Effect of tibial tunnel position on arthroscopically assisted anterior cruciate ligament reconstruction using bone-patellar tendon-bone grafts: a prospective study

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ABSTRACT

Introduction: The aim of this research was to study the effect of the tibial tunnel position in anterior cruciate ligament (ACL) reconstruction using bone-patellar tendon-bone (BPTB) grafts in ensuring optimal knee functioning.

Methods: A prospective study was conducted on 41 patients who underwent arthroscopically assisted ACL reconstruction using a BPTB graft and who were followed up for a minimum period of two years. The radiographic position of the tibial tunnel was compared with the clinical outcome using the International Knee Documentation Committee (IKDC) and modified Lysholm knee scores at two years after surgery.

Results: Six out of eight patients with a fair outcome based on the modified Lysholm score and five out of eight patients with an abnormal outcome based on the IKDC score had their tibial tunnel within the 10 percent to 25 percent anteroposterior width of the tibial plateau. The tibial tunnel of patients with a fair Lysholm outcome (mean 22.2 percent) was significantly anterior compared to that of those with an excellent (mean 38.1 percent) and good (mean 34.1 percent) outcome (p is less than 0.01). The analysis using the IKDC score showed a similar trend.

Conclusion: Placing the tibial tunnel in the anterior 25 percent of the tibial plateau is associated with a poor knee outcome. More predictable results can be achieved through 35 percent to 46 percent anteroposterior placement of the tibial tunnel.

Keywords: anterior cruciate ligament, bone-patellar tendon-bone graft, treatment outcome

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INTRODUCTION

Arthroscopically assisted anterior cruciate ligament (ACL) reconstruction using autologous bone-patellar tendon-bone (BPTB) graft has become one of the mainstays of treatment for ACL tears.

Over the years, there has been considerable debate regarding the placement of the graft, and several studies have been conducted to identify the best location for the placement of the tibial tunnel in order to ensure optimal knee functioning.[1-5] Initially, researchers proposed the placement of the graft in the anatomical position on the tibial plateau.[4] However, with the advent of the concept of isometricity in graft positioning, either an anteromedial or a posterior isometric placement of the graft was recommended.[5] Other studies found that an anterior placement resulted in the impingement of the graft in the intercondylar notch, causing limitations in movement.[6-8]

Despite the large number of studies relating to the ideal placement of the graft, no clear consensus has been reached thus far. We hypothesised that anterior and medial tibial tunnel placement in ACL reconstruction using a BPTB graft can lead to a poor functional outcome in terms of knee function. This study assessed the positioning of the tibial tunnel of the BPTB graft to determine its effect on knee function.

METHODS

This prospective study, conducted from April 2004 to May 2006, reports the results of 41 cases of ACL reconstruction using BPTB grafts that were followed up for a minimum period of two years. The study was approved by the ethics committee of the institution, and informed consent was obtained from all the patients. The patient exclusion criteria included: (1) adolescents

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Fig. 1 Lateral radiograph of the knee joint shows the sagittal tibial tunnel position. AB represents the anterior-posterior diameter of the tibial plateau. Point C represents the intersection of a line through the axis of the tibial tunnel with the tibial plateau. The sagittal tunnel position (percentage) is calculated by BC/AB × 100.

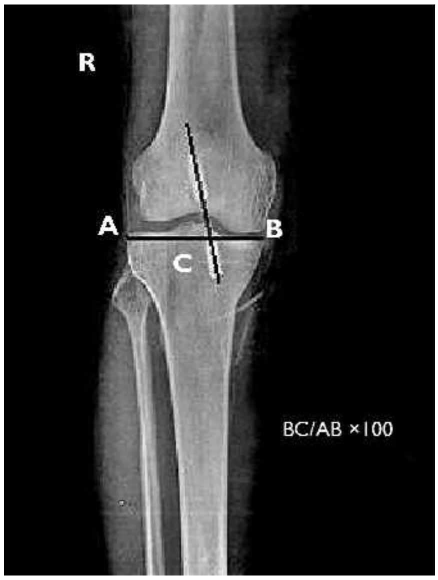

Fig. 2 Anteroposterior radiograph of the knee joint shows the coronal tibial tunnel position. AB represents the mediolateral diameter of the tibial plateau. Point C represents the intersection of a line through the axis of the tibial tunnel with the tibial plateau. The coronal tunnel position (percentage) is calculated by BC/AB × 100.

with open physes; (2) patients with an acute lesion of the ACL (i.e., if the interval between the injury and the operation was less than 30 days); (3) patients with other ligament tears; (4) patients who had any prior operation on the same knee; (5) patients with associated fractures involving the knee; (6) patients with injury to the contralateral knee; (7) patients in whom bioabsorbable interference screws were used that could not be visualised in the postoperative radiograph; and (8) patients in whom the presence of Grade III or IV degenerative changes according to the Outerbridge classification system was confirmed at arthroscopy.[9] The mean age of the patients at the time of surgery was 27 (range 16–43) years. The right knee was involved in surgery in 23 patients and the left knee in 18. Of the 41 patients, 14 had isolated ACL tears, while 12 had a medial meniscal injury and 11 had a lateral meniscal injury along with the ACL injury.

