Second-look arthroscopic findings and clinical results after polyethylene terephthalate augmented anterior cruciate ligament reconstruction

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Abstract

Purpose Based on the revival of artificial ligaments containing polyethylene terephthalate, this study aimed to evaluate objective intra-articular findings within scheduled second-look arthroscopy, patient-reported clinical outcome and stability after isolated augmented ACL reconstruction with polyethylene terephthalate (Trevira®) augmented patella-bone-tendon-bone graft.

Methods In a retrospective analysis of our institutional database, we found 126 patients with polyethylene terephthalate (Trevira®) augmented ACL reconstruction. All these patients underwent standardised second-look arthroscopic evaluation when removal of the augmentation became necessary. These second-look arthroscopic analyses focused on graft integration and remodelling in line with the polyethylene terephthalate augmentation. Arthroscopic re-examination comprised a graft evaluation including a structural and functional classification according to the Marburger Arthroscopy Score (MAS).

Additional clinical evaluation was performed via the IKDC score and the scores of Tegner and Lysholm. Instrumental anterior laxity testing was carried out with a KT-1000™ arthrometer. Furthermore, a correlation analysis between the clinical parameters, the instrumental stability assessment and the corresponding arthroscopic graft condition was performed.

Results The arthroscopic evaluation showed rupture of 87 (69 %) of 126 augmentation devices. In 27 (31 %) of these 87 cases, synovial reactions were found particularly in the anterior compartment. An intact synthetic augmentation with signs of graft integration with intact synovial coating was only found in 30 %. Evaluation according to the MAS showed good to excellent structural and functional characteristics in 88 % of patients. Presence of a type III graft (MAS) was found in an additional 11 %. A rudimentary (type IV) graft was only detected once. Eighty-five percent of patients were graded A or B according to IKDC score. The Lysholm score was 92.4 ± 4.8 . Correlation analysis demonstrated a significant relationship between clinical outcome according to the IKDC score ($p < 0.05$), instrumental stability performance according to the KT-1000™ assessment ($p < 0.05$) and the corresponding arthroscopic graft evaluation according to the MAS.

Conclusion Graft integration and remodelling has complex and multi-factorial origins, particularly with artificial augmentation. Correlation analysis showed a significant relation between clinical condition, instrumental stability performance and arthroscopic graft constitution. The release of polyethylene terephthalate fibres caused inflammation of synovial tissue of the knee. Characteristic sub-clinical graft changes of structural, morphological and functional qualities of the inserted graft appear on second-look arthroscopy despite good clinical results.

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Introduction

Injuries of the anterior cruciate ligament (ACL) are common in both in professional and amateur sports [1]. In the current literature, there is a revival in the use of synthetic materials despite the discouraging results and loss of confidence by the scientific community, and a recent resurgence of interest in the use of artificial ligaments. Lavoie et al. [2] reported their results after the implantation of LARS ligaments (Ligament Advanced Reinforcement System, Surgical Implants and Devices, Arc-sur-Tille, France). These ligaments are made of polyethylene terephthalate and their structure is designed to allow tissue ingrowth in the intra-articular part as a modification and advancement of the well known polyethylene terephthalate augmentation by the Trevira® ligament [3]. Based on this trend of artificial ligaments containing polyethylene terephthalate, our study aimed to evaluate objective intra-articular findings within scheduled second-look arthroscopy, patient-reported clinical outcome and stability after isolated augmented ACL reconstruction with Trevira® augmented patella-bone-tendon-bone (PBTB) graft. The basic concept of any supplemental graft augmentation within ACL reconstruction represents the idea of additional graft protection within the vulnerable phase of graft integration and remodelling. Synthetic grafts made of different materials such as carbon fibre, polypropylene, Dacron and polyester have been employed either as a single ACL prosthesis or as an augmentation for a biological ACL graft substitute. One of the most commonly used artificial augmentation devices since the 1980s is the polyethylene terephthalate (PET) ligament (Trevira® Hochfest, Hoechst, Frankfurt, Germany) [7]. The Trevira® ligament provides good mechanical properties (ultimate tensile strength of 1,866 N, stiffness 68.3 N/mm [9]) and reduced water adsorption. On the other hand, every material used has serious drawbacks, such as adverse immunological responses, debris dispersion, failed intra-articular integration of the inserted augmentation or even breakage of the augmentation device, leading to synovitis, chronic effusions and recurrent knee instability [8, 11, 12]. Therefore, ACL reconstruction in the 1990s was characterised by a loss of trust by orthopaedic surgeons in artificial ligaments [8, 12–15]. As follow-up arthroscopic evaluations are only indicated for clinical diagnosis and serial second-look arthroscopic studies are not ethically defensible, there is an obvious lack of information based on arthroscopic surveys and re-examinations of patients with good clinical outcome. In the literature there are only a couple of surveys focusing on arthroscopic morphological graft condition and the correlative clinical status particularly in line with polyethylene

terephthalate augmentation [16–18]. In our study second-look arthroscopic evaluation was carried out when removal of the synthetic polyethylene terephthalate augmentation, used as supplemental PBTB graft protection, became necessary. The primary objective of the study was to evaluate patient-reported clinical outcome, knee joint stability and the associated objective intra-articular findings.

