SBOT SOCIEDADE BRASILEIRA DE ORTOPEDIA E TRAUMATOLOGIA

RBO REVISTA BRASILEIRA DE ORTOPEDIA

www.rbo.org.br

Original article

Transtibial technique *versus* two incisions in anterior cruciate ligament reconstruction: tunnel positioning, isometricity and functional evaluation☆

Ricardo Hideki Yanasse, Alisson Amoroso Lima, Rodrigo Silveira Antoniassi, Danilo Abu Ezzedin, Marcos Henrique Ferreira Laraya, Roberto Ryuiti Mizobuchi*

Service of Orthopedy and Traumatology, Faculdade de Medicina de Marília (Famema), Marília, SP, Brazil

ARTICLE INFO

Article history:
Received 10 February 2015
Accepted 24 April 2015
Available online 9 April 2016

Keywords:
Knee
Anterior cruciate ligament reconstruction
Radiography

ABSTRACT

Objective: To compare the transtibial and two-incision techniques for anterior cruciate ligament (ACL) reconstruction using a single band.

Methods: A prospective and randomized study was conducted in blocks. Patients underwent ACL reconstruction by means of two techniques: transtibial (group 1: 20 patients) or two incisions (group 2: 20 patients). The radiographic positioning of the tunnel, inclination of the graft, graft isometricity and functional results (IKDC and Lysholm) were evaluated.

Results: The positioning of the femoral tunnel on the anteroposterior radiograph, expressed as a mean percentage relative to the medial border of the tibial plateau, was 54.6% in group 1 and 60.8% in group 2 ($p < 0.05$). The positioning of the femoral tunnel on the lateral radiograph, expressed as a mean percentage relative to the anterior border of Blumensaat's line, was 68.4% in group 1 and 58% in group 2 ($p < 0.05$). The mean inclination of the graft was 19° in group 1 and 27.2° in group 2 ($p < 0.05$). The mean graft isometricity was 0.96 mm in group 1 and 1.33 mm in group 2 ($p > 0.05$). Group 2 had better results from the pivot-shift maneuver ($p < 0.05$).

Conclusion: The technique of two incisions allowed positioning of the femoral tunnel that was more lateralized and anteriorized, such that the graft was more inclined and there was a clinically better result from the pivot-shift maneuver. There was no difference in isometricity and no final functional result over the short follow-up time evaluated.

© 2016 Published by Elsevier Editora Ltda. on behalf of Sociedade Brasileira de Ortopedia e Traumatologia. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

☆ Study conducted at the Service of Orthopedy and Traumatology, Faculdade de Medicina de Marília (Famema), Marília, SP, Brazil.

* *Corresponding author.*
E-mail: ronibas@hotmail.com (R.S. Antoniassi).

http://dx.doi.org/10.1016/j.rboe.2016.04.001

2255-4971/© 2016 Published by Elsevier Editora Ltda. on behalf of Sociedade Brasileira de Ortopedia e Traumatologia. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Técnica transtibial *versus* duas incisões na reconstrução do ligamento cruzado anterior: posicionamento dos túneis, isometricidade e avaliação funcional

Palavras-chave:
Joelho
Reconstrução do ligamento cruzado anterior
Radiografia

RESUMO

Objetivo: Comparar as técnicas transtibial e de duas incisões na reconstrução do ligamento cruzado anterior (LCA) com banda única.

Métodos: Foi feito um estudo prospectivo e randomizado em bloco. Os pacientes foram submetidos a reconstrução do LCA por meio de duas técnicas: transtibial (grupo 1: 20 pacientes) ou de duas incisões (grupo 2: 20 pacientes). Foram avaliados o posicionamento radiográfico dos túneis, a inclinação do enxerto, a isometricidade do enxerto e os resultados funcionais (IKDC e Lysholm).

Resultados: O posicionamento do túnel femoral na radiografia em AP expresso em porcentagem em relação à borda medial do planalto tibial no grupo 1 foi em média de 54,6% e no grupo 2 foi de 60,8% ($p < 0{,}05$). O posicionamento do túnel femoral na radiografia em P expresso em porcentagem em relação à borda anterior da linha de Blumensaat no grupo 1 foi em média de 68,4% e no grupo 2 foi de 58% ($p < 0{,}05$). A inclinação do enxerto no grupo 1 foi em média de 19 graus e no grupo 2 foi de 27,2 graus ($p < 0{,}05$). A isometricidade do enxerto no grupo 1 foi em média de 0,96 mm e no grupo 2 foi de 1,33 mm ($p > 0{,}05$). O grupo 2 apresentou melhores resultados pela manobra de Pivot-Shift ($p < 0{,}05$).