The surgical technique described by Mariani et al for BPTB grafts was adopted[10] and the surgery was performed by the senior authors. The central third of the patellar tendon, measuring 9 mm, was used. Notchplasty was not done routinely; it was performed only when the intercondylar notch was found to be narrow. The tibial tunnel was placed in line with the inner margin of the anterior horn of the lateral meniscus, just posterior to the centre of the ACL footprint lying about 6 mm anterior to the posterior cruciate ligament and 2–3 mm anterior to the peak of the medial tibial spine. The femoral tunnel was drilled transtibially using an external guide. The graft was then fixed with one interference screw each for the tibia and the femur, with the screw on the medial side of the graft. A partial medial and lateral meniscectomy was performed in 12 and 11 knees, respectively.

All patients were rehabilitated with the accelerated ACL rehabilitation protocol advocated for by Shelbourne and Nitz.[11] A written rehabilitation protocol with clear drawings of every single exercise was also provided to all the patients so as to achieve maximum compliance. Knee swelling was managed with rest, ice, nonsteroidal anti-inflammatory drugs and partial weight bearing. Muscle strengthening exercises were started on the first postoperative day with isometric quadriceps contractions and progressed to active closed-chain exercises by 4–6 weeks postoperatively. Patients were allowed full weight-bearing three weeks postoperatively and returned to running after three months.

True anteroposterior and lateral radiographs of the operated knee were obtained on the tenth postoperative day. The tibial tunnel position was identified by the placement of the interference screws used for graft fixation. The coronal and sagittal positions of the tunnel on the radiograph were determined using the method described by Odensten and Gillquist[2,4] (Figs. 1 & 2). All the measurements were taken by a blinded examiner who had no knowledge of the functional outcome of the patients. In order to ensure that these radiological measurements were reproducible, 41 radiographs were measured by the same investigator on separate occasions

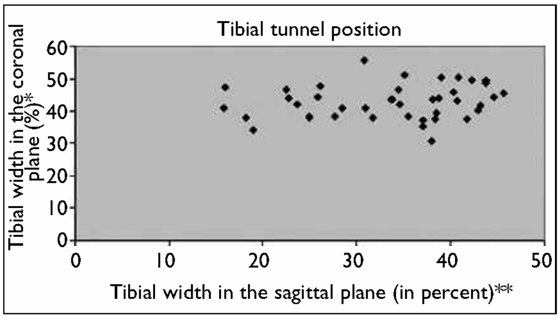

Fig. 3 Graph shows the distribution of the sagittal and coronal tibial tunnel position in 41 patients.
*Measured from the medial margin of the articular surface of the tibia. **Measured from the anterior margin of the articular surface of the tibia.

Table I. Outcomes of surgery in 41 knees as assessed by the Lysholm and IKDC scoring systems (n = 41).

Lysholm outcome	IKDC outcome			
	Normal	Nearly normal	Abnormal	Severely abnormal
Excellent	0	17	0	0
Good	0	15	1	0
Fair	0	1	7	0
Poor	0	0	0	0

IKDC: International Knee Documentation Committee

Table II. Univariate analysis of variables affecting the outcome.

Variable	p-value	
	Lysholm	IKDC
Age at surgery	0.59	0.32
Presence of associated meniscal injury	0.43	0.48
Tibial tunnel position in the coronal plane	0.31	0.12
Tibial tunnel position in the sagittal plane	< 0.01	< 0.01
Femoral tunnel position in the coronal plane	0.19	0.25
Femoral tunnel position in the sagittal plane	0.39	0.28
Coronal angle of tibial tunnel	0.32	0.27

IKDC: International Knee Documentation Committee

and 20 radiographs were measured independently by two investigators.

The patients were evaluated monthly by a blinded examiner for up to three months after surgery, every three months up to one year after surgery, and at two years thereafter. The modified Lysholm knee score was used for subjective evaluation of the knee post surgery. The final score at two years was then categorised into one of the four groups (Excellent: 95–100, Good: 84–94, Fair: 65–83 and Poor: < 64).[12] The International Knee Documentation Committee (IKDC) score was also used to assess the patients two years post surgery.[13] The final outcome categorised each patient into one of four groups (A: Normal, B: Nearly normal, C: Abnormal, D: Severely abnormal).