Methods

In total, 407 polyethylene terephthalate (Trevira®) augmented primary ACL reconstructions were performed between the years 1997 and 2005 at our institution. After establishment of ACL reconstruction via autologous hamstring grafts, the procedure described here was abandoned as the primary operative method for ACL reconstruction in our department. Therefore, in a retrospective analysis of our institutional database we found 126 (76 male, 50 female) patients with Trevira® augmented ACL reconstruction and standard second-look arthroscopic evaluation. The overall follow-up rate of patients with second-look arthroscopy was 31 %. The reason for the high drop out rate was partly due to the strict inclusion criteria on primary ACL reconstruction. Additional reasons included geographical limitations with an inability to attend follow-up examinations, operative removal of the augmentations in other institutions or patient rejection of hardware removal. The average age was 32 years (range 19–60). In 65 cases the right knee joint was affected, in 61 cases the left knee. Follow-up examination, including clinical evaluation according to IKDC scale and the scores of Tegner and Lysholm, took place on average at 29 months (range 24–36) after ACL reconstruction. Second-look arthroscopy was performed in all patients according to our institutional guideline on average at 12 months (range 11–14) after initial ACL reconstruction. All these patients underwent standardised second-look arthroscopic evaluation within the course of the removal of the augmentation. Second-look arthroscopic evaluation was performed as a standard supplementary procedure in order to guarantee complete removal of the augmentation devices. Further inclusion criteria consisted of an (1) isolated arthroscopic ACL reconstruction (no concurrent meniscus or cartilage surgery); (2) no previous knee ligament surgery; (3) a normal contralateral knee. Exclusion criteria were additional ligamentous injuries, significant articular surface damage or meniscus lesions, or obvious osteoarthritic lesions or concomitant medial collateral ligament repair at the time of reconstruction. All patients gave their informed consent for re-arthroscopic evaluation.

Operative technique and rehabilitation

Operative technique was standardised in all patients: ACL reconstruction was performed using an autogenous, polyethylene terephthalate (Trevira®) augmented PBTB graft from the middle third of the patellar tendon. The central third of the patella (10 mm in width) was harvested through a single longitudinal incision. The graft was removed with a rectangular bone plug (20–25 mm in length). Afterwards an arthroscopic-assisted reconstruction was performed. The ruptured ACL was debrided and the anatomical tibial and femoral footprints were identified and left intact. The tibial tunnel was drilled using a drillguide under arthroscopic view through the posterior part of the middle of the tibial ACL footprint. 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 120° of flexion using the 5-mm offset instrument. Bone blocks were positioned in the tunnel and the autograft was placed with its cortical edge oriented posteriorly within the femoral tunnel. Femoral graft fixation was performed by press-fit positioning in the tunnels and by additional joint-distant mini-plate-fixation via a lateral incision. Augmentation consisted of a synthetic 3-mm strong polyethylene terephthalate (Trevira®), which was centrally sewed in, under preliminary tension as a coaxial stabiliser. Exact intra-articular graft placement of the tibial tunnel was performed with the knee in 90° 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 several times to assess graft fixation and isometry, and finally tibial fixation, staples were used to fix the threads outside the tunnel. Postoperative rehabilitation allowed a free range of motion (ROM) and full weight bearing according to the patient's pain level. During the entire rehabilitation period of six weeks we provided no additional external protection.

