Fig. 4. — Prevalence of osteoarthritis according to the Kellgren Lawrence score in both groups.
Abbreviations : TW, tunnel widening ; PTBT, patella-bone-tendon-bone ; STS, semitendinosus tendon.

Table II. — Evaluation of tunnel shapes in both groups

	midterm follow-up				long-term follow-up			
Shape	PBTB group		STS group		PBTB group		STS group	
	Percentage	Total	Percentage	Total	Percentage	Total	Percentage	Total
Line	84.9	107	84.5	83	86.4	63	78.9	41
Cavitory	10.3	13	10.2	10	10.9	8	13.5	7
Cone	4.8	6	5.1	5	2.7	2	7.7	4

Abbreviations : PTBT, patella-bone-tendon-bone ; STS, semitendinosus tendon.

the tibial tunnel. No significant progression of TW was found in comparison to the two-year results on long-term follow-up in the PBTB group. 13.5 years after ACLR in 39.7% a grade I, in 27.4% a grade II, in 21.9% a grade III and in additional 11.0% a grade IV TW of the tibial tunnel was detected (Fig 4). In the STS group radiological evaluation showed in 32.6% a grade I, in 32.6% a grade II, in 23.2% a grade III and in additional 11.5% a grade IV TW of the tibial tunnel on long-term follow-up.

In the STS group radiological evaluation showed a slight but not significant increase of the evaluated tunnel diameters. Tunnel shape evaluation predominantly revealed equal expansion of the tibial tunnels on two-year follow-up as well on long-term follow-up in both groups. Linear expansion was predominant on radiological evaluation in both groups (Table II).

No significant correlation was found between the amount of tibial TW and clinical results according to the IKDC score (p>0.05) or the scores of Lysholm (p >0.05) or Tegner (p>0.05) on long-term follow-up in both groups. Furthermore, the study group found no significant correlations in both study subgroups between the amount of tibial TW, increased anterior joint laxity (p>0.05) measured by a KT-1000® arthrometer or progression of degenerative changes according to Kellgren-Lawrence scale (p>0.05).

DISCUSSION

The results confirmed that long-term clinical outcome and prevalence of OA are significantly correlated to restoration and conservation of stability after ACLR. This cardinal assumption was significantly shown in both subgroups and independent of the used graft type or fixation technique.

Evaluation of clinical and functional results according to the questionnaire of IKDC score on long-term follow-up showed a decrease in both subgroups in comparison to the midterm results. The results were comparable to those found by other study groups *(27,29,34)*. Various authors reported of high satisfaction rates and good to excellent clinical outcomes according to the IKDC (75-92 points on average) score based on a population of similar age and overall constitution *(27,29,35)*. In the present study about 75 % of all patients on long-term follow-up could be evaluated an IKDC A or IKDC B graduation without any significant intergroup difference with regard to the used graft types. The scores of Lysholm and Tegner also showed a deterioration of the patient's clinical constitution in comparison to the two-year results. The mean Tegner score of 5 at final follow-up in both groups is comparable to other studies with long-term follow-up *(27,29,34,35)*. The mean Lysholm score of 88 vs 90 points on long-term follow-up was similar to other studies with more than 10 years follow-up that have reported of scores between 82-94 points *(27,29,34)*. Again, correlation analysis could not draw any significant intergroup difference with regard to the used STS or PBTB graft. Assessment of long-term anterior laxity via the KT-1000® arthrometer showed a deterioration of the average values for both subgroups. Moreover, overall anterior laxity performance through the entire period of follow-up remained excellent. As shown in previous studies, more than 80% of all patients showed a differential laxity < 3mm on long-term evaluation in both groups *(29,34)*. Radiographic evaluation of degenerative changes radiological revealed radiological changes in up to 80% of patients on long-term course. The majority of these changes were graded I and II OA according to the Kellgren-Lawrence classification. The rate of severe OA (grade III and IV OA) was 25%-29% with regard to both groups, which is comparable to other published long-term studies after ACL reconstruction *(27,29,34,36)*. Evaluation of potential persisting tibial TW in the present study showed no significant impact of further bone tunnel lysis on long-term follow-up with regard to the 2 year results. Long-term analysis of the tibial TW showed in consensus with other study groups a slight predominance of TW on midterm and on long-term follow in the STS subgroup *(23,28)*. Moreover, the presented data could not draw a significant correlation for the influence of tibial tunnel widening on patient-reported long-term clinical outcome, long-term stability and prevalence of osteoarthritis with regard to the different grafts und fixation techniques. Our results confirmed that long-term clinical outcome and prevalence of OA are significantly correlated to restoration and conservation of stability after ACLR. This cardinal assumption was significantly shown in both subgroups and furthermore independently of the used graft type or fixation technique.