Conclusão: A técnica de duas incisões permitiu um posicionamento do túnel femoral mais lateralizado e anteriorizado e que o enxerto ficasse mais inclinado e demonstrou clinicamente um melhor resultado pela manobra de Pivot-Shift. Não houve diferença na isometricidade e no resultado funcional final no curto tempo de seguimento avaliado.

© 2016 Publicado por Elsevier Editora Ltda. em nome de Sociedade Brasileira de Ortopedia e Traumatologia. Este é um artigo Open Access sob uma licença CC BY-NC-ND (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

Historically, the parameters of tunnel positioning in single-band reconstruction of the anterior cruciate ligament (ACL) have been adjusted and modified in search of an ideal clinical result. The isometric positioning in the sagittal plane has been the main concern in initial intra-articular ACL reconstructions. It was determined that the isometric zone on the femur would be smaller than that of the tibia, which remains the same for a point located both in the anterior and posterior edge of ACL insertion.[1–3] An eccentric positioning in the tibia, *i.e.*, in the most anteromedial portion of ACL insertion, as well as the positioning in the center of ACL insertion, was recommended for ACL reconstruction by some authors.[4,5] Howell et al.,[1] with the transtibial technique, associated the positioning in the center of ACL insertion on the tibia with intercondylar roof impingement. Therefore, for a long time, it was recommended that the graft was positioned in the posteromedial insertion area on the tibia and in the posterior insertion area on the femur.[6–8]

The concern with residual rotational instability in ACL reconstruction is more modern. Loh et al.[9] demonstrated that femoral positioning at 10 o'clock presents a more effective resistance to rotational loads than the positioning at 11 o'clock. Pinczewski et al.[6] correlated the radiographic positioning of the tunnels and the angle of the graft with clinical results and established the ideal radiographic parameters for a better long-term result. They also demonstrated a relation between verticalization of the graft and an increased incidence of positive pivot-shift and radiographic abnormalities.[6]

There are controversies regarding whether the transtibial technique would allow for a more horizontal positioning of the femoral tunnel; many authors recommend the two-incision technique[10] or creating the femoral tunnel through the anteromedial portal. Although several studies have correlated the positioning of the femoral tunnel with clinical and biomechanic results, no studies correlating positioning with the isometricity obtained in the intraoperative period were retrieved in the literature.

This study aimed to compare the radiographic tunnel positioning, graft inclination, graft isometricity in the intraoperative period, and the final functional result of single-band ACL reconstruction using the transtibial or the two-incision techniques.

Methods

This was a prospective study with block randomization, including 40 patients who consecutively underwent ACL reconstruction from December 2009 to October 2011. All patients were operated on using the single-band technique, with semitendinosus and gracilis tendon grafts and metal interference screw fixation. The femoral tunnel was made through two techniques: transtibial (group 1: 20 patients) or two-incision (group 2: 20 patients).

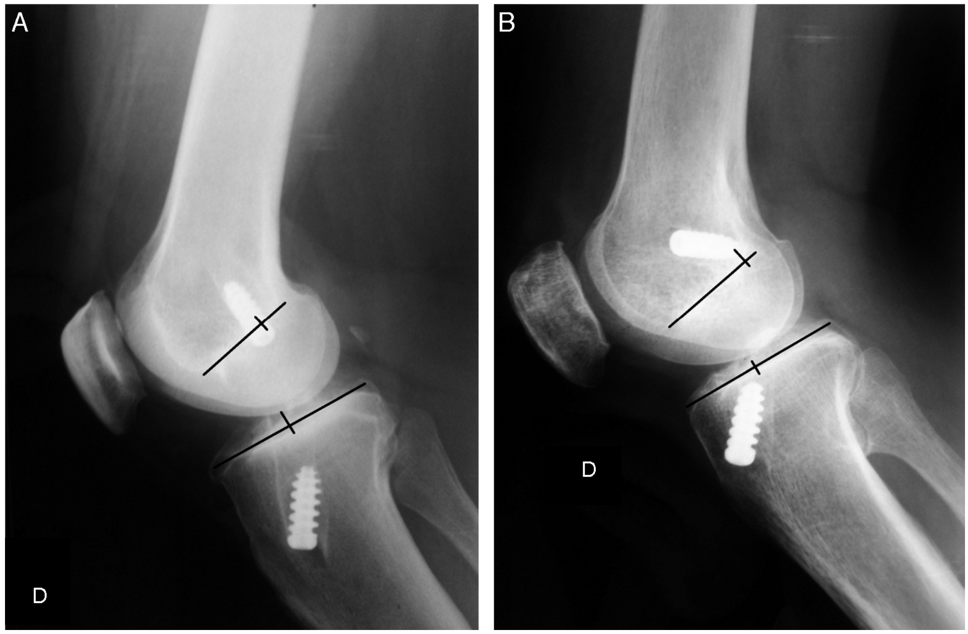

Fig. 1 – (A, B) Measurement of the femoral and tibial tunnel in lateral X-ray in the transtibial and two-incision techniques, respectively.