Statistical analysis was conducted using the Statistical Package for the Social Sciences version 13.0 (SPSS Inc, Chicago, IL, USA). A comparison of the differences between the groups was done using the Student's *t*-test, with one-way analysis of variance for the continuous variables, while the chi-square test was applied to compare differences among the categorical variables. A multivariate analysis of variance was used to study the effect of all the compounding variables. In all the tests, an alpha level of 0.05 was considered to be significant.

RESULTS

The interobserver variability ($p = 0.392$ for the sagittal position, $p = 0.335$ for the coronal position) and intraobserver variability ($p = 0.191$ for the sagittal position, $p = 0.089$ for the coronal position), performed by the Student's *t*-test, were not found to be statistically significant.

Although there was a wide variation in the tibial placement in the sagittal plane (range 16%–46%), in nearly two-thirds of patients, the tibial tunnel was within 30%–45% of the anteroposterior width of the tibial plateau. The position of the tibial tunnel in the coronal plane ranged from 31%–56% (mean 42.9%) (Fig. 3).

Of the 41 patients, 31 had either an excellent or a good outcome based on the Lysholm score, while 33 knees were found to be nearly normal based on the IKDC scoring system. No knee was graded as normal or severely abnormal on the IKDC score (Table I).

The age of the patient at the time of surgery, the presence of associated meniscal injury and the position of the tibial tunnel in the coronal plane, the position of the femoral tunnel and the coronal angle of the tibial tunnel did not influence the outcome. However, the position of the tibial tunnel in the sagittal plane did affect the knee function (Table II). Multivariate analysis of variance confirmed the same results ($p = 0.031$ for the tibial tunnel position in the sagittal plane).

A closer analysis of the results showed that a more posterior placement of the tunnel yielded better results (Table III and IV). The tibial tunnel placement of groups with fair outcome (mean 22.2%) was significantly anterior ($p < 0.01$) in comparison to that in the groups with excellent (mean 38.1%) and good (mean 34.1%) outcomes.

Of the 41 patients, 21 had an excellent or good outcome when the tibial tunnel was within the 35%–46% anteroposterior width of the tibial plateau (Table III). Analysis of the IKDC outcome also showed that knees

Table III. Distribution of the Lysholm outcome of patients based on the sagittal tunnel position groups (n = 41).

Sagittal tibial tunnel position (%)	Lysholm outcome		
	Excellent	Good	Fair
10–25	1	2	6
25.01–35	2	7	2
35.01–46	14	7	0

Table IV. Distribution of the IKDC outcomes in the sagittal tunnel position groups (n = 41).

Sagittal tibial tunnel position (%)	IKDC outcome	
	Nearly normal	Abnormal
10–25	4	5
25.01–35	8	3
35.01–46	21	0

IKDC: International Knee Documentation Committee

with an abnormal outcome (mean 22.9) had significantly ($p < 0.01$) anteriorly placed tibial tunnels compared to those with a near normal outcome (mean 35.9%). It was also observed that 21 of the 41 patients who had a nearly normal knee following surgery had their tibial tunnels placed within the 35%–46% anteroposterior width of the tibial plateau (Table IV).

DISCUSSION

There has been significant controversy over the years regarding the placement of the tibial tunnel for optimal knee functioning.(1-4,8) Earlier studies have demonstrated that medial placement of more than 40% and greater than 60° of the coronal angle of the tibial tunnel adversely affects the functional outcome; however, we found that the angle of the tibial tunnel and its positioning in the coronal plane did not affect knee functionality at all.(2,11) A probable cause for this result could be due to the reasonably consistent coronal placement of the tibial tunnel in the 35%–45% range and 50°–60° of the tibial tunnel angle, which would account for the similar mean in all the groups.

Clancy et al advocated for anterior graft placement as early as 1982, to ensure optimal knee functioning.(3) In contrast, other studies have found that anterior placement of the tibial tunnel leads to deficits in the knee range of motion.(5-8) Our study confirmed the hypothesis that the anterior placement of the tibial tunnel results in poor postoperative knee function. Although these patients did not have significant instability, they did demonstrate extension deficits (mean 7° using a fluid goniometre).

Our results suggest that the sagittal plane tibial tunnel position affects the functional outcome of the knee. Specifically, placing the tunnel in the anterior 25% of the tibial plateau was associated with a fair Lysholm score and an abnormal IKDC score. When the tibial tunnel was placed posterior to 25% of the anteroposterior width of the tibial plateau, this resulted in a more favourable outcome. This is comparable to the results of Romano et al.(2) Patients with their tibial tunnel in the 35%–46% anteroposterior width of the tibial plateau had the most favourable postoperative knee function, and this position is probably the ideal sagittal plane tibial tunnel placement. Such a placement can be identified by taking an intraoperative radiograph or by using a measuring device.