Assessments

Clinical follow-up evaluation was performed according to the IKDC standard evaluation form [19] and the scores of Tegner and Lysholm [20, 21]. Clinical evaluation was performed 29 months on average after ACL reconstruction. Furthermore, pre-trauma status was documented. Assessment of anterior laxity was carried out with the KT-1000™ arthrometer (Medmetric, San Diego, CA, USA) according to a modified IKDC scale under establishment of four groups concerning the degree of differential instrumental laxity in side comparison. Group I was defined as a side difference of 0–1 mm, a side difference of 2–3 mm was

defined as group II, a differential laxity of 3–4 mm constituted for group III and a side difference of more than 5 mm was defined as group IV [22]. Arthroscopic re-examination comprised a graft classification according to structural and functional criteria of the Marburger Arthroscopy Score (MAS [23]) for graft evaluation. The MAS focuses on graft morphology and synovial coverage of the inserted graft. Type I grafts are characterised by a tight cruciate ligament-like structured graft with complete synovial coating. Type II grafts are characterised by an incomplete, or absent, synovial covering but an intact graft with cruciate ligament like structured bundles. Furthermore the ligamentous structure was arranged only in a bundle like structure. Type III grafts are defined on the one hand by a lack of any synovial coverage and on the other by irregularly structured fibres and bundles with partially formed strong scarifications and synovial surface reactions on the graft. Type IV grafts are characterised only by a rudimentary graft without any evidence of biomechanical stability and function (Fig. 1).

Statistical analyses

Statistical analysis was performed by using the software SPSS 17.0. version for windows. Correlations were regarded as significant at $p < 0.05$ concerning the Pearson-Chi square test and the Kruskal-Wallis test.

Fig. 1 Arthroscopic graft classification according to the MAS: the four stage ranking system distinguishes: Type I: tight cruciate ligament like structured graft with complete synovial coating. Type II: tight, bundle-like structured graft with incomplete or lacking synovial coating. Type III: lax, messily structured graft without synovial coating. Type IV: rudimentary graft

Fig. 2 Correlation of graft evaluation (MAS) vs. clinical condition according to the IKDC score

Results

Arthroscopic findings

Arthroscopic evaluation according to the Marburger Arthroscopy Score showed in 54.8 % a type I, in 33.3 % a type II, in 11.1 % a type III and in an additional 0.8 % a type IV graft (Table 1). The arthroscopic re-evaluation proved the rupture of 87 (69 %) of 126 augmentation devices. In 27 (31 %) of these 87 cases synovial reactions were found in particular in the anterior knee compartment. An intact synthetic augmentation with signs of graft integration with intact synovial coating was only found in 30 %. Additionally, we could find a physiological synovial coating of the polyethylene terephthalate augmentation in another part of the re-evaluated knee joints without any clinical significance. An evident biological defense reaction was missing (Fig. 2). On arthroscopical evaluation, type II (Fig. 3) grafts were characterised by an incomplete, or absent, synovial coating. Furthermore, the ligamentous structure was arranged only in a bundle-like structure. On the other hand, those grafts classified as a type I graft (Fig. 2) showed a complete synovial coating and were homogeneously structured. Type III grafts (Fig. 4) were characterised on the one hand by a lack of any synovial coating and on the other by irregularly structured fibres and bundles with partially formed strong scarifications and synovial surface reactions

Fig. 3 Correlation of graft evaluation (MAS) vs. instrumental stability performance according to a modified IKDC scale (KT-1000™ assessment)

on the graft. The assigned type IV graft (Fig. 5) demonstrated only a rudimentary graft without any evidence of biomechanical stability and function on re-arthroscopic examination.

A detailed specification via histological analysis of the synovial surface reactions, particularly in type III and IV grafts, was not performed. On the other hand, clinical evaluation according to the IKDC scale and the scores of Tegner and Lysholm showed a functional decline in those patients with marked synovial reactions in the form of unspecific knee pain and episodes of swelling and additional intermittent intra-articular effusions.

Clinical evaluation

Clinical evaluation according to the IKDC score showed good to excellent results on follow-up examination (Table 1). The functional assessment revealed 85 % of all patients with an IKDC A grade or IKDC B grade evaluation. An additional 17 patients (13.5 %) were graded with a grade C scoring and only one patient (0.8 %) was graded D according to the IKDC criteria. Criteria for a deterioration of the clinical results on follow-up consisted, e.g., of pain and progressive swelling of the knee joint under heavy load or symptoms of graft withdrawal within the subjective IKDC questionnaire. Furthermore, an evident extensive 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 according to the Lysholm score and the Tegner score showed a satisfactory to excellent

Table 1 A. evaluation of clinical results according to the IKDC score. B. evaluation of anterior laxity via the KT-1000™ arthrometer according to the IKDC score. C. graft evaluation according to the MAS

