Palpation and fluoroscopy are valid but unreliable for the assessment of femoral tunnel position after medial patellofemoral ligament reconstruction

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ABSTRACT
Objectives: The purpose of this study was to evaluate the validity and reliability of two techniques, palpation and fluoroscopy, for assessing medial patellofemoral ligament (MPFL) reconstruction femoral tunnel position accuracy.

Methods: Twenty-one fresh frozen cadaveric knees had an MPFL femoral tunnel drilled and filled with a metal screw. Tunnels were created in a nonstandard fashion to ensure the sample included a range of tunnel positions from poor to ideal. Six experienced sport medicine and arthroscopy surgeons evaluated the placement of the femoral tunnel by palpating the screw in relation to anatomic landmarks and by fluoroscopy related to Schottle’s Point. They evaluated 1) the accuracy of femoral tunnel placement, 2) the direction of tunnel error, and 3) the clinical acceptability of the tunnel position. Validity measures included sensitivity, specificity, and correlation to clinical acceptability, which were calculated for the palpation and fluoroscopic assessments. Reliability measures included interrater reliability (ICC 2,k) for femoral tunnel accuracy and percent agreement of the raters’ tunnel direction assessment.

Results: The palpation method demonstrated a sensitivity of 0.79 and specificity of 0.84 for assessing the accuracy of femoral tunnel placement, while the fluoroscopic method showed a sensitivity of 0.83 and specificity of 0.92. Pearson correlation coefficients for clinical acceptability of tunnel position were high, with both techniques ranging from .589 to .854. Interrater reliability for the palpation and fluoroscopic techniques for assessment of tunnel accuracy were 0.31 and 0.55 (ICC 2,k), respectively. Assessment of the direction of tunnel error was good with the fluoroscopic technique slightly more accurate than palpation.

Conclusion: This study demonstrated that both palpation and fluoroscopy are valid techniques for assessing femoral tunnel position after MPFL reconstruction. Despite demonstrating good validity, the accuracy of assessing tunnel position was unreliable in a group of six experienced knee surgeons. Further research into MPFL reconstruction femoral tunnel assessment techniques, including patient-specific reference standards, is warranted.

Level of Evidence: Level 2.

What are the new findings?

1. Palpation of anatomic structures and the use of fluoroscopy are valid techniques to assess the accuracy of the femoral tunnel in medial patellofemoral ligament reconstruction.

2. Neither palpation nor fluoroscopy is reliable for the assessment of femoral tunnel accuracy after medial patellofemoral ligament reconstruction in a group of experienced sport medicine arthroscopists.

3. Both palpation and fluoroscopy have a positive predictive value in assessing femoral tunnel position for medial patellofemoral ligament reconstruction.

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INTRODUCTION

Patellofemoral instability is a common knee injury that results in significant functional impairment, pain, chondral injury, and persistent instability [1–3]. Medial patellofemoral ligament (MPFL) reconstruction is designed to reestablish restraint of lateral patellar translation in cases of recurrent patellofemoral instability. There is strong agreement regarding the importance of an anatomically placed MPFL reconstruction [4–7]. Numerous biomechanical studies have demonstrated that the femoral tunnel position is the most important factor affecting the isometric behavior of the MPFL graft [8–12]. Malposition of the femoral tunnel can cause changes in the isometry of the graft, leading to increased patellofemoral contact pressures and is the most common technical cause of graft failure [7,12–17]. Based on this evidence, correct femoral tunnel placement is paramount to successful MPFL reconstruction.

During surgical reconstruction of the MPFL, the position of the femoral tunnel is determined using one of two techniques: palpation of anatomic structures or fluoroscopy using radiographic landmarks. The palpation technique involves feeling the structures of the medial side of the distal femur and using these landmarks to locate the anatomic insertion point of the MPFL [18–20]. The fluoroscopic technique uses an image intensifier to direct the placement of the femoral tunnel according to radiographic bony landmarks on a true lateral image [20–23]. Challenges related to palpation include variations in the anatomy, especially in patients with high-grade dysplasia of the distal femur. There are also challenges using fluoroscopy, as a slight rotation of the image can compromise femoral tunnel accuracy [24–26]. This is especially true in patients with distal femoral dysplasia, where hypo or hyperplasia of the condyles makes it difficult to align the condyles for a true lateral view [27,28].

