Research Paper

Magnetic Resonance Imaging Assessment of the Femoral Tunnel Position in Medial Patellofemoral Ligament Reconstruction
用磁共振掃瞄來評估在內側髕韌帶重建手術中股骨隧道的位置

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ABSTRACT

Background/Purpose: Correct femoral tunnel position in medial patellofemoral ligament (MPFL) reconstruction is essential to maintain proper biomechanics of the patellofemoral joint throughout the range of movement. Several techniques have been described for MPFL reconstruction, however, there are few reports describing the accuracy of femoral tunnel positioning assessed postoperatively.
Methods: Ten patients having recurrent patellar dislocation with MPFL reconstruction performed in our centre from 2009 to 2013 were analysed. Femoral tunnel position was guided by intraoperative X-ray with landmarks described by Schottle et al, 2007. Postoperative magnetic resonance imaging (MRI) was performed on both knees, and femoral tunnel was assessed with reference to the femoral origin of the MPFL in the nonoperated side.
Results: All cases showed an intact MPFL graft, with the majority demonstrating satisfactory femoral tunnel position based on postoperative MRI.
Conclusion: MPFL reconstruction with anatomic positioning of the femoral tunnel guided by intraoperative X-ray showed satisfactory accuracy in postoperative MRI results, indicating that a well-positioned MPFL graft results in better clinical outcomes.

中文摘要

簡介: 在內側髕韌帶（MPFL）重建手術中，正確的股骨隧道位置是確保髕股關節在活動時，有正常生物力學的關鍵。雖然文獻上有幾種MPFL重建的技術，但是僅少數報告描述手術後股骨隧道位置的準確度。
方法: 我們分析了十名因復發性髕骨脫位，於2009 - 2013年在我們的中心進行MPFL重建手術的病人。手術中應用了X光和由PB Schottle等人描述的解剖標誌來決定股骨隧道的位置。手術後病人接受兩邊膝蓋的磁共振掃瞄MRI，並用非手術那邊MPFL的股骨原點來評估手術邊的股骨隧道位置是否準確。
結果: 術後MRI顯示所有病例中的MPFL接技（graft）完整，股骨隧道的位置大部分令人滿意。
討論: 在MPFL重建手術中，用術中X光引導和解剖標誌來決定股骨隧道的位置，有不錯的準確度。一個放在準確位置的MPFL graft，有較好的臨床效果。

Introduction

Recurrent patellar instability is distressing to patients, resulting in loss of function, impaired quality of life, and premature patellofemoral joint (PFJ) arthrosis. Causes of recurrent patellar instability could be osseous, such as a malalignment problem, trochlear hypoplasia, or patella alta; muscular problems, with failure of the vastus medialis obliquus (VMO); excess lateral retinaculum tightness or destabilization of the medial patella due to failure of the medial ligaments.

Different surgical procedures were described to tackle the instability problem. Recently, there has been increased focus on

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medial patellofemoral ligament (MPFL) reconstruction. It was shown that the MPFL is the most consistently injured anatomical structure after a patellar dislocation.[1,2] It is the essential lesion of this injury. Biomechanically, it was shown that the MPFL provides 50–60% of the medial patella-stabilizing force.[3] Therefore, interest has been focused on MPFL reconstruction in the management of recurrent patella instability.

Correct femoral tunnel position in MPFL reconstruction is essential to maintain proper biomechanics of the patellofemoral joint. A well-positioned MPFL allows isometry of the graft throughout the range of movement, resulting in good clinical outcomes. Although the patella side was relatively easy to locate, the femoral tunnel was more difficult. Too proximal or anterior a femoral tunnel will result in medial patellofemoral joint overload.[4] However, if the tunnel is too distal, it may lead to a nontensioned graft and subsequent dysfunction as a medial restraint.[5]

Determining the MPFL femoral insertion after ligament rupture can be difficult both preoperatively and intraoperatively due to tissue injury, scar formation, and inability to accurately identify osseous landmarks. Intraoperative fluoroscopic guidance could aid positioning of the femoral-graft tunnel. A previous study by Schottle et al[6] suggested that the MPFL femoral insertion can be found approximately 1 mm anterior to the posterior cortex extension line, 2.5 mm distal to the posterior origin of the medial femoral condyle, and proximal to the level of the posterior point of the Blumensaat line on a lateral radiograph. However, despite efforts to ensure anatomical tunnel placement, errors in positioning are still common, with the main positioning error being proximal.