2 year follow-up		
A. Evaluation clin. results according to the IKDC score	IKDC A	38.1 % (N=48)
	IKDC B	47.6 % (N=60)
	IKDC C	13.5 % (N=17)
	IKDC D	0.8 % (N=1)
B. Evaluation ant. laxity according to the IKDC score	IKDC A (0–1 mm)	52.4 % (N=66)
	IKDC B (2–3 mm)	35.7 % (N=45)
	IKDC C (3–4 mm)	11.1 % (N=14)
	IKDC D (>5 mm)	0.8 % (N=1)
C. Graft evaluation according to the MAS	Type I graft	54.8 % (N=69)
	Type II graft	33.3 % (N=42)
	Type III graft	11.1 % (N=14)
	Type IV graft	0.8 % (N=1)

clinical performance. Most of the patients demonstrated an activity level comparable to the pre-trauma level (Table 2). Practice of “pivot” and “contact” sports were reported in 87.8 % of patients. Furthermore, competitive involvement was evident in 65 % of patients. Assessment of the anterior translation with the KT-1000™ arthrometer according to a modified IKDC scale showed a satisfactory to excellent overall performance two years after anterior cruciate ligament reconstruction (Table 1).

Correlation analysis

A. Graft evaluation (MAS) vs. clinical condition according to the IKDC score

The correlation analysis showed a significant correlation. ($p<0.001$; $r=0.318$). An excellent clinical condition according to the IKDC (IKDC A / IKDC B rating) score was associated with assessment of a type I graft in over 90 %. Evidence of an IKDC D evaluation never occurred in patients with a type I graft. Assessment of a type III or type IV graft according to the MAS indicated a significant increase in IKDC C and IKDC D evaluations (Fig. 6).

B. Graft evaluation (MAS) vs. Instrumental stability performance (KT-1000™ assessment)

The statistical analysis, showed a significant correlation of the KT-1000™ assessment and the arthroscopic evaluation of the grafts according to the MAS ($p<0.001$; $r=0.414$). A differential laxity of over 3 mm along with assessment of a type I graft A rating was found in over 95 % (Fig. 7). The performed correlative data analysis demonstrated differences concerning type I and type II grafts (Type I on average 0.97 mm; Type II on average 2.0 mm); although arthroscopic re-examination could point out distinct divergences of graft morphology.

No significant correlation was found between an increased anterior joint laxity measured by the KT-1000™ arthrometer and the presence of ruptured intra-articular polyethylene terephthalate augmentations on second-look arthroscopic evaluation.

Table 2 Knee function and activity level according to the Lysholm scoring scale and the Tegner activity scale, respectively throughout the entire study period. The results are given as mean values and range

	Before injury	2 years
Knee function: Lysholm scoring scale	95.7 (65–100)	92.4 (35–100)
Activity level: Tegner activity score	5.8 (3–10)	5.8(2–10)

Discussion

Based on the revival of artificial ligaments containing polyethylene terephthalate (LARS®), our study aimed to evaluate objective intra-articular findings during scheduled second look arthroscopy, patient-reported clinical outcome and stability after isolated polyethylene terephthalate (Trevira®) augmented ACL reconstruction with patella-bone-tendon-bone graft [3]. The basic idea of the evaluation was that the advanced design of the polyethylene terephthalate containing the LARS® ligament might be comparable to the well known polyethylene terephthalate based Trevira® augmentation.

The LARS® is a non-absorbable synthetic ligament device made of terephthalic polyethylene polyester fibres [3]. In the literature there are only two surveys focusing on arthroscopic morphological graft condition and the correlative clinical status in polyethylene terephthalate augmentation; therefore, this retrospective evaluation gives an insight into intra-articular findings after polyethylene terephthalate augmentation on a non-selected patient sample.

The most important finding was that, despite satisfactory to excellent clinical outcome, distinct sub-clinical structural, morphological and functional qualities of the inserted graft appear on second-look arthroscopy. Arthroscopic re-evaluation during the removal of the synthetic augmentation demonstrated a significant correlation between clinical condition, instrumental stability performance and arthroscopic graft constitution. Supplementary graft augmentation over the last few decades of ACL reconstruction represented the idea of additional graft protection during the vulnerable phase of graft integration and remodelling becoming an attractive alternative to biological grafts [7, 10, 11, 13, 14, 24]. The initial enthusiasm in the 1980s for the use of artificial ligaments was based on lack of donor morbidity, abundant supply, and significant strength and immediate loading leading to a potentially shortened postoperative rehabilitation [7–10]. Different procedures and various materials were established for ACL reconstruction [24]. Synthetic grafts made of different materials such as carbon fibres, polypropylene, Dacron and polyester have been employed either as a single ACL prosthesis or as an augmentation for a biological ACL graft substitute [7, 13, 14, 24–26]. One of the most commonly used artificial augmentation devices since the 1980s is the polyethylene terephthalate (PET) ligament (Trevira®) [7]. Krudwig et al. [9] demonstrated good results in terms of patient satisfaction and AP stability at eight years after the implantation of 160 artificial Trevira-Hochfest devices using an over the top technique. Radiographic signs of osteoarthritis were found only in patients with previous history of meniscal surgery.