The need to accurately assess a femoral tunnel is not limited to the operating theater, where, when training new surgeons, the ability to evaluate femoral tunnel accuracy postoperatively is essential for providing constructive feedback to ensure technically sound procedures. It is also required for postoperative care and is crucial, particularly in cases where the patient is experiencing difficulties or graft failure. Although several studies explore the assessment of tunnel placement intraoperatively, the use of palpation and fluoroscopy to postoperatively assess femoral tunnel position following MPFL reconstruction has not been investigated. The purpose of this study was to evaluate the validity and reliability of two techniques, palpation and fluoroscopy, for assessing MPFL reconstruction femoral tunnel position accuracy.

MATERIALS AND METHODS

Twenty-one fresh frozen cadaveric knee specimens were thawed and labeled for identification. Specimens and approval to conduct the study were obtained from Science Care (Phoenix, USA). None of the cadaveric specimens had trochlear dysplasia. All specimens had an MPFL reconstruction femoral tunnel drilled through a 2–3 cm incision over the medial epicondyly. The tunnels were placed in varying proximity to the anatomic MPFL femoral insertion to create tunnel positions ranging from poor to ideal for assessment. Metal screws (Propel Interference Screw 7 × 25mm, Conmed Linvatec, Largo, USA) were placed in the drilled femoral tunnel of the specimens and remained 1 mm prominent for ease of palpation. Once the screws were placed, true lateral images were taken of the cadaveric specimens using an image intensifier.

Six experienced, fellowship-trained sport medicine and arthroscopy knee surgeons participated in the study as raters. Years in practice, experience in MPFL reconstruction surgery, and the usual method of determining femoral tunnel location were documented.

Reference standards

The reference standard for assessing femoral tunnel position accuracy using the palpation method was the saddle located posterior to the medial epicondyly, approximately 9 mm distal to the adductor tubercle depending on the size of the specimen [29,30]. The reference standard for the fluoroscopic method was Schottle’s point [22]. An education sheet was provided to the raters, defining the rating categories and describing the aforementioned reference standards.

Rating of tunnel position

For both the palpation and the fluoroscopic methods, rating of femoral tunnel position accuracy relative to the reference standard was defined a priori as ideal (0–6 mm), good (>6–12 mm), or poor (>12 mm) [31,32]. The direction of tunnel error for those ranked as “good” or “poor” was described using up to two of the following: “too anterior,” “too posterior,” “too proximal,” and/or “too distal.” Tunnels ranked as ideal were excluded from this analysis as the direction of error was minimal. Each rater was asked to use their best clinical judgment to rate each femoral tunnel position as “clinically acceptable” or “clinically unacceptable.” This method whereby raters provide a “gestalt impression” of their clinical assessment has previously shown a strong correlation with multifaceted assessment tools [33,34].

Assessment protocol

Surgeon raters evaluated the specimens in random order by palpating the anatomic structures of the medial knee and the femoral tunnel screw through a 2–3 cm skin incision. True lateral fluoroscopic images were provided on a laptop in random order for evaluation by each rater. For each specimen and fluoroscopic image, the raters recorded 1) the accuracy of femoral tunnel placement (ideal, good, poor) from the reference standard, 2) the direction of tunnel error (if any), and 3) their evaluation of the clinical acceptability of the tunnel position. All raters were blinded to each other’s results.

STATISTICAL CONSIDERATIONS

Validity

Validity was reported using the Standards for Reporting Diagnostic Accuracy (STARD) principles [35], including the traditional use of sensitivity and specificity testing to validate a diagnostic test [36]. Schottle’s point was used as the gold standard for both the palpation and fluoroscopic methods to permit comparison between techniques. For sensitivity and specificity calculations, data categories for tunnel position (ideal, good, poor) were collapsed into a dichotomous classification of “acceptable” and “unacceptable,” where acceptable included “ideal” or “good” tunnels, and unacceptable included “poor” tunnels (Table 1).

