Evaluation of the mechanical property of posterolateral structures in supporting posterolateral stability

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<ABSTRACT>

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Despite the inferior biomechanical property of the popliteofibular ligament (PFL) in terms of cross-sectional area and ultimate strength, the PFL seemed to make a greater contribution in resisting external rotation of the tibia than the popliteus tendon (PT) in some biomechanical studies.

The objectives of this study are to evaluate the contributions of the popliteofibular ligament (PFL), the popliteus tendon (PT) and the lateral collateral ligament (LCL) to the posterolateral stability of the knee by changing the sequence of selective transection, and to quantify their cross-sectional areas. Twelve fresh-frozen cadaveric knees were divided into two groups. Group 1 (PFL-PT-LCL) has a following cutting sequence: PFL, PT, LCL. Group 2

(PT-PFL-LCL) has a following cutting sequence: PT, PFL, LCL. Each specimen was mounted on the apparatuses using the Ilizarov external fixator for measuring external rotatory and varus laxities at every 30° from 0° to 90° of knee flexion. In both groups, there was no significant difference between PFL and PT in the increment of respective external rotatory laxity after transection at each of the knee flexion angle, except 0° in Group 2. The transection of the LCL increased the external rotatory laxity in 0° and 30° with statistical significance. The varus laxity was increased significantly only after cutting the LCL at every knee flexion angle. The mean cross-sectional areas of the PFL, the PT and the LCL were 6.9±1.6 mm^2, 16.7±3.8 mm^2 and 9.8±1.9 mm^2 respectively. In conclusion, both PFL and PT equally contribute to the external rotatory stability. The LCL also contributes to the external rotatory stability at early range of knee flexion. The LCL is a main structure for varus stability in the knee.

Key words : the popliteus tendon, the popliteofibular ligament, the lateral collateral ligament, external rotatory laxity, varus laxity

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1. Introduction

Posterolateral stability is provided by numerous static and dynamic components in posterolateral corner of the knee.[1,2] The static components include the lateral collateral ligament, the arcuate ligament, the fabellofibular ligament, the popliteofibular ligament and the posterolateral capsule. The dynamic components include the biceps tendon, the iliotibial tract, the lateral head of the gastrocnemius muscle and the popliteus muscle-tendon complex. Once these structures are injured, the external rotatory instability is usually accompanied by the varus instability. Since Gollehon et al. described through the selective cutting technique,[3] it has been recognized that varus instability is caused by disruption of the lateral collateral ligament (LCL), and external rotatory instability is caused by the disruption of the popliteus muscle-tendon unit and the popliteofibular ligament (PFL). [4,5] All of these three structures have been determined as the main static structures at the posterolateral corner of the knee and recently among these key structures, the PFL has come into the spotlight[4-7] as the most important structure sustaining the posterolateral stability.

The PFL was recognized as a fibular origin of the popliteus muscle-tendon complex once, but through recent biomechanical studies, it has been found out that the PFL plays a major role in external rotatory stability rather than popliteus muscle-tendon unit. [4,6,8] Though the PFL has a longer lever arm and can more effectively restrain external tibial rotation than popliteus tendon in terms of biomechanical property, the PFL has smaller diameter and lower ultimate strength than the popliteus tendon. [6,8,9]

We've questioned that the result might be related to the sequence of selective cutting in posterolateral structures. Despite its inferior biomechanical property in terms of cross-sectional area and ultimate strength, the PFL seemed to make a greater contribution in resisting external rotation of tibia in some biomechanical studies than the PT. [4,10]

We designed an experiment that one group has a selective cutting in a sequence of PT first, PFL second and then LCL last. The other group has in a sequence of the PFL first, PT second and then LCL last. In addition to this, since there are few reports regarding the quantitative measurement of posterolateral structures in Korean, we gauged the mean cross-sectional area of the PT, the PFL and the LCL respectively at midpoint of their attachments sites using a constant pressure micrometer.[11]

So, our objectives are as follows; First, measurement of how much the PT and the PFL contributes to the external rotatory stability according to the knee flexion angle by means of changing the sequence in selective transection of the PFL and the PT; Second, the quantification of mean cross-sectional area of the LCL, the PFL and the PT in Korean.