In general the high expectations of a supplementary synthetic stabilisation of the ACL graft have not been delivered. Use of a synthetic augmentation was associated with undesirable serious foreign body reactions due to stress-shielding leading to loss of trust by orthopaedic surgeons in implantation of artificial ligaments [8, 9]. The reported complications during the first decade of use of synthetic materials (breakage, foreign-body reaction, debris, synovitis, recurrent instability, etc.) forced the abandonment of synthetic grafts [8, 14, 15, 24, 27–30]. Even though studies by Seitz et al. [12] on sheep could demonstrate that, in particular, the PET augmentation device may count as the best acceptable and most solid augmentation, and still has its value in endoprosthetic tumour joint surgery and posterior cruciate ligament reconstruction, the same investigations indicated a high incidence of adverse foreign body reactions and concomitant synovitis mainly in cases of structural discontinuity of the synthetic augmentation [7, 8, 27, 29, 30]. Studies focusing on arthroscopic morphological graft condition and biomechanical graft function, particularly the clinical status have been published only occasionally [16, 31–34]. Despite the past results there is a revival of interest in the ligament as a non-absorbable synthetic ligament made of terephthalic polyethylene polyester fibres. In the current literature, some studies indicate that, under particular conditions, artificial ACL reconstruction can be successful [3, 35]. Lavoie et al. [2] reported their results after a follow-up of 8–45 months on 47 patients with good clinical results. They showed an average KOOS score of 93 and a satisfying level of activity according to the Tegner score.

But, based on the literature, there are only two surveys focusing on arthroscopic morphological graft condition and the correlative clinical status, specifically in line with polyethylene terephthalate augmentation.

Ahn et al. [36] re-evaluated 208 patients after ACL reconstruction during the scheduled removal of the augmentation, focusing on graft evaluation with regard to surface condition, graft continuity, physical strain, synovial coverage, prevalence of a potential cyclops formation and influence of a potential tibial notch impingement. They reported unrecognised partial ruptures of the inserted graft in 10 % of cases and intra-articular pathological laxity of the grafts in 13 % of patients despite good clinical results on clinical re-examination. Sub-clinical cyclops formation was detected in 21 % of cases. Kinugasa et al. [31] carried out a re-arthroscopic evaluation focusing on influence of the patient's age onto morphology of the inserted ACL graft and demonstrated a significant decline of the synovial coverage of the graft with increasing age. Toritsuka et al. [18] reported pathological elongation of the grafts in at least 11 % of all patients on arthroscopic evaluation and a further 34 % of partially ruptured grafts despite good clinical results.

Lee et al. [33] reported of comparative analysis of clinical results and corresponding second-look arthroscopic findings after ACL reconstruction using three different types of grafts. They found no significant difference with regard to objective knee testing measures among the three different grafts except that the allograft group showed a greater postoperative ROM than the autograft group. However, the hamstring autograft group showed better synovial coverage on second-look arthroscopy and, furthermore, a better synovial coverage associated with better clinical results. On the other hand, an exact and standardised arthroscopic graft classification focusing on clinical status and the corresponding structural, morphological and functional graft condition is not provided in any of the studies. Only Yasuda et al. [37] and Ahn et al. [36] used a score-like evaluation depending on the quality of the synovial coating of the graft. However, a comprehensive division of graft alterations focusing particularly on graft function was not carried out. Arthroscopic graft evaluation in our study was done via the Marburger Arthroscopy Score for Graft Evaluation, which is well established at our institution [23]. The score provides a simple and standardised evaluation of graft morphology and function under the establishment of four different types of grafts. Correlation analysis demonstrated a significant relationship between clinical outcome according to the IKDC score, instrumental stability performance and arthroscopic graft evaluation according to the MAS. Type I and type II grafts constitute distinct structural differences with regard to graft morphology, but otherwise there is no evident functional deficit of the inserted graft. On arthroscopic evaluation, type II grafts were characterised by an incomplete, or absent, synovial coverage. Furthermore, the ligamentous structure was arranged only in a bundle like structure. On the other hand, those grafts classified as a type I graft showed a complete synovial coating and were homogeneously structured. Furthermore, a decline of instrumental stability performance via the KT-1000™ arthrometer showed distinct alterations of the graft morphology and its functional impact. Arthroscopic evaluation demonstrated an increase in the presence of type III and type IV grafts. Type III grafts were characterised on the one hand by a lack of any synovial coverage and on the other hand by irregularly structured fibres and bundles with partially formed strong scarifications and synovialytic surface reactions of the inserted graft. In the case of the type IV graft, only a rudimentary graft without evidence of biomechanical stability and function was found on arthroscopic re-examination. Evaluation of the clinical and functional results according to the subjective and objective questionnaire of IKDC score on follow-up were comparable to those found in literature [5,