Patients from group 1 underwent surgery from December 2009 to December 2010, and those from group 2, from December 2010 to October 2011.

The inclusion criteria were: patients with no other ligament injuries; no mechanical axis alignment abnormalities; age 18–45 years old; no complications during the post-operative period, such as arthrofibrosis and deep infection; no history of prior knee surgeries, in accordance with the free and informed consent form; and Tegner activity level ≥4 prior to the injury.[11–13]

The exclusion criteria were: patients who reported pregnancy, left the study, or asked to be excluded; those who did not return for the X-rays and IKDC assessment; and those who did not follow physiotherapy rehabilitation in accordance with the rehabilitation protocol. According to these criteria, eight patients were excluded, six from group 1 and two from group 2.

All patients were assessed between eight to 22 months (mean of 13) after the surgery. Two orthopedic surgeons (knee specialists) who had not participated in the surgical procedure were asked to assess the patients; the surgical wound was covered with crepe bandages during examination, so that the surgeons could not identify the incisions.

The statistical tests were conducted using a significance level of 5% ($p < 0.05$).

This study was approved by the institution's Research Ethics Committee under No. 1440/11.

Radiographic assessment

The radiographic assessment was conducted with unmarked X-rays, which were independently examined by two trained authors/investigators; the measurements were compared and, in case of disagreement, a third trained investigator was consulted, to ensure reliability in the radiographic analyses.

X-rays were taken between six months and two years after the surgery. The following radiographic views were used for the evaluation: anteroposterior (AP), lateral (L), and tunnel view with 30° flexion. The positioning of the center of the femoral tunnel in the lateral X-ray was performed by measuring the length of the Blumensaat's line; the anterior and posterior edges of the tunnel were identified and the center of the femoral tunnel was determined. Next, the position of the center of the tunnel was expressed as a percentage of the length of the Blumensaat's line from its anterior limit (Fig. 1A and B).[14,15]

The femoral tunnel positioning was assessed at the tunnel-view X-ray as a percentage of the width of the tibial plateau from the medial edge, as described by Khalfayan et al.[16] (Fig. 2A and B).

The positioning of the tibial tunnel was measured at the lateral X-ray; the length of the tibial plateau and the anterior and posterial edges of the tunnel relative to the tibial plateau were determined. The center of the tibial tunnel was expressed as a percentage of the length of the tibial plateau (Fig. 1A and B).[17] At the AP X-ray, the total length of the tibial plateau was measured and the medial and lateral edges of the tunnel were determined. The position of the center of the tibial tunnel was expressed as a percentage relative to the total length of the tibial plateau (Fig. 2A and B).

The inclination of the graft was measured in accordance with the method used by Pinczewski in AP tunnel-view X-ray with 30° of flexion.[6] The angle formed by the line that connects the medial wall of the femoral tunnel to the medial wall of the tibial tunnel with the line of the tibial plateau defines the inclination of the graft (Fig. 3A and B).

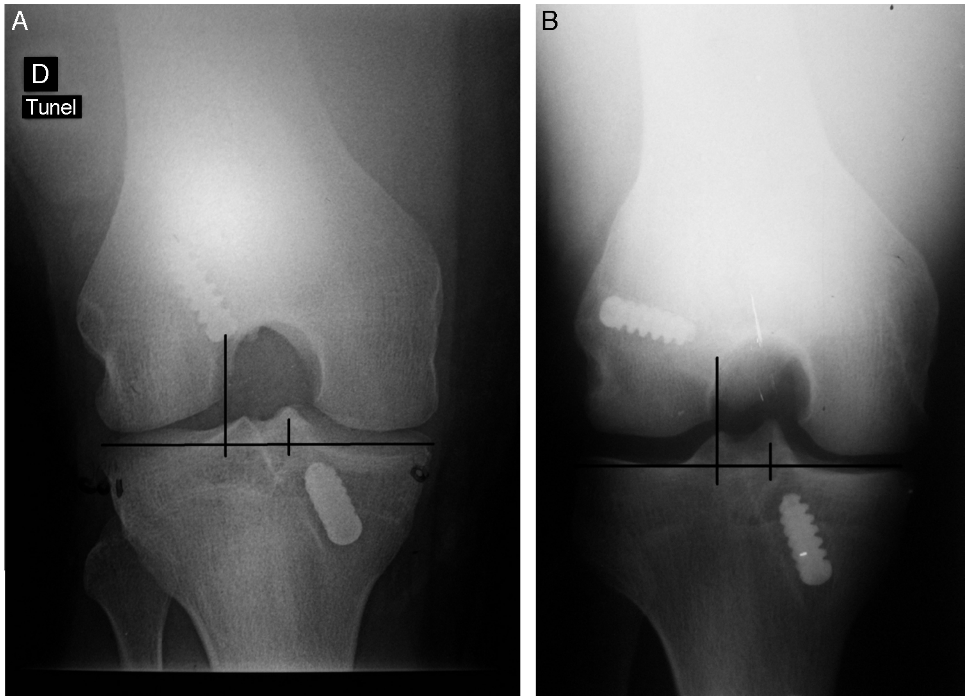

Fig. 2 – (A, B) Measurement of the femoral and tibial tunnel positioning in the transtibial and two-incision techniques, respectively.

