Systematic Review

Treating Patella Instability in Skeletally Immature Patients

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Purpose: The purpose of this study was to comprehensively and systematically review the current evidence for orthopaedic treatment of immature and adolescent patients with acute and chronic patellar instability. **Methods:** We searched the online databases PubMed, CINAHL, EMBASE, Cochrane Central Register of Controlled Trials, and Cochrane Database of Systematic Reviews for relevant publications on patellar instability. All dates and languages were included. **Results:** Twenty articles reporting on a total of 456 knees in 425 patients (131 male patients, 294 female patients) followed-up for 56.7 ± 42.2 months on average were included in the analysis. Two studies focused specifically on conservative versus surgical treatment in acute dislocations and reported no difference in outcomes after 7 and 14 years, even in the face of slight trochlear dysplasia. For recurrent instability, we found consistent beneficial effects from surgical stabilization on clinical scores, postoperative stability, and radiographic assessment. There is no evidence for growth disturbance with surgical patellar stabilization in immature patients. **Conclusions:** The current best evidence does not support the superiority of surgical intervention over conservative treatment in an acute patellar dislocation. However, anatomic variations and their effect on healing should be considered and included in decision making. In recurrent patellar instability in pediatric and adolescent patients with normal or restored knee anatomy, reconstruction of the medial patellofemoral ligament (MPFL) is the most effective treatment option and can be done safely, together with extensor realignment as needed. **Level of Evidence:** Level IV, systematic review of mixed-level studies.

Patellofemoral problems are considered to be among the most frequent causes of knee pain in young and adolescent patients. However, the use of terminology such as "patellofemoral problem" or "anterior knee pain" shows the elusiveness of the underlying problems and the lack of clear-cut diagnostic criteria. Although anterior patellofemoral pain can be caused by a number of pathologic entities, such as patellar hypercompression and chondromalacia, this study focuses on patellar instability, both acute and recurrent, and the evidence concerning its management in pediatric and adolescent patients.

The discussion of treatment options in patellar instability in skeletally immature patients is overshadowed by concerns of damage to physes and subsequent growth disturbances.[1] Similar concerns have also materialized as barriers to the development of other musculoskeletal procedures in skeletally immature patients, (e.g., in the management of anterior cruciate ligament injuries) but have been found to be largely unsubstantiated.[2]

Treatment is chosen analogously to that in adult patients. Acute dislocations are typically treated with conservative treatment unless there is evidence of osteochondral damage. The latter are treated surgically as are recurrent dislocations.[3-5] However, it is prudent to assess the knee anatomy in acute dislocations and differentiate between those with normal anatomic features and those with underlying anatomic abnormalities, as suggested by DeJour et al.[6] In the latter, anatomic deficiencies should be considered equivalent to osteochondral damage, and early surgical intervention might be chosen to counter lateral forces that might interfere with healing, particularly of the medial patellofemoral ligament (MPFL).

This systematic review had 3 objectives: (1) to comprehensively and systematically review the current

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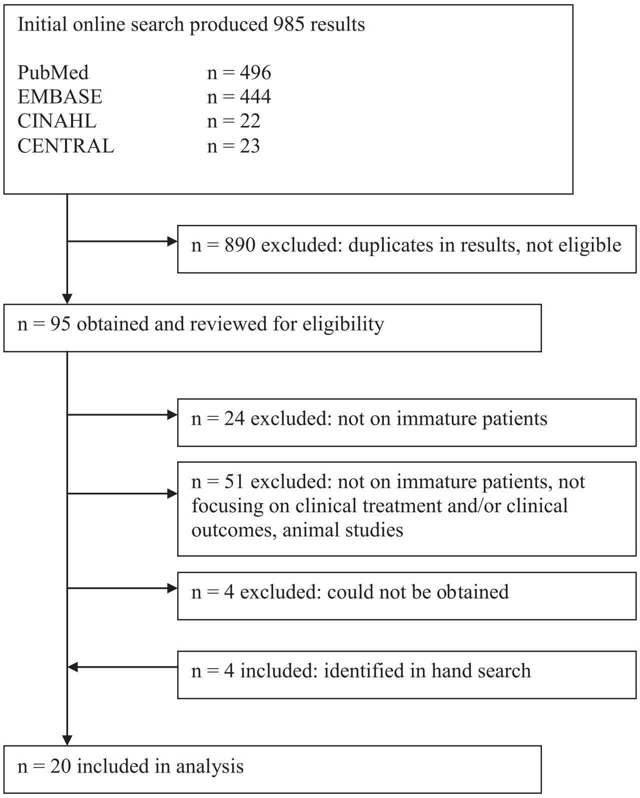

Fig 1. Flow chart of this systematic review.

evidence for orthopaedic treatment of immature and adolescent patients with patellar instability, with a special focus on acute versus recurrent instability in the sense explained earlier, (2) to systematically assess the current evidence for the different types of surgical treatments that are clinically available, and (3) to provide a summation of what is known to help identify the open questions and the pieces of evidence needed in the management of pediatric patellar instability.

