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ORIGINAL PAPER

Are the tubular grafts in the femoral tunnel in an anatomical or isometric position in the reconstruction of medial patellofemoral ligament?

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Abstract
Purpose The purpose of this study was to evaluate the biomechanical results from the in vitro reconstruction of medial patellofemoral ligament (MPFL) using a navigation-assisted technique on a cadaveric model and its effects on patellar stability and kinematics. The authors investigated the hypothesis that patellar kinematics after reconstruction with a tubular graft are not optimal when compared with the original fan-shaped MPFL.
Methods In six fresh-frozen cadaveric knees, lateral loads (25 N) were applied on the patella at 0°, 30°, 60° and 90° of knee flexion in three different MPFL states: intact, cut and reconstructed. The arrangement allowed positional measurements of patellar motion to be tracked in six degrees of freedom. Medial to lateral patellar translation and patellar tilt were recorded. The kinematics after a technique of MPFL reconstruction, performed with a gracilis tendon in a blind femoral tunnel guided by navigation, were compared against kinematics recorded in the MPFL intact state. A temporary fixation of adequate tension to engage the lateral patellar facet in extension was applied to the MPFL and, after graft cycling, the final fixation was done at 70° knee flexion with an interference screw.
Results There was a comparable medial to lateral patellar translation and tilting of the patella in the MPFL-intact and the MPFL-reconstructed state. Static patellar translation in the MPFL-reconstructed state, with and without the application of load, was comparable to patellar translation in the MPFL-intact state. The dynamic patellofemoral shift kinematics recorded an under-constraint in early flexion and over-constraint in late flexion, while an opposite effect was recorded in patellar tilt. However, these differences were not statistically significant.
Conclusion The study confirmed the major role of the MPFL in case of medial loading between 0° and 60°, by focusing on the importance of kinematically identifying the proper femoral point for fixation. While the study demonstrates the importance of kinematic determination of the proper femoral point of fixation, as the anatomical insertion remains difficult to identify. Even in dissected cadavers, the authors recorded a slightly anterior placement than native MPFL. After reconstruction, patellar stability in terms of lateral translation and tilt was similar to the intact MPFL, but patellar kinematics were not optimal with the use of a smaller and tubular graft than the native wider and fan-shaped MPFL.

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Introduction

The medial patellofemoral ligament (MPFL) is a well-recognized primary static stabilizer of lateral patellar dislocation and is always found to be deficient or ruptured in acute and chronic cases of patellar dislocation [1–5]. Since the importance of MPFL in patellar stability has been documented, several authors have studied its anatomic reconstruction [6–8], either as a isolated procedure, or combined with other patellofemoral surgery [6, 9–13]. The numerous methods published for its reconstruction differ in terms of the graft used, the site of patellar and femoral fixation, the fixation method and especially, the degree of knee flexion for anatomical reconstruction [9, 12, 14, 15]. Review of the

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literature reveals a trend towards mini-open methods for MPFL reconstruction using a tubular graft (e.g. hamstrings) through patellar tunnels, or fixed with anchors, and as close as possible to its anatomical femoral insertion [16] in a blind tunnel fixed with an interference screw [17–21].

Regardless of the surgical approach, it appears that there is popularity among knee surgeons who treat patellar instability, to reconstruct the MPFL through a single bone tunnel in the femoral origin of MPFL between the medial epicondyle and adductor tubercle, with or without X-ray control, and to finally fix the construct in variable degrees on knee flexion [18, 20, 22–28]. The natural behaviour of this naturally fan-shaped ligament is not fully understood, the correct landmarks for its femoral attachment are defined but difficult to imitate and there is no consensus about the angle of knee flexion for the graft [29].

The optimal MPFL reconstruction would implement a new ligamentous complex that should prevent pathological lateral translation of the patella, while being neither too tense to allow for full knee flexion and to decrease medial facet contact pressures or increase medial tilt, nor too loose to allow for patella dislocation in full extension [22, 23, 26, 30, 31]. On one hand, there have been many reports on the anatomy, the surgical technique, the site of patellar and especially femoral insertions, the knee angle of graft fixation and the type of fixation. The femoral insertion of the natural MPFL is a very thin and fan-shaped layer [32]. Its radiographic landmarks have been identified [16], as well as the complications from malpositioning [26], especially too anteriorly and too proximally [33]. On the other hand, there has been less interest on the shape of the graft used for the reconstruction in comparison to the natural MPFL, whose original fan-shaped anatomy in the femur leads to a wider insertion area that is difficult to reproduce by a smaller and tubular-shaped grafts (e.g. hamstrings). Due to this difficulty with the disproportion between the natural MPFL and the available tubular-shaped grafts, some authors tried to fine-tune the radiographic femoral placement in order to better represent the natural anatomy [26].