Surgical technique

The reconstruction using the transtibial technique was performed through a small incision in the flexor tendons (semitendinosus and gracilis) insertion region, with their harvesting and preparation of the quadruple graft. Then, the tibial tunnel was made with help of a guide (Fig. 4A). The entry of the tunnel was adjacent to the medial collateral ligament. Subsequently, the femoral transtibial guide was positioned (Fig. 4B) and the surgeon sought the most anatomical point for creating the femoral tunnel. After making the tunnels, the graft was passed through them in a retrograde fashion; it was firstly

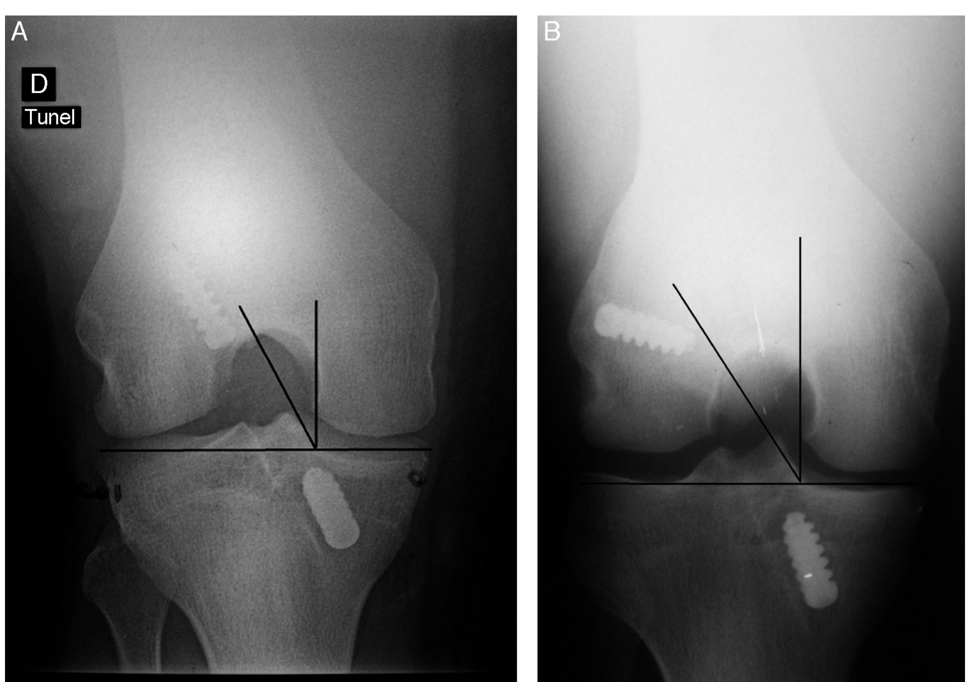

Fig. 3 – (A, B) Measurement of graft inclination using the Pinczewski method in the transtibial and two-incision techniques, respectively.

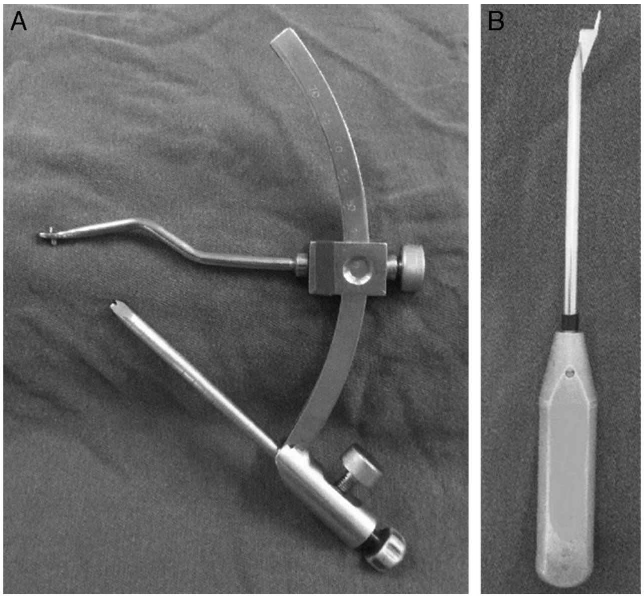

Fig. 4 – (A, B) Tibial and femoral guides for the transtibial technique.

fixed in the femur with an interference screw through a small lateral approach, and then fixed in the tibia with the knee in 30° of flexion, discreet valgus stress, and discreet external rotation of the tibia with another interference screw. Subsequently, the ligament tests (Lachman and anterior drawer) were performed to assess stability.