Methods

We performed this study after the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses)[7,8] and QUOROM (Quality Of Reporting Of Meta-analyses)[9] statements, as described in a previous article in *Arthroscopy*.[2] Studies were included if they reported on surgical or conservative treatments (or both) of patellar instability in skeletally immature individuals or adolescents, with at least 6 months of follow-up. For the purpose of this study, immature individuals were defined as either those with radiologic proof of open physes or those at the appropriate Tanner stage (stage 4 or lower). Age was not intended as a primary inclusion criterion, but age 19 was considered the cut-off threshold between adolescence and adulthood if neither physeal status nor Tanner stage was reported. Recent anatomic studies have shown that physeal union around the knee is completed at this age in both sexes.[10-12] This age refers to the age at surgery, not at dislocation. For example, the Nomura et al.[13] study on MPFL reconstruction in 22 patients with initial trauma at a mean age of 14.8 years, but surgery at a mean age of 22.5 years, was therefore excluded.

To be included, studies had to report on clinical outcome (validated scores or recurrence of instability or dislocation, or both), and complications[14] or radiographic analyses, or both. We included studies from all levels of evidence in this review. Patellar instability in association with syndromes (e.g., Turner syndrome) was not included in this study.

We searched the online databases PubMed, CINAHL, EMBASE, Cochrane Central Register of Controlled Trials, and Cochrane Database of Systematic Reviews for relevant publications. All dates and languages were included. The last search was performed on October 1, 2012. The search algorithm was "((MPFL) OR (patellofemoral ligament) OR (patella instability)) AND ((young) OR (child) OR (pediatric) OR (paediatric) OR (immature) OR (adolescent)) AND (treatment OR management OR conservative OR surgical) AND ("humans" [MeSH] NOT "animals" [MeSH])" using keywords and medical subject heading (MeSH) terms as well. All searches were unlimited, i.e., publications in all languages and at all dates were considered. All online searches were done in duplicate. In addition to the online searches, the bibliographies of the included studies were reviewed manually to identify further publications.

Titles and abstracts from all search results were screened for eligibility. Studies were excluded if title or abstract, or both, clearly refuted eligibility. Full texts were reviewed for all studies matching the inclusion criteria and all studies with unclear eligibility. All study selections were made independently in duplicate and cross-referenced. Disagreement was resolved by consensus. Studies were grouped by acute versus recurrent instability and then by type of treatment, i.e., conservative or surgical. All surgical trials were grouped as proximal realignment, distal realignment, combined procedures, and osseous procedures. Data were extracted independently and in duplicate using standardized data collection sheets. Duplicate data extractions were compared for difference, and disagreement was resolved by consensus.

Given the heterogeneity of the included studies, a descriptive analysis was chosen instead of quantitative data synthesis. Although reporting of clinical scores and percentages of good and bad outcomes theoretically offers a chance for quantitative data synthesis and meta-analysis, we did not follow this path because of the substantial clinical heterogeneity of the patient populations, treatments, and study methodologies, which render such mathematical analysis invalid. Thus, only descriptive statistics were used.

Table 1. Characteristics of the Included Articles

Reference	Level of Evidence	Acute or Recurrent	Age (y)	Diagnosis	Control Group	Intervention Group
Palmu et al.,[18] 2008	II	Acute	13	Children younger than 16 years with an evident or suspected acute patellar dislocation	Knee immobilizer 3 wk, then patella-stabilizing orthosis 3 wk	LR and MPFL repair
Apostolovic et al.,[17] 2011	III	Acute	13.8	Patellar dislocation or instability	Closed reduction, immobilization, cold packs, eventually aspiration of effusion, isometric quadriceps exercises	LR and MPFL and medial capsular repair
Ma et al.,[20] 2012	II	Recurrent	13.5	Patellar dislocation or instability	LR and medial capsule reefing	LR and MPFL suture repair
Zhao et al.,[21] 2012	II	Recurrent	14.95	Recurrent patellar dislocation with an open epiphyseal plate at both the distal femur and proximal tibia	Medial retinaculum plication	Vastus medialis plasty
Luhmann et al.,[35] 2011	IV	Recurrent	14.1	Recurrent patellar instability (minimum 2 dislocation/subluxation episodes)	–	LR and medial reef and tendon transfer
Aulisa et al.,[32] 2012	IV	Recurrent	11.6	Recurrent dislocations (at least 2-3), Tanner stage <3, no associated meniscal or cartilaginous injuries	–	Galeazzi ST tenodesis and LR
Benoit et al.,[30] 2007	IV	Recurrent	10.3	Habitual patellar dislocation associated with patella alta	–	Lateral release and medial advancement of VMO plus patellar tendon transfer
Camp et al.,[23] 2010	IV	Recurrent	19	Recurrent lateral patellar dislocation	–	MPFL repair
Drez et al.,[24] 2001	IV	Traumatic	16.8	First or recurrent dislocation	–	MPFL and MPTL reconstruction
Grannatt et al.,[33] 2012	IV	Recurrent	11.1	Documented patellar subluxation or dislocation refractory to at least 6 mo of nonoperative treatment	–	Galeazzi ST tenodesis and LR
Ji et al.,[22] 2012	IV	Recurrent	15	More than one traumatic episode, disruption of the normal position of the patella within the femoral groove	–	Medial patella retinaculum plasty
Joo et al.,[31] 2007	IV	Recurrent	6.1	No patient had a history of trauma or previous operation associated with dislocation	–	Four-in-one (lateral release, proximal patella realignment, ST tenodesis, patellar tendon transfer)
Kumahashi et al., 2012[26]	IV	Recurrent	13.6	Recurrent or habitual dislocation of the patella	–	MPFL reconstruction
Letts et al.,[34] 1999	IV	Recurrent	14.3	Recurrent dislocation of the patella	–	ST tenodesis and LR
Yercan et al.,[27] 2011	IV	Recurrent	8.7	Habitual patellar dislocation	–	MPFL tenodesis to AM
Deie et al.,[25] 2003	IV	Recurrent	8.5	Habitual and recurrent patellar dislocation	–	ST tenodesis through MCL pulley
Nelitz et al.,[28] 2012	IV	Recurrent	12.2	Recurrent dislocation or the patella (at least 2 episodes)	–	MPFL reconstruction (intraosseous)
Ramaswamy et al.,[36] 2009	V	Habitual	17	Congenital dislocation	–	Bilateral rotational tibial osteotomies and TTO
Kwon et al.,[19] 2012	V	Acute	14	Dancing injury	–	Arthroscopic MPFL repair
Savarese et al.,[29] 2011	V	Recurrent	10	Recurrent dislocation of patella	–	Patellar tendon transfer

