A comparison of the transtibial single-tunnel vs. the anatomical double-tunnel technique for the reconstruction of the anterior cruciate ligament

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ABSTRACT

Objective: To compare two series of patients who underwent anterior cruciate ligament reconstruction using hamstring tendon autografts, identical bone fixations, and one of the two standard surgical approaches: transtibial single-tunnel and anatomical double-tunnel technique. To draw conclusions regarding functional outcomes. **Materials and Methods:** This was a retrospective study consisting in two series of 30 patients, followed up for more than a year, who had undergone an anterior cruciate ligament reconstruction with hamstring tendon graft placement using the transtibial single-tunnel or the anatomical double-tunnel technique. The latter employed retrograde tunneling, as well as an adjustable cortical fixation for the femur and a retrograde screw fixation for the tibia. Patients were assessed using the International Knee Documentation Committee (IKDC) Questionnaire, the Lachman Test, the Lateral Pivot-Shift Test and the Single Leg Hop Test with the aim of determining if they were ready to return to their previous daily and sports activities. Radiological examination of the bone tunnels was also performed to assess progress. **Results:** The anatomical double-tunnel technique yields significantly ($P<0.05$) better results on the IKDC Questionnaire, the Lateral Pivot-Shift Test and the Hop Test and allows patients to resume sports activities in a shorter time. The Lachman Test showed similar results with both techniques. There were no cases of tunnel osteolysis in either of the two series. **Conclusions:** The anatomical double-tunnel ligament reconstruction technique was better rated by patients and more efficient than the transtibial single-tunnel technique, especially in patients who engage in demanding sports activities. In patients who do not practice high-impact activities, results were equally satisfactory. The tibial retrograde screw fixation did not result in significant tunnel osteolysis.

Keywords: Anterior cruciate ligament; ligament reconstruction; double-tunnel technique; anatomical; retrograde screw; comparative study.

Level of Evidence: III

Ligamentoplastia del ligamento cruzado anterior monotúnel transtibial y bitúnel anatómica: estudio comparativo

RESUMEN

Objetivo: Comparar dos series de pacientes sometidos a ligamentoplastia con tendones isquiotibiales autólogos mediante las dos técnicas quirúrgicas preferentes: monotúnel transtibial y bitúnel anatómica, utilizando idénticas fijaciones óseas, y establecer conclusiones funcionales. **Materiales y Métodos:** Estudio retrospectivo de dos series de 30 pacientes, con un seguimiento superior a un año, sometidos a ligamentoplastia del ligamento cruzado anterior con tendones isquiotibiales mediante técnicas monotúnel transtibial y bitúnel con tunelización retrógrada, utilizando fijación elástica cortical en fémur y fijación tibial mediante tornillo retrógrado. Se los evaluó con la escala del IKDC, y las pruebas de Lachman, de resalte (*pivot-shift)* y del salto monopodal, valorando la reincorporación a la actividad previa habitual y deportiva, y examen radiológico de la evolución de los túneles óseos. **Resultados:** La técnica bitúnel anatómica logra resultados significativamente mejores ($p <0,05$) en la evaluación subjetiva de la escala del IKDC, en las pruebas de resalte, del salto y en la recuperación de la actividad deportiva previa a la lesión, sin diferencias en la prueba de Lachman. No hubo casos de osteólisis en los túneles óseos, en ninguna de las dos series. **Conclusiones:** La técnica de ligamentoplastia bitúnel anatómica es mejor valorada y más eficaz que la técnica monotúnel transtibial, fundamentalmente en pacientes con actividad deportiva exigente, ya que en aquellos sin actividades de impacto, los resultados son satisfactorios de igual forma. Con el atornillado retrógrado tibial no hubo osteólisis significativa en el túnel tibial.

Palabras clave: Ligamento cruzado anterior; ligamentoplastia; técnica bitúnel; anatómica; tornillo retrógrado; comparativo.

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INTRODUCTION

Developments concerning ligament reconstruction techniques are quite a challenge, since the surgery itself and the current tunneling and fixation systems pose technical and economic hurdles, the available graft material is limited, and there is no conclusive evidence that any improvement in the outcome (which is a difficult variable to measure) may be achieved by means of these developments. For these reasons, the transtibial single-tunnel approach using a bone-tendon-bone (BTB) autograft or a tendon graft with an interference, a cortical or a transversal screw is still considered the gold standard.[1] Some published series comprising many patients have success rates of 70-90%.