The reconstruction through the two-incision technique (Chambat) was done in the same way as the previous technique; the only difference was in making the femoral tunnel, which was drilled using a outside-in guide (Chambat) (Fig. 5).[10,18]

Graft isometricity assessment in the intraoperative period

After the femoral fixation of the graft, repeated flexion-extension of the knee was performed for its accommodation. Subsequently, isometricity was assessed using an intraoperative maneuver starting by applying traction on the distal end of the graft on maximum flexion. A thin mark at the level of the anterior edge of the tibial tunnel was made on the graft with methylene blue. The knee was brought to complete extension, when which a new mark was made. With the help of a ruler, the authors measured whether or not the graft moved. The procedure was conducted as quickly as possible to avoid diffusion of the pigment through the graft tissue, in order to ensure better precision of the marking.

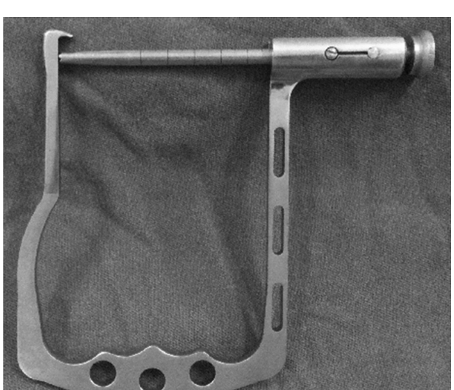

Fig. 5 – Femoral guide used in the two-incision technique.

Clinical/functional evaluation

IKDC, Lysholm Knee Scale, and Tegner score were used for functional and clinical evaluation.[11,12,19–22]

Examination was performed independently by two orthopedic surgeons (knee specialists). The results were compared; in case of disagreement a third trained investigator was consulted to ensure reliability in the clinical analyses.

Statistical analysis

The Mann–Whitney *U* test was used for the comparisons between groups 1 and 2 regarding age, time between injury and surgery, tunnel positioning, graft thickness, graft inclination in the coronal plane, isometricity, IKDC, Lachman and pivot-shift maneuvers, and Lysholm and Tegner scores.

The relation between the variables was analyzed with Spearman's correlation coefficient.

Statistical analyses were performed with Statistica version 8.0.

The significance level was set at 5% ($p < 0.05$).

Results

There was no difference between both groups regarding age ($p = 0.8$), time between injury and surgery ($p = 0.78$), level of activity (Tegner) before injury ($p = 0.62$), and Lysholm score before surgery ($p = 0.61$).

One patient from group 2 presented graft rupture and was excluded from the analyses of functional results (IKDC, pivot-shift and Lachman exams, and post-operative Lysholm and Tegner scores), and eight patients (six from group 1 and two from group 2) did not return for clinical and radiographic evaluations.

Positioning of the femoral tunnel and tibial tunnel in AP and L X-rays

The mean positioning of the femoral tunnel in the AP X-ray in group 1 was 54.6% (SD 4.1) and in group 2, 60.8% (SD 4.5; $p = 0.0004$; Table 1).

The mean positioning of the femoral tunnel in the L X-ray in group 1 was 68.4% (SD 10.9) and in group 2, 58% (SD 9.9; $p = 0.0005$; Table 1).

Regarding the tibial tunnel, there was no difference between both groups.

Graft inclination

In group 1, mean graft inclination was 19° (SD 3.7) and in group 2, 27.2° (SD 5.7; $p = 0.0005$; Table 2)

Table 1 – Mean values of tunnel positioning, expressed as percentage and standard deviation (SD), in groups 1 and 2.

	Mean (SD)		p-Value (Mann–Whitney)
	Group 1 – transtibial	Group 2 – two-incision	
AP femoral tunnel (%)	54.6 (4.1)	60.8 (4.5)	0.0004
L femoral tunnel (%)	68.4 (10.9)	58.0 (9.9)	0.005
AP tibial tunnel (%)	45.4 (6.4)	45.2 (4.9)	0.11
L tibial tunnel (%)	43.5 (9.3)	38.1 (9.8)	0.12

AP, measurement performed in anteroposterior X-ray; L, measurement performed in lateral X-ray.

Table 2 – Mean values and standard deviation (SD) of graft inclination and isometricity in groups 1 and 2.

	Mean (SD)		p-Value (Mann–Whitney)
	Group 1 – transtibial	Group 2 – two-incision	
Graft inclination (°)	19.0 (3.7)	27.2 (5.7)	0.0005
Isometricity (mm)	0.96 (0.8)	1.33 (1.6)	0.69

Isometricity of the graft

There was no difference between both groups (Table 2).