AM, adductor magnus; CA, congruence angle; EUA, exam under anaesthesia; FWB, full weight bearing; LR, lateral release; MCL, medial collateral ligament; MPFL, medial patellofemoral ligament; MPTL, medial patellotibial ligament; N/R, not reported; POD, post operative day; PTA, patella tilt angle; PWB, partial weight bearing; ROM, range of motion; ST, semitendinosus; TTO, tibial tubercle osteotomy; TTWB, toe touch weight bearing; VMO, vastus medialis obliquus.

NOTE. Numbers in parentheses signify SD or range.

Graft	Indication for Surgery	Postoperative Treatment	Tanner Stage	Physeal Status	Boys	Girls	Treated Knees			Follow-up (mo)
							Total	Control	Intervention	
–	Necessitating activity reduction, the ability to dislocate in EUA	Knee immobilizer 3 wk, then patella-stabilizing orthosis 3 wk	N/R	Open tubercle apophysis	20	51	74	28	36	166
–	Loose body ≥8 mm	N/R	N/R	N/R	9	28	37	23	14	73.2
–	Clinical and radiographic parameters (PTA, CA, sulcus angle)	PWB for 4 wk Flexion 30° at 1 wk, 60° at 2 wk, 90° at 3 wk	N/R	Open physes	25	36	61	29	32	50
–	Not further specified	Knee brace 6 wk	N/R	Open physes	9	45	60	28	26	56.8
–	Not further specified	TTWB in immobilizer for 6 wk	N/R	N/R	5	22	27	–	27	61
ST tenodesis	Not further specified	Recurrent patellar dislocations (at least 2-3 episodes), Tanner stage <3, no associated meniscus or cartilage injuries	≤3	N/R	4	10	16	–	16	52.8
–	Habitual patellar dislocation leading to functional limitation in activities of daily living	6 wk cast or splint	N/R	N/R	4	4	12	–	12	162
–	Failed an appropriate nonoperative and experienced at least one recurrent lateral patellar dislocation	6 wk PWB and immobilizer	N/R	N/R	15	14	29	–	29	48
Autologous HS/FL	Recurrent instability or loose body	3 wk PWB and brace	N/R	N/R	10	5	19	–	19	31.5
–	Not further specified	TTWB in immobilizer for 4-6 wk	N/R	Open physes	9	19	34	–	34	70
–	Not further specified	ROM at POD No. 3, FWB after 4 wk	N/R	N/R	7	10	17	–	17	20.7
–	Frequent dislocations, considerable problems such as anterior knee pain, recurrent falls and extensor weakness despite use of patellar braces	Long-leg cast in 20° flexion for 6 wk, then brace and ROM exercises	N/R	Open physes	0	5	6	–	6	54.5
Autologous ST	Recurrent or habitual dislocation of the patella, did not respond to conservative treatment for longer than 3 mo	Knee brace at 30° for 3 mo, PWB at 2 wk, FWB at 4 wk	N/R	Open physes	2	3	5	–	5	27.8
–	Not further specified	Cylinder cast for 3 wk, fiberglass cast for 3 wk	N/R	N/R	3	19	26	–	26	36
–	Not further specified	Limited to 30° flexion using an above-knee splint for 2 wk	N/R	N/R	0	4	4	–	4	17.7
–	Not further specified	N/R	N/R	N/R	2	2	4	–	4	88.8
Autologous gracilis	Not further specified	PWB for 2 wk, no brace	N/R	Open physes	6	15	22	–	22	33.6
–	Not further specified	NWB for 4 wk	N/R	N/R	1	0	1	–	1	48
–	Not further specified	Immobilizer, ROM at 2 wk	N/R	N/R	0	1	1	–	1	8
–	Failed conservative treatment (11 mo)	Immobilizer and PWB for 4 wk with 0°-90° for patellar tendon	N/R	N/R	0	1	1	–	1	24

