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Anatomy of the posterior cruciate ligament

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The purpose of the study was to explain the architecture of the posterior cruciate ligament because the views on its structure presented in the literature are inconsistent — from those considering it as indivisible to those presenting it as a multifascicular structure. Twenty formalin-fixed ligaments from human knee joints were tested using the preparation technique. All posterior cruciate ligaments clearly divided into the anterolateral bundle and the posteromedial bundle (20/20). In all ligaments, 2 fascicles were identified in the posteromedial bundle (20/20). In most cases, 2 fascicles were also seen in the anterolateral bundle (14/20). Less commonly, it consisted of multiple fascicles (6/20). (Folia Morphol 2009; 68, 1: 8–12)

Key words: knee joint, anterolateral bundle, posteromedial bundle

INTRODUCTION

The posterior cruciate ligament (PCL) originates at the internal surface of the medial condyle of the femur, it goes slightly posteriorly, laterally, and downwards, and has its insertion at the posterior intercondylar area of the tibia. The terminal insertion also extends a few millimetres on the adjacent posterior surface of the tibia [1, 7, 9]. The PCL has a primary function in resisting posterior translation of the tibia on the femur and a secondary role in limiting external, varus, and valgus rotations [4, 10].

Views on the architecture of the posterior cruciate ligament are inconsistent. The inconsistencies refer to the ligament anatomy — whether it is indivisible [5, 8, 21], or its structure is more complex, or even multifascicular [3, 4, 11]. The clinical posterolateral complex of PCL includes (except for the posterior cruciate ligament) the anterior and posterior meniscofemoral ligaments (AMFL, PMFL) [14]. The explanation of the structure seems significant from a clinical point of view. In the past, the reconstruction of the cruciate ligament was only performed using a single bundle, just replacing the anterolateral bundle (AL-PCL). At present, techniques using two bundles to reconstruct the anterolateral and the posteromedial (PM-PCL) bundles are preferred [12, 19].

MATERIAL AND METHODS

The study was performed on the material of 20 human knee joints from the collection of the Department of Anatomy of the Medical University of Warsaw. The preparations were knee joints of adults who had no gross pathologies of the osteoarticular system of the lower limbs, or from lower limbs amputated due to pathologies of an area of the lower limb other than the knee region. The knee joints were fixed in formaldehyde solution. The capsuloligamentous structures of the knee joint were removed, excluding the posterior cruciate ligament, the lateral meniscus, and the possible meniscofemoral ligaments. Osteoligamentous blocks were cut; the blocks contained the medial condyle of the femur and a wedge-shaped section from the proximal end of the tibia. The posterior cruciate ligaments were

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Table 1. Structure of posterior cruciate ligament (PCL) and occurrence of meniscofemoral ligament (MFL)

No. of knee	Side	Structure of PCL bundles					Occurrence of MFL	
		Anterolateral bundle			Posteromedial bundle		Anterior meniscofemoral ligament	Posterior meniscofemoral ligament
		Centr.	Ant.	Ant.-lat.	Ant.-med.	Post.-lat.		
I	R	x		x	x	x	x	
II	L		Multifasc.		x	x		x
III	R	x	x		x	x	x	x
IV	R		Multifasc.			Parallel	x	x
V	L	x	x			Parallel		
VI	L		Multifasc.		x	x	x	
VII	R	x	x			Parallel	x	x
VIII	R	x		x		Inversed*	x	
IX	R	x		x	x	x	x	x
X	R	x	x		x	x	x	
XI	L	x		x	x	x	x	
XII	L	x	x		x	x	x double	
XIII	L		Multifasc.		x	x	x	
XIV	L	x	x		x	x	x	x
XV	L	x	x			Parallel	x	x
XVI	L	x		x	x	x	x	x
XVII	R		Multifasc.		x	x	x	
XVIII	L	x		x		Inversed*	x	x
XIX	L	x	x		x	x	x	x
XX	R		Multifasc.		x	x		

*PM: anterolateral and posteromedial fascicles

prepared using an operation microscope with microsurgical instruments.

