PETRI SILLANPÄÄ

Traumatic Patellar Dislocation and Clinical Significance of Medial Patellofemoral Ligament Injury

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ACADEMIC DISSERTATION
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University of Tampere, Medical School
Tampere University Hospital, Department of Orthopedic Surgery and Trauma
Centre for Military Medicine, Lahti
Finland

Supervised by
Docent Harri Pihlajamäki
University of Helsinki
Finland
Docent Ville Mattila
University of Tampere
Finland

Reviewed by
Docent Arsi Harilainen
University of Helsinki
Finland
Docent Juhana Leppilahti
University of Oulu
Finland

Distribution
Bookshop TAJU
P.O. Box 617
33014 University of Tampere
Finland

Tel. +358 3 3551 6055
Fax +358 3 3551 7685
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TIIVISTELMÄ

Traumaattinen polvilumpion sijoiltaanmeno on tavallinen liikuntasuoritukseen liittyvä nuoren aikuisen akuutti nivelsidevamma, joka aiheuttaa veripolven. Sijoiltaanmeno vaurioittaa mediaalisen patellofemoraaliligamentin (MPFL), joka on pääasiallinen polvilumpion tukirakenne. Ensimmäisen sijoiltaanmenon jälkeen monilla esiintyy toistuvia polvilumpion muljahteluja tai sijoiltaanmenoja, polven kipua, liikunnallisen aktiivisuustason heikkenemistä ja polvilumpion liukupinnan nivelkulumaa. Polvilumpion ensimmäisen sijoiltaanmenon paras hoitotapa on ollut epäselvä, koska laadukkaita tutkimuksia on niukasti. Perinteisesti suurin osa polvilumpion ensimmäisistä sijoiltaanmenoista on hoidettu ilman leikkausta.

Tämän väitöskirjan tarkoituksena oli selvittää polvilumpion ensimmäisen sijoiltaanmenon ilmaantuvuus, riskitekijät ja vertailla eri hoitomenetelmiä. Lisäksi tutkimus selvitti MPFL-rekonstruktioleikkauksen pitkäaikaistulokset ja MPFL vammakohdan kliinistä merkitystä. Tutkimus kohdistui vuosina 1994-2002 varusmiespalveluksensa suorittaneisiin nuoriin miehiin ja naisiin. Tutkimusaineisto käsitti yli 130 000 nuoren, iältään 17-30 vuotiaan aikuisen kohortin, jota käytettiin polvilumpion ensimmäisen sijoiltaanmenon saaneiden väestötason ilmaantuvuutta ja riskitekijöitä koskevaan tutkimukseen. Toisena aineistona oli retrospektiivinen kohortti varusmiehiä, jotka oli leikattu toistuvan polvilumpion sijoiltaanmenon vuoksi joko MPFL rekonstruktiolla tai perinteisemmällä polvilumpion stabilointitoimenpiteellä. Päävastemuuttujina polvilumpion instabiliteetti ja polvilumpion liukupinnan nivelkuluman kehittyminen. Väitöskirjatutkimukseen kuului kaksi prospektiivista polvilumpion ensimmäisen sijoiltaanmenon sairastaneiden kohorttia. Tähystystekniikalla tehtävää polvilumpion stabilointileikkausta verrattiin ilman leikkausta hoidettuihin ja vastaavasti satunnaistetussa asetelmassa avoleikkausta verrattiin ilman leikkausta hoidettuihin.

Lisäksi analysoitiin kolmen eri MPFL vauriokohdan ennuste saranalastalla hoidetuilla potilailla. Päätemuuttujina tutkimuksissa oli vamman jälkeinen polvilumpion stabiliteetti ja liikunta-aktiivisuustason säilyminen.

Väitöskirjatutkimuksen perusteella polvilumpion ensimmäinen sijoiltaanmeno on aiemmin arvioitua yleisempi polvivamma, jonka vuotuinen ilmaantuvuus on 77/100 000 nuoressa aikuisväestössä. Potilaan pituus ja paino todettiin olevan traumaattisen polvilumpion sijoiltaanmenon riskitekijöitä. Huono fyysinen suorituskyky, ylipaino tai heikko lihaskunto ei lisännyt sijoiltaanmenon riskiä. MPFL-rekonstruktioleikkauksella saavutettiin perinteistä leikkaustekniikkaa vastaava polvilumpion stabiliteetti, mutta polvilumpionivelen kulumaa kehittyi merkitsevästi vähemmän. Prospektiivisessa tutkimuksessa ei todettu merkitsevää hyötyä akuuttivaiheen tähystysleikkauksesta konservatiiviseen hoitoon verrattuna. Sen sijaan prospektiivinen satunnaistettu tutkimus polvilumpion ensimmäisen sijoiltaanmenon hoidosta avoleikkauksella tai ilman paljasti, että konservatiivisesti hoidetut kärsivät tilastollisesti merkitsevästi enemmän polvilumpion instabiliteetista. Leikatut eivät silti olleet oireettomampia muissa mittauksissa. MPFL repeämä reisiluun kiinnityskohdasta aiheutti merkitsevän fyysisen suoritustason laskun ja merkitsevästi instabiilimman polvilumpion kuin MPFL repeämä polvilumpion kiinnityskohdassa tai ligamentin keskiosassa, kun hoito oli ollut konservatiivinen.

Väitöskirjatutkimuksen perusteella magneettikuvauslöydösten tulkitseminen auttaa oikean hoitomuodon valinnassa. Traumaattinen polvilumpion ensimmäinen sijoiltaanmeno, johon liittyy MPFL repeämä reisiluun kiinnityskohdassa, näyttää olevan hyödyllistä hoitaa alkuvaiheen leikkauksella. Lisäksi jos traumaattiseen sijoiltaanmenoon liittyy nivelpinnan rustomurtuma, tai jos polvilumpio on jo alkuvaiheessa huomattavan instabiili, alkuvaiheen leikkaushoito on tarpeen, etenkin korkean vaatimustason potilailla, kuten liikunnallisesti aktiivisilla.

Väitöskirjatutkimuksen tulokset osoittivat, että polvilumpionivelen kuluma on merkittävä ilmiö polvilumpion sijoiltaanmenon sairastaneilla. Aiemmissa tutkimuksissa nivelkulumaa on esiintynyt runsaasti sekä ilman leikkausta hoidetuilla että perinteisin leikkausmenetelmin hoidetuilla. Tämän tutkimuksen mukaan anatomiseen korjaukseen pyrkivä MPFL rekonstruktio vähentää nivelkuluman kehittymistä. Tämän perusteella polvilumpion stabilointileikkaukseksi suositellaan MPFL rekonstruktiota, etenkin polvilumpion traumaattisen sijoiltaanmenon jälkeen. Polven anatomiset poikkeavuudet tulee huomioida leikkaushoitoa suunnitellessa, joskin traumaattinen polvilumpion sijoiltaanmeno tapahtuu varsin usein ilman instabiliteetille altistavia rakenteellisia poikkeavuuksia. Väitöskirjatutkimuksen perusteella annetaan suositus traumaattisen polvilumpion ensimmäisen sijoiltaanmenon hoidon suunnittelemiseksi.

Content

1. ABBREVIATIONS

ACL	Anterior cruciate ligament
CT	Computed tomography
ICRS	International Cartilage Repair Society
LRR	Lateral retinacular release
MCL	Medial collateral ligament
MPFL	Medial patellofemoral ligament
MPML	Medial patellomeniscal ligament
MPTL	Medial patellotibial ligament
MRI	Magnetic resonance imaging
NHDR	National Hospital Discharge Register
OA	Osteoarthritis
PF	Patellofemoral
ROM	Range of motion
TG	Trochlear groove
TT	Tibial tuberosity
TT-TG	Tibial tuberosity-trochlear groove (distance)
VAS	Visual analog scale
VMO	Vastus medialis obliquus

2. ORIGINAL COMMUNICATIONS

I Sillanpää P, Mattila VM, Iivonen T, Visuri T and Pihlajamäki H (2008).
Incidence and risk factors of acute traumatic primary patellar dislocation.
Med Sci Sports Exerc 40: 606-11.

II Sillanpää P, Mattila VM, Visuri T, Mäenpää H and Pihlajamäki H (2008).
Ligament reconstruction versus distal realignment for patellar dislocation.
Clin Orthop Relat Res 466:1475-84.

III Sillanpää PJ, Mäenpää H, Mattila VM, Visuri T and Pihlajamäki H (2008).
Arthroscopic surgery for primary traumatic patellar dislocation: a prospective, nonrandomized study comparing patients treated with and without acute arthroscopic stabilization with a median 7-year follow-up.
Am J Sports Med 36: 2301-9.

IV Sillanpää PJ, Mattila VM, Mäenpää H, Kiuru M,Visuri T and Pihlajamäki H. (2009). Treatment with and without initial surgical stabilization for primary traumatic patellar dislocation: a prospective randomized study.
J Bone Joint Surg Am 91: [Epub ahead of print]

V Sillanpää PJ, Peltola E, Kiuru M, Mattila VM, Visuri T and Pihlajamäki H.
Femoral avulsion of the medial patellofemoral ligament predicts subsequent instability in men: a nonoperative follow-up study of mean 7 years.
Am J Sports Med [Accepted]

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3. ABSTRACT

First-time (primary) traumatic patellar dislocations are considered to be a consequence of active lifestyle and defined as acute ligamentous knee injury. After first-time patellar dislocation various subsequent problems may occur such as anterior knee pain, recurrent patellar instability, decreased level of sporting activity, and development of patellofemoral osteoarthritis (OA). The management of a primary traumatic patellar dislocation has been controversial with no evidence-based consensus how a clinician should treat these injuries to achieve the best possible result. Traditionally, most primary patellar dislocations have been treated nonoperatively. Recently, however, increasing interest has been focused on investigating primary traumatic patellar dislocation and the possible benefits of initial surgical management. This phenomenon has arisen since the medial patellofemoral ligament (MPFL) has been recognized as the primary medial stabilizer of the patella and MPFL injury has been associated with traumatic patellar dislocations.

The purpose of this thesis was to investigate the incidence, risk factors and initial management of primary traumatic patellar dislocation, the long-term results of MPFL reconstruction and the clinical significance of the MPFL injury in primary traumatic patellar dislocation. The study population consisted of Finnish military conscripts who served during 1994-2002. Five data sets were used. The first data was obtained from a large military health care database of over 130 000 young adults 17-30 years of age. This information was combined with the Finnish National Hospital Discharge Register in order to assess the incidence and risk factors for

primary traumatic patellar dislocation. The second data compared MPFL reconstructions and distal realignment procedures performed in Central Military Hospital in 1994-2000. The outcome variables in this study were long-term recurrent instability and the presence of patellofemoral OA. The third and fourth data consisted of two prospective cohorts comparing initial arthroscopic medial repair and nonoperative treatment, and stabilizing surgery and nonoperative treatment (randomly allocated), respectively. These patients were clinically followed-up and the outcome variables were subsequent patellar instability and clinical symptoms. The fifth data consisted of a cohort of conscripts with nonoperatively treated primary patellar dislocation with MPFL injury. In this cohort, the predictive value of the MPFL injury location was assessed when subsequent instability was used as the primary outcome.

The follow-up review of these physically active young adults disclosed that primary traumatic patellar dislocation is a common knee injury yielding an incidence rate of 77/100 000 person-years in males. The risk factors for primary traumatic patellar dislocation were height and weight, not poor physical performance or muscle fitness. MPFL reconstruction compared to distal realignment procedure achieved comparable patellar stability but significantly less patellofemoral OA progression. The prospective study comparing initial arthroscopic medial repair to nonoperative management failed to show any benefit with initial arthroscopic stabilization. The prospective randomized study with or without initial stabilizing surgery revealed that patients who underwent surgery had more stable patellae at follow-up. To explore the clinical significance of the MPFL injury location, the magnetic resonance imaging (MRI) evaluation of nonoperatively treated patients proved that a femoral avulsion of the MPFL predicted subsequent instability and lower return to preinjury level of activity when compared to other MPFL injury locations (patellar and midsubstance).

While previous studies have concluded that MPFL injury is frequently associated with primary traumatic dislocations with variation in the location of the MPFL tear, the studies in this thesis are the first to indicate a clinical aspect of using MRI findings in guiding the treatment pathway. In primary traumatic patellar dislocation, MR images should be evaluated because of the predictive value they carry. It may be concluded that patients who have high demands of patellar stability are likely to benefit from initial surgical repair or reconstruction. If we look at the long-term consequences of patellar dislocation, there are specific circumstances where initial stabilizing surgery should be considered; cases presenting substantial disruption of the MPFL at its femoral attachment, an osteochondral fracture that requires surgery, a laterally subluxated instable patella in patients with high demand of patellar stability, and in patients not improving with appropriate rehabilitation.

This thesis also indicates that PF OA is a frequent sequel of patellar dislocation. Based on the previous findings of PF OA presence after nonoperative management and traditional distal realignment surgery, there is a role for anatomic MPFL reconstruction that seems to reduce the risk of OA progression. Especially when stabilizing surgery is considered after traumatic patellar dislocation, MPFL reconstruction should be preferred. Based on the findings of this study and previous literature, a treatment algorithm for primary traumatic patellar dislocation is proposed.

4. INTRODUCTION

Acute patellar dislocation is a common knee injury among physically active young adults (Visuri and Mäenpää 2002; Stefancin and Parker 2007). A patellar dislocation is the second most common cause of acute knee hemarthrosis (Harilainen et al. 1988) and the most common acute knee injury among Finnish military conscripts (Visuri et al. 1993). A primary (first-time) traumatic patellar dislocation has been characterized as a typical acute knee injury in young active persons (Atkin et al. 2000). Over the long-term, patellar dislocations can result in patellar instability with recurrent dislocations, pain, decreased level of sporting activity, and patellofemoral OA. Recurrence rates after primary dislocation are high, for up to 44-70% suffer subsequent patellofemoral instability after nonoperative treatment (Mäenpää et al. 1997; Nikku et al. 2005). While primary traumatic patellar dislocation has been described as one of the most common knee injuries (Harilainen et al. 1988; Visuri et al. 1993), patellofemoral instability is among the most challenging problems that sports medicine clinicians face in their daily practices.

Patellar instability is a multifactorial problem. Patellar dislocations have been traditionally attributed to several predisposing factors, since patellar dislocation can occur without substantial trauma in a dysplastic patellofemoral (PF) joint (Insall et al. 1972; Blackburne and Peel 1977; Runow 1983; Malghem and Maldague 1989; Dejour et al. 1994; Mäenpää and Lehto 1996). Recently, however, traumatic primary patellar dislocation was reported not to be significantly associated with dysplastic features in the PF joint (Atkin et al. 2000; Stefancin and Parker 2007). This controversy can be interpreted to be suggestive of two different injuries, and may originate from the fact that the definition of primary patellar dislocation has remained imprecise in the literature despite the large number of studies published on patellar dislocations. Dysplastic bony architecture of the PF joint may predispose to patellar instability, while on the other hand, patellar instability may be influenced by the injured soft-tissue constraints after traumatic patellar dislocation in a well-aligned PF joint with normal structure (Colvin and West 2008). Epidemiology of primary patellar dislocation has been poorly studied and initial management has been controversial with no evidence-based consensus to guide decision making.

Acute primary traumatic patellar dislocation is accompanied by hemarthrosis of the knee, caused by rupture of the medial restraints of the patella (Kirsch et al. 1993; Virolainen et al. 1993; Spritzer et al. 1997). Several studies have concluded that the MPFL is the most important medial restraint of the patella, providing 50-60% of the soft tissue restraint against lateral translation (Conlan et al. 1993; Desio et al. 1998; Hautamaa et al. 1998; Nomura et al. 2000; Dopirak et al. 2008). In a traumatic primary patellar dislocation, the MPFL is injured (Avikainen et al. 1993; Sallay et al. 1996; Nomura 1999; Ahmad et al. 2000; Sanders et al. 2001; Elias et al. 2002; Nomura et al. 2002; Stefancin and Parker 2007; Dopirak et al. 2008). The importance of the MPFL has been noted since the early 1990s and since then, a number of reconstructive surgical procedures aiming to restore this ligament function have been published (Lind et al. 2008). As the MPFL and its function have been relatively recently established, orthopedic textbooks still fail to recognize MPFL injuries and, instead, focus mainly on correcting the dysplastic features of the PF joint when discussing surgical treatment of patellar dislocation.

Most primary traumatic patellar dislocations have been traditionally treated nonoperatively despite an obvious MPFL injury. The clinical importance of MPFL injury itself has not been studied. Many case series with MPFL reconstructive procedures have shown excellent short-term results (Avikainen et al. 1993; Drez et al. 2001; Ellera Gomes et al. 2004; Deie et al. 2005; Schöttle et al. 2005; Steiner et al. 2006; Lind et al. 2008), and a long-term follow-up study has recently been published with promising results (Nomura et al. 2007). It has been suggested that MPFL reconstruction might prevent PF OA progression (Nomura et al. 2007), which would significantly affect the long-term prognosis of patellar dislocation. In up to half of cases, primary dislocation results in PF OA within 10 years, when the patients are in their late 20s to early 30s (Mäenpää and Lehto 1997).

Since we are facing two different clinical situations in which patellar dislocation may occur, we may fairly conclude that their initial treatment should not be similar. In order to minimize long-term morbidity and to find better solutions to treat these patients, we need to investigate the nature and risk factors for primary traumatic patellar dislocations and evaluate the outcomes of different operative and nonoperative methods of treatment in primary patellar dislocations.

This thesis aimed to investigate the incidence and risk factors for primary traumatic patellar dislocation. In addition, the long-term results of MPFL reconstruction by adductor magnus tenodesis versus conventional distal realignment procedure with special regard to patellofemoral OA development were investigated. To explore clinical aspects of initial operative management, a prospective cohort study was designed to compare long-term outcomes after arthroscopic medial restraint repair with those after nonoperative treatment. A prospective, randomized study was designed to investigate whether initial stabilizing surgery is better than nonoperative treatment in primary traumatic patellar dislocations. The clinical significance of the MPFL injury location was investigated in a nonoperative follow-up study, in which the primary outcome was overall patellar instability.

5. REVIEW OF THE LITERATURE

5.1 Patellar function in the human knee

The extensor mechanism of the knee produces leg extension. Knee extension-flexion movement is needed for normal gait. The quadriceps femoris muscle, in the anterior aspect of the thigh, produces the extensor function. The patella produces a gliding movement of the extensor mechanism over the knee joint (Figure 1). Distally, the patellar tendon attaches to the tibia. Without the patella, efficient extensor mechanism of the knee cannot be achieved and normal gait is impossible. The patellar articular surface facing against the anterior aspect of the femur forms the PF joint. During the extension forces produced by the quadriceps femoris muscle, the pressure is elevated in the patellafemoral articular surfaces (Heegaard et al. 1994). The contact area of the PF joint varies with the angle of knee flexion (Feller et al. 2007). The extensor mechanism must be aligned with axis of the lower limb, and the patella has the critical role to control it within the knee arc of motion. A malalignment of the extensor mechanism may be sometimes present producing lateralization forces influencing the patella (Feller et al. 2007). Patellar tracking and stability is controlled by soft tissue restraints of the PF joint in extension and early flexion and by the femoral trochlear groove (TG) in deep flexion (Hughston 1968; Andrikoula et al. 2006).

Figure 1. Patellar stability relies on the limb alignment, the osseus architecture of the patella and the trochlea, the integrity of the soft-tissue constraints, and the interplay of the surrounding muscles.

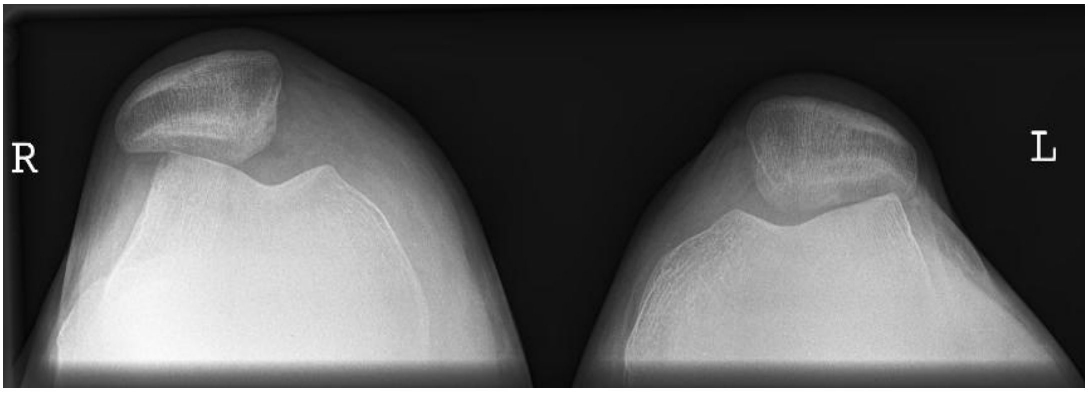
5.2 Clinical features of patellar dislocation

Primary traumatic patellar dislocation can result in patellar instability and patellofemoral pain when subsequent healing of the joint supporting structures has been deficient. If the knee has anatomic abnormalities which predispose the patella to dislocate, only minor trauma may be needed for the initial dislocation to occur, whereas forceful knee trauma may cause traumatic dislocation and substantial injuries to the supporting structures of the patella. Treatment of patellar dislocation demands understanding of these features and of the management of related injuries.

5.2.1 Terminology of patellar dislocation

Patellar dislocation has been defined as an interposition of the patella out of the femoral TG to the lateral direction (Hughston 1968) (Figure 2). Sometimes the term lateral patellar dislocation is used. European authors prefer to speak of luxation. Usually a reference to patellar dislocation means a lateral patellar dislocation. After the patella has dislocated outside the TG, the patella usually relocates spontaneously into the TG. In some instances, the patella may remain dislocated and needs to be repositioned. A medial patellar dislocation is a very rare condition, which is not discussed in this thesis.

Figure 2. Patellar dislocation on the right (R). A Laurin axial view.



There have been several, confusing terms over the past decades used in the literature in relation to patellar dislocation (Grelsamer 2005). Authors and speakers should clearly clarify the meanings that they attach to patellar terms. Acute patellar dislocation is a term that has been used in the past literature without specifying either the time of injury or whether only primary dislocations are discussed, or it has been used in combination with secondary dislocations, which significantly affects the interpretation of the study results. Acute patellar dislocation can be a first-time injury or a secondary dislocation. The imprecise term "acute" should not be used without an implication for its primary or secondary nature.

When patellar dislocation occurs for the first time, the exact term is primary patellar dislocation. When a dislocation has occurred once previously and occurs again, it is diagnosed as secondary dislocation. Occasionally, the term secondary dislocation is used as a synonym for recurrent or periodic patellar dislocation. Periodic, recurrent patellar dislocation may occur once in a while, usually during physical performance, whereas patellar subluxations are mostly daily sensations of patellar instability. Both can affect the patient's physical activity level and cause knee pain. Recurrent patellar dislocation and subluxation are the most usual forms of patellar instability.

Patellar subluxation is defined as a partial movement of the patella out of the TG, which is usually a subjective feeling of patellar instability (Hughston 1968; Arendt et al. 2002). A physician may find this by palpating a hypermobile patella, which is easily pulled out of the TG to an excessive extent. An instable patella may also subluxate during knee arc of motion (positive J sign (Fithian et al. 2004)), and may be visible by lateralizing in early flexion when riding on the lateral femoral condyle before becoming engaged by the deeper TG as flexion progresses. Subluxation may be an annoying complaint, and it may cause pain. Terms like hypermobile patella, patellar subluxation, and patellar laxity all describe subjective sensation of patellar instability. The term subluxation can also refer to a radiographic sign (Merchant et al. 1974). The term displacement is preferable to subluxation in radiographic setting (Grelsamer 2005).

The term patellar instability is defined as a clinical sign that can refer to subjective sensation of instability (subluxation) and/or patellar dislocation (Grelsamer 2005). Importantly, a patient may find daily or weekly subluxations more disabling than periodic, recurrent dislocations. Studies of patellar dislocation should always include a proper definition of the outcome variables; secondary dislocation and/or patellar instability including subluxation.

When patellar dislocation occurs in a situation where significant forces affect the knee joint such as valgus or rotational stress, usually during sport activities or in falling or collision accidents, primary dislocation is defined as traumatic dislocation (Stefancin and Parker 2007). If primary patellar dislocation occurs without external trauma energy, e.g. while squatting, the dislocation is defined as nontraumatic. Nontraumatic dislocation is related to dysplastic features of the PF joint.

Habitual patellar dislocation can refer to situations when the patella slips completely out of the TG in every knee flexion cycle. It is also strongly related to congenital dysplastic features of the PF joint and not discussed in this study. Permanent patellar dislocation is a rare situation in which the patella is permanently dislocated and manual repositioning into the TG fails. This is usually due to severe congenital dysplastic features of the PF joint. Permanent patellar dislocation is not discussed in this study.

In this study, *primary patellar dislocation* refers to first-time patellar dislocation with no previous sensations of abnormal patellar instability; *traumatic* and *nontraumatic patellar dislocation* describe the etiology of the injury; and *patellar instability* includes both recurrent dislocations and sensations of subluxation. The use of this terminology is encouraged when discussing anything related to patellar dislocation. It is also important to understand that the term *patellar instability* includes both subjective instability and an objective diagnosis of a patellar dislocation.

5.2.2 Surgical terminology of patellar dislocation

Surgical procedures to control patellar tracking include both soft-tissue approaches at the stabilizing structures of the patella and osteotomies to correct the extensor mechanism alignment. The procedure is selected with the aim to meet the patient’s individual needs in terms of personal anatomy and demands. The following terms are frequently used when discussing surgical techniques for patellar stabilization; a *proximal realignment* procedure includes surgical approaches to the proximal parapatellar stabilizing structures of the patella, e.g. medial reefing or MPFL reconstruction (Grelsamer 2005). A *distal realignment* procedure includes surgical procedures distal to the patella, e.g. transferring osteotomies of the patellar tendon attachment, the tibial tuberosity (TT) (Grelsamer 2005). *Anatomic* surgical stabilizing is defined as reconstruction of an anatomic structure, such as MPFL reconstruction. *Nonanatomic* surgical techniques include distal realignment and proximal realignment procedures that are not aimed at restoring normal anatomic features of the PF joint.

5.3 Primary traumatic patellar dislocation

Two kinds of patellar dislocations can occur; the *traumatic* primary dislocation associated with acute knee injury caused by an external force, and the *nontraumatic* primary dislocation that occurs without any additional physical stress in normal daily activities. The division into traumatic and nontraumatic patellar dislocation has been described lately in the literature (Atkin et al. 2000; Stefancin and Parker 2007).

A primary traumatic patellar dislocation occurs from external forces in a knee trauma, usually forces toward valgus direction or rotational knee stress result in patellar dislocation. A primary traumatic patellar dislocation causes an acute knee hemarthrosis (Visuri and Mäenpää 2002; Stefancin and Parker 2007). As the primary dislocation may involve injury to the medial restraints, whose function is to prevent lateral displacement of the patella, a secondary dislocation may thus occur without any substantial disruption of the supporting medial structures. Sometimes only minor hemarthrosis or swelling of the knee is observed if the dislocation occurs as a result of very low-energy trauma in a PF joint that have some dysplastic features predisposing to patellar instability (Stefancin and Parker 2007).

5.3.1 Clinical features of primary traumatic patellar dislocation

Traumatic patellar dislocation usually occurs at an age of 20 to 30 years, typically to an active young adult (Atkin et al. 2000). Traumatic patellar dislocation may occur without any conventional predisposing factors, such as patella alta, trochlear dysplasia, increased Q-angle, and be occasionally accompanied by other knee injuries such as simultaneous anterior cruciate ligament (ACL) injury secondary to valgus torque stress with rotational force (Stefancin and Parker 2007). It is obvious that a difference in the etiology of the primary dislocation, whether traumatic or nontraumatic, has a significant effect on the choice of treatment between repair of an injured ligamentous restraint or correcting malalignment of the patella (Cofield and Bryan 1977; Jensen and Roosen 1985; Cash and Hughston 1988; Harilainen and Sandelin 1993; Mäenpää and Lehto 1997; Atkin et al. 2000; Stefancin and Parker 2007). Reports noting a redislocation rate of up to 44% and a recurrent instability symptom rate greater than 50% after initial nonoperative management of primary traumatic dislocations (Cofield and Bryan 1977; Mäenpää et al. 1997; Nikku et al. 2005) have increased studies on initial operative repair or reconstruction of the medial patellar stabilizers.

5.3.2 Diagnosis of primary traumatic patellar dislocation

In the event that there is suspicion of an acute patellar dislocation, physical examination is the important and principal tool for making the diagnosis of primary traumatic patellar dislocation and for noting any concurrent knee or lower extremity injury (Hinton and Sharma 2003; Stefancin and Parker 2007). An accurate patient history is, however, equally important, since the mechanism of the injury and any previous complaints should always be assessed and documented (Mäenpää and Lehto 1995). Palpation is valuable for detecting areas of medial retinacular tenderness and a potential injury to the medial soft-tissue stabilizers. Palpable defects in the medial soft-tissue restraints, and a grossly dislocatable patella are prognostic factors for poor nonoperative outcomes (Hinton and Sharma 2003). Patellar apprehension and mobility are assessed by medial and lateral patellar translation.

Aspiration of the knee joint can be both diagnostic and therapeutic, and should be performed in patients with moderate to severe effusions. Acute patellar dislocation is the second most common injury noted for acute knee hemarthrosis next to ACL rupture (Harilainen et al. 1988). The volume of the hemarthrosis may represent the severity of the injury to the medial patellar stabilizers and presence of an osteochondral injury (Vainionpää et al. 1990). It has been suggested that a larger volume of effusion in the joint indicates a more traumatic dislocation and subsequent damage as compared to milder or missing hemarthrosis in patients with lower energy mechanism, one or several predisposing risk factors and a less traumatic injury (Stefancin and Parker 2007). Additionally, the aspiration relieves pain and improves the clinical examination and radiographic assessment (axial view (Laurin et al. 1979) and weight-bearing views, which are difficult to obtain in patients with acute hemarthrosis).

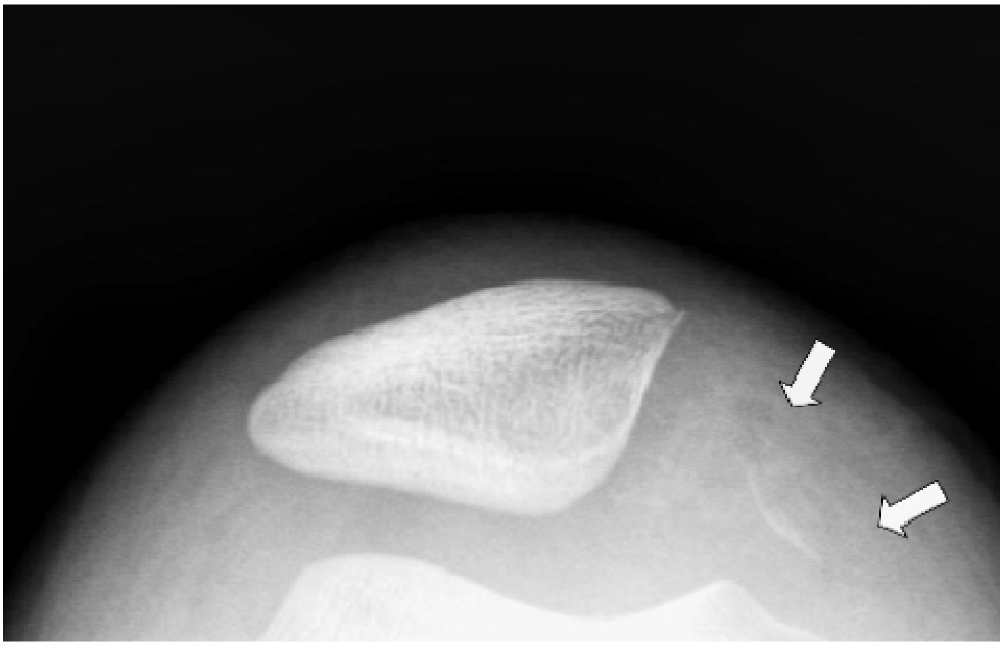
Physical examination should include assessment of the lower extremity alignment and of hypermobility of the contralateral knee (Stanitski 1995). Knee joint stability should be tested to rule out any concomitant injury to other structures, probably most frequently to the ACL or medial collateral ligament (MCL)(Vainionpää et al. 1986). Also, hypermobility of other articular joints may represent ligamentous laxity and be related to subsequent instability (Stanitski 1995). Osteochondral fractures should be suspected in primary traumatic dislocations until proven otherwise by imaging studies (Stefancin and Parker 2007). Studies of patients who did not progress well after initial functional rehabilitation have demonstrated that intra-articular loose bodies can represent a substantial factor for poor outcomes after closed treatment (Hawkins et al. 1986; Nikku et al. 2005). It is important to recognize, and potentially address, the underlying factors predisposing to patellar dislocations (e.g. patella alta, trochlear dysplasia, increased Q-angle), especially in the event of a redislocation (Arendt et al. 2002; Colvin and West 2008).