Table 2. Postoperative Clinical Scores

	Intervention Group					Control Group				
Reference	Type of Treatment	Kujala	Lysholm	Other Score	Score Values	Type of Treatment	Kujala	Lysholm	Other Score	Score Values
Apostolovic et al.,[17] 2011	Medial retinacular and capsular repair and lateral release			Cincinnati	362.9 (170-420)	Conservative			Cincinnati	332.14 (210-420)
Palmu et al.,[18] 2008	LR ± medial repair	83 (18)				Conservative	84 (13)			
Ma et al.,[20] 2012	LR and MPFL repair	82.2 (3.4)				LR and medial capsule reefing	78.1 (3.6)			
Zhao et al.,[21] 2012	Medial retinaculum plication	76.6 (4.3)	70.7 (5.1)	IKDC	62.5 (6.1)	VMO plasty	82.9 (4.8)	79.4 (5.5)	IKDC	71.8 (7.1)
Aulisa et al.,[32] 2012	Galeazzi ST tenodesis and LR			Crosby Insall	62.5% excellent, 37.5% good	None				
Benoit et al., [30] 2007	Lateral release and medial advancement of VMO plus P tendon transfer		98 (95-100)			None				
Camp et al.,[23] 2010	MPFL repair	92.1 (57-105)	85.5 (42-100)			None				
Deie et al.,[25] 2003	ST tenodesis through MCL pulley	96.3 (89-100)				None				
Drez et al.,[24] 2001	MPFL and MPTL reconstruction	(57-100)		Fulkerson	93 (80-100)	None				
Grannatt et al.,[33] 2012	Galeazzi ST tenodesis and LR	79		IKDC	63	None				
Ji et al.,[22] 2012	Medial patella retinaculum plasty	93.4 (88-100)	92.3 (87-99)			None				
Joo et al.,[31] 2007	Four-in-one	95.3 (88-98)				None				
Kumahashi et al., 2012[26]	MPFL reconstruction					None				
Kwon et al.,[19] 2012	asc MPFL repair					None				
Letts et al.,[34] 1999	ST tenodesis and LR		68 (35-93)			None				
Luhmann et al.,[35] 2011	LR and medial reef and tendon transfer		69.3 (38-100)	IKDC	65.6 (31-100)	None				
Savarese et al.,[29] 2011	Patellar tendon transfer					None				
Nelitz et al.,[28] 2012	Gracilis MPFL reconstruction	92.8 (74-100)		Tegner	5.8 (3-9)	None				
Yercan et al.,[27] 2011	MPFL tenodesis to AM	89.5 (2.1)				None				

AM, adductor magnus; asc, arthroscopic; IKDC, International Knee Documentation Committee; LR, lateral release; MCL, medial collateral ligament; MPFL, medial patellofemoral ligament; MPTL, medial patellotibial ligament; ST, semitendinosus; VMO, vastus medialis obliquus.

NOTE. Numbers in parentheses signify SD or range.

Table 3. Instability, Dislocations, and Complications

Reference	Intervention Group				Control Group			
	Type of Treatment	Instability	Dislocations	Complications	Type of Treatment	Instability	Dislocations	Complications
Apostolovic et al.,[17] 2011	Medial retinacular and capsular repair and LR	2 (14%)	2 (9%)	2 redislocations	Conservative	3 (13%)	One (7%)	One redislocation
Palmu et al.,[18] 2008	LR ± medial repair	24 (67%)		None	Conservative	20 (71%)		None
Ma et al.,[20] 2012	LR and MPFL repair	2		2 extension weakness (transient), 2 anterior knee pain	LR and medial capsule reefing	9		3 extension weakness (transient), one anterior knee pain
Zhao et al.,[21] 2012	Medial retinaculum plication	14	5	None	VMO plasty	5	2	None
Aulisa et al.,[32] 2012	Galeazzi ST tenodesis and LR	–	–	Transient saphenous nerve sensory deficit in 4 knees	None			
Benoit et al., [30] 2007	LR and medial advancement of VMO plus P tendon transfer	0	1	One superficial infection, one drop foot in plaster cast, one revision b/o redislocation, 2 asymptomatic patellae inferae	None			
Camp et al.,[23] 2010	MPFL repair	–	8 (28%)	8 recurrent distortions (2 TTO and MPFL; 3 MPFL, 3 consecutive treatments)	None			
Deie et al.,[25] 2003	ST tenodesis through MCL pulley	1	0	–	None			
Drez et al.,[24] 2001	MPFL and MPTL reconstruction	1	0	One unrelated meniscus tear, one subluxation (consecutive treatment), 10 PF crepitus (7 mild, 3 moderate), 9 quadratus atrophy (all <3 cm)	None			
Grannatt et al.,[33] 2012	Galeazzi ST tenodesis and LR	28 (82%)		12 instability revisions (1 MPFL, 2 Roux/Goldthwaite, 3 LR and MP, 5 TTO)	None			
Ji et al.,[22] 2012	Medial patella retinaculum plasty	0	0	8 quadratus atrophy (all <3 cm), 3 flexion losses <10°	None			
Joo et al.,[31] 2007	Four-in-one	0	1	2 skin necroses	None			
Kumahashi et al., 2012[26]	MPFL reconstruction	0	0	None	None			
Kwon et al.,[19] 2012	asc MPFL repair	0	0	None	None			
Letts et al.,[34] 1999	ST tenodesis and LR	1	1	One scar hypertrophy, one neuroma of the infrapatellar branch of the saphenous nerve, one redislocation (medial tightening), one medial subluxation (medial lengthening)	None			
Luhmann et al.,[35] 2011	LR and medial reef and tendon transfer	2	0	2 nondisplaced tibial fractures, 1 superficial infection, 10 PF mechanical symptoms (consecutive treatment)	None			
Savarese et al.,[29] 2011	P tendon transfer	0	0	None	None			