Functional results – IKDC and Lysholm

There was no difference between both groups regarding IKDC (Table 3), as well as post-operative Lysholm and Tegner scores (Table 4).

Analysis of Lachman and pivot-shift maneuvers

There was no difference between both groups for Lachman maneuvers ($p = 0.87$).

Group 2 presented better results for pivot-shift maneuver when compared with group 1 ($p = 0.04$; Table 5)

Correlation of tunnel positioning with functional results

In both groups, the individual parameters of tunnel positioning (AP femoral tunnel, L femoral tunnel, AP tibial tunnel, L tibial tunnel) were not correlated ($p > 0.05$) with functional results (IKDC, pivot-shift and Lachman maneuvers, and Lysholm and Tegner score).

Table 3 – Results of the International Knee Documentation Comitee (IKDC) score in groups 1 and 2.

	Group 1 – transtibial Number of patients (%)	Group 2 – two-incision Number of patients (%)	p-Value (Mann–Whitney U)
Subjective IKDC			
A	12 (85.7%)	11 (64.7%)	0.16
B	2 (14.3%)	4 (23.5%)	
C	0 (0.0%)	2 (11.8%)	
IKDC range of movement			
A	10 (71.4%)	6 (35.3%)	0.09
B	3 (21.4%)	11 (64.7%)	
C	1 (7.2%%)	0 (0.0%)	
IKDC ligament exam			
A	2 (14.3%)	6 (35.3%)	0.19
B	12 (85.7%)	11 (64.7%)	
C	0 (0.0%)	0 (0%)	
IKDC final			
A	2 (14.3%)	3 (17.6%)	0.96
B	11 (78.6%)	12 (70.6%)	
C	1 (7.1%)	2 (11.8%)	

Obs: The “D” score was not observed in any of the groups.

Correlation of graft inclination in the coronal plane with functional results

Within group 1, higher graft inclination was significantly correlated with Lysholm score ($r = 0.62$, $p = 0.02$).

Within group 2, higher graft inclination was associated with better IKDC results and was significantly correlated with IKDC functional test ($r = 0.56$, $p = 0.02$).

When analyzing both groups together, graft inclination was significantly correlated with pivot-shift maneuver ($r = 0.38$, $p = 0.04$).

Correlation of isometricity with tunnel positioning, inclination, and functional results

Within group 1, higher graft isometricity was associated with better IKDC results and was significantly correlated with pivot-shift maneuver ($r = 0.59$, $p = 0.03$), functional test (hop test; $r = 0.64$, $p = 0.01$), and final IKDC ($r = 0.67$, $p = 0.009$).

Within group 2, higher graft isometricity was only significantly correlated with subjective IKDC ($r = 0.58$, $p = 0.01$).

When analyzing both groups together, higher graft isometricity was significantly correlated with subjective IKDC ($r = 0.53$, $p = 0.02$) and functional test ($r = 0.36$, $p = 0.04$).

There was no correlation of isometricity with graft inclination ($p > 0.05$).

Table 4 – Mean and standard deviation (SD) of the post-operative Lysholm and Tegner scores in groups 1 and 2.

	Group 1 – transtibial mean (SD)	Group 2 – two-incision mean (SD)	p-Value (Mann–Whitney's U)
Post-operative Lysholm score	96.6 (4.5)	94.6 (4)	0.09
Post-operative Tegner score	5.9 (1.4)	5.2 (1.9)	0.32

Table 5 – Comparative results of the Lachman and Pivot-Shift maneuvers in groups 1 and 2.

	Group 1 – transtibial Number of patients (%)	Group 2 – two-incision Number of patients (%)	p-Value (Mann–Whitney's U)
Lachman			
0–2 mm	7 (50%)	8 (47.1%)	0.87
3–5 mm	7 (50%)	9 (52.9%)	
6–10 mm	0 (0.0%)	0 (0%)	
Pivot shift			
Negative	4 (28.6%)	11 (64.7%)	0.04
+ glide	10 (71.4%)	6 (35.3%)	
++ clunk	0 (0%)	0 (0%)	

Within groups 1 and 2 and in the analysis of both groups together, graft isometricity was not correlated with tunnel positioning ($p > 0.05$).

Within groups 1 and 2 and in the analysis of both groups together, among the patients with ideal isometricity (<2 mm), tunnel positioning was not statistically different from the other patients ($p > 0.05$).

