Original Articles

Arthroscopic Visualization Is a Reliable Method of Confirming Femoral Button Placement During Anterior Cruciate Ligament Reconstruction

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Purpose: To compare arthroscopic visualization with intraoperative fluoroscopy for confirming proper femoral button placement during ACLR. **Methods:** Fifty consecutive patients undergoing soft-tissue ACLR between March 2021 and February 2022 were evaluated for inclusion in this study. Both primary and revision ACLR cases using suspensory fixation were included. Surgeons rated their confidence of proper button placement from both an intra-articular perspective (through the femoral tunnel) and an extra-articular perspective (through the iliotibial band) by grading confidence with a Likert scale. Fluoroscopy was also performed for confirmation of proper button placement. **Results:** Fifty consecutive patients (35.1 ± 14.5 years of age) with soft-tissue ACLR were included. Mean surgeon Likert confidence scores for accurate button placement were as follows: 4.1 of 5 ± 0.9 from an intra-articular perspective, 4.6 of 5 ± 0.7 from an extra-articular perspective, and 8.7 of 10 ± 1.4 based on the sum of intra- and extra-articular perspectives. Fluoroscopic findings demonstrated that 48 of 50 cases had an appropriate flipped button on the lateral cortex of the femur. I total, 2 of 50 had soft-tissue interposition. Cases in which surgeons had high confidence from both intra- and extra-articular perspectives (≥9/10 sum score) were indicative of proper button placement 97% of the time. **Conclusions:** Arthroscopic visualization is a reliable method of confirming femoral button placement during ACLR and is sufficient to rule out intraoperative fluoroscopy during surgery. ACLR cases with high surgeon confidence from both intra- and extra-articular perspectives (sum score of 9 or greater out of 10) resulted in proper femoral button placement in 97% of cases as confirmed by intraoperative fluoroscopy. **Level of Evidence:** Level II, prospective cohort study.

A commonly used method of anterior cruciate ligament (ACL) reconstruction (ACLR) involves suspensory fixation of soft-tissue grafts.[1,2] Intraoperative fluoroscopy is often implemented during fixation of the graft to confirm proper button placement on the femoral cortex. This technique has been invaluable to clinicians, as errors in button placement are detected by intraoperative fluoroscopy as frequently as 25.5% of cases.[3] Although valuable, intraoperative fluoroscopy may not be practical to some clinics because of the associated risks, additional cost, or limited availability of the fluoroscope. Surgical techniques have been described to circumvent the need for intraoperative fluoroscopy during femoral button fixation through direct visualization of the fixed button. One technique uses the anteromedial portal to visualize the femoral tunnel from an intra-articular perspective,[4] whereas another commonly described technique uses a lateral portal to obtain an extra-articular perspective of the button fixed on the femoral cortex.[4,5] However, there is limited literature investigating the reliability of direct visualization for ensuring proper fixation in comparison with intraoperative fluoroscopy.

The purpose of this study is to compare arthroscopic visualization with intraoperative fluoroscopy for confirming proper femoral button placement during ACLR. We hypothesized that arthroscopic visualization would be as reliable as intraoperative fluoroscopy, and that

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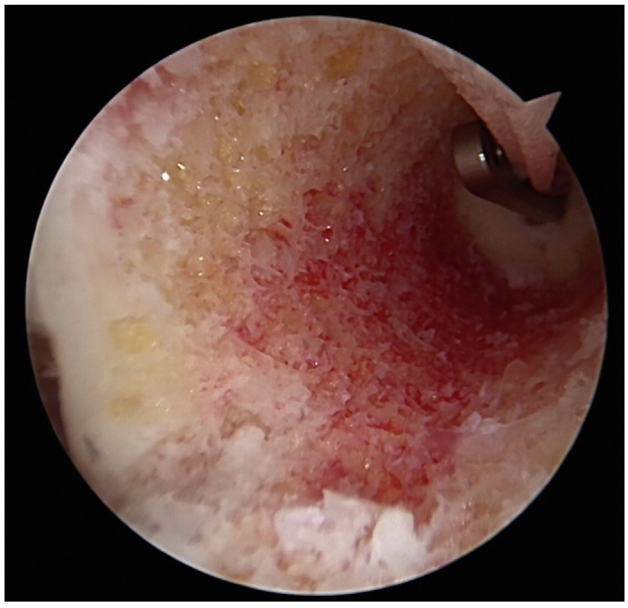

Fig 1. This is the intra-articular perspective, visualizing the femoral button being passed through the bony aperture from inside of the ACL graft tunnel in a subject's left knee. (ACL, anterior cruciate ligament.)