(continued)

Table 3. Continued

	Intervention Group				Control Group			
Reference	Type of Treatment	Instability	Dislocations	Complications	Type of Treatment	Instability	Dislocations	Complications
Nelitz et al.,[28] 2012	Gracilis MPFL reconstruction	2	0	One loss of flexion requiring prolonged physical therapy	None			
Yercan et al.,[27] 2011	MPFL tenodesis to AM	0	0	None	None			

AM, adductor magnus; asc, arthroscopic; b/o, because of; LR, lateral release; MCL, medial collateral ligament; MP, medial plication; MPFL, medial patellofemoral ligament; MPTL, medial patellotibial ligament; PF, patellofemoral; ST, semitendinosus; TTO, tibial tubercle osteotomy; VMO, vastus medialis obliquus.

NOTE. Numbers in parentheses signify SD or range.

Data were extracted independently and in duplicate for all end points. Levels of evidence were assessed for all included studies using the *Journal of Bone and Joint Surgery* ranking system (http://jbjs.org/public/instructionsauthors.aspx#LevelsofEvidence), which is also used by *Arthroscopy*.

The risk of bias was assessed through categorization by levels of evidence. We decided against the use of a composite score of study quality because these scores have been shown to be unreliable in some of the included study types and because there are no scores that allow a valid assessment across different study designs.[15] Studies with a particularly high risk of bias are pointed out explicitly in the description of the studies in the results section.[2,16]

Results

Our search produced 985 results in total; 95 publications were obtained and reviewed in total based on the criteria described earlier. Four articles were identified by bibliographic cross-reference. Four articles, 2 in Chinese and 2 in French published before 1990, could not be retrieved. Finally, 20 articles reporting on a total of 456 knees in 425 patients (131 male patients, 294 female patients) followed-up for 56.7 ± 42.2 months on average, were included in the analysis (Fig 1). The average age across all studies was 12.9 ± 3.1 years. Seven studies expressly mentioned open physes, and one study gave Tanner stages. A median number of 18 (range, 1 to 74) patients were included per study. Table 1 summarizes the characteristics of these studies.

For the included articles, the levels of evidence ranged from II to V. There were 3 Level II studies, 1 Level III study, and 16 Level IV and V studies. There is considerable risk of bias in most of the included studies. Most are longitudinal analyses of a single cohort without controls and without randomization. This situation, however, is representative of the studied field.[16] Clinical scores showed consistently satisfactory results after surgical treatment (Table 2).

Recurrence rates for dislocations were fairly high, ranging from 4% to 20% (Table 3). The highest rates were seen in the oldest patients and with the oldest arthroscopic techniques. All recurrences were treated with revision surgery, the success of which was not consistently reported. Similar rates were seen for recurrent instability without frank dislocation.

Radiographic assessment of the patellar tilt angle, the lateral patellofemoral angle, and the congruence angle showed marked improvements in these values after surgical treatment, supporting the clinical effects. Interestingly, there were also changes in the sulcus angle, i.e., the opening angle of the trochlea, even without trochleaplasty. These changes could be attributed to measurement errors or normal growth, but the question remains whether improved patellar tracking has a beneficial effect on the shape of the trochlea (Table 4). No growth disturbances were seen in this patient collective.

Three studies focused on acute dislocations.[17-19] Two studies presented data on a direct comparison of conservative and surgical treatments of patellar instability after acute patellar dislocation in pediatric and adolescent patients.[17,18] Apostolovic et al.[17] found no difference in outcome between surgical and conservative treatment. However, they did not report on a formal power analysis in the face of $P = .091$ for functional outcome. Assessment of patellofemoral anatomy was not reported. Palmu et al.[18] published a study of 71 patients with patellar dislocation treated with medial restraint repair or conservatively and followed for 14 years. All patients had slight trochlear dysplasia (>150° average sulcus angle) and some level of patella alta (average Insall-Salvati ratio of 1.3), but no data were reported on Q angles or the tibial tuberosity-trochlear groove distance. However, at 7 and 14 years of follow-up, there was no difference in outcome.