2. Material and Method

Specimen preparation and measurement of external rotatory and varus laxities

Twelve fresh-frozen cadaveric knees were used in this study ranging from 69 to 86 years old (mean age: 73.1 years old), (Table 1). All of the knees were intact macroscopically and demonstrated no surgical wound and instability. Each specimen was kept frozen at -20˚C and then they were allowed to thaw at room temperature for 24 hours before the experiment. Once the specimens thawed, the femur and tibia were cut approximately 25 cm from the joint line respectively. Prior to cutting, to compensate for the absence of the distal tibiofibular joint, we inserted a 36mm cortical screw through the tibia and fibula in their anatomical position. The knees were dissected carefully, stripping off the skin and the surrounding extraneous soft tissue except for the LCL, the popliteus muscle-tendon unit, the PFL and the joint capsuloligamentous structures.

	Sex	Age	Side
Group 1 (N=6)	F	86	R
	M	72	L
	M	70	L
	F	71	R
	F	70	R
	M	69	L
Group 2 (N=6)	F	86	L
	M	72	R
	M	70	R
	F	72	R
	F	70	L
	M	69	R

Table 1. The demographic characteristics of the cadavers. M, male; F, female, L, left; R, right.

The PT, the PFL and the LCL were well exposed for the selective cutting. Throughout the dissection and test, the specimens were protected from dehydration by intermittent application of saline-soaked gauze.

To measure the external rotatory and varus laxities under applied load, we applied the Ilizarov external fixator (JOYM. Co. Ltd, Seoul, Korea) to the specimen using half-pins through far cortex, which assures more secure fixation than clamp and bone cement. The specimens were rigidly secured by an Ilizarov external fixator using half-pins and care was taken to insert the half-pins perpendicular to the long axis of the femur and the tibia so that the moving crosshead of the apparatus could be parallel to the epicondyle and the joint line. Of those two apparatuses, one is for measuring external rotatory laxity by applying external rotation torque (Fig. 1a) and the other is for varus laxity by varus torque (Fig. 1b).

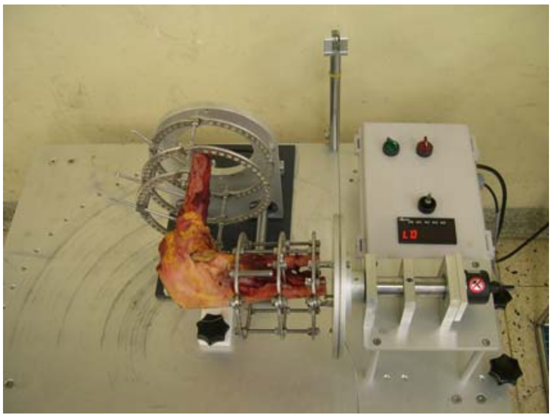

Figure 1(a). The apparatus for measuring the external rotatory laxity using the Ilizarov external fixator.

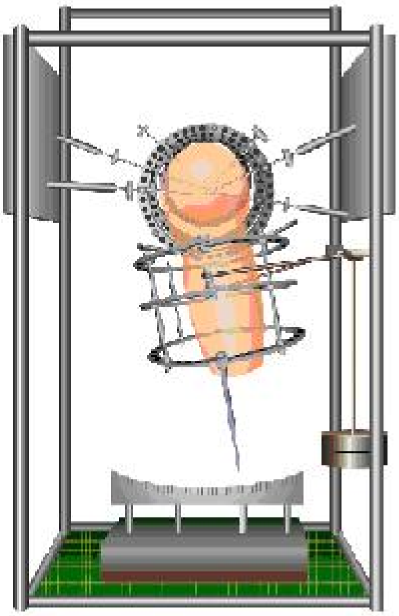

Figure 1(b). The apparatus for measuring the varus laxity using the Ilizarov external fixator.

To quantify the external rotatory laxity, the specimens were mounted on the device and subjected to external rotatory torque of 5N·m using cable and pulley system at every 30° from 0° to 90° of knee flexion. The angles produced by external rotatory torque were confirmed by digital recorder. To quantify the varus laxity, the specimens were also mounted on another device and subjected to varus toque of 3N·m using cable and pulley system.

The twelve knees were divided into two groups. Group 1 (PFL-PT-LCL) had a selective cutting sequence as following: First, the intact knee was tested for the external rotatory and varus laxities at every 30° from 0° to 90°. Second, the PFL was transected at its midpoint and external rotatory and varus laxities were measured in the same manner. Third, the PT was transected at midpoint between its femoral attachment and the PFL attachment and then, external rotatory and varus laxities were measured. Lastly, the LCL was transected and external rotatory and varus laxities were also measured. Group 2 (PT-PFL-LCL) had a following sequence: First, like Group 1, the intact knee was tested and then, the PT was transected at its tibial attachment without any injury to the fibular attachment of the popliteus muscle-tendon complex, or the PFL. Then, the external rotatory and varus laxities were measured. Next, the PFL was transected at its midpoint and the laxities were measured in the same manner and lastly, the LCL was transected and tested. All structures were transected at their midpoint for measuring the cross-sectional areas of each structure. In Group 2, the PT transected at the tibial attachment was severed again at its midpoint between its femoral attachment and the PFL attachment for measuring the cross-sectional area.

