The Knee 21 (2014) 1151–1155

Contents lists available at ScienceDirect

The Knee

Clinical features and injury patterns of medial collateral ligament tibial side avulsions: "Wave sign" on magnetic resonance imaging is essential for diagnosis

Shuji Taketomi [a,*], Eiji Uchiyama [b], Takumi Nakagawa [c], Hideki Takeda [a], Shuichi Nakayama [b], Atsushi Fukai [b], Takaki Sanada [b], Hiroshi Iwaso [b]

[a] Department of Orthopaedic Surgery, Faculty of Medicine, The University of Tokyo, Tokyo, Japan
[b] Department of Orthopaedic Sports Surgery, Kantoh Rosai Hospital, Kanagawa, Japan
[c] Department of Orthopaedic Surgery, Teikyo University School of Medicine, Tokyo, Japan

ARTICLE INFO

Article history:
Received 19 November 2013
Received in revised form 21 July 2014
Accepted 20 August 2014

Keywords:
Medial collateral ligament injury
Tibial side avulsion
Wave sign
Detachment
Magnetic resonance imaging

ABSTRACT

Background: Medial collateral ligament tibial avulsion is rare. Consequently, diagnostic criteria and a treatment regimen for medial collateral ligament tibial side avulsions remain to be established. The purpose of this study is to clarify the clinical features of medial collateral ligament tibial side avulsions.
Methods: We performed a retrospective clinical and magnetic resonance imaging review of a consecutive series of 12 medial collateral ligament tibial side avulsions. All patients were treated operatively and the final diagnosis was made based on the intraoperative findings. Post-injury magnetic resonance imaging studies were reviewed to assess injury patterns with respect to the intraoperative findings.
Results: Eleven of 12 cases (92%) had grade III valgus laxity (unstable to valgus stress at both 0° and 30° of flexion) on an examination under anesthesia. Concomitant anterior cruciate ligament tear was noticed in all cases. Intraoperative findings were classified into 3 types depending on the location of the ruptured end of the superficial medial collateral ligament with respect to the pes anserinus tendons. Magnetic resonance imaging depicted characteristic waving ("wave sign") of the superficial layer of medial collateral ligament in all cases.
Conclusions: "Wave sign" of the superficial layer of medial collateral ligament on magnetic resonance imaging is essential for diagnosing medial collateral ligament tibial side avulsions. Based on the clinical features and injury patterns, operative treatment is primarily recommended for medial collateral ligament tibial side avulsions.
Level of evidence: Case series, Level IV.

1. Introduction

Medial collateral ligament (MCL) injury is one of the most common knee injuries. Until now, many studies of non-operative treatment of MCL injury, with early functional rehabilitation, have described good outcomes commensurate with those obtained from operative intervention [1–8]. While instances of femoral insertion have constituted the most widely documented cases of MCL injury [9,10], MCL tibial side injury is rare, and only a few studies have described MCL tibial side avulsion [11–15]. These reports indicated that the patients with rupture of the superficial and deep MCL from the tibia continued to have symptomatic valgus instability after conservative treatment. Therefore, early and accurate detection of MCL tibial side avulsion may be necessary for complete recovery without much delay. Early surgical repair is recommended for athletes with complete MCL tibial side avulsion, and thorough knowledge of the pattern of ligament damage is essential to plan definitive treatment.

Magnetic resonance imaging (MRI) is useful in detecting soft tissue pathology such as MCL injury. While a number of MRI studies have described MCL injuries, there is no MRI study describing a large number of cases with MCL tibial side avulsions. In the previous seven years, we have treated 12 cases of acute MCL tibial side avulsions. We hypothesized that MRI and the operative findings in these cases, which could help in accurate diagnosis and successful treatment, included some distinctive features. Therefore, the purpose of this retrospective study was to clarify the clinical features of this clinically rare entity.