Undoubtedly, the type of patient, the patient's level of physical demand, and the tests results may have a significant impact on the outcome of an anterior cruciate ligament (ACL) surgery and may represent a problem when comparing published studies. This problem worsens if taken into account that up to a third of the untreated patients could return to their daily activities,[2] and therefore there is a risk to overestimate results. The anatomical double-tunnel technique, which, when properly executed, enables for a reconstruction as close as possible to the original anatomy of the ligament, is performed by either antegrade drilling (transportal approach) or retrograde drilling and is gaining ground due to improvements in the hardware and the fixation systems. A further step forward was the development of the double-bundle anatomical approach, which attempts to recreate the theoretical division into two ACL bundles, although its results have not achieved conclusive improvements to compensate for its technical complexity and greater cost.[3] It has become apparent that placing the graft in an anatomical position is a fundamental requirement to which we can only aspire: extracting and preparing a graft is never free from limitations, and primary fixation must be effective so as to procure an early functional recovery; meniscus reconstruction should be considered; the condition of the articular cartilage is determinant for the success of the surgery and proper long-term function of the joint; and postoperative activities involving pivoting and high-impact sports are decisive factors affecting the graft result and survival.

We present a study of two series of 30 patients who were operated on by the same surgeon, using the same type of graft (ipsilateral hamstring autografts), the same surgical techniques (standard transtibial single-tunnel and anatomical double-tunnel with femoral retrograde tunneling), and the same fixations for the graft (adjustable cortical fixation for the femur and a retrograde screw fixation for the tibia) in order to compare the outcomes.

MATERIALS AND METHODS

The study compares 2 series of 30 patients who were operated on by the same surgeon using a multiple autograft consisting of 3-5 bundles, and autologous, ipsilateral tendons from the semitendinosus muscle and the gracilis muscle. The series differed in the technique employed: transtibial single-tunnel with over-the-top guidance for femoral tunneling, and double-tunnel with femoral retrograde drilling of a blind socket using FlipCutter® (Arthrex, Naples, FL, USA). In both techniques, fixation was achieved proximally using the cortical system ACL TightRope® (Arthrex, Naples, FL, USA) and distally using an interference retrograde screw (Arthrex, Naples, FL, USA). Tibial insertion of the graft was placed in the posterior area of the anatomical footprint, posterior to the anterior horn of the lateral meniscus, in order to prevent intercondylar friction, using a tunnel sagittal angle of 55º. Femoral insertion of the graft was placed in the posterior over-the-top position, 2 mm from the wall, using the transtibial single-tunnel technique (Figure 1), and in the posterior position at 10 o'clock (right knees) or at 2 o'clock (left knees) using the anatomical double-tunnel technique (Figure 2). The average hospital stay was that of the drainage period, i.e. 48 hours. The procedures allowed patients to regain immediate mobility and partial weight-bearing 48 hours after surgery. Postoperative rehabilitation was similar for all patients: it started 3 weeks after surgery and lasted a minimum of 2 months and an average of 3 months.

The subjective evaluation was performed using the last version of the International Knee Documentation Committee (IKDC 2000) subjective evaluation knee questionnaire (activity, pain, pain severity, swelling, joint locking and failure, ability to perform daily and sports activities, and subjective knee function) to rate knee function on a scale of 0 to 100, with the highest scores representing a milder limitation on daily and sports activities, and fewer symptoms. The objective evaluation was performed using instability test maneuvers: the Lateral Pivot-Shift Test to assess combined rotational and sagittal instability[4], the Lachman Test to assess anterior laxity, and the Single Leg Hop functional test, which was considered positive if the patient was able to hop three times without losing stability and negative if patients were unable to perform the test or required their two feet to maintain balance. Sports activities considered as high-impact activities were soccer, basketball, handball, tennis, squash, padel and other similar sports. Objective radiological findings, such as tunnel osteolysis, were analyzed.

Figure 1. X-ray showing a transtibial single-tunnel ligament reconstruction.

Figure 2. X-ray showing an anatomical double-tunnel ligament reconstruction.

The cross-sectional study of two independent samples for assessing parametric variables, such as the IKDC score, was conducted using the Student-Fisher Test, and non-parametric variables were analyzed using the Mann-Whitney test. Correlation coefficient tests were performed using the Spearman's and Pearson's coefficient. Statistical analysis was carried out using IBM SPSS Statistics 22 software. The level of significance was set at P<0.05.