There are few reports describing the accuracy of femoral tunnel positioning assessed postoperatively. Research showed that radiographic landmarks determined by fluoroscopy can be used to accurately reproduce the femoral insertion of the medial patellofemoral ligament in ligament reconstruction, however, cadaveric knees instead of those of real patients were studied.[7]

The purpose of this study was to analyse our femoral tunnel position in MPFL reconstruction in correlation with our clinical results by using magnetic resonance imaging (MRI) and clinical scores.

Materials and methods

Ten patients having recurrent patellar dislocations with MPFL reconstruction performed in our centre from 2009 to 2013 were analysed. Femoral tunnel position was guided by intraoperative X-ray with landmarks described by Schottle et al[6]. Postoperative MRI was performed on both knees, and the femoral tunnel assessed with reference to the femoral origin of the MPFL in the nonoperated side. A Kujala scoring questionnaire was given to patients during follow up, and clinical outcomes were assessed.

Operations were performed by the Sports Medicine surgeons in the department. Among the MPFL grafts, eight were harvested from the gracilis, and two were harvested from semitendinosus (Figure 1).

The patellar tunnel was located over the upper half of the medial facet and the double-bone tunnel technique was utilized. Femoral tunnel position was identified radiologically according to Schottle et al[6], and the graft was fixed using an interference screw. (Figures 2 and 3).

From "Radiographic landmarks for femoral tunnel placement in medial patellofemoral ligament reconstruction" by P.B. Schottle et al, 2007, *American Journal of Sports Medicine*, 35, p.801–4. Copyright 2007, *Williams & Wilkins*. Reprinted with permission.

Postoperative MRI was performed on both operated and non-operated knees. The MPFL femoral origin of the nonoperated contralateral knee in the MRI image was used as the reference point.

Figure 1. Clinical photograph showing medial patellofemoral ligament reconstruction using a hamstring graft.
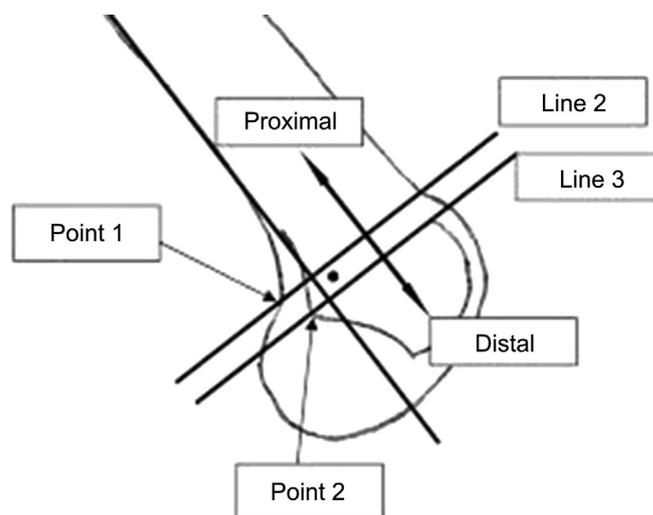

Figure 2. Medial patellofemoral ligament insertion can be found approximately 1.3 mm anterior to the posterior cortex extension, 2.5 mm distal to a perpendicular line intersecting the origin of the posterior medial femoral condyle, and 3 mm proximal to a perpendicular line intersecting the posterior point of the Blumensaat line, based on a lateral view with the posterior condylar margin overlapped.

MPFL origin was identified from the coronal- and axial-cut images of the nonoperated knee. The centre of the native MPFL origin was marked and its location labelled by a two-dimension axis: the X-axis represents the distance from the posterior articular surface of the medial femoral condyle in the axial image, and the Y-axis represents the distance from the distal articular surface of the medial femoral condyle in the coronal image (Figure 4).

The femoral tunnel of our graft was identified from the MRI sagittal sequence. The first medial cut that showed the femoral tunnel was used and the centre of the femoral tunnel was identified as the femoral tunnel position (Point A).