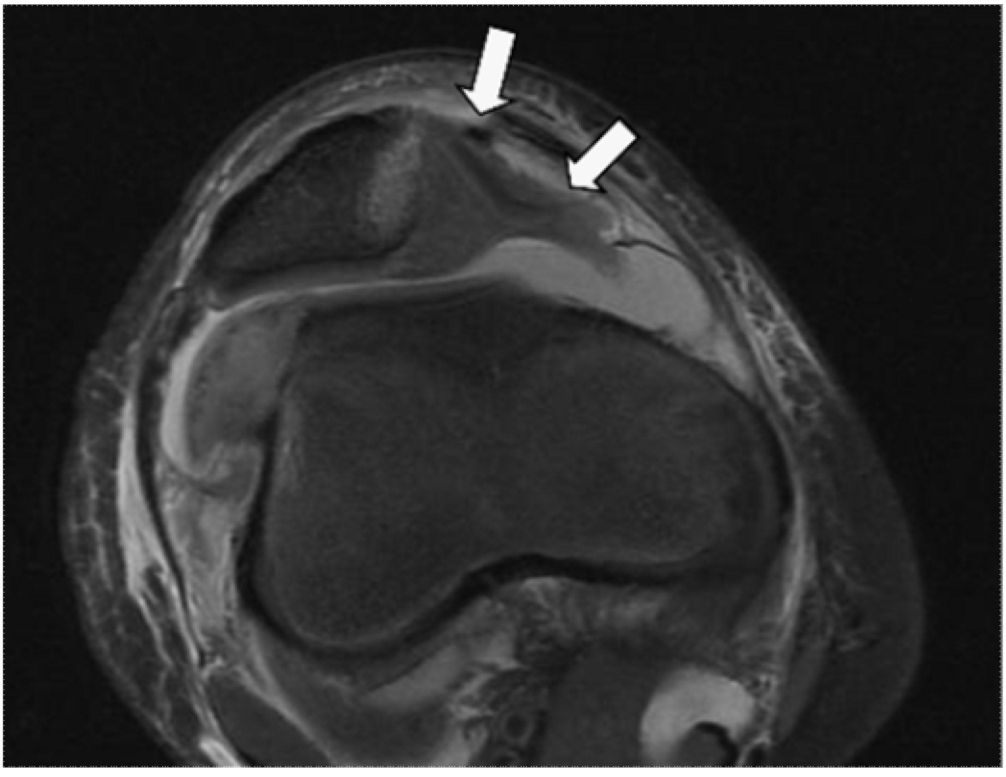
5.3.3 Traumatic patellar dislocation and osteochondral fractures

Osteochondral fractures (Figure 3) and PF cartilage lesions have been commonly associated with primary patellar dislocation (Stanitski 1995; Stanitski and Paletta 1998; Stefancin and Parker 2007). According to a review by Stefancin and Parker, the relative occurrence of osteochondral fractures in primary patellar dislocation was 24.3% among 1765 primary dislocations (Stefancin and Parker 2007). It is obvious that initial cartilage lesions predispose to subsequent problems such as PF pain and PF OA. Mäenpää and Lehto (Mäenpää and Lehto 1997) reported a mean 13-year follow-up of 85 patients with primary patellar dislocation. The long-term occurrence of PF OA visible on plain radiographs ranged from 12% to 35%, but it must be noticed that mild or moderate PF cartilage loss is not visible on plain radiographs. Osteochondral fractures are usually seen in Laurin (Laurin et al. 1979) or Merchant (Merchant et al. 1974) view on plain radiographs or detected by MRI. A secondary patellar dislocation does not necessarily involve any substantial damage to the articular cartilage surface, and osteochondral fractures are quite rarely seen, because no significant pressure load is likely to be produced to cartilage tissue if medial patellar restraints are loose.

The incidence of articular cartilage injuries in primary traumatic dislocations has been reported to be up to 71-95% (Virolainen et al. 1993; Stanitski and Paletta 1998; Elias et al. 2002; Nomura et al. 2003; Stefancin and Parker 2007), based on arthroscopy, open surgery or MRI studies. Over the long term, these articular cartilage lesions can result in symptomatic patellofemoral OA and a decreased level of sporting activity (Hawkins et al. 1986; Harilainen and Sandelin 1993; Mäenpää and Lehto 1997; Atkin et al. 2000; Arendt et al. 2002; Visuri and Mäenpää 2002; Hinton and Sharma 2003; Fithian et al. 2004; Nikku et al. 2005; Nomura et al. 2007; Stefancin and Parker 2007). There are no studies published regarding the management of osteochondral fractures related to primary traumatic patellar dislocation. However, a reasonably strong clinical consensus exists that large (10-20 mm or larger) fractures involving the articular surface of the patella require initial fixation to avoid subsequent problems (Stefancin and Parker 2007; Colvin and West 2008). Smaller fragments may act as loose bodies and should probably be removed (Colvin and West 2008). Biomechanically, a patellar attachment of the MPFL involves osteochondral avulsion fractures of the medial patellar margo, which is uncommonly described in the literature, but sometimes seen in primary traumatic patellar dislocations (Vainionpää et al. 1990).

Figure 3. Medial osteochondral fracture (at patellar insertion of the MPFL). Plain axial radiograph and axial MR image of the same patient.





5.3.4 Treatment of primary traumatic patellar dislocation

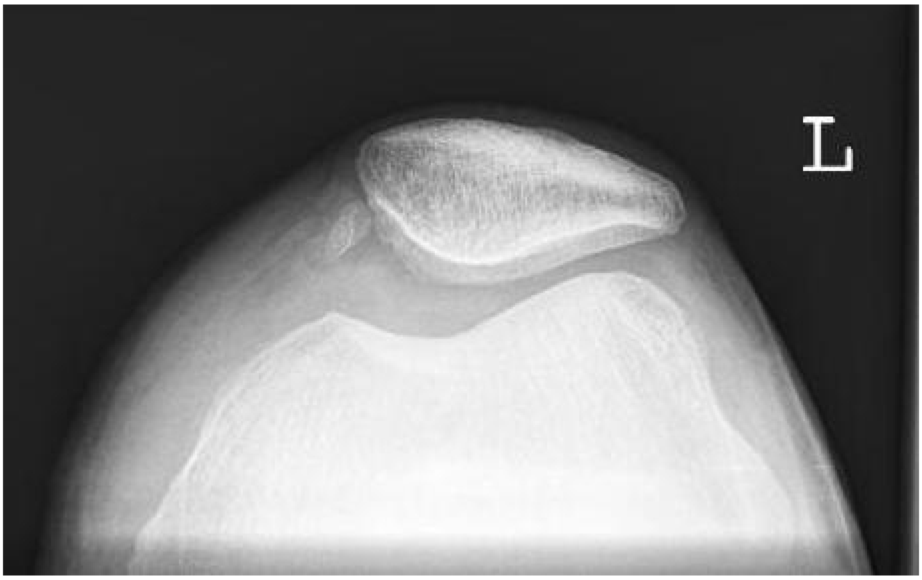
Previous studies have shown a preference for initial nonoperative management of primary patellar dislocations (Arendt et al. 2002; Buchner et al. 2005; Nikku et al. 2005; Christiansen et al. 2008), whereas patients with recurrent dislocations and patellofemoral instability seem to benefit from reconstructive surgery (Koskinen et al. 1998; Fithian et al. 2004; Colvin and West 2008). It is noteworthy, however, that only two studies are prospective and randomized (Nikku et al. 2005; Christiansen et al. 2008). Stefancin and Parker recommended initial nonoperative treatment for a first-time traumatic patellar dislocation in their systematic review of 70 articles, except in some specific circumstances such as presence of an osteochondral fracture, substantial disruption on the medial patellar stabilizers, or a laterally subluxated patella with normal alignment of the contralateral knee (Stefancin and Parker 2007). To a sports medicine clinician or an orthopedic surgeon, it is very important to recognize whether the injury is primary or secondary. Since there are some implications in favour of initial operative management (Stefancin and Parker 2007), careful radiographic and clinical assessment of the primary dislocation cannot be over-emphasized. A patient experiencing a recurrent dislocation will usually benefit from a short immobilization period and proper aftercare instructions, and operative management might be considered at a later date (Mehta et al. 2007).

5.4 Nontraumatic and secondary patellar dislocations

Nontraumatic patellar dislocation is associated with dysplastic features of the PF joint (Mulford et al. 2007; Colvin and West 2008). Several factors predisposing to patellar dislocations have been reported, including the most frequently described:

patella alta, trochlear dysplasia, increased Q-angle with lateralized TT, and poor performance of the vastus medialis obliquus (VMO) (Larsen and Lauridsen 1982; Dejour et al. 1994; Mäenpää and Lehto 1996; Sallay et al. 1996; Atkin et al. 2000; Arendt et al. 2002; Buchner et al. 2005; Nikku et al. 2005; Andrikoula et al. 2006; Stefancin and Parker 2007). A patient who has some of these dysplastic features resulting in patellar malalignment usually sustains a primary dislocation or experiences sensations of instability at a very young age. A subluxated patella with trochlear hypoplasia is shown in Figure 4.

Figure 4. Axial view of the patella with lateral subluxation and trochlear dysplasia (shallow trochlear groove).



Since most primary traumatic patellar dislocations have been usually treated nonoperatively except for those with associated, displaced osteochondral fractures of the patella (Figure 3) or the lateral femoral condyle, the subsequent instability may produce nontraumatic secondary dislocations, even in a PF joint that may not have any dysplastic features. Fithian et al. reported that if the patient has a secondary dislocation after the primary incident, there is a 49% chance of recurrent instability complaints (Fithian et al. 2004). Recurrence rates after initial nonoperative management have been described ranging from 15% to 44% (Cofield and Bryan 1977; Hawkins et al. 1986; Arnbjornsson et al. 1992; Mäenpää et al. 1997; Nikku et al. 2005).

The risk factors for secondary dislocations have been evaluated in the doctoral thesis of Heikki Mäenpää, “The Dislocating Patella,” which summarizes five articles describing acute patellar dislocations (Mäenpää 1997). The author reported three prognostic factors for redislocation after closed treatment of primary patellar dislocation; radiographically confirmed unstable patellar type (Wiberg II/III-Jägerhut) (Wiberg 1941), spontaneous reduction of the primary acute patellar dislocation, and a mild hemarthrosis (Mäenpää and Lehto 1997; Mäenpää 1998). If surgical stabilization is considered due to recurrent instability, it is very important to assess whether the primary dislocation was a traumatic knee injury resulting in ligamentous laxity of the medial restraints of the patella or a nontraumatic injury with some underlying dysplastic characteristic of the PF joint (Mulford et al. 2007; Colvin and West 2008). Understanding of these features is required for succesful management of chronic patellar instability.

5.5 Radiology of the traumatic patellar dislocation

Standard radiographs and MRI are important for assessment of osseus abnormalities such as patella alta, excessive TT-TG distance, and trochlear dysplasia, or soft-tissue injuries, such as MPFL disruptions (Elias et al. 2002). This section reviews the radiology of the PF joint related to primary traumatic patellar dislocation.

5.5.1 Radiographs of the patellofemoral joint

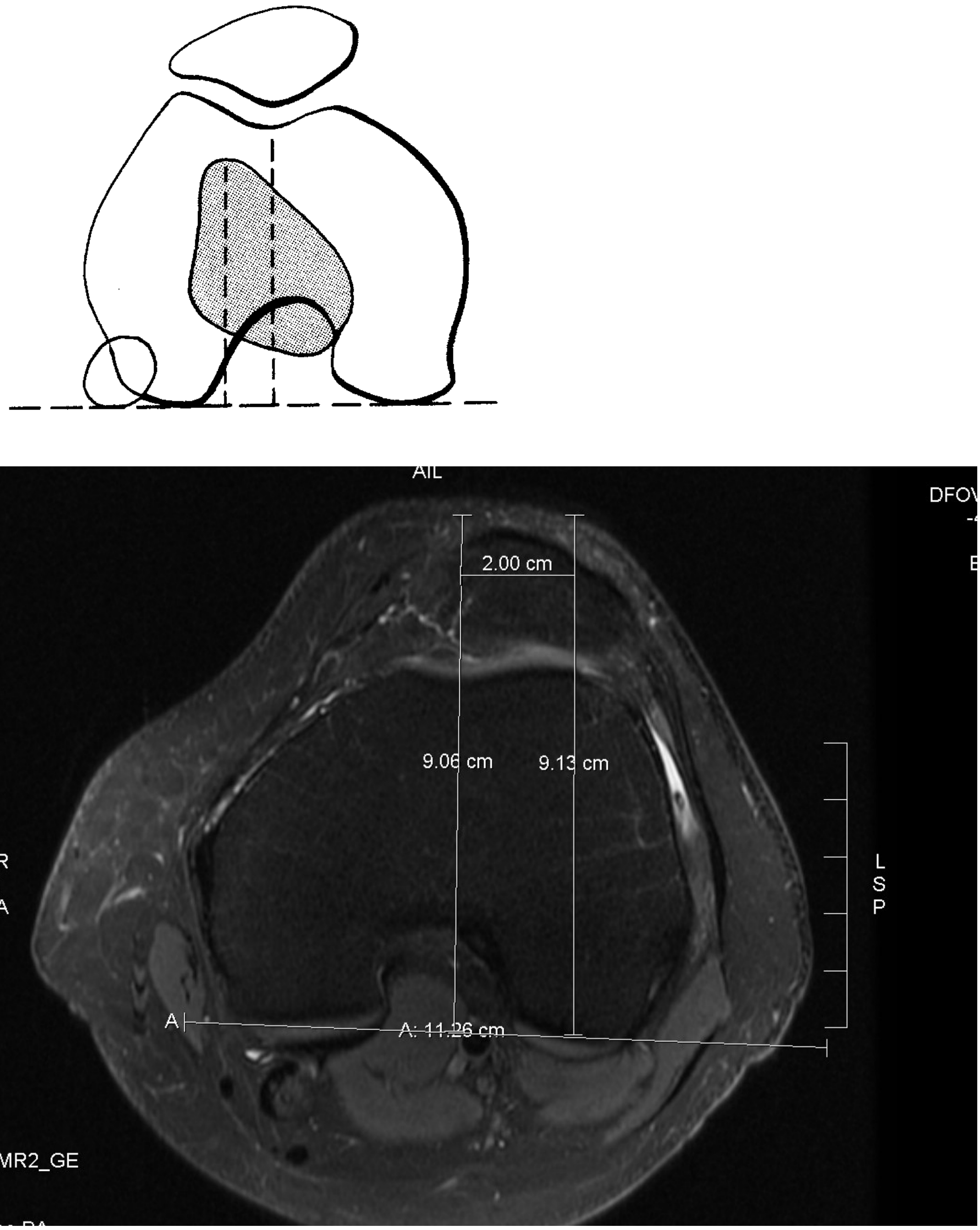
Radiographic assessment of the PF joint should include an anteroposterior knee weight-bearing view, a Merchant (Merchant et al. 1974) or Laurin (Laurin et al. 1979) axial view (Figure 2) with comparison of the contralateral side in the same image (Nayak and Bickerstaff 1995), and a 30° flexion lateral view. An axial view of a primary traumatic patellar dislocation is important for detecting an osteochondral fracture of the articular surfaces of the patella (Stefancin and Parker 2007; Colvin and West 2008). Axial radiographs are important since visualizing the PF joint in the greatest possible degree of extension helps to diagnose trochlear dysplasia and plan surgical procedures. Laurin (Laurin et al. 1979) axial view of the PF joint, which is obtained with the knee in 30° flexion, is probably the most used followed by Merchant (Merchant et al. 1974) axial view. Merchant axial view is obtained with the knee in 45° flexion and the x-ray beam angled at 30° from the horizontal position and directed towards the feet (Merchant et al. 1974). The upper part of the TG is probably best explored using a Merchant view (Tecklenburg et al. 2006). To determine trochlear dysplasia, the sulcus angle is measured, which describes the shallowness of the groove (Figure 4). Troclear dysplasia can be visualized in Merchant or Laurin views as a shallow TG with over 146-150° sulcus angle considered as abnormal, depending on the study (Brattström 1964; Dejour et al. 1994).

Patella alta can be measured from a lateral view of the knee joint by using the Blackburne-Peel (Blackburne and Peel 1977), Insall-Salvati (Insall and Salvati 1971) or Caton-Dechamps (Caton et al. 1982) ratios. Insall-Salvati ratio, assessed by comparing the length of the patellar tendon (LT) with the length of the patella (LP), has gained wide success. A patella alta is diagnosed if the ratio of LT/LP exceeds 1.2, according to Schlenzka and Schwesinger (Schlenzka and Schwesinger 1990). A disadvantage of the Insall-Salvati ratio is that the LP measure includes abnormal patellar shapes in which the distal part is elongated. The Blackburne-Peel index takes into account only the articular surface of the patella, and might be considered a more reliable method for assessing patella alta (Blackburne and Peel 1977). A Blackburne-Peel index over 1.06 is considered abnormal (Blackburne and Peel 1977). The Blackburne-Peel index is used in the studies of this thesis.

There are some indications for a computed tomography (CT) scan, but if MRI is performed, CT does not significantly improve the decision-making about treatment. CT can be used to evaluate the PF alignment, as described by Dejour et al. (Dejour et al. 1994). They have created a method in which the relationship of the TT with the TG is determined by obtaining a superimposed CT scan at the section which best represents the trochlea and the section which passes through the TT (Figure 5) (Dejour et al. 1994). Two lines, one beginning at the bottom of the TG and another at the centre of the TT, are then subtended perpendicular to the posterior femoral condylar line. The TT-TG translation can be measured in millimetres, taking into account the radiographic magnification factor. TT-TG can also be defined as the lateral offset of the TT (Arendt et al. 2002). The threshold for an abnormal value of the TT-TG distance is 20 mm. A median for asymptomatic controls was 13 mm in the study by Dejour et al. (Dejour et al. 1994).

CT might also be helpful in evaluating and determining the rotational relationship between the TT and the femoral sulcus in varying degrees of knee flexion (Hinton and Sharma 2003; Hing et al. 2006; Feller et al. 2007). Of the recent technical developments, the 3-D CT is suitable for this scanning as well. A dynamic MRI study has been described as helping to assess patellar tracking (McNally et al. 2000).

Figure 5. Measurement of the tibial tubercle to trochlear groove distance. MRI scan showing the distance between the lateralized tibial tubercle and the bottom of the trochlear groove.

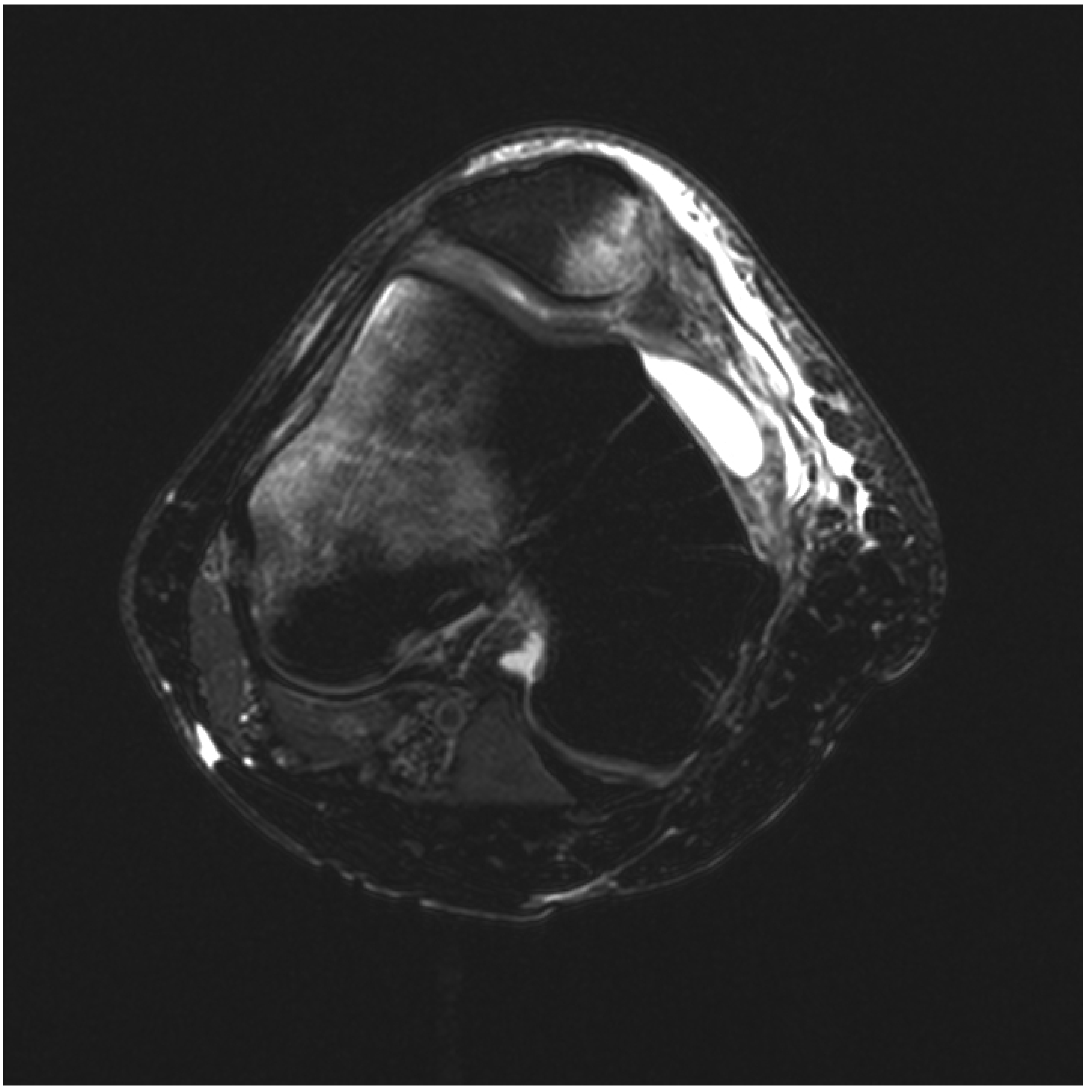


Recently also MRI has been described to be reliable for TT-TG assessment (Figure 5) (Schöttle et al. 2006; Wittstein et al. 2006), even preferable due to the lack of harmful radiation. In contrast to MRI, CT has only a limited use in detection of the location and extent of soft-tissue defects of the medial patellar stabilizers and is rarely needed for evaluating patellar instability (Schöttle et al. 2006).

5.5.2 Magnetic resonance imaging of the patellofemoral joint

With the technical advancements of MR imaging and the information obtainable utilizing newer types of magnetic resonance sequencing, the use of MRI for patellar dislocation is becoming a helpful tool for the surgeon in deciding between nonoperative versus operative management (Sallay et al. 1996; Sanders et al. 2001; Elias et al. 2002; Stefancin and Parker 2007). MRI is increasingly being used and may be helpful in considering operative intervention (Kirsch et al. 1993; Lance et al. 1993; Quinn et al. 1993; Virolainen et al. 1993; Spritzer et al. 1997; Pope 2001; Stefancin and Parker 2007; Colvin and West 2008). A variety of MRI findings have been associated with primary patellar dislocation (Elias et al. 2002; Elias and White 2004; Stefancin and Parker 2007). Hemarthrosis can be diagnosed on MRI (Lundberg et al. 1996). The lateral femoral condylar or medial patellar contusion (bone bruise) may be seen in up to 80% to 100% of patients with patellar dislocation, and is hence probably the most common MRI finding related to patellar dislocation (Figure 6) (Kirsch et al. 1993; Virolainen et al. 1993; Spritzer et al. 1997; Elias et al. 2002).

Figure 6. Axial MRI scan of primary traumatic patellar dislocation with lateral femoral condylar and medial patellar contusions.



Today, MRI is preferred for evaluation of the chondral surfaces of the PF joint and to examine the location and extent of injuries to the medial patellar stabilizers and to diagnose osteochondral fragments (Quinn et al. 1993; Pope 2001; Nomura et al. 2002; Elias and White 2004). Osteochondral fractures have been reported to be overlooked in up to 40% of the initial radiographs based on both surgical and MRI studies (Desio et al. 1998; Stanitski and Paletta 1998). Especially if an axial view of the PF joint is not obtained, an osteochondral fracture might not be found.

Compared with an ACL injury, the femoral bone contusion associated with patellar dislocation is seen more anteriorly, laterally and superiorly (Figure 6).

Patellar subchondral bone contusions have been noted in 61% of patients (Elias et al. 2002). These almost always occur on the medial and inferior aspects of the patella. Because the mechanism by which these contusions are produced is compression during subluxation of the medial aspect of the patella against the lateral femoral condyle, the resulting injuries have been called ‘kissing contusions’ (Pope 2001). Partial MCL injury has been identified in 33% patients with primary traumatic patellar dislocation in a study by Virolainen et al. (Virolainen et al. 1993).

MPFL injuries associated with traumatic patellar dislocation are usually easily visible on MRI, and include attenuation, thickening, irregularity, partial discontinuity, or complete avulsion of the MPFL (Elias et al. 2002). These injuries may occur near the patellar insertion, at the femoral MPFL attachment (Elias et al. 2002), or in the midsubstance of the MPFL (Nomura 1999). In a study in which MRI results were compared with operative findings, the sensitivity of MRI was 85% and accuracy was 70% in detecting disruption of the MPFL (Sanders et al. 2001). Since then, MRI technology has improved and even higher figures may be expected. Elias et al. (Elias et al. 2002) have best described the injury patterns of acute patellar dislocation on MR images. In their study, knee MRIs were obtained within 8 weeks after patellar dislocation and the images were evaluated for medial retinacular and MPFL disruption, VMO edema and/or elevation, and other derangements. A group of 100 patients with no evidence of patellar dislocation served as controls. The authors described very precisely how the MR images should be analyzed to assess an MPFL injury; the medial ligamentous stabilizers are examined on transverse images and divided into three regions: the medial retinaculum at the level of its patellar insertion, the medial retinaculum at its midsubstance, and the MPFL at its femoral origin. However, this division was somewhat different than Nomura (Nomura 1999) had surgically classified, but logical for the purpose of assessing the whole ligament complex. In addition, Elias et al. (Elias et al. 2002) used the term medial retinaculum for the analysis of basically the midsubstance region of the MPFL. They concluded that the MPFL was considered to have been visualized if low-signal-intensity fibres were seen arising between the region of the adductor tubercle and the medial epicondyle of the femur, running just inferior to the inferior border of the VMO and passing forward and inferiorly toward the medial patella. Furthermore, they determined a partial MPFL disruption to have occurred if some MPFL fibres were identified but there was also presence of partial discontinuity, marked irregularity of fibre contour, and/or intra-ligamentous or extensive periligamentous edema. The MPFL fibres had to be completely discontinuous or apparently absent, with extensive surrounding edema, to be determined as complete disruption. Using similar criteria, the authors evaluated the midsubstance and patellar insertion of the MPFL as normal or as partially or completely disrupted. This classification of Elias et al. (Elias et al. 2002) was used in this thesis to determine MPFL injuries.

MRI has been deemed to be a reliable method for determining the TT-TG distance for assessing patellofemoral alignment (Figure 5) (Schöttle et al. 2006; Wittstein et al. 2006). In a comparative study between CT scans and MRI, Schöttle et al. showed that TT-TG can be assessed by MRI (Schöttle et al. 2006). Moreover, further MRI analysis of more proximal cartilage landmarks of TG was possible and superior to CT scan, which is capable of assessing only bony landmarks (Schöttle et al. 2006). Using MRI for determination of TT-TG distance has been reported later also by Wittstein et al. (Wittstein et al. 2006), who used a somewhat lower level of the femoral section than did Schöttle et al. (Schöttle et al. 2006). Schöttle especially focused on the proximal TG, considering it important in determination of the TT-TG distance. MRI may prove to be more accurate than CT when analyzing the cartilaginous proximal TG (Carrillon et al. 2000; Escala et al. 2006; Schöttle et al. 2006).

It may be concluded that MRI is useful in planning the treatment of primary traumatic patellar dislocation and should be performed prior to surgery (Elias and White 2004; Colvin and West 2008). In chronic patellar instability, patellar alignment can also be assessed by MRI prior to surgery (Schöttle et al. 2006). The decision-making on whether operative treatment is chosen over nonoperative treatment should, however, be based on studies in which the MRI findings of primary patellar dislocations are assessed and patients are followed to evaluate whether the medial restraint complex injury patterns have a prognostic value for outcome with similar treatment. Regrettably, the clinical role of using MRI information in treatment of patients with traumatic dislocations has not been studied. The subject of MRI findings related to MPFL injuries and their clinical correlations warrants further research.

5.6 Epidemiology and risk factors

Only two papers concerning the incidence rate of primary patellar dislocation in a population-based setting among adults have been published (Atkin et al. 2000; Fithian et al. 2004). However, both of these publications are from the same group in San Diego, United States. The incidence of primary patellar dislocations in Fithian's study was 5.8/100 000 with a peak incidence among ten to seventeen year-olds being 29/100 000 (Fithian et al. 2004). In their study, approximately one third of the patients had dislocation not related to sports or physical activity and the dislocations had not been proven to be caused by a significant external trauma. An annual incidence rate of 43/100 000 children under 16 years of age for primary patellar dislocations was found in Helsinki region, Finland (Nietosvaara et al. 1994).

5.6.1 The role of predisposing factors in patellar instability

Stability of the PF joint is grounded on the architecture of the joint, including osseus geometry, and the integrity of soft-tissue restraints. Some contributions to greater patellar instability are found due to specific anatomic features of the PF joint (Dejour et al. 1994; Mäenpää 1998). Several conventional predisposing factors have been reported to be associated with patellar dislocation including: patella alta (Figure 7), abnormal patella morphology, lateral patellar displacement, trochlear dysplasia (Figure 4), increased Q-angle (lateralized TT) (Figure 5), limb malalignment (genu valgum), VMO hypoplasia, ligament hyperlaxity, external tibial torsion, subtalar joint pronation and increased femoral anteversion (Larsen and Lauridsen 1982; Harilainen and Sandelin 1993; Mäenpää and Lehto 1996; Sallay et al. 1996; Mäenpää 1998; Atkin et al. 2000; Arendt et al. 2002; Buchner et al. 2005; Nikku et al. 2005).

Of these dysplastic features of the PF joint, three of the most frequent anatomic factors have been identified to increase the risk for recurrent patellar instability: excessive patella height (patella alta), trochlear dysplasia, and increased Q-angle / (TT-TG) distance (Arendt et al. 2002; Colvin and West 2008). A fair suggestion is that these features should always be taken into account when planning surgical treatment for patellar instability (Colvin and West 2008). There are some treatment algorithms published which have been based on expert consensus rather than on published data of the anatomic corrections needed to be performed (Dejour et al. 1994; Mehta et al. 2007).

Patella alta is probably the most frequent (Atkin et al. 2000), and perhaps also the most significant anatomic factor predisposing to patellar instability (Blackburne and Peel 1977; Dejour et al. 1994; Arendt et al. 2002). In a normal knee, the patella usually engages by 60° of flexion, resulting in osseus stability provided by the lateral trochlear wall (Feller et al. 2007). In patella alta, even in a normal TG without hypoplasia, the high-riding patella does not get sufficient support from bony engagement, and soft-tissue restraints are fully responsible for the stability of the patella near extension (Dejour et al. 1994). Especially if the TT-TG exceeds 20 mm, a high-riding patella will likely lateralize (Dejour et al. 1994; Wittstein et al. 2006; Colvin and West 2008). In a knee trauma with valgus stress, patella alta challenges the medial restraints excessively, and a lateral dislocation may occur. Obviously, an excessively high patellar position combined with trochlear dysplasia produces an even higher load to the medial restraints in early flexion.

Figure 7. Patella alta.

The femoral trochlear anatomy has been recognized as being important for patellofemoral stability. Trochlear anatomy includes not only the depth of the TG but also its length (Dejour et al. 1994; Escala et al. 2006; Schöttle et al. 2006). The patella achieves increasing stability in flexion when it engages fully within the trochlear walls (Colvin and West 2008). The depth of the groove thus plays a significant role in patellar stability. Also the shape of the groove and the relationship to patella has a stabilizing effect, or a lack of it, because in early flexion a high-riding patella alta demands a lot more from the soft-tissue medial restraints before a bony support in deeper flexion is guaranteed.

An increased Q-angle is one of the most frequently reported factors predisposing to patellar dislocation (Mäenpää and Lehto 1996; Smith et al. 2008). A malalignment of the extensor mechanism may be produced if the Q-angle exceeds 15-20°, while the normal values are between 8-12° in males and between 10-15° in females (Arendt et al. 2002; Herrington and Nester 2004; Grelsamer et al. 2005; Smith et al. 2008). Because a valid Q-angle measurement needs radiographs of the entire lower limb alignment, it has been infrequently reported in scientific papers. If assessed clinically during a physical examination of the patient, too much uncontrolled bias is evident and the measurement is unreliable (Smith et al. 2008). The TT-TG distance describes limb alignment, and has the same aspect as the Q angle in measuring the angle between the lines of action of the patella and the quadriceps tendon. As the TT-TG distance is measured in millimetres and the Q angle in degrees, the measurements are not directly comparable.

Regarding nonanatomic risk factors for patellar dislocation, the emphasis in primary traumatic dislocations has recently shifted from the traditional dislocators, i.e. inactive females with weak muscle strength, toward athletic populations which also show high occurrence rates (Atkin et al. 2000; Fithian et al. 2004; Stefancin and Parker 2007). Although it has been reported that patellar instability has a young female preponderance (Cash and Hughston 1988; Mäenpää 1997; Buchner et al. 2005; Nikku et al. 2005), no study exists in which the nonanatomic risk factors have been adequately analyzed. Particularly, there seems to be a lack of prospective, population-based studies investigating the demographic features associated with primary patellar dislocation.

5.7 Factors related to patellar stability

The medial soft-tissue stabilizing structures prevent lateral displacement of the patella before it engages in the femoral TG after 30° of flexion. The patella is most likely to dislocate in near knee extension (Feller et al. 2007). If the patella dislocates out of the femoral TG, the medial stabilizers are usually injured (Vainionpää et al. 1990; Avikainen et al. 1993; Sallay et al. 1996; Nomura 1999; Stefancin and Parker 2007). The MPFL is the primary soft-tissue restraint against lateral patellar displacement (Dopirak et al. 2008). This section summarizes the anatomic features of the soft-tissue stabilizers of the patella.

