Patellar tendon graft position after anterior cruciate ligament reconstruction

Interobserver variability on lateral radiographs

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We compared the reliability and validity of graft position measurements made by 4 orthopedic surgeons on intraoperative radiographs obtained using fluoroscopic control and postoperative radiographs obtained from the same 17 patients 6 weeks after ACL reconstruction. Measurements from postoperative radiographs varied significantly more than those from intraoperative radiographs. There was little agreement between the postoperative and intraoperative measurements of the tibial and femoral graft position. We conclude that postoperative radiographs are not a sufficient tool for assessing graft placement after ACL reconstruction using patellar tendon autografts. In order to consider graft position in follow-up studies and to compare results from various surgeons, we suggest intraoperative fluoroscopy to produce radiographs for accurate and reliable measurements.

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Graft placement is important in anterior cruciate ligament (ACL) reconstruction (Harner et al. 1994, Howell and Barad 1995). However, only a limited number of follow-up studies (Boden et al. 1996, Khalfayan et al. 1996) have included graft position as a parameter. In order to consider graft position in follow-up studies, consensus on the criteria for measuring graft position on radiographs is needed. Specifically, a reliable and valid method with low interobserver variation is necessary so that graft position measurements obtained by numerous surgeons can be compared.

We assessed two methods for acquiring lateral radiographs after ACL reconstruction with the objective of determining the validity and reliability of graft position measurements. Measurements were acquired from intraoperative radiographs and compared to those from postoperative radiographs. We hypothesized that measurements from postoperative radiographs would be less reliable than those from intraoperative radiographs.

Patients and methods

ACL reconstruction using middle-third patellar tendon autograft and endoscopic fixation was performed on 17 subjects (13 men). Their average age at surgery was 26 (16–37) years. The surgical technique included the use of aiming guides during drilling of the tibial and femoral tunnels. Tibial tunnel placement was referenced to the location of the posterior cruciate ligament (PCL-oriented) using Arthrex (Arthrex Inc, Naples, FL, USA) equipment (Morgan et al. 1995). Fluoroscopic images were obtained before and after guidewire insertion to verify placement, and radiographic films were obtained before overdrilling the guidewire (Figure 1). The tibial tunnel was created by overdrilling the guidewire with an 11 mm cannulated drill. Tibial fixation was obtained with an 8 mm interference screw placed anterior to the graft.

The femoral guiding instrument was positioned with a transtibial, 7 mm offset, over-the-top hook (Morgan et al. 1995). Lateral fluoroscopy was again used to guide placement of the femoral guidewire, and radiographs were obtained to verify its position. The femoral graft tunnel was created using a 10-11 mm cannulated drill. The femoral guidewire was then drilled through the anterior cortex and used to pull the graft into position (Figure 2). A 7 mm interference screw was used to fix the graft in the dorsal/medial aspect of the tunnel. Arthroscopic and fluoroscopic feedbacks were used to assist with graft placement

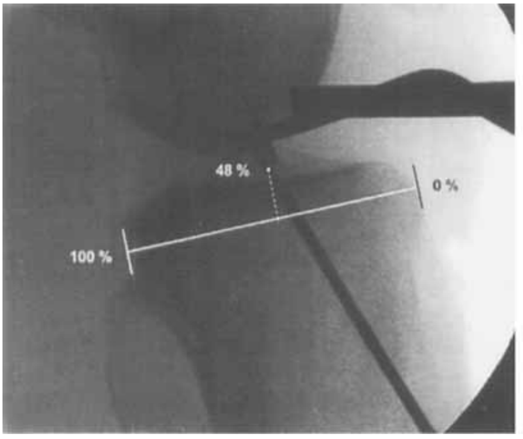

Figure 1. Intraoperative fluoroscopic image with tibial guidewire and measurement by Staubli's technique.