2. Materials and methods

Between April 2002 and March 2009, we had 45 operative cases of MCL injury at our institution. Of these, 16 were intraoperatively diagnosed as MCL tibial side avulsion, and MCL repair was performed. The MRI and operative findings of the 12 of 16 cases were referable and

* Corresponding author at: Department of Orthopaedic Surgery, Faculty of Medicine, The University of Tokyo, Tokyo, Japan, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan. Tel.: +81 3 3815 5411; fax: +81 3 3818 4082.
E-mail address: takeos-tky@umin.ac.jp (S. Taketomi).

http://dx.doi.org/10.1016/j.knee.2014.08.019
0968-0160/

were used in this study. MRI films were not retrospectively referable in 4 cases, because they were returned to the previous hospital. The sample group included 4 females and 8 males with a mean age of 25.1 years (range: 16–40 years). Patient information is given in Table 1. The clinical features of these patients were reviewed retrospectively, including for valgus instability, type of disruption assessed operatively, concomitant knee injuries, and the MRI findings.

The clinical evaluation of stability was performed by valgus stress test at both 0° and 30° of flexion under anesthesia. MCL injuries were graded according to the classification of the American Medical Association with a modification by Fetto and Marshall [2]. The cases were divided into 3 grades: grade I, full stability to valgus stress at both 0° and 30° of flexion; grade II, full stability at 0° of flexion but unstable to valgus stress at 30° of flexion; and grade III, unstable to valgus stress at both 0° and 30° of flexion. Concomitant knee injuries such as meniscal injury or other ligament injuries were also reviewed.

The authors considered MCL tibial side avulsion as an indication for acute surgical repair. Our strategy of treatment for combined anterior cruciate ligament (ACL) injury and MCL tibial side avulsion was a two-stage operation. In the first surgical stage, the MCL tibial side avulsion was repaired. In the second stage, after an approximate full range of motion was regained, the ACL was reconstructed.

The operative findings were evaluated from the surgical records. The duration of the interval from injury to surgery ranged from 2 to 53 days (mean: 14.3 days). The location of the ruptured end of the superficial MCL with respect to the pes anserinus tendons was recorded, as well as the location of the disruption to the deep layer (meniscotibial or meniscofemoral ligament).

Post-injury MRI studies were reviewed by two orthopedic surgeons to assess the injury patterns with respect to the intraoperative findings. Evaluation of MRI was performed on the fat-suppressed T2-weighted coronal images. The duration of interval from injury to MRI examination ranged from one to six days (mean: 2.1 days). The MRIs were conducted at various institutions. The imaging protocol was accordingly different.

All patients were informed that data from their cases would be used for research and submitted for publication, and all provided their consent prior to the study. Our institutional review board approved the study protocol.

3. Results

3.1. Clinical findings

Eleven of 12 cases (92%) had grade III valgus instability, whereas 1 (8%) had grade II valgus instability (Table 1).

3.2. Operative and MRI findings

Operative findings of the superficial MCL were classified into 3 types depending on the location of the ruptured end with respect to the pes anserinus tendons. Of the 12 cases, 3 (25%) were classified as type 1, where the superficial MCL was detached from the original tibial insertion and the ruptured end was identified beneath the pes anserinus tendons; 7 (58%) as type 2, located over or above the pes anserinus tendons; and 2 (17%) as type 3, entrapped in the medial knee joint space. These 3 types of superficial MCL tibial side avulsion are illustrated schematically in Fig. 1. In all cases, disruptions to the deep layer were confirmed during surgery. The location of disruption was the meniscotibial ligament in 4 cases (33%) and the meniscofemoral ligament in 8 (67%), respectively.

Review of the MRI images revealed the characteristic waving of the superficial layer, which we called "wave sign" (Fig. 2a–c), in all cases with MCL tibial side avulsion. When the MRI images were compared to the operative findings, the distal end of the superficial layer could not be identified in any of the type 1 cases (Fig. 2a). In contrast, the ruptured ends of the superficial MCL in type 2 were identified in 7 of 7 cases (Fig. 2b). In 2 cases classified as type 3 by the operative findings, the displacement of the ruptured end of the superficial layer into the medial knee joint was confirmed by MRI (Fig. 2c) (Table 1).