5.7.1 Anatomy of the medial soft-tissue stabilizers of the patella

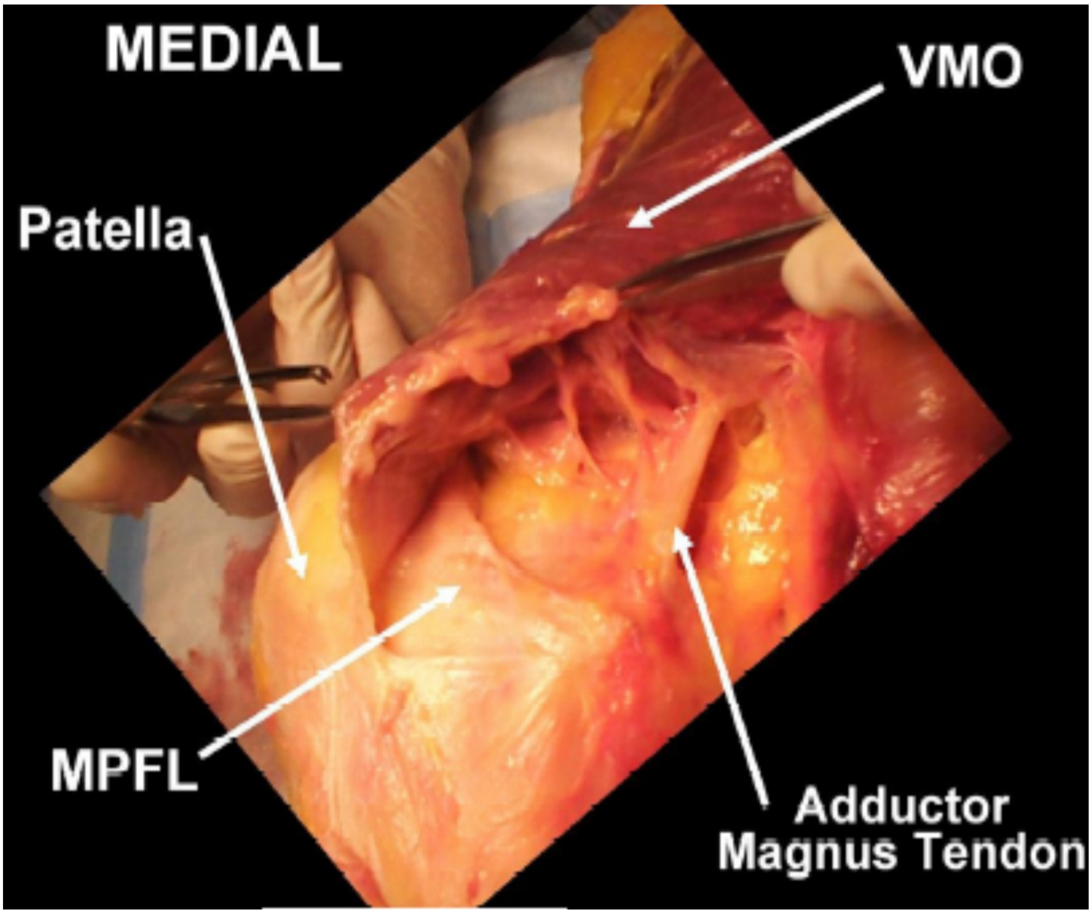
The medial patellar stabilizers are composed of the medial retinaculum, the MPFL, the medial patellotibial ligament (MPTL), the medial patellomeniscal ligament (MPML), and the VMO (Hautamaa et al. 1998; Andrikoula et al. 2006; LaPrade et al. 2007). These are important structures in preventing lateral displacement of the patella and in controlling patellar tracking (Warren and Marshall 1979; Reider et al. 1981; Conlan et al. 1993; Hautamaa et al. 1998; Nomura et al. 2000; Nomura et al. 2005). The ligaments and the retinaculum prevent passively the patella from lateralizing, and the VMO acts as an active restraint as the muscle contracts by pulling the patella in medial, cranial and posterior direction (Andrikoula et al. 2006;

Colvin and West 2008). Thus, the VMO does not act as a restraint when the muscle is relaxed. The ability of the VMO to prevent patellar lateralization is associated with muscle strength, and some studies have concluded that VMO muscle hypoplasia is associated with patellar instability (Nove-Josserand and Dejour 1995; Andrikoula et al. 2006; Colvin and West 2008). The significance of the MPFL as the main soft-tissue stabilizer of the patella has been recognized only quite recently, in the past ten years.

5.7.1.1 Medial patellar stabilizers and the medial ligament complex of the knee

The medial patellar stabilizers are closely related to other medial structures of the knee. The whole medial ligament complex of the knee includes the large MCL and a series of capsular thickenings and tendinous attachments (LaPrade et al. 2007). There are some aspects in the medial ligament complex and the tendinous attachments of the knee that should be acknowledged when discussing medial patellar stabilizers (Figure 8). In addition to the MPFL, the other tendinous medial patellar restraints include the medial retinaculum, the MPTL and the MPML, but these play only a minor role in stabilizing the patella (Hautamaa et al. 1998). A cadaveric study (Hautamaa et al. 1998) showed that in a patellar dislocation with torn medial stabilizers of the patella, and with a repaired MPFL, the repair of other medial stabilizers did not produce any significant further stabilizing effect.

Figure 8. The medial patellofemoral ligament and the adductor magnus tendon are shown. (Permission to reprint was granted by Professor E. Arendt, MI, USA.)



While a better understanding of the functional anatomy, biomechanics, and healing of the medial patellar stabilizers has been obtained over the past ten years, some anatomic details of the primary soft-tissue stabilizer, the MPFL, have only recently been described qualitatively, and there has been controversy about some aspects of its anatomic descriptions as being contradictory or incomplete (Desio et al. 1998; Ahmad et al. 2000; Elias et al. 2002; Buchner et al. 2005).

5.7.1.2 Injury to the soft-tissue stabilizers in primary traumatic patellar dislocation

Rupture of the medial retinaculum has been frequently discovered in connection with a primary patellar dislocation (Nomura 1999; Elias et al. 2002; Stefancin and Parker 2007). Until the importance of the MPFL as the main medial patellar stabilizer was understood, the operative management of patellar dislocation was mainly targeted to the repair of the medial retinaculum. The medial retinaculum is an extracapsular layer, which is located deep in the subcutaneous tissue, under the VMO of its proximal part and outside the medial joint capsule (LaPrade et al. 2007). The medial retinaculum is strongly associated with the MPFL, within the medial fascial layer II (Nomura et al. 2005; LaPrade et al. 2007). This three-layered structure pattern of the medial side of the knee was introduced by Warren and Marshall (Warren and Marshall 1979) who described the fibres of the MPFL existing within the layer II. According to their study, the medial retinaculum was located in layer II and the MPFL was a thickening of the medial retinaculum. The surgical implications related to the medial retinaculum are described in Section 5.9.3.1 of this thesis.

The MPTL and MPML have been described to be injured in primary patellar dislocation (Palmu et al. 2008). These structures do not have a significant restraint function to prevent lateral displacement of the patella (Hautamaa et al. 1998). There exists only one study in which the repair of some of these ligaments was addressed (Palmu et al. 2008). Cadaveric studies have shown that these ligaments are part of the medial complex of the knee (Andrikoula et al. 2006; LaPrade et al. 2007), but as their stabilizing functions are found to be ineffective in preventing lateral displacement of the patella, no further clinical studies have been published to date.

5.7.2 Osseus landmarks of the medial knee

Regarding the bony structure of the medial knee, the analyses of the femora from cadaveric specimens have revealed that the medial epicondyle is the most anterior and distal osseous prominence over the medial aspect of the medial femoral condyle (Warren and Marshall 1979; Conlan et al. 1993; Feller et al. 1993; Tuxoe et al. 2002; Smirk and Morris 2003; Steensen et al. 2004; LaPrade et al. 2007). The adductor tubercle is located at the distal edge of a thin ridge of bone, called the medial supracondylar line, along the medial aspect of the distal part of the femur, and slightly proximal and posterior to the medial epicondyle (LaPrade et al. 2007). A third osseous prominence has been identified, the structure of which is slightly distal and posterior to the adductor tubercle and close to a small depression which corresponds to the location of the attachment of the medial gastrocnemius tendon (LaPrade et al. 2007). The femoral attachment of the primary medial patellar stabilizer, the MPFL, is located primarily between the attachments of the adductor magnus tendon and the superficial MCL (Figure 8) (Nomura et al. 2005; LaPrade et al. 2007). The superficial MCL is thus attached at the medial epicondyle of the femur, whereas the MPFL is attached slightly posterior and proximal at the medial epicondyle of the femur, towards the more proximal and posterior adductor tubercle.

5.7.3 The medial patellofemoral ligament

5.7.3.1 The medial patellofemoral ligament is the primary medial stabilizer of the patella

The MPFL (Figure 8) was first described by Kaplan in 1957 as a transverse reinforcement between the base of the patella and the tendon of the medial head of the gastrocnemius (Kaplan 1957). According to the anatomic cadaveric study by Nomura (Nomura et al. 2005), and over the past decades, many authors have used the term MPFL (Ellera Gomes 1992; Avikainen et al. 1993; Conlan et al. 1993; Feller et al. 1993; Burks et al. 1998; Desio et al. 1998; Hautamaa et al. 1998; Ahmad et al. 2000; Arendt et al. 2002; Davis and Fithian 2002; Amis et al. 2003; Nomura et al. 2005). In the recent years, the importance of the MPFL in lateral patellar dislocation has become widely accepted both biomechanically and clinically (Hautamaa et al. 1998; Nomura et al. 2000; Sanders et al. 2001; Tuxoe et al. 2002; Fithian et al. 2004; Nomura et al. 2005; Nomura et al. 2007; Stefancin and Parker 2007).

In the past years, ever since the MPFL was described as a distinct structure and its major stabilizing effect was recognized, its location and function have been increasingly studied (Hautamaa et al. 1998; Arendt et al. 2002; Fithian et al. 2004; Feller et al. 2007; Dopirak et al. 2008). A large consensus has been reached with regard to its anatomic structure and variations. It is widely accepted that its attachment is along the superomedial border of the patella (Steensen et al. 2004; Nomura et al. 2005; LaPrade et al. 2007), from which it then courses just distal-anterior to the adductor tubercle to its femoral attachment (Warren and Marshall 1979; Reider et al. 1981; Avikainen et al. 1993; Conlan et al. 1993; Feller et al. 1993; Hautamaa et al. 1998; Tuxoe et al. 2002; Nomura et al. 2005; LaPrade et al.

2007). However, the exact femoral attachment site has been controversial in the past (Warren and Marshall 1979; Reider et al. 1981; Avikainen et al. 1993; Conlan et al. 1993; Feller et al. 1993; Hautamaa et al. 1998; Tuxoe et al. 2002; Amis et al. 2003; Nomura et al. 2005). The proposed locations have included those at either the medial epicondyle (Feller et al. 1993; Steensen et al. 2004), at the anterior aspect of the medial epicondyle (Tuxoe et al. 2002), or just distal to the adductor tubercle (Tuxoe et al. 2002; LaPrade et al. 2007). The most recent cadaveric studies suggest that its femoral attachment is located closer to the adductor tubercle than to the medial epicondyle (Tuxoe et al. 2002; LaPrade et al. 2007) and consensus seems to have been reached in favour of this location.

According to studies with cadaveric specimens, the MPFL is a distinct extra-articular structure and located anterior to the medial joint capsule (LaPrade et al. 2007). The distal border of the VMO attaches along the majority of the proximal edge of the MPFL (Figure 8). Distally, the MPFL can be distinguished as a distinct thickening within the fascial layer, which courses between the proximal-medial edge of the patella and its femoral attachment (LaPrade et al. 2007). The MPFL has a broad attachment to the superomedial aspect of the medial border of the patella. The MPFL courses medially toward the femoral attachments of the adductor magnus tendon and the superficial MCL and attaches between these two structures. In a recent cadaveric study (LaPrade et al. 2007), the MPFL attachment on the femur was an average of 10.6 mm (range, 8.0 to 13.4 mm) proximal and 8.8 mm (range, 6.7 to 10.3 mm) posterior to the medial epicondyle and 1.9 mm (range, 1.3 to 3.2 mm) anterior and 3.8 mm (range, 2.1 to 6.3 mm) distal to the adductor tubercle. The average length of the MPFL was 65 mm (range, 56.8 to 77.8 mm) between its patellar and femoral attachment sites. In another recent study (Nomura et al. 2005), the total length of the MPFL was 58.8 ± 4.7 mm (range, 48 to 64 mm). The width and thickness of the MPFL was 12.0 ± 3.1 mm and 0.44 ± 0.19 mm at the middle point. According to Nomura et al. (Nomura et al. 2005), the attachment length of the MPFL to VMO was 20.3 ± 6.1 mm (range, 10 to 32 mm) and 35 ± 10% (range, 19 to 50%) of the total length of the MPFL. Andrikoula et al. reported that MPFL was approximately 54.2 mm long (SD 6.08 mm) (Andrikoula et al. 2006).

It has been reported that the MPFL has both superficial and deep fibres (Nomura et al. 2005; Dopirak et al. 2008). The superficial fibres of the MPFL extend further into the posteromedial capsule. The undersurface or the deep fibres of the MPFL are anchored to the bone just distal to the adductor tubercle (Nomura et al. 2005). In their study, when only the deep fibres of the femoral attachment were sectioned, it was found that the MPFL was continuous to the posteromedial capsule although the lateral restraining function of the patella by the MPFL was decreased (Nomura et al. 2005). In 50% of the knees of the 20 patients in Nomura's study, some of the superficial fibres of the MPFL extended to the oblique fibres or parallel fibres of the superficial MCL (Nomura et al. 2005).

In conclusion, when the patella is in near-extension, proximal to the deepening TG, the major restraints to patellar displacement are produced by soft tissues, especially the MPFL (Conlan et al. 1993; Desio et al. 1998; Hautamaa et al. 1998). As the knee flexion progresses, the major restraints to patellar displacement are produced by femoral trochlear geometry and in particular by the lateral wall of the trochlea (Dejour et al. 1994; Farahmand et al. 1998; Arendt et al. 2002; Feller et al. 2007).

5.7.3.2 Functional anatomy of the medial patellofemoral ligament

The MPFL is the primary soft-tissue restraint against lateral patellar displacement (Conlan et al. 1993; Desio et al. 1998; Hautamaa et al. 1998); however it is only significant during early flexion, between 0 to 30° (Feller et al. 2007; Parker et al.

2008). By 60°, the patella is contained within the TG in a normal PF joint (Feller et al. 2007). In trochlear dysplasia, the TG is often not only flattened but also shortened (Schöttle et al. 2006). The shortened groove combined with a high-riding patella (patella alta) will create a larger arc of motion before the patella is protected by the confines of the lateral trochlear wall (Feller et al. 2007). In near-extension, when the patella is proximal to the deepening TG, the major restraints against patellar displacement are produced by the soft tissues, especially the MPFL (Conlan et al. 1993; Desio et al. 1998; Hautamaa et al. 1998). The patella is least stable in the first 30° of knee flexion (Feller et al. 2007).

Nomura et al. studied the functional anatomy of the MPFL (Nomura et al. 2005). From their evaluation of the changes in the tension of the MPFL in six fresh-frozen cadaver knees with a 1-kg force applied to the quadriceps tendon, the MPFL was found very taut at 0° of knee flexion, slightly relaxed within the range of 15°–30° of knee flexion, and relatively taut in 45°–150° of knee flexion. If the 1-kg force was not applied to the quadriceps tendon, the lateral mobility of the patella increased slightly at 0° of knee flexion, because the patella moved distally and the MPFL became slightly relaxed.

The MPFL probably does not function isometrically (Feller et al. 2007; Parker et al. 2008). The MPFL is longest in full extension with the quadriceps muscle tensed (Arendt et al. 2002; Nomura et al. 2005; Parker et al. 2008). However, with the muscle relaxed, the greatest length of the MPFL throughout the range of motion (ROM) is debated (Feller et al. 2007; Parker et al. 2008).

5.7.3.3 Clinical aspects of the medial patellofemoral ligament

It has been experimentally shown that repair or reconstruction of the MPFL restores the normal patellar tracking (Hautamaa et al. 1998; Nomura et al. 2000; Sandmeier et al. 2000). Moreover, MPFL injury has been found by MRI or surgical exploration to occur at an extremely high rate after primary traumatic patellar dislocation (Avikainen et al. 1993; Sallay et al. 1996; Spritzer et al. 1997; Ahmad et al. 2000; Elias et al. 2002). Therefore, the importance of the MPFL in patellar dislocation has been widely acknowledged (Colvin and West 2008). Although reports on surgical intervention of the MPFL for acute or chronic patellar dislocation are still scarce (Arendt et al. 2002; Davis and Fithian 2002; Amis et al. 2003; Stefancin and Parker 2007; Dopirak et al. 2008), an increasing trend is that knee surgeons focus on the restoration of the MPFL to stabilize the medial patellar restraints (Arendt et al. 2002; Davis and Fithian 2002; Amis et al. 2003), especially if there are no existing abnormalities such as excessive TT-TG distance, an increased Q-angle, or a shallow TG (Colvin and West 2008).

The increasing interest in MPFL repair or reconstruction began in the late 1990s, when the significance of the MPFL in lateral translation of the patella was found (Stefancin and Parker 2007; Dopirak et al. 2008). It has been reported that the MPFL is identifiable in all or nearly all knees (Feller et al. 1993; Tuxoe et al. 2002; Smirk and Morris 2003). In most knees, the MPFL can be easily observed under the medial retinaculum when the distal part of the VMO is reflected anteriorly (Figure 8). In knees with previous medial restraint injuries, exposing the MPFL might be difficult on account of the scar tissue found in the soft tissues and in the vicinity of the MPFL. The fibres of the MPFL near the patella usually blend with those of the medial retinaculum (Nomura et al. 2005).

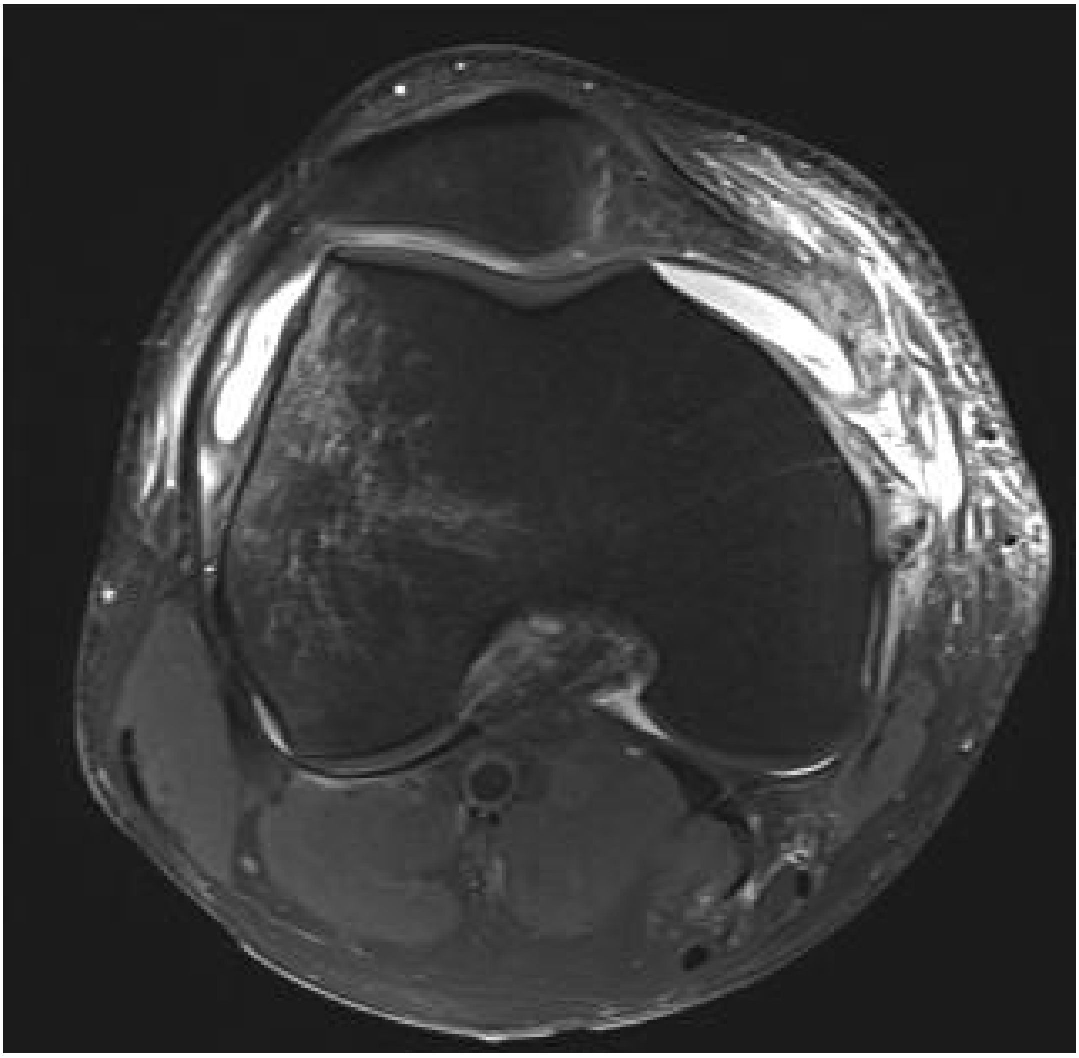
In a cadaveric study, Warren and Marshall (Warren and Marshall 1979) described that the fibres of the MPFL existing within the layer II were wispy in some specimens while being quite heavy and well-developed in others. Many recent studies have observed presence of an MPFL in all the dissected knees (Feller et al. 1993; Tuxoe et al. 2002; LaPrade et al. 2007) or in more than 90% of knees (Conlan et al. 1993). The thickness of the MPFL has been reported to be less than 1 mm on the average, which is a very thin ligament structure compared with the other knee ligaments. However, Amis et al. (Amis et al. 2003) reported that with a mean tensile strength of 208 N the MPFL is surprisingly strong for such a thin appearance. They also pointed out that the experimental knees were from cadavers with a mean age of approximately 70 years. Arendt et al. reported a lower mean tensile strength of 140 N (Arendt 2007; Feller et al. 2007). Burks et al. noted a peak of 209 N at 25 mm of displacement for failure of the MPFL during lateral patellar dislocation (Burks et al. 1998). Amis et al. described a mean 26 mm elongation of the MPFL before failure (Amis et al. 2003). The elongation of the native MPFL before failure is significantly higher than that of the native ACL (Arendt 2007). The semitendinosus and gracilis tendons that have been used for MPFL reconstruction graft materials are very strong and only mildly elongated (Noyes et al. 1984) if compared to native MPFL.

5.7.3.4 Injury to the medial patellofemoral ligament

After the importance of the MPFL as the main medial patellar stabilizer was understood, the MRI for patellar dislocation has been increasingly targeted to evaluate MPFL injuries. Both Tuxoe et al. (Tuxoe et al. 2002) and Nomura et al. (Nomura et al. 2005) demonstrated that the deep fibres of the MPFL attached to the femur just distal to the adductor tubercle. The superficial fibres of the MPFL extend to the posteromedial capsule (Nomura et al. 2005). These anatomic features explain the MPFL injury types as presented by the MRI or dissection studies (Nomura 1999; Elias et al. 2002). Previously, in a primary traumatic patellar dislocation, only the more superficial medial retinaculum disruption has been identified and the MPFL disruption has been overlooked.

In surgical and radiocraphic studies, it has been demonstrated that there are two or three types of MPFL injuries involved in traumatic patellar dislocation (Nomura 1999; Elias et al. 2002). Based on surgical explorations, Nomura et al. described two types of injuries, substantial and avulsion-tear type (Nomura 1999). Additionally, patellar attachment injuries have been described (Elias et al. 2002) as well as MPFL midsubstance injuries (Nomura 1999), although not much is known about their incidence rates or clinical aspects. The femoral attachment of the MPFL has been reported to be injured more frequently (Sallay et al. 1996; Elias et al. 2002). The femoral attachment injury of the MPFL can be seen on MRI as an avulsion of the deep fibres of the MPFL from the bone (Figure 9) (Elias et al. 2002).

Figure 9. The femoral attachment injury of the medial patellofemoral ligament.



According to a cadaveric study (LaPrade et al. 2007), the femoral attachment of the MPFL is superoposterior to the medial femoral epicondyle and just distal to the adductor tubercle. Thus it is important to ensure that the MR images are sectioned at this level for injury evaluation (Elias et al. 2002). MRI data may be useful when initial repair or reconstruction of the MPFL is considered. Correspondingly, MPFL injuries at the patellar attachment or the midsubstance region should be assessed on MR images along the course of the ligament. Some pitfalls that are poorly described in the literature should also be recognized; MPFL avulsion injury from its patellar attachment may be combined with an avulsed osteochondral fragment within the ligamentous insertion. Such fragment should be regarded as an MPFL injury as well. Until the MPFL structure was properly understood, a medial retinacular tear was widely described, and if reefed or duplicated with the aim to stabilize the patella, the underlying location of additional MPFL injury was not addressed.

5.7.3.5 Clinical significance of medial patellofemoral ligament injury

Although the MPFL and its significance for patellar stability have been acknowledged, no studies regarding the prognosis and clinical importance of a specific MPFL injury have been published. Furthermore, it is unknown whether MPFL injuries, if treated by identical nonoperative methods, will heal and restore the stabilizing function. In addition, no researchers have investigated how a knee with an MPFL injury should be immobilized to prevent loosening of the injured ligament. One study advocated MPFL reconstruction as an anatomic surgical stabilizing procedure, with an outcome resulting in potentially less OA than expected in a long-term follow-up. In their study, however, no controls were used

(Nomura et al. 2007). Appropriate timing of the reconstruction or repair has not yet been determined.

5.8 Nonoperative management of primary traumatic patellar dislocation

5.8.1 Initial nonoperative management of primary traumatic patellar dislocation

The initial evaluation of a primary traumatic patellar dislocation should include an appropriate physical examination, patient history-taking, family history of patellar dislocations, assessment of predisposing anatomic features, and diagnostic studies (Colvin and West 2008). The aspects of clinical assessment of primary traumatic patellar dislocation are reviewed in Section 5.3.2.

The proposed nonoperative treatment regimens for primary patellar dislocation range from immediate mobilization to cast or splint immobilization in extension for six weeks (Mäenpää and Lehto 1997; Hinton and Sharma 2003; Mehta et al. 2007). In a consensus opinion, orthopedic experts have suggested that the initial nonoperative management of a primary patellar dislocation should include an initial immobilization period of 4-6 weeks followed by functional rehabilitation (Mehta et al. 2007). They also suggested strengthening the entire quadriceps muscle group, with quadriceps activity incorporated into functional patterns early in the rehabilitation process, even though they had no research evidence to support their views. On the other hand, early mobilization is generally considered beneficial to help maintain articular cartilage health (Hinton and Sharma 2003).

The method of immobilization has been studied by Mäenpää and Lehto, who compared treatments using a posterior splint, cylinder cast or patellar bandage/brace (Mäenpää and Lehto 1997). The cast and splint were worn for six weeks. The posterior splint group had the lowest proportion of knee joint restriction, lowest redislocation frequency per follow-up year, and fewest subjective complaints at final follow-up. No studies have described the efficacy of physical therapy in the treatment of patellar instability. However, the aim of improving the VMO performance seems to be important, since weak VMO function has been related to patellar instability (Nove-Josserand and Dejour 1995). Immobilization in extension may help the medial stabilizers to heal, but knee stiffness might be a secondary problem. The length of immobilization time has not been studied.

5.8.2 Results of nonoperative management of primary traumatic patellar dislocation

Prospective randomized studies investigating the initial management of primary patellar dislocations have described similar outcomes for operative and nonoperative management for patellar dislocation (Nikku et al. 2005; Christiansen et al. 2008; Palmu et al. 2008). Therefore, nonoperative management has been favoured, since no clear benefits from initial stabilizing surgery have been reported. However, only three such studies have been published, of which one included only children and adolescents (Palmu et al. 2008), and another included a considerable proportion of skeletally immature patients as well (Nikku et al. 2005). In their study, Nikku et al. did not evaluate MPFL injury (Nikku et al. 2005). Christiansen et al. (Christiansen et al. 2008) conducted a prospective, randomized study in which a delayed MPFL anchoring to the femoral attachment was compared to nonoperative treatment.

Redislocation rates were similar in both groups, but the follow-up time was quite short, only two years.

According to present research evidence, initial nonoperative management should be mostly used for primary patellar dislocations, and a brief immobilization period should be followed by a muscle strengthening programme (Mäenpää and Lehto 1997; Stefancin and Parker 2007; Colvin and West 2008). Some implications toward initial operative management still exist, as in the case of an osteochondral fracture requiring fixation and of substantial instability of the patella caused by torn MPFL (unstable patella not following the TG alignment in the arc of motion of the knee) (Stefancin and Parker 2007). If the nonoperative treatment fails, stabilizing surgery is considered. The demand for patellar stability and preference for surgery varies between patients. Patients with a high demand for patellar stability are usually active young adults and an unstable patella may significantly affect their level of activity or quality of life (Atkin et al. 2000; Stefancin and Parker 2007).

5.9 Surgical treatment of patellar dislocation

More than 100 operative procedures have been described for the treatment of acute or chronic patellar dislocation (Hawkins et al. 1986; Cash and Hughston 1988; Vainionpää et al. 1990; Avikainen et al. 1993; Mäenpää and Lehto 1995; Sallay et al. 1996; Ahmad et al. 2000; Arendt et al. 2002; Hinton and Sharma 2003; Fithian et al. 2004; Buchner et al. 2005; Nikku et al. 2005; Nomura et al. 2005; Nomura et al. 2007; Stefancin and Parker 2007). However, due to poor documentation, the surgical treatment strategy for patellar dislocation has remained controversial and no surgical method has gained preference due to a superior outcome. Moreover, there have been no prospective randomized studies regarding specific techniques of operative management for primary traumatic dislocations (Arendt et al. 2002; Stefancin and Parker 2007).

Stefancin and Parker concluded in their review of traumatic primary patellar dislocation that the relative indications for early surgical treatment included concurrent osteochondral injury, palpable disruption of the MPFL-VMO-adductor mechanism, MRI findings of a large, complete avulsion or midsubstance rupture of the MPFL, patellar subluxation detectable on plain Merchant view (Merchant et al. 1974) as compared to the other knee, and patients who fail to improve after nonoperative management (Stefancin and Parker 2007). However, the shortcomings of their study are that the conclusions are not fully based on long-term studies. Stefancin and Parker further concluded that it is obvious that large defects or avulsions of the MPFL will not heal and that a good functional outcome after closed treatment will not be regained, especially in individuals with high demands for patellar stability and in those with evidence of one or more predisposing factors (Stefancin and Parker 2007).

5.9.1 Initial surgical management of primary traumatic patellar dislocation

According to the existing literature, the initial management of primary patellar dislocation is mainly nonoperative. However, some exceptions should be mentioned. A strong clinical consensus indicates that if patellar dislocation has clinical, radiographic, CT, and/or MRI findings of osteochondral fractures, open repair should be performed if the fragment is amenable to fixation (Mehta et al. 2007; Stefancin and Parker 2007). If concomitant, large medial patellar stabilizer defects and MPFL injury are detected on MRI or diagnosed during a surgical procedure, a repair or reconstruction of the MPFL should be performed, especially in patients with a high demand for patellar stability (Stefancin and Parker 2007). Arthroscopy should be performed if extensive chondral injury or osteochondral fracture is suspected. All patients with traumatic primary patellar dislocation should be suspected of having an osteochondral injury until proven otherwise by plain radiographs or MRI (Stefancin and Parker 2007). Therefore, a careful examination of the PF joint should be performed, for which MRI should be considered.

If we look at the studies investigating acute patellar dislocations, only few have adequately assessed the primary nature of the incident. Correspondingly, the traumatic or nontraumatic etiology has been poorly documented in most of the reports. Eight studies have assessed nonoperative treatment, the majority having retrospective designs and only short-term follow-ups (Cofield and Bryan 1977; Henry and Crosland 1979; Larsen and Lauridsen 1982; Jarvinen 1997; Mäenpää et al. 1997; Mäenpää and Lehto 1997; Mäenpää 1998; Atkin et al. 2000). Five studies have compared nonoperative versus open operative treatment for acute patellar dislocations in adults (Hawkins et al. 1986; Cash and Hughston 1988; Buchner et al. 2005; Nikku et al. 2005; Christiansen et al. 2008). In all of those studies, the authors recommended nonoperative treatment for primary traumatic patellar dislocations except in cases where there was an osteochondral fragment present. Two of the studies were prospective and randomized (Nikku et al. 2005; Christiansen et al. 2008), advocating nonoperative management. In the case of an osteochondral fracture, arthroscopy was recommended for extraction of the fragment or open fixation if the fracture size was amenable to this.

The well-designed, prospective randomized study by Nikku et al. (Nikku et al. 2005) compared operative versus nonoperative treatment in 125 patients with a 7-year follow-up. The results were evaluated subjectively by the patient’s own overall opinion (excellent, good, fair, and poor), the Lysholm score (Lysholm and Gillquist

1982), and the Hughston visual analog scale (Flandry et al. 1991). The authors concluded that operative and nonoperative treatment gave almost identical outcomes after 2 years in terms of subjective score, recurrent instability, and function (Nikku et al. 1997). Their 7-year follow-up, which comprised the same population, had similar clinical outcomes between the nonoperative and operative groups (Nikku et al. 2005). The nonoperative treatment consisted of immobilization and functional rehabilitation and was compared with individually adjusted proximal realignment surgery (extensor mechanism realignment, repair of the MPFL, and/or lateral release). In conclusion, Nikku recommended nonoperative management for first-time patellar dislocations. The episodes of redislocation and recurrent subluxation were grouped together, which was likely to contribute to the high recurrence rate (64 to 70%) in their study. They also included skeletally immature patients and the majority of the patients were female, both being factors which have been reported to be associated with high recurrence rates of instability (Larsen and Lauridsen 1982; Nietosvaara et al. 1994).