RESULTS

Nine right and eleven left posterior cruciate ligaments were examined (Table 1). All ligaments divided into at least 2 bundles: anterolateral (AL) and posteromedial (PM) (Fig. 1). In 14 cases, the AL bundle divided into a further 2 parts. These was a larger fascicle located more centrally (central) and a smaller anterior part which accompanied it either only anteriorly (anterior; 8 cases), or anteriorly and laterally (anterolateral; 6 cases). These 2 fascicles could be separated mainly at the femoral insertion, and the lower it was, the more difficult it was to separate the central fascicle (Fig. 2). In the remaining 6 cases, the anterolateral bundle of the posterior cruciate ligament consisted of many parallel fascicles (multifascicular). The PM bundle always consisted of 2 parts. One part was usually positioned more vertically, i.e. longitudinally, and was located medially, and the other part was positioned more diagonally and was located laterally. In these knees, the fascicles were mutually arranged one behind the other: the longitudinal one anteriorly (anteromedial) and the oblique one posteriorly (posterolateral; 14 cases) (Fig. 3). In 4 knee joints, the 2 fascicles forming the posteromedial bundle of the posterior cruciate ligament went parallel to each other (medial and lateral) (Fig. 4), and in the remaining joints the longitudinal fascicle was positioned behind the oblique fascicle (anterolateral and posteromedial; 2 cases). On the medial condyle of the femur, the insertion of the longitudinal part was

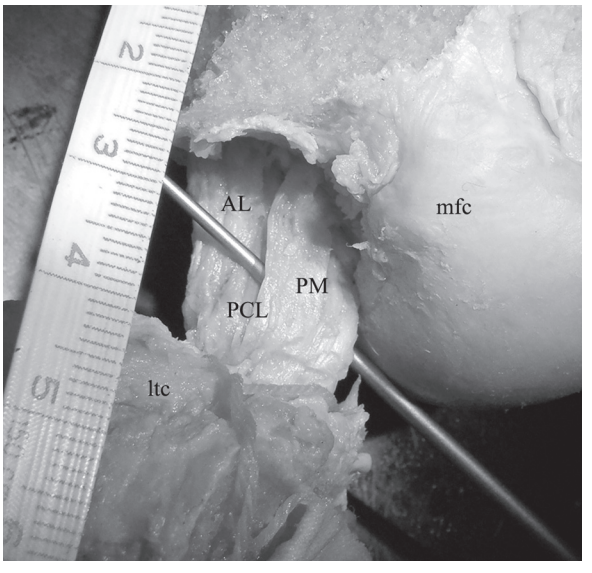

Figure 1. Posterior cruciate ligament (PCL); AL — anterolateral bundle, PM — posteromedial bundle, mfc — medial femoral condyle, ltc — lateral tibial condyle.

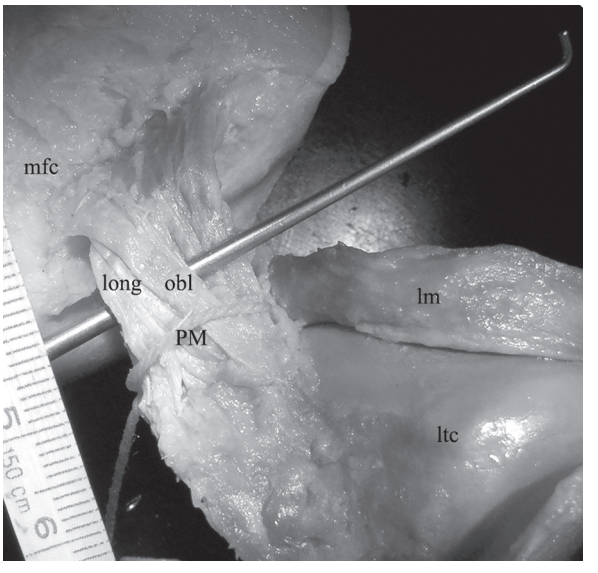

Figure 3. Posteromedial bundle of posterior cruciate ligament — posteromedial bundle (PM); long — longitudinal fascicle, obl — oblique fascicle, ltc — lateral tibial condyle, mfc — medial femoral condyle, lm — lateral meniscus.