RESULTS

In the series of 30 patients that underwent surgery using the transtibial single-tunnel technique, the age range was between 24 and 54 years with a mean age of 28 years, and the follow-up period was between 15 and 72 months with a mean of 37 months. Fifteen patients (50%) practiced high-impact sports activities and 20 had meniscus injuries (67%): 14 medial meniscus injuries and 6 lateral meniscus injuries; 7 meniscus suture repairs were successfully performed. Eleven patients (37%) had significant cartilage injuries; grade 3-4 injuries were treated using the Pridie drilling technique in 3 young patients and the microfracture technique in 3 patients over 40 years of age. The mean graft caliber was 8.5 mm (9 mm [10 cases], 8 mm [16 cases], 10 mm [3 cases], and 7 mm [1 case]), and the median for the tibial retrograde screw was 9 mm (9 mm [19 cases], 10 mm [5 cases], and 8 mm [6 cases]). There were no cases of significant tunnel osteolysis. The average IKDC score was 82.96 (62-100). The Lachman Test was negative in 5 cases, positive 1+ (3-5 mm firm end-feel) in 22 cases and 2+ (6-10 mm soft end-feel) in 3 cases (83% positive). The Lateral Pivot-Shift Test was negative in 14 cases, positive 1+ in 11 cases and positive 2+ in 5 cases (53% positive). The Single Leg Hop Test, with similar results to the Lateral Pivot-Shift Test, was positive (patient able to hop properly 3 consecutive times) in 14 cases (47%). Four patients (13%) required a new graft following a new sports trauma resulting in rupture, 3 reconstructions were made with bone-patellar tendon-bone autografts and 1 reconstruction was made with contralateral hamstrings. Seventeen patients (57%) recovered to their full level of daily activity, and the remaining 13 patients recovered to a lesser level of activity. Only 5 (33%) of the 15 patients that practiced high-impact and pivoting sports recovered to their full level of activity. There were no cases of significant postoperative complications (Tables 1, 2 and 3).

The results to the IKDC Questionnaire showed a significant difference between the series (Table 4): the results from the anatomical double-tunnel technique series were better (P<0.01), which shows that patients were more satisfied with the results of the anatomical double-tunnel technique. The Lachman Test showed similar results with both techniques. The Lateral Pivot-Shift Test and the Single Leg Hop Test results showed a significant difference between the series (P<0.01). The overall recovery to the previous level of activity showed no differences, except for the subgroup of patients who practiced the most demanding sports involving jumping and high-impact activities (soccer, basketball, tennis): full recovery was achieved in 5 of the 15 patients (33%) that underwent the single-tunnel surgery, and in 15 of the 22 (64%) that underwent the double-tunnel surgery; the results were significantly better (P>0.05) with the latter (Table 5). The Lateral Pivot-Shift Test and the Single Leg Hop Test were the tests that had more correlation with full recovery to high-impact sports. The incidence of meniscus and cartilage incidental injuries was similar in both series, and consequently no contributory factor was defined from these results. The mean graft caliber was larger with the anatomical double-tunnel technique (9.2 mm) than with the transtibial single-tunnel technique (8.5 mm). This result may be considered a contributory factor and was due to the tendency to widen the caliber at the expense of graft length. There was no incidence of tunnel osteolysis in either of the two series, regardless of the graft and the tibial retrograde screw calibers.

Table 1. Results summary of both series

Series	Age in years (range)	Progression in months (range)	High-impact sports activity	Associated injuries	Meniscus injuries	Meniscus suture repair	Articular cartilage injuries	Management of articular cartilage injuries
Transtibial single-tunnel technique	24-54	15-72	15	21	14 medial 6 lateral	7	11	3 Pridie drillings 3 microfracture surgeries
Anatomical double-tunnel technique	18-55	17-48	22	22	14 medial 5 lateral	9	12	3 Pridie drillings 3 microfracture surgeries

Table 2. Results summary of both series (other parameters)

Series	IKDC score	Lachman Test	Lateral Pivot-Shift Test	Single Leg Hop Test	Removed grafts	Recovery to the previous level of activity
Transtibial single-tunnel technique	82.96 (62-100)	- (5 patients) + 22 (patients) ++ 3 (patients)	- 14 (patients) + 11 (patients) ++ 5 (patients)	+ (14 patients)	4	17 5/15 (high-impact sports)
Anatomical double-tunnel	89.13 (60-100)	- in 7 + in 21 ++ in 2	- in 23 + in 7	+ (23 patients)	2	25 14/22 (high-impact sports)

Table 3. Summary of graft calibers, retrograde screw diameter and radiological findings in tibial tunnels

Series	Graft caliber	Tibial retrograde screw diameter	Tibial tunnel osteolysis
Transtibial single-tunnel technique	9 mm in 10 cases 8 mm in 16 cases 10 mm in 3 cases 7 mm in 1 case	9 mm in 19 cases 10 mm in 5 cases 8 mm in 6 cases	0
Anatomical double-tunnel technique	9 mm in 16 cases 8 mm in 4 cases 10 mm in 10 cases,	9 mm in 10 cases 10 mm in 20 cases	0