Christiansen et al. (Christiansen et al. 2008) authored a prospective, randomized study in which a delayed MPFL anchoring to the femoral attachment was compared to nonoperative treatment. Lower redislocation rates were not achieved by surgery, but specific subjective patella scores improved after surgery. However, in their delayed surgical procedure the primary site of the MPFL injury was not assessed, instead, every patient underwent the same femoral anchoring irrespective of the underlying MPFL injury locations.

With its main focus on chronic patellar instability, the patellar dislocation surgery can be generally divided into five categories: proximal realignment of the extensor mechanism (surgery at the medial parapatellar structures), distal realignment of the extensor mechanism (surgery at the TT), a combined proximal and distal realignment procedure, release of the lateral retinaculum, and trochleaplasty for TG dysplasia (Colvin and West 2008). Arthroscopic evaluation can be performed during all procedures and lateral release, if necessary, can be performed via arthroscopy. Most of the proximal realignment surgeries, including medial restraint repair or reconstruction, are open procedures (Dopirak et al. 2008). Also mini-invasive proximal realignment procedure (Nam and Karzel 2005) and MPFL reconstruction have been recently described (Sillanpää et al. 2009). Distal realignment procedures that involve TT transfer are suitable only after the physis is closed.

To date, no specific method of surgery exists that would ensure universal success in the operative management of patellar instability. The procedure must be tailored to meet individual needs in terms of personal anatomy and demands (Colvin and West 2008). In the past ten years, consensus has been reached stating that proximal realignment should include MPFL reconstruction and that a distal realignment procedure should be performed only when indicated by a pathological Q-angle (Mehta et al. 2007; Stefancin and Parker 2007; Colvin and West 2008). The following section reviews the most important surgical techniques for patellar stabilization.

5.9.2 Traditional patellofemoral surgery

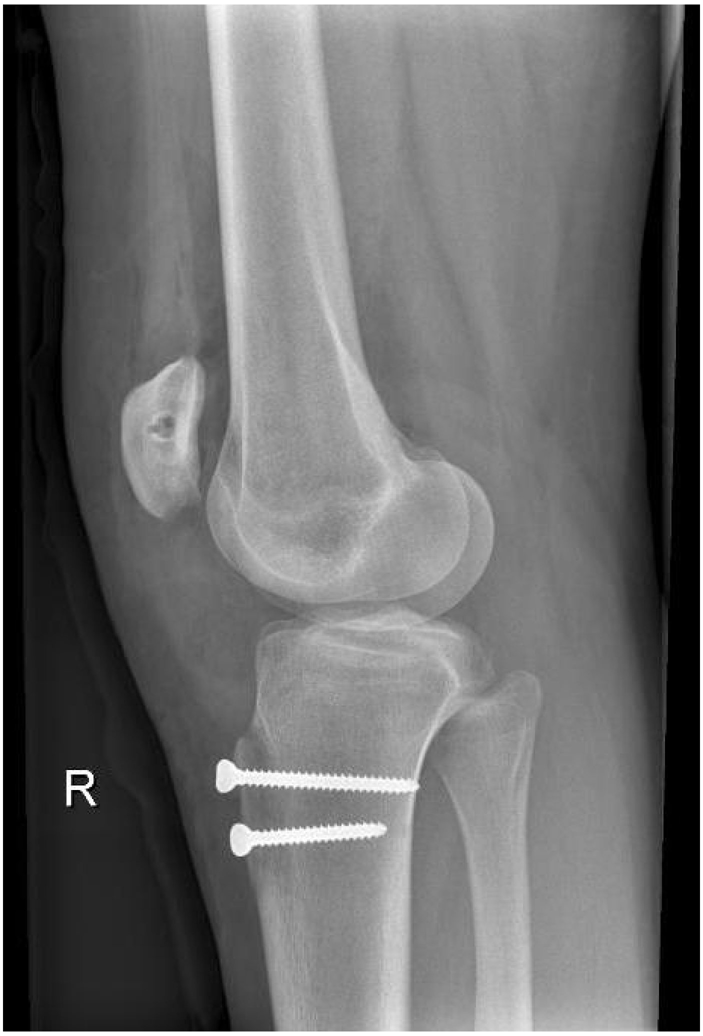
5.9.2.1 The role of tibial tubercle transfer

Several distal realignment procedures have been described for the treatment of patellar instability. TT transfer (Figure 10) has been a frequently used method for correcting patellar malalignment, and several techniques are available (Trillat et al. 1964; Fulkerson et al. 1990; Fulkerson 2002; Palmer et al. 2004). Indications for TT transfer include patellar malalignment with an abnormal Q-angle (over 20°) (Smith et al. 2008) or TT-TG distance of more than 15-20 mm (Schöttle et al. 2005; Colvin and West 2008). The direction of TT transfer is medially to control patellar tracking. Sometimes, medialization is combined with anteriorization, which may be useful for PF OA or PF pain (Fulkerson 2002). TT transfer should not be used in skeletally immature patients; they are best managed with soft-tissue approach with proximal realignment.

Hauser (Hauser 1938) described a transfer in which the tuberosity is osteotomized medially and placed relatively posterior. This resulted in increased pressure to the PF joint, and late OA progression has been described (Crosby and Insall 1976; Juliusson and Markhede 1984). Hauser combined lateral retinacular release (LRR) and medial duplication with TT transfer. Due to the OA risk, the Hauser's procedure is no longer recommended. This method has been modified towards anteriomedialization transfer by several authors (Trillat et al. 1964; Boring and O'Donoghue 1978; Rantanen and Paananen 1996; Fulkerson 2002).

Elmslie-Trillat (Trillat et al. 1964) procedure and its modifications have been widely used with satisfactory results (Fulkerson et al. 1990). Shelbourne, Porter and Rozzi (Shelbourne et al. 1994) modified this technique, in which the TT is medialized 8 to 10 mm through a 6 cm distal anterolateral incision while patellar tracking is monitored via arthroscopy. They started with LRR and performed proximal realignment only if necessary. Fulkerson and Cox reported 66% satisfactory results in a 7-year follow-up after modified Elmslie-Trillat operation with anterior displacement of the TT (Fulkerson et al. 1990). Fulkerson also described an oblique osteotomy of the tuberosity that transfers the tuberosity medially and anteriorly (Fulkerson 2002). Usually a slightly oblique osteotomy is preferred, because anterior displacement has been reported to relieve PF joint pressure (Ferguson et al. 1979) and to possibly improve OA symptoms (Fulkerson 2002).

Figure 10. Postoperative lateral radiograph of a patient requiring tibial tubercle osteotomy and a medial patellofemoral ligament reconstruction.



There are reports suggesting that stress fractures and osteotomy fractures are associated with TT transfers (Colvin and West 2008). An oblique osteotomy technique may have less stress load and hence may protect from fractures (Cosgarea et al. 1999). Due to these risks, however, TT transfer should not be used at all unless there is abnormal TT-TG distances present (Dejour et al. 1994). Dejour et al. measured TT-TG distances in patients with and without patellar instability, and found a median TT-TG of 13 mm in healthy controls and a pathologic threshold of

20 mm (Dejour et al. 1994). Therefore, TT transfer may be considered for correction of patellar instability when the TT-TG distance is more than 15 mm (Schöttle et al. 2005; Schöttle et al. 2006) and preferably in excess of 20 mm (Dejour et al. 1994). Regarding extensor mechanism alignment, patellar instability associated with a high-riding patella may benefit from TT transfer, because in early flexion, before the patella engages into the TG, a minor Q-angle increase may produce maltracking in the beginning of the arc of motion. There is a risk of over-medialization of the TT if patellar tracking is not observed during the procedure. The amount of medialization of the TT should thus be determined intra-operatively, despite an objective pre-operative measurement of the TT-TG distance (Lustig et al. 2006).

The need for TT transfer is based on physical examination and evaluation of patellar maltracking, and should include assessment of the TT-TG distance or Q-angle (Colvin and West 2008). Plain radiographs and CT and/or MR images should be obtained and evaluated for surgical planning. TT transfer is usually needed if medial restraint deficiency is accompanied by an excessive Q-angle or TT-TG distance (Colvin and West 2008). Moreover, TT transfer can be easily combined with proximal realignment procedures (Figure 10). Visual inspection of the knee is unreliable in determining the TT-TG distance or Q-angle (Shakespeare and Fick 2005; Smith et al. 2008).

5.9.2.2 The role of traditional realignment surgery

César Roux was one of the first surgeons to describe a realignment procedure, TT transfer, for the patella in 1888 (Roux 1888; Roux 1979). Years later, Goldthwait described a distal realignment procedure in which the lateral half of the patellar tendon is transferred behind the medial half of the tendon, and the transferred lateral half is attached to the medial tibia to prevent lateral dislocation (Goldthwait 1903). This technique has come to be called the Roux-Goldthwait procedure in the United

States and in the English language literature (Grelsamer 2005). Postoperative treatment includes a cast or a commercial patellar orthosis for an immobilization period. The outcome of the Roux-Goldthwait procedure has been quite well documented, and good patellar stability has been achieved (Jalovaara et al. 1988). Although use of the procedure has lost some of its success, it is still a method of choice in adolescents, because there is contraindication to perform TT transfer due to the open physis. In a study by Jalovaara et al. (Jalovaara et al. 1988), a better outcome was found among patients after the Roux-Goldthwait procedure than after the Krogius procedure (Krogius 1904). Krogius was a Finnish surgeon who described a procedure in which he advanced the VMO and the medial retinaculum together while loosening the lateral structures (Krogius 1904). A strip of the medial retinaculum was elevated and the lateral retinaculum was divided. The elevated strip was then transferred into the opening in the lateral retinaculum and the medial incision was finally closed. This procedure was used in Finland during the past decades, but has since been superseded by other proximal realignment techniques.

Proximal realignment techniques that involve the medial retinaculum and the MPFL are reviewed in Sections 5.9.3 and 5.9.4.

5.9.2.3 The role of lateral retinacular release

Lateral retinacular release (LRR) has been described as an isolated procedure, in which the lateral parapatellar retinaculum is incised. It has been indicated for excessive lateral pressure syndrome, for PF OA, and to be used in combination with a proximal realignment technique if a tight lateral retinaculum prevents medialization of the patella. LRR has been described in connection with all of these indications but the outcomes have not been described separately for each indication. In older series, an overall good or excellent result in 85% of patients was reported

(Merchant and Mercer 1974), and for patellar instability, a success rate of 67-68% has been described (Henry et al. 1986; Arendt et al. 2002; Fithian et al. 2004).

In recent studies, LRR has been shown to be ineffective for the treatment of patellar instability (Fulkerson 2002). On the contrary, it might worsen the symptoms of patellar instability (Christoforakis et al. 2006). Marumoto et al. showed that LRR should include a release of the retinaculum from the distal third of the vastus lateralis muscle down to the TT level to include the lateral patellofemoral and patellotibial ligaments (Marumoto et al. 1995). LRR can be performed as an open procedure or via arthroscope. Nowadays, a majority of the LRR techniques are performed arthroscopically. However, the procedure involves a risk of damage to the superolateral geniculate artery and postoperative hemarthrosis is a common complication.

LRR can be complicated by medial patellar instability. If patellar dislocation has traumatic etiology and proximal realignment is performed, LRR should not be performed unless excessive tightness of the lateral retinaculum is noted. When correcting chronic PF instability, the lateral structures might exhibit excessive tightness and LRR should be considered in combination with proximal and/or distal realignment surgery. LRR alone does not improve stability, but may help in centralizing the patella within the femoral TG.

To date, the role of LRR is somewhat unclear. Desio et al. (Desio et al. 1998) suggested that LRR increases lateral patellar instability. Their biomechanical study found that the lateral retinaculum contributes 10% of the lateral restraining force. It has been hypothesized that LRR may cause additional instability in a hypermobile PF joint. It is unknown whether LRR should be performed if overtightness of the lateral structures is not found, but it seems not to have any stabilizing effect on the patella and should not be performed in primary traumatic patellar dislocation (Lattermann et al. 2007).

5.9.3 Modern approach to patellofemoral surgery

Which procedure should be chosen for traumatic patellar dislocation to achieve maximum benefit for the patient? The morbidity and some poor results associated with the traditional surgical techiques have changed the patellofemoral surgery towards modern techniques, particularly after the significance of the anatomy and function of the medial restraints became understood (Arendt et al. 2002; Stefancin and Parker 2007). Today's preference for initial nonoperative management is grounded on the prospective randomized studies (Nikku et al. 2005; Christiansen et al. 2008) and recommendation against initial medial repair for the treatment of first-time patellar dislocations has been given. However, there is a recurrent instability rate of up to 50-70% reported in some studies with initial nonoperative management (Hawkins et al. 1986; Mäenpää et al. 1997; Fithian et al. 2004; Nikku et al. 2005).

5.9.3.1 Early modifications for medial restraint repair

Traditionally, medial restraint repair has been understood as a medial duplication or medial reefing of the medial patellar retinaculum. Before the MPFL structure and function were understood, the duplication methods ignored the presence of the MPFL in that, for example, the sutures were placed without any respect to the MPFL injury, though usually near the medial border of the patella. The medial retinacular duplication was first introduced by Helfet (Helfet 1963), and duplication has been widely used during the past decades. Reasonably good results have been reported after medial duplication and the complication rates have been relatively low (Vainionpää et al. 1986; Harilainen et al. 1988; Vainionpää et al. 1990). However, deterioriation on outcomes over the long-term have been reported (Harilainen and Sandelin 1993).

Overtightening of the medial retinaculum by medial duplication and LRR may cause medial subluxation of the patella (Hughston and Deese 1988). This undesired outcome is, however, potentially associated with every medial parapatellar repair technique. Nowadays, we can assume that the results of this procedure may depend on the duplication sutures ignoring the MPFL, which have sometimes tightened the MPFL and sometimes perhaps not. This might also be the reason for the overall good results achieved with the Helfet procedure, although some poor results with recurrent instability have been noted. However, introduction of Helfet's procedure marked a significant step towards anatomic reconstruction of the medial patellar stabilizers.

A reasonable success rate of 81% good and excellent results was reported (Baker et al. 1972) for a medial reefing technique in which a strip of the medial retinaculum was dissected while the proximal end was left intact. The strip was then sutured to the medial femoral epicondyle area, near the adductor tubercle, close to the anatomic MPFL attachment.

5.9.3.2 Arthroscopic surgery for patellar dislocation

After the medial restraint repair was developed and due to the evolution of arthroscopy, arthroscopic treatment of patellar dislocation has been a subject of continuing interest. Open procedures, which have been widely described in the literature (Stefancin and Parker 2007), are associated with some formation of scar tissue, nerve morbidity, and artery lesions that might be avoided with arthroscopic techniques. Due to the relatively short history of arthroscopy and patellar dislocation, arthroscopic surgery for acute primary patellar dislocation has been poorly documented. The recently documented surgical techniques for arthroscopic proximal realignment procedures described relatively small case series with no controls and short follow-ups (Small et al. 1993; Henry and Pflum 1995; Ahmad and Lee 2001; Halbrecht 2001; Haspl et al. 2002).

Yamamoto (Yamamoto 1986) was the first to describe an arthroscopically-assisted technique for the treatment of patellar dislocation. Transcutaneous passage of sutures was used to repair medial restraint injury. Small et al. (Small et al. 1993) and Henry and Pflum (Henry and Pflum 1995) modified the technique by passing the sutures through needles after a small medial incision. Halbrecht (Halbrecht 2001) described all-arthroscopic medial reefing by percutaneous passage of the suture through needle combined with knot tying inside the joint. All-arthroscopic knots were also introduced by Ahmad and Lee (Ahmad and Lee 2001), Haspl et al. (Haspl et al. 2002) and Fukushima et al. (Fukushima et al. 2004), who described a method in which anchor sutures are placed near the patella.

Since Yamamoto (Yamamoto 1986) published his article on arthroscopic repair of the medial retinaculum and capsule in acute patellar dislocations, there have been some later arthroscopic case series with good or excellent overall results. Yamamoto noted only one redislocation in 30 operated knees, and Small et al. (Small et al. 1993) reported good or excellent results in 92.5% (27 knees) of the patients. Haspl et al. (Haspl et al. 2002) reported 100% good results and no redislocations in their study of 17 knees with a follow-up of only 13 months. Halbrecht’s 20-month follow-up of an arthroscopic medial plication showed 93% clinical improvement. Henry and Pflum (Henry and Pflum 1995) described arthroscopically assisted techniques of medial reefing, but no follow-up data has been published.

A major concern in arthroscopic techniques is that they always ignore the primary patellar restraint, namely, the MPFL and its repair or reconstruction, because the MPFL is an extracapsular structure in layer II (Warren and Marshall 1979; LaPrade et al. 2007). All arthroscopic techniques are based on medial reefing, which does not restore the normal anatomy or function of the MPFL. However, when performed due to recurrent patellar dislocation, arthroscopic techniques may be suitable producing reasonable stability to medial soft-tissue restraints.

Another step from medial reefing towards more anatomic reconstruction is the mini-open procedure. Nam and Kartzel (Nam and Karzel 2005) described a mini-open medial reefing technique and, in a follow-up of 22 knees for a mean period of 4.4 years, showed an average follow-up Kujala score of 88 points. The procedure was combined with arthroscopic LRR.

5.9.3.3 Trochleaplasty for patellar instability

Recurrent patellar instability with femoral trochlear dysplasia can be treated with trochleaplasty, in which the hypoplastic lateral condyle is elevated by osteotomy line (Utting et al. 2008). Another way to restore the TG is by deepening it by removing bone beneath the cartilage (Dejour et al. 1994). Employing these techniques, a shallow TG can be corrected or deepened. Trochleaplasty aims to correct the osseous lateral wall and restore its ability to prevent lateral displacement of the patella (Shih et al. 2004). The procedure is suitable for dysplastic PF joints, and medial restraint reconstruction is usually necessary in most cases (Utting et al. 2008). However, trochleaplasty has not gained success over soft-tissue corrections and distal TT osteotomies for patellar instability. In preventing subsequent dislocations, the short-term results have been good, but postoperative arthrofibrosis and progression of PF OA are the concerns about trochleaplasty (Verdonk et al. 2005; Donell et al. 2006; von Knoch et al. 2006; Utting et al. 2008).

5.9.4 Medial patellofemoral ligament reconstruction

The MPFL is injured in primary traumatic patellar dislocation (Vainionpää et al. 1990; Avikainen et al. 1993; Sallay et al. 1996). The MPFL is the primary medial restraint of the patella (Conlan et al. 1993; Desio et al. 1998; Hautamaa et al. 1998). Laxity of the MPFL seems to be associated with chronic patellar instability (Stefancin and Parker 2007). Not until the functional anatomy of the MPFL was understood did orthopedic surgeons recognize this ligament. In the following sections, the clinical and surgical aspects of the MPFL are reviewed.

5.9.4.1 Clinical significance of the medial patellofemoral ligament and indications for reconstruction

There is no doubt that MPFL reconstruction is indicated when PF instability produces symptomatic problems after MPFL disruption. Today, it is reasonable to emphasize the importance of MPFL reconstruction over medial reefing or duplication, even though there are no existing publications comparing these techniques (Mulford et al. 2007). The potential advantages of MPFL reconstruction are promising: anatomic correction of the medial structures has been hypothesized to prevent PF OA progression (Nomura et al. 2007). However, no comparative studies are available. It has not been studied whether the type or location of the MPFL injury carries any prognostic value for subsequent instability. MPFL reconstruction is the only surgical procedure that addresses the frequent MPFL injury location in the femoral attachment.

5.9.4.2 Overview of surgical techniques and clinical results

Advancement in understanding the significance of MPFL injury and its frequent occurrence has led to a substantial increase in research regarding specific surgical techniques to reconstruct the MPFL. During the past ten years, several reconstructive techniques have been reported, but comparative studies with traditional realignment techniques are still absent. This section reviews the literature for specific MPFL reconstruction techniques. The clinical results are summarized in Table 1.

Table 1. Results of prior studies using medial patellofemoral ligament reconstructive techniques for patellar dislocations.

Study and year	**Number of cases (age range[*])**	**Controls**	**Follow-up time (years)**	**Result (score)**	**Graft type**	**Osteoarthrosis evaluated at follow-up (result)**
Drez et al., 2001	19 (5-51 years)	none	2.6	88 (Kujala)	Hamstring tendon	not evaluated
Ellera-Gomes et al., 1992	30 (unknown)	none	3.3	(83% improved)	Polyester ligament	not evaluated
Steensen et al., 2005	14 (unknown)	none	3.1	(redislocations: none)	Quadriceps tendon	not evaluated
Nomura et al., 2007[†]	24 (7-24 years)	none	11.9	94 (Kujala)	Polyester tape	1 moderate, 23 none-mild
Avikainen et al., 1993	14 (15-27 years)	none	7	84 (Lysholm)	Adductor magnus tendon	not evaluated
Deie et al., 2005	39 (unknown)	none	5	92 (Kujala)	Semitendinosus tendon	not evaluated
Cossey and Paterson, 2001	19 (unknown)	none	2	95 (Lysholm)	Medial retinaculum	not evaluated
Schottle et al., 2005	15 (unknown)	none	4	87 (Kujala)	Semitendinosus tendon	not evaluated
Steiner et al., 2006	34 (unknown)	none	2-10	90 (Kujala)	Adductor magnus tendon	not evaluated

[*]Age at the time of surgery; [†]the longest follow-up study of Nomura's several studies

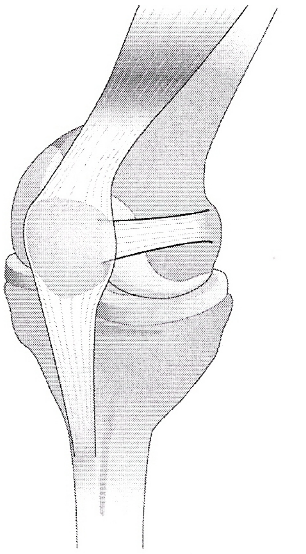
Various soft tissues have been utilized as graft materials, which are inserted by different techniques to prevent dislocation of the patella. Grafts have been made from the adductor magnus tendon (Avikainen et al. 1993; Steiner et al. 2006; Sillanpää et al. 2009), the quadriceps tendon (Steensen et al. 2005), semitendinosus tendon (Drez et al. 2001; Nomura and Inoue 2006), and artificial ligament material (Nomura et al. 2000).

MPFL reconstruction can be combined with TT transfer or LRR, if needed. It is not known if primary repair is preferable to primary reconstruction. In a study of children and adolescents, primary repair did not produce better stability than nonoperative management (Palmu et al. 2008).

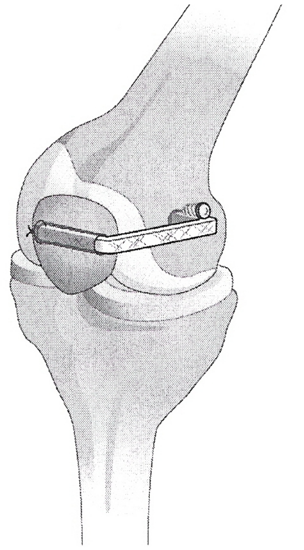
In four studies, primary dislocation was initially treated by direct repair. Sallay et al. used sutures for midsubstance MPFL tears and anchor fixation for femoral avulsion type MPFL tears (Sallay et al. 1996). There were no redislocations in their report of 16 patients. Ahmad et al. reported 8 patients with MPFL tear near the femoral attachment, all of whom underwent primary repair, resulting in patient satisfaction of 97% in a mean follow-up of 3 years and no subsequent redislocations (Ahmad et al. 2000). Two prospective, randomized studies using direct repair in acute setting did not achieve any significant improvement in stability (Nikku et al. 2005; Christiansen et al. 2008). Therefore, indications for initial MPFL repair or reconstruction have remained controversial.

For recurrent patellar dislocation, various surgical techniques have been described to reconstruct the MPFL (Figure 11) (Lind et al. 2008). Avikainen et al. described an adductor magnus tenodesis technique which was originally performed in addition to acute MPFL repair (Avikainen et al. 1993). The distal part of the adductor magnus tendon was cut approximately 8 cm proximal to its distal insertion and the graft was then fixed with nonresorbable sutures near the medial border of the patellar periosteum to reconstruct the MPFL. In the original study, Avikainen (Avikainen et al. 1993) performed this surgery mainly on acute traumatic primary dislocations and reinserted the MPFL into the periosteum of the medial femoral epicondyle. Mid-term follow-up of mean 6.9 years was reported with 14 patients and only one patient had a redislocation.

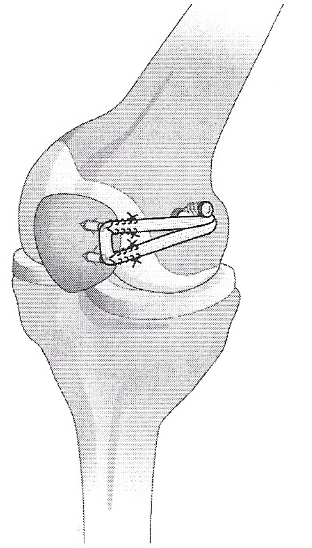
Figure 11. Medial patellofemoral ligament reconstructive techniques for patellar dislocations. (Reprinted with the permission from the Informa Healthcare Publications.)



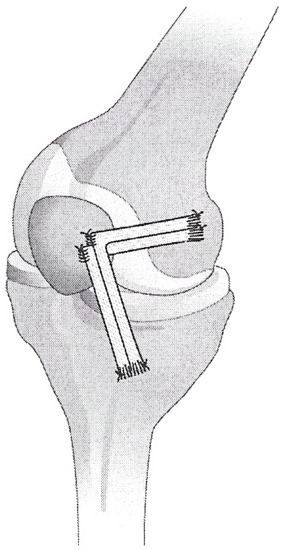
A. The normal MPFL, which inserts at the proximal two-thirds of the medial patella border and runs posteriorly to the medial adductor tubercle to insert in close relation to the proximal MCL insertion and the adductor magnus insertion.



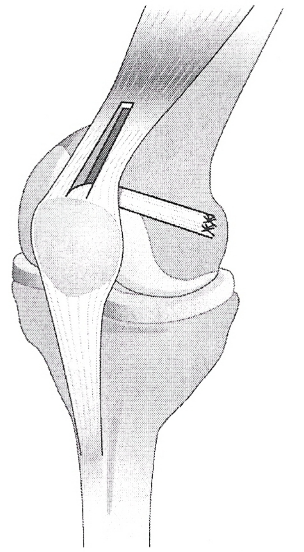
B. MPFL reconstruction with an autograft or allograft tendon fixed in bone canals in both patella and femoral condyle.



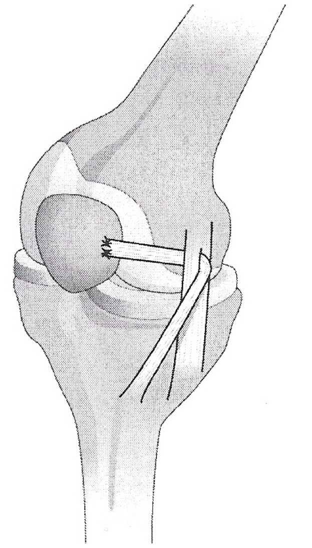
C. MPFL reconstruction avoiding drilling in the patella, using anchor fixation of the semitendinosus graft at the medial aspect of the patella and interference screw in the medial femoral condyle.



D. A technique with combined reconstruction of MPFL and medial patellatibial ligament. Here semitendinosus and gracilis tendons are folded and sutured to the medial patella edge and medial femoral condyle. A distal limb of the tendon grafts is sutured to the proximal medial tibial periosteum to reconstruct the medial patellotibial ligament.



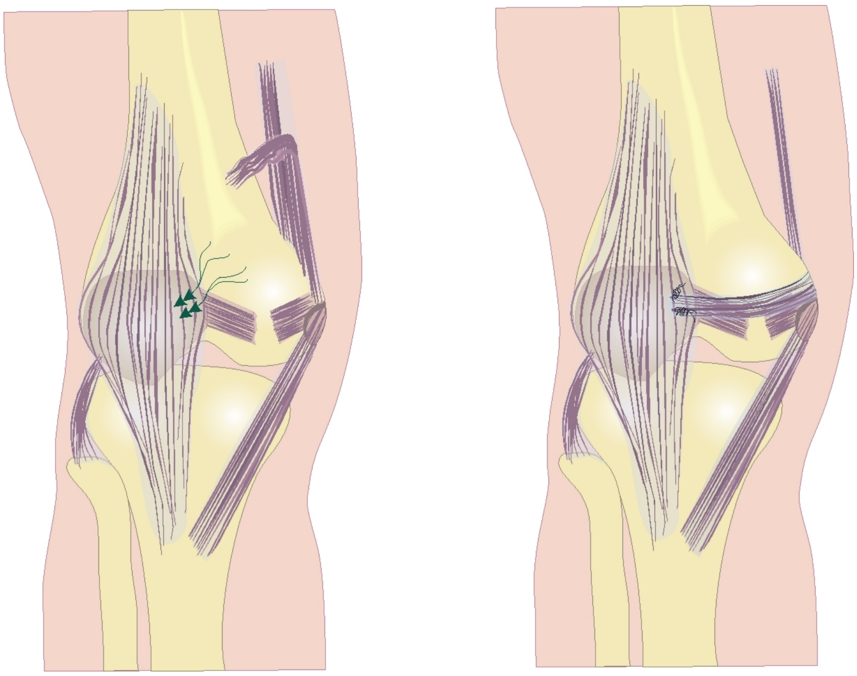
E. MPFL reconstruction using the central portion of the quadriceps tendon. The tendon is released proximally and the patella insertion left intact. The tendon flap is passed subcutaneously to the medial femoral condyle, where fixation is performed by osteosutures.



F. MPFL reconstruction with the semitendinosus tendon. The tendon maintains its insertion at the pes anserinus and the proximal end of the tendon is transferred to the femoral insertion of the medial collateral ligament (MCL). The graft is then passed through an incision in the MCL femoral insertion, which subsequently acts as a pulley. Finally, the graft is sutured to the medial aspect of the patella.

Recently a mini-invasive method for MPFL reconstruction has been presented (Sillanpää et al. 2009), in which the adductor magnus tendon is transferred and attached to the patella with suture anchors (Figure 12). By use of this 3 to 4 cm single-incision technique, morbidity of soft tissue is minimized and hamstring tendons extending below the knee are preserved as functional knee joint stabilizers. Because drilling on the femoral epicondyle region is avoided, it is also suitable for skeletally immature patients.

Figure 12. A mini-invasive medial patellofemoral ligament reconstruction technique by adductor magnus tenodesis (Reprinted with the permission from Springer)



Ellera Gomes et al. (Ellera Gomes et al. 2004) used synthetic material, polyester ligament, attached to the patella by passing the ligament through the patellar tunnel and then fixing it to the medial epicondyle of the femur. Screw fixation was used on the femoral side and the patellar tunnel was drilled through the patella from medial to lateral. The lateral end of the artificial graft was fixed with sutures. This was the first described technique that was later modified into using a semitendinosus graft via the osteoperiosteal tunnel for femoral fixation. The later technique has been followed for a minimum of 5 years with good patient satisfaction (13 of 15 patients).

Drez et al. (Drez et al. 2001) used hamstring or iliotibial band grafts attached to the superomedial aspect of the patella and the adductor tubercle, and the lower limb of the graft was sutured into the tibial periosteum 15 mm distal to the tibiofemoral joint line. This was a two-limbed reconstruction of both the MPFL and the MPTL. A mean follow-up of less than three years was reported at the end of which 14 of 15 patients were satisfied with the result and only one had redislocation.

Deie at al. (Deie et al. 2005) described a technique for MPFL reconstruction which included transfer of the semitendinosus tendon to the patella with use of the posterior one-third of the MCL as a pulley. This reconstruction was combined with VMO advancement or LRR in some patients. Ninety-one per cent of the patients were satisfied after a mean 5-year follow-up.

Cossey and Paterson (Cossey and Paterson 2005) reported a study of 21 knees with a mean two-year follow-up employing an MPFL reconstruction technique using a strip of the medial retinaculum. Attachment was anatomic near the medial epicondyle and at the middle and proximal thirds of the medial margin of the patella. All patients reported good or excellent outcome with no subluxation or dislocation.

Nomura and Inoue (Nomura and Inoue 2003) performed MPFL reconstruction with use of a semitendinosus graft, which they passed through the patellar bone tunnel reaching from the patellar medial margin to the middle anterior surface of the patella. Femoral attachment was distal to the adductor tubercle or posterosuperior to the medial epicondyle. After a mean 4-year follow-up, 10 of the 12 knees examined were good or excellent, and no redislocations occurred.

Nomura et al. (Nomura et al. 2000) have also used artificial ligament (mesh-type Leeds-Keio) and medial retinaculum strip coverage for MPFL reconstruction. Attachment locations were similar to those described above. The mean follow-up time of just over 5 years described 26 of the 27 knees having good or excellent results, but one redislocation was recorded.

Schöttle et al. (Schöttle et al. 2005) published a study of 15 knees in which the MPFL reconstruction was performed using an ipsilateral semitendinosus autograft. The patellar attachment was superomedial, and tendon fixation to the bone tunnel was done with an interference screw. Similarly, femoral attachment at the adductor tubercle was achieved with an interferenece screw. TT-TG distance over 15 mm was noticed in eight patients and these underwent TT medialization. A mean follow-up of almost five years reported 13 of 15 patients had good or excellent results. TT transfer was not associated with better outcome, but the comparison had limited power for that analysis. Recently, the authors also described MPFL reconstruction with double-bundle technique (Schöttle et al. 2008). A semitendinosus graft is fixed to the patella with two interference screws at the proximal medial margin and the middle medial margin of the patella. The graft is then fixed to a fluoroscopically assessed point between the adductor tubercle and the medial epicondyle, in which a bone tunnel is drilled through the femur from medial to lateral. No follow-up results of this technique have been published.