Sensitivity (a/(a + c)) represents the circumstance when the tunnel position is acceptable, and the rater agreed that the tunnel position was acceptable. Specificity (d/(b + d)) represents the circumstance when a tunnel is unacceptable and the raters’ agreed that the tunnel position was unacceptable. Positive predictive value (a/(a + b)) and negative predictive value (d/(c + d)) were calculated for both methods. The positive predictive value represents the percent likelihood that the tunnel position has been rated as acceptable and the femoral tunnel is acceptable. A negative predictive value represents the percent likelihood that the tunnel position will be rated as unacceptable and the femoral tunnel is unacceptable.

Pearson r correlations were calculated to assess the relationship between tunnel position and the rater’s interpretation of clinical acceptability. Statistical significance was set at 0.01 for a two-tailed test.

Reliability

Interrater reliability for assessing femoral tunnel position accuracy was evaluated using the six raters’ accuracy categories (ideal, good, or poor) and calculated using an intraclass correlation coefficient (ICC) 2,k.
The reliability statistics were calculated using SPSS, IBM © version 29. The raters documented the most important direction/s of tunnel error. Pair-wise agreements across all raters and specimens were calculated, and an average “Rater Percent Agreement” was calculated. Agreement was noted if the raters identified the same direction(s) of tunnel error as measured using the gold standard. The Rater Percent Agreement (per specimen) was then compared to the reference standard. This was calculated for both the palpation and fluoroscopy techniques.

### Results

Twenty-one specimens with an average age of 71.7 years (range 49–91), and an average weight of 79.5 kg (range 52.7–118.2) were used in this study. There were five males and 16 females, nine right knees, and 12 left knees. Using Schöttle’s point as the reference standard and the a priori rating system, nine specimens had ‘ideal’ tunnels (mean 4.3 ± 1.5 mm), 10 had ‘good’ tunnels (9 ± 1.9 mm) and two had ‘poor’ tunnels (19.3 ± 4.6 mm). The average distance to Schöttle’s Point was 8 mm (range 1.5–22.5 mm).

Six experienced, fellowship-trained sport medicine and arthroscopy knee surgeons were the raters for this study. They ranged in experience with MPFL reconstruction and years in practice (Table 2).

### Validity

Both the palpation and fluoroscopic method were sensitive (0.79 and 0.84 respectively) and specific (0.83 and 0.92 respectively) for assessing femoral tunnel position after MPFL reconstruction. Both methods had a very high positive predictive value. The palpation method had a low negative predictive value while the fluoroscopic method had a high negative predictive value (Table 3).

Both techniques demonstrated a statistically significant correlation (P < 0.01) between the raters’ evaluation of clinical acceptability (acceptable or unacceptable) and their assessment of tunnel accuracy (“ideal,” “good,” “poor”). Statistical significance was observed for all six raters regardless of technique (Table 4).

### Table 1

<table>
<thead>
<tr>
<th>Rater’s evaluation</th>
<th>Reference standard</th>
<th>Not acceptable (poor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptable (ideal or good)</td>
<td>True accurate</td>
<td>False inaccurate</td>
</tr>
<tr>
<td>Not acceptable (poor)</td>
<td>The tunnel was accurate and the rater thought it was accurate</td>
<td>The tunnel was accurate but the rater thought it was inaccurate</td>
</tr>
</tbody>
</table>

The palpation method demonstrated fair interrater reliability with r = 0.75 (ICC 2,k). The percent agreement for all six raters ranged from 70% to 90%, indicating a moderate level of reliability among the raters.