38, 39]. Various authors reported high satisfaction rates and good to excellent clinical outcomes according to the IKDC (84–94 points on average) score based on a population of similar age and overall constitution [4, 5]. The mean subjective IKDC score was 83.4 points on follow-up. However, 85 % of all patients were evaluated as IKDC A or IKDC B. Criteria for a deterioration of the clinical results on follow-up consisted, e.g., of pain and progressive swelling of the knee joint under heavy load or symptoms of graft withdrawal within the subjective IKDC questionnaire. Furthermore, an extension deficit, intermittent intra-articular effusion formation or a noticeable differential laxity on assessment with the KT-1000™ arthrometer accounted for worse results within the objective IKDC evaluation. The median Tegner score of 6 is similar in comparison to studies with two year follow-up which have reported Tegner scores between 5 and 7. The mean Lysholm score of more than 92 points was similar to other studies that have reported scores between 87 and 94 points [4, 5, 38]. Overall performance concerning the anterior translation measured on KT-1000™ arthrometer showing satisfactory to excellent results is comparable with results provided in the literature, with 80 % to 90 % of patients having a KT-1000™ arthrometer result of less than three millimetres [5, 6, 22, 39]. The authors hold the view that the deterioration of the clinical results was influenced by adverse foreign body reactions of released polyethylene terephthalate fibres, at least to a certain extent. The MAS does not associate synovitis with the PET fibres. In contrast those foreign body reactions might influence the results of the IKDC.

On arthroscopic re-evaluation, 69 % the augmentation devices were ruptured and a protective synovial coating in the sense of a positive biological response was found only on occasion. Otherwise we could not detect a significant correlation to the performance on instrumental stability examination. Therefore, the authors draw the conclusion that initial stress-shielding of the graft can not be neutralised by synthetic augmentation devices. In contrast, it was remarkable that, particularly in the case of a rupture of the augmentation devices, (30 %) a concomitant synovitis could be found.

On the other hand, our study has some limitations. An additional histopathological examination augmenting the standard graft classification would be desirable. Furthermore, the second-look arthroscopic results after Trevira® augmentation represent clinical and arthroscopic results based on an historical operative procedure. Otherwise the study was based on an homogenous study sample, a standardised operative procedure and standardised second-look arthroscopic evaluation, and, therefore, might give information on potential intra-articular

problems after polyethylene terephthalate based augmentation. The standardised second-look arthroscopic findings based on the patient sample with good clinical outcome might provide additional data and potential adverse effects against the background of the revival of polyethylene terephthalate based augmentation and, in particular, as second-look arthroscopic results for these patients are not available.

Finally, the basic idea of our standardised second-look arthroscopy was to assure removal of synthetic material to avoid potential foreign body adverse reactions. In the patient sample presented second-look arthroscopic intervention could guarantee complete removal in almost all cases without compromise for the enclosed graft. Furthermore, we could detect distinct, but, in most of the patients, sub-clinical intra-articular graft differences with regard to the MAS. In nearly 70 %, the augmentation was ruptured and in a definite proportion an additional synovitis was found. On the other hand, we hold the view that a standardised second-look arthroscopy on all patients remains unethical, bearing in mind that most of the detected intra-articular findings remained sub-clinical. But, if the clinical scores deteriorate, physicians must be aware of distinct intra-articular pathology, particularly in cases of synthetic augmentation. In those cases a second-look arthroscopic evaluation and potential therapeutic intervention is mandatory. However, a generalised necessity for second-look arthroscopy as a secondary standard procedure does not exist in our opinion.

Conclusions

Second-look arthroscopic results after Trevira® augmentation showed a significant relation between clinical condition, instrumental stability performance and arthroscopic graft constitution based on a non-selected patient sample with satisfactory to excellent clinical outcome. The release of polyethylene terephthalate fibres caused inflammation of synovial tissue of the knee. Characteristic sub-clinical graft alterations to structural, morphological and functional qualities of the graft appear on second look arthroscopy despite good clinical results. The second look arthroscopic findings presented might provide additional data and potential adverse effects against the background of the revival of polyethylene terephthalate based augmentation. However a generalised necessity for second-look arthroscopy as secondary standard procedure does not exist. Graft integration and remodelling remains of complex and multi-factorial origin, particularly with artificial augmentation.