5.9.4.3 Clinical aspects for medial patellofemoral ligament reconstruction

The decision to perform surgery due to loss of the medial patella stabilizer needs proper documentation of the laxity by physical examination and radiography (Colvin and West 2008). At initial event, MRI is preferred especially to determine the MPFL injury location and presence of intra-articular lesions. An examination under anesthesia and arthroscopy can be used to document passive restraint laxity without VMO action.

A large number of surgical techniques for MPFL reconstruction have been described (Dopirak et al. 2008; Lind et al. 2008; Parker et al. 2008). A major concern related to MPFL reconstructive surgery is the lack of an objective tool which would help tensioning the MPFL graft adequately. The methods to identify anatomic attachment locations are reliable, but as the MPFL graft tensioning depends on the skill of the surgeon, it still is the crucial phase of the procedure. Some studies have shown that excessive tension in the graft could result in medial patellar cartilage overload (Elias and Cosgarea 2006; Beck et al. 2007).

It is quite difficult to determine the proper tension on the graft, despite intraoperative assessment with the patella placed in the TG at the ROM where the graft length is longest. Parker et al. (Parker et al. 2008) measured the PF joint pressures with isometric and nonisometric femoral fixation of the MPFL graft, and discovered that the anatomic reconstruction restored patellar tracking better than the isometric technique. According to Beck et al. (Beck et al. 2007), overtightening the graft in anatomic MPFL reconstruction does not significantly improve patellar tracking, and an overtightened graft may increase the pressure within the PF joint.

The MPFL grafts should have same stiffness of the native MPFL while being stronger than the native MPFL (Bicos et al. 2007). Potentially, if the graft used in MPFL construction is much stiffer than the native MPFL, the pressure across the PF joint can increase because the graft may not function optimally during the arc of motion in which the length and tension of the native MPFL vary. The native MPFL has a load failure of 208N (Amis et al. 2003) while a hamstring graft used to reconstruct MPFL can load up to 1600N before failure (Noyes et al. 1984). There is some evidence that the MPFL length change pattern depends principally on the femoral attachment point. The least change was at a point more distal to the patella and more proximal to the femur (Steensen et al. 2004). This was also the site that had the greatest native MPFL length between the two points. In one cadaver study (Smirk and Morris 2003), the femoral attachment site was the one most sensitive to position change, especially superior and anterior. The ligament was "longest" at 60° of flexion.

The graft length should allow the patella to enter the trochlea from a lateralized position, as dictated by normal PF kinematics, and allow the slope of the lateral trochlear wall and the lateral patellar facet to engage its trochlear position gradually (Feller et al. 2007). Intra-operatively, the attachment sites should be adjusted to minimize the length change with knee flexion. If lengthening occurs in flexion, the femoral attachment site can be moved towards more distal. If lengthening occurs in extension, the femoral attachment site can be moved towards more proximal.

The type of graft fixation of the MPFL includes several techniques. Mountney et al. performed a biomechanical study comparing different fixation techniques, suture repair, suture anchor repair, and femoral attachment with either blind-tunnel or through-tunnel fixation (Mountney et al. 2005). Through-tunnel fixation, at the lateral femoral condyle, was equal strenght to the native MPFL.

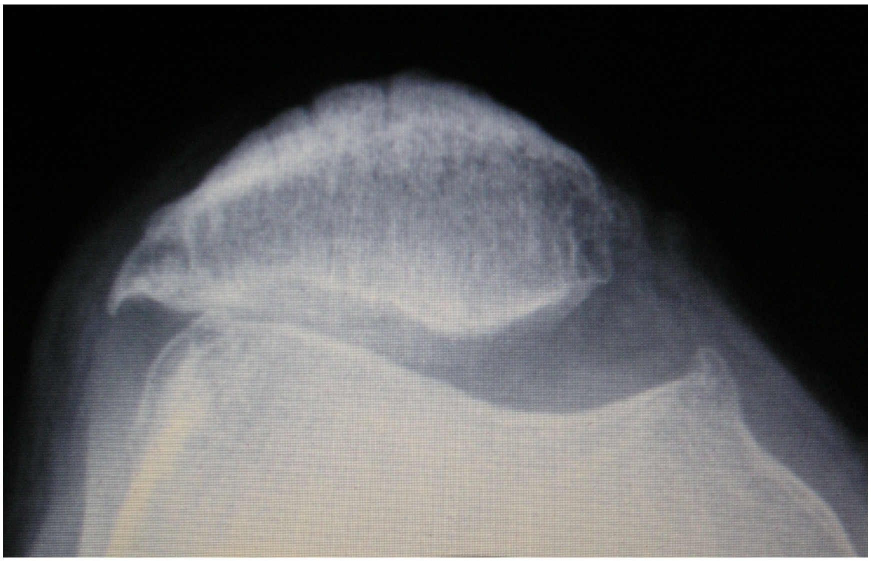
The postoperative protocol usually includes a short immobilization period, somewhat similar to the one following initial nonoperative management of traumatic primary patellar dislocation (Mehta et al. 2007). It depends on the graft fixation technique, and theoretically, patients with bone-tendon fixation using an interference screw might be immediately mobilized with reasonable physical stress. Anchor fixation and sutures usually need some time for scar tissue formation. Unfortunately, the postoperative methods have been poorly described in many studies and the immobilization protocol remains procedure-dependent (Lind et al. 2008).

5.10 The natural course of patellar instability - osteoarthritis

Patellar instability has been associated with the risk for PF OA (Figure 13) progression (Mäenpää 1997). We may hypothesize that articular cartilage lesions may also occur in secondary dislocations, but osteochondral lesions are not likely to occur if chronic instability produces subluxation rather than recurrent forceful dislocation (Cash and Hughston 1988). It seems that the nature of recurrent episodes of instability may cause PF cartilage to break down if the recurrent dislocation is traumatic and hemarthrosis is present. If chronic instability produces daily subluxations in knees with a shallow femoral TG, the forces needed to dislocate the patella are minor and no articular damage is instantly produced at the instability event, but over time, PF cartilage loss is frequently found.

Ahlbäck (Ahlbäck 1968) and Iwano (Iwano et al. 1990) classifications for PF OA have been used, but MRI evaluation of PF cartilage loss has not been utilized in any publications. Mäenpää and Lehto (Mäenpää and Lehto 1997) reported a mean 13-year follow-up of 85 patients with primary patellar dislocation. The occurrence of PF OA visible on plain radiographs ranged from 12% to 35%, depending on whether there were redislocations or not and whether the injury management was nonoperative or surgical. However, mild or moderate PF cartilage loss is not visible on plain radiographs. PF OA has been associated with osteochondral fractures (Figure 3) related to primary patellar dislocations (Stanitski 1995; Stanitski and Paletta 1998; Stefancin and Parker 2007). The PF OA progression after primary traumatic patellar dislocation has not been studied regarding primary lesions and long-term articular cartilage defects. MRI is significantly better than plain radiographs in determination of cartilage lesions and PF OA, but no long-term studies using MRI examinations on PF cartilage exist.

Figure 13. Patellofemoral osteoarthritis.



5.10.1 Prevention of patellofemoral osteoarthritis

Anatomic patellar tracking after patellar dislocation should prevent PF OA development. Surgical corrections are aimed at MPFL reconstruction and TT transfer, if needed for alignment correction (Arendt et al. 2002; Colvin and West 2008). The role of trochleaplasty in OA progression is unknown. Nomura et al. (Nomura et al. 2007) published a 12-year long-term follow-up of MPFL reconstruction and reported that 21 of 24 knees did not have PF OA. The result was superior to other follow-ups of patellar dislocations with regard to PF OA (Chrisman et al. 1979; Mäenpää and Lehto 1997). However, no comparative studies of different surgical techniques have been published that would report PF OA findings. Moreover, OA characteristics analysis by MRI has not been used for patellar dislocations, which would be likely to improve the analysis significantly. OA progression in the PF joint after patellar dislocation is frequent, but might be reduced by performing anatomic MPFL reconstruction rather than nonanatomic surgical procedures (Nomura et al. 2007).

6. AIMS OF THE STUDY

The principal aim of this study was to investigate the incidence and risk factors of primary traumatic patellar dislocation and the nature and clinical aspects of MPFL injury. The outcomes after different forms of treatment for primary and recurrent patellar dislocation were investigated. During the past ten years, extensive research has been conducted concerning the anatomic and functional aspects of the MPFL. Since the clinical aspects of the MPFL injuries have been poorly understood, this study consisted of the following detailed aims:

(I) To assess the incidence and risk factors of acute primary traumatic patellar dislocations in young adults.

(II) To compare the long-term results of MPFL reconstruction and traditional realignment surgery in patients with recurrent patellar dislocation with special focus on comparison of radiographic signs of OA in the PF joint between the methods of surgical treatment.

(III) To compare the long-term results in patients with primary traumatic patellar dislocation following initial management with and without acute arthroscopic stabilization.

(IV) To compare treatment with and without initial surgical stabilization for primary traumatic patellar dislocation in a prospective randomized setting.

(V) To evaluate whether MPFL injury location predicts a different prognosis following nonoperative treatment in patients with primary traumatic patellar dislocation.

7. MATERIALS AND METHODS

The data of this thesis was based on a large sample of Finnish young adults who were serving their military period during 1994-2002. For epidemiological assessment of primary traumatic patellar dislocation, this study used a large military service database comprising over 130 000 conscripts. The data from the military training database was combined with data drawn from the National Hospital Discharge Register (NHDR) identifying individuals hospitalized in the Central Military Hospital. The clinical data sets (II to V) consisted of over 180 patients, who were followed-up and reviewed, with two prospective series and both surgical and nonoperative retrospective series of patients (Table 2).

Table 2. Materials and methods of studies in this thesis.

Study and year	**Number of cases (age range)**	**Primary study aim**	**Follow-up time (years)**	**Number of controls (type)**	**Study type**	**Primary outcome measures**
Study I, 1998-2002	130 708 (17-30)	Incidence of PTPD*	96200 (person years)	128,436 (non-dislocators)	Prospective cohort	Incidence, risk factors for PTPD*
Study II, 1994-2000	47 (19-24)	Results of MPFL reconstruction	10.0	29 (distal realignment)	Retrospective cohort	Recurrent instability, PF OA
Study III, 1996-1999	76 (19-22)	Initial arthroscopic medial repair for PTPD*	7.5	46 (nonoperative)	Prospective cohort	Recurrent instability, regain of preinjury activity level
Study IV, 1997-2000	44 (18-22)	Initial stabilizing surgery for PTPD*	7.0	22 (nonoperative)	Prospective, randomized cohort	Recurrent instability, regain of preinjury activity level
Study V, 1997-2002	53 (19-23)	The prognosis of MPFL injury location	7.0	Three groups (femoral, midsubstance, patellar)	Retrospective cohort	Recurrent instability, regain of preinjury activity level

* Primary traumatic patellar dislocation

7.1 Study populations and outcome measurements

7.1.1 Sample for determining the incidence and risk factors for primary traumatic patellar dislocation (Data I)

The first data included all Finnish conscripts who started their service between January 1, 1998 and December 31, 2002. The sample consisted of 130 708 young adults including 1994 (1.5%) women. The length of the service period was 6, 9, or 12 months, and a new batch of conscripts entered twice a year, in January and July. Military service is compulsory to all Finnish men deemed fit for service at the entrance medical examination, and 80% of them serve their service period to the full. Women have been able to enter the military service on a voluntary basis since 1994. During the military service period all conscripts were required to use the services of the military hospitals. Using the personal ten-digit identification number assigned to all Finnish residents, the conscripts' primary diagnosis, medical records, and background data were linked to the NHDR, the reliability of which has been reported to be good (Mattila et al. 2008).

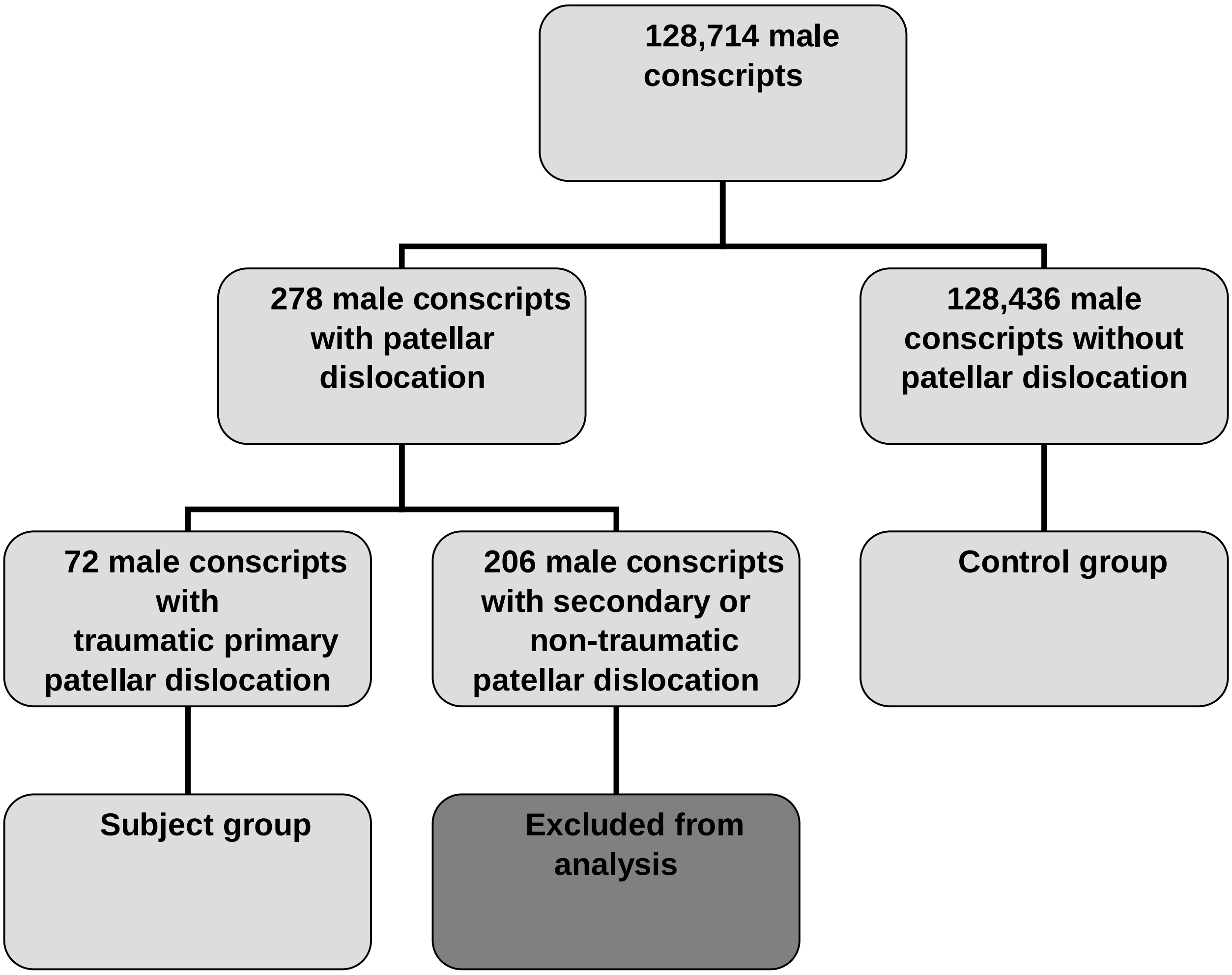
The dates of entry and transfer or discharge of every conscript were registered, allowing us to calculate the total time at risk. During the 5-year study period, Finnish conscripts aged 17 to 30 years (median, 20 years) served a total of 96 200 person-years. The primary outcome variable in the first data was patellar dislocation, obtained from the NHDR. The original medical records of all patients hospitalized with the main diagnosis of S83.0 were then re-evaluated and decided by reviewing the hospital documents whether dislocation was primary traumatic or not.

7.1.1.1 Outcome measurements

The incidence rate for traumatic primary patellar dislocations was calculated by dividing the number of knees with a first-time traumatic patellar dislocation by the total exposure time. For the risk factor analysis, the population was analyzed as two groups; the subject group consisting of 72 patients with a total of 73 primary traumatic dislocations, and the control group consisting of 128 436 male conscripts without patellar dislocation (206 male conscripts whose secondary or nontraumatic dislocations occurring during the military service were excluded from the risk factor analysis) (Figure 14). The female recruits, 1994 of the total sample of 130 708 (1.5%) were excluded from the analysis due to the small size of the group.

The corresponding 95% confidence intervals (CIs) were calculated, and the incidence rate was presented per 100 000 persons per year. The computer-stored risk factor data by age and gender, with height and weight of every conscript, were analyzed including the aerobic and physical fitness levels assessed during the first weeks of military service. Aerobic fitness was based on the Cooper 12-min run test (Cooper 1968), and a physical fitness score on five measures was obtained for muscle strength (five standardized Finnish Defence Forces muscle strength tests: standing long jump distance, number of sit-ups, push-ups, pull-ups, and back extensions), each with a test score of 0 to 3 points.

Figure 14. Primary traumatic patellar dislocations among 128 714 Finnish male conscripts and selection of study participants for risk factor analysis.



7.1.2 Patients treated for recurrent patellar dislocation with medial patellofemoral ligament reconstruction or distal realignment surgery (Data II)

All patients operated on for recurrent patellar dislocation at the Central Military Hospital, Helsinki, between 1994 and 2000 were identified using a computer search. After reviewing the records regarding the surgical procedures, a total of 47 consecutive conscripts diagnosed with recurrent patellar dislocation and who underwent an MPFL reconstruction or a distal realignment procedure were identified. Excluded from the study were patients operated on for acute primary patellar dislocation and patients whose data regarding previous dislocations were missing before the surgery. Eighteen knees underwent MPFL reconstruction by adductor magnus tenodesis (Avikainen et al. 1993) and 29 knees underwent distal realignment by the Roux-Goldthwait procedure (Goldthwait 1903).

7.1.2.1 Outcome measurements

The number of patients with subsequent instability (redislocation, and/or subluxation) was the primary outcome in studies II-V. In this study, the secondary outcome included special focus on comparison of radiographic signs of OA in the PF joint between the methods of surgical treatment. Clinical follow-up examinations were performed at the Central Military Hospital, Helsinki during the years 2005-2006. The patients were first interviewed with the aim to perform a reliable assessment of the number of subsequent redislocations, subjective instability (painful subluxation), and other problems related to the PF joint. The PF scoring scale by Kujala et al. (Kujala et al. 1993) was used for assessment during the follow-up visit. A 100-mm visual analog scale (VAS) (Flandry et al. 1991) (rated as 0 = no pain to 100 = most severe pain) was used to assess the patient’s subjective pain in the affected knee. Physical activity levels were assessed on the Tegner (Tegner and Lysholm 1985) scale (0-10), with 0 denoting severe disability and 10 indicating a national or international-level competing athlete. Information regarding subsequent surgery or other major knee complaints, hospital admissions, and contralateral knee complaints were collected during the follow-up visit. A physical examination was performed and any restriction of the knee ROM, sign for retropatellar crepitation, positive apprehension test and loss of quadriceps muscle circumference were assessed.

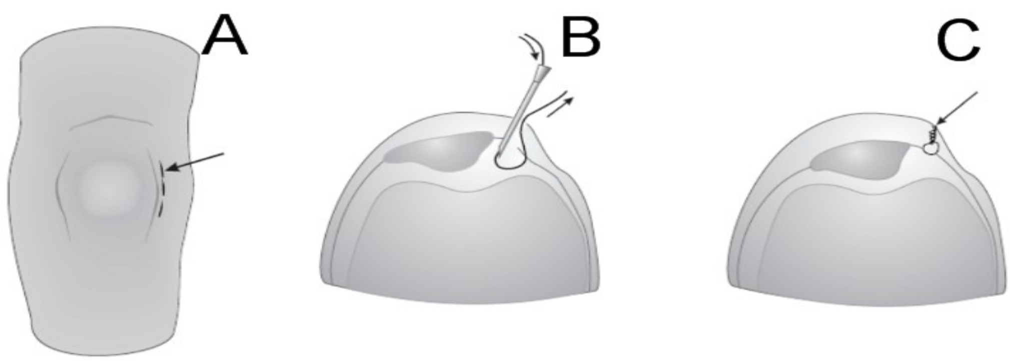
The radiographic analysis obtained on every patient included plain radiographs of the PF joint with posteroanterior, lateral, and PF axial views (Laurin et al. 1979). The parameter measured on the axial views included the sulcus angle as described by Brattström (Brattström 1964) with a measurement over 150° representing trochlear dysplasia. Patellar height was measured on the lateral views so that a Blackburne-Peel (Blackburne and Peel 1977) ratio greater than 1.06 was considered as patella alta. The severity of PF OA was assessed by plain radiographs and MRI. PF OA severity was graded from 0 to V by using the classification of Ahlbäck (Ahlbäck 1968): Grade 0 representing normal, Grade I joint narrowing, Grade II joint obliteration, and Grades III to V more severe destructive characteristics.

Control MRI was performed and the chondral lesions were classified by MRI according to their depth using the numeric grading system developed by the International Cartilage Repair Society (ICRS) and described by Brittberg and Winalski (Brittberg and Winalski 2003). Grade I lesions were excluded because of the difficulties in differentiating these lesions from normal (ICRS Grade 0) cartilage on 1.0 T MRI (Friemert et al. 2004). The ICRS Grade II describes articular cartilage defects extending down to less than 50% of the cartilage depth, Grade III extending deeper than 50% of the cartilage depth, and Grade IV are defects with full-thickness articular cartilage loss.

7.1.3 Prospective cohort of patients with primary traumatic patellar dislocation: treatment with and without acute arthroscopic stabilization (Data III)

Seventy-six patients admitted to the Central Military Hospital, Helsinki, for acute traumatic primary patellar dislocation between 1996 and 1999 were treated either by arthroscopic medial retinacular repair or nonoperatively. To be included in the study, the patient's diagnosis of primary traumatic patellar dislocation had to be confirmed by arthroscopy (in patients treated with arthroscopic medial retinacular repair) or by MRI (a medial patellar restraint injury in patients treated nonoperatively). The treatment pathway of this prospective cohort depended on the availability of the orthopedic surgeon to perform the initial arthroscopic medial retinacular repair procedure (Figure 15).

Figure 15. Arthroscopic medial retinacular repair.



7.1.3.1 Outcome measurements

The number of patients with subsequent instability (redislocation, painful subluxation) was the primary outcome in this study. Patients were also asked whether they had regained their preinjury level of activity by follow-up. Clinical follow-up examinations were performed at the Central Military Hospital, Helsinki during the years 2005-2006, as described in Section 7.1.2.1. The radiographic analysis was performed as described in Section 7.1.2.1.

The third data described the initial medial patellar stabilizing complex injury in terms of MRI findings of acute MPFL injuries and the follow-up MRI results at a median of seven years after the dislocation, with special focus on PF articular cartilage lesions. In the nonoperative group, MPFL injuries were further classified into three regions: MPFL at the level of its patellar insertion, MPFL at its midsubstance, and MPFL at its femoral origin, as assessed from transverse MR images. The chondral lesions at follow-up were classified by MRI according to their depth as described in Section 7.1.2.1.

7.1.4 Prospective cohort of patients with primary traumatic patellar dislocation: a randomized study of treatment with and without initial surgical stabilization (Data IV)

Between 1997 and 2000, the 44 conscripts admitted to the Central Military Hospital, Helsinki, with an acute primary traumatic patellar dislocation were randomized to surgically stabilized and nonsurgically treated groups, if eligible. This study included patients who had sustained an acute primary traumatic patellar dislocation. Those meeting any of the following criteria were then excluded: previous traumatic or nontraumatic dislocation of the patella, previous subluxation of the patella, pre-existing ipsilateral or contralateral knee pathology, previous ligamentous injury or fracture of the involved knee, patellar fracture, or large osteochondral lesion of the involved knee needing surgery. The patients were randomly allocated using a sealed envelope method into two treatment groups, one for initial patellar stabilization surgery and the other for nonoperative treatment with a knee orthosis (as well as arthroscopic removal of an osteochondral fragment if necessary).

7.1.4.1 Outcome measurements

The number of patients with subsequent instability (redislocation, painful subluxation) was the primary outcome in this study. Patients were also asked whether they had regained their preinjury level of activity by follow-up. Clinical follow-up examinations were performed at the Central Military Hospital, Helsinki during the years 2005-2006, as described in Section 7.1.2.1. The radiographic analysis was performed as described in Section 7.1.2.1.

Initial and control MRIs were obtained, and the chondral lesions at follow-up were classified by MRI according to their depth as described in Section 7.1.2.1.

7.1.5 Patients with primary traumatic patellar dislocation and medial patellofemoral ligament injury: the outcome after nonoperative treatment (Data V)

Between January 1, 1997 and December 31, 2002, a total of 163 consecutive military conscripts were admitted to the Central Military Hospital, Helsinki, as inpatients with acute traumatic patellar dislocation. The patients were identified from the hospital discharge register using the appropriate diagnosis code S83.0 of the 10th revision of the International Classification of Diseases (1996-2002: ICD-10), and the original medical records of these patients were retrieved for re-evaluation. The main inclusion criterion for the present study was primary traumatic patellar dislocation confirmed by physical examination by an orthopedic surgeon and by MR imaging (within 21 days from injury). All patients with a history of previous patellar dislocation or subluxation were excluded. In addition, as the purpose of this study was to investigate long-term, nonoperative healing of the injured MPFL, any patient who had had patellofemoral surgery of any kind (open or arthroscopic, proximal or distal realignment procedure) during the first 6 months after injury was excluded. Multi-ligamentous knee injuries and patients with other previous traumas or major complaints of the knee joint were excluded as well. To be included, aftercare was documented to have been supervised and successfully completed. After careful review of the records, 53 of the 163 patients identified with a dislocated patella were classified as having sustained a first-time traumatic patellar dislocation without any patellofemoral surgery performed during the first 6 months after the incident.

The study hypothesis was that the MPFL injury location may predict different prognosis, and that the healing capacity for stabilizing the patella after identical nonoperative treatment may vary according to the MPFL injury location. In addition, the possible chondral lesions initially occurring at the primary event, their relation to the MPFL injury, and the outcome after nonoperative treatment were evaluated. Using the initial MR images, MPFL injuries were classified into three regions: MPFL at the level of its patellar insertion, MPFL at its midsubstance, and MPFL at its femoral origin, as assessed from transverse MR images.

7.1.5.1 Outcome measurements

The number of patients with subsequent instability (redislocation, painful subluxation) was the primary outcome in this study. Patients were also asked whether they had regained their preinjury level of activity by follow-up. Clinical follow-up examinations were performed at the Central Military Hospital, Helsinki during the years 2006-2007, as described in Section 7.1.2.1. The radiographic analysis was performed as described in Section 7.1.2.1. The chondral lesions at follow-up were classified by MRI according to their depth as described in Section 7.1.2.1.

7.2 Methods of analysis

7.2.1 Statistical methods for calculating the incidence and risk factors for primary traumatic patellar dislocation (Data I)

In the statistical analysis, the Kruskal-Wallis test was used to test differences in the non-parametric ordinal data (age), and the independent samples *t*-test in the continuous normally distributed data (height, weight, BMI, muscle strength, run test) between the groups (primary traumatic patellar dislocation yes/no). Differences in the two-way tables were determined with the Pearson chi-square test. Significance was set at $P \leq 0.05$. SPSS 12.0.1 for Windows software (SPSS Inc, Chicago, Illinois) was used for statistical analysis.

7.2.2 Statistical methods for the outcome variables for data II, III and V

The Kruskal-Wallis test was used to test differences in non-parametric ordinal data and the independent samples *t*-test in the continuous normally distributed data between the groups (Data II and III) or injury locations (Data V). Differences in the two-way tables were determined with the Pearson chi-square test or Fisher’s exact test when appropriate. As the chi-square test is not reliable if the expected values are small (as was the case in data V; other than femoral MPFL injury locations), further testing to localize a significant finding was performed using either a subset of the original six cell table (femoral, midsubstance and patellar locations) or the two by two table statistics (femoral location compared to any other location) with Fisher’s exact test (Data V). Significance was set at $P \leq .05$. SPSS 14.0 for Windows software (SPSS Inc, Chicago, Illinois) was used for statistical analysis.

7.2.3 Statistical methods for the prospective, randomized study (Data IV)

The Kruskal-Wallis test was used to test differences in non-parametric ordinal data between the groups and the independent samples *t*-test in the continuous normally distributed data between the groups. Differences in the two-way tables were determined with the Pearson chi-square test or Fisher's exact test when the expected cell count was less than five. Significance was set at $P \leq 0.05$. SPSS 14.1 for Windows software (SPSS, Chicago, Illinois) was used for the statistical analysis.

The sample size calculation was based on the assumption that the redislocation rate would be 50% in the nonsurgically treated group and 10% in the surgically stabilized group, which would require seventeen patients in each group for a power of 80%, a type-I error ([alpha]) of 0.05, and an estimated effect size of 1.0. Using the same assumption, (50% and 10%, correspondingly), assessing subjective instability (subluxation) and end-point articular cartilage lesions would require seventeen patients in each group to provide similar study power and type-I error numbers as above. The sample size requirement of sixteen patients per study group was calculated with use of a study power of 80%, a type-I error ([alpha]) of 0.05 and an estimated effect size of 1.0 regarding the subjective end-point outcome measured by the Kujala scoring system. This was based on an assumption that the mean Kujala symptom score would be 70 for the nonoperatively treated and 85 for the surgically stabilized group.

8. RESULTS

8.1 Epidemiology and risk factors of primary traumatic patellar dislocation

The number of acute traumatic primary patellar dislocations among male conscripts was 73 and the calculated incidence was 77.4 (95% CI: 61.1 to 96.8) per 100 000 persons per year, while the corresponding figures in females were 2 and 104.6 (95% CI: 0 to 248.1) per 100 000 persons per year. Due to the small number of female cases, they were excluded from the risk factor analysis. The median age of the male patients was 20 years (range, 18 to 23 years) (Table 3), and the median duration of the military service before onset of the primary patellar dislocation was 3 months (range, 0 to 11 months). Twenty-two male patients (30%) suffered an acute traumatic patellar dislocation during the first month of service. Forty-six cases (63%) occurred in sports activities and 27 cases (37%) in military training. The most common injury events were a same level fall in 21 cases (29%), near-fall with valgus knee stress in 20 cases (27%), collision with other person in 16 cases (22%), and other event (wrestling, climbing, weight lifting, combat training) in 16 cases (22%) during military exercises or sporting activities. Knee flexion with tibial valgus position was the leading mechanism of injury (93% of the cases), while a direct impact to the knee from falling to the ground was the cause of patellar dislocation in 7% of the cases.

Table 3. Risk factors for acute traumatic primary patellar dislocation among Finnish male conscripts (mean and standard deviation).

Risk factor	**Acute traumatic primary patellar dislocation (n=72)**	**Healthy controls (n=128 436)**	**p-value**
	mean (SD)	**mean (SD)**	
Age (y)	19.8 (0.9)	20.0 (1.3)	0.287
Height (cm)	180.5 (7.3)	178.7 (6.6)	0.033*
Weight (kg)	77.2 (14.5)	73.3 (12.7)	0.018*
Muscle strength (points)	16.4 (3.6)	16.4 (3.6)	0.913
Run test (m)	2500 (372)	2520 (355)	0.719
Body mass index	23.6 (3.9)	22.9 (3.5)	0.125

* considered significant with p-value < 0.05

In 28 male patients (38%) who underwent MRI scans, the specific findings included visualized MPFL and medial retinacular ruptures in all 28 dislocated kneecaps (100%). Concomitant injuries occurred in 32 (44%) patients, including osteochondral fracture (present in 12/28 of the MRI cases), three meniscal ruptures (4%), and an ACL rupture in one patient (1%). Ten patients were permanently discharged from military service due to patellar dislocation (one with ruptured ACL) and five patients were transferred to physically less demanding duties. Of the 72 patients, 57 (79%) were able to return to normal military service and training activities within a median of 51 days (range, 15 to 120 days). One redislocation occurred during the follow-up period. The patients with traumatic primary patellar dislocations were taller (180.5cm vs. 178.7cm, p=0.03) and they weighed more (77.2kg vs. 73.3kg, p=0.02) than the controls (Table 3). The occurrence of acute traumatic primary patellar dislocation was not associated with body mass index (p=0.13), result of the 12-min run test (p=0.72), or muscle strength (p=0.91).

8.2 Long-term outcome of medial patellofemoral ligament reconstruction compared with distal realignment

A relatively low redislocation rate was found in both of the study groups. There was one redislocation (1/15, 6.7%) in the MPFL reconstruction group treated with adductor magnus tenodesis, and three redislocations (3/21, 14.3%) in the comparison group treated by the Roux-Goldthwait distal realignment procedure (p=0.52). Painful subluxations and PF reoperations due to patellar instability were similarly infrequent in both groups. The reoperation rate for redislocations was 7% (1/15) in the MPFL reconstruction group and 14% (3/21) in the distal realignment group (p=0.68) (Table 4). The subjective and functional outcomes were good in both groups. The median Kujala score for subjective symptoms and functional outcome in the MPFL reconstruction group was 88 points (range, 57-100) and in the distal realignment group 86 points (range, 58-100) (p=0.68). The median Tegner activity scores were 4 (range, 2-8) and 5 (range, 2-7) (p=0.84), respectively. Clinical examination including assessment of ROM (values 141 [range 130-155] and 144 [135-155], respectively) did not reveal any significant differences between the groups.