Table 4. Statistical analysis of the IKDC score for both series

Type of technique	N	Mean IKDC Score	Deviation	Mean Error Deviation	Levene's Test (significance, homogeneity, variances)	Student's t-test	Significance	Mean Difference	Standard Error of Mean
Single-tunnel technique	30	82.97	8.915	1.628	0.816	-2.689	0.009 (P<0.01)	-6.167	2.293
Double-tunnel technique	30	89.13	8.846	1.615					

Technique/IKDC crossed table		Value	Asymptotic Standard Error	Estimated T	Significance
Interval-by-interval	Pearson's correlation	0.333	0.122	2.686	0.009 P<0.01
Ordinal-by-ordinal	Spearman's correlation	0.351	0.117	2.858	0.006 P<0.01

Table 5. Comparative statistical analysis of the variables for both series

Variable differences between series	Associated injuries	Graft caliber	Lachman Test	Lateral Pivot-Shift Test	Single Leg Hop Test	Recovery to the previous level of over-all activity	Recovery to the previous level of sports activity
Mann-Whitney's U	435.000	194.500	410.500	283.000	268.500	313.500	278.300
Wilcoxon's W	900.000	659.500	875.500	748.000	733.500	778.500	240.210
Z	-0.224	-4.014	-0.740	-3.053	-3.369	-2.556	-3.124
Bilateral Asymptotic Significance	0.776 P>0.05	0.000 P<0.05	0.460 P>0.05	0.002 P<0.05	0.001 P<0.05	0.11 P>0.05	0.001 P<0.005
Interval-by-interval Pearson's correlation	0.037 Significance 0.779 P>0.05	0.520 Significance 0.000 P<0.05	-0.96 Significance 0.464 P>0.05	-0.396 Significance 0.002 P<0.05	-0.434 Significance 0.001 P<0.05	-0.317 Significance 0.14 P>0.05	-0.412 Significance 0.001 P<0.001
Ordinal-by-ordinal Spearman's correlation	0.037 Significance 0.779 P>0.05	0.523 Significance 0.000 P<0.05	-0.96 Significance 0.464 P>0.05	-0.397 Significance 0.002 P<0.05	-0.439 Significance 0.000 P<0.001	-0.333 Significance 0.09 P>0.05	-0.416 Significance 0.001 P<0.001

DISCUSSION

The ACL reconstruction technique has evolved towards a reconstruction as close as possible to the original anatomy, which is only achievable through a better understanding of its function. The most important morphological features are well known:[5,6] it is considered that the functional structure of the ACL has two bundles (a posterolateral one and an anteromedial one)[7]. The femoral origin is oval, with a diameter of 15-18 x 8-11 mm, while the tibial insertion is triangular, with a diameter of 16-17 x 11 mm[8,9]. As it approaches its insertion point, the ACL caliber grows larger; at this point, the ligament caliber is three times as wide as the caliber in the middle section[10], which is an anatomic paradox considering that, in order to avoid the cyclops lesion, the graft must be located in a farther posterior position, with the tibial tunnel at the posterolateral bundle footprint level. In order to achieve an anatomical femoral tunnel placement, we must go down the intercondylar notch to place the graft horizontally and use as much of the anatomical origin as possible.[11] Such placement will improve rotation stability and prevent a limited flexion and a failure rate of 63% due to this problem.[12] Double-bundle reconstruction surgery, considered to be the procedure that achieves the result closest to the original anatomical structure and which has even enabled to identify three bundles,[6] poses certain disadvantages: a complex technique, the inadequate caliber of the graft's bundles, the limited availability of such grafts, the increasing number of fixations, and the overuse of the original footprint as a result of having to use two independent tunnels, which has led to unification of the double-bundle technique into a single distal tunnel.[13-15] The results of the double-bundle technique vary when compared to the single-bundle technique and, although in some studies the double-bundle technique has been deemed better,[15,16] the largest series show no objective or subjective significant differences with the single-bundle anatomical technique.[17-19] This situation resulted in the single-bundle technique being the approach of choice, preferably performed through an accessory anteromedial portal and using a BTB graft, according to published reports.[20]

