

## The influence of graft placement on clinical outcome in anterior cruciate ligament reconstruction

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### Abstract

**Purpose:** the aim of the present study was to investigate the influence of graft tunnel position on both clinical outcome and instrumental knee stability in patients submitted to arthroscopic ACL reconstruction using a bone-patellar tendon-bone (BPTB) graft.

**Methods:** thirty patients (24 men and 6 women) who underwent ACL reconstruction performed using an autologous bone-patellar tendon-bone graft were studied at a mean follow-up of 18 months. Clinical outcome was assessed on the basis of the Lysholm score, Tegner activity level, International Knee Documentation Committee (IKDC) subjective form and the Short Form-36. Clinical outcomes were correlated with both femoral and tibial tunnel placement measured on standard anteroposterior and lateral knee radiographs, in accordance with established guidelines.

**Results:** tibial tunnel position on the lateral view correlated significantly with both the IKDC subjective form ( $r = -0.72$ ;  $p < 0.05$ ) and the Lysholm score ( $r = -0.73$ ;  $p < 0.05$ ). Tibial tunnel position on the lateral view also correlated with stability measured using a KT-1000 arthrometer at 30N of force ( $r = 0.57$ ;  $p < 0.05$ ). No correlation was found between  $\alpha$  angle and anteroposterior (AP) laxity measured by KT-1000 arthrometer. No significant correlation was found between femoral tunnel position (on either view) and Lysholm score, IKDC score and Tegner activity level. Similarly, no correlation

was found between AP laxity measured by KT-1000 arthrometer and femoral tunnel position.

**Conclusions:** these results suggest that the more anterior the placement of the tibial tunnel, the better the clinical outcome will be. On the basis of literature data and our findings, we discuss the hypothesis that there exists a "correct area" for tunnel placement, making it possible to obtain the best results.

**Level of evidence:** Level IV, case series.

**Keywords:** anterior cruciate ligament, graft placement, tibial tunnel, femoral tunnel, clinical outcome.

### Introduction

The literature shows that correct femoral and tibial tunnel placement is one of the most important requisites for a successful anterior cruciate ligament (ACL) reconstruction (1-7), in terms of its overall impact on the patient's quality of life. Instead, incorrect graft positioning is one of the most frequent causes of ACL reconstruction failure. Howell et al. showed that femoral tunnel placement anterior to the Blumensaat line can result in graft impingement by the intercondylar roof and thus lead to graft failure (1, 2). Zijl et al. found poor outcomes with placement of the tibial tunnel anterior or posterior to the extension of the Blumensaat line, and good outcomes with central positioning of the graft (i.e., when the Blumensaat line fell within the tunnel) (3). Romano et al. reported restricted knee motion with anterior placement of the tibial tunnel (4). Furthermore, Behrend et al. found that the more anterior the position of the femoral tunnel, the poorer was the score obtained on the In-

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ternational Knee Documentation Committee (IKDC) rating scale (5).

In the study by Khalfayan et al., the clinical results correlated positively with posterior femoral tunnel placement on lateral radiograph and negatively with excessive anterior tibial tunnel placement (6).

Different radiographic techniques for measuring tunnel placement are reported in the literature (6-12). Only a few prospective studies have evaluated the effect of graft placement on the clinical outcome of patients (6, 13, 14). The aim of the present study was to investigate the influence of tunnel position on different measures of clinical outcome and on instrumental knee stability in patients submitted to arthroscopic ACL reconstruction using a bone-patellar tendon-bone (BPTB) graft. We hypothesized that the tunnel position influences the clinical outcome and that it is possible to determine the best position for obtaining optimal ACL reconstruction results.