The purpose of the present study was to evaluate the kinematic results from the application of a technique in the reconstruction of the MPFL with a tubular graft and its effects on patella stability and kinematics, using a cadaveric model. The authors studied the hypothesis that patella kinematics after reconstruction with a smaller and tubular graft are not optimal when compared with the original wider and fan-shaped MPFL.

Materials and methods

Six non-pathological and not previously operated, fresh-frozen, unpaired lower limbs (two males and four females), disarticulated at the hip, with an average age of 50 years (range 41–60 years), were chosen for the study. Each limb was thawed to 20° over 24 hours, laid supine, and clamped proximally at the femoral diaphysis to eliminate femur anteversion and to allow free tibial rotation during 10–90° knee flexion-extension. The skin and subcutaneous tissue were dissected proximally for 20 cm, the extensor apparatus of the knee was isolated and an axial load of 60 N was applied via a set of pulleys along the quadriceps at the musculotendinous junction. The magnitude of the axial quadriceps load was 60 N as it was found adequate to reproduce in-vitro kinematics as reported in literature [34–36]. Navigation was done with a validated setup and protocol (BLUIGS, Orthokey LLC, Lewes, Delaware) to acquire the anatomy of the limb and patellar kinematics (Table 1) [35–37]. Accuracy of the system was 0.5 mm/0.5°. The limb was held in neutral rotation, while the navigation system was used to control the position of the tibial tubercle and the patella during the tests. A provision was made to apply a 25 N laterally directed load via a hand-held manometer at 0°, 30°, 60° and 90° of knee flexion. Consistent position of the lateral load was controlled by navigation. The MPFL was isolated, resected and reconstructed as described below. Three repetitions of each test provided an average result. Repeatability was found to be 1.5 mm and 1.5°. Since, the study focused on approximation of the reconstructed MPFL to the native MPFL, the kinematics of the intact MPFL were used as control.

Coordinate system

Anatomical acquisition was used to reconstruct an axis system for the limb (Table 1). The transepicondylar line formed the medio-lateral axis, the femoral mechanical axis formed the proximal-distal axis and their cross-product was used as the antero-posterior axis. The poles of the patella (superior, inferior, medial & lateral) defined its longitudinal and transverse axis, while their cross-product defined the antero-posterior

Table 1 Navigated acquisition of anatomy and kinematics

Anatomy
Distal femoral surface (trochlea & condyle)
Surface tibial plateau
Antero-posterior patellar surface
Medial patellofemoral ligament (MPFL) insertion on femur and patella (Fig. 3)
MPFL extent
Kinematic tests: 10–90° knee flexion-extension
MPFL-intact and MPFL-reconstructed bundles
○ Change in length
○ Change in distance between insertion points
Patella motion in six degrees
○ With and without a laterally directed load

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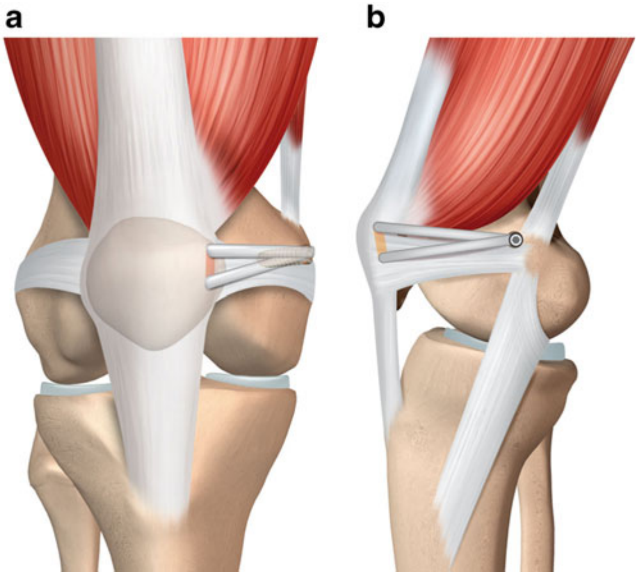