3.3. Concomitant injuries

ACL was torn in all cases (100%). Lateral meniscus was injured in 6 cases (50%), while medial meniscus was injured in 1 (8%). Other concomitant injuries are shown in Table 1.

4. Discussion

The review of 12 consecutive cases with MCL tibial avulsion injuries revealed that most MCL tibial side avulsions were caused by a contact or by a bad landing in sports. Considering the causes of injury and the fact that all cases had other associated ligament injuries, MCL tibial side avulsion was found to be a comparatively high-energy injury. The ACL was torn in all cases and the lateral meniscus was injured in half. Hence, extreme caution must be taken not to overlook the concomitant ACL and lateral meniscal injuries. Grade III valgus instability was observed in all cases except one case with MCL tibial side avulsion. In the latter, the intraoperative finding revealed that the posterior oblique ligament was not torn and the ruptured end of the superficial MCL was avulsed from the original insertion while staying beneath the pes anserinus tendons; this was a case of grade II valgus instability (case 10).

Review of the operative findings revealed that there were 3 types of disruption to the superficial MCL from the tibial insertion, a majority of which were either type 2 or 3. Nine of 12 cases (75%) were classified as type 2 or 3; the superficial MCL was detached from the original tibial insertion and the ruptured end was dislocated over the pes anserinus tendons or into the medial joint. In the remaining 3 of 12 cases (25%), the superficial MCL was detached from the tibial bone and it sagged while the ruptured end was beneath the pes anserinus tendons. The pathological anatomy of the cases with type 2 and 3 was similar to the total

Table 1
Patient information and clinical findings.

Case	Age	Gender	Cause of injury	Valgus laxity	Operative findings	MRI findings			Concomitant injury
					Location of the ruptured end	Wave sign	Identification of the ruptured end	Entrapment	
1	22	Female	Snow board (contact with a tree)	III	Type 3	+	+	+	ACL
2	31	Male	Soccer (contact)	III	Type 1	+			ACL + LM
3	21	Female	High-jump (landing)	III	Type 1	+			ACL + LM
4	40	Male	Horse riding (contact with a tree)	III	Type 2	+	+		ACL
5	18	Male	Basketball (landing)	III	Type 2	+	+		ACL + LM
6	35	Female	Volleyball (landing)	III	Type 2	+	+		ACL + LM + MM + MPFL
7	29	Male	Soccer (contact)	III	Type 2	+	+		ACL
8	22	Male	Circus (landing)	III	Type 2	+	+		ACL + PCL + LM
9	21	Male	Hockey (contact)	III	Type 3	+	+	+	ACL
10	25	Male	Basketball (landing)	II	Type 1	+			ACL + LM
11	21	Male	Mountain climbing (fall)	III	Type 2	+	+		ACL
12	16	Female	Volleyball (contact)	III	Type 2	+	+		ACL + MPFL

Grading of MCL injuries: grade I, full stability to valgus stress at both 0° and 30° of flexion; grade II, full stability at 0° of flexion but unstable to valgus stress at 30° of flexion; grade III, unstable to valgus stress at both 0° and 30° of flexion.
The superficial MCL tibial side avulsions were classified as type 1 (the ruptured end is located beneath the pes anserinus tendons), type 2 (the ruptured end is located over or above the pes anserinus tendons), and type 3 (the ruptured end is entrapped into the medial joint).
Wave sign: The waving of the superficial MCL on coronal MRI; ACL: anterior cruciate ligament; PCL: posterior cruciate ligament; LM: lateral meniscus; MM: medial meniscus; MPFL: medial patellofemoral ligament.