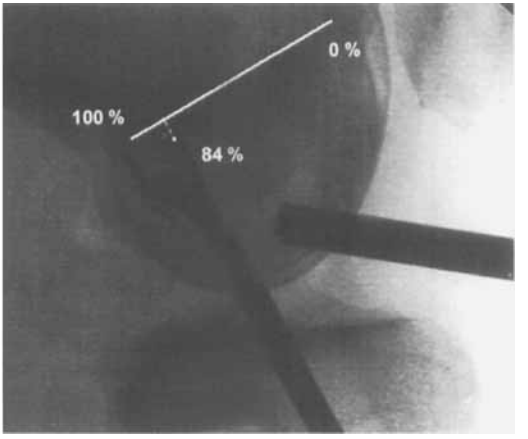

Figure 2. Intraoperative fluoroscopic image with femoral aiming device and guidewire, with measurement by Harner's (modified) technique.

and to check interference screw placement. Care was taken to ensure adequate stability of the guidewire so that tunnel locations were precisely centered along the guidewire.

Intraoperative lateral fluoroscopic images were obtained on all subjects with the guidewires or drill bits in position to mark the tibial and femoral tunnel locations clearly (Figures 1 and 2). A lateral radiograph was taken in all subjects at their 6-week follow-up evaluation (Figure 3). Radiology technicians were instructed to produce lateral radiographs in full extension, taking care to ensure overlapping contours of both medial and lateral femoral condyles. Only cases with properly aligned intraoperative and postoperative radiographs were included in this study. 4 orthopedic surgeons experienced with the technique of ACL reconstruction independently identified the tibial and femoral tunnel locations and measured the graft position on each of the intraoperative and postoperative radiographs.

Methods described by Staubli and Rauschning (1994) were used for measuring the graft position in the proximal tibia. The anterior and posterior tibial cortex were located and a line was drawn perpendicular to the tibial axis at the proximal tibia connecting the anterior and posterior cortex. On the intraoperative radiographs, the linear distance from the anterior cortex to the tip of the guidewire at the entry point into the joint was measured along the line drawn perpendicular to the tibial axis (Figure 1). On the postoperative radiographs, the linear distance from the anterior cortex to the center of the articular opening of the drill tunnel was measured along the line drawn perpendicular to the tibial axis (Figure 3). All measurements were normalized as a percentage of the total anteroposterior tibial dimension.

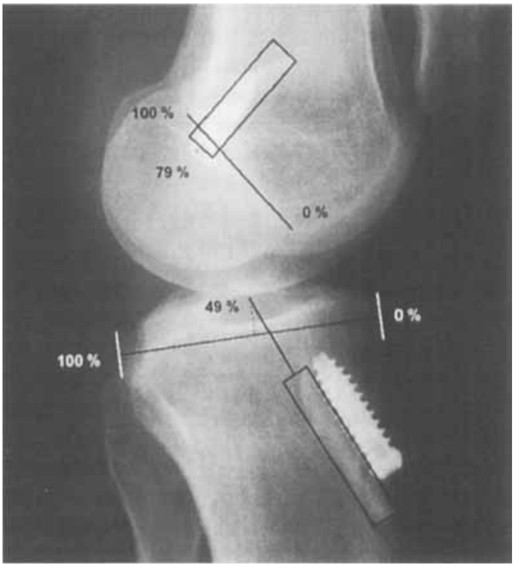

Figure 3. Postoperative radiographic image with bone blocks and interference screws. Measurement techniques shown.

A modification of Harner's method (Harner et al. 1994), using the intercondylar notch (Blumensaat's) line as a reference, was used to measure the graft position in the distal femur. On the intraoperative radiographs, the distal entry point of the K-wire into the femur was identified. This point was projected onto the intercondylar notch by a line drawn perpendicular to Blumensaat's line (Figure 2). On the postoperative radiographs, the center of the articular opening of the drill tunnel cannot be visualized. The graft margins were outlined and a line intersecting the center of the graft and the intercondylar notch was drawn perpendicular to Blumensaat's line (Figure 3). The distance

Table 1. Tibial graft position. Mean (SD) [range]