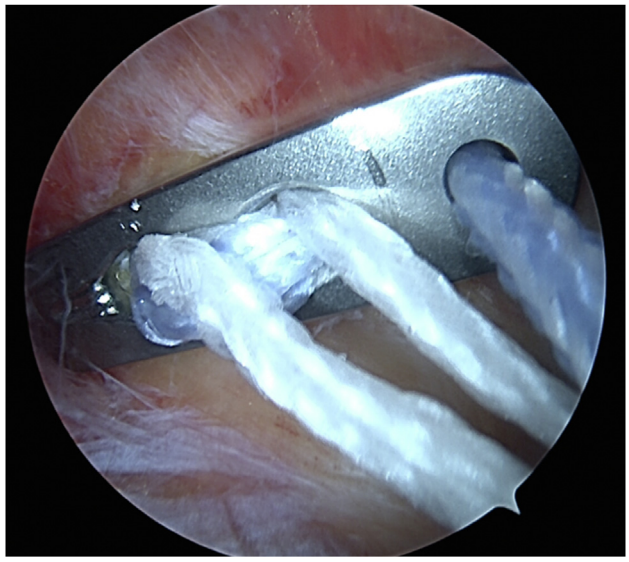

Fig 2. This is the extra-articular perspective, directly visualizing the button fixed to the lateral femoral cortex from the lateral portal passed the iliotibial band in a subject's left knee.

sum-articular Likert scores of 9 or greater out of 10, implying 5 out of 5 confidence for at least one perspective, would be sufficient to rule out the need for intraoperative fluoroscopy during femoral button fixation of an ACLR.

Methods

This study was reviewed and qualified to receive institutional review board exempt status by Greenwich Hospital Institutional Review Board (#2021007). Consecutive ACLR cases performed at an ambulatory surgery center using hamstring or quadriceps grafts were identified from March 2021 through February 2022. Patients undergoing both primary and revision surgeries were included. We excluded patients receiving patellar tendon bone grafts since we did not use femoral buttons during this type of surgery. Surgeons used an adjustable loop (ACL TightRope Arthrex Inc., Naples, FL) button system.

Confidence scores were obtained from 6 board-certified orthopaedic surgeons. Data collection occurred during 3 different points of the operation. The first confidence score obtained was evaluated from an intra-articular perspective, directly after placing the button through the femoral tunnel. Intra-articular confidence was arthroscopically assessed viewing the cortical aperture through the medial portal of the knee within the ACL femoral tunnel (Fig 1). The surgeon would rate their confidence of proper button placement on a Likert scale of 1 to 5, with 5 being greatest confidence that the button is properly fixed. After this, the arthroscope was positioned in the lateral portal to collect the second confidence score, the extra-articular score. Extra-articular confidence was assessed endoscopically, after directly visualizing the button's placement against the lateral femoral cortex from the superior-lateral portal just below the iliotibial band (Figs 2 and 3). At this point, the surgeon would again rate their confidence of proper button placement out of 5. After obtaining the 2 subjective confidence scores, the values were added together to determine the sum intra- and extra-articular score.

After surgeon-reported scoring from these perspectives, an intraoperative radiograph was taken with a mini-C-arm fluoroscope to confirm proper button placement. This was only performed after surgeons rated their confidence of proper button placement from both the intra-articular and extra-articular perspectives. Fluoroscopy results served as our control since the nature of this technique allows for button visualization on the femoral cortex with minimal obfuscation by soft tissue. We determined proper button placement of a given case from its fluoroscopy results, which we then compared with the surgeon-reported confidence scores. Photographs of the radiographs obtained via mini-C-arm fluoroscopy were then obtained for further analysis.