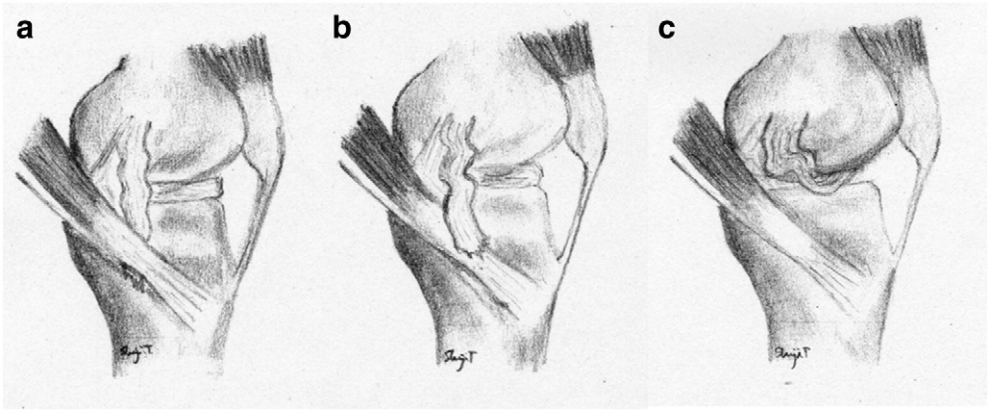

Fig. 1. Scheme of the superficial MCL tibial side avulsions. a, type 1: The ruptured end is located beneath the pes anserinus tendons. b, type 2: The ruptured end is located over or above the pes anserinus tendons. c, type 3: The ruptured end is trapped in the medial joint.

ruptured ulnar collateral ligament of the metacarpophalangeal joint of the thumb, more commonly known as Stener lesion [16]. Corten et al. named MCL tibial side avulsion as a "Stener-like lesion" in their two case reports [11]. In general, Stener lesion is an indication for operative treatment, because the adductor aponeurosis becomes interposed between the ruptured end of the ligament and its insertion.

Similarly, due to the interposed pes anserinus tendons between the ruptured end of the superficial MCL and the tibial bone surface, direct healing to the tibial insertion was presumed impossible with conservative treatment for cases with type 2 or 3 MCL injury. In the cases with type 1, direct healing to near the tibial insertion may be possible, but it is expected that the ruptured end of the superficial MCL would remain displaced proximal to the tibial insertion and adhere to the loose proximal ligament. Therefore, symptomatic valgus laxity may also persist with conservative treatment for type 1 avulsion. In this series, 2 cases of type 1 and type 2 (case 3 and 12) were resistant to 8 weeks of conservative treatments. As expected, during the surgeries in these 2 cases, the ruptured ends of the superficial MCL were noticed to locate proximal to the tibial insertion and to adhere there with loose proximal ligament. These experiences support the notion that displaced MCL tibial side avulsion, treated conservatively, can lead to chronic symptomatic valgus instability. Similarly, according to Wilson et al., complete avulsions of the superficial and deep MCL from the tibia have a poor prognosis with conservative treatment and should be managed with acute surgical repair for maximum benefits [13]. From the review article by Phisitkul et al., operative treatment was also recommended for a complete injury of both the superficial and deep MCL from the tibia [12]. Our current study supports their opinion. Overall, we primarily recommend surgical treatment with acute repair for MCL tibial side avulsion.

