In Vivo Positioning Analysis of Medial Patellofemoral Ligament Reconstruction

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Background: Several techniques have been described for reconstruction of the medial patellofemoral ligament (MPFL). The anatomical insertion of the MPFL has been defined; however, there are no reports describing the accuracy of femoral graft positioning assessed postoperatively.

Purpose: To analyze our femoral tunnel positioning for MPFL reconstruction in correlation with our clinical results.

Study Design: Case series; Level of evidence, 4.

Methods: The authors reported a prospective series of 29 MPFL reconstructions with a minimum follow-up of 24 months. The tunnel positioning analysis was performed using plain radiographs and magnetic resonance imaging at 1-year follow-up.

Results: Twenty-nine femoral tunnels were analyzed; 20 femoral tunnels (69%) were considered to be in good position on plain radiographs. On magnetic resonance imaging, the authors found 19 femoral tunnels (65%) in a proper location, 5 (17.5%) in a high position, and 5 in an anterior and/or high position.

Conclusion: The study highlights the difficulty of reproducible MPFL reconstruction. The surgical procedure continues to be improved and finding a reliable technique to anatomically place the graft remains challenging. Verifying femoral tunnel placement radiographically may be recommended during surgery.

Keywords: medial patellofemoral ligament reconstruction (MPFL); graft positioning; femoral tunnel positioning; anatomy; patella

In cases of recurrent patellar dislocation, instability is the main symptom requiring surgical intervention. Different surgical procedures may be considered, including bony procedures[9,22,28] (trochleoplasty, anterior tibial tubercle osteotomy) and/or soft tissue procedures[4,16] (lateral release, vastus medialis obliquus plasty, medial patellofemoral ligament [MPFL] reconstruction). Recently, there has been an increased focus on reconstruction of the MPFL. It has been clearly shown that the MPFL is the most consistently injured anatomical structure after a patellar dislocation.[2,8] It is the essential lesion of this injury.

Several techniques of MPFL reconstructions have been described with encouraging clinical results. Many techniques utilize a femoral tunnel for graft fixation[5,7,8,10,14,17,18,20] and the positioning of this femoral tunnel may influence the MPFL isometry.[2] Schöttle et al[21] were the first to determine the radiographic landmarks for control of MPFL reconstruction in a laboratory study. Previous biomechanical studies report that nonanatomical reconstruction with an excess of tension is correlated with an increased medial patellofemoral contact pressure.[15]

Thus our hypothesis was that the femoral tunnel should be the closest to the natural anatomy to restore the optimal patellofemoral tracking.[23]

The purpose of the study was to analyze our femoral tunnel positioning on MRI and plain radiographs in correlation with our clinical results.

MATERIALS AND METHODS

From 2005 to 2007, we performed 35 MPFL reconstructions for recurrent patellar dislocation in our department. Of the 35 knees, complete imaging (plain radiographs and MRI) and a minimum 24-month follow-up were obtained in 29.

The indication for MPFL reconstruction was any patient with recurrent patellar dislocation. Patients with open physes and patellofemoral arthritis were excluded from the study. The Caton-Deschamps index was used to

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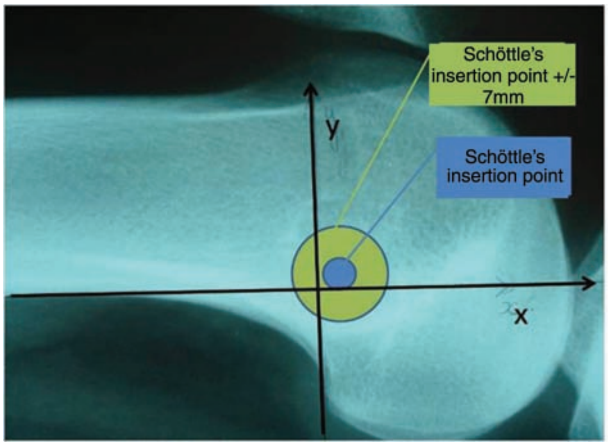

Figure 1. Tunnel femoral positioning with Schöttle's method. The tunnel femoral positioning is measured with coordinates (x, y). Line 1: tangent line to the posterior condyle; line 2: perpendicular to line 1, passing through the blue point (Schöttle's point). The green zone represents the proper positioning of the femoral tunnel with regard to Schöttle's point ±7 mm.