Table 4. Results of MPFL reconstruction compared with distal realignment.

Study Parameter	**MPFL reconstruction (median; range)**	**Distal realignment (median; range)**	**Statistical Value (p)**
Redislocation, number (%)	1 (6.7%)	3 (14.3%)	0.52
Kujala score (maximum 100 points)	88.0 (57-100)	86.0 (58-100)	0.68
Excellent (95-100 points), number	4	5	
Good (85-94 points), number	6	7	
Fair (65-84 points), number	4	6	
Poor (64 or less points), number	1	3	
Visual Analog Scale (0-100 mm)	10 (0-50)	10 (0-60)	0.51
Tegner activity level (1-10)	4 (2-8)	5 (2-7)	0.55
Control MRI	13	17	
Painful subluxations	2	2	
Chondral lesions[*] on MRI	10/13	12/17	0.20
Full-thickness[†] articular cartilage loss	7/13	7/17	0.11
Reoperated	2	3	0.93
Arthrosis on native radiographs[‡] Grade I or more severe	0	5	0.04

[*]Chondral lesion Grade II or more severe; [†]chondral lesion Grade IV (chondral lesions classified according to their depth using the numeric grading system developed by the International Cartilage Repair Society; [‡]Grade I or more severe according to Ahlbäck

Radiographic signs of PF OA were more frequent among patients treated with the Roux-Goldthwait procedure. In this group, five patients had OA (at least Ahlbäck Grade I) in the PF joint compared with none in the MPFL reconstruction group, indicating a statistically significant difference (p=0.04) (Table 4). OA (according to Ahlbäck) was not seen in the PF joint on plain radiographs at the time of surgery.

Likewise, the tibiofemoral joint was graded as normal in all of the cases. Regarding the tibiofemoral joint, at follow-up, none of the patients in either group had chondral lesions on MRI (Grade II or more severe), and the plain radiographs were graded as normal (Ahlbäck Grade 0) for all patients. Distributions of the chondral lesions showed no statistically significant differences between the groups. In the distal realignment group, it was noted that the patients with full-thickness articular cartilage loss on MRI also had severe OA deformities on the plain radiographs. In the MPFL reconstruction group, full-thickness articular cartilage lesions were also detected, even in up to 50% of the patients, but none of them had developed major articular cartilage loss typical of PF OA.

8.3 Arthroscopic surgery for primary traumatic patellar dislocation: a comparison of treatment with and without initial medial retinacular repair

During the follow-up period, five of the 26 patients (19%) in the arthroscopic surgery group and eight of the 35 patients (23%) in the nonoperative group had patellar redislocation, but the difference was statistically nonsignificant (p=0.84). Painful patellar subluxation occurred in three patients who underwent arthroscopic surgery and in eight nonoperatively treated patients (p=0.18). Patellar instability was thus present in eight of the 26 patients (31%) in the arthroscopic surgery group and in 16 of the 35 patients (46%) in the nonoperative group (p=0.34). The median Kujala score was 87 points among patients after arthroscopic medial retinacular repair (range, 52-100) and 90 points after nonoperative treatment (range, 59-100) (p=0.22), both indicating a good overall functional outcome. The median Tegner activity scores were 5 (range, 3-7) and 5 (range, 3-10) (p=0.91), respectively.

After arthroscopic medial retinacular repair, 81% (21/26) of the patients were able to regain their preinjury activity level by follow-up compared with 57% (20/35) in the nonoperative group (p=0.05). Three arthroscopic surgery patients and five nonoperative patients underwent later operations due to patellar redislocation or instability (p=0.81).

At the time of injury, hemarthrosis was present in all patients in both groups. In 44 of the 46 (96%) original nonoperative cases, MPFL rupture was detected by MRI. The most common MFPL injury was avulsion of the femoral attachment, which occurred in 25 patients (57%), followed by midsubstance MPFL tear in 10 patients (23%) and patellar avulsion in the remaining 9 patients (20%). Ten of the 19 MPFL tears classified as other than femoral avulsions had signs of partial disruption also at the femoral attachment, seen as wavy and stretched ligament fibres on the MRI scans. Two MPFL structures were continuous but wavy and stretched, and classified as partially ruptured. Since only 8 of the 30 patients (27%) in the arthroscopic group underwent initial MRI, no conclusions on a specific medial structure injury pattern could be made in this group.

At follow-up, altogether 29 patients representing both study groups underwent a control MRI. All of these patients had superficial, at least grade II chondral lesions in the patellar articular cartilage detected by MRI, and over 50% of the lesions were severe, Grade III to IV lesions. Regarding presence of OA characteristics in the PF joint, no statistically significant differences were found between the groups.

8.4 Treatment with or without initial stabilizing surgery for primary traumatic patellar dislocation: a prospective randomized study

In the group treated with surgical stabilization, no redislocations were identified within a median follow-up time of 7.0 years (range, 6 to 8 years). Six (29%) of the twenty-one nonoperatively treated had had a redislocation within a median follow-up of 7.0 years (range, 5 to 9 years) (p=0.02). Patellar subluxation was noted in 2 patients in the group treated with surgical stabilization and in 4 patients in the nonoperatively treated group (p=0.67), but none of these patients underwent a later operation during the follow-up period. Thus patellar instability (redislocation or subluxation) of the patella was reported in 2 (2/17, 12%) patients in the group treated with surgical stabilization and in 10 (10/21, 48%) patients in the nonoperatively treated group (p=0.02). Three of the 6 patients with redislocation in the nonoperatively treated group were operated on during the follow-up.

The median Kujala score was 91 points (range, 52 to 100), and in the group treated with surgical stabilization and 90 points (range, 59 to 100) in the nonoperatively treated group (p=0.82). The Tegner activity level score was 5 (range, 2 to 9) in the group treated with surgical stabilization and 5 (range, 3 to 10) in the nonoperatively treated group (p=0.65). Four patients in the group treated with surgical stabilization and 6 patients in the nonoperatively treated group were unable to return to their previous level of physical activity after the last follow-up. Of the two kinds of surgical stabilizing procedures that were performed, the 13 patients who underwent acute medial repair were analyzed separately, and the following scores were found: a median Kujala score of 92 points (range, 68 to 100) and a

Tegner activity level of 6 (range, 3 to 9). No redislocations occurred in this subgroup of 13 patients and none had painful subluxations.

An osteochondral fracture in the PF joint detected by MRI was observed in 7 (7/22, 32%) patients in the nonoperatively treated group and in 6 in the group treated with surgical stabilization (6/18, 33%) (p=0.92) with an overall occurrence of 33% (13/40). The MPFL was found ruptured in all patients in the nonoperatively treated group and in 17 patients in the group treated with surgical stabilization.

One patient in the nonoperatively treated group had a mild patella alta, and lateral patellar displacement was seen in 4 patients (Table 5). MRI was performed at follow-up on 29 of the 38 patients (76%) who were evaluated at long term. Of those evaluated by MRI at long term, we found 11 patients (38%) with full-thickness patellofemoral articular cartilage lesions visible on either side of the joint. When comparing the development of osteoarthritic characteristics between patients with and without redislocation, we found that severe patellar chondral lesions were more frequent among the redislocators, but the differences were not statistically significant. Three of the 6 (50%) redislocators had an initial osteochondral fracture compared with 10 (31%) of the 32 patients without redislocation.

Table 5. Radiographic findings in the surgical stabilization and nonoperatively treated groups.

Study Parameter	**Surgical Stabilization** Median (Range)	**Nonoperative Treatment** Median (Range)	**Normal Value**
Sulcus angle*	143 (135-148)	141 (135-148)	< 150 degrees
Lateral patellar angle*	0.0 (-6 to +5)	-0.5 (-8 to 0)	Horizontally or laterally
Lateral patellar displacement*	0.0 (-2 to +8)	+2.0 (-4 to +5)	> 0 mm
Blackburne-Peel ratio	0.94 (0.88–1.00)	0.96(0.85-1.08)	0.54-1.06

*Measured on the follow-up radiographs; the initial measurements were highly pathological because of acute knee effusion, etc.

8.5 Femoral avulsion of the medial patellofemoral ligament predicts subsequent instability after primary traumatic patellar dislocation

Of the 53 patients, 35 patients (66%) had femoral MPFL avulsion, 11 (21%) had midsubstance MPFL disruption, and 7 (13%) had patellar MPFL disruption. At follow-up, of the 42 patients who were controlled, there were 25 MPFL disruptions in the femoral, 11 in the midsubstance, and 6 in the patellar region. Patellar instability (including redislocation and painful subluxation) was significantly associated with femoral MPFL avulsion. Unstable patellae were reported by 13 patients (13/25 [52%]) in the femoral MPFL avulsion group, compared with 1 (1/11 [9%]) in the midsubstance group, and 1 in the patellar group (1/6 [17%]) (p=0.01). There were 8 subsequent patellar redislocations that were documented at an emergency visit to a physician (8/25) in the femoral group, compared with 1 redislocation (1/11) in the midsubstance group, and 0 in the patellar group (0/6) (p=0.05) (Table 6). Six patients who reported subsequent PF stabilizing surgery due to patellar redislocation (5 in the femoral and 1 in midsubstance group) were considered as instable after initial nonoperative management in the final follow-up results.

The overall subjective and functional outcomes were not related to MPFL injury location. The median Kujala score for subjective symptoms and functional outcome was 90 points in the femoral (range, 76-100), 91 in the patellar (range, 59-100), and 96 points in the midsubstance region (range, 68-100) (p=0.76). When we excluded the 5 patients with femoral MPFL injury who underwent later stabilizing surgery, the median Kujala score for the 20 remaining patients in the femoral group was 85 points (range, 76-100) compared to 94 points (range, 59-100) in patients with MPFL injury in the midsubstance or patellar region (p=0.59). The median follow-up Tegner activity scores were 5 for femoral (range, 3-8), 6 for patellar (range, 4-7), and 5 for midsubstance (range, 2-7) region MPFL injury, respectively (p=0.32). Preinjury activity level had been best regained in the midsubstance region group (9/11, 82%), followed by the patellar region group (4/6, 67%) and the femoral region group (13/25, 52%). When the femoral region was compared to other groups, a significant correlation not to regain preinjury activity level was found (p=0.05).

Table 6. Results of the follow-up examinations regarding MPFL injury location.

Study Parameter	**Femur†** (Range, *proportions*)	**Patella†** (Range, *proportions*)	**Midsubstance†** (Range, *proportions*)	***P* Value**
Number of patients	35	7	11	
Followed-up patients	25/35 *(71%)*	6/7 *(86%)*	11/11 (100%)	
Redislocation	8/25 *(32%)*	none	1/11 *(9%)*	0.05*
Overall Instability‡	13/25 *(52%)*	1/6 *(17%)*	1/11 *(9%)*	0.01*
Kujala score (maximum 100 points)	90(76-100) 85(76-100)≠	91(59-100)	96(68-100)	0.76
Subjective result:				
Excellent (95-100 points), number	8/25 *(32%)*	2/6 *(33%)*	6/11 *(55%)*	0.32
Good (85-94 points), number	10/25 *(40%)*	4/6 *(66%)*	3/11 *(27%)*	0.81
Fair (65-84 points), number	6/25 *(24%)*	none	2/11 *(18%)*	0.70
Poor (64 or less points), number	1/25 *(4%)*	none	none	
Tegner activity level (1-10), at follow-up	5(3-9)	6(4-7)	5(2-7)	0.32
Regain preinjury activity level	13/25 *(52%)*	4/6 *(67%)*	9/11 *(82%)*	0.05*
Visual Analog Scale (0-100 mm)	10(0-70)	10(0-50)	10(0-20)	0.96
Subsequent surgery	5/25 *(20%)*	none	1/11*(9%)*	0.39

† Major injury location divided into three regions and assessed by two radiologists in consensus; ‡ Overall instability including subjective symptoms of patellar instability (multiple subluxations); ≠ A subset of patients who did not undergo subsequent stabilizing surgery, the median Kujala score for the remaining patients in the femoral group; ***** Considered significant ($P \leq .05$) when femoral MPFL injury was compared to patella and midsubstance injuries.

Initial osteochondral fractures were seen in 28% (15/53) of cases, but they did not predict subsequent instability ($p=0.74$). The occurrence of osteochondral fractures was not related to MPFL injury location ($p=0.97$). Distributions of the initial chondral lesions showed no statistically significant differences between the MPFL injury locations. In radiographic measurements at the time of dislocation, 5 of 53 patients (9%) had an abnormal TG, 11 patients (21%) had patella alta, and 4 patients (8%) had an increased TT-TG distance. However, the majority of values in each MPFL injury group were normal.

At follow-up, full-thickness articular cartilage lesions as signs of PF OA development were frequently found; in 45% of cases at the medial or lateral patellar facets and in 31% of cases at the articular surface of the femoral TG. This finding was unrelated to the MPFL injury location. Patellar instability was not significantly more frequent in patients with initial osteochondral fracture when compared with patients without osteochondral fracture.

9. DISCUSSION

This thesis summarizes the incidence and risk factors of primary traumatic patellar dislocation and the long-term results of MPFL reconstruction and, furthermore, the clinical aspects of primary traumatic patellar dislocation and MPFL injury.

Primary traumatic patellar dislocation is a common injury. The population-based incidence of primary traumatic patellar dislocation is described in a sample of 130 708 young adults and the follow-up period was 96,200 person-years. Our findings indicated that patellar dislocation represents a substantial cause of morbidity in a population of young male adults. The incidence rate of 77 per 100 000 males per year was relatively high. Previously, an incidence of 43 per 100 000 was found in a Finnish pediatric population of 0 to 16 years old (Nietosvaara et al. 1994). However, the rarity of primary dislocations during the first five or ten years of age may have lowered their incidence rate. Another study has reported an incidence of primary patellar dislocations to be 31 per 100 000 in 10 to 19-year-olds and 11 per 100,000 in 20 to 29-year-olds (Atkin et al. 2000). However, the older age group included only 14 patients, and of all the patients, only 63% had medial restraint injury. A low average annual risk for primary patellar dislocation of only 9 per 100 000 was found in 18 to 29-year-olds (Fithian et al. 2004), although the incidence presented was based on patients seen at the follow-up visit. Only 49% of all their patients had an MPFL rupture, as had been shown in their previous study (Elias et al. 2002), indicating that they did not limit their sample to traumatic dislocations only. Also, the authors did not mention whether all their patients had traumatic disruption of the medial restraints.

In the first study of this thesis, when MRI or open surgery was performed the MPFL was always found ruptured (100%), indicating that a relatively high-energy trauma had occurred, mostly during sports activities, to previously noninjured medial restraints of the knee. The finding is in agreement with previous reports showing that MPFL rupture is present in about 90-100% of acute patellar dislocations (Avikainen et al. 1993; Sallay et al. 1996; Nomura 1999; Sanders et al. 2001). Traumatic patellar dislocation occurred mostly on a distally fixed extremity, in either flexed or rotated position with valgus stress, a situation typical of sport activities or military training exercises, and resulting in acute knee hemarthrosis. Most (79%) of the patients returned to physically demanding military service, which is an indication of a somewhat better recovery rate than has been previously reported (Atkin et al. 2000). The form of treatment, with or without surgery, was not associated with the number of days the patients were released from duty, which is in line with the results of the prospective studies regarding the treatment modalities for primary patellar dislocation (Nikku et al. 2005; Christiansen et al. 2008).

Height and weight were associated with an increased risk for primary patellar dislocation; the patients were somewhat taller and weighed more than the controls. It can be assumed that the energy impact on the knee during trauma may be greater in heavier and taller persons, thus contributing to patellar dislocation. It was also found that the dislocators were individuals with a normal body-mass index rather than overweight. Aerobic performance and muscle strength did not differ between the male patients with traumatic primary patellar dislocation and the controls, which can be regarded as an interesting finding. Female gender has been found to be associated with increased rates of patellar dislocation in some studies (Larsen and Lauridsen 1982; Nikku et al. 2005). In the present study, female subjects were excluded because of their small proportion (1.5%) and the bias effect due to the voluntary nature of female recruitment into the military, which would be likely to render any conclusion regarding incidence and risk factors in females inaccurate.

In the long-term follow-up, MPFL reconstruction prevented PF OA progression, as reported in the second study of this thesis. In the MPFL reconstruction group, only one patellar redislocation occurred during the median follow-up period of 10.1 years. The patients who underwent distal realignment surgery (comparison group) were treated by the Roux-Goldthwait procedure, which has been considered a reliable method for recurrent patellar dislocation in the literature (Chrisman et al. 1979; Jalovaara et al. 1988; Marcacci et al. 1995; Koskinen et al. 1998). Good long-term results were achieved in both groups with the redislocation rate being 11% (4/36). No statistically significant differences were found between the groups with the exception of PF OA seen on the plain radiographs in the distal realignment group. Recurrent patellar subluxation or dislocation may predispose to the development of PF OA (Arendt et al. 2002), although this was not confirmed by the subjective scores. There is, however, some evidence that the severity of PF OA and PF scoring do not correlate very well (Niskanen et al. 2001; Han et al. 2005).

Based on the findings of the second study, early signs of OA in the PF joint can be seen on MRI at the age of 30 years in patients with patellar dislocation. Of the 35 patients, there were five patients (14%) with PF OA visible on plain radiographs as well, all in the distal realignment group. Previously published data on patients with PF OA changes after operatively treated patellar dislocation have shown proportions between 4% and 70% (Hampson and Hill 1975; Crosby and Insall 1976; Iwano et al. 1990; Arnbjornsson et al. 1992; Mäenpää and Lehto 1997). However, these studies included a wide range of patients with ages up to 50 to 60 years, suggesting PF OA may have been caused by factors other than patellar dislocation. In this study, although the median follow-up for the MPFL reconstruction group was 3 years longer than for the distal realignment group, no PF OA was seen on plain radiographs following the MPFL reconstruction. It might be that the MPFL reconstruction technique prevented further deterioration of articular cartilage lesions and initiation of PF OA deformities.

In the third study of this thesis, the long-term outcomes after initial arthroscopic medial retinacular repair were compared with those after nonoperative treatment for primary traumatic patellar dislocation. We found that the redislocation rate after arthroscopic medial retinacular repair was not significantly lower compared to nonoperative treatment, which suggested that the initial arthroscopic medial retinacular repair showed only limited efficacy for stabilizing the patella after acute injury to the medial restraints. The only statistically significant improvement achieved by arthroscopic medial retinacular repair was that these patients were able to approach their preinjury physical activity level more closely than those treated without a stabilization procedure. Previous studies with arthroscopic PF stabilizing surgery have all, except one (Yamamoto 1986), included mainly patients with chronic patellar instability (Small et al. 1993; Henry and Pflum 1995; Ahmad and Lee 2001; Halbrecht 2001; Haspl et al. 2002; Schöttle et al. 2006); this study included only primary traumatic patellar dislocations.

Previous studies have revealed a high incidence (90% to 100%) of MPFL injuries in connection with acute patellar dislocations (Avikainen et al. 1993; Nomura 1999; Ahmad et al. 2000; Garth et al. 2000; Sanders et al. 2001). It has been hypothesized that the failure to identify and correct incompetence of the MPFL at the site of disruption may contribute to recurrent instability (Hautamaa et al. 1998). The potential benefit of the less traumatic arthroscopic surgery is that surgical complications are rare, e.g. descending and/or inferior genicular artery lesions (Andrikoula et al. 2006) and infrapatellar nerve (branch of the saphenous nerve) injuries (Andrikoula et al. 2006), which are both potential risks of open surgery. In this study, an injury to the medial restraints was seen in every patient. In the arthroscopic medial retinacular repair group, the medial restraint repair was aimed at the injury site to correct the defect. Because the MPFL is an extracapsular structure (Warren and Marshall 1979), there might not be enough visibility to assess the MPFL injury site when viewed through the arthroscope from inside the joint in case of a fresh retinacular injury. If the medial retinacular tear and midsubstance rupture of the MPFL are accompanied by MPFL avulsion off the femur, MPFL function may be inadequately restored by arthroscopic surgery only. It is known that the site of an MPFL injury varies significantly; the seen injury site may not be the only defect (Nomura 1999; Elias et al. 2002).

Based on the results of this study with a 7-year median follow-up, initial arthroscopic medial retinacular repair should be considered with caution as a treatment option for acute traumatic primary patellar dislocation when compared with nonoperative treatment. It seems likely that this procedure will not reduce the incidence of redislocations as compared with patients without a stabilizing procedure. The main explanation for the relatively unsatisfactory results of the initial arthroscopic medial retinacular repair in this study may be that it is not appropriate for all of the traumatic MPFL and medial retinacular injury patterns. An MPFL rupture site at its femoral attachment cannot be repaired by the arthroscopic medial repair technique used in this study. The significance of the stabilizing role of the MPFL was unclear at the onset of this study in 1996, and therefore we focused on confirming the diagnosis of patellar dislocation by medial restraint injury by MRI rather than assessing the specific MPFL injury sites. Recently, a mini-open medial reefing procedure (Nam and Karzel 2005) and a mini-invasive MPFL reconstruction technique (Sillanpää et al. 2009) have been described, which may have a superior role to the arthroscopic surgery for stabilizing patella.

The fourth study in this thesis was a prospective randomized controlled study comparing the outcome after treatment with and without initial stabilizing surgery for primary traumatic patellar dislocations. The principal finding was that initial stabilizing surgery significantly reduced patellar redislocations (six versus none). Within a median follow-up of seven years, however, no significant improvements in clinical scores were achieved by performing the initial stabilizing surgery. As the primary outcome of the study was subsequent patellar instability after primary dislocation, the reoperated patients in the nonoperative group were included in the follow-up evaluation even though some of them had to undergo subsequent surgery during the follow-up period. Based on the results of this study, it may be concluded that patients who have high demands of patellar stability are likely to benefit from initial surgical repair or reconstruction, since the expected rate for subsequent patellar instability after nonoperative management in previous follow-up studies has been 20-70% (Hawkins et al. 1986; Mäenpää et al. 1997; Nikku et al. 2005; Christiansen et al. 2008).

Two previous, well-designed, randomized and prospective studies of acute primary dislocations in adults were found (Nikku et al. 2005; Christiansen et al. 2008), one of which comprised mostly females (65%) and included also skeletally immature patients less than 18 years of age (Nikku et al. 2005). No significant improvement after initial operative management was demonstrated in their study. Nikku et al. did not perform MRI to find a possible traumatic injury to the medial structures, and the inclusion of skeletally immature patients may have had a confounding effect (Nikku et al. 2005). The authors discussed the study outcome with caution, considering that younger age and female preponderance have been associated with higher redislocation rates in some studies (Larsen and Lauridsen 1982; Nikku et al. 1997; Mäenpää 1998; Nikku et al. 2005). Another recent, randomized, prospective study of acute primary dislocations in patients treated with either delayed surgical reinsertion of the MPFL to its femoral attachment or by nonoperative management was reported by Christiansen et al. (Christiansen et al.

2008), who, similarly to Nikku et al. (Nikku et al. 2005), found no significant improvement after operative management. However, since initial MRI was not performed, they did not report whether femoral avulsion of the MPFL was noted in cases undergoing delayed surgical reinsertion of the MPFL to the femoral attachment. They discussed this limitation, and it is reasonable to hypothesize that some of their patients had an MPFL injury located in another site than the femoral attachment.

An interesting finding of the fourth study was that the radiographs did not reveal any traditional predisposing factors (Dejour et al. 1994; Mäenpää and Lehto 1996; Atkin et al. 2000), such as femoral trochlear dysplasia and patella alta, among the redislocators. Initial stabilizing surgery was associated with a lower redislocation rate but no difference was seen in the subjective results. The median Tegner physical activity level was also the same in both groups. On the basis of this study, MPFL and medial retinacular injuries and hemarthrosis are definite signs of an acute primary traumatic patellar dislocation. According to current clinical and research evidence, it seems rational that if traumatic patellar dislocation has occurred and an MPFL injury is identified, the choice of procedure would be medial repair or MPFL reconstruction rather than a distal realignment procedure (Mehta et al. 2007; Colvin and West 2008).

With regard to the anatomic location of the MPFL injury, the principal finding of the fifth study was that MPFL avulsion at the femoral attachment in primary traumatic patellar dislocation predicted subsequent patellar instability. A significantly lower proportion of patients with femoral avulsion type MPFL injury regained their previous activity level compared to patients with MPFL disruption in the midsubstance or patellar region. Although many studies have reported MPFL injury to be closely related to primary patellar dislocation, this study is the first to explore the clinical relevance of the anatomic location of MPFL injury after primary traumatic patellar dislocation. Thirteen of the 15 patients who had subsequent patellar instability after the primary incident suffered MPFL rupture at its femoral attachment, indicating a significant relationship between patellar instability and a femoral avulsion type MPFL injury. Based on the evidence from the present study, femoral avulsion of the MPFL is strongly associated with subsequent patellar instability if stabilizing procedures are not performed. Ruptures at the MPFL midsubstance or patellar insertion regions, or presence of primary disruption and additional partial MPFL tear, were not related to subsequent instability. These results indicate that a rupture of the MPFL at its midsubstance or at its patellar attachment can be successfully treated nonoperatively with infrequent subsequent symptoms of patellar instability. Furthermore, it may be assumed that a nonoperatively treated femoral avulsion of the MPFL may result in some potential lengthening or loosening of the MPFL ligament and in subsequent patellar instability. Therefore, if initial surgery is considered, it should be targeted at repairing the femoral MPFL avulsion, and reconstructive surgery should be aimed at restoring the integrity of the anatomic femoral attachment of the MPFL in order to ensure better stability. It must be kept in mind, that the increased Q-angle and other major dysplastic features of the PF joint should be observed before surgery.

In the current study, nonoperative treatment included the use of a commercial patellar orthosis, in which the ruptured MPFL is believed to heal with scar tissue formation while the ROM is restricted to prevent distension of the injured medial restraints. After a total rupture of the MPFL, a natural healing process might be likely to take place, but also potential lengthening of the ligament structure may follow (Mehta et al. 2007). It is not known whether knee flexion restriction prevents the MPFL lengthening, but biomechanical studies have shown that the MPFL is loose at full knee extension and tightens immediately as knee flexion progresses, though it has been debated (Feller et al. 2007). Whether the MPFL healing with scar tissue formation results in increased length in recurrent instability after primary patellar dislocation is also unknown. In the case of femoral avulsion of the MPFL, on the other hand, the ligament may theoretically fail to heal altogether due to loss of integrity of the ligamentous structure. Whether the knee should be immobilized in nearly full extension to prevent further loosening of the MPFL femoral attachment is unknown (Mäenpaa and Lehto 1997; Mehta et al. 2007). There is certainly a role for initial nonoperative management with patellar orthosis, but prospective studies are needed in the future with respect to patient suitability for different treatment modalities.

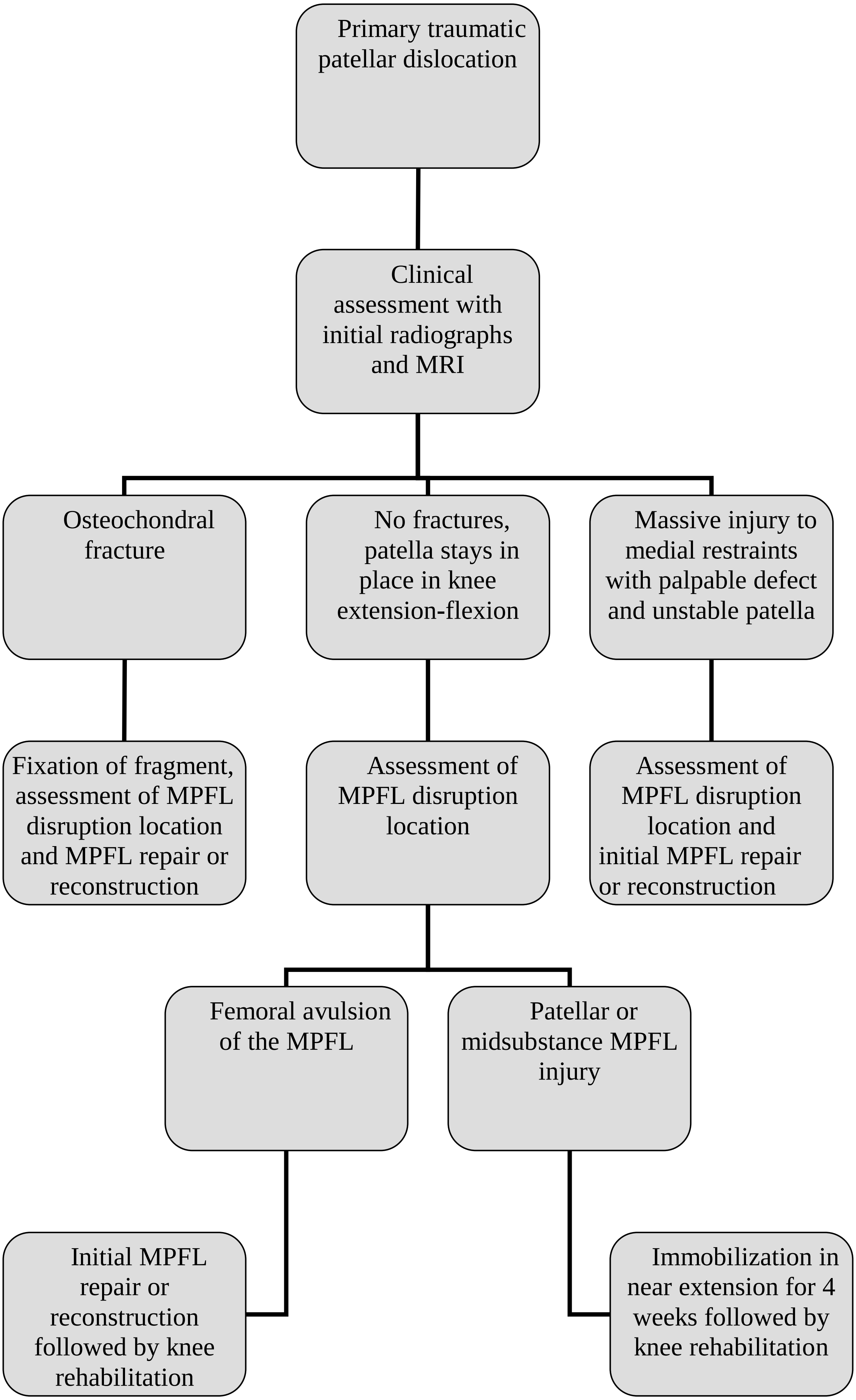
9.1 Limitations of the study

A limitation of the study was the small number of female patients. Some additional limitations were included in the data settings of this study. The first data which calculated the incidence and risk factors of primary traumatic patellar dislocation had no long-term follow-up data available. However, an opportunity to follow patients intensively during their military service was available as well as to record any possible health problems during the physically demanding military training period. The limitation of the second data was the lack of a nonoperative control group, which would have given more data of the potential benefits of MPFL reconstruction. The third data was limited by the lack of initial MRI, which was not performed on all of the arthroscopic medial retinacular repair group patients, since the treatment pathway depended of the availability of immediate arthroscopic medial repair surgery. Thus, it was impossible to determine whether patients in the arthroscopic medial retinacular repair group who suffered instability at follow-up had femoral avulsion of the MPFL. Despite this limitation, both groups consisted of relatively active young adults, with similar ages and follow-up times. Again, a limitation was the small number of female patients, and hence our findings only apply to men. Combining LRR with arthroscopic medial retinacular repair technique made it difficult to assess whether such combination was responsible for the result. The surgical procedures employed for this thesis may be considered a limitation, and hence conclusions concerning techniques other than those presented here should be drawn with caution. However, with modern MPFL reconstruction techniques, equal or even superior results could theoretically be expected.

9.2 Proposed treatment algorithm for primary traumatic patellar dislocation

The initial evaluation of a primary traumatic patellar dislocation should include appropriate patient history-taking, family history of patellar dislocation and hyperlaxity, physical examination, and diagnostic studies, especially MRI in primary traumatic patellar dislocation. A treatment algorithm for primary traumatic patellar dislocation is proposed (Figure 15) on the basis of the current literature and the results of this study.

Figure 15. Treatment algorithm for primary traumatic patellar dislocation.



10. SUMMARY AND CONCLUSIONS

The incidence, nature and clinical aspects of primary traumatic patellar dislocation were studied in this thesis. The clinical significance of MPFL injury was studied. A population-based incidence and nonanatomic risk factors for traumatic patellar dislocations were assessed among over 130 000 male adults. As pointed out in the first study, a primary traumatic patellar dislocation is a relatively common injury. It is noteworthy that a higher incidence rate was found in this study than previously reported from smaller selected populations. However, it became clear that some of the terms used in the previous literature did not have precise definitions or consistent use (e.g. acute dislocation, instability, and malalignment).

The MPFL is the primary soft-tissue restraint of the patella, and several techniques with promising results exist today to reconstruct this ligament. Restoration of the MPFL function seems to be clinically important and prevent OA progression, as shown by the second study. The role of arthroscopic stabilization of the patella remains unclear. If arthroscopic medial repair was performed in primary traumatic patellar dislocation, no stabilizing effect was achieved when compared to nonoperative treatment. The MPFL is an extra-articular structure that cannot be reconstructed arthroscopically.

The literature lacks level I trials, which would improve physicians' ability to select the best type of treatment. The prospective randomized study of this thesis was somewhat different than the two former studies published, and the only study with only traumatic primary dislocations included. Primary patellar dislocation is likely to occur in sports activities or strenuous physical stress and, therefore, a typical primary traumatic patellar dislocation is infrequently associated with traditional anatomic dysplastic features. The most important finding of the study was that if traumatic primary dislocation has occurred, patients with high demands for patellar stability are likely to benefit from initial stabilizing surgery. Although initial stabilizing surgery contributed to a more stable patella than nonoperative treatment, no difference in functional outcome scores was seen.