In this study, we also evaluated the MRI findings of the cases with MCL tibial side avulsion and compared them with operative findings. Importantly, a characteristic waving of the superficial MCL midsubstance portion ("wave sign") was observed in all cases with MCL tibial side avulsion on MRI. The injury pattern could be diagnosed based on the MRI findings. To our knowledge, there has been little literature discussing this waving feature, although several signs of MCL injury on MRI have been described, including ligament discontinuity, subcutaneous edema, internal change of signal intensity, and bone bruises [17,18]. Even studies specific to MCL tibial side avulsion have so far failed to focus on the waving of the superficial layer, while the "wave sign" was visible on the figures in each paper [13–15]. Corten et al. referred to a feature of waving in the midsubstance portion of the MCL, using the word "bunched" [11]. Why does the superficial MCL appear waved on MRI when avulsed from the tibial insertion? When the superficial MCL is torn proximally, the ruptured end is not completely displaced because the proximal superficial MCL is connected to soft tissue such as the posterior oblique ligament and the medial patellofemoral ligament [19]. On the other hand, the distal tibial attachment of the superficial MCL is directly connected to the bone [20]. Consequently, once the superficial MCL avulse from the tibial bone, the ruptured end displaces proximally and the superficial MCL sags in the middle due to its lack of connection with soft tissue. This may be one of the reasons why the superficial MCL appears waved on MRI

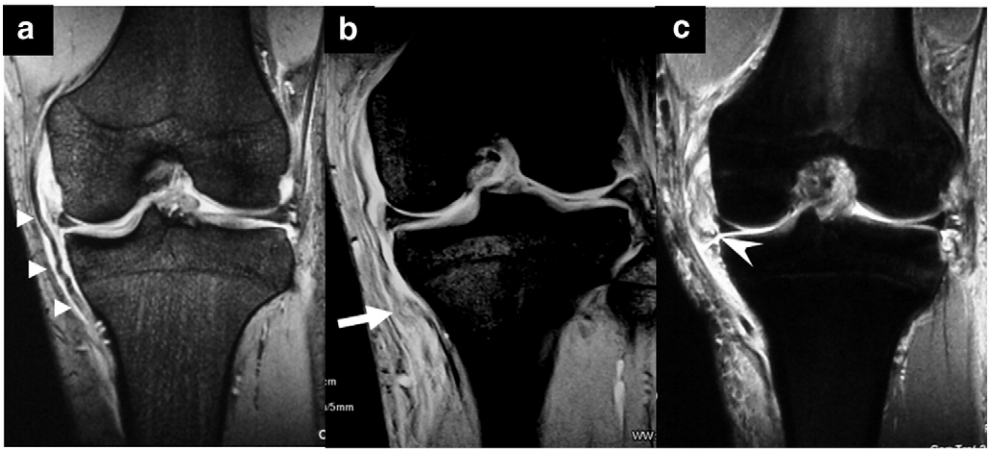

Fig. 2. a, "Wave sign": the waving of the superficial layer (triangle). b, The distal end of the superficial MCL (arrow). c, The entrapment of the distal end of the superficial layer into the medial knee joint (arrow head).

when avulsed from the tibial insertion. However, the "wave sign" cannot be explained fully by this anatomical consideration and the reason why the distal tibial attachment with a relatively broad insertion area to the bone can completely be avulsed is unclear [20]. In order to elucidate the reason why only tibial side avulsion shows the "wave sign", further anatomical or biomechanical studies are needed. Overall, our current study showed that "wave sign" detected on MRI is essential for diagnosing MCL tibial side avulsion.

In answer to the question "does the wave sign indicate only MCL tibial side avulsion?", MRI films of 9 consecutive cases who underwent MCL reconstruction for femoral or midsubstance injury in one of our institutions were reviewed. The results showed that none of 9 cases demonstrated the wave sign. This indicated not only the sensitivity of the wave sign but also the specificity. A typical MRI of MCL femoral side injury without the wave sign is shown in Fig. 3. However, the specificity of the "wave sign" could not be calculated in this study. To clarify the sensitivity and specificity of the "wave sign", another prospective study is needed in the future.