measure the patellar height,[6] and a preoperative CT-scan assessed the tibial tuberosity–trochlear groove (TT-TG) value.[11]

The study group included 29 knees (26 patients) with 16 female and 10 male patients. The mean age of the patients at the first dislocation was 17 years (range, 9-39 years; standard deviation [SD], 6 years). The mean age at the time of operation was 23 years (range, 15-43 years; SD, 8 years). The right knee was affected in 15 cases and the left knee in 14 cases. Medial patellofemoral ligament reconstruction was performed by 2 senior surgeons (E.S. and P.N.) using the technique described by Davis and Fithian.[4] Hamstring tendon autograft was used for reconstruction. Two patellar tunnels were created 1 cm apart at the proximal medial border of the patella using a short incision along its medial edge. After the bony landmarks were palpated through the soft tissue, another incision was performed and a 25 × 7-mm tunnel drilled at the midpoint between the medial epicondyle and the adductor tubercle. The location of the femoral tunnel was identified by visual inspection during the surgery. The graft was fixed with a bioabsorbable screw at the femur and bioabsorbable sutures at the patella with the knee at 30° of flexion. The 2 free graft ends were fixed by stitching them to themselves at 30° of flexion while tensioning each bundle.

In addition, a tibial tubercle transfer was performed distally and/or medially (n = 7) on any patient with patella alta[6] (Caton-Deschamps index >1.2) and/or a TT-TG greater than 20 mm. In case of abnormal TT-TG, we targeted an average 14-mm value as considered to be normal.[6] Twenty knees had an isolated MPFL reconstruction. No lateral retinaculum release was performed.

The mean follow-up was 31 months (range, 24-42 months; SD, 7 months). The International Knee Documentation Committee (IKDC) subjective score[12] was used

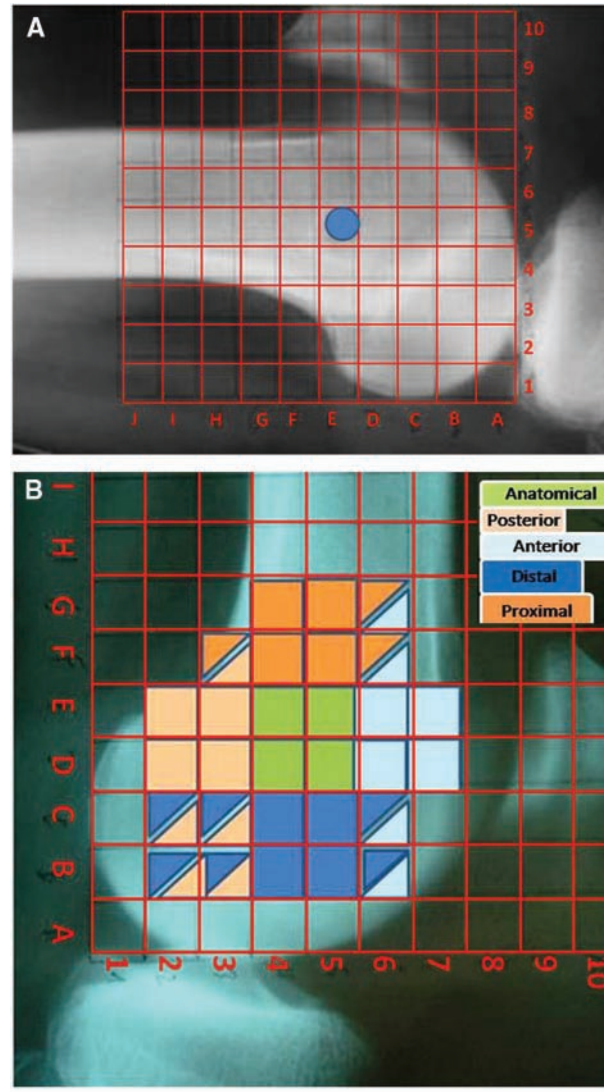

Figure 2. Assessment method of tunnel positioning with the squares method.

preoperatively and at the final follow-up. Range of motion, pain, Fairbank sign (apprehension test), and hypermobility were assessed.

Radiographic evaluation included AP, lateral, and axial views obtained both preoperatively and at the final follow-up, and MRI performed at 1 year postoperatively. Two methods were used to evaluate femoral tunnel placement on plain radiographs, and the position of the entry to the femoral tunnel from fixed anatomical landmarks measured using MRI.