Fig. 1 Schematic presentation of the applied medial patellofemoral ligament (MPFL) reconstruction. **a** Anteroposterior view of the two tunnels in the superior-medial border of the patella. **b** Lateral view of the graft secured in the femur

axis. In the tibia the mechanical axis was taken as the proximal-distal axis. The line connecting the medial one-third of the tibial tuberosity to the centre of the tibial spine was taken as the antero-posterior tibial axis. The cross-product of these two axes defined the medio-lateral axis. The Grood and Suntay method was used to decompose the movement of the bone segments. Spline curves were used to analyse change in length of MPFL fibres over knee motion [38]. The insertion of the native and reconstructed MPFL were acquired, along with the fibres of the two individual MPFL bundles (Fig. 2) as it has previously been reported by Amis et al. [32]. Fibres were chosen at the superior and inferior border of the MPFL, and then two more representative fibres were acquired within the substance, equidistant from each border. The change in the distance between the femoral and patellar insertion points of these fibers was computed (Fig. 3) using proprietary routines (Matlab, © 1984–2013 The MathWorks, Inc.).

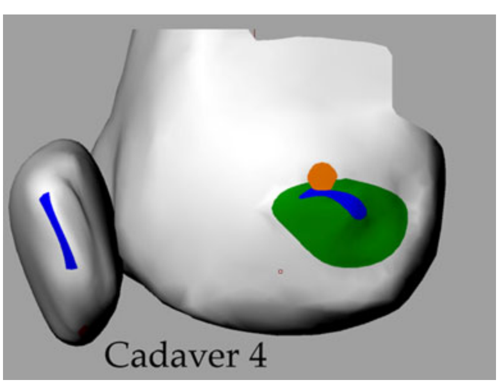

Fig. 2 Schematic representation of the relationship between the original medial patellofemoral ligament (MPFL) femoral insertion (*green area*) and the position of the graft (*circular orange area*). The graft was consistently positioned proximally to the MPFL insertion

Surgical technique for MPFL reconstruction

Standard hamstring harvesting was performed over the pes anserinus, and a 22–25 cm length of gracilis tendon was stripped and detached from its tibial insertion and prepared with longitudinal absorbable sutures (2–0 Vicryl) throughout 3 cm on each side. The patellar side was then prepared over the superior-medial 2/3 of the patella. Without violating the synovial membrane, subperiosteal dissection of the antero-medial patellar was performed. Drilling of the patella insertion site followed in an anterior to posterior fashion without violating the articular surface; two 3.5-mm wide tunnels were created starting from 10 mm below the superior patellar pole and separated by a bone bridge of 20 mm. The two tunnels were aligned 15 mm lateral to the medial patellar pole in order to avoid iatrogenic fractures. With the use of a curved clamp, the two tunnels were connected resulting in one U-shaped tunnel (Fig. 1). A small longitudinal incision was performed 1 cm medially to the patella, and the medial retinaculum was opened to serve as a pulley for the later passage of the graft. For the preparation of the femoral insertion, when the surgical technique was applied in the clinical setting, the authors used fluoroscopy in order to identify the anatomic site of MPFL origin [16]. When the anatomical landmark was identified, a K-wire was inserted and a cannulated 7-mm drill was used to drill the blind tunnel. This allowed the graft be free to move in the tunnel before fixation. For the purposes of the present cadaveric study, the authors dissected the knees, and the original insertion of the intact MPFL was recognized, then MPFL was cut and it was finally reconstructed in each case on the femoral side. The goal was to reconstruct the MPFL to the anatomic femoral insertion, but as the anatomic insertion of the MPFL was wider than the 7 mm tunnel, care was taken not to err towards a more anterior and distal graft fixation than the original femoral insertion.

Graft passage was performed in a standard fashion using suture passers from the U-shaped patella tunnel, under the medial retinaculum pulley, subcutaneously to layer 2 and out to the femoral insertion (Fig. 1b). Using a suture passer the graft was inserted in the femoral blind tunnel and the attaching sutures were temporarily secured with a Kocher clamp on the lateral surface of the femur. Then the knee was cycled ten times for pre-tensioning. Lateral patella translation was assessed in full knee extension: (a) the medial patellar facet should not translate more than one quadrant of the patellar width, (b) a firm end-point should be recorded, and (c) absence of medial tilt should be noticed. On the other hand, over-medialization of the patella or restriction of full knee flexion were the results of