Quantitative measurement of structures

After the measurement of the external rotatory and varus laxities, we removed the Ilizarov system from the specimen and performed measurements of cross-sectional area for each structure at its midpoint using the constant pressure micrometer (Fig. 2). During the measurement, the applied load to the micrometer was set to produce a constant pressure of 0.1 MPa as used by Torzilli.[11]

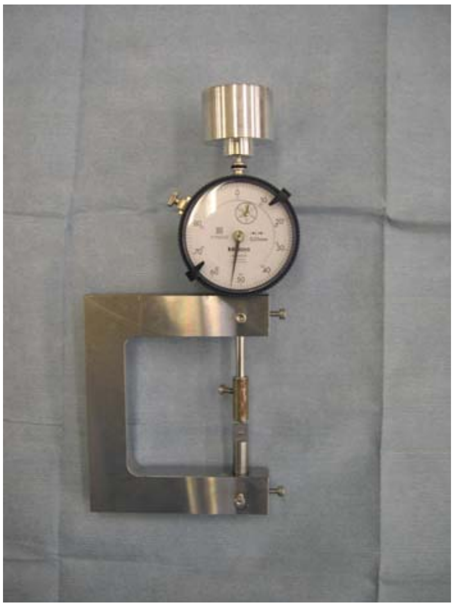

Figure 2. The constant pressure micrometer measuring the cross-sectional area

for each structure.

Data analysis

The external rotatory and varus laxities were measured as angles at every 30° from 0° to 90°. They were measured twice and the mean of two trials was used for data analysis. For comparing the amount of the increased external rotatory laxity after transection of the PFL and the PT in a different sequence in both groups respectively at each of knee flexion angle, the Wilcoxon signed rank test was employed (SAS v.8.2. Inc. North Carolina). We also compared Group 1 (PFL-PT-LCL) and Group 2 (PT-PFL-LCL) in terms of the amount of the increased external rotatory laxity after the transection of each structure in a different sequence at each of knee flexion angle in the setting of the Wilcoxon rank sum test (SAS v.8.2. Inc. North Carolina). For measuring the contribution of the LCL to the external rotatory laxity, compared with the PFL and the PT at each of knee flexion angle in both groups, the Wilcoxon signed rank test was employed (SAS v.8.2. Inc. North Carolina). For measuring the contribution of the LCL to the varus laxity, compared with the PFL and the PT, at each of knee flexion angle, the Wilcoxon signed rank test also was employed (SAS v.8.2. Inc. North Carolina). The difference was considered significant as $p < 0.05$.

3. Result

In Group 1 (PFL-PT-LCL), in terms of the increment of the external rotatory laxities, there was no statistically significant difference between the PFL and the PT at each of knee flexion angle (0°, $p > 0.05$; 30°, $p > 0.05$; 60°, $p > 0.05$; 90°, $p > 0.05$) (Fig. 3), (Table 2). In Group 2 (PT-PFL-LCL), in terms of the increment of the external rotatory laxities produced respectively by sequential transection of the PT and the PFL, there was no statistically significant difference between the PT and the PFL at each of knee flexion angle except 0° (0°, $p < 0.05$; 30°, $p > 0.05$; 60°, $p > 0.05$; 90°, $p > 0.05$) (Fig. 4), (Table 3). At 0° of knee flexion, the increment of the external rotatory laxity after cutting the PT was greater than that after cutting the PFL with a statistical significance ($p < 0.05$). As we compared Group 1 (PFL-PT-LCL) and Group 2 (PT-PFL-LCL) in term of the amount of increased external rotatory laxity after cutting each structure in a different sequence at each of knee flexion angle, there was no statistically significant difference between Group 1 and Group 2 at each of knee flexion angle (0°, $p > 0.05$; 30°, $p > 0.05$; 60°, $p > 0.05$; 90°, $p > 0.05$)

Compared with the PFL or the PT, the LCL which was always cut lastly increased the external rotatory laxity as much as statistical significance at 0° and 30° of knee flexion in both groups (Group 1, $p < 0.05$; Group 2, $p < 0.05$), (Fig. 3, 4), (Table 2,3). While there was no statistical significance at the other knee flexion angles, the increment of the external rotatory laxity after cutting the LCL diminished along with the increase of knee flexion angle (Fig. 3, 4), (Table 2,3).