We used the method described by Schöttle et al.[21] On 8 cadaver knees, the authors determined the anatomical insertion of the MPFL at the femur on sagittal radiographs. Schöttle et al[21] described a location of 5-mm diameter for the femoral insertion; we modified their method and enhanced the anatomical zone to ±7 mm because of the diameter of the femoral tunnel (Figure 1). The femoral

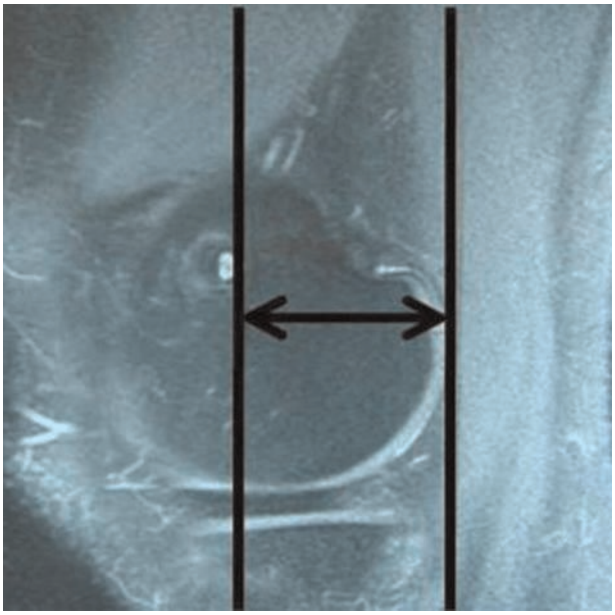

Figure 3. Measurement on MRI with posterior condyle referencing.

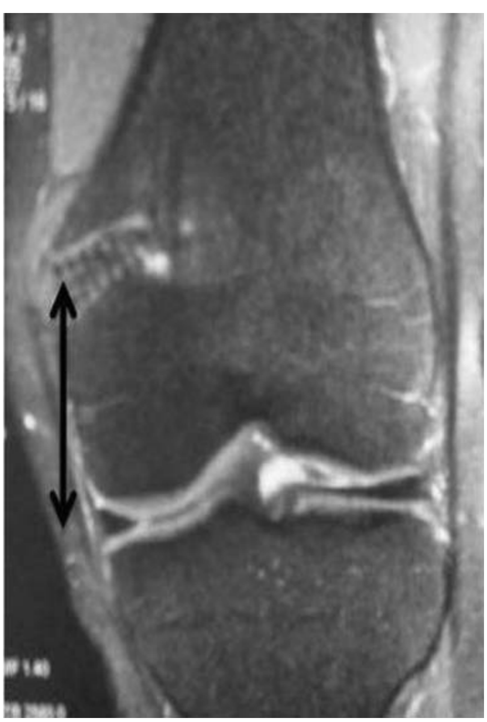

Figure 4. Femoral tunnel height in the frontal plane.

tunnel was 7 mm in diameter. A malpositioned tunnel was considered as a tunnel at least 7 mm away from any part of the Schöttle point (anatomical center of the "native" MPFL).

The second method involved creating a grid of 1 × 1-cm squares and overlaying them on the lateral radiograph

Figure 5. Good positioning on radiographs with Schöttle and squares methods.

using the posterior condyle, distal condyle, and posterior femoral cortex as positioning landmarks (Figure 2A). This allowed the creation of a reproducible framework for defining where each individual tunnel had been placed. Numbers were assigned to each square describing the tunnel position in its anterior-posterior axis, while letters were assigned to each square in the proximal-distal position. The squares at position D4, D5, E4, and E5 represented satisfactory tunnel position as described by Schöttle (Figure 2B). If the tunnel center lay in square 6 or greater, it was considered too anterior; if in position 3 or less, it was too posterior. The same technique was used for assessment of proximal-distal placement.

Magnetic resonance imaging was performed in the same center by 1 radiologist (C.L.) at 1-year follow-up, and all measurements were performed by a single physician (R.D.) using DICOM (Digital Imaging and Communications in Medicine) software (Rubo Medical Imaging BV, Uithoorn, the Netherlands). On the sagittal plane (Figure 3), we used the first slice passing through the tunnel to measure the anterior-posterior positioning of the femoral tunnel with reference to the articular surface of the posterior medial femoral condyle. We defined the "normal" values for the center of the femoral tunnel to be between 20 and 30 mm from the posterior medial condyle. A distance over 30 mm was considered too anterior and a distance under 20 mm too posterior. However, there are no references in the literature for MPFL location on MRI. Thus to define "exact distances as normal," we extrapolated the position on MRI from anatomical landmarks (medial epicondyle).