Two studies compared surgical treatments for recurrent patellar instability. Ma et al.[20] assessed relative effectiveness of MPFL repair and medial reefing. Zhao et al.[21] compared medial plication with a vastus medialis obliquus (VMO) advancement plasty.

Three studies presented data on 4 groups of patients with recurrent instability treated with proximal realignment, such as a medial retinacular or VMO plasty.[20-22] Ji et al.[22] found high clinical scores after medial retinacular plication, but there was no control group. Zhao et al.[21] compared medial retinacular plication with VMO plasty and found better stability and clinical scores in the stronger repair with the VMO plasty. Ma et al.[20] compared medial capsular reefing with MPFL repair and found better results with the latter.

Camp et al.[23] and Kwon et al.[19] presented data on open and arthroscopic MPFL repair (to the patella) and found them to be feasible and effective techniques to treat recurrent instability despite recurrence rates as high as 28%. Five studies reported on classic MPFL reconstruction with a hamstring graft. Drez et al.[24] and Deie et al.[25] sutured autologous semitendinosus to the patella, although Deie et al. left the distal insertion and used the medial collateral ligament (MCL) as a dynamic pulley. Kumahashi et al.,[26] Yercan et al.,[27] and Nelitz et al.[28] used intraosseous fixation of semitendinosis or gracilis grafts with good clinical results and no reported growth disturbances or fractures.

For the purpose of this study, we defined distal realignment as all distally based procedures, such as patellar tendon transfers, as well as the Galeazzi procedure, a distally based semitendinosus tenodesis of the patella. Savarese et al.[29] reported on the patellar tendon transfer, in which the tendon is partially mobilized from the tibial tubercle but is left anchored to the distal periosteum and is medialized and sutured to the tibia. Benoit et al.[30] and Joo et al.[31] used the same technique as part of their surgical procedure, which also included proximal realignment. All 3 groups achieved excellent clinical scores and adequate patellar stability. Aulisa et al.[32] and Grannatt et al.[33] reported on the use of the Galeazzi procedure and found good midterm results but recurrent instability in up to 82% of patients. Letts et al.[34] performed a lateral release and semitendinosus tenodesis supported with a plication of the medial capsule and retinaculum, thus reducing the recurrence rate substantially.

Luhmann et al.[35] combined lateral releases with medial reefing and a patellar tendon transfer. Benoit et al.[30] added a VMO advancement to this combination, and Joo et al.,[31] in what they called a "4-in-one" procedure, combined lateral release, medial reefing, a semitendinosus tenodesis, and a patellar tendon transfer. All 3 groups produced clinical results similar to those seen in individual proximal or distal procedures. We could identify only one study on osseous procedures. Ramaswamy et al.[36] reported on one case of bilateral rotational tibial osteotomies and tubercle distalization.

Discussion

This study focused on treatment options for patellar instability in pediatric and adolescent patients. Probably the most important stabilizer of the patella is the MPFL, providing more than 50% of medial restraint; in most patellar dislocations, the MPFL undergoes some level of injury. The MPFL is supported in its function by anatomic features such as the Q angle, the tibial tuberosity-trochlear groove distance, and the shape of the trochlea. Anatomic variants of these features will increase the stress on the MPFL and predispose the patella to dislocations and will also interfere with healing.

The current best evidence suggests conservative treatment in first acute patellar dislocations to allow the MPFL and other medial structures to heal. This approach is both biologically plausible and has shown success in other dislocated joints such as the shoulder. An important factor that allows high healing rates with such conservative treatment is that in adolescent patients ligaments mostly tear off their insertion, whereas in adults they tear at midsubstance. However, just as in glenohumeral dislocations too, there is a high rate of recurrence in patellofemoral dislocations too, many of which will eventually require surgical stabilization. Like others before us, we want to caution the reader to assess and consider the anatomy of the patient's knee when choosing from the treatment options outlined in this article. Abnormal extensor alignment will cause abnormal patellar tracking and