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References

- van Eck CF, Schreiber VM, Mejia HA, Samuelsson K, van Dijk CN, Karlsson J, Fu FH (2010) "Anatomic" anterior cruciate ligament reconstruction: a systematic review of surgical techniques and reporting of surgical data. *Arthroscopy* 26(9 Suppl):2–12
- Lavoie P, Fletcher J, Duval N (2000) Patient satisfaction needs as related to knee stability and objective findings after ACL reconstruction using the LARS artificial ligament. *Knee* 7(3):157–163
- Machotka Z, Scarborough I, Duncan W, Kumar S, Perraton L (2010) Anterior cruciate ligament repair with LARS (ligament advanced reinforcement system): a systematic review. *Sports Med Arthrosc Rehabil Ther Technol* 2:29
- Laxdal G, Kartus J, Ejerhed L, Sernert N, Magnusson L, Faxen E, Karlsson J (2005) Outcome and risk factors after anterior cruciate ligament reconstruction: a follow-up study of 948 patients. *Arthroscopy* 21(8):958–964
- Oiestad BE, Engebretsen L, Storheim K, Risberg MA (2009) Knee osteoarthritis after anterior cruciate ligament injury: a systematic review. *Am J Sports Med* 37(7):1434–1443
- Wipfler B, Donner S, Zechmann CM, Springer J, Siebold R, Paessler HH (2011) Anterior cruciate ligament reconstruction using patellar tendon versus hamstring tendon: a prospective comparative study with 9-year follow-up. *Arthroscopy* 27(5):653–665
- Boszotta H, Helperstorfer W (1994) Long-term results of arthroscopic implantation of a Trevira prosthesis for replacement of the anterior cruciate ligament. *Aktuelle Traumatol* 24(3):91–94
- Boszotta H, Helperstorfer W, Pflanzl W (1993) Foreign body synovitis—a limiting factor in use of the Trevira ligament in cruciate ligament surgery? *Unfallchirurgie* 19(3):138–143
- Krudwig WK (2002) Anterior cruciate ligament reconstruction using an alloplastic ligament of polyethylene terephthalate (PET – Trevira – hochfest). Follow-up study. *Biomed Mater Eng* 12(1):59–67
- Letsch R, Sturmer KM, Kock HJ, Schmit-Neuerburg KP (1993) Suture protection of acute ruptured anterior cruciate ligament by the Pet-band (Trevira extra strong). Indications, technique results of a five-year study. *Unfallchirurg* 96(10):499–507
- Fithian DC, Paxton LW, Goltz DH (2002) Fate of the anterior cruciate ligament-injured knee. *Orthop Clin N Am* 33(4):621–636
- Seitz H, Marlovits S, Schwendenwein I, Muller E, Vecsei V (1998) Biocompatibility of polyethylene terephthalate (Trevira hochfest) augmentation device in repair of the anterior cruciate ligament. *Biomaterials* 19(1–3):189–196
- Barrett GR, Field LD (1993) Comparison of patella tendon versus patella tendon/Kennedy ligament augmentation device for anterior cruciate ligament reconstruction: study of results, morbidity, and complications. *Arthroscopy* 9(6):624–632
- Barrett GR, Line LL Jr, Shelton WR, Manning JO, Phelps R (1993) The Dacron ligament prosthesis in anterior cruciate ligament reconstruction. A four-year review. *Am J Sports Med* 21(3):367–373
- Klein W, Jensen KU (1992) Synovitis and artificial ligaments. *Arthroscopy* 8(1):116–124
- Ahn JH, Choi SH, Wang JH, Yoo JC, Yim HS, Chang MJ (2011) Outcomes and second-look arthroscopic evaluation after double-bundle anterior cruciate ligament reconstruction with use of a single tibial tunnel. *J Bone Joint Surg Am* 93(20):1865–1872
- Otsubo H, Shino K, Nakamura N, Nakata K, Nakagawa S, Koyanagi M (2007) Arthroscopic evaluation of ACL grafts reconstructed with the anatomical two-bundle technique using hamstring tendon autograft. *Knee Surg Sports Traumatol Arthrosc* 15(6):720–728
- Toritsuka Y, Shino K, Horibe S, Mitsuoka T, Hamada M, Nakata K, Nakamura N, Yoshikawa H (2004) Second-look arthroscopy of anterior cruciate ligament grafts with multistranded hamstring tendons. *Arthroscopy* 20(3):287–293
- Anderson AF, Irrgang JJ, Kocher MS, Mann BJ, Harrast JJ (2006) The international knee documentation committee subjective knee evaluation form: normative data. *Am J Sports Med* 34(1):128–135