TABLE 1
Femoral Tunnel Placement Assessment

	MRI	Squares Method	Schöttle Method
Good positioning	65% (n = 19)	69% (n = 20)	69% (n = 20)
Proximal	17% (n = 5)	21% (n = 6)	17% (n = 5)
Anterior	11% (n = 3)	7% (n = 2)	11% (n = 3)
Proximal and anterior	7% (n = 2)	3% (n = 1)	3% (n = 1)
Distal	0%	0%	0%
Posterior	0%	0%	0%

In the frontal plane (Figure 4), we measured the distance between the center of the femoral tunnel and the articular surface of the femoral condyle. We considered as "normal" a distance between 25 and 35 mm from the articular surface. Where it was over 35 mm, the tunnel was considered too proximal; where it was under 25 mm, the tunnel was considered too distal.

The preoperative and postoperative data were evaluated using the Mann-Whitney U test and the χ^2 test. Statistical significance was set at $P < .05$.

RESULTS

The subjective IKDC score improved significantly ($P = .01$) from 52 (range, 38-76; SD, 9) preoperatively to 79 (range, 52-100; SD, 15) at the final follow-up.

On radiographs, we did not find any significant difference between methods of measurement. Seventy percent of the femoral tunnels were properly placed (Figure 5) as defined by our protocol. The main positioning error was proximal (20%) (Table 1, Figure 6).

On MRI (Table 1), anatomical tunnel placement was achieved in 65% and improper positioning was found in 35% of cases (Figure 7). In the sagittal plane, the center of the femoral tunnel was located at an average of 27 mm (range, 20-38 mm; SD, 3.6) from the medial posterior condyle. In the frontal plane, the average distance between the femoral tunnel and the joint line averaged 29 mm (range, 25-41 mm; SD, 5.8).

Four patients had pain in the region of the femoral tunnel. One patient (bilateral procedure) had an arthrolysis at 6 months and recovered full range of motion at the final follow-up.

Two patients had a positive apprehension sign. For 1 of those patients, the femoral tunnel was considered too proximal as well as too anterior on MRI and radiographs. Both patients had a trochlear dysplasia grade 3.[6]

We did not find any correlation between the femoral tunnel positioning and the subjective IKDC score or range of motion (Table 2). Among the 4 patients with pain in the region of the femoral tunnel, the IKDC score averaged 67. Two of these 4 patients had a high femoral tunnel with the average distance from the ideal location being 10 mm. No correlation was seen between these patients and those with ideal tunnel placement with regard to their IKDC.

Figure 6. High femoral tunnel on radiograph.

Figure 7. High femoral tunnel on MRI.

DISCUSSION

Many surgical procedures have been described to restore the MPFL. Authors have used the hamstring tendon,[5,10,19,20] the quadriceps tendon,[18] the adductor magnus tendon,[25] or artificial ligament.[17] There is no consensus regarding the best technique for graft fixation. We prefer to use a bone fixation,[4] supported by a recent

TABLE 2
Comparison of Clinical Outcomes With Tunnel Placement[a]

	IKDC Score	Knee Flexion
Series	79 (range, 52-100; SD, 15)	140° (range, 135°-160°; SD, 5)
Optimal tunnel placement (n = 19)	79 (range, 57-98;SD, 15)	140° (range, 140°-160°; SD, 5)
Nonoptimal tunnel placement (n = 10)	81 (range, 52-100; SD, 15)	140° (range, 135°-160°; SD, 5)
P	ns	ns

[a]IKDC, International Knee Documentation Committee; SD, standard deviation; ns, not significant.

biomechanical study that reported a better resistance with bone fixation.[29] There are no reports in the literature assessing the positioning of graft after MPFL reconstruction.