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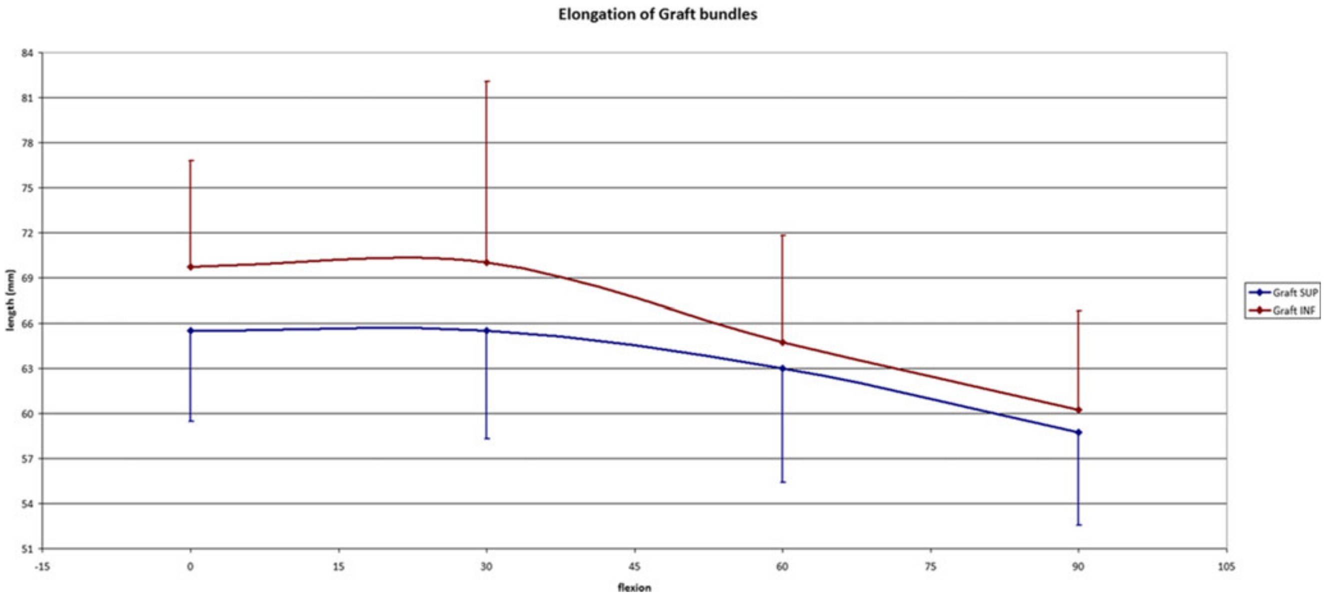

Fig. 3 The recorded distance (measured in mm) between the femoral and the patellar insertion of the graft bundles (superior and inferior) in different degrees of knee flexion

excessive medial forces. If required, further graft tensioning or loosening was possible by adjusting the sutures in the Kocher clamp. When isometric pull-out forces where obtained, the graft was finally fixed in 70° of flexion with an appropriately-sized interference screw (Ligafix 60 7/25 mm SBM™; SBM Z.I. du Monge, 65100 Lourdes, France).

Statistical analysis

The relation of MPFL femoral insertion to medial epicondyle for all specimens was analyzed descriptively as mean ± standard deviation (Table 2). Unpaired Wilcoxon test was used ($p = 0.05$) to compare differences in lateral patellar translation and patellar tilt throughout the range of flexion in loaded and unloaded knee. The distance between insertion points of the native-MPFL bundles and the graft-MPFL, at four different degrees of flexion, were compared using Kruskal-Wallis test with contrast against position at 0° using Bonferroni error protection method. Non-parametric tests were chosen because the number of specimens did not provide normal distribution of data. The difference in patellar tracking among the MPFL-intact, MPFL-cut and MFPL-reconstructed state were analysed using non parametric Kruskal-Wallis test using MPFL-intact state as a reference, wherein significance was set at $p<0.05$.

Results

Anatomical data: MPFL femoral tunnel

The femoral tunnel for the MPFL graft bundles was relatively consistent compared to the spatial variability of the natural MPFL femoral insertion and medial epicondyle, seen in specimens included in the study (Table 2). The surface area of the femoral insertion was determined to be 36.7±11.74 mm^2. On average, the femoral insertion of the graft was significantly proximal and slightly anterior in relation to the medial epicondyle and the navigation-

Table 2 Spatial orientation of native-MPFL insertion and tunnel for MPFL graft in mm, on the medial femoral condyle, in relation to the medial epicondyle