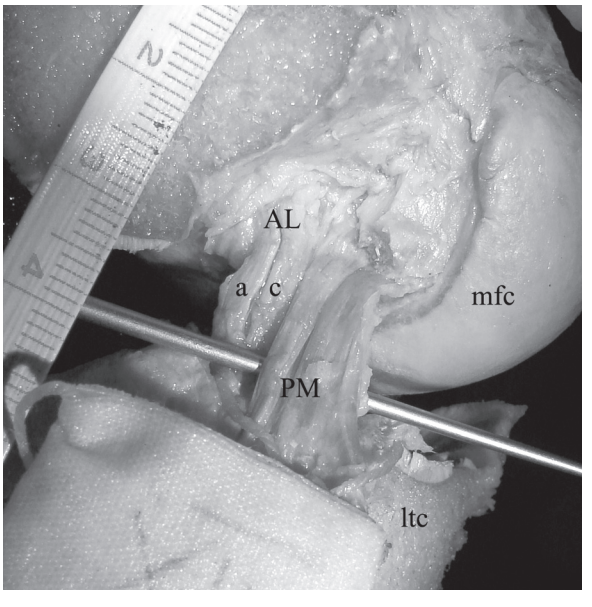

Figure 2. Anterolateral bundle of posterior cruciate ligament (PCL) — anterolateral bundle (AL); a — anterior fascicle, c — central fascicle, PM — posteromedial bundle of PCL, mfc — medial femoral condyle, ltc — lateral tibial condyle.

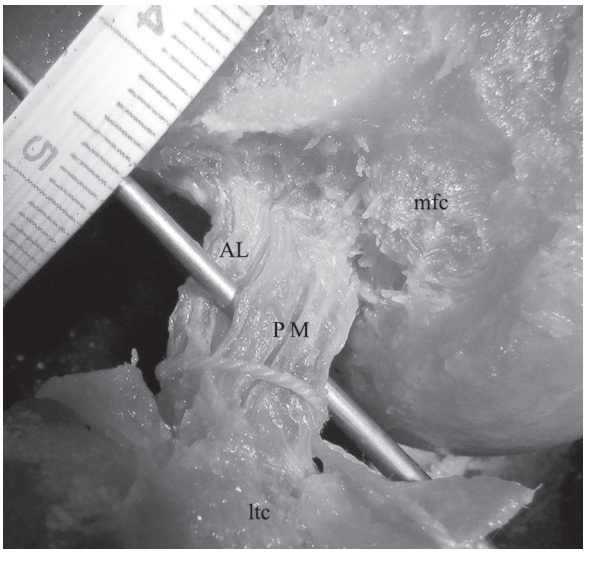

Figure 4. Posteromedial bundle of posterior cruciate ligament (PCL) — posteromedial bundle (PM) — parallel fascicles; AL — anterolateral bundle of PCL, mfc — medial femoral condyle, ltc — lateral tibial condyle.

located more anteriorly, reaching the intercondylar fossa, and the oblique part had its insertion more inferiorly. The 2 fascicles divided most easily at the tibial insertion. In 17 cases, the posterior cruciate ligament was accompanied by the anterior meniscofemoral ligaments (Fig. 5), and in 11 cases the posterior meniscofemoral ligaments (Fig. 6).

DISCUSSION

Division of posterior cruciate ligament based on its arrangement

Views on the structure of the posterior cruciate ligament may be classified as those regarding the ligament as indivisible and those presenting it as

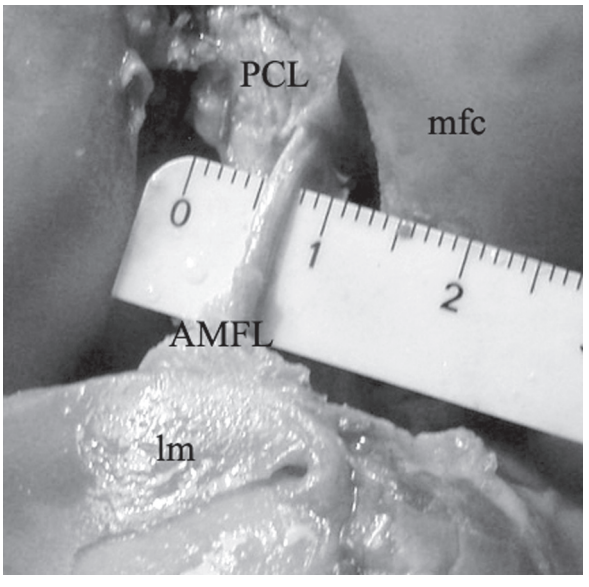

Figure 5. Anterior meniscofemoral ligament (AMFL); mfc — medial femoral condyle, lm — lateral meniscus; PCL — posterior cruciate ligament.