Discussion

The two-incision technique for ACL reconstructions was developed before the transtibial technique, which became more used due to the convenience of a single incision during the arthroscopic procedure.[18] Currently, the two-incision technique has regained popularity due to the possibility of femoral tunnel positioning regardless of the angle of the tibial tunnel, aiming to position the graft anatomically (at the center of the proximal ACL insertion).[10] There are controversies regarding whether it is possible to anatomically position the femoral tunnel in the transtibial technique, since in the anatomical positioning of the tunnel the graft is tilted (more horizontal), hindering its achievement using this technique.[9]

In the present study, the authors preferred the transtibial technique to make the femoral tunnel due to its anatomical location. The tibial guide was positioned more medially, so that the entry of the tunnel was closer to the medial collateral ligament.[23] However, it was observed that the positioning of the femoral tunnel was significantly different comparing both techniques, probably due to the difficulties previously described. In the two-incision technique, the femoral tunnel in AP X-rays was more lateral; in L, it was more anterior; and in tunnel-view, more inclined. The authors believe that this positioning is indeed more anatomical.

The functional results did not demonstrate difference between both techniques. Nonetheless, in the isolated evaluation of the pivot-shift maneuver, the two-incision technique presented significantly better results, possibly for better reproducing the ACL anatomy. The better rotational control obtained in the two-incision technique took place without compromising the control of anteroposterior stability, which confirms what has been reported in the literature.[24] To the best of the authors' knowledge, to date, only biomechanical[25,26] and retrospective[27] studies have demonstrated the superiority of the anatomical reconstruction regarding rotational control, and this has not yet been reported in a randomized clinical trial.

For a long time, in the transtibial technique, isometricity was considered fundamental to ACL reconstruction; obtaining an isometric point was associated with a tunnel positioning in the insertion area of the posterolateral band in the tibia and anteromedial band in the femur. With anatomical reconstruction, the positioning in the center of the insertion area gained importance. Regarding graft isometricity, the present study did not observe statistically significant differences between both techniques. This finding is in agreement with recent studies, in which the gliding on maximum extension was similar in both techniques.[28–30]

In both groups, graft inclination was correlated with functional results; when assessed together, the higher the graft inclination, the better the pivot-shift result. This confirms the hypothesis that anatomical positioning and higher graft inclination leads to a higher rotational stability.

The authors believe that absence of graft isometricity may cause slackening after repetitive movements of flexion-extension. In the transtibial group, it was observed that patients with worse isometricity presented worse functional results, even in the pivot-shift maneuver. In the two-incision group, worse isometricity was only correlated with subjective IKDC; the authors believe that it is due to the anatomical positioning of the graft in this technique.

The limitations of the study are associated with its small sample and short follow-up time for clinical evaluations. KT-1000 evaluations were not performed.

Conclusions

The two-incision technique allowed for a more lateral and anterior positioning of the femoral tunnel, and for higher graft inclination, presenting better clinical result in the pivot-shift maneuver. No differences in isometricity and functional results were observed in the short follow-up period.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgement

To Carina da Costa Freitas, from the National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais [INPE]) for the statistical analyses.