## Methods

Thirty patients (24 men and 6 women) submitted to ACL reconstruction using an autologous BPTB graft were studied at a mean follow-up of 18 months. The mean age of the patients was  $24.2 \pm 6.8$  years at the time of the surgery. The diagnosis of ACL injury was clinical and confirmed by magnetic resonance imaging. The exclusion criteria were bilateral ACL injury and/or reconstruction, other significant knee ligament injuries, chondroplasty and meniscal repair at the time of surgery. Each patient underwent subjective evaluation for which we used the Lysholm knee scoring scale, Tegner activity level scale, validated Italian version of the IKDC subjective questionnaire (15, 16) and the Short Form-36 (SF-36) questionnaire (17, 18). Postoperative clinical testing included anteroposterior (AP) laxity measurement using the KT-1000 while imaging consisted of standard AP and lateral X-rays to measure tunnel positioning. All the patients completed the subjective evaluation with all the instruments.

The Lysholm knee scoring scale is an eight-item questionnaire used to measure knee function, symptoms and disability. It gives a maximum score of 100.

The Tegner activity level scale is a subjective scale that allows the patient's pre-injury activity level and present activity level to be documented and compared. By

comparing the pre-injury and post-surgery Tegner activity scores, it is possible to determine whether the patient has managed to return to his previous level of sporting activity. The different levels of sporting activity are classified using a scale ranging from 0 (corresponding to a state of complete inactivity) to 10 (corresponding to high-level competition).

The IKDC rating scale consists of both a subjective questionnaire and an objective evaluation. The IKDC Subjective Knee Form consists of 18 items that inquire about symptoms, function and sports activity relevant to orthopaedic disorders of the knee, such as meniscal and ligament injuries, patellofemoral disease and articular cartilage lesions. This questionnaire is a part of a complete Documentation Form promoted by the IKDC evaluation system that includes personal information (e.g., demographic and educational data, comorbidity index), a general health-status questionnaire (SF-36), and an objective form on clinical and radiographic data ([www.esska.org](http://www.esska.org)). An ordinal method is used to score the response to each item and the questionnaire provides a single main score. Higher IKDC Subjective Knee Form scores indicate a lower level of symptoms and a higher level of function, and lower scores indicate a higher level of symptoms and a lower level of function. Thus, the maximum score of 100 corresponds to no symptoms and no limitations in activities of daily living or sports activities.

The SF-36 questionnaire is used to investigate the general health status of the patient. It consists of 36 items that cover eight domains corresponding to eight different scales, called: Physical Functioning (PF), Role-Physical (RP), Bodily Pain (BP), General Health (GH), Vitality (VT), Social Functioning (SF), Role Emotional (RE), Mental Health (MH). The domains are clustered into two summary measures to give a Physical Composite Score (PCS) and a Mental Composite Score (MCS). A poor PCS score indicates the presence of major physical impairment, pain, asthenia, i.e. a negative health status evaluation, while a poor MCS score identifies the presence of psychological disease.

The KT-1000 examination was performed with the patient in the supine position. The legs were placed on the thigh support and foot rest, which positioned the knees in  $20^\circ$  of flexion and at  $15 \pm 5^\circ$  of external rotation. The arthrometer was applied to the anterior aspect of the leg and secured in place with circumferential Velcro straps. The two sensor pads were placed at the

patella and the proximal tibia (tibial tubercle). The subject was asked to relax. Laxity measurements, expressed in millimeters, were performed preoperatively and postoperatively in the uninjured knees and in the injured knees at 15 pounds (67 Newtons, N), 20 pounds (89N) and 30 pounds (133N) of force according to the procedures indicated by the manufacturer (19). The value obtained at 15 pounds of anterior pull were subtracted from those obtained at 20 pounds of anterior pull to determine the end point compliance index, that is, the end-point stiffness. Also maximal manual (Mm) and maximal personal (Mp) measurements were taken. Each test was performed three times on each knee and the mean of these tests was recorded. If the excursion of any measurement differed by more than 2 mm, the test was deleted and the sequence was repeated.