Relation to medial epicondyle of femur	Proximal insertion of native-MPFL		Distal insertion of native-MPFL		Barycentre of native-MPFL		Femoral tunnel for MPFL graft	
	AP	PD	AP	PD	AP	PD	AP	PD
Mean ± SD (mm)	−5.0±7.2	6.5±3.8	−10.1±8.2	−2.3±2.3	−7.6±7.2	2.5±2	−6.3±3	12.3±3.3

AP anterior-posterior, *PD* proximal-distal, *SD* standard deviation, *MPFL* medial patello-femoral ligament

MPFL position expressed as positive (+) if anterior and/or proximal to the medial epicondyle, while a position posterior and distal to the medial epicondyle was expressed in negative (−) values

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produced geometric centre of the natural MPFL insertion (barycentre). The position of the reconstructed MPFL and its relationship with the intact MPFL in every cadaver is shown in Fig. 2. From the study of the population, we recorded that there was no patella alta and there was neither trochlear dysplasia nor significant variation in trochlear anatomy in our study population to explain variance in patellar kinematics in the three different states.

Kinematic data: MPFL-intact, MPFL-cut and MPFL-reconstructed models without lateral loads

The kinematics of the two bundles of the MPFL graft could be recorded separately. The distance between their femoral and patellar insertion attained a maximum distance at 30° and moved closer on further knee flexion, while the graft bundles remained parallel to each other (Fig. 3). The kinematic behaviour of the graft bundles was different from the bundles tracked in the natural MPFL (Fig. 3). The superior bundles of the natural MPFL exhibited isometric behaviour, while the inferior slackened in flexion. While the patella medialized after reconstruction, compared to the MPFL-cut state, it appeared under-constrained (i.e. laterally positioned) in early flexion and over-constrained (i.e. medially positioned) in late flexion compared to the MPFL-intact state, with transition around 45°. The initial medial translation was restored after MPFL-reconstruction (Fig. 4). Contrary to patellar translation, patellar tilt kinematics seemed over-constrained in early flexion and underconstrained after 80° of knee flexion (Fig. 5). There was no difference in the variability of patellar translation in all three states. However, these differences were not found to be statistically significant, except at 70° for lateral patellar translation (Fig. 4) and between 35° and 65° for patellar tilt (Fig. 5).

Kinematic data: MPFL-intact, MPFL-cut and MPFL-deficient models with lateral loads

Excessive lateral patellar translation was significantly curtailed after MPFL reconstruction, compared to the deficient state, especially at 30° and 60° of knee flexion (Fig. 6). Patella laxity after reconstruction closely matched the MPFL-intact state at all angles of flexion (Table 3).

Discussion

The most important finding of this study is that patellar stability, in terms of lateral patellar translation and patellar tilt, was comparable to intact MPFL after reconstruction, but the normal kinematics of the original fan-shaped MPFL were not reproduced with the tubular graft and the femoral bone tunnel fixation. The importance of MPFL in lateral patellar translation and patellar tilt was documented and the reconstruction of MPFL reduced that laxity comparable to normal anatomy. While our study suggests that translation was under-constrained below 45° (i.e. patella was laterally positioned) and tilt was over-constrained up to 80° in early degrees of flexion, with the reverse effect seen in later flexion, these differences were not statistically significant.

Since its early description in the literature, MPFL has gained enormous popularity among orthopaedic surgeons [39]. First, it was well-established that MPFL is a consistent and present anatomic structure in patellofemoral anatomy [40–42], and then, its importance in patella stability was emphasized as the primary static restraint to lateral patellar translation, providing more than 50 % of the medial stabilization [4, 42]. Consequently, it has been widely reported that MPFL-deficiency is a consistent result of pathological

Fig. 4 Medial to lateral patellar translation (shift) in three different states of medial patello-femoral ligament (MPFL) (intact/cut/reconstructed) in different degrees of flexion. Medial translation (in mm) expressed in negative (−) values and lateral translation expressed in positive (+) values