Surgeon	Intraoperative graft position %	Postoperative graft position %	Difference	P-value	Correlation r (p)
1	47 (3)	41 (5)	7 (4) [0–14]	< 0.01	0.47 (0.06)
2	47 (6)	42 (4)	6 (5) [1–22]	< 0.01	0.48 (0.05)
3	44 (5)	43 (6)	5 (5) [1–15]	0.44	0.15 (0.57)
4	45 (5)	44 (5)	4 (3) [0–8]	0.22	0.63 (0.01)

Table 2. Femoral graft position. Mean (SD) [range]

Surgeon	Intraoperative graft position %	Postoperative graft position %	Difference	P-value	Correlation r (p)
1	80 (3)	74 (5)	7 (4) [1–15]	< 0.01	0.13 (0.62)
2	73 (5)	58 (9)	15 (7) [0–25]	< 0.01	0.72 (< 0.01)
3	76 (4)	80 (8)	9 (5) [2–20]	0.07	0.20 (0.47)
4	77 (4)	77 (7)	5 (4) [0–11]	0.98	0.29 (0.27)

from the intersection point on Blumensaat's line to the anterior margin of the intercondylar notch was measured on both radiographs. These measurements were normalized as a percentage of the total anteroposterior length of Blumensaat's line.

Graft position measurements by each surgeon were grouped according to the measurement site (tibia or femur) and the radiographic image type (intraoperative or postoperative) for statistical analysis. Analysis of variance for repeated measures and the Student-Newman-Keuls post-hoc multiple comparison were used to compare tibial and femoral graft positions measured on each radiograph by each surgeon. The differences between the intraoperative and postoperative data for each surgeon were calculated. The validity of measurements from postoperative radiographs was established by calculating correlation coefficients (Pearson's Correlation (r)) with the criterion data obtained from intraoperative radiographs. Plots of the postoperative data versus the intraoperative data were generated and their level of agreement was compared to a line of equality indicating perfect agreement. Intraclass correlation coefficients (ICC) (Shrout and Fleiss 1979) were calculated to determine the relative contributions of intersubject and interobserver variations to the overall measurement reliability.

Results

The mean graft position from intraoperative radiographs ranged from 44% to 47% at the tibial site and 73% to 80% at the femoral site. The mean graft position from postoperative radiographs ranged from 41% to 44% at the tibial site and 58% to 80% at the femoral site. There were significant differences between the measurements from the two radiographs when each surgeon's data were compared (Tables 1 and 2). Mean absolute differences between the intraoperative and postoperative measurements by each surgeon varied from 4% to 7% for the tibial graft position and 5% to 15% for the femoral graft position. When all measurements were considered, there was a low correlation between the intraoperative and postoperative measurements of the tibial ($r = 0.39$, $p = 0.006$) and femoral ($r = 0.46$, $p < 0.001$) graft positions. Only one surgeon (4) had statistically similar mean position measurements and a significant correlation between the intraoperative and postoperative measurements of tibial graft position (Table 1). None of the surgeons had statistically similar mean position measurements and a significant correlation between the intraoperative and postoperative measurements of femoral graft position (Table 2). This shows that high correlation does not necessarily indicate that the measurements are in agreement, as further demonstrated by the large differences between measurements by each surgeon. Measurements from postoperative radiographs did not consistently over- or underestimate the criterion graft position and had lower intraclass correlation coefficients for both the tibial and femoral graft positions when compared to measurements of intraoperative radiographs (Table 3). Low intraclass correlation coefficients indicate that measurement errors, not differences between subjects, largely contributed to variations in the data.