Injury to the MPFL has been under surveillance for the last ten years. The functional anatomy of this primary patellar stabilizer has been quite well established. The clinical significance, however, has not been studied. According to the results of this study, a significant correlation to poor outcome was found if the MPFL was avulsed from the femoral attachment. A proper approach to primary patellar dislocation should include MR imaging, and the planning of treatment for first-time traumatic patellar dislocations should be based on the location and type of the MPFL injury.

With the synthesis of the results of the fifth study, it is reasonable to further conclude that patients with primary traumatic patellar dislocations and femoral avulsion of the MPFL will benefit from initial stabilizing surgery. The surgical procedure should include MPFL reconstruction and anatomic aberrations should be addressed. Based on the results of this study, a treatment algorithm is proposed. A recommendation for nonoperative treatment for primary traumatic patellar dislocations is advocated except in the following situations: (1) femoral avulsion of the MPFL is detected on MRI; (2) osteochondral fracture are detected amenable for fixation or in need of removal; (3) MPFL injury and lateral subluxation of the patella are found in a patient with high demands for patellar stability; and (4) if the initial nonoperative management fails. Based on the studies of this thesis, initial surgical management is not needed if there is a midsubstance MPFL injury or a patellar attachment MPFL injury without a substantial osteochondral fragment. The arthroscopic procedure used in this study is not recommended for primary traumatic patellar dislocation.

In conclusion, traumatic primary patellar dislocation is not a negligible cause of morbidity among physically active young adults. MPFL reconstruction is the preferred stabilizing procedure for patellar instability, and seems to prevent OA progression in the PF joint. A recommendation is given to consider initial MPFL repair or reconstruction for primary traumatic patellar dislocation with femoral MPFL avulsion or in patients with high demands for patellar stability. A proper initial assessment of primary traumatic patellar dislocation including MR imaging should be performed.

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Petri Sillanpää

12. REFERENCES

Ahlbäck S (1968): Osteoarthrosis of the knee. A radiographic investigation. Acta Radiol Diagn (Stockh): Suppl 277:7-72.

Ahmad CS, Stein BE, Matuz D and Henry JH (2000): Immediate surgical repair of the medial patellar stabilizers for acute patellar dislocation. A review of eight cases. Am J Sports Med 28: 804-10.

Ahmad CS and Lee FY (2001): An all-arthroscopic soft-tissue balancing technique for lateral patellar instability. Arthroscopy 17: 555-7.

Amis AA, Firer P, Mountney J, Senavongse W and Thomas NP (2003): Anatomy and biomechanics of the medial patellofemoral ligament. Knee 10: 215-20.

Andrikoula S, Tokis A, Vasiliadis HS and Georgoulis A (2006): The extensor mechanism of the knee joint: an anatomical study. Knee Surg Sports Traumatol Arthrosc 14: 214-20.

Arendt EA, Fithian DC and Cohen E (2002): Current concepts of lateral patella dislocation. Clin Sports Med 21: 499-519.

Arendt EA (2007): Patellofemoral and patellotibial ligaments: Anatomy and biomechanics, paper #134. ISAKOS, Florence, Italy, May 2007.

Arnbjornsson A, Egund N, Rydling O, Stockerup R and Ryd L (1992): The natural history of recurrent dislocation of the patella. Long-term results of conservative and operative treatment. J Bone Joint Surg Br 74: 140-2.

Atkin DM, Fithian DC, Marangi KS, Stone ML, Dobson BE and Mendelsohn C (2000): Characteristics of patients with primary acute lateral patellar dislocation and their recovery within the first 6 months of injury. Am J Sports Med 28: 472-9.

Avikainen VJ, Nikku RK and Seppänen-Lehmonen TK (1993): Adductor magnus tenodesis for patellar dislocation. Technique and preliminary results.Clin Orthop: 12-6.

Baker RH, Carroll N, Dewar FP and Hall JE (1972): The semitendinosus tenodesis for recurrent dislocation of the patella. J Bone Joint Surg Br 54: 103-9.

Beck P, Brown NA, Greis PE and Burks RT (2007): Patellofemoral contact pressures and lateral patellar translation after medial patellofemoral ligament reconstruction. Am J Sports Med 35: 1557-63.

Bicos J, Fulkerson JP and Amis A (2007): Current concepts review: the medial patellofemoral ligament. Am J Sports Med 35: 484-92.

Blackburne JS and Peel TE (1977): A new method of measuring patellar height. J Bone Joint Surg Br 59: 241-2.

Boring TH and O'Donoghue DH (1978): Acute patellar dislocation: results of immediate surgical repair. Clin Orthop Relat Res: 182-5.

Brattström H (1964): Shape Of The Intercondylar Groove Normally And In Recurrent Dislocation Of Patella. A Clinical And X-Ray-Anatomical Investigation. Acta Orthop Scand Suppl 68: SUPPL 68:1-148.

Brittberg M and Winalski CS (2003): Evaluation of cartilage injuries and repair. J Bone Joint Surg Am 85-A Suppl 2: 58-69.

Buchner M, Baudendistel B, Sabo D and Schmitt H (2005): Acute traumatic primary patellar dislocation: long-term results comparing conservative and surgical treatment. Clin J Sport Med 15: 62-6.

Burks RT, Desio SM, Bachus KN, Tyson L and Springer K (1998): Biomechanical evaluation of lateral patellar dislocations. Am J Knee Surg 11: 24-31.

Carrillon Y, Abidi H, Dejour D, Fantino O, Moyen B and Tran-Minh VA (2000): Patellar instability: assessment on MR images by measuring the lateral trochlear inclination-initial experience. Radiology 216: 582-5.

Cash JD and Hughston JC (1988): Treatment of acute patellar dislocation. Am J Sports Med 16: 244-9.

Caton J, Deschamps G, Chambat P, Lerat JL and Dejour H (1982): [Patella infera. Apropos of 128 cases]. Rev Chir Orthop Reparatrice Appar Mot 68: 317-25.

Chrisman OD, Snook GA and Wilson TC (1979): A long-term prospective study of the Hauser and Roux-Goldthwait procedures for recurrent patellar dislocation. Clin Orthop Relat Res: 27-30.

Christiansen SE, Jakobsen BW, Lund B and Lind M (2008): Isolated repair of the medial patellofemoral ligament in primary dislocation of the patella: a prospective randomized study. Arthroscopy 24: 881-7.

Christoforakis J, Bull AM, Strachan RK, Shymkiw R, Senavongse W and Amis AA (2006): Effects of lateral retinacular release on the lateral stability of the patella. Knee Surg Sports Traumatol Arthrosc 14: 273-7.

Cofield RH and Bryan RS (1977): Acute dislocation of the patella: results of conservative treatment. J Trauma 17: 526-31.

Colvin AC and West RV (2008): Patellar instability. J Bone Joint Surg Am 90: 2751-62.

Conlan T, Garth WP, Jr. and Lemons JE (1993): Evaluation of the medial soft-tissue restraints of the extensor mechanism of the knee. J Bone Joint Surg Am 75: 682-93.

Cooper KH (1968): Testing and developing cardiovascular fitness within the United States Air Force. J Occup Med 10: 636-9.

Cosgarea AJ, Schatzke MD, Seth AK and Litsky AS (1999): Biomechanical analysis of flat and oblique tibial tubercle osteotomy for recurrent patellar instability. Am J Sports Med 27: 507-12.

Cossey AJ and Paterson R (2005): A new technique for reconstructing the medial patellofemoral ligament. Knee 12: 93-8.

Crosby EB and Insall J (1976): Recurrent dislocation of the patella. Relation of treatment to osteoarthritis. J Bone Joint Surg Am 58: 9-13.

Davis DK and Fithian DC (2002): Techniques of medial retinacular repair and reconstruction. Clin Orthop: 38-52.

Deie M, Ochi M, Sumen Y, Adachi N, Kobayashi K and Yasumoto M (2005): A long-term follow-up study after medial patellofemoral ligament reconstruction using the transferred semitendinosus tendon for patellar dislocation. Knee Surg Sports Traumatol Arthrosc 13: 522-8.

Dejour H, Walch G, Nove-Josserand L and Guier C (1994): Factors of patellar instability: an anatomic radiographic study. Knee Surg Sports Traumatol Arthrosc 2: 19-26.

Desio SM, Burks RT and Bachus KN (1998): Soft tissue restraints to lateral patellar translation in the human knee. Am J Sports Med 26: 59-65.

Donell ST, Joseph G, Hing CB and Marshall TJ (2006): Modified Dejour trochleoplasty for severe dysplasia: operative technique and early clinical results. Knee 13: 266-73.

Dopirak RM, Steensen RN and Maurus PB (2008): The medial patellofemoral ligament. Orthopedics 31: 331-8.

Drez D, Jr., Edwards TB and Williams CS (2001): Results of medial patellofemoral ligament reconstruction in the treatment of patellar dislocation. Arthroscopy 17: 298-306.

Elias DA, White LM and Fithian DC (2002): Acute lateral patellar dislocation at MR imaging: injury patterns of medial patellar soft-tissue restraints and osteochondral injuries of the inferomedial patella. Radiology 225: 736-43.

Elias DA and White LM (2004): Imaging of patellofemoral disorders. Clin Radiol 59: 543-57.

Elias JJ and Cosgarea AJ (2006): Technical errors during medial patellofemoral ligament reconstruction could overload medial patellofemoral cartilage: a computational analysis. Am J Sports Med 34: 1478-85.

Ellera Gomes JL (1992): Medial patellofemoral ligament reconstruction for recurrent dislocation of the patella: a preliminary report. Arthroscopy 8: 335-40.

Ellera Gomes JL, Stigler Marczyk LR, Cesar de Cesar P and Jungblut CF (2004): Medial patellofemoral ligament reconstruction with semitendinosus autograft for chronic patellar instability: a follow-up study. Arthroscopy 20: 147-51.

Escala JS, Mellado JM, Olona M, Gine J, Sauri A and Neyret P (2006): Objective patellar instability: MR-based quantitative assessment of potentially associated anatomical features. Knee Surg Sports Traumatol Arthrosc 14: 264-72.

Farahmand F, Senavongse W and Amis AA (1998): Quantitative study of the quadriceps muscles and trochlear groove geometry related to instability of the patellofemoral joint. J Orthop Res 16: 136-43.

Farahmand F, Tahmasbi MN and Amis AA (1998): Lateral force-displacement behaviour of the human patella and its variation with knee flexion--a biomechanical study in vitro. J Biomech 31: 1147-52.

Feller JA, Feagin JA, Jr. and Garrett WE, Jr. (1993): The medial patellofemoral ligament revisited: an anatomical study. Knee Surg Sports Traumatol Arthrosc 1: 184-6.

Feller JA, Amis AA, Andrish JT, Arendt EA, Erasmus PJ and Powers CM (2007): Surgical biomechanics of the patellofemoral joint. Arthroscopy 23: 542-53.

Ferguson AB, Jr., Brown TD, Fu FH and Rutkowski R (1979): Relief of patellofemoral contact stress by anterior displacement of the tibial tubercle. J Bone Joint Surg Am 61: 159-66.

Fithian DC, Paxton EW and Cohen AB (2004): Indications in the treatment of patellar instability. J Knee Surg 17: 47-56.

Fithian DC, Paxton EW, Post WR and Panni AS (2004): Lateral retinacular release: a survey of the International Patellofemoral Study Group. Arthroscopy 20: 463-8.

Fithian DC, Paxton EW, Stone ML, Silva P, Davis DK, Elias DA and White LM (2004): Epidemiology and natural history of acute patellar dislocation. Am J Sports Med 32: 1114-21.

Flandry F, Hunt JP, Terry GC and Hughston JC (1991): Analysis of subjective knee complaints using visual analog scales. Am J Sports Med 19: 112-8.

Friemert B, Oberlander Y, Schwarz W, Haberle HJ, Bahren W, Gerngross H and Danz B (2004): Diagnosis of chondral lesions of the knee joint: can MRI replace arthroscopy? A prospective study. Knee Surg Sports Traumatol Arthrosc 12: 58-64.

Fukushima K, Horaguchi T, Okano T, Yoshimatsu T, Saito A and Ryu J (2004): Patellar dislocation: arthroscopic patellar stabilization with anchor sutures. Arthroscopy 20: 761-4.

Fulkerson JP, Becker GJ, Meaney JA, Miranda M and Folcik MA (1990): Anteromedial tibial tubercle transfer without bone graft. Am J Sports Med 18: 490-6; discussion 496-7.

Fulkerson JP (2002): Diagnosis and treatment of patients with patellofemoral pain. Am J Sports Med 30: 447-56.

Garth WP, Jr., DiChristina DG and Holt G (2000): Delayed proximal repair and distal realignment after patellar dislocation. Clin Orthop: 132-44.

Goldthwait JE (1903): Slipping or recurrent dislocation of the patella: with the report of eleven cases. American Journal of Orthopedic Surgery 1: 293-308.

Grelsamer RP (2005): Patellar nomenclature: the Tower of Babel revisited. Clin Orthop Relat Res: 60-5.

Grelsamer RP, Dubey A and Weinstein CH (2005): Men and women have similar Q angles: a clinical and trigonometric evaluation. J Bone Joint Surg Br 87: 1498-501.

Halbrecht JL (2001): Arthroscopic patella realignment: An all-inside technique. Arthroscopy 17: 940-5.

Hampson WG and Hill P (1975): Late results of transfer of the tibial tubercle for recurrent dislocation of the patella. J Bone Joint Surg Br 57: 209-13.

Han I, Chang CB, Lee S, Lee MC, Seong SC and Kim TK (2005): Correlation of the condition of the patellar articular cartilage and patellofemoral symptoms and function in osteoarthritic patients undergoing total knee arthroplasty. J Bone Joint Surg Br 87: 1081-4.

Harilainen A, Myllynen P, Antila H and Seitsalo S (1988): The significance of arthroscopy and examination under anaesthesia in the diagnosis of fresh injury haemarthrosis of the knee joint. Injury 19: 21-4.

Harilainen A and Sandelin J (1993): Prospective long-term results of operative treatment in primary dislocation of the patella. Knee Surg Sports Traumatol Arthrosc 1: 100-3.

Haspl M, cicak N, Klobucar H and Pecina M (2002): Fully arthroscopic stabilization of the patella. Arthroscopy 18: E2.

Hauser ED (1938): Total tendon transplant for slipping patella: a new operation for recurrent dislocation of the patella. Clin Orthop Relat Res 452: 7-16.

Hautamaa PV, Fithian DC, Kaufman KR, Daniel DM and Pohlmeyer AM (1998): Medial soft tissue restraints in lateral patellar instability and repair. Clin Orthop: 174-82.

Hawkins RJ, Bell RH and Anisette G (1986): Acute patellar dislocations. The natural history. Am J Sports Med 14: 117-20.

Heegaard J, Leyvraz PF, Van Kampen A, Rakotomanana L, Rubin PJ and Blankevoort L (1994): Influence of soft structures on patellar three-dimensional tracking. Clin Orthop Relat Res: 235-43.

Helfet AJ (1963): Disorders of the knee. J.B. Lippincott company, Philadelphia.

Henry JE and Pflum FA, Jr. (1995): Arthroscopic proximal patella realignment and stabilization. Arthroscopy 11: 424-5.

Henry JH and Crosland JW (1979): Conservative treatment of patellofemoral subluxation. Am J Sports Med 7: 12-4.

Henry JH, Goletz TH and Williamson B (1986): Lateral retinacular release in patellofemoral subluxation. Indications, results, and comparison to open patellofemoral reconstruction. Am J Sports Med 14: 121-9.

Herrington L and Nester C (2004): Q-angle undervalued? The relationship between Q-angle and medio-lateral position of the patella. Clin Biomech (Bristol, Avon) 19: 1070-3.

Hing CB, Shepstone L, Marshall T and Donell ST (2006): A laterally positioned concave trochlear groove prevents patellar dislocation. Clin Orthop Relat Res 447: 187-94.

Hinton RY and Sharma KM (2003): Acute and recurrent patellar instability in the young athlete. Orthop Clin North Am 34: 385-96.

Hughston JC (1968): Subluxation of the patella. J Bone Joint Surg Am 50: 1003-26.

Hughston JC and Deese M (1988): Medial subluxation of the patella as a complication of lateral retinacular release. Am J Sports Med 16: 383-8.

Insall J and Salvati E (1971): Patella position in the normal knee joint. Radiology 101: 101-4.

Insall J, Goldberg V and Salvati E (1972): Recurrent dislocation and the high-riding patella. Clin Orthop Relat Res 88: 67-9.

Iwano T, Kurosawa H, Tokuyama H and Hoshikawa Y (1990): Roentgenographic and clinical findings of patellofemoral osteoarthrosis. With special reference to its relationship to femorotibial osteoarthrosis and etiologic factors. Clin Orthop Relat Res: 190-7.

Jalovaara P, Seppänen-Lehmonen T and Lindholm RV (1988): Krogius and Roux-Goldthwait operations for recurrent patellar dislocation. Acta Orthop Belg 54: 380-3.

Järvinen M (1997): Acute patellar dislocation--closed or operative treatment? Acta Orthop Scand 68: 415-8.

Jensen CM and Roosen JU (1985): Acute traumatic dislocations of the patella. J Trauma 25: 160-2.

Juliusson R and Markhede G (1984): A modified Hauser procedure for recurrent dislocation of the patella. A long-term follow-up study with special reference to osteoarthritis. Arch Orthop Trauma Surg 103: 42-6.

Kaplan EB (1957): Factors responsible for the stability of the knee joint. Bull Hosp Joint Dis 18: 51-9.

Kirsch MD, Fitzgerald SW, Friedman H and Rogers LF (1993): Transient lateral patellar dislocation: diagnosis with MR imaging. AJR Am J Roentgenol 161: 109-13.

von Knoch F, Bohm T, Burgi ML, von Knoch M and Bereiter H (2006): Trochleaplasty for recurrent patellar dislocation in association with trochlear dysplasia. A 4- to 14-year follow-up study. J Bone Joint Surg Br 88: 1331-5.

Koskinen SK, Rantanen JP, Nelimarkka OI and Kujala UM (1998): Effect of Elmslie-Trillat and Roux-Goldthwait procedures on patellofemoral relationships and symptoms in patients with patellar dislocations. Am J Knee Surg 11: 167-73.

Krogius A (1904): Zur Operative Behandlung der habituellen Luxation der Kniescheibe. Zentralbl Chir 31: 254-257.

Kujala UM, Jaakkola LH, Koskinen SK, Taimela S, Hurme M and Nelimarkka O (1993): Scoring of patellofemoral disorders. Arthroscopy 9: 159-63.

Lance E, Deutsch AL and Mink JH (1993): Prior lateral patellar dislocation: MR imaging findings. Radiology 189: 905-7.

LaPrade RF, Engebretsen AH, Ly TV, Johansen S, Wentorf FA and Engebretsen L (2007): The anatomy of the medial part of the knee. J Bone Joint Surg Am 89: 2000-10.

Larsen E and Lauridsen F (1982): Conservative treatment of patellar dislocations. Influence of evident factors on the tendency to redislocation and the therapeutic result. Clin Orthop Relat Res: 131-6.

Lattermann C, Toth J and Bach BR, Jr. (2007): The role of lateral retinacular release in the treatment of patellar instability. Sports Med Arthrosc 15: 57-60.

Laurin CA, Dussault R and Levesque HP (1979): The tangential x-ray investigation of the patellofemoral joint: x-ray technique, diagnostic criteria and their interpretation. Clin Orthop Relat Res: 16-26.

Lind M, Jakobsen BW, Lund B and Christiansen SE (2008): Reconstruction of the medial patellofemoral ligament for treatment of patellar instability. Acta Orthop 79: 354-60.

Lundberg M, Odensten M, Thuomas KA and Messner K (1996): The diagnostic validity of magnetic resonance imaging in acute knee injuries with hemarthrosis. A single-blinded evaluation in 69 patients using high-field MRI before arthroscopy. Int J Sports Med 17: 218-22.

Lustig S, Servien E, Ait Si Selmi T and Neyret P (2006): [Factors affecting reliability of TT-TG measurements before and after medialization: A CT-scan study]. Rev Chir Orthop Reparatrice Appar Mot 92: 429-36.

Lysholm J and Gillquist J (1982): Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. Am J Sports Med 10: 150-4.

Malghem J and Maldague B (1989): Depth insufficiency of the proximal trochlear groove on lateral radiographs of the knee: relation to patellar dislocation. Radiology 170: 507-10.

Marcacci M, Zaffagnini S, Iacono F, Visani A, Petitto A and Neri NP (1995): Results in the treatment of recurrent dislocation of the patella after 30 years' follow-up. Knee Surg Sports Traumatol Arthrosc 3: 163-6.

Marumoto JM, Jordan C and Akins R (1995): A biomechanical comparison of lateral retinacular releases. Am J Sports Med 23: 151-5.

Mattila VM, Sillanpää P, Iivonen T, Parkkari J, Kannus P and Pihlajamäki H (2008): Coverage and accuracy of diagnosis of cruciate ligament injury in the Finnish National Hospital Discharge Register. Injury 39: 1373-6.

McNally EG, Ostlere SJ, Pal C, Phillips A, Reid H and Dodd C (2000): Assessment of patellar maltracking using combined static and dynamic MRI. Eur Radiol 10: 1051-5.

Mehta VM, Inoue M, Nomura E and Fithian DC (2007): An algorithm guiding the evaluation and treatment of acute primary patellar dislocations. Sports Med Arthrosc 15: 78-81.

Merchant AC and Mercer RL (1974): Lateral release of the patella. A preliminary report. Clin Orthop Relat Res: 40-5.

Merchant AC, Mercer RL, Jacobsen RH and Cool CR (1974): Roentgenographic analysis of patellofemoral congruence. J Bone Joint Surg Am 56: 1391-6.

Mountney J, Senavongse W, Amis AA and Thomas NP (2005): Tensile strength of the medial patellofemoral ligament before and after repair or reconstruction. J Bone Joint Surg Br 87: 36-40.

Mulford JS, Wakeley CJ and Eldridge JD (2007): Assessment and management of chronic patellofemoral instability. J Bone Joint Surg Br 89: 709-16.

Mäenpää H and Lehto MU (1995): Surgery in acute patellar dislocation--evaluation of the effect of injury mechanism and family occurrence on the outcome of treatment. Br J Sports Med 29: 239-41

Mäenpää H and Lehto MU (1996): Patellar dislocation has predisposing factors. A roentgenographic study on lateral and tangential views in patients and healthy controls. Knee Surg Sports Traumatol Arthrosc 4: 212-6.

Mäenpää H (1997): The Dislocating Patella. Academic Dissertation. University of Tampere, Finland.

Mäenpää H, Huhtala H and Lehto MU (1997): Recurrence after patellar dislocation. Redislocation in 37/75 patients followed for 6-24 years. Acta Orthop Scand 68: 424-6.

Mäenpää H and Lehto MU (1997): Patellar dislocation. The long-term results of nonoperative management in 100 patients. Am J Sports Med 25: 213-7.

Mäenpää H and Lehto MU (1997): Patellofemoral osteoarthritis after patellar dislocation. Clin Orthop: 156-62.

Mäenpää H (1998): The dislocating patella. Predisposing factors and a clinical, radiological and functional follow-up study of patients treated primarily nonoperatively. Ann Chir Gynaecol 87: 248-9.

Mäenpää H, Latvala K and Lehto MU (2000): Isokinetic thigh muscle performance after long-term recovery from patellar dislocation. Knee Surg Sports Traumatol Arthrosc 8: 109-12.

Nam EK and Karzel RP (2005): Mini-open medial reefing and arthroscopic lateral release for the treatment of recurrent patellar dislocation: a medium-term follow-up. Am J Sports Med 33: 220-30.

Nayak RK and Bickerstaff DR (1995): Acute traumatic patellar dislocation: the importance of skyline views. Injury 26: 347-8.

Nietosvaara Y, Aalto K and Kallio PE (1994): Acute patellar dislocation in children: incidence and associated osteochondral fractures. J Pediatr Orthop 14: 513-5.

Nikku R, Nietosvaara Y, Kallio PE, Aalto K and Michelsson JE (1997): Operative versus closed treatment of primary dislocation of the patella. Similar 2-year results in 125 randomized patients. Acta Orthop Scand 68: 419-23.

Nikku R, Nietosvaara Y, Aalto K and Kallio PE (2005): Operative treatment of primary patellar dislocation does not improve medium-term outcome: A 7-year follow-up report and risk analysis of 127 randomized patients. Acta Orthop 76: 699-704.

Niskanen RO, Paavilainen PJ, Jaakkola M and Korkala OL (2001): Poor correlation of clinical signs with patellar cartilaginous changes. Arthroscopy 17: 307-310.

Nomura E (1999): Classification of lesions of the medial patello-femoral ligament in patellar dislocation. Int Orthop 23: 260-3.

Nomura E, Horiuchi Y and Kihara M (2000): A mid-term follow-up of medial patellofemoral ligament reconstruction using an artificial ligament for recurrent patellar dislocation. Knee 7: 211-215.

Nomura E, Horiuchi Y and Kihara M (2000): Medial patellofemoral ligament restraint in lateral patellar translation and reconstruction. Knee 7: 121-127.

Nomura E, Horiuchi Y and Inoue M (2002): Correlation of MR imaging findings and open exploration of medial patellofemoral ligament injuries in acute patellar dislocations. Knee 9: 139-43.

Nomura E and Inoue M (2003): Surgical technique and rationale for medial patellofemoral ligament reconstruction for recurrent patellar dislocation. Arthroscopy 19: E47.

Nomura E, Inoue M and Kurimura M (2003): Chondral and osteochondral injuries associated with acute patellar dislocation. Arthroscopy 19: 717-21.

Nomura E and Inoue M (2004): Injured medial patellofemoral ligament in acute patellar dislocation. J Knee Surg 17: 40-6.

Nomura E, Inoue M and Osada N (2005): Anatomical analysis of the medial patellofemoral ligament of the knee, especially the femoral attachment. Knee Surg Sports Traumatol Arthrosc 13: 510-5.

Nomura E, Inoue M and Osada N (2005): Augmented repair of avulsion-tear type medial patellofemoral ligament injury in acute patellar dislocation. Knee Surg Sports Traumatol Arthrosc 13: 346-51.

Nomura E and Inoue M (2006): Hybrid medial patellofemoral ligament reconstruction using the semitendinous tendon for recurrent patellar dislocation: minimum 3 years' follow-up. Arthroscopy 22: 787-93.

Nomura E, Inoue M and Kobayashi S (2007): Long-term follow-up and knee osteoarthritis change after medial patellofemoral ligament reconstruction for recurrent patellar dislocation. Am J Sports Med 35: 1851-8.

Nove-Josserand L and Dejour D (1995): [Quadriceps dysplasia and patellar tilt in objective patellar instability]. Rev Chir Orthop Reparatrice Appar Mot 81: 497-504.

Noyes FR, Butler DL, Grood ES, Zernicke RF and Hefzy MS (1984): Biomechanical analysis of human ligament grafts used in knee-ligament repairs and reconstructions. J Bone Joint Surg Am 66: 344-52.

Palmer SH, Servant CT, Maguire J, Machan S, Parish EN and Cross MJ (2004): Surgical reconstruction of severe patellofemoral maltracking. Clin Orthop: 144-8.

Palmu S, Kallio PE, Donell ST, Helenius I and Nietosvaara Y (2008): Acute patellar dislocation in children and adolescents: a randomized clinical trial. J Bone Joint Surg Am 90: 463-70.

Parker DA, Alexander JW, Conditt MA, Uzodinma ON and Bryan WJ (2008): Comparison of isometric and anatomic reconstruction of the medial patellofemoral ligament: a cadaveric study. Orthopedics 31: 339-43.

Pope TL, Jr. (2001): MR imaging of patellar dislocation and relocation. Semin Ultrasound CT MR 22: 371-82.

Quinn SF, Brown TR and Demlow TA (1993): MR imaging of patellar retinacular ligament injuries. J Magn Reson Imaging 3: 843-7.

Rantanen J and Paananen M (1996): Modified Hauser operation for patellar instability. Immediate mobilization of 35 knees, a 5-8 year follow-up study. Acta Orthop Scand 67: 455-8.

Reider B, Marshall JL, Koslin B, Ring B and Girgis FG (1981): The anterior aspect of the knee joint. J Bone Joint Surg Am 63: 351-6.

Roux C (1888): Luxation habituelle de la rotule: Traitement opératoire. Rev Chir.: 682-9.

Roux C (1979): The classic. Recurrent dislocation of the patella: operative treatment. Clin Orthop Relat Res: 4-8.

Runow A (1983): The dislocating patella. Etiology and prognosis in relation to generalized joint laxity and anatomy of the patellar articulation. Acta Orthop Scand Suppl 201: 1-53.

Sallay PI, Poggi J, Speer KP and Garrett WE (1996): Acute dislocation of the patella. A correlative pathoanatomic study. Am J Sports Med 24: 52-60.

Sanders TG, Morrison WB, Singleton BA, Miller MD and Cornum KG (2001): Medial patellofemoral ligament injury following acute transient dislocation of the patella: MR findings with surgical correlation in 14 patients. J Comput Assist Tomogr 25: 957-62.

Sandmeier RH, Burks RT, Bachus KN and Billings A (2000): The effect of reconstruction of the medial patellofemoral ligament on patellar tracking. Am J Sports Med 28: 345-9.

Schlenzka D and Schwesinger G (1990): The height of the patella: an anatomical study. Eur J Radiol 11: 19-21.

Schöttle PB, Fucentese SF and Romero J (2005): Clinical and radiological outcome of medial patellofemoral ligament reconstruction with a semitendinosus autograft for patella instability. Knee Surg Sports Traumatol Arthrosc 13: 516-21.

Schöttle PB, Scheffler SU, Schwarck A and Weiler A (2006): Arthroscopic medial retinacular repair after patellar dislocation with and without underlying trochlear dysplasia: a preliminary report. Arthroscopy 22: 1192-8.

Schöttle PB, Zanetti M, Seifert B, Pfirrmann CW, Fucentese SF and Romero J (2006): The tibial tuberosity-trochlear groove distance; a comparative study between CT and MRI scanning. Knee 13: 26-31.

Schöttle PB, Romero J, Schmeling A and Weiler A (2008): Technical note: anatomical reconstruction of the medial patellofemoral ligament using a free gracilis autograft. Arch Orthop Trauma Surg 128: 479-84.

Shakespeare D and Fick D (2005): Patellar instability-can the TT-TG distance be measured clinically? Knee 12: 201-4.

Shelbourne KD, Porter DA and Rozzi W (1994): Use of a modified Elmslie-Trillat procedure to improve abnormal patellar congruence angle. Am J Sports Med 22: 318-23.

Shih YF, Bull AM and Amis AA (2004): The cartilaginous and osseous geometry of the femoral trochlear groove. Knee Surg Sports Traumatol Arthrosc 12: 300-6.

Sillanpää PJ, Mäenpää HM, Mattila VM, Visuri T and Pihlajamäki H (2009): A mini-invasive adductor magnus tendon transfer technique for medial patellofemoral ligament reconstruction: a technical note. Knee Surg Sports Traumatol Arthrosc Epub 2009 Jan: DOI: 10.1007/s00167-008-0713-9.

Small NC, Glogau AI and Berezin MA (1993): Arthroscopically assisted proximal extensor mechanism realignment of the knee. Arthroscopy 9: 63-7.

Smirk C and Morris H (2003): The anatomy and reconstruction of the medial patellofemoral ligament. Knee 10: 221-7.

Smith TO, Hunt NJ and Donell ST (2008): The reliability and validity of the Q-angle: a systematic review. Knee Surg Sports Traumatol Arthrosc 16: 1068-79.

Spritzer CE, Courneya DL, Burk DL, Jr., Garrett WE and Strong JA (1997): Medial retinacular complex injury in acute patellar dislocation: MR findings and surgical implications. AJR Am J Roentgenol 168: 117-22.

Stanitski CL (1995): Articular hypermobility and chondral injury in patients with acute patellar dislocation. Am J Sports Med 23: 146-50.

Stanitski CL and Paletta GA, Jr. (1998): Articular cartilage injury with acute patellar dislocation in adolescents. Arthroscopic and radiographic correlation. Am J Sports Med 26: 52-5.

Steensen RN, Dopirak RM and McDonald WG, 3rd (2004): The anatomy and isometry of the medial patellofemoral ligament: implications for reconstruction. Am J Sports Med 32: 1509-13.

Steensen RN, Dopirak RM and Maurus PB (2005): A simple technique for reconstruction of the medial patellofemoral ligament using a quadriceps tendon graft. Arthroscopy 21: 365-70.

Stefancin JJ and Parker RD (2007): First-time Traumatic Patellar Dislocation: A Systematic Review. Clin Orthop Relat Res 455: 93-101.

Steiner TM, Torga-Spak R and Teitge RA (2006): Medial patellofemoral ligament reconstruction in patients with lateral patellar instability and trochlear dysplasia. Am J Sports Med 34: 1254-61.

Tecklenburg K, Dejour D, Hoser C and Fink C (2006): Bony and cartilaginous anatomy of the patellofemoral joint. Knee Surg Sports Traumatol Arthrosc 14: 235-40.

Tegner Y and Lysholm J (1985): Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res: 43-9.

Trillat A, Dejour H and Couette A (1964): [Diagnosis And Treatment Of Recurrent Dislocations Of The Patella.]. Rev Chir Orthop Reparatrice Appar Mot 50: 813-24.

Turba JE, Walsh WM and McLeod WD (1979): Long-term results of extensor mechanism reconstruction. A standard for evaluation. Am J Sports Med 7: 91-4.