Statistical Analysis

Likert scores were reported as means with standard deviations. Data were analyzed by using analysis of variance tests and Welch's t tests to determine statistically significant differences based on variables within a given population. If statistical significance was found,

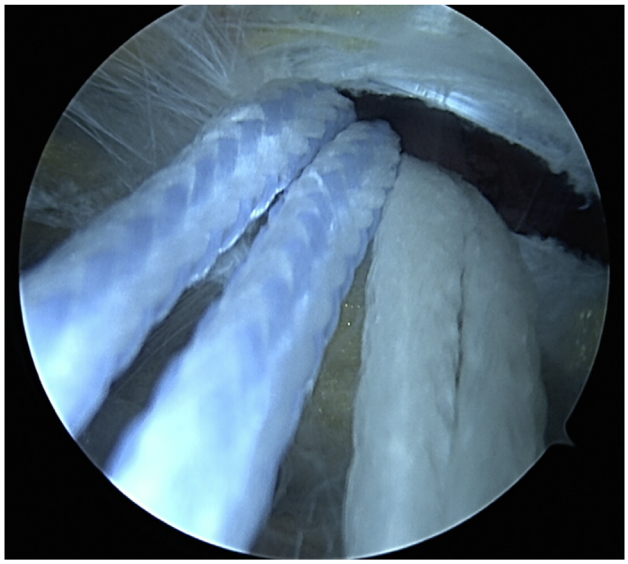

Fig 3. This view shows the sutures passing through the iliotibial band, superficial to the femoral cortex and button in a subject's left knee.

post-hoc power analysis was used to determine the power of the sample sizes. The threshold for statistical significance was set at $P < .05$, whereas we determined the sample sizes to be underpowered if power <0.80 or 80% In addition, we calculated positive predictive values (PPVs) to illustrate the probability of proper button placement based on the observation perspective and given Likert score. We calculated a PPV for each group of samples at a given perspective and confidence rating. The equation we used for each perspective group was: PPV = (number of samples fluoroscopy determined properly placed) / (total number of samples).

Results

Fifty suspensory fixation ACL reconstructions were included in this study (Table 1). The patient population's mean age was 35.1 years with a range of 14-65 years at the time of surgery. Radiographic findings revealed that 48 subjects had an appropriately flipped button on the lateral cortex of the femur. In 2 cases, the radiograph revealed soft-tissue interposition: one in the capsular tissue, one in the iliotibial band. None of the cases reported inappropriately placed intra-tunnel or extra-tunnel perched button placement. The mean Likert scores for all 50 cases among the 6 observing physicians out of 5 are as follows: 4.1 ± 0.9 from an intra-articular perspective, 4.6 ± 0.7 from an extra-articular perspective. Welch's *t*-testing and post-hoc power analysis revealed that extra-articular visualization yielded significantly greater scores (P = .0031, 87.3% power) than intra-articular visualization. The mean sum of intra-articular and extra-articular Likert scores out of 10 is 8.7 ± 1.4, with the following breakdown: 2 cases scoring 5 of 10, 2 cases scoring 6 of 10, 6 cases scoring 7 of 10, 8 cases scoring 8 of 10, 12 cases scoring 9 of 10, and 20 cases scoring greater than 9 of 10. Fluoroscopy confirmed proper button placement in 96% (48/50) of all cases. In regard to the probability of proper button placement based on surgeon-reported Likert scores, if surgeons rated intra-articular Likert scores ≥4 of 5, the PPV was 0.97 (n = 35). If surgeons rated extra-articular 154 Likert scores ≥4 of 5, the PPV was 0.96 (n = 47) (Table 2).

We found no statistically significant differences in confidence scores based on secondary procedure, patient sex, age, or primary versus revision surgery. This analysis further revealed statistically significant differences in Likert scores based on graft type, with quadriceps grafts receiving lower intra-articular (3.7 vs 4.3 out of 5, $P = .034$) and sum scores (8.1 vs 9.0 out of 10, P = .040) compared with those receiving hamstring grafts. However, upon post-hoc power analysis, the sample populations had powers of 0.605 and 0.584 to detect statistically significant differences between graft type in intra-articular and sum-articular averages, respectively.