REFERENCES

1. Howell SM, Clark JA, Farley TE. A rationale for predicting anterior cruciate graft impingement by the intercondylar roof. A magnetic resonance imaging study. Am J Sports Med. 1991;19(3):276–82.
2. Bradley J, FitzPatrick D, Daniel D, Shercliff T, O'Connor J. Orientation of the cruciate ligament in the sagittal plane. A method of predicting its length-change with flexion. J Bone Joint Surg Br. 1988;70(1):94–9.
3. Sidles JA, Larson RV, Garbini JL, Downey DJ, Matsen FA 3rd. Ligament length relationships in the moving knee. J Orthop Res. 1988;6(4):593–610.
4. Gillquist J, Odensten M. Arthroscopic reconstruction of the anterior cruciate ligament. Arthroscopy. 1988;4(1):5–9.
5. Good L, Odensten M, Gillquist J. Precision in reconstruction of the anterior cruciate ligament. A new positioning device compared with hand drilling. Acta Orthop Scand. 1987;58(6):658–61.
6. Pinczewski LA, Salmon LJ, Jackson WF, von Bormann RB, Haslam PG, Tashiro S. Radiological landmarks for placement of the tunnels in single-bundle reconstruction of the anterior cruciate ligament. J Bone Joint Surg Br. 2008;90(2):172–9.
7. Jackson DW, Gasser SI. Tibial tunnel placement in ACL reconstruction. Arthroscopy. 1994;10(2):124–31.
8. Morgan CD, Kalman VR, Grawl DM. Definitive landmarks for reproducible tibial tunnel placement in anterior cruciate ligament reconstruction. Arthroscopy. 1995;11(3):275–88.
9. Loh JC, Fukuda Y, Tsuda E, Steadman RJ, Fu FH, Woo SL. Knee stability and graft function following anterior cruciate ligament reconstruction: comparison between 11 o'clock and 10 o'clock femoral tunnel placement. 2002 Richard O'Connor Award paper. Arthroscopy. 2003;19(3):297–304.
10. Garofalo R, Mouhsine E, Chambat P, Siegrist O. Anatomic anterior cruciate ligament reconstruction: the two-incision technique. Knee Surg Sports Traumatol Arthrosc. 2006;14(6):510–6.
11. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res. 1985;(198):43–9.
12. Marx RG, Jones EC, Allen AA, Altchek DW, O'Brien SJ, Rodeo SA, et al. Reliability, validity, and responsiveness of four knee outcome scales for athletic patients. J Bone Joint Surg Am. 2001;83(10):1459–69.
13. Lee DY, Karim SA, Chang HC. Return to sports after anterior cruciate ligament reconstruction – a review of patients with minimum 5-year follow-up. Ann Acad Med Singapore. 2008;37(4):273–6.
14. Bernard M, Hertel P, Hornung H, Cierpinski T. Femoral insertion of the ACL. Radiographic quadrant method. Am J Knee Surg. 1997;10(1):14–21.
15. Zantop T, Wellmann M, Fu FH, Petersen W. Tunnel positioning of anteromedial and posterolateral bundles in anatomic anterior cruciate ligament reconstruction: anatomic and radiographic findings. Am J Sports Med. 2008;36(1):65–72.
16. Khalfayan EE, Sharkey PF, Alexander AH, Bruckner JD, Bynum EB. The relationship between tunnel placement and clinical results after anterior cruciate ligament reconstruction. Am J Sports Med. 1996;24(3):335–41.
17. Stäubli HU, Rauschning W. Tibial attachment area of the anterior cruciate ligament in the extended knee position. Anatomy and cryosections in vitro complemented by magnetic resonance arthrography in vivo. Knee Surg Sports Traumatol Arthrosc. 1994;2(3):138–46.
18. Harner CD, Marks PH, Fu FH, Irrgang JJ, Silby MB, Mengato R. Anterior cruciate ligament reconstruction: endoscopy versus two-incision technique. Arthroscopy. 1994;10(5):502–12.
19. Irrgang JJ, Ho H, Harner CD, Fu FH. Use of the International Knee Documentation Committee guidelines to assess outcome following anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc. 1998;6(2):107–14.
20. Hefti F, Müller W, Jakob RP, Stäubli HU. Evaluation of knee ligament injuries with the IKDC form. Knee Surg Sports Traumatol Arthrosc. 1993;1(3–4):226–34.
21. Kocher MS, Steadman JR, Briggs K, Zurakowski D, Sterett WI, Hawkins RJ. Determinants of patient satisfaction with outcome after anterior cruciate ligament reconstruction. J Bone Joint Surg Am. 2002;84(9):1560–72.
22. Peccin MS, Ciconelli R, Cohen M. Questionário específico para sintomas do joelho Lysholm Knee Scoring Scale: tradução e validação para a língua portuguesa. Acta Ortop Bras. 2006;14(5):268–72.
23. Rue JP, Ghodadra N, Bach BR Jr. Femoral tunnel placement in single-bundle anterior cruciate ligament reconstruction: a cadaveric study relating transtibial lateralized femoral tunnel position to the anteromedial and posterolateral bundle femoral origins of the anterior cruciate ligament. Am J Sports Med. 2008;36(1):73–9.
24. Harner CD, Poehling GG. Double bundle or double trouble? Arthroscopy. 2004;20(10):1013–4.
25. Scopp JM, Jasper LE, Belkoff SM, Moorman CT 3rd. The effect of obliqúe femoral tunnel placement on rotational constraint of the knee reconstructed using patellar tendon autografts. Arthroscopy. 2004;20(3):294–9.
26. Driscoll MD, Isabell GP Jr, Conditt MA, Ismaily SK, Jupiter DC, Noble PC, et al. Comparison of 2 femoral tunnel locations in anatomic single-bundle anterior cruciate ligament reconstruction: a biomechanical study. Arthroscopy. 2012;28(10):1481–9.
27. Kim MK, Lee BC, Park JH. Anatomic single bundle anterior cruciate ligament reconstruction by the two anteromedial portal method: the comparison of transportal and transtibial techniques. Knee Surg Relat Res. 2011;23(4):213–9.
28. Lee JS, Kim TH, Kang SY, Lee SH, Jung YB, Koo S, et al. How isometric are the anatomic femoral tunnel and the anterior tibial tunnel for anterior cruciate ligament reconstruction? Arthroscopy. 2012;28(10):1504–12.
29. Yonetani Y, Toritsuka Y, Yamada Y, Iwahashi T, Yoshikawa H, Shino K. Graft length changes in the bi-socket anterior cruciate ligament reconstruction: comparison between isometric and anatomic femoral tunnel placement. Arthroscopy. 2005;21(11):1317–22.
30. Vieira RB, Tavares LAP, Lasmar RCP, Cunha FA, Lisboa LAM. Análise radiológica do posicionamento do túnel femoral com as técnicas de reconstrução isométrica ou de reconstrução anatômica do LCA. Rev Bras Ortop. 2014;49(2):160–6.