Discussion

The importance of graft placement in successful ACL

Table 3. Reliability of tibial and femoral graft position measurements. Intraclass correlation coefficients (ICC)

Location	Radiograph	ICC
Tibial site	Intraoperative	0.52
	Postoperative	0.44
Femoral site	Intraoperative	0.32
	Postoperative	0.13

reconstruction has been shown (Howell et al. 1991, Amis and Zavras 1995, Lintner et al. 1996) and measurements of graft position are beginning to be included in outcome studies (Boden et al. 1996, Khalfayan et al. 1996). Since radiographic parameters and three-dimensional isometric graft placement are correlated (Colette et al. 1996), graft position is routinely measured on postoperative radiographs (Harner et al. 1994, Bernard et al. 1997). However, the validity and reliability of these measurement techniques have not been established. We measured the location of ACL grafts, using Staubli's technique (Staubli and Rauschning 1994) for the tibia, and a modification of Harner's technique (Harner et al. 1994) for the femur. We found that the tibial and femoral graft positions as assessed on postoperative radiographs differed significantly from the graft positions measured on intraoperative radiographs. When the effect of various observers was assessed, higher interobserver agreement was achieved and measurement variability decreased when intraoperative radiographs were used. We conclude that postoperative radiographs are unreliable for measuring graft position after ACL reconstruction. More reliable measurements of graft position can be obtained from intraoperative radiographs taken with the drill guidewires in-situ.

Several factors inherent to the surgical technique and radiographic images may have influenced our findings. First, the interference screw was placed on the anterior side of the bone block in all cases which could have pushed the graft more posterior such that measurements of intraoperative tunnel position would not estimate actual graft position. However, measurements from the postoperative images did not consistently show a more posterior location than those from the intraoperative images. This suggests that systematic divergence between the drill tunnel and bone block did not occur during screw fixation. Guiding instrumentation enabled a stable guidewire position to be maintained, which limited any drift during overdrilling. Secondly, the observers commented that it was especially difficult to see the position of the femoral bone block on the postoperative radiographs since the margins were often obscured by the interference screw and the surrounding bone. This may have contributed to greater variation in the measurements from the postoperative images. In contrast, guidewires were easily identified in the intraoperative images, which facilitated identification and measurement of the graft position.

Postoperative radiographs have been routinely used to determine the graft position. However, measurement techniques based on these radiographs are limited by errors in knee position, inadequate contrast, and difficulties in locating the tibial and femoral tunnels and fixation devices (Boden et al. 1996). Identification of the graft tunnels and the approximate bone block position requires either slight bone sclerosis to highlight the tunnel edges or the presence of fixation devices. While bone tunnel sclerosis may become more obvious in time due to graft movement in the tunnel, especially at the tibial site (Fahey and Indelicato 1994), such tunnel demarcation is not always present at follow-up. These difficulties in image acquisition and identification of the graft may have contributed to the larger variability we observed in the femoral graft position measurements on postoperative radiographs. When confined by such limitations, reliable measurements were not obtained and the measurement errors we encountered would accumulate with any multi-center outcome comparisons. Although CT or MRI could be useful for postoperative visualization and measurement of the bone block position, we are unaware of any reliable and reproducible methods that have used them.

In contrast, several factors associated with intraoperative radiographs facilitate the identification and measurement of graft position for incorporation into follow-up studies (Halbrecht and Levy 1993, Goble et al. 1995). Intraoperative fluoroscopy enabled the knee to be positioned for exact lateral radiographic projections, which limits rotation errors in the measurements. Images were obtained with the tunneling hardware in-situ, which delineated the exact location of the tibial and femoral tunnels. Although more reliable data were obtained from the intraoperative images, improvements in the measurement technique are still necessary to reduce measurement variability and error. Other methods for measuring graft position relative to anatomic landmarks in radiographic images need to be investigated. Since surgical methods with fluoroscopy are used to obtain the proper tunnel position (Halbrecht and Levy 1993, Larson et al. 1995), only minimal accommodations may be required to expand the use of this existing technology. Thus, intraoperative fluoroscopy can be readily utilized to produce radiographs for accurate and reliable graft position measurements. The use of such measurements in future prospective studies will eventually help to identify the most appropriate graft placement at the tibial and femoral sites to ensure optimal outcomes after ACL reconstruction. We are following this patient group to find any correlation between graft placement and outcome.

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