Table 1. Patient Demographics

Characteristics	n
Mean age, y	35.1
Standard deviation, y	14.5
Range, y	14-65
ACLR type	
Primary	44
Revision	6
Sex	
Male	20
Female	30
Laterality	
Left	25
Right	25
Graft type	
Hamstring	34
Quadriceps	16
Age cohorts	
<20 years old	11
20-29 years old	6
30-39 years old	13
40-49 years old	7
≥50 years old	12
Secondary procedures	
None	14
Medial meniscectomy	12
Lateral meniscectomy	14
Medial meniscal repair	7
Lateral meniscal repair	7
Bilateral meniscal repair	4
Lateral augmentation	7

ACLR, anterior cruciate ligament reconstruction.

Table 2. Positive Predictive Values for ACLR Cases Having Proper Button Placement Based on Individual Surgeon-Reported Likert Scores

Score	Positive Predictive Value based on Intra-Articular perspective	Positive Predictive Value based on Extra-Articular Perspective
3/5	0.92 (n = 13)	1.00 (n = 2)
4/5	1.00 (n = 11)	0.92 (n = 12)
5/5	0.95 (n = 21)	0.97 (n = 33)
<4/5	0.93 (n = 15)	1.00 (n = 3)
≥4/5	0.97 (n = 35)	0.96 (n = 47)

NOTE. The aforementioned table demonstrates the positive predictive values of proper femoral button placement during ACLR based on the surgeon-reported Likert scores. For instance, during an ACLR where the surgeon rates their confidence of proper button placement as 3/5 while looking through the intra-articular perspective, then that case is 92% likely to have proper button placement.

ACLR, anterior cruciate ligament reconstruction.

Table 3. Positive Predictive Values for ACLR Cases Having Proper Button Placement Based on Sum-Articular Likert Scores

Sum-Articular Likert Score	Positive Predictive Value Based on Intra-Articular Perspective
8/10	1.00 (n = 8)
9/10	1.00 (n = 12)
10/10	0.95 (n = 19)
<9/10	0.94 (n = 18)
≥9/10	0.97 (n = 32)

NOTE. The aforementioned table demonstrates the positive predictive values of proper femoral button placement during ACLR based on the sum of surgeon-reported Likert scores (intra- and extra-articular scores). For instance, during ACLR cases where the surgeons rated their confidence of proper button placement at least 9/10 from combined intra- and extra-articular scores, the button was in proper position 97% of the time.

ACLR, anterior cruciate ligament reconstruction.

Discussion

Our primary finding is that arthroscopic visualization is a reliable modality to evaluate femoral button placement during ACLR, comparable to the accuracy of intraoperative fluoroscopy. Furthermore, we determined that of the perspectives used to evaluate this, the sum-articular perspective is the most reliable arthroscopic view, demonstrated by positive predictive values of our data. The reliability of this method also proved our hypothesis correct, with the majority of cases with high sum-articular confidence scores (greater than or equal to 9/10) having proper button placement confirmed by and comparable to intraoperative fluoroscopy.

Our data show that, in general, surgeons reported greater average Likert scores for the extra-articular perspective than the intra-articular perspective. This may be due to the order of how the data were collected, with extra-articular confidence being assessed after intra-articular confidence, or due to the direct visualization of the button in its final position from the extra-articular perspective. Nonetheless, the intra-articular perspective is useful to surgeons, as it was helpful to avoid intra-tunnel button wedging since the interior of the tunnel is directly visualized by this view and this type of mispositioned button would be obvious to detect. Intratunnel malposition was not observed in this study presumably because of the direct visualization from the medial portal. However, it Is important to note that in 6% of cases (3/50), surgeons' confidence level from an intra-articular perspective was high, but extra-articular views revealed improper button placement. This intra-articular perspective cannot account for graft passage beyond the bony aperture because the arthroscope is limited to the interior of the tunnel. Therefore, intra-articular confidence scores alone were not as reliable predictors of overall button placement.