Although MCL tibial side avulsions were thought to be rare, their rate among operative cases of MCL injury in this series seemed to be relatively high. This was thought to be due to our treatment strategy for MCL injuries. MCL tibial side avulsion is, in principle, treated operatively, while MCL femoral side injury is at first conservatively treated. Only if residual valgus laxity was present after conservative treatment for MCL femoral side injury, was MCL reconstruction performed. The fact that most patients were referred to our institute for surgical purposes may be one of the reasons why the rate of MCL tibial side avulsion was high. On the other hand, 384 cases of MCL injury were treated non-operatively during the study period. Accordingly, it can be said that MCL tibial side avulsion is a rare injury. Most studies about conservative or operative treatment of complete MCL injuries fail to describe the site of injury. With regard to indications for operative treatment, MCL injury should be classified according to not only the clinical instability but also to the location of the disruption site. In Hughston's series, the location of tenderness indicated the injury site of the superficial MCL in 76% of cases [21]. They concluded that the site of pain and tenderness was an accurate indication of the site of the tear. In fact, most cases had tenderness at proximal tibia in our series. The deep layer of MCL was ruptured and blood leaked out of the knee joint. Consequently, despite the existing ACL injury, physical examination showed no significant effusion other than medial soft tissue swelling around the proximal tibia in most MCL tibial side avulsion cases. This finding can be helpful in the clinical diagnosis of MCL tibial side avulsion. We recommend that MRI be routinely employed in cases of grade II or III valgus instability and tenderness at the proximal tibia. When "wave sign" is detected on MRI, caution should be taken for MCL tibial side avulsion, and surgical repair should be considered because of the pathological anatomy.

There were some limitations to this study. The first was that clinical features and MRI findings of MCL tibial side avulsion were not compared to those of other MCL injuries. Another limitation is that this study did not clarify clinical outcomes after the surgery. The clinical results after the surgery are needed to answer the questions whether acute repair for MCL tibial side avulsion will serve to achieve better stability of the knee joint. The further clinical comparative studies between acute repair and conservative treatment are required.

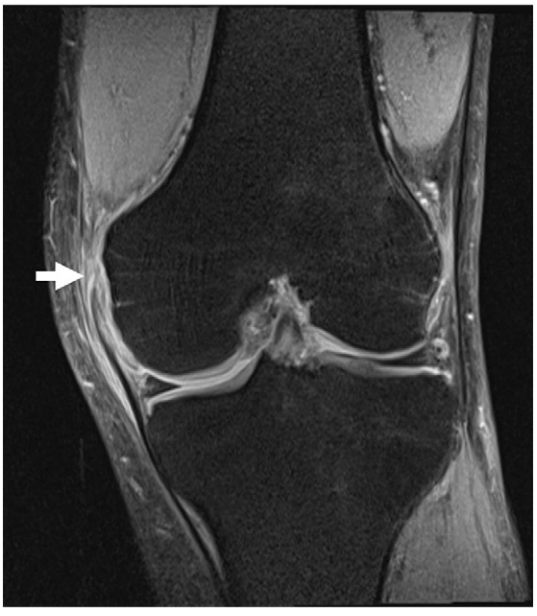

Fig. 3. MRI of the MCL femoral side injury. The arrow shows the site of the injury. A "wave sign" was not detected on MRI.

5. Conclusion

We recommended that MRI should be routinely examined when clinical examinations reveal grade II or III valgus instability and tenderness at the proximal tibia. Caution should be taken because most cases with MCL tibial side avulsion have associated ACL injury. "Wave sign" detected on MRI is a useful indicator of MCL tibial side avulsion. Hence, most MCL tibial side avulsions should be treated surgically with acute repair because of the pathological anatomy.

Conflict of interest

The authors declare that they have no conflict of interest associated with this manuscript and there has been no significant financial support for this work that could have influenced its outcome.