With regard to our results, TW is most commonly observed within the short to midterm intervals and subsequently stabilises on mid- and long-term follow-up, if initial graft incorporation was successfully. Nonetheless, with regard to literature 0.7-10% of patients need operative revision because of recurrent instability due to graft failure *(9,26)*. Therefore in consent with other study groups initial graft incorporation at the tendon to bone interface region continues to be a critical factor in anterior cruciate ligament surgery and remains of vital importance *(11,12,14,26)*. Mechanisms of ACL graft failure were classified as related to surgical technique, trauma and in particular failure of successive graft incorporation *(26)*. Variables used as criteria for graft failure include recurrent functional instability, a decline in activity level with respect to pre-injury status and increased pain *(1,8,9,27,29)*. Biological failure of graft incorporation and ligamentization directly interacts with several biomechanical factors to transform the graft into a functional ACL replacement *(37)*. Those include the strength of the tendon-bone interface, the mineralization and the degree of tendon-bone incorporation, growth factors, in particular the Bone Morphogenetic Proteins (BMPs) *(38-40)*. In accordance to literature, ACLR by use of hamstring autografts in comparison to BTB grafts have exhibited higher rates of TW *(8,25,28,30)*. Fixation via hamstring tendons is characterized as a low stiffness construct, that is, fixation point distant from the joint line. This allows more graft elongation to occur with flexion and extension of the knee, and has been referred to as bungee effect *(8,25,28,30)*. This longitudinal motion occurs particularly at the graft-tunnel interface. Subsequently, the femur has been the primary location of TW secondary to it's long tunnel length and subsequent pistoning of the graft within the tunnel *(13,30,41)*.

The bottom line is that mechanical and biological theories have been proposed for the explanation of tibial TW as a predominant radiological finding. Mechanical theories focus on graft motion within the tunnel, fixation methods/devices, stress shielding of the graft, improper graft placement, and accelerated rehabilitation *(1,5,42,43)*. With regard to our results, the autologous BPTB graft complex as used for the PBTB subgroup provides a stiff construct along with rapid biologic bone-to-bone healing. Typically, the tibial bone plug is fixed at a point distal to the joint line at a non-anatomic site, allowing increased graft motion within the proximal tibial tunnel. Moreover, this graft is of rectangular shape creating a dead space within the tibial tunnel proximal to the bone plug. This potential mismatch between the rectangular graft and the tunnel might constitute for persistent micro-motion in the sagittal plane (windshield wiper effect) (5, 8, 44). Complete graft to tunnel healing requires at least 10-12 weeks post reconstruction and was stated to be of cardinal assumption to prevent progressive TW *(7,11,12,16)*. With ongoing graft maturation remodelling from fibrous tissue to mature bone occurs. The graft-to-tunnel fixation therefore seems to have an initial critical period prior to complete adherence *(7,12,13,16)*. Regarding the PBTB graft and the STS graft as used for reconstruction in the present study, in general healing and incorporation of the bone block of the patellar tendon grafts is faster than hamstring grafts, and early stabilization is achieved, resulting in less micro-motion at the graft-tunnel interface. Apparently, the difference in biologic incorporation between the two graft types might be a reason for complete obliteration of the femoral tunnel of patellar tendon graft patients in our study as well as reported previously *(7,12,16)*. Therefore, we were not able to reliably determine the femoral tunnels on radiological evaluation because of complete tunnel obliteration. Therefore, additional measurements of the femoral tunnels in the STS group were not made because of lacking possibility of intergroup correlation analysis.

This study has certain limitations**.** The overall follow-up rate in both groups was only about 50%. Reasons for the high dropout rate of consisted mainly of the strict exclusion criteria after ACLR and intermittent operative treatment like partial meniscectomy. Additional reasons accounted for geographical limitations and the inability to attend for follow-up evaluation. Furthermore, the present study is of retrospective design and principally focuses on a descriptive analysis. In addition, the presented trans-tibial ACLR in the PBTB group definitely does not represent standard operative technique. Furthermore, the measurement of the tibial tunnel via x-ray imaging is not the gold standard like CT-based measurements. CT-based calculation of the tibial tunnel was not applicable due to the local ethic committee. Furthermore we were not able to evaluate the impact of TW of the femoral tunnel as on the femoral side the tunnel diameters were difficult to identify in particular in the PBTB group on long-term follow-up due to total incorporation and therefore reliable measurements and graft comparisons to the STS group could not made. In addition, the initial tunnel diameter was only calculated from the width of the drill to create the tunnels during reconstruction. To minimize potential miscalculation of the tunnel size based variable guide wire position, potentially leading to a larger tunnel diameter than the initial drill size, we tried to standardise intra-operative tunnel placement and drill guide positioning via intra-operative x-ray imaging.

The presented study intended to evaluate long-term impact of tibial tunnel widening on long-term outcomes in particular focussing on long-term knee joint stability and prevalence of knee osteoarthritis based on a homogenous study sample with a standardised operative procedure and postoperative rehabilitation as well as a short interval from injury to ACLR of only 2-3 weeks in both subgroups. With regard to our results, overall success of ACLR depends on initial graft fixation and subsequent biological integration, proper graft remodeling, and incorporation at the tendon-bone interface. Tibial TW therefore seems to remain a radiological phenomenon which is most commonly observed within the short to midterm intervals and subsequently stabilises on mid- and long-term follow-up if initial graft incorporation was successfully. The long-term goal remains to elucidate the exact mechanism for regenerating the ligament-to-bone interface in order to optimize operative reconstruction and postoperative rehabilitation.

CONCLUSION

ACL reconstruction using the PBTB or STS autograft resulted in high patient satisfaction levels and good clinical results on midterm and on long-term evaluation in both groups. Tibial TW within the present study occurred mainly within the first two years after reconstruction in both groups with a slight predominance in the STS subgroup on midterm and long-term follow-up. Correlation analysis gave no significant relationship between tibial TW, long-term clinical results, increased anterior joint laxity or prevalence of osteoarthritis.

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