Similarly, the extra-articular perspective was helpful to confirm proper button placement, but this view is also not as reliable by itself. In 4% of cases, surgeons had high confidence Likert ratings, but the button was not properly placed upon fluoroscopy confirmation (Table 2). Despite direct visualization of the femoral button fixed on the lateral cortex of the femur, the extra-articular perspective has the same limitation of being a single perspective and cannot account for any intraosseous complications.

Our findings suggest that each perspective offers a unique but limited benefit. Therefore, we found that the ideal practice was for surgeons to visualize button placement through both perspectives. This is consistent with our data, as we found that the sum of the intra- and extra- articular score was the most accurate indicator of proper button placement, with 97% of high-scoring cases properly placed (Table 3). Moreover, the value we determined to be high confidence (9/10) for this score implies 5/5 confidence on at least one visual perspective. For this reason, cases with high sum Likert scores recorded instances of proper button placement most reliably compared to other arthroscopic visualization methods.

Button placement errors can occur as frequently as 15% during ACLR. One study by Toftoy et al.[6] reports suboptimal button malposition in 3.6% of ACLR cases due to intraosseous malposition and 7.8% of cases due to at least partial button placement >2 mm from the femoral cortex. The cases included in our study reported zero instances of intraosseous button placement and only 4% of cases reporting any malposition after fluoroscopy. Accounting for both intra- and extra-articular perspectives with direct visualization allowed for confirmation from multiple perspectives to reduce the instance of these types of mispositioned buttons.

A similar study conducted by Matassi et al.[7] also investigated the benefits of using arthroscopic confirmation of proper button placement. This study used a direct visualization perspective through the anterolateral portal analogous to the view we described as extra-articular. The study demonstrated that in 7.4% of ACLR cases, soft-tissue interposition was detected with arthroscopic visualization and corrected before postoperative fluoroscopy. Subsequently, zero cases of tissue interposition were reported postoperatively when arthroscopic confirmation was used, compared with 8% of cases presenting this complication without using arthroscopic confirmation.[7]

Based on the data we collected, intraoperative fluoroscopy is an effective tool at a surgeon's disposal to determine proper femoral button placement during an ACLR surgery; however, it is not necessarily required. Our initial hypothesis stated that when surgeons rated the sum confidence of 9 or greater out of 10 from intra-articular and extra-articular perspectives (5/5 confidence from at least one view), these scores would be sufficient to determine proper button placement on the lateral femoral cortex. Of the 32 patients with an intra-articular and extra-articular sum score of 9 or greater, the majority of patients (97%) had proper button placement confirmed by fluoroscopy, after receiving a high sum Likert score.

As stated previously, intraoperative fluoroscopy carries inherent risks to both the patient and operating clinicians. Miniature C-arm imaging machines can test positive for contamination in up to 37.5% of cases in ambulatory surgery center operating rooms, with this figure increasing to up to 46.2% in the hospital setting.[8] In addition, orthopaedic surgeons are at significantly greater risk of developing tumors compared with non-orthopaedic surgeons as the result of frequent radiation exposure.[9] Finally, using intraoperative fluoroscopy introduces increased operative time. These downsides should be considered when determining the use of intraoperative fluoroscopy. However, especially in environments in which access to this equipment is limited, the visualization Likert scores are a useful tool to help surgeons determine proper button placement on the lateral femoral cortex.

Limitations

We were able to identify limitations in this study that are worth consideration. First, the nature of scoring confidence of proper button placement with Likert scores is a subjective metric that can vary between surgeons. As 6 different observers contributed to data collection, the heterology of surgeon-rated Likert scores could have impacted the results. Similarly, because of the nature of collecting data from operating surgeons, it would have been logically impossible to blind surgeons to the objectives of the study. Finally, all cases were conducted at the same ambulatory surgery center facility, which may limit generalizability. This is especially applicable for the hospital setting, where reduced time constraints and access to resources like fluoroscopy machines may contribute to different overall Likert scores.

Conclusions

Arthroscopic visualization is a reliable method of confirming femoral button placement during ACLR and is sufficient to rule out intraoperative fluoroscopy during surgery. ACLR cases with high surgeon confidence from both intra- and extra-articular perspectives (sum score of 9 or greater out of 10) resulted in proper femoral button placement in 97% of cases as confirmed by intraoperative fluoroscopy.

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