It has been established that proper tunnel placement is required to optimally restore patellofemoral kinematics. Various groups have described how nonanatomical graft placement can interfere with normal patellofemoral function.[2,7,15,24,27] Conversely, Elias and Cosgarea[7] suggested that a proximal femoral tunnel may overload the medial patellofemoral compartment, increasing the medial patellofemoral pressure and leading to early arthritis, graft rupture, and/or graft failure. Thaunat and Erasmus[26] suggested a nonanatomical positioning may lead to an overtight graft and to a stiff knee, particularly if the femoral tunnel is placed too proximal. A too-distal tunnel may lead to a nontensioned graft that is subsequently nonfunctional as a medial restraint. The understanding of nonanatomical tunnel placement continues to evolve, and there remains much discussion regarding the exact effects of nonanatomical reconstruction. Amis et al[2] reported that incorrect positioning in the frontal plane will have a major influence on the graft isometry, while anteroposterior malpositioning of the graft may be better tolerated. Melegari et al[15] reported that the patellofemoral contact area and pressure are not affected by a nonisometric femoral attachment in MPFL reconstruction. Lessons learned in anterior cruciate ligament reconstruction[1] suggest that anatomical placement of ligament reconstruction is critical to reproducing normal kinematics, but further research is needed to confirm this with regard to the MPFL. Even though we did not find any effect from a malpositioned graft at 2-year follow-up, we remain concerned that those with malpositioned tunnels may have an increased incidence of osteoarthritis in the long term. There are several reasons no correlation was observed between tunnel position and outcome in our study. First, the amount by which the "malpositioned" tunnels deviated from the ideal position may not have been sufficient to observe a significant difference. Second, the length of follow-up is insufficient for the difference to become apparent. This is particularly relevant with regard to the risk of developing osteoarthritis. Third, the outcome measurement tools are not sensitive enough to detect the differences. Finally, the role of abnormal anatomy seen in patients with recurrent instability may alter the significance of MPFL positioning. Patella alta and trochlea dysplasia may alter the insertions of the MPFL with corresponding alterations in MPFL kinematics, making comparisons of tunnel positioning in these patients against a standardized "normal" population less useful.

Intraoperative placement of the femoral tunnel can be achieved using either anatomical or radiographic landmarks, or both. However, we can point out the weakness of our surgical procedure and thus our study. It seems likely that the placement was sometimes erroneous because the exposure was limited. However, a small incision may not be the true issue because direct visualization is only more accurate if the landmarks being visualized can be easily and reproducibly identified. The medial epicondyle is not such a landmark, as can be seen from the total knee replacement literature, in which the adductor tubercle is not more easily identified.[13] The anatomical landmarks of the medial epicondyle and adductor tubercle may be difficult to precisely locate, and our series shows that using these anatomical landmarks alone is unreliable. In 30% of our cases, the femoral tunnel was outside our defined zone of optimal placement using postoperative radiographs, and this increased to 35% when measured using MRI. The most common error was to place the tunnel too proximal, with or without additional anterior displacement. We found no tunnels that were placed too distal or posterior. Further consideration must be given to the possibility that variations of these anatomical landmarks that may occur in the setting of altered knee anatomy present in many cases of recurrent patellar instability. In cases where there is altered normal anatomy, such as patella alta and trochlea dysplasia, it is reasonable to consider that the anatomy of the medial epicondyle and adductor tubercle, as well as the MPFL itself, may also be altered. This requires further investigation as there are no reports in the literature regarding MPFL anatomy in reference to these other anatomical variations.[24]

Intraoperative fluoroscopy may be helpful and would increase the reliability of tunnel placement. Despite approximately one-third of our femoral tunnels being located outside the optimal position, we did not find any correlation between tunnel placement and outcome. However, our follow-up may be too short to detect a difference with regard to proximal placement of the tunnel. This effect would be expected to result in problems with medial facet cartilage and then osteoarthritis, and will take a minimum of several years to be seen.[5]

This is the first prospective study assessing the accuracy and reliability of femoral tunnel placement using intraoperative anatomical landmarks alone, measured against previously described ideal radiographic landmarks and correlated with clinical outcomes. There are some weaknesses to our study, including cohort size, inability to measure location of patellar fixation, and short follow-up.

In conclusion, this prospective study highlights the difficulty of anatomical positioning of the femoral tunnel in MPFL reconstruction surgery. Although the MPFL is a forgiving graft, and there was no correlation between tunnel location and clinical outcome in our series, anatomical reconstruction of this important medial constraint is a priority and further refinement of our surgical technique is being implemented to achieve this goal.

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