From the same MRI results and based on the X- and Y-axis information obtained from the nonoperated side, the reference point (Point B) was marked, assuming that the location of the MPFL origin was the same as that observed in the nonoperated knee.

We measured the distance between the centre of the femoral tunnel (Point A) and the reference point (Point B), and recorded whether it was superior, inferior, anterior, or posterior to the reference point (Figure 5).

Figure 3. Femoral tunnel location was identified using fluoroscopic guidance according to that described by Schottle et al.[6]

Interobserver measuring error was minimized by having all measurements performed by one single radiologist using a standard protocol. There is a chance of intraobserver error, as the interdistance was measured once by the radiologist, however, it was being measured by a radiologist subspecialized in musculoskeletal imaging using the same measuring method in order to decrease the error.

Outcome assessment

The Kujula score was assessed at 1-year following the operation. This clinical score included 13 different subjective scores[8].

Statistical analysis

Statistical analyses were performed using IBM SPSS version 22 (IBM Corp., Armonk, NY, USA). Mann-Whitney *U* test was used for descriptive statistics of non-normally distributed continuous variables between the two groups, i.e., Kujula scores between interdistances <12 mm and interdistances >12 mm, and Kujula scores between MPFL reconstruction and MPFL reconstruction plus tibial tuberosity transfer.

A Kruksal-Wallis test was used for descriptive statistics of non-normally distributed continuous variables between multiple groups, i.e., Kujula scores between interdistances ≤10 mm, 11–15 mm, or >15 mm.

Results

There were 10 patients recruited into this study. The sex ratio was 8:2, with females dominant. The mean age of our patients was 22 years (range, 14–36 years). Seven had isolated MPFL reconstruction performed, and three had combined MPFL reconstruction and tibial tuberosity transfer performed. The mean follow-up time was 26 months. At the time of MRI assessment, all MPFL grafts were intact.

In 90% of cases, the femoral tunnel position was within 12 mm interdistance from the MPFL femoral origin derived from the contralateral knee (Table 1). It is more common to have the graft positioned too proximal and/or anterior over the femoral footprint, which is compatible with other studies,[5] however, there was no statistically significant on the Kujula score between interdistance <12mm group and interdistance >12mm group and interdistance (*p* = 0.295).
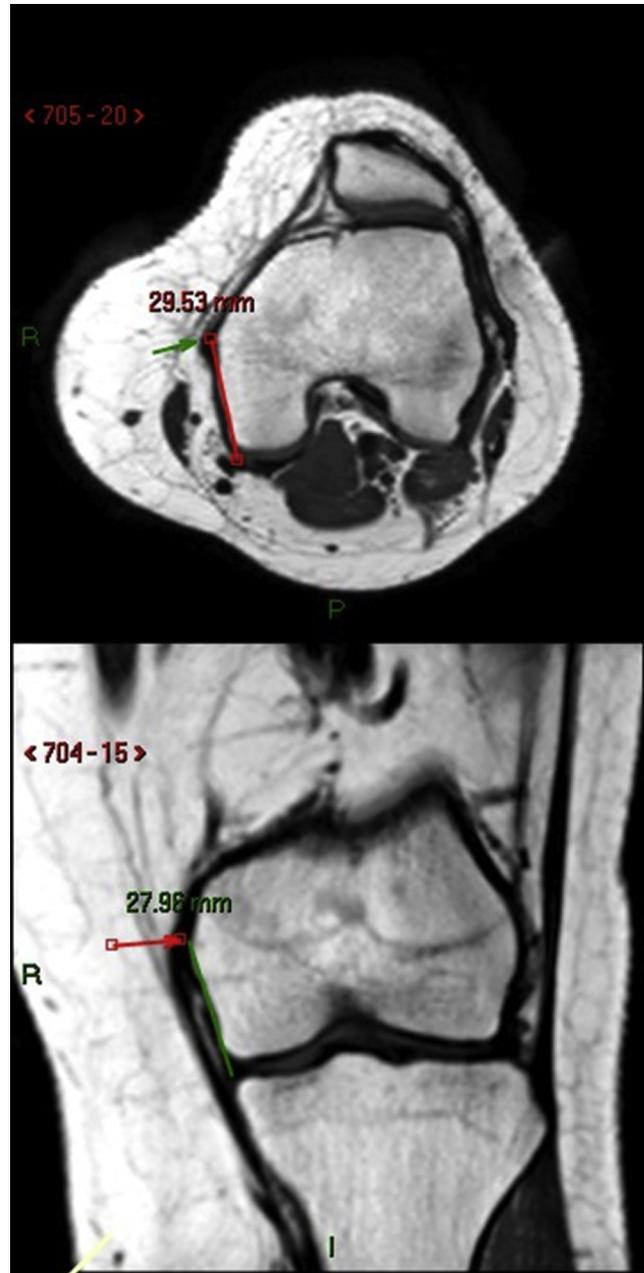

