Clinical Biomechanics 30 (2015) 448–453

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

# Effect of posterior cruciate ligament rupture on the radial displacement of lateral meniscus

Pengfei Lei [a], Rongxin Sun [b], Yihe Hu [a], Kanghua Li [a], Zhan Liao [a,*]

[a] Department of Orthopedics, Xiangya Hospital, Central South University, PR China
[b] Department of Orthopedics, The Sixth Affiliated Hospital of Xinjiang Medical University, PR China

ARTICLE INFO

*Article history:*
Received 3 December 2014
Accepted 9 March 2015

*Keywords:*
Posterior cruciate ligament
Lateral meniscus
Radial displacement
Rupture

ABSTRACT

*Background:* The relationship between lateral meniscus tear and posterior cruciate ligament injury is not well understood. The present study aims to investigate and assess the effect of posterior cruciate ligament rupture on lateral meniscus radial displacement at different flexion angles under static loading conditions.
*Methods:* Twelve fresh human cadaveric knee specimens were divided into four groups such as posterior cruciate ligament intact, anterolateral band rupture, posteromedial band rupture and posterior cruciate ligament complete rupture groups, according to the purpose and order of testing. Radial displacement of lateral meniscus was measured under different loads (200–1000 N) at 0°, 30°, 60°, and 90° of knee flexion.
*Findings:* Compared with posterior cruciate ligament intact group, the displacement values of lateral meniscus in anterolateral band rupture group increased at 0° flexion with 600 N, 800 N, and 1000 N and at 30°, 60° and 90° flexion under all loading conditions. Posteromedial band rupture group exhibited higher displacement at 0° flexion under all loading conditions, at 30° and 60° flexion with 600, 800 N and 1000 N, and at 90° flexion with 400 N, 600 N, 800 N, and 1000 N than the posterior cruciate ligament intact group. The posterior cruciate ligament complete rupture group had a higher displacement value of lateral medial meniscus at 0°, 30°, 60° and 90° flexion under all loading conditions, as compared to the posterior cruciate ligament intact group.
*Interpretation:* The study concludes that partial and complete rupture of the posterior cruciate ligament can trigger the increase of radial displacement on lateral meniscus.



## 1. Introduction

The menisci are two semilunar-shaped fibrocartilaginous structures, which are interposed between the femoral condyles and tibial plateau (Maffulli et al., 2010). They provide mechanical stability to femorotibial gliding, protect the articular cartilage, and provide congruity between femoral and tibial articular surfaces (Breitenseher et al., 1997). Magnetic resonance imaging (MRI) shows that meniscus is often seen to be radially displaced to the periphery. This phenomenon is known as radial displacement or extrusion of the meniscus (Breitenseher et al., 1997; Brody et al., 2006; Kenny, 1997; Rennie and Finlay, 2006). Several reports have focused on radial displacement of the medial meniscus (Choi et al., 2010; De Coninck et al., 2013; Kenny, 1997; Lee et al., 2011; Magee, 2008; Puig et al., 2006; Sharma et al., 2008; Yanagisawa et al., 2014), and reports on radial displacement as a complication after meniscal transplantation are reported in the literature (Choi, 2006; Lee et al., 2010). However, radial displacement of the lateral meniscus are reported rarely (Brody et al., 2006; Ichiba and Makuya, 2012; Koga et al., 2012). Radial displacement can be associated with reduced meniscal function.

The posterior cruciate ligament (PCL) of the human knee is usually considered to be the primary restraint against posterior tibial displacement. After PCL injury, cartilage degeneration is predominantly found in the medial compartment of the tibiofemoral joint and in the patellofemoral joint (Boynton and Tietjens, 1996; Moyer and Marchetto, 1993; Shelbourne et al., 1999; Strobel et al., 2003). Previous studies mainly focused on the effects of PCL injury on the knee joint (Gao et al., 2011). Some reports have assessed the altered kinematics of the knee joint after PCL injury during flexion with weight bearing (Gao et al., 2011). While other research has evaluated the effects of PCL injury and different PCL reconstruction techniques on the biomechanics of the knee (Gao et al., 2011). However, the impact of PCL rupture on the other parts of knee joint are rarely reported, especially in regard to the effects of partial or complete rupture of the PCL on the lateral meniscus under different physiological loading conditions.

In this study, radial displacement of the lateral meniscus was recorded under different conditions, including anterolateral bundle (ALB) rupture, posteromedial bundle (PMB) rupture and PCL complete rupture. The aim of this study was to investigate the impact of rupture of PCL on the radial

* Corresponding author at: Department of Orthopedics, Xiangya Hospital, Central South University, 87 Xiangya Road, Changsha, Hunan 410008, PR China.
*E-mail address:* liaozhan88@yeah.net (Z. Liao).

http://dx.doi.org/10.1016/j.clinbiomech.2015.03.011
0268-0033/

displacement of the lateral meniscus by using biomechanical testing under different axial loads (200–1000 N) and flexion angles (0°, 30°, 60° and 90°).

## 2. Methods

### 2.1. Specimen preparation

Twelve fresh-frozen cadaver knees (six right and six left) from six healthy adult male donors were used in this study. All the cadaveric knees underwent macroscopic inspection and X-ray examination to exclude the possibility of gross anomalies, degenerative joint disease, fracture, tumor and obvious osteoporosis. The posterior drawer test was used to exclude PCL injuries. The average age of the cadavers was 30.6 years, with a range from 25–38 years. The femur and tibia were each cut at approximately 30 cm from the joint line, keeping the skin and soft tissue intact. All specimens were maintained in a moist state with saline-saturated gauze. After sealed with double polyvinyl chloride bags, the specimens were frozen at −70 °C. The length of cryopreservation time was not longer than 3 months. The study was approved by the medical ethics committee of Xiangya Hospital, Central South University, and was conducted according to Declaration of Helsinki Principles. Informed written consent was obtained from the candidate relatives.