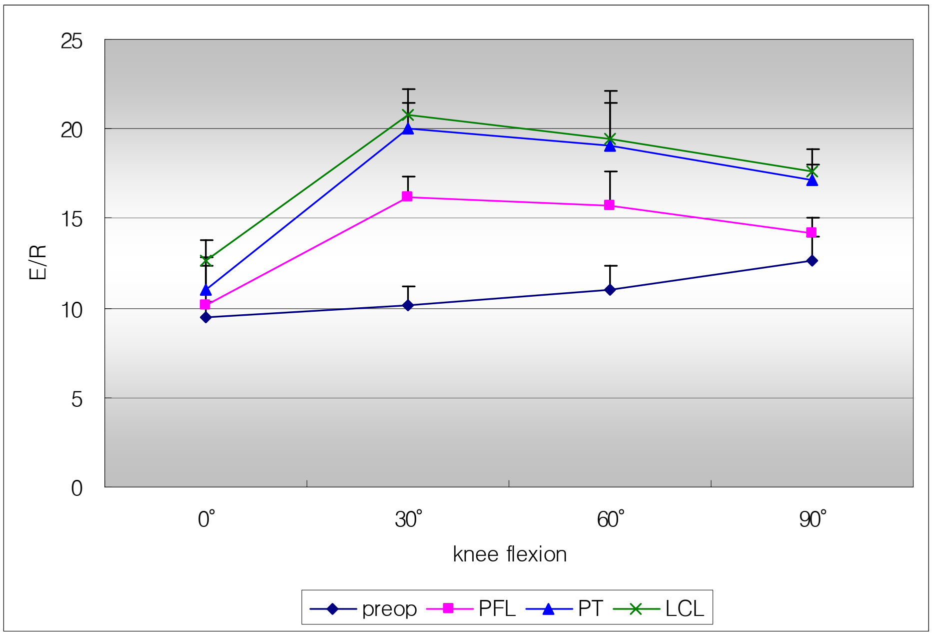

Figure 3. In Group 1 (PFL-PT-LCL), the mean external rotation angle of tibia (mean±SD) in response to 5N·m of external rotation torque at each of knee flexion in a following sequential cutting: PFL, PT, LCL. PFL, popliteofibular ligament; PT, popliteus tendon; LCL, lateral collateral ligament; E/R, external rotation. (N=6)

	intact	PFL	PT	LCL
0°	9.5±0.9	10.2±2.1	11.1±1.8	12.6±1.2
30°	12.7±1.0	16.2±1.2	20.0±1.5	20.8±1.5
60°	12.4±1.3	15.7±1.9	19.0±2.4	19.4±2.7
90°	11.2±1.3	14.2±0.9	17.15±0.9	17.63±1.3

Table 2. In Group 1 (PFL-PT-LCL), the mean external rotation angle of tibia (mean±SD) in response to 5N·m of external rotation torque at each of knee flexion in a following sequential cutting: PFL, PT, LCL. PFL, popliteofibular ligament; PT, popliteus tendon; LCL, lateral collateral ligament; E/R, external

rotation. (N=6)