Tuxoe JI, Teir M, Winge S and Nielsen PL (2002): The medial patellofemoral ligament: a dissection study. Knee Surg Sports Traumatol Arthrosc 10: 138-40.

Utting MR, Mulford JS and Eldridge JD (2008): A prospective evaluation of trochleoplasty for the treatment of patellofemoral dislocation and instability. J Bone Joint Surg Br 90: 180-5.

Vainionpää S, Laasonen E, Pätiälä H, Rusanen M and Rokkannen P (1986): Acute dislocation of the patella. Clinical, radiographic and operative findings in 64 consecutive cases. Acta Orthop Scand 57: 331-3.

Vainionpää S, Laasonen E, Silvennoinen T, Vasenius J and Rokkanen P (1990): Acute dislocation of the patella. A prospective review of operative treatment. J Bone Joint Surg Br 72: 366-9.

Warren LF and Marshall JL (1979): The supporting structures and layers on the medial side of the knee: an anatomical analysis. J Bone Joint Surg Am 61: 56-62.

Verdonk R, Jansegers E and Stuyts B (2005): Trochleoplasty in dysplastic knee trochlea. Knee Surg Sports Traumatol Arthrosc 13: 529-33.

Wiberg G (1941): Röntgenographic and anatomical studies on the patellofemoral joint: with special reference to chondromalacia patella. Acta Orthop Scand 12: 319-410.

Virolainen H, Visuri T and Kuusela T (1993): Acute dislocation of the patella: MR findings. Radiology 189: 243-6.

Visuri T, Koskenvuo M and Dahlstrom S (1993): Hemarthrosis of the clinically stable knee due to sports and military training in young recruits: an arthroscopic analysis. Mil Med 158: 378-81.

Visuri T and Mäenpää H (2002): Patellar dislocation in army conscripts. Mil Med 167: 537-40.

Wittstein JR, Bartlett EC, Easterbrook J and Byrd JC (2006): Magnetic resonance imaging evaluation of patellofemoral malalignment. Arthroscopy 22: 643-9.

Yamamoto RK (1986): Arthroscopic repair of the medial retinaculum and capsule in acute patellar dislocations. Arthroscopy 2: 125-31.

ORIGINAL COMMUNICATIONS

Clinically Relevant

Incidence and Risk Factors of Acute Traumatic Primary Patellar Dislocation

PETRI SILLANPÄÄ[1,2], VILLE M. MATTILA[1,2], TUOMO IIVONEN[2], TUOMO VISURI[2,3], and HARRI PIHLAJAMÄKI[2,3,4]

[1]*Tampere University Hospital, Tampere, FINLAND;* [2]*Centre for Military Medicine, Lahti, FINLAND;* [3]*Centre for Military Medicine, Research Department, Helsinki, FINLAND; and* [4]*Department of Orthopaedic Surgery, Central Military Hospital, Helsinki, FINLAND*

ABSTRACT

SILLANPÄÄ, P., V. M. MATTILA, T. IIVONEN, T. VISURI, and H. PIHLAJAMÄKI. Incidence and Risk Factors of Acute Traumatic Primary Patellar Dislocation. *Med. Sci. Sports Exerc.*, Vol. 40, No. 4, pp. 606–611, 2008. **Purpose:** The purpose of this study was to investigate incidence, nature, and risk factors of primary traumatic patellar dislocations. **Methods:** We identified acute first-time traumatic patellar dislocations from a national hospital discharge register. Patients with previous patellar dislocations, subluxations, or knee traumas were excluded. The sample consisted of 128,714 Finnish male conscripts (median age 20). Background risk factor data were obtained from a Finnish conscript service database. The dislocators were observed during their service period for a short-term outcome. **Results:** From the 128,714 male conscripts, 278 had patellar dislocations, and 72 were classified as having sustained first-time traumatic patellar dislocations. The 128,436 nondislocators served as a control group. The incidence of acute traumatic primary patellar dislocations among male conscripts was 77.4 (95% CI: 61.1–96.8) per 100,000 persons per year. The male patients with traumatic primary patellar dislocations were taller ($P = 0.03$) and weighed more ($P = 0.02$) than the controls. Hemarthrosis was present in all patients, and when MRI or open surgery was performed, medial retinacular disruption and medial patellofemoral ligament (MPFL) injury were identified. Patients' return to military service was unrelated to the choice of treatment. **Conclusion:** Primary patellar dislocation is not a negligible cause of morbidity among young male adults. It can be concluded that hemarthrosis and MPFL rupture are the definite signs of an acute traumatic primary patellar dislocation. Height and weight were significant risk factors, whereas poor physical performance was not associated with primary patellar dislocation. **Key Words:** PATELLA, EPIDEMIOLOGY, MEDIAL PATELLOFEMORAL LIGAMENT, MILITARY TRAINING, WOUNDS AND INJURIES

Primary dislocation of the patella is a common cause of morbidity in physically active young adults (37,38). Atkin and colleagues (3) characterized the first-time patella dislocators as young active persons with few conventional predisposing factors. Acute traumatic patellar dislocation has been described as one of the most common causes of acute traumatic hemarthrosis of the knee (13,37). Moreover, recurrence rates after primary dislocation can be relatively high, up to 40% (22). Despite the substantial overall morbidity caused by patellar dislocations among young, active persons, the incidence of primary traumatic dislocations of the patella has been poorly described. The limitations of the existing studies include an imprecise definition of the primary patellar dislocation, meaning that acute, traumatic, first-time dislocations have not been adequately distinguished from habitual or nontraumatic dislocations (35).

One of the common findings related to acute, primary, traumatic patellar dislocations is hemarthrosis of the knee, caused by rupture of the medial restraints of the patella (18,34,36). Dislocations without an acute knee hemarthrosis may be associated with the pathology of the patellofemoral joint, such as patella alta (5,16), increased femoral sulcus angle (9,26), increased Q-angle, and ligament hyperlaxity with loose medial restraints, which may cause malalignment of the patella (23,30). Thus, patients with these proposed predisposing factors usually have a history of previous patellar subluxations or dislocations, and a dislocation may occur even while doing normal daily activities and without sustaining additional traumas, such as forceful internal rotation and knee valgus stress. To investigate the accurate incidence and risk factor figures of a first-time patellar dislocation, this study focused only on traumatic primary patellar dislocations.

In addition to the pathology of the patellofemoral joint, only a few nonanatomic risk factors for patellar dislocations

Address for correspondence: Petri Sillanpää, M.D., Kerkkäkatu 5, FIN-33820 Tampere, Finland; E-mail: petri.sillanpaa@uta.fi.
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have been described, including female sex and overweight (8,21). Although there is no consensus regarding female preponderance (3,15), the female sex has been found to predict a higher recurrence rate (28). To our knowledge, the association between modifiable risk indicators, such as muscle strength and physical fitness, and patellar dislocation, has not been previously described. There is some evidence that quadriceps muscular weakness is associated with patellar dislocations (29), but no population-based data exist.

The importance of a patient's first patellar dislocation cannot be overemphasized. The sequelae can be harmful and have been well described in the literature (2,21). More than 50% of patients have complaints after the first-time dislocation of the patella (24), and some level of osteoarthrosis of the patellofemoral joint will likely develop with long-term follow-up (25). Previous studies show a preference for nonoperative treatment of primary patellar dislocations (1,6,28), whereas patients with habitual dislocations and patellofemoral symptoms seem to benefit from reconstructive surgery (11,19). Stefancin and Parker recommended initial nonoperative treatment of a first-time traumatic patellar dislocation in their systematic review of 70 articles (35). The differentiation of acute primary patellar dislocation from habitual dislocation is, therefore, important because of the varying treatment recommendations in response to these two clinical situations.

Only two papers concerning the incidence rate of primary patellar dislocation in a population-based setting among adults have been published (3,12). However, those publications, from the same group in San Diego, CA, included nontraumatic dislocations, and approximately one third of the patients had injuries not related to sports or physical activity. The aim of the present study was to investigate the incidence, nature, and risk factors of acute primary traumatic patellar dislocations in young male adults.

MATERIALS AND METHODS

Between January 1, 1998 and December 31, 2002, all Finnish conscripts admitted to a military hospital as inpatients for the treatment of patellar dislocation were analyzed to assess the epidemiological figures, as described later. The total number of conscripts who started their service during the study period 1998–2002 was 130,708, including 1994 (1.5%) women. The length of the service period was 6, 9, or 12 months, and a new batch of conscripts entered twice a year, in January and July. The dates of entry and transfer or discharge of every conscript in our study were registered, and these data were used in this study to calculate the total time at risk. During the 5-yr study period, Finnish conscripts aged 17–30 yr (median = 20 yr) served a total of 96,200 person-years.

Military service is compulsory to all Finnish men deemed fit for service at the entrance medical examination, and 80% of them serve their service period to the full. Women have been able to enter the military service on a voluntary basis since 1994. All residents of Finland are assigned a 10-digit number, which, after approval by the appropriate authority and ethical committee, may be used in scientific research. Using this identification number, we linked the conscripts' primary diagnosis, medical records, and background data to the Finnish National Hospital Discharge Register (NHDR). In addition to diagnosis, the NHDR provides information about the cause of injury, length of hospitalization, and age and domicile of the patient. Established in 1967, the Finnish NHDR is continually updated and monitored for quality by the Department of Registers and Statistics of the National Research and Development Center for Welfare and Health, Helsinki, Finland.

During their military service period, all conscripts were required to use the services of the military hospitals. Admission or visit to a private hospital or clinic is forbidden for conscripts, and, even if they were first attended to (against regulations) in a civilian hospital, they were promptly transferred to a military hospital. Therefore, any interruption of daily military service is registered, and injury data are recorded in the NHDR database.

This study focused on patellar dislocations meeting the definition of an acute traumatic physical injury resulting in a first-time patellar dislocation. To identify the patients, first, the appropriate diagnosis code S83.0 of the 10th (1996–1999: ICD-10) revision of the International Classification of Diseases (39) for acute traumatic patellar dislocation was used (both primary and secondary dislocations included). Patellar dislocation data were obtained from the NHDR concerning all Finnish conscripts admitted alive to military hospitals as inpatients for the treatment of patellar dislocation between January 1, 1998 and December 31, 2002. The original medical records of all patients hospitalized with the main diagnosis of S83.0 were then obtained for reevaluation by the authors. Altogether, 287 conscripts with patellar dislocations were identified.

The inclusion criterion for the present study was an acute, first-time traumatic patellar dislocation confirmed by MRI, arthroscopy, or physical examination by an orthopedic surgeon (palpable defect or tenderness of the medial patellar stabilizers and dislocatable patella). The exclusion criteria were a history of previous patellar dislocations in the same knee, subluxations, or other previous traumas or major complaints of the knee joint, and first-time patellar dislocation without trauma. Thus, nontraumatic situations, such as dislocation during normal gait or squatting, or dislocation without forceful knee stress, were excluded. Traumatic dislocations occurred mainly during sports activities or military exercises, and the patients were admitted, almost immediately afterward, to hospital for acute knee pain.

After careful reconsideration of the medical records, 74 of the 287 conscripts identified with a dislocated knee were classified as having sustained a first-time traumatic patellar dislocation without a history of previous knee trauma or knee joint complaint. One patient had sustained a bilateral dislocation (two independent traumatic dislocations); thus, a total of 75 knees were involved. Only two females were found; therefore, we excluded them from the analysis.

The population of 128,714 male conscripts was analyzed as two groups: the subject group, consisting of 72 patients with a total of 73 primary traumatic dislocations; and the control group, consisting 128,436 male conscripts without patellar dislocation (206 male conscripts with secondary or nontraumatic dislocations occurring during military service were excluded from the risk factor analysis) (Fig. 1). The remaining 1994 (1.5%) females from a total of 130,708 conscripts were excluded from the analysis, because no reliable generalization to a female population can be drawn The incidence rate for traumatic primary patellar dislocations was calculated by dividing the number of knees with a first-time traumatic patellar dislocation by the total exposure time. The corresponding 95% confidence intervals (CI) were calculated, and the incidence rate was presented per 100,000 persons per year.

We followed the patients from the day of entrance until completion of their military service. According to army regulations, conscripts with health complaints preventing them from attending normal military service (such as patellar dislocation) were required to seek medical assistance without delay, as provided by the Finnish Defence Forces. The number of days exempted from duty was used to describe the morbidity as well as the consequences of the acute, traumatic, first-time patellar dislocations in this study. In cases of severe impairment from trauma, the service of the conscript could be postponed for 6–12 months, after consideration by physician. The IRB accepting this study was the medical ethics committee of the Finnish Defence Forces. Because the study was based on register data, and no clinical patients were enrolled, informed written consent was not required.

Information on conscripts' background variables, such as service data and physical fitness, has been collected, since

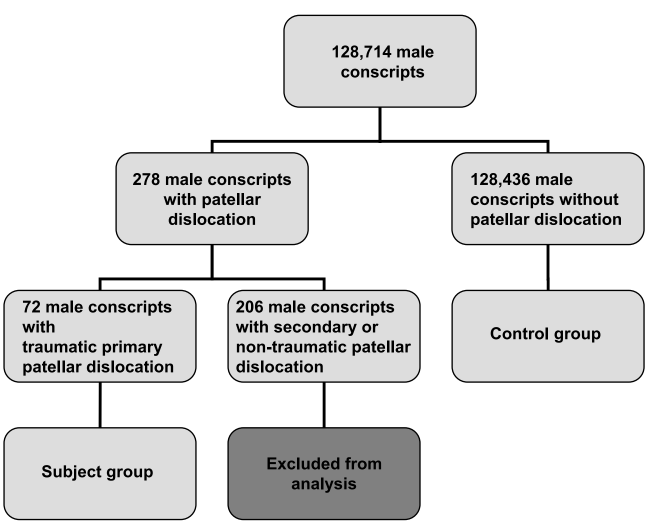

FIGURE 1—Primary traumatic patellar dislocations among 128,714 Finnish male conscripts, and selection of study participants for risk factor analysis.

1997, into a computer-stored database. The data include the age, sex, height, and weight of every conscript, as measured during the first days of military service. In addition, aerobic and physical fitness are assessed during the first weeks of the military service; aerobic fitness is based on the Cooper 12-min run test and a physical fitness score with five measures obtained for muscle strength. Muscle strength was assessed using five standardized Finnish Defence Forces muscle strength tests: standing long-jump distance, and the number of sit-ups, push-ups, pull-ups, and back extensions, each with a test score of 0–3 points. Standing long jump using both feet was performed twice, and the better result was recorded. Sit-ups were done with the subject lying supine on the floor, with hands behind the neck and directing the elbows straight forward. The knees were flexed at an angle of 90°. The result of this test was expressed as the number of sit-ups completed in 60 s. The number of push-ups in 60 s were recorded, from the lowest face-down position until arms were fully extended while keeping the torso straight. The number of completed pull-ups in 60 s was recorded. Back extensions were done, with hands behind the neck while lying face down, and the number of times the shoulder was raised 30 cm from the floor during 60 s was calculated. Summing the scored items yielded an overall muscle strength score, with a maximum of 15 points.

MRI was performed at the time of the primary traumatic dislocation, both to ensure diagnosis and to define the possible injuries of the medial restraints (disruptions of medial retinaculum and the medial patellofemoral ligament (MPFL)). MRI was not an inclusion criterion, and, thus, MRI was not performed in all of the 73 dislocations. All MR images were viewed by the same senior, musculoskeletally specialized radiologist, to minimize interobserver error. An MRI 1.0-T scanner was used (Signa Horizon, GE Medical Systems, Milwaukee). A knee coil with a field of view (FOV) of 10–16 cm was used. Slice thickness was 3 mm, with a 0.5- or 1.0-mm intersection gap. Sagittal proton density (PD) spin-echo (SE) sequence images with fat suppression (repetition time (TR)/echo time (TE) = 3400 ms/17 ms, with two signals averaged and a 256 × 256 (516) matrix) and sagittal T1-weighted spin-echo (SE) sequence images (680/11, with two signals averaged and a 256 × 256 (512) matrix) were obtained. T2-weighted fast spin-echo (FSE) sequences with fat suppression were obtained in the axial images (2560/85, with two signals averaged and a 256 × 256 (512) matrix) and in the coronal images (4000–4600/72–90, with two signals averaged and a 256 × 256 (512) matrix).

The Kruskal–Wallis test was used to test differences in the continuous skewed data (age), and the independent-samples *t*-test was used for the continuous unskewed data (height, weight, BMI, muscle strength, run test) between groups (primary traumatic patellar dislocation: yes/no). Differences in the two-way tables were determined with the Pearson chi-square test. Significance was set at $P \leq 0.05$.

SPSS 12.0.1 for Windows (SPSS Inc., Chicago, IL) was used for the statistical analysis.

RESULTS

The number of acute traumatic primary patellar dislocations among male conscripts was 73, and the calculated incidence was 77.4 (95% CI: 61.1–96.8) per 100,000 persons per year; the corresponding figures in females were 2 and 104.6 (95% CI: 0 to 248.1) per 100,000 persons per year. Because of the small amount of female cases, they were excluded from the analysis. The median age of the male patients was 20 yr (range, 18–23 yr) (Table 1). Twenty-two male patients (30%) suffered acute traumatic patellar dislocations during the first month of service. The median service time before dislocation was 90 d (range, 4–313 d). Forty right patellae and 35 left patellae were involved (including one male patient with two independent dislocations in both knees).

Forty-six male cases (63%) occurred in sports activities, and 27 male cases (37%) occurred in military training. The most common injury events were a same level fall in 21 cases (29%), near-fall with valgus knee stress in 20 cases (27%), collision with other person in 16 cases (22%), and other event (wrestling, climbing, weight lifting, combat training) in 16 cases (22%) during military exercises or sporting activities. Knee flexion with tibial valgus position was the leading mechanism of injury (93% of the cases), and a direct impact to the knee from falling to the ground was the cause of patellar dislocation in 7% of the cases. In most cases, the diagnosis of acute traumatic patellar dislocation was made on the day of the onset of the injury (range, 0–15 d).

Hemarthrosis, either seen during arthroscopy or confirmed by puncture, was found in all of the patients with an acute traumatic primary patellar dislocation (100%). Even though hemarthrosis was not an inclusion criterion, it was present in all of the 73 male conscripts' dislocations. In 28 male patients (38%) who underwent MRI scans, the specific findings included visualized MPFL and medial retinacular ruptures in all 28 dislocated kneecaps (100%), and in three patients who underwent open surgery, a rupture of MPFL was found in all three cases. MRI was performed within a median of 4 d (range, 1–28 d) from the injury. Concomitant injuries included 32 (44%) patients with an osteochondral fracture (present in 12/28 MRI cases), three meniscal ruptures (4%), and an ACL rupture in one patient (1%).

TABLE 1. Risk factors for acute traumatic primary patellar dislocations among Finnish male conscripts (mean and standard deviation).

	Acute Traumatic Primary Patellar Dislocation (*N* = 72)	Healthy Controls (*N* = 128,436)	
Risk Factor	Mean (SD)	Mean (SD)	*P* Value
Age (yr)	19.8 (0.9)	20.0 (1.3)	0.287
Height (cm)	180.5 (7.3)	178.7 (6.6)	0.033*
Weight (kg)	77.2 (14.5)	73.3 (12.7)	0.018*
Muscle strength (points)	16.4 (3.6)	16.4 (3.6)	0.913
Run test (m)	2500 (372)	2520 (355)	0.719
Body mass index	23.6 (3.9)	22.9 (3.5)	0.125

* Significant with *P* value < 0.05.

The treatment of the traumatic primary patellar dislocations in male adults at the military hospitals was nonoperative (without arthroscopy) in 27 cases (37%). It included knee-immobilization orthosis and quadriceps-setting exercises, which were started as soon as possible. With the use of orthosis, the affected knee flexion was allowed to progress 90° within 4 wk, after which all motion restrictions were withdrawn. After regaining an adequate quadriceps function, the patient was returned to his military unit and exempted from strenuous military training. Crutches were used if needed. Initial arthroscopy was performed in the acute phase in 30 knees (41%) (less than 1 wk from the injury) because of osteochondral fractures or meniscal ruptures. Sixteen knees (22%) underwent initial patellar dislocation surgery, including open repair of the medial retinaculum by duplication in 11, arthroscopic repair by duplication in two, and MPFL reconstruction by adductor magnus tenodesis in three (4).

Ten male patients were permanently discharged from military service because of patellar dislocation (one with ruptured ACL), and five patients were transferred to physically less demanding duties; thus, 57 of 72 patients (79%) were able to return to military service. Those continuing regular military service returned to the normal training activity within a median of 51 d (range, 15–120 d). One redislocation occurred during the follow-up period. The type of treatment (operative vs nonoperative) was not associated with the number of days exempted from duty (P = 0.26). The male patients with traumatic primary patellar dislocations were taller (180.5 vs 178.7 cm; P = 0.03) and weighed more (77.2 vs 73.3 kg; P = 0.02) than the controls (Table 1). The occurrence of acute traumatic primary patellar dislocation was not associated with body mass index (P = 0.13), results in the 12-min run test (P = 0.72), or muscle strength (P = 0.91).

DISCUSSION

In this study, the incidence of acute traumatic primary patellar dislocations was described in a large sample of 130,708 young adults, and the follow-up period was 96,200 person-years. Our findings indicate that patellar dislocations represent a substantial cause of morbidity among the young, active, male population. The incidence rate of 77 per 100,000 males per year was relatively high. An incidence of 43 per 100,000 was found by Nietosvaara et al. (27) in a Finnish pediatric population 0–16 yr old. However, a rare occurrence of primary dislocations during the first 5 or 10 yr of age may lower their incidence. Atkin and colleagues (3) report incidences of primary patellar dislocation of 31 per 100,000 in 10- to 19-yr-olds and 11 per 100,000 in 20- to 29-yr-olds. However, their older age group included only 14 patients, and of all the patients, only 63% had medial retinacular injury. Fithian et al. (12) found the average annual risk for primary patellar dislocation to be only 9 per 100,000 in 18- to 29-yr-olds, although the incidence presented was based on patients seen at the follow-up visit. Only 49% of all their patients had MPFL ruptures (10). The limitations of those studies include a relatively small number of patellar dislocations in those age groups. Additionally, traumatic dislocations were not emphasized in those two studies, which also failed to prove whether all their patients had traumatic disruption of the medial restraints. Consequently, presence of hemarthrosis was not shown in all of their cases. The sample of the present study closely conformed to the characterization of Atkin and colleagues (3), who has described first-time patella dislocators as active, young persons.

In this study, with a sole focus on acute, traumatic, primary patellar dislocations, hemarthrosis was found in every dislocated kneecap. When MRI or open surgery was performed, the MPFL was always (100%) ruptured, indicative of a relatively high-energy trauma to previously noninjured medial restraints of the knee, occurring mostly during sports activities. The clinical significance of this ligament is well established, because it has been reported that the MPFL is responsible for more than 50% of the medial restraining force against lateral dislocation of the patella (7,14). Furthermore, the previous reports show that MPFL rupture is present in about 90–100% of acute dislocations of the knee (4,31,33).

In the present study, traumatic patellar dislocation occurred mostly on a distally fixed extremity, in either flexed or rotated position with valgus stress—a situation typical of military training or sport activities, and resulting in knee hemarthrosis. Seventy-nine percent of the male patients returned to their physically demanding military service, which is an indication of a better recovery rate than previously reported (3). Furthermore, they resumed normal training within a median of 51 d after injury. Although our aim was not to evaluate the treatment outcome for primary traumatic patellar dislocations, it is noteworthy that if measured by the number of days the patient was released from active military duty, the rehabilitation time was only slightly longer for the operated versus nonoperated male patients. Thus, the type of treatment was not associated with the days exempted from duty.

The strengths of this study include that the data of injury hospitalizations were obtained from the Finnish National Hospital Discharge Register, which is the oldest nationwide discharge register in the world. It includes the entire population of Finland, and its accuracy has been shown to be excellent (17,32). To avoid overestimation of the incidence of acute, traumatic, primary patellar dislocations, all medical records were reviewed, and all cases with a history of previous patellar dislocations were excluded. Moreover, because the exposure times were precisely known during conscription, the incidence figures could be calculated with great accuracy.

A limitation of the present study was the lack of female cases and a relatively short follow-up period. Although we had the opportunity to observe patients intensively during their military service, and to record any possible health problems during their physically demanding training period, no data were available for the postmilitary time. However, the primary aim of this study was to describe the population-based incidence of acute, traumatic, primary patellar dislocation—not to delineate the outcome of the treatment.

The type of treatment, with or without surgery, was not associated with the number of days exempted from duty. It must be remembered that the patients were not randomized between the treatment groups; thus, it is possible that patients with fewer symptoms and findings in their knees had been treated conservatively. This finding is, nonetheless, in line with the previous literature (6,28,35). The existing follow-up studies suggest that primary patellar dislocations may be treated conservatively (28,35). In this study, nonoperatively treated patients underwent a brief 2- to 4-wk immobilization period and rehabilitation program starting with isometric quadriceps exercises, allowing the medial retinacular and MPFL ruptures to heal. The importance of initial MPFL reconstruction in primary dislocation of the patella has been unclear. According to the 38% of male patients with MRI performed in this study, no short-term benefits are produced by initial surgery when the MPFL is ruptured.

The male patients were somewhat taller and weighed more than the controls. It can be assumed that the energy impact on the knee during trauma may be greater in heavier and taller persons, thus contributing to patellar dislocation. Aerobic performance and muscle strength did not differ between the male patients with traumatic primary patellar dislocation and the controls. Female gender has been found to be associated with increased rates of patellar dislocations in some studies (20,28). In the present study, female subjects were excluded because their small proportion (1.5%) and a bias effect attributable to the voluntary nature of female recruitment into the military was likely to render any conclusion regarding incidence and risk factors in females inaccurate.

To sum up, with an incidence of 77 per 100,000 person-years in male military conscripts, acute traumatic primary patellar dislocations are not a negligible cause of morbidity among physically active young male adults. No association was found between conscripts' poor aerobic fitness or muscle strength and traumatic primary patellar dislocations. Patients' return to service was unrelated to the choice of treatment, and 79% returned to normal training activity within a median of 51 d after injury. Hemarthrosis was found in all of the patients, and when MRI or open surgery was performed, the MPFL was always ruptured. It can be concluded that hemarthrosis and medial retinacular and MPFL ruptures are the definite signs of an acute, traumatic, primary patellar dislocation. Furthermore, our findings suggest that in this population, no short-term benefits are produced by initial surgery when the MPFL is ruptured.

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CLINICAL SCIENCES

REFERENCES

1. Arendt EA, Fithian DC, Cohen E. Current concepts of lateral patella dislocation. *Clin Sports Med*. 2002;21:499–519.
2. Arnbjornsson A, Egund N, Rydling O, Stockerup R, Ryd L. The natural history of recurrent dislocation of the patella. Long-term results of conservative and operative treatment. *J Bone Joint Surg Br*. 1992;74:140–2.
3. Atkin DM, Fithian DC, Marangi KS, Stone ML, Dobson BE, Mendelsohn C. Characteristics of patients with primary acute lateral patellar dislocation and their recovery within the first 6 months of injury. *Am J Sports Med*. 2000;28:472–9.
4. Avikainen VJ, Nikku RK, Seppanen-Lehmonen TK. Adductor magnus tenodesis for patellar dislocation. Technique and preliminary results. *Clin Orthop*. 1993:12–6.
5. Blackburne JS, Peel TE. A new method of measuring patellar height. *J Bone Joint Surg Br*. 1977;59:241–2.
6. Buchner M, Baudendistel B, Sabo D, Schmitt H. Acute traumatic primary patellar dislocation: long-term results comparing conservative and surgical treatment. *Clin J Sport Med*. 2005;15:62–6.
7. Conlan T, Garth WP Jr, Lemons JE. Evaluation of the medial soft-tissue restraints of the extensor mechanism of the knee. *J Bone Joint Surg Am*. 1993;75:682–93.
8. Crosby EB, Insall J. Recurrent dislocation of the patella. Relation of treatment to osteoarthritis. *J Bone Joint Surg Am*. 1976;58:9–13.
9. Dejour H, Walch G, Nove-Josserand L, Guier C. Factors of patellar instability: an anatomic radiographic study. *Knee Surg Sports Traumatol Arthrosc*. 1994;2:19–26.
10. Elias DA, White LM, Fithian DC. Acute lateral patellar dislocation at MR imaging: injury patterns of medial patellar soft-tissue restraints and osteochondral injuries of the inferomedial patella. *Radiology*. 2002;225:736–43.
11. Fithian DC, Paxton EW, Cohen AB. Indications in the treatment of patellar instability. *J Knee Surg*. 2004;17:47–56.
12. Fithian DC, Paxton EW, Stone ML, et al. Epidemiology and natural history of acute patellar dislocation. *Am J Sports Med*. 2004;32:1114–21.
13. Harilainen A, Myllynen P, Antila H, Seitsalo S. The significance of arthroscopy and examination under anaesthesia in the diagnosis of fresh injury haemarthrosis of the knee joint. *Injury*. 1988;19:21–4.
14. Hautamaa PV, Fithian DC, Kaufman KR, Daniel DM, Pohlmeyer AM. Medial soft tissue restraints in lateral patellar instability and repair. *Clin Orthop*. 1998:174–82.
15. Hughston JC. Subluxation of the patella. *J Bone Joint Surg Am*. 1968;50:1003–26.
16. Insall J, Goldberg V, Salvati E. Recurrent dislocation and the high-riding patella. *Clin Orthop Relat Res*. 1972;88:67–9.
17. Keskimaki I, Aro S. Accuracy of data on diagnosis, procedures and accidents in the Finnish Hospital Discharge Register. *Int J Health Sci*. 1991;2:15–21.
18. Kirsch MD, Fitzgerald SW, Friedman H, Rogers LF. Transient lateral patellar dislocation: diagnosis with MR imaging. *AJR Am J Roentgenol*. 1993;161:109–13.
19. Koskinen SK, Rantanen JP, Nelimarkka OI, Kujala UM. Effect of Elmslie-Trillat and Roux-Goldthwait procedures on patellofemoral relationships and symptoms in patients with patellar dislocations. *Am J Knee Surg*. 1998;11:167–73.
20. Larsen E, Lauridsen F. Conservative treatment of patellar dislocations. Influence of evident factors on the tendency to redislocation and the therapeutic result. *Clin Orthop Relat Res*. 1982:131–6.
21. Maenpaa H. The dislocating patella. Predisposing factors and a clinical, radiological and functional follow-up study of patients treated primarily nonoperatively. *Ann Chir Gynaecol*. 1998;87:248–9.
22. Maenpaa H, Huhtala H, Lehto MU. Recurrence after patellar dislocation. Redislocation in 37/75 patients followed for 6–24 years. *Acta Orthop Scand*. 1997;68:424–6.
23. Maenpaa H, Lehto MU. Patellar dislocation has predisposing factors. A roentgenographic study on lateral and tangential views in patients and healthy controls. *Knee Surg Sports Traumatol Arthrosc*. 1996;4:212–6.
24. Maenpaa H, Lehto MU. Patellar dislocation. The long-term results of nonoperative management in 100 patients. *Am J Sports Med*. 1997;25:213–7.
25. Maenpaa H, Lehto MU. Patellofemoral osteoarthritis after patellar dislocation. *Clin Orthop*. 1997:156–62.
26. Malghem J, Maldague B. Depth insufficiency of the proximal trochlear groove on lateral radiographs of the knee: relation to patellar dislocation. *Radiology*. 1989;170:507–10.
27. Nietosvaara Y, Aalto K, Kallio PE. Acute patellar dislocation in children: incidence and associated osteochondral fractures. *J Pediatr Orthop*. 1994;14:513–5.
28. Nikku R, Nietosvaara Y, Aalto K, Kallio PE. Operative treatment of primary patellar dislocation does not improve medium-term outcome: a 7-year follow-up report and risk analysis of 127 randomized patients. *Acta Orthop*. 2005;76:699–704.
29. Nove-Josserand L, Dejour D. Quadriceps dysplasia and patellar tilt in objective patellar instability. *Rev Chir Orthop Reparatrice Appar Mot*. 1995;81:497–504.
30. Runow A. The dislocating patella. Etiology and prognosis in relation to generalized joint laxity and anatomy of the patellar articulation. *Acta Orthop Scand Suppl*. 1983;201:1–53.
31. Sallay PI, Poggi J, Speer KP, Garrett WE. Acute dislocation of the patella. A correlative pathoanatomic study. *Am J Sports Med*. 1996;24:52–60.
32. Salmela R, Koistinen V. Is the discharge register of general hospitals complete and reliable? [in Finnish]. *Sairaala*. 1987;49:480–2.
33. Sanders TG, Morrison WB, Singleton BA, Miller MD, Cornum KG. Medial patellofemoral ligament injury following acute transient dislocation of the patella: MR findings with surgical correlation in 14 patients. *J Comput Assist Tomogr*. 2001;25:957–62.
34. Spritzer CE, Courneya DL, Burk DL, Garrett WE, Strong JA. Medial retinacular complex injury in acute patellar dislocation: MR findings and surgical implications. *AJR Am J Roentgenol*. 1997;168:117–22.
35. Stefancin JJ, Parker RD. First-time traumatic patellar dislocation: a systematic review. *Clin Orthop Relat Res*. 2007;455:93–101.
36. Virolainen H, Visuri T, Kuusela T. Acute dislocation of the patella: MR findings. *Radiology*. 1993;189:243–6.
37. Visuri T, Koskenvuo M, Dahlstrom S. Hemarthrosis of the clinically stable knee due to sports and military training in young recruits: an arthroscopic analysis. *Mil Med*. 1993;158:378–81.
38. Visuri T, Maenpaa H. Patellar dislocation in army conscripts. *Mil Med*. 2002;167:537–40.
39. World Health Organization. *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision*. Geneva (Switzerland): World Health Organization; 1994. p. 1–86.