Radiographic measurements of tunnel position were performed in accordance with the guidelines of Amis et al. (8). To assess the tibial tunnel position on the AP X-ray view we measured the  $\alpha$  angle (5): this is the angle between the center of the tibial tunnel and the line tangent to the tibial plateau (Fig. 1). On the lateral X-ray view the tibial tunnel position was determined from the anterior corner of tibial plateau to the center of the tibial tunnel and compared to the entire length of the tibial plateau (10) (Fig. 2). To evaluate the femoral tunnel position on the lateral view, we calculated the distance from the posterior surface of the femoral condyle along the Blumensaat line and compared this to the entire length of the femoral condyle. To account for variations in skeletal size and radiographic magnification, we converted all measurements to percentage values (11). To

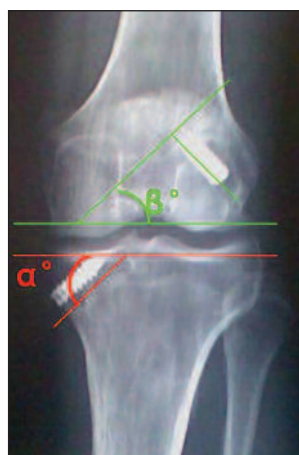
evaluate the femoral tunnel position on the AP view we measured the  $\beta$  angle: this is the angle between the center of femoral tunnel and the line perpendicular to the tibial plateau (Fig. 1). For all variables, the normality of data was ascertained using the Kolmogorov-Smirnov test. Data are presented as mean  $\pm$  standard deviation. A correlation matrix was used to evaluate relationships between the variables. Correlations were regarded as significant at  $p < 0.05$ .

## Results

The patients recorded a mean Lysholm score of  $92.4 \pm 8$  (ranging from 75 to 100); their mean preoperative Tegner activity level was  $7.75 \pm 1.61$  versus a postoperative score of  $7.07 \pm 1.54$ . Their mean IKDC subjective score was  $83.8 \pm 14$ , ranging from 48.27 to 95.4. The SF-36 data are reported in Table 1 and the KT-1000 results in Table 2. On the AP X-ray view, the mean  $\alpha$  angle of the tibial tunnel was found to be  $29.7 \pm 11.6^\circ$ . On the lateral X-ray view the mean tibial tunnel position was  $44 \pm 6\%$ . As regards the measurement of femoral tunnel placement, on the AP view the  $\beta$  angle of the femoral tunnel was  $27 \pm 11^\circ$ , whereas on the lateral view the femoral tunnel position was  $30 \pm 10\%$ . The correlation matrix showed a significant correlation between tibial tunnel placement on the lateral view and both subjective IKDC score ( $r = -0.72$ ;  $p < 0.05$ ) and Lysholm score ( $r = -0.73$ ;  $p < 0.05$ ): the more anterior the position of the tunnel, the better the clinical outcome. Tibial tunnel position on the lateral view also correlated with stability measured using a KT-1000 arthrometer at 30N of force ( $r = 0.57$ ;  $p < 0.05$ ). No correlation was found between  $\alpha$  angle and AP laxity measured by the KT-1000 arthrometer. No significant correlation was found between femoral tunnel position and Lysholm score, IKDC score or Tegner activity level on either view. Similarly, no correlation was found between AP laxity measured by KT-1000 arthrometer and femoral tunnel placement.

## Discussion

In the literature there are several accepted ACL reconstruction techniques, but it is possible to find different opinions regarding tunnel placement. Tunnel position



**Fig. 1.** Femoral and tibial tunnel measurement technique on the anteroposterior view.



**Fig. 2.** Femoral and tibial tunnel measurement technique on the lateral view.

**Table 1.** KT-1000 anteroposterior laxity measurement results (means and standard deviations) and maximal manual (Mm) and maximal personal (Mp) values (means and standard deviations).

KT-1000 (Newtons)	Healthy knee (mm)	Operated knee (mm)	side-to-side difference (mm)
15	4.5±2.2	5.4±1.8	1.95±1.4
20	5.5±2.2	6.5±1.9	2±1.54
30	6.8±2.7	7.4±2.2	2.5±2.33
Mm	7.4±3.2	7.88±2.9	2.5±2.4
Mp	6.6±2.6	8.5±2.5	2.7±2.2

**Table 2.** SF-36 Questionnaire results: mean values and standard deviations.

Items	Mean ± SD
Comorbidity Index	0.42±0.8
Physical function	93.2±8
Role-Physical	94.6±14
Bodily Pain	85.5±15
General Health	82.6±11
Vitality	71.4±8
Social Functioning	86.8±17
Role Emotional	92.8±19
Mental Health	73.7±12
Physical Composite Score	55±4
Mental Composite Score	50.8±6
Physical Health and Pain	91.2±10

in ACL reconstruction is widely discussed in relation to clinical outcome (1, 2, 20). However, no univocal relationship between tunnel position and outcome has been demonstrated using instrumental measures and subjective scores.