More recently, however, double-bundle ACL reconstruction has been proposed as an alternative to the conventional single-bundle technique. In a prospective randomised study comparing double-bundle and single-bundle reconstructions, Yasuda et al demonstrated better results with double-bundle reconstruction with respect to anterior stability compared to single-bundle reconstruction.(14) It has also been shown that in an anatomical double-bundle reconstruction, the tibial footprint of the anteromedial bundle lies significantly anterior in the tibial plateau, while the femoral footprint lies more inferiorly in the clockface. Moreover, studies have demonstrated that single-incision transtibial techniques are not always anatomic.(15) This could explain the poor results obtained with a transtibially drilled femoral tunnel among our patients. Furthermore, Shen et al have studied three techniques of drilling the femoral anteromedial tunnel: (1) drilling through the tibial anteromedial tunnel; (2) drilling through the tibial posterolateral tunnel; and (3) drilling through the accessory anteromedial portal. They observed that the tibial anteromedial tunnel was able to achieve the femoral anteromedial tunnel at its anatomic insertion site in only 10% of the knees, while the tibial posterolateral tunnel and the anteromedial portal could achieve this in 60%–99% of the knees, respectively.(16)

One of the limitations of this study is that it was not conducted in an isolated ACL tear, which would have been ideal. However, this would have reduced our study group to only 14 patients, as 66% of the study group had an associated meniscal tear. Although it was observed in the present study that meniscal injury did not make a statistically significant difference to the knee function at two years post surgery, it is likely that the long-term outcome in these patients would deteriorate. There were also no control or cohort matched groups in our study. In addition, this study did not investigate the effects of other variables inherent to the reconstruction, such as graft length, graft size and the intercondylar roof inclination.

In conclusion, the position of the tibial tunnel is intimately related to postoperative knee function in arthroscopically assisted ACL reconstruction using BPTB grafts. Placement of the tunnel within the anterior 25% width of the tibial plateau resulted in unfavourable knee function when the femoral tunnels were drilled transtibially. It was also noted that tunnels placed between the 35% and 46% anteroposterior width of the tibial plateau provided the maximum favourable results.

REFERENCES

1. Jones KG. Reconstruction of the anterior cruciate ligament. A technique using the central one-third of the patellar ligament. J Bone Joint Surg Am 1963; 45:925-32.
2. Romano VM, Graf BK, Keene JS, Lange RH. Anterior cruciate ligament reconstruction. The effect of tibial tunnel placement on range of motion. Am J Sports Med 1993; 21:415-8.
3. Clancy WG Jr, Nelson DA, Reider B, Narechania RG. Anterior cruciate ligament reconstruction using one-third of the patellar ligament, augmented by extra-articular tendon transfers. J Bone Joint Surg Am 1982; 64:352-9.
4. Odensten M, Gillquist J. Functional anatomy of the anterior cruciate ligament and a rationale for reconstruction. J Bone Joint Surg Am 1985; 67:257-62.
5. Howell SM, Clark JA. Tibial tunnel placement in anterior cruciate ligament reconstructions and graft impingement. Clin Orthop Relat Res 1992; 283:187-95.
6. 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; 19:276-82.
7. Howell SM, Clark JA, Farley TE. Serial magnetic resonance study assessing the effects of impingement on the MR image of the patellar tendon graft. Arthroscopy 1992; 8:350-8.
8. Yaru NC, Daniel DM, Penner D. The effect of tibial attachment site on graft impingement in an anterior cruciate ligament reconstruction. Am J Sports Med 1992; 20:217-20.
9. Outerbridge RE. The etiology of chondromalacia patellae. J Bone Joint Surg Br 1961; 43:752-7.
10. Mariani PP, Camillieri G, Margheritini F. Transcondylar screw fixation in anterior cruciate ligament reconstruction. Arthroscopy 2001; 17:717-23.
11. Shelbourne KD, Nitz P. Accelerated rehabilitation after anterior cruciate ligament reconstruction. Am J Sports Med 1990; 18:292-9.
12. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res 1985; 198:43-9.
13. Hefti F, Müller W, Jakob RP, Stäubli HU. Evaluation of knee ligament injuries with the IKDC form. Knee Surg Sports Traumatol Arthrosc 1993; 1:226-34.
14. Yasuda K, Kondo E, Ichiyama H, Tanabe Y, Tohyama H. Clinical evaluation of anatomic double-bundle anterior cruciate ligament reconstruction procedure using hamstring tendon grafts: comparisons among 3 different procedures. Arthroscopy 2006; 22:240-51.
15. Arnold MP, Kooloos J, van Kampen A. Single-incision technique misses the anatomical femoral anterior cruciate ligament insertion: a cadaver study. Knee Surg Sports Traumatol Arthrosc 2001; 9:194-9.
16. Shen W, Forsythe B, Ingham SM, Honkamp NJ, Fu FH. Application of the anatomic double-bundle reconstruction concept to revision and augmentation anterior cruciate ligament surgeries. J Bone Joint Surg Am 2008; 90:20-34.