References

[1] Ellsasser J, Reynolds F, Omohundro J. The non-operative treatment of collateral ligament injuries of the knee in professional football players. An analysis of seventy-four injuries treated non-operatively and twenty-four injuries treated surgically. J Bone Joint Surg Am 1974;56(6):1185–90.
[2] Fetto J, Marshall J. Medial collateral ligament injuries of the knee: a rationale for treatment. Clin Orthop Relat Res 1978;132:206–18.
[3] Indelicato P. Non-operative treatment of complete tears of the medial collateral ligament of the knee. J Bone Joint Surg Am 1983;65(3):323–9.
[4] Indelicato P, Hermansdorfer J, Huegel M. Nonoperative management of complete tears of the medial collateral ligament of the knee in intercollegiate football players. Clin Orthop Relat Res 1990;256:174–7.
[5] Kannus P. Long-term results of conservatively treated medial collateral ligament injuries of the knee joint. Clin Orthop Relat Res 1988;226:103–12.
[6] Reider B, Sathy M, Talkington J, Blyznak N, Kollias S. Treatment of isolated medial collateral ligament injuries in athletes with early functional rehabilitation. A five-year follow-up study. Am J Sports Med 1994;22(4):470–7.
[7] Sandberg R, Balkfors B, Nilsson B, Westlin N. Operative versus non-operative treatment of recent injuries to the ligaments of the knee. A prospective randomized study. J Bone Joint Surg Am 1987;69(8):1120–6.
[8] Woo S, Inoue M, McGurk-Burleson E, Gomez M. Treatment of the medial collateral ligament injury. II: Structure and function of canine knees in response to differing treatment regimens. Am J Sports Med 1987;15(1):22–9.
[9] Bergfeld J. Symposium: functional rehabilitation of isolated medial collateral ligament sprains. First-, second-, and third-degree sprains. Am J Sports Med 1979;7(3):207–9.
[10] Nakamura N, Horibe S, Toritsuka Y, Mitsuoka T, Yoshikawa H, Shino K. Acute grade III medial collateral ligament injury of the knee associated with anterior cruciate ligament tear. The usefulness of magnetic resonance imaging in determining a treatment regimen. Am J Sports Med 2003;31(2):261–7.
[11] Corten K, Hoser C, Fink C, Bellemans J. Case reports: a Stener-like lesion of the medial collateral ligament of the knee. Clin Orthop Relat Res 2010;468(1):289–93.
[12] Phisitkul P, James S, Wolf B, Amendola A. MCL injuries of the knee: current concepts review. Iowa Orthop J 2006;26:77–90.
[13] Wilson T, Satterfield W, Johnson D. Medial collateral ligament "tibial" injuries: indication for acute repair. Orthopedics 2004;27(4):389–93.
[14] Hash II TW. Magnetic resonance imaging of the knee. Sports Health 2013;5(1):78–107.
[15] Wijdicks CA, Griffith CJ, Johansen S, Engebretsen L, LaPrade RF. Injuries to the medial collateral ligament and associated medial structures of the knee. J Bone Joint Surg Am 2010;92(5):1266–80.

[16] Stener B. Displacement of the ruptured ulnar collateral ligament of the metacarpophalangeal joint of the thumb, a clinical and anatomical study. J Bone Joint Surg Br 1962;44:869–79.
[17] Schweitzer M, Tran D, Deely D, Hume E. Medial collateral ligament injuries: evaluation of multiple signs, prevalence and location of associated bone bruises, and assessment with MR imaging. Radiology 1995;194(3):825–9.
[18] Yao L, Dungan D, Seeger L. MR imaging of tibial collateral ligament injury: comparison with clinical examination. Skeletal Radiol 1994;23(7):521–4.
[19] Wymenga AB, Kats JJ, Kooloos J, Hillen B. Surgical anatomy of the medial collateral ligament and the posteromedial capsule of the knee. Knee Surg Sports Traumatol Arthrosc 2006;14(3):229–34.
[20] LaPrade R, Engebretsen A, Ly T, Johansen S, Wentorf F, Engebretsen L. The anatomy of the medial part of the knee. J Bone Joint Surg Am 2007;89(9):2000–10.
[21] Hughston J, Andrews J, Cross M, Moschi A. Classification of knee ligament instabilities. Part I. The medial compartment and cruciate ligaments. J Bone Joint Surg Am 1976; 58(2):159–72.