Table 4. Radiographic Findings

		Preoperative					Postoperative				
Reference	Imaging	PTA	LPFA	Sulcus Angle	Congruence Angle	Patella Ht	PTA	LPFA	Sulcus	Congruence Angle	Patella Ht
Aulisa et al.,[32] 2012	CT	4.6 (−4-10)		152 (145-168)			8 (0-14)		150 (145-168)		
Benoit et al.,[30] 2007	XR			160 (153-169)		Caton Deschamps: 1.54 (1.46-1.62)			145.7 (143-147)		Deschamps: 104 (0.93-1.14)
Camp et al.,[23] 2010	XR									Improved by 22 (3-44)	
Deie et al.,[25] 2003	XR						5.2 (2.4)		153.2 (2.7)	−6.2 (6.4)	Insall Salvati: 1.4 (0.1)
Deie et al.,[51] 2007	XR		−0.3 (8.3)		25.3 (18.7)	Blackburne Peel: 0.93 (0.16)		10.1 (5.4)		5.5 (8.0)	Blackburne Peel: 0.92 (0.12)
Ji et al.,[22] 2012	XR	12.2 (5-16)					6.8 (5-9)				
Joo et al.,[31] 2007	XR								143.2 (142-156)		
Kumahashi et al., 2012[26]	XR	18 (6.5)		151.3 (15.1)	12.9 (14.7)	Insall Salvati: 1.3 (0.2)	6.6 (5.0)		150.1 (16.4)	−8 6 (5.0)	Insall Salvati: 1.2 (0.2)
Palmu et al.,[18] 2008 (conservative treatment)	XR			153 (6)		Insall Salvati: 1.3 (0.2)					
Palmu et al.,[18] 2008 (surgical treatment)	XR			152 (8)		Insall Salvati: 1.3 (0.2)					
Ma et al.,[20] 2012 (medial capsule reefing)	CT	14.5 (2.7)		135.5 (3.9)	18.7 (2.6)	Insall Salvati: 1.02 (0.2)	8.4 (2.1)			5.3 (3.7)	
Ma et al.,[20] 2012 (MPFL repair)	CT	14.3 (3.1)		134.7 (4.7)	19.2 (2.8)	Insall Salvati: 1.06 (0.2)	8.0 (1.9)			3.1(1.7)	
Zhao et al.,[21] 2012 (medial plication)	CT	25.3 (15.7)	−7.1 (16.9)		−23.9 (17.4)		19.7 (8.9)	−12.5 (10.3)		−17.7 (8.9)	
Zhao et al.,[21] 2012 (VMO plasty)	CT	26.5 (17.1)	−0.5 (16.3)		−26.2 (15.6)		13.6 (6.9)	−7 4 (7.1)		−12.4 (6.7)	

CT, computed tomography; Ht, height; LPFA, lateral patellofemoral angle; MPFL, medial patellofemoral ligament; PTA, patella tilt angle; VMO, vastus medialis obliquus; XR, radiography.
NOTE. Numbers in parentheses signify SD or range.

interfere with soft tissue healing after patellar dislocation; early surgical intervention for extensor realignment might be warranted.

Conservative treatment, allowing the torn MPFL to heal, is the mainstay of patellar instability management, and probably one of the most effective methods. We included 2 studies assessing the effectiveness of conservative treatment, and both studies showed that there is no significant difference in clinical scores and recurrence between conservative and surgical treatments of patellar instability in children and adolescents. Similar findings have been shown for acute and recurrent patellar dislocations in adults. However, recent studies in adult patients were able to present some clinical benefit of surgical realignment, which might be an effect of improved surgical techniques.

A subject that deserves more attention is a closer assessment of the different options in conservative treatment that would alleviate patellar instability, especially in younger patients. Braces have been shown to stabilize the patella successfully, at least temporarily, but lead to stiffness in the long-term.[4,37] Similar problems were seen with the use of braces in patients who underwent anterior cruciate ligament reconstruction.[38] Cast immobilization for 6 weeks results in a 3-fold reduction of redislocation compared with patellar braces but is associated with an even higher risk of joint stiffness.[4,37]

VMO strengthening and proprioceptive training do improve patellofemoral symptoms in principle, but the details of such treatments are still controversial.[39-41] Open-chain exercises are accepted to be less effective than closed-chain strengthening, especially for the VMO, but they do stress the cartilage and should generally be avoided.[42] What should not be overlooked is the frequent gluteal and short external rotator weakness in patients with chronic patellar instability. The weak gluteal muscles lead to increased internal rotation and adduction, thus increasing the Q angle and patellar instability.[3]

Of note, the findings presented for conservative treatment options have been established primarily in adult patients; thus, the primary studies are not included in our review. There is good reason to believe that most of these principles are also valid for skeletally immature patients, but this stipulation has not been scientifically tested.

Proximal realignment is probably the most common approach to patellar instability and is chosen when conservative treatment fails or cannot succeed because of anatomic malalignment. Proximal realignment typically consists of some combination of reduction of lateral pull and improvement of medial patellar restraint. A frequently and probably disproportionately used procedure is the release of the lateral retinaculum, which can be performed in an open procedure or arthroscopically. However, cadaveric studies have shown that lateral release increases patellar instability.[43] In contrast to lateral patellar hypercompression, isolated lateral release or lateral lengthening is not sufficient to treat patellar instability.[3,44,45] Also, overzealous lateral release that extends into the vastus lateralis obliquus can lead to medial instability of the patella.[45] Given these shortcomings, lateral retinacular decompression is usually only recommended in chronically fixed lateral patella subluxation and has to be combined with some form of medial restraining procedure.