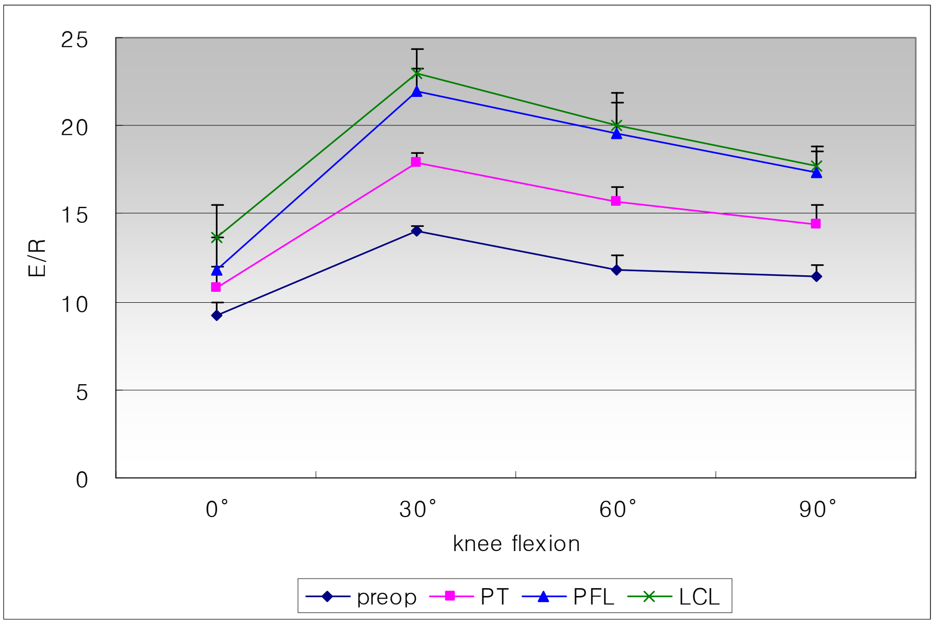

Figure 4. In Group 2 (PT-PFL-LCL), the mean external rotation angle of tibia (mean±SD) in response to 5N·m of external rotation torque at each of knee flexion in a following sequential cutting: PT, PFL, LCL. PT, popliteus tendon; PFL, popliteofibular ligament; LCL, lateral collateral ligament; E/R, external rotation. (N=6)

	intact	PT	PFL	LCL
0°	9.3±0.7	10.8±1.2	11.8±1.9	13.6±1.9
30°	14.0±0.3	17.9±0.6	21.9±1.4	22.0±1.4
60°	11.8±0.8	15.7±0.8	19.6±1.8	20.0±1.9
90°	11.5±0.6	14.4±1.1	17.4±1.2	17.7±1.2

Table 3. In Group 2 (PT-PFL-LCL), the mean external rotation angle of tibia (mean±SD) in response to 5N·m of external rotation torque at each of knee flexion in a following sequential cutting: PT, PFL, LCL. PT, popliteus tendon; PFL, popliteofibular ligament; LCL, lateral collateral ligament; E/R, external

rotation. (N=6)

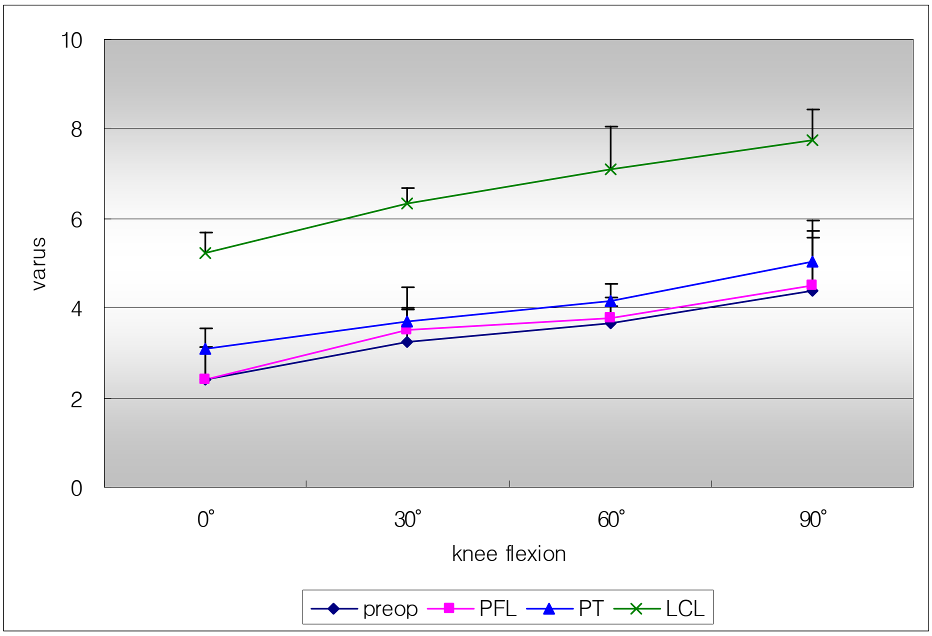

Figure 5. In Group 1 (PFL-PT-LCL), the mean varus angulation of tibia (mean±SD) in response to 3N·m of varus torque at each of knee flexion in a following sequential cutting: PFL, PT, LCL. PFL, popliteofibular ligament; PT, popliteus tendon; LCL, lateral collateral ligament; varus, varus angulation. (N=6)

	intact	PFL	PT	LCL
0°	2.4±0.7	2.4±0.7	3.1±0.5	5.2±0.5
30°	3.3±0.7	3.5±0.5	3.7±0.7	6.3±0.4
60°	3.7±0.4	3.8±0.5	4.2±0.4	7.1±1.0
90°	4.4±1.2	4.5±1.2	5.0±0.9	7.7±0.7

Table 4. In Group 1 (PFL-PT-LCL), the mean varus angulation of tibia (mean±SD) in response to 3N·m of varus torque at each of knee flexion in a following sequential cutting: PFL, PT, LCL. PFL, popliteofibular ligament; PT, popliteus tendon; LCL, lateral collateral ligament; varus, varus angulation.