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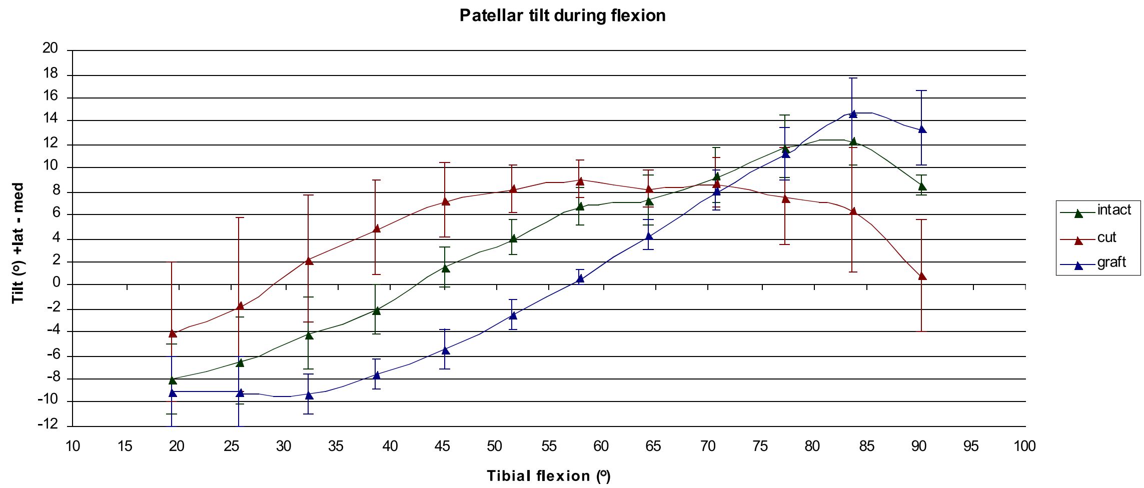

Fig. 5 Changes of patellar tilt in three different states of medial patello-femoral ligament (MPFL) (intact/cut/reconstructed) in different degrees of flexion. Medial tilt expressed in negative (−) values and lateral tilt expressed in positive (+) values

lateral patellar translation [1, 2, 5, 43]. This led to a more detailed description of the ligament's anatomy. Steensen et al. [23] defended the isometric pattern and described the insertions of MPFL under layer 2 of the knee, from the two proximal thirds of the medial patella to a fan-shaped insertion between the medial femoral epicondyle and the proximal adductor tubercle. Amis et al. [32] described the MPFL more like a non-isometric structure; he found that MPFL is interdigitated and closely working in concert with the deep fibres of the vastus medialis obliquus, which acts as a dynamic medial stabilizer. MPFL is tight in full knee extension and acts as a static medial stabilizer during early degrees of flexion (15–20°), bringing the patella into the trochlear grove, and in greater degrees of flexion (>30°) is loose and the trochlea serves as a guide for normal patellar kinematics [44, 45].

The results of the present study also support that the specific reconstruction does not lead to excessive patellar tilt on the horizontal plane during knee flexion. The femoral insertion of the original MPFL is fan-shaped and of larger diameter in the specimens studied than the cylindrical 7-mm graft used for the reconstruction. In every technique for reconstruction, the femoral insertion is identified either by anatomic (palpation) or by radiological landmarks. The difference of the original diameter and shape between the intact and the reconstructed MPFL and the position of the graft results in a non-anatomic insertion in the femur. The biomechanical properties of the reconstructed graft are different than the intact MPFL, and these could be strong factors for the inability to restore prior-to-injury MPFL biomechanics. In the present study the choice to position the graft in dissected cadavers at the anatomic insertion of the native MPFL and not to err