In this study, we were able to prove that the anatomical double-tunnel single-bundle technique allows for results that are closer to the ACL original anatomy[21] and improve the rotational stability during impact activities, jumping and running. However, the technique did not prove to be superior in patients who did not practice this type of demanding activities. In these patients, the transtibial single-tunnel technique was equally satisfactory, and large series of patients have reported good outcomes during subjective evaluations,[22] and in terms of residual pain, walking up and down the stairs, and genuflexion.[23-26] Some authors claim that this technique allows for a more anatomical placement of the graft in 48% of the cases,[27] although the femoral tunnel is usually more vertical, parallel and deep[28] when performed through the transtibial technique. Even anatomical techniques have a significant rate of graft placement failure: 40% for the femoral side and 56% for the tibial side.[29] An analysis of comparative studies showed that grafts placed in a more horizontal position (placed in the intercondylar notch at a 10 o'clock or a 2 o'clock position, depending on the side) limit tibial rotations more than vertically oriented grafts,[30-35] which allow for a better performance when jumping, running and pivoting. However, they have reduced isometry, since the vertically-placed grafts (placed at a 12 o'clock position and 2 mm anterior to the posterior edge of the intercondylar notch) are the most isometric, with a variation of 2-3 mm at full extension[36,37]. Therefore, they offer better results in terms of anteroposterior stability.[38] Isometry is a relative concept, since most of the fibers that are more posterior to the ligament attach below the femoral isometric point and, nonetheless, these fibers are the most effective in procuring anterior and rotational stability during knee flexion.[39] The anatomical technique and the standard transtibial single-tunnel technique should present no significant differences for patients who do not practice sports involving single-leg jumping and pivoting; the anatomical technique would be appropriate for patients who engage in more demanding sports. According to the relevant studies,[40-43] currently, there is no technique that provides full recovery of the rotational stability, not even the double-bundle approach. This is a result of the limitations of the current techniques and the fact that rotational stability is not exclusively determined by the ACL: intrinsic anatomical conditions as well as peripheral stabilizers are vital, which largely accounts for the differences found in published studies on objective and subjective evaluations. For this reason, some surgeons combine the reconstruction of the anterior lateral ligament (such as a Lemaire tenodesis, that controls the rotation of the tibia on the femur) with the ACL reconstruction[44]. However, this combination should only be used in patients with residual instability, excessive laxity, poor condition of external fixators or those undergoing a revision surgery. Although the resistance of standard autografts is superior to that of the native ACL, multiple-fascicle hamstring grafts are the best suited for the double-tunnel technique. Some series showed fewer failures than with the patellar tendon graft reconstruction[45,46] and less residual pain at the donor site (11.8%), as long as the graft caliber is >8 mm and the graft is a multiple-fascicle one[47,48]. However, their biologic incorporation is slower and partial within the tunnels.[49] In our study, the graft caliber was 8.5 mm for the transtibial single-tunnel technique and 9.2 mm for the anatomical double-tunnel technique. There is a tendency to harvest multiple fascicles out of limited and unstable grafts,[50] but a 6 cm graft would suffice. Using the patellar tendon for anatomical grafts requires making small bone plugs to adapt it to the femur, which implies a more difficult fixation and the well-known complication of anterior knee pain in 14-47% of patients.[51] For this reason, tendon autografts are gaining ground over BTB grafts, which are the preferred choice for single-tunnel procedures.[51,52] Other options, such as quadriceps tendon grafts with bone plugs[53] or allografts, are second-line options due to poorer management and results.[54] In the interface between the tendon graft and the epiphysis, reactive sclerosis occurs as a result of a polyaxial micromotion that may widen the tunnel. This is considered significant when the area increases 50%, a phenomenon that is more common during the first year in tibial tunnels (50%) than in femoral tunnels (15%), and that is affected by the vertical placement and the length of the unfixed graft.[55-57] This may be minimized using a retrograde screw, which locks the graft to the articular surface and has the advantage of tensing the graft during insertion, thus sealing the tunnel. We found the retrograde transosseous technique to be adequate for femoral bone tunneling, an opinion shared by other authors,[58-60] since it allows for the creation, without portal limitations, of blind sockets using flexible reamers, which is more adequate for fertile growth plate and revision surgeries; however, no significant differences were found between the retrograde technique and the medial transportal technique.[61-63]

CONCLUSIONS

The anatomical double-tunnel ligament reconstruction technique is better rated by patients, as efficient as the transtibial single-tunnel technique regarding anteroposterior stability, and more efficient in terms of rotary stability, as shown by the Lateral Pivot-Shift Test and the Single Leg Hop Test. This results in a higher rate of patients being able to resume the same level of sports activities. In patients who do not practice high-impact and pivoting sports, results were equally satisfactory. The use of a retrograde screw did not result in significant tunnel osteolysis. The strength of this study lies in the comparison of two series of similar patients who underwent surgeries performed using two different techniques and the same graft fixations, as well as performed by the same surgeon. The main limitation is that it was not a randomized prospective study.

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