(N=6)

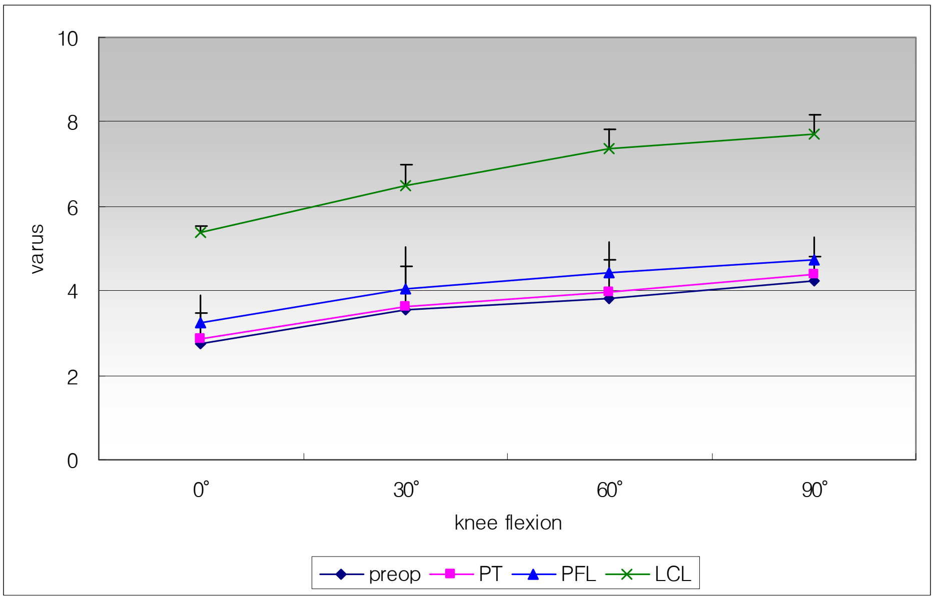

Figure 6. In Group 2 (PT-PFL-LCL), the mean varus angulation of tibia (mean±SD) in response to 3N·m of varus torque at each of knee flexion in a following sequential cutting: PT, PFL, LCL. PT, popliteus tendon; PFL, popliteofibular ligament; LCL, lateral collateral ligament; varus, varus angulation. (N=6)

	intact	PT	PFL	LCL
0°	2.8±0.7	2.9±0.6	3.3±0.7	5.4±0.2
30°	3.6±0.8	3.6±0.9	4.1±1.0	6.5±0.5
60°	3.8±0.7	4.0±0.8	4.4±0.7	7.4±0.5
90°	4.2±0.3	4.4±0.4	4.7±0.6	7.7±0.5

Table 5. In Group 2 (PT-PFL-LCL), the mean varus angulation of tibia (mean±SD) in response to 3N·m of varus torque at each of knee flexion in a following sequential cutting: PT, PFL, LCL. PT, popliteus tendon; PFL, popliteofibular ligament; LCL, lateral collateral ligament; varus, varus angulation. (N=6)

The varus laxity was increased with a statistical significance only after cutting the LCL, compared with other structures at each of knee flexion angle in both groups (Group 1: 0°, $p < 0.05$; 30°, $p < 0.05$; 60°, $p < 0.05$; 90°, $p < 0.05$), (Group 2: 0°, $p < 0.05$; 30°, $p < 0.05$; 60°, $p < 0.05$; 90°, $p < 0.05$) (Fig. 5, 6), (Table 4,5).

The mean cross-section areas of the PFL, the PT and the LCL were 6.9±1.6 mm^2, 16.7±3.8 mm^2 and 9.8±1.9 mm^2 respectively.