Figure 4. Magnetic resonance imaging of the contralateral nonoperated knee showing the location of the medial patellofemoral ligament femoral origin (marked by the arrow), with reference to the posterior and distal margins of the medial femoral condyle. R = right.

Our results indicated that for patients with bony procedures, specifically tibial tuberosity transfers in addition to MPFL reconstruction, the Kujula scores were lower (Table 2). However, there was no statistically significant difference between the Kujula scores between the MPFL reconstruction group and the MPFL reconstruction plus tibial tuberosity transfer group (*p* = 0.11).

Considering only the patients who received MPFL reconstruction as the sole procedure, shorter interdistances between the femoral tunnel and the MPFL femoral origin derived from the contralateral nonoperated knee resulted in a better Kujula functional score (Table 3), however, there was no statistically significant difference in Kujula scores between interdistances ≤ 10 mm, 11–15 mm, or >15 mm (*p* = 0.208).
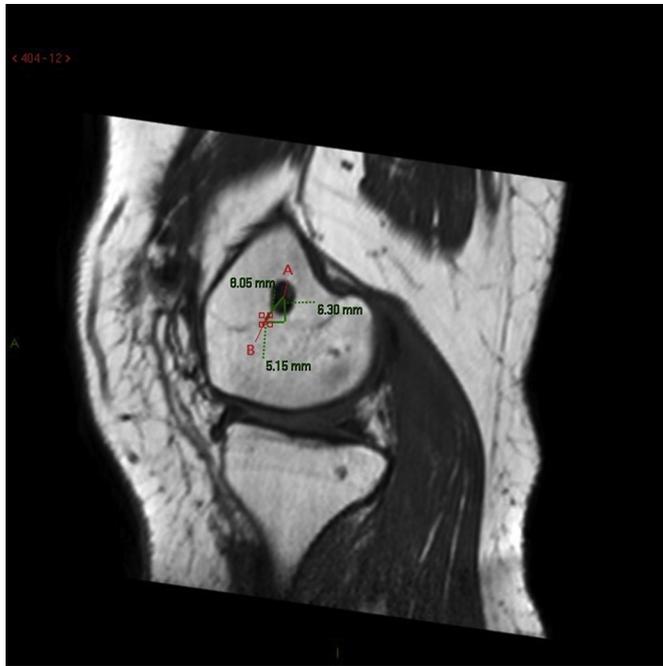
Figure 5. Magnetic resonance imaging of the operated knee showing the measurement of the distance between the centre of the femoral tunnel (Point A) and the reference medial patellofemoral ligament femoral origin derived from the nonoperated contralateral knee (Point B).

Table 1
Distance between the femoral tunnel and the medial patellofemoral ligament femoral origin derived from the contralateral nonoperated knee

	Procedure	Interdistance (mm)	Superior (+) inferior (−) (mm)	Anterior (+) posterior (−) (mm)	Kujala score
1	M	7	5	4	98
2	M	8	3	−7	93
3	M	10	9	4	89
4	M	11	9	−4	92
5	M	11	−10	−5	90
6	M	12	12	10	86
7	M	17	16	10	83
8	M + T	8	6	5	70
9	M + T	9	6	6	80
10	M + T	11	9	8	90

M = medial patellofemoral ligament reconstruction; T = tibial tuberosity transfer.

Table 2
Comparison of the clinical score between patients with MPFL reconstruction alone and patients with MPFL reconstruction together with tibial tuberosity transfer

Procedure (n)	Kujula score, median (range)
M (7)	90 (83–98)
M + T (3)	80 (70–90)

M = medial patellofemoral ligament reconstruction; MPFL = medial patellofemoral ligament; T = tibial tuberosity transfer.