### Table 2

<table>
<thead>
<tr>
<th>Surgeon</th>
<th>Years in practice</th>
<th>Total # MPFL-R performed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>26–50</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>26–50</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>0–10</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>51–75</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>11–25</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>&gt;100</td>
</tr>
</tbody>
</table>

### Table 3

<table>
<thead>
<tr>
<th>Method</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive predictive value</th>
<th>Negative predictive value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palpation method</td>
<td>0.79</td>
<td>0.83</td>
<td>97.8%</td>
<td>29.4%</td>
</tr>
<tr>
<td>Fluoroscopy method</td>
<td>0.84</td>
<td>0.92</td>
<td>99.0%</td>
<td>92.0%</td>
</tr>
</tbody>
</table>

### Table 4

<table>
<thead>
<tr>
<th>Rater</th>
<th>Palpation method</th>
<th>Fluoroscopic method</th>
<th>Usual method of determining femoral tunnel position</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pearson r</td>
<td>Pearson r</td>
<td></td>
</tr>
<tr>
<td>Rater 1</td>
<td>0.854a</td>
<td>0.794</td>
<td>Fluoroscopy</td>
</tr>
<tr>
<td>Rater 2</td>
<td>0.718a</td>
<td>0.589</td>
<td>Fluoroscopy</td>
</tr>
<tr>
<td>Rater 3</td>
<td>0.816a</td>
<td>0.638</td>
<td>Fluoroscopy</td>
</tr>
<tr>
<td>Rater 4</td>
<td>0.814</td>
<td>0.682</td>
<td>Fluoroscopy</td>
</tr>
<tr>
<td>Rater 5</td>
<td>0.835</td>
<td>0.772</td>
<td>Palpation</td>
</tr>
<tr>
<td>Rater 6</td>
<td>0.814</td>
<td>0.814</td>
<td>Palpation</td>
</tr>
</tbody>
</table>

*a Correlation statistically significant at the 0.01 level (2-tailed).

### Reliability

The palpation method demonstrated fair interrater reliability with r = 0.31 (ICC 2,k) for assessing femoral tunnel position accuracy (ideal, good, poor), and the fluoroscopic method demonstrated moderate interrater reliability with r = 0.55 (ICC 2,k). The percent agreement for the direction of tunnel error was 81% for the palpation assessment and 96% for the fluoroscopic assessment.

### Discussion

This study has demonstrated that both the palpation and fluoroscopic techniques are valid methods for assessing femoral tunnel position after MPFL reconstruction. Despite demonstrating good validity, the accuracy of assessing tunnel position was unreliable in a group of six experienced knee surgeons. A moderate level of consistency was observed among raters when deciding if the femoral tunnel met clinical standards, suggesting an overall “gestalt impression” exists with both techniques. Fluoroscopy and palpation are low-cost and effective techniques to determine femoral tunnel position during MPFL reconstruction that are readily available and currently used globally. The lack of interrater reliability of these methods is cause for concern.

Although the debate regarding the use of palpation or fluoroscopy for the creation of the femoral tunnel during surgical reconstruction of the MPFL continues, the ability of surgeons to use palpation and fluoroscopy to assess correct tunnel placement has not been studied. The ability to assess the accuracy of a femoral tunnel is an important skill both in the operating theater and for assessing patients in the postoperative period. When teaching trainees, a surgeon must be able to assess femoral tunnel accuracy during the operative procedure and provide immediate feedback to the trainee. This process ensures the performance of a high-quality and technically correct procedure. In addition, when assessing patients in the postoperative period, femoral tunnel position is a key
metric to consider, especially in cases where the patient is experiencing difficulties or has had a graft failure.

Validity

This study demonstrated high sensitivity and specificity for both the palpation and fluoroscopic methods to evaluate the accuracy of femoral tunnel placement following MPFL reconstruction. These findings indicate that surgeons can use either method to determine whether a drilled femoral tunnel is accurate or inaccurate. The high positive predictive value demonstrated for both methods adds further confidence that tunnels rated as “ideal” or “good” are truly accurate. Interestingly, the negative predictive value for the palpation method was much lower (29.4%) than the fluoroscopic method (92%), suggesting that raters are less adept at identifying a poor tunnel with the palpation technique. There was a very strong correlation for assessing clinical acceptability for both the palpation and fluoroscopic methods. If a surgeon graded the tunnel accuracy as “ideal” or “good,” they also ranked the tunnel as “clinically acceptable” indicating concurrent validity for these measurement scales and supports the practical application of these scales in the clinical setting.