### 2.2. Experiment design

Prior to the experiment, the specimens were thawed at 4 °C for 24 h and at room temperature for another 24 h. The soft tissues of the proximal portion of the femur were removed whereas the remaining soft tissues surrounding the knee joint were left intact. The ends of the femur and tibia were then fixed in cylinders to enable rigid fixation during testing.

The specimens were categorized into four groups according to the order of the test: PCL intact group (n = 12), anterolateral bundle (ALB) rupture group (n = 6), posteromedial bundle (PMB) rupture group (n = 6), and complete PCL rupture group (n = 12).

The whole 12 specimens were each fixed in clamps with the femur inferiorly and tibia superiorly. The quadriceps was fixed to the femur holding clamp with wire at a tension of 100 N. Through a posterior midline incision (about 3 cm), the posterior articular capsule was incised to expose but not severed the PCL. A longitudinal incision was made to expose the middle point of the lateral margin of the lateral meniscus. During this process, the soft tissues of the lateral margin of tibial plateau (approximately 1.5 cm × 1.0 cm area) were removed. A load of 250 N was repeated 20 times at a speed of 0.5 mm/s to eliminate the influence of the innate viscosity of the specimens.

The specimens were positioned at 0°, 30°, 60° and 90° of flexion (Fig. 1) and the static strain measuring device was calibrated in balance. A continuous axial load (0–1000 N) was loaded at a speed of 0.5 mm/s, with an interval of 10 min to allow restoration of elasticity. Radial displacement of the lateral meniscus under different loads was measured as the distance from the midpoint of peripheral border of the lateral meniscus extruding from the midpoint of the edge of the lateral tibial plateau with a digital caliper. Data were acquired by three observers, and the average values between the three observers were quantified.

After finishing the above tests, the specimens were separated randomly into two groups: ALB rupture group (n = 6) in which the ALB was severed, and PMB rupture group (n = 6) in which the PMB was severed. The test procedure described above was repeated in these two groups. Next, the PCLs of all 12 specimens were severed completely to model complete PCL rupture and the test procedure described above was again repeated. During the complete test, the surface of the knee joint was maintained in a moist state with normal saline-saturated gauze. All the testing procedure described above was conducted at a temperature of 25 °C and humidity of at 60–80%.

### 2.3. Statistical analysis

Data were analyzed with the SPSS package (version 15.0 for Windows; SPSS Inc., Chicago, IL, USA). Data were expressed as mean ± SD. A one-way analysis of variance (ANOVA) was used for multisample means comparison, SNK-q for homogeneity of variance, and Dunnett's T3 for heterogeneity of variance. Differences were considered statistically significant when $P < 0.05$.

## 3. Results

### 3.1. Radial displacements at 0° flexion

At 0° of knee flexion, the radial displacements of lateral meniscus in all groups under different loading conditions were summarized in Table 1. In comparison with the PCL intact group, the displacement value increased significantly in PMB rupture and PCL complete rupture groups under all five loading conditions and in ALB rupture group under 600 N, 800 N and 1000 N loads ($P < 0.05$). Also, compared with the ALB rupture group, the displacement value had significantly difference in PMB rupture and PCL rupture groups under all five loading conditions. However, when compared with the PMB rupture group, the displacement values of the PCL complete rupture group under load of 200 N and 400 N showed no significant increases ($P > 0.05$), whereas under loads of 600 N, 800 N and1000 N, the increase became significant ($P < 0.05$).

### 3.2. Radial displacements at 30° flexion

When flexed to 30°, the displacement values in the ALB rupture group and PLC complete rupture group were significantly higher as compared to the PCL intact group under different loads ($P < 0.05$). Compared with the PCL intact group, the PMB rupture group had no significantly different displacement values under loads of 200 N and 400 N ($P > 0.05$), whereas under loads of 600 N, 800 N and 1000 N the displacement values were markedly increased ($P < 0.05$). In comparison with the ALB rupture group, displacement value had significant difference in PMB rupture group under all five loading conditions and in PCL complete rupture group under 600 N, 800 N and 1000 N loads ($P < 0.05$). Significant increases can be observed in the PCL complete rupture group as compared to the PMB rupture group under different loads ($P < 0.05$). The detailed data was shown in Table 2.

### 3.3. Radial displacements at 60° flexion

Radial displacement of lateral meniscus at 60° of flexion was similar to that at 30° of flexion (Table 3). Compared to the PCL intact group, displacement value increased significantly in ALB rupture and PCL complete rupture groups under all five loading conditions and in PMB rupture group under 800 N and 1000 N loads ($P < 0.05$). In comparison with the ALB rupture group, displacement value in PMB rupture group had significantly difference under all five loading conditions and in PCL rupture group under 600 N, 800 N and 1000 N loads ($P < 0.05$). Significant increase in displacement values was found in the PCL complete rupture group compared with the PMB rupture group under different loads ($P < 0.05$).

### 3.4. Radial displacements at 90° flexion

The trends with respect to radial displacement of lateral meniscus were similar between 90° of flexion and 30° of flexion (Table 4). Compared to the PCL intact group, displacement value also increased significantly in ALB rupture and PCL complete rupture groups under all five loading conditions and in PMB rupture group under 400 N, 600 N, 800 N and 1000 N loads ($P < 0.05$). In comparison with the ALB rupture group, displacement value in PMB rupture group had