Table 3
Kujula scores of patients with medial patellofemoral ligament reconstruction alone

Interdistance (n)	Kujula score, median (range)
≤10 mm (3)	93 (89–98)
11–15 mm (3)	89 (86–92)
>15 mm (1)	83

Shorter interdistance indicated better clinical scores.

Discussion

From the observation of the anatomical shape of the original MPFL, it was apparent that the patellar insertion was much wider than that of the femoral insertion,[4] Thus rendering the location of MPFL patella insertion much more forgiving.

However, too proximal or anterior a femoral tunnel placement will result in medial PFJ overload upon flexion, as the distance to the patella increases as the knee flexes.[6] This could lead to early PFJ arthritis development. However, too distal or posterior a placement of the femoral tunnel will lead to inadequate tension of the graft upon flexion, resulting in loss of medial restraint. Smirk and Morris[4] showed that a distance of ≤5 mm from anatomical femoral MPFL insertion did not change MPFL isometry.

Our literature search revealed only one study reporting the accuracy of postoperative positioning of the MPFL femoral tunnel.[5] From their result using MRI assessment, anatomical tunnel placement was achieved in 65% of cases. In that study, the "normal" values for the centre of the femoral tunnel were defined to be between 20 mm and 30 mm from the posterior medial condyle. A distance >30 mm was considered too anterior, and a distance <20 mm too posterior. They also considered the "normal" values for the centre of the femoral tunnel to be between 25 mm and 35 mm from the distal articular surface. When the distance was >35 mm, the tunnel was considered too proximal, and when it was <25 mm, the tunnel was considered too distal. However, there were no references quoted in their study supporting the "normal " values used for the anatomical location of the MPFL femoral origin, therefore, its accuracy remained doubtful.

The Kujula scores obtained at follow up showed that an anatomical femoral tunnel position was apparently associated with better clinical outcomes. It is expected that a well-reconstructed MPFL could provide a good medial restraint to the patella over the whole range of motion without causing excessive pressure on the PF joint. From our results, it appears that an interdistance of <12 mm gives satisfactory clinical outcomes, although statistical significance of this result could not be demonstrated.

From our results, patients with tibial tuberosity transfer in addition to MPFL reconstruction apparently performed less well compared with patients with MPFL reconstruction alone. One reason may be because this group of patients, in general, exhibited worse clinical presentation and worse clinical scores before operation.

There were some limitations in our study. First, the sample size was small and had a short follow-up period. Limited cases were performed after careful selection of patients with good indications for surgery in a regional hospital over the study period. The small sample size limited our ability to show any statistical significance for the results, however, we did observe a trend of higher Kujula scores among shorter interdistance cases compared with longer interdistance cases. More cases were needed to improve our ability to demonstrate statistical significance. However, any long-term differences in the clinical results related to abnormal MPFL femoral tunnels may not be detected in our study due to the short follow-up period.

Second, identification of MPFL femoral origin was sometimes difficult. In our study, we defined the anatomical femoral origin of the MPFL based on MRI results of the contralateral nonoperated knee. However, anatomical studies showed that there were strong relationships between the MPFL and the superficial bundle of the MCL.[9] The continuity of fibres between the MPFL and the medial collateral ligament (MCL) somehow made differentiating femoral MPFL insertion and femoral origin of the upper bundle of the MCL difficult even with MRI. In short, even MRI may not be absolutely

precise in locating the anatomical femoral origin of MPFL for our patients.

Third, other factors, such as presence of skeletal dysplasia and graft tension, were not taken into account. The effect of these factors could not be eliminated. Any residual undiagnosed skeletal dysplasia condition could give rise to worse clinical postoperative scores.

Conclusion

MPFL reconstruction with anatomic positioning of the femoral tunnel guided by intraoperative X-ray showed satisfactory accuracy in postoperative MRI. A well-positioned MPFL graft apparently gives better clinical outcomes. Further studies with a larger number of cases, as well as changes in pre- and postoperative Kujula scores in the later stages of our studies, would allow presentation of more concrete results.

Conflicts of interest

The authors declare no conflicts of interest.

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