The findings in this study are consistent with previous literature on using palpation and fluoroscopy intraoperatively to create the femoral tunnel for MPFL reconstruction [31,37]. While it is plausible to extrapolate our results to the intraoperative scenario, it’s important to consider the limitations of cadaveric studies for studies on tunnel placement during MPFL reconstruction. One of the most challenging issues for cadaveric studies on femoral tunnel accuracy is using radiographic landmarks identified on aged specimens with no patellofemoral instability, especially those with high-grade trochlear dysplasia, may have altered radiographic landmarks [27,28]. Three-dimensional (3D) imaging has added to our understanding of the insertion of the MPFL and how dysplasia of the distal femur affects the isometry of the MPFL graft [38]. Studies comparing patients with lateral patellofemoral instability to those without demonstrate that Schöttle’s point may not be acute in those with instability [39–41]. These studies force the question of whether Schöttle’s point or any 2D radiographically determined point should be considered the gold standard for creating and assessing the femoral tunnel for MPFL reconstruction, especially in trochlear dysplasia.

If the anatomic insertion point, relative to each patient, should be the gold standard, does palpation of the bony landmarks more appropriately guide the tunnel to the correct location? Multiple anatomic studies have identified the insertion of the MPFL as the most consistent relationship with the adductor tubercle, approximately 8–10 mm distal to the insertion of the adductor magnus [9,23,42,43]. Studies that have assessed the accuracy of the palpation method have used Schöttle’s point as the reference standard, which may account for the variance in accuracy reported [32,44–47]. Tunnels reported as inaccurate in previous studies may have been more anatomically placed than reported. Research that assesses techniques used to achieve accurate tunnel placement and the influence of MPFL reconstruction femoral tunnel placement on medium- and long-term patient outcomes is warranted.

Reliability

Poor reliability was demonstrated in a group of six experienced knee surgeons using the palpation and fluoroscopic methods of femoral tunnel assessment after MPFL reconstruction. McConkey et al. [48] also found poor reliability between surgeons to assess tunnel placement for anterior cruciate ligament reconstruction. The lack of reliability in assessing femoral tunnel position after MPFL reconstruction is concerning and could be attributed to the specimens, the assessment scale, or the surgeon-raters. The specimens used for this study had no trochlear dysplasia, a pathoanatomic feature common in patients with lateral patellofemoral instability. Using relatively “normal” specimens should have improved the reliability of the raters compared to specimens with dysplastic femurs whose anatomic landmarks may be less obvious. The assessment scale used in the current study was quite coarse, with only three options for rating the accuracy of the femoral tunnel position. A more robust scale, such as a 10 cm Visual Analogue Scale, may have provided more nuance to guide the raters’ judgment and offered a more reliable rating [49]. However, the most likely explanation behind the lack of reliability is the raters. The substantial variability in anatomic [11,30,50] and radiographic studies describing the MPFL’s femoral insertion point [20,21,23] may have contributed to the raters’ lack of consistency in the present study. Although provided with an education sheet that outlined the scales used in this study, the raters may have been influenced by their experience and understanding of the background literature, leading to different interpretations of the classifications. Other rater characteristics, such as eyesight and handedness, could have influenced the ratings and reliability.

Limitations of this study include the fact that none of the cadaveric specimens had trochlear dysplasia or evidence of patellofemoral instability. Assessment of the femoral tunnels’ accuracy may have been more reliable with a more robust scoring system such as a Visual Analogue Scale. The weak intrarater reliability may be secondary to poor intrarater reliability [51], although the logistic challenges to testing intrarater reliability precluded this assessment in our study. The raters’ experience with patellofemoral instability was broad, but all were experienced sport medicine surgeons. This may have influenced the ratings and the generalizability of the results. Finally, the low number of poor tunnels in our sample may have influenced findings.

Conclusion

This cadaveric study demonstrated that both the palpation and fluoroscopic methods were valid for assessing femoral tunnel position accuracy following MPFL reconstruction. Despite good validity, the assessment of tunnel position accuracy was unreliable among experienced knee surgeons. To provide optimal surgical management and patient outcomes, a more reliable method to ensure an accurate femoral tunnel position, that is patient-specific, would be ideal.

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