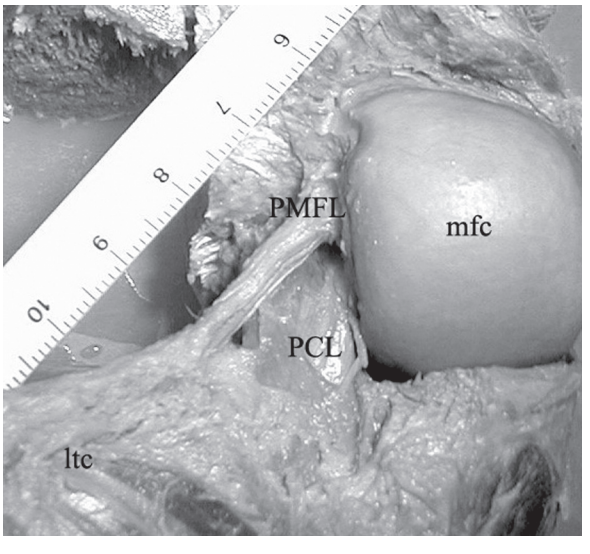

Figure 6. Posterior meniscofemoral ligament (PMFL); mfc — medial femoral condyle, ltc — lateral tibial condyle, PCL — posterior cruciate ligament.

composed of many fascicles. Some investigators claim that the PCL has a monofascicular structure [5, 7, 8]. A similar view was presented by Satku et al. [21], according to whom, although the cruciate ligaments have anterolateral and posteromedial fibres, they are not clearly separated. More commonly, the posterior cruciate ligament is believed to have a complex structure. According to Girgis and Marshall [9], the PCL consists of 2 parts but they are inseparable. The most common view presents the ligament as a structure containing 2 separated bundles which are sometimes referred to as the anterior and posterior parts: aPC and pPC [19], and usually as the AL-PCL and PM-PCL [2, 6, 13–15, 20, 23]. Some authors even found the 2 bundles to have a different ultrastructure [11]. Other anatomists believe that the division of the PCL into 2 bundles is too simple. Trent and Kurosawa et al. [17, 22] divide the PCL fibres into the anterior, middle, and posterior fascicles. Some authors identify, as in this study, the posterior oblique fascicle of the posterior cruciate ligament, which has nothing in common with the posterior meniscofemoral ligament (PMFL) because it clearly attaches to the tibia [16]. The posterior fibres of the posterior cruciate ligament forming the oblique part should not be mistaken for the PMFL, which goes diagonally from the posterior margin of the initial insertion of the PCL on the femur to the lateral meniscus or the tibia near the terminal insertion of the PCL [1, 5]. Harner and Hoher [12] consider the posterior meniscofemoral ligament as one of the three components of the PCL. Many authors also describe the posterior cruciate ligament as a continuum of fibres. In this case it consists of 4 regions: anterior, central, posterior longitudinal, and posterior oblique [4]. Makris et al. [18] divide the ligament into 4 fascicles: anterior, central, posterior longitudinal, and posterior oblique. In this study, however, the separation of the anterior and the central part was not possible in some cases.

Division of posterior cruciate ligament based on its function

Even if the ligament is viewed as a single bundle, tensions in individual ligament fibres differ during movement. Some authors believe that there is a bundle which is constantly stretched [21]. From among the two bundles, the anterolateral PCL is stretched while flexed, relaxed while extended, and the posteromedial PCL is visibly stretched while extended and slightly relaxed while flexed [9, 11, 12, 14, 15]. Fuss divides the ligament into three functional groups: fibres stretched in transitional positions, fibres stretched in full extension, and fibres stretched in full flexion [8].

In the case of division of the PCL into 4 elements: anterior, central, posterior longitudinal, and posterior oblique, the anterior fibres are totally relaxed in full extension, the central fibres are less stretched

than the anterior compartment, and the posterior longitudinal and oblique fibres are stretched. During flexion the anterior and central fibres become stretched, with the posterior fibres becoming slightly relaxed. With increasing knee flexion, the posterior bundle stretches again, the anterior bundle remains stretched, and the central bundle shows no signs of relaxation [18]. However, functional aspects were not the subject of this study.

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