4. Discussion

Sequential selective transection of three principal structures in posterolateral corner of knee: the PT, the PFL and the LCL

Our study set in from the question about the idea that the PFL plays a greater role in resisting the external rotation of tibia than the PT. Since Higgins reported the existence of the fibular attachment of the popliteus,[12] this structure has been called as the popliteofibular fascicle, the fibular origin of the popliteal tendon, the popliteal muscle with origin from the fibular head and the PFL.[6,13,14] The PFL had not been defined as a separate entity until Veltri et al. described its role in contributing to posterolateral stability[5] by selective cutting technique and since then, the PFL has been regarded as a key element of the posterolateral structures in resisting external rotation of the tibia.[4,6]

Most of in vitro study which evaluated these three principal structures in posterolateral corner including the popliteus tendon, the popliteofibular ligament and the lateral collateral ligament, employed the selective cutting technique. However, many authors indicated that the selective cutting technique shows results which depend on the order of cutting and if secondary restraint is not transected, the transection of primary restraint will produce just a little increase in laxity.[15-18]

Typically, cadavers used in biomechanical study are those of old aged people and so if repeatedly subjected under loads applied in the mechanical study, there might be not only some loosening between specimen and a measuring device but also some attenuation of the tissue itself, and to date, the established articles tried to reveal all of the mechanical properties of the posterolateral structures such as anterior and posterior translation, internal and external rotation, varus and valgus angulation at each predetermined angles.[3,5,15,19] Thus, those repeated test can have adverse effects on the result by attenuating the subjected structure even before it would be transected.

The present study evaluated only varus and external rotation, and repeated the experiment only twice at each step to minimize the accumulated stress on subjected structures.

In addition, we applied the Ilizarov external fixator to the specimen using half -pins through far cortex, which assures more secure fixation than clamp and bone cement fixation which were employed in many in vitro studies. In the clamp and bone cement fixation, there could be some movement between the specimen and custom jig or metal cylinder using clamp with or without bone cement.

In Group 1 (PFL-PT-LCL), the respective increments of the external rotatory laxity after transecting the PFL first and then the PT were similar and did not show statistically significant difference at every 30° from 0° to 90°of knee flexion. In Group 2 (PT-PFL-LCL), except the result of 0°, the respective increments of the laxity after transecting the PT first and then the PFL were also similar and did not show significant difference, either. Thus, both PT and PFL evenly contribute to the external rotatory stability. Also, LaPrade et al. presented in experimental study, the load responses of each structure were similar at every 30° from 0° to 90° by external rotation torque applied to both PT and PFL.[19] Therefore, we don't think that one component has a priority over the other component between these two structures in resisting the external rotation of the tibia. Rather, we consider that the PFL plays a role not as an independent structure but as a part of the popliteus muscle-tendon complex. Pasque et al. are in agreement with our result describing the role of the PFL and the PT as a unit.[7] Many authors noted the LCL played a great role in resisting external rotation at low angles of knee flexion.[3,15,19] LaPrade et al. measured the force on the LCL to external rotation load and found that the LCL was highly loaded in early range of knee flexion.[19] Pasque et al. found, through a sequential selective transection, there was increase in external rotatory laxity at early range of the knee flexion after cutting the LCL.[7] In the present study, after the LCL was cut, at 0° and 30° of the knee flexion there was statistically significant increase in external rotatory laxity in both groups. Along with the increase of the knee flexion angle, the amount of the increased external rotatory laxity diminished. This is similar to the reports of other authors.[7,19] The LCL has been considered as the main structure providing the varus stability. Our study reflected that only after transection of the LCL, a significant varus laxity was produced at each of knee flexion angle, despite of previous selective transection of both PT and PFL.

The mean cross-sectional areas of the PFL, the LCL and the PT

The second objective of this study is measuring the mean cross-sectional area of the LCL, the PT and the PFL at their midpoint in Korean. Maynard et al. examined 20 cadaveric knees and described the cross-sectional areas of the PFL, the LCL and the PT; the measurements were 6.9±2.1mm^2, 7.2±2.7mm^2 and 13.7±2.6mm^2 respectively.[6] LaPrade et al. report the mean cross-sectional areas of same structures were 17.9±1.9mm^2, 11.9±2.9mm^2 and 21.9±3.9mm^2 in 8 cadaveric knees.[9] While we expected that the mean cross-sectional areas in Korean would be smaller than those in Westerner, our result was in the middle between Maynard's and LaPrade's result. The cross-sectional area of the PFL is about or more than a half of the PT in Westerner (50%, Maynard; 82%, LaPrade), but in Korean, it is less than a half of the PT (41%).

Clinical application of the current study

In the posterolateral instability, the varus laxity is accompanied by external rotatory laxity. Our study and previous studies reflected that the LCL plays an important role in limiting external rotatory laxity at early range of knee flexion.[3,15,19] Therefore, when addressing the posterolateral instability, we should include the reconstruction or augmentation of the LCL for the external rotatory laxity as well as the varus laxity. Our study also showed that the PT and the PFL play a crucial role in limiting external rotatory laxity equally. It means that neither of the two structures has superiority to the other structure. Both PT and PFL function not independently but as a unit or group. The PFL should be regarded as the fibular attachment of the popliteus muscle-tendon complex.