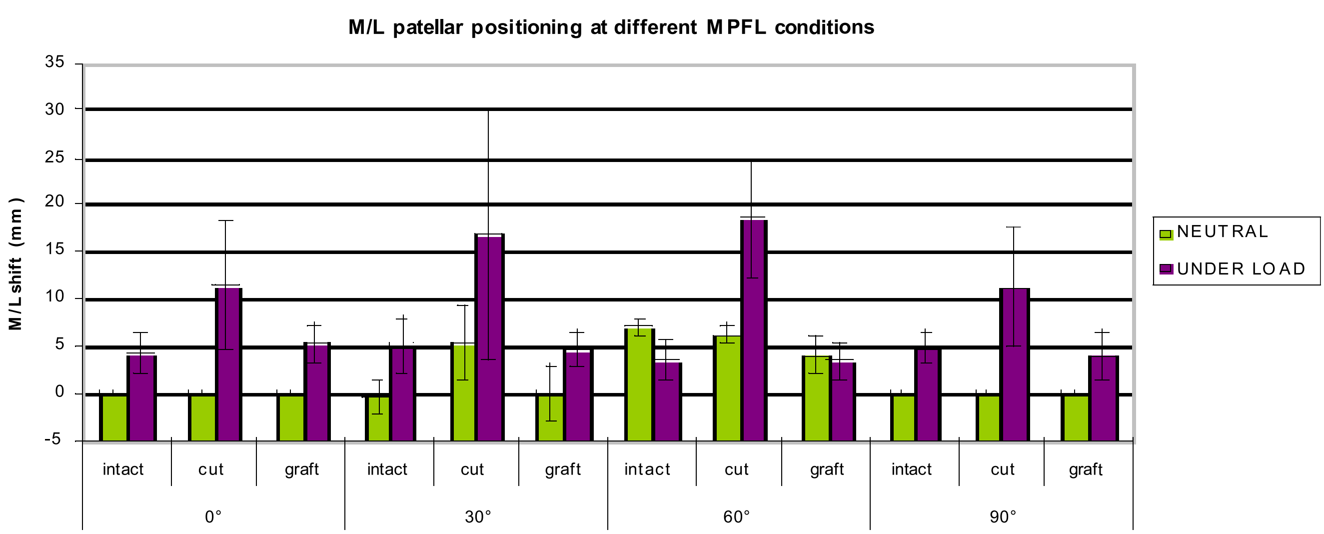

Fig. 6 Medial to lateral patellar positioning in three different states of medial patello-femoral ligament (MPFL) (intact/cut/reconstructed) in different degrees of flexion with and without the application of loads

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Table 3 Lateral patellar translation (measured in mm) in medial patello-femoral ligament (MPFL)-intact, MPFL-cut and MPFL-reconstructed (MPFL recon) state

Specimen	Lateral patellar translation under 25 N stress											
	0° tibial flexion			30° tibial flexion			60° tibial flexion			90° tibial flexion		
	MPFL recon	MPFL cut	MPFL intact	MPFL recon	MPFL cut	MPFL intact	MPFL recon	MPFL cut	MPFL intact	MPFL recon	MPFL cut	MPFL intact
Cadaver 1	4.6	9.4	5.5	2.7	1.5	4.8	1.2	11.2	0.8	3.2	3.7	7
Cadaver 2	6.7	8	4.4	3.9	17.4	5.7	2.9	21	5.1	0.8	20.5	5.1
Cadaver 3	3.5	7.6	5.8	7.6	7.2	3.3	5.2	14.3	3.3	4.7	4.9	3
Cadaver 4	4.5	5.1	2.8	5.7	17.9	4.7	2.5	19.3	2.6	5.5	15	4.9
Cadaver 5	8.7	24.1	5.8	4.4	40.8	10.4	6.3	29.6	6.7	7.6	10.8	5.8
Cadaver 6	3.6	13.8	0.7	2.7	16.3	1.9	2.7	15.9	1.5	2.2	12.8	2.8
Mean ± SD	5.2±2	11.3±6.8	4.1±2	4.5±1.8	16.8±13.4	5.1±2.8	3.4±1.9	18.5±6.4	3.3±2.2	3.9±2.4	11.2±6.3	4.7±1.6

MPFL medial patello-femoral ligament, *SD* standard deviation

towards anterior and distal placement showed that patellar stability was comparable between the native and the reconstructed MPFL, but the kinematics results were not reproduced. Since in this cadaveric population there were no additional factors for patellar instability like trochlear dysplasia and patella alta, the difference in the anatomical femoral insertion played a role because of the different surfaces between the larger anatomic MPFL insertion (36 mm^2) and the graft used (7 mm). The graft was always proximal to the femoral insertion of the natural MPFL and the position on the anteroposterior plane varied. From the study of the results a pattern emerged although it was not statistically significant, i.e. when the graft was placed anteriorly, the lateral translation, on laterally directed load, compared to intact MFPL was greater in extension and less in flexion. On the contrary, when the graft insertion was more proximal and posterior, the opposite effect was recorded; the lateral translation, on laterally directed loads, compared to the intact MPFL was less in extension and greater in flexion. These results show that the option to position the femoral side of the graft at the proximal part of the anatomic insertion of the MPFL is a reliable and efficient position.