Khalfayan et al. found the best clinical results (evaluated as Tegner and Lysholm scores) in patients in whom the femoral tunnel was placed in a position 60%, or more, posteriorly along the Blumensaat line from anterior to posterior and tibial tunnel placement ranged from 20 to 40% along the tibial plateau (6). Moisala et al. found that more posterior femoral and tibial graft placement was associated with a better Lysholm score, using a specific sum score (14). Behrend et al. found a significant correlation between femoral tunnel position and IKDC objective results (5): the more anterior the position of the femoral tunnel the lower the IKDC objective results. Similar results were found by other Authors (6, 10, 13), and also by Lee et al. (21), although in their study subjective outcomes were influenced by graft inclination in the pivot shift-positive group (better results with more oblique ligament positioning).

The literature suggests that the correct ligament position

can be considered to be about 27% (±7%) along the total femoral depth on the lateral femoral view and that the tibial tunnel position should be around 44% (±4%) along the tibial plateau on the lateral view (5, 22-24). These literature findings seem to indicate the possibility of identifying a “correct area” for femoral and tibial tunnel placement can guarantee satisfactory stability of the knee.

Our results are consistent with these previous reports and confirm the importance of this graft placement (1, 2, 22); in fact in our patients the tibial tunnel position corresponding to 44.0±6%, measured on lateral X-ray images, was correlated with satisfactory clinical and instrumental results. Femoral tunnel placement corresponding to 30±10%, measured on lateral view X-ray images, showed good results in terms of both subjective and mechanical stability of the knee. These results may be interpreted in the light of the fact that all the reconstructed ACLs in our patients were in the “correct area” described above. The small differences in ACL positioning in our population, statistically revealed, do not seem to have clinical relevance. Even statistically significant differences were not clinically relevant for the patients. Nevertheless, within the “correct area” we were able to establish that more anterior placement of the tibial tunnel corresponded to better subjective results.

With regard to coronal imaging measurements, no univocal position is considered “correct”. Some papers studied clinical results and position on the coronal view (20, 25), stating that the 10 o’clock position could guarantee better results without instrumental confirmation. A cadaveric study involving the application of biomechanical rotatory loads demonstrated that a 10 o’clock graft position was better than an 11 o’clock one (20). Jepsen et al. (25) found a positive correlation between IKDC subjective results and femoral tunnel position at 10 o’clock (quadrant method), and no correlation



between IKDC objective results and femoral tunnel position. With regard to coronal view imaging, our study found no significant correlation between tibial tunnel angle ( $\alpha$  angle) and AP laxity measured by KT-1000 arthrometer; similarly, Howell et al. (1, 2) found that changing the tibial angle within a range below  $75^\circ$ , as in our study, did not affect anterior laxity whereas a tibial angle above  $75^\circ$  was associated with more laxity and flexion deficit.

The weaknesses of the present study, which could have introduced biases, are the fact that we did not study graft tensioning, which can substantially change clinical outcome, the mechanical measures detected by KT1000 were not as sensitive and specific as reported in the literature, and the imaging measures could be inaccurate; moreover, it is possible that a knee can present intrinsic stability even in the presence of a complete ACL lesion. Moreover, there is no validated Italian version of either the Lysholm scale or the Tegner activity level scale.

In conclusion, in line with what has been reported in the literature, we confirm the existence of a significant correlation between tibial tunnel placement and clinical outcome; on the basis of our findings, we were able to hypothesize a so-called correct area for tunnel placement. We believe that further study, focused on ACL reconstruction position, could aim to clarify the limits of the “correct area”.

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