The reconstruction of all three components is practically difficult on the point of insufficient tendon length and isometricity for each structure. Thus, most surgeons address two components, one for varus laxity, namely the LCL and the other for external rotatory laxity, the PFL or the PT. Many authors documented that the PFL should be reestablished because it had a greater moment arm than the PT in withstanding the external rotatory instability.[8,20] However, the reestablishment of the PT has several advantages over that of PFL. The reconstruction of the PFL is conducted with the assumption that proximal tibiofibular joint is intact. While normally, the fibular head moves in the proximal tibiofibular joint during the knee range of motion[21] and it is well controlled by several static and dynamic stabilizers around the knee. However, in posterolateral corner injury, there might be some injury in the proximal tibiofibular joint. Besides, according to the documentation by Sugita, the diversity in position of the fibular head around the lateral and posterior aspect of the tibia could be correlated to the variable success rate of reconstructing the PFL.[8] Addressing the PFL on the posterosuperior aspect of the fibular head, if the fibular head is relatively posteriorly placed, it would be more efficient in resisting external rotation as well as posterior translation of the tibia due to less steep angle in sagittal plane. If the fibular head is not relatively posteriorly placed, it would not be efficient and this accounts for the variable success rate.

In 2004, we published a new technique for the posterolateral reconstruction addressing the LCL and the PT,[22] and we statically stabilized the proximal tibiofibular joint by allogenous posterior tibialis. Thus, through the stabilization of the proximal tibiofibular joint, we expect the reconstructed LCL can compensate for the absence of the PFL. In this technique, the isometric point for the LCL is placed on the femoral epicondyle and for the PT, on the popliteal sulcus near the femoral attachment of the PT that is always anterior to the femoral attachment of the LCL as LaPrade et al. described.[23]

In conclusion, the present result reflected the PT equally shares the role in resisting the external rotatory laxity as much as the PFL and also at the early knee flexion, the LCL plays a role in resisting the external rotation of tibia.

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< ABSTRACT (IN KOREAN) >

슬관절의 후외방 안정성에 기여하는 슬관절의 후외방 구조물의 선택적 절단의 순서 변경을 통한 역학적 특성

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단면적이나 강도에 있어서 슬와비골건이 생역학적으로 슬와건보다 열위에 있음에도 불구하고, 그간의 생역학적 연구에서 슬와비골건이 경골의 후외방 회전을 막는 데 있어서 슬와건보다 더 큰 역할을 하는 것처럼 보였다. 본 연구의 목적은 선택적 절단의 순서 변경을 통해서 슬와비골건, 슬와건, 외측 측부 인대등이 슬관절의 후외방 안정성에 기여하는 정도를 알아보고 그들의 단면적을 측정하는 것이다. 12개의 신선 냉동 사체의 슬관절을 두 군으로 나누었다. 1군은 절단 순서를 슬와비골건, 슬와건, 외측 측부 인대로 하였고, 2군은 슬와건, 슬와비골건, 외측 측부 인대 순서로 절단을 하였다.

매 구조물 절단시, 일리자로프를 이용한 기계 장치로 슬관절의 후외방 이완 정도와 내반 이완 정도를 0도, 30도 60도 90도에서 측정하였다. 2군의 0도에서 측정된 결과를 제외하고는 두 군내에서 슬와비골건을 절단하였을 때와 슬와건을 절단하였을 때 증가되는 후외방 이완정도의 차이는 없었다. 외측 측부 인대를 절단하였을 때, 0도와 30도에서 통계학적으로 유의하게 후외방 이완을 증가시켰다. 내반 이완은 외측 측부 인대가 절단된 후에만 유의하게 증가하였다. 슬와비골건, 슬와건, 외측 측부 인대의 단면적은 각각

$6.9 \pm 1.6\ mm^2$, $16.7 \pm 3.8\ mm^2$ and $9.8 \pm 1.9\ mm^2$이었다.

결론적으로 슬와비골건과 슬와건 둘 다 같은 정도로 후외방 안정성에 기여를 하지 어느 하나가 우위에 있지 않다. 외측 측부 인대도 또한 슬관절의 굴곡 각도가 적은 범위에서 후외방 안정성에 기여를 한다. 외측 측부 인대는 슬관절에서 내반 안정성을 유지하는 주요 구조물이다.

핵심되는 말 : 슬와비골건, 슬와건, 외측 측부 인대, 후외방 이완, 내반 이완