With the present reconstruction technique, the role of MPFL (to prevent excessive lateral translation during extension and early flexion and then deliver the patella into the trochlea for the remaining of flexion) was achieved. It can be attributed to: cyclical pre-tensioning of the graft prior to fixation; fixation of the femur in 70°; and, last in order, to permit the graft to gain adequate length so that it allows greater degrees of flexion, during which the patella is mostly stabilized by a normal trochlear groove. Furthermore, the patellar side included two tunnels connected in a U-shape fashion that avoids the possible complication of fractures with instrument trans-patellar fixation. The passage of the graft through the pulley created in the retinaculum also prevented excessive lateral tilting, which was not observed with the reconstruction. The findings of the previously-published manuscripts on MPFL tension are also based on normal knees with no trochlear dysplasia and with no concern of abnormal patellar height or shape [33]. The authors believe that the most important steps for the reconstruction will be the correct identification of both the original patellar and femoral insertion and the ability of the reconstruction to produce a similar sized and shaped construct in the femoral insertion of the natural MPFL. The patellar insertion is easy to identify because it involves an open technique, but for the femoral insertion the identification is more controversial and the use of the fluoroscopy is recommended. It is very important that the new reconstructed ligament would be tensed in a way to prevent pathological lateral patellar translation in full extension and in early degrees of flexion, while not being overconstrained [46] in order to allow for further knee flexion and for the normal lateral to medial engagement of the patella on the proximal trochlea [32, 47].

Regardless of the technique followed for MPFL reconstruction, after establishing the proper anatomic sites for femoral and patellar insertion, there is some skepticism on the ideal degrees of knee flexion and the amount of tension applied to the graft for isometric fixation. According to biomechanical studies, most surgeons chose to tension the ligament at 20–30° of flexion where the greatest amount of patellar instability occurs [2], but others chose to tension the reconstructed ligament in greater degrees of flexion, when the patella is more fully captured by the trochlea [2, 32]. But in order for this to succeed, a normal trochlear anatomy is of paramount importance, and therefore in cases of trochlear dysplasia (which account for 96 % of the objective patellar instability population [45]), the lack of trochlear depth and patella containment must be taken into account. In theses cases there is a trend towards overtensioning the graft to

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avoid lateral patellar translation [48]. The authors do not recommend the traditional graft tensioning between 20° and 30° of flexion. The exact knee position during fixation is less important if knee cycling and graft pre-tensioning precede the final fixation. Testing the lateral patellar translation in extension (in order not to exceed 1/3 of patella width), graft pre-tensioning, and making the femoral fixation last in order were the key steps of the reconstruction.

The orientation of the graft towards the femoral insertion creates a simultaneous posteromedially directed force on the medial side of the patella, thus increasing medial facet contact pressures and elevating the lateral facet [48]. This subsequently could lead to early degenerative cartilage damage that commonly exists in patients with patellar instability and worsens future results. There have been some biomechanical reports that test patellar translation and contact pressures after MPFL reconstruction [4, 13, 30, 42, 48, 49]. Although it is clear that MPFL reconstruction restores the pathological lateral patellar translation, the contact patellofemoral pressure changes still remain to be further studied [13, 42]. Ostermeier et al. [49] reported insignificant changes on patellofemoral pressures even after the application of significant loads, while Beck et al. [48] recorded significant increases on the medial facet contact pressures with the application of loads over 40 N, which where restored to normal values with the application of very small loads of 2 N of graft tension [48].

Bollier et al. stated that probably none of the existing MPFL reconstruction techniques are truly anatomic or restore normal knee biomechanics [33]. The correlation between proper femoral placement and clinical outcome has been questioned [26]. Proper MPFL reconstruction techniques successfully restore mediolateral patellar displacement in early flexion, but probably additional surgery (e.g. trochleoplasty, distal re-alignment procedures) are required when co-existing anatomic abnormalities occur, in order to reduce patellar laxity over the whole range of knee motion and to reduce the increased patellofemoral contact pressures resulting from the reconstruction [2]. This finding has been supported by other authors who emphasized the importance of not over-weighing the evidence on the detailed technical MPFL reconstruction while under-estimating concomitant factors contributing to patellar instability, like patella alta and trochlear dysplasia [33, 46]. A prerequisite for a successful MPFL reconstruction is the return to normal osseous knee anatomy and geometry [2, 33].

Conclusions

The presence and the importance of MPFL in patella stability were emphasized from the biomechanical results of this reconstruction technique. It is probably difficult to fully reproduce the biomechanics of the natural ligament throughout the whole range of knee motion, even in vitro on knees with no additional osseous pathology, because of the different shape and width of the tubular grafts currently used other than the MPFL. Identification and reproduction of the femoral ligamentous insertion is the most challenging part of the reconstruction. Differences between the original shape and diameter of the femoral insertion and the graft are key factors for this. The exact position of knee flexion during fixation is not considered a key factor, only when fixation is performed after graft pre-tensioning and assessment of the lateral patellar translation in extension not to exceed 1/3 of patella width. Further research is required to test the results from the use of fan-shape grafts that would probably reproduce more closely the layer of the native femoral MPFL insertion.

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