- Lysholm J, Gillquist J (1982) Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. *Am J Sports Med* 10(3):150–154
- Tegner Y, Lysholm J (1985) Rating systems in the evaluation of knee ligament injuries. *Clin Orthop Relat Res* 198(198):43–49
- Tyler TF, McHugh MP, Gleim GW, Nicholas SJ (1999) Association of KT-1000 measurements with clinical tests of knee stability 1 year following anterior cruciate ligament reconstruction. *J Orthop Sports Phys Ther* 29(9):540–545
- Ishaque BA, Ziring E, Gotzen L, Petermann J (2000) Arthroscopic classification of the ACL substitute. Results of a prospective study. *Arthroscopie* 13:159–165
- Legnani C, Ventura A, Terzaghi C, Borgo E, Albisetti W (2010) Anterior cruciate ligament reconstruction with synthetic grafts. A review of literature. *Int Orthop* 34(4):465–471
- Denti M, Bigoni M, Dodaro G, Monteleone M, Arosio A (1995) Long-term results of the Leeds-Keio anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 3(2):75–77
- Engstrom B, Wredmark T, Westblad P (1993) Patellar tendon or Leeds-Keio graft in the surgical treatment of anterior cruciate ligament ruptures. Intermediate results. *Clin Orthop Relat Res* 295:190–197
- Amis AA, Kempson SA (1999) Failure mechanisms of polyester fiber anterior cruciate ligament implants: a human retrieval and laboratory study. *J Biomed Mater Res* 48(4):534–539
- Ishibashi Y, Toh S, Okamura Y, Sasaki T, Kusumi T (2001) Graft incorporation within the tibial bone tunnel after anterior cruciate ligament reconstruction with bone-patellar tendon-bone autograft. *Am J Sports Med* 29(4):473–479
- Olson EJ, Kang JD, Fu FH, Georgescu HI, Mason GC, Evans CH (1988) The biochemical and histological effects of artificial ligament wear particles: in vitro and in vivo studies. *Am J Sports Med* 16(6):558–570
- Ventura A, Terzaghi C, Legnani C, Borgo E, Albisetti W (2010) Synthetic grafts for anterior cruciate ligament rupture: 19-year outcome study. *Knee* 17(2):108–113
- Kinugasa K, Mae T, Matsumoto N, Nakagawa S, Yoneda M, Shino K (2011) Effect of patient age on morphology of anterior cruciate ligament grafts at second-look arthroscopy. *Arthroscopy* 27(1):38–45
- Kondo E, Yasuda K (2007) Second-look arthroscopic evaluations of anatomic double-bundle anterior cruciate ligament reconstruction: relation with postoperative knee stability. *Arthroscopy* 23(11):1198–1209
- Lee JH, Bae DK, Song SJ, Cho SM, Yoon KH (2010) Comparison of clinical results and second-look arthroscopy findings after arthroscopic anterior cruciate ligament reconstruction using 3 different types of grafts. *Arthroscopy* 26(1):41–49
- Watanabe BM, Howell SM (1995) Arthroscopic findings associated with roof impingement of an anterior cruciate ligament graft. *Am J Sports Med* 23(5):616–625
- Nau T, Lavoie P, Duval N (2002) A new generation of artificial ligaments in reconstruction of the anterior cruciate ligament. Two-

- year follow-up of a randomised trial. *J Bone Joint Surg Br* 84 (3):356–360
36. Ahn JH, Yoo JC, Yang HS, Kim JH, Wang JH (2007) Second-look arthroscopic findings of 208 patients after ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc* 15(3):242–248
37. Yasuda K, Tomiyama Y, Ohkoshi Y, Kaneda K (1989) Arthroscopic observations of autogeneic quadriceps and patellar tendon grafts after anterior cruciate ligament reconstruction of the knee. *Clin Orthop Relat Res* 246(246):217–224
38. Andersson D, Samuelsson K, Karlsson J (2009) Treatment of anterior cruciate ligament injuries with special reference to surgical technique and rehabilitation: an assessment of randomized controlled trials. *Arthroscopy* 25(6):653–685
39. Stengel D, Klufmoller F, Rademacher G, Mutze S, Bauwens K, Butenschon K, Seifert J, Wich M, Ekkernkamp A (2009) Functional outcomes and health-related quality of life after robot-assisted anterior cruciate ligament reconstruction with patellar tendon grafts. *Knee Surg Sports Traumatol Arthrosc* 17(5):446–455