Some data exist for medial procedures in proximal realignment in pediatric and adolescent patients. Surgical options include the repair of the medial structures, including the capsule and retinaculum; strengthening the medial structures through plication, imbrication, or VMO plasty; and reconstruction of the MPFL.

Ma et al.[20] compared medial repair of the MPFL with reefing of the medial capsule and found better subjective scores and postoperative stability in the repair group. Zhao et al.[21] compared medial capsule plication with VMO plasty for medial support of the patella and, consistent with the findings by Ma et al., found that simple medial capsule plication affords less subjective and objective improvement than does VMO plasty. These findings show that re-establishing a strong anatomic support on the medial side, e.g., through MPFL repair, produces better clinical results. Zhao et al.[46] also directly compared medial plication with MPFL reconstruction in adult patients and found better clinical scores and less recurrent instability at 60 months in the reconstruction group.

A potential reason for the consistently better outcomes after MPFL repair or reconstruction compared with medial plication is that 50% to 80% of medial restraint injuries occur at the femoral MPFL attachment.[47,48] As mentioned above, in juvenile and adolescent patients these injuries are frequently avulsions, compared to the midsubstance tears seen in adults. MPFL procedures address these injuries, whereas medial plication does not. However, there are potential problems with MPFL reconstruction. A hamstring autograft or allograft is much stiffer and stronger than the native MPFL (roughly 8 times at 1,600 N *v* 208 N).[3] Thus, even minimal malpositioning might lead to significantly increased stress on the patellofemoral joint and a heightened risk of patellofemoral degeneration.[49,50] Again, these data were obtained in adult patients, but it is very plausible that they are also valid for the more vulnerable pediatric musculoskeletal apparatus.

To avoid iatrogenic hypercompression and ensuing cartilage damage, 2 strategies have emerged. One is dynamic reconstruction of the MPFL, in which the MPFL is anchored to the adductor magnus, as described by Yercan et al.,[27] or the MCL is used as a pulley, as reported by Deie et al.[25,51] Both methods have been used in pediatric patients, but tethering of the MCL or adductor insertion is a potential complication. The second strategy is tensioning in 60° to 90° of flexion rather than the conventional 30° position.[3,52-55]

One more point of interest for MPFL reconstruction in pediatric patients is the risk to the growing skeleton. Kepler et al.[56] showed in an MRI study that the femoral MPFL insertion is on average 5 mm distal to the physis.[56] Two recent radiographic studies put it at 6.4 and 6.5 mm distal to the physis.[57,58] Thus, there is enough room for secure and safe placement of a suture anchor or tunnel in an anatomic location without jeopardizing growth. In our collected population, no patellar fractures occurred, but this has been reported as a complication in MPFL reconstruction.[52]

We found data on 2 types of distal realignment procedures. One is a distally based tenodesis that typically uses the semitendinosus. The obvious concern with such a procedure is the nonanatomic restraint in a medial-inferior direction, which is effective in superolateral dislocations, but not in mid- or inferior lateral instability. The recurrence rates of up to 82% support this notion. However, it is a minimally invasive procedure and can be considered if a temporizing solution is sought.[33]

Alternatively, the patellar tendon can be transferred to a more medial position.[29] Because it should remain attached more distally, distalization cannot be done reliably.[29-31] Interestingly, Ostermeier et al.[59] have shown that MPFL reconstruction is superior to tubercle transfer in restoring patellar stability.

Three studies offer data on combined distal and proximal realignment. What stands out from these studies is that neither clinical scores nor recurrence rates are substantially better than those in simple proximal realignment. Given that the patient population in question is particularly vulnerable because of ongoing growth and that even with the best treatments recurrence rates are in double-digit percentages and revision surgery is likely, a light touch with minimal tissue disruption seems to be a prudent approach, especially in light of the lack of added clinical benefits from an extensive procedure.

We found only one study reporting on osseous procedures for patellar instability. In general, tibial osteotomies should be avoided in pediatric and adolescent patients because of the implied risk to the physes. Fortunately, Ostermeier et al.[60] showed that MPFL reconstruction is a superior patella stabilizer compared with osteotomies and can be performed safely in young patients.

Limitations

A general shortcoming of all systematic reviews is that they depend on the quality of the included primary studies. The level of evidence of the included studies was limited but is not unrepresentative of studies in orthopaedic clinical research.[61,62] A particular problem with this area of research is the often unclear terminology and reporting of data. A number of studies mixed adolescent and adult patients together. We also found a few studies on patellar instability that did not report patient age at all. None of these studies were included in this review, but it is likely that they contained at least some valuable data that could not be extracted.[47,48]

Conclusions

The current best evidence does not support the superiority of surgical intervention over conservative treatment in acute patellar dislocation. However, anatomic variations and their effect on healing should be considered and included in decision making. In recurrent patellar instability in pediatric and adolescent patients with normal or restored knee anatomy, reconstruction of the MPFL is the most effective treatment option and can be done safely, together with extensor realignment as needed.

References

1. Trentacosta NE, Vitale MA, Ahmad CS. The effects of timing of pediatric knee ligament surgery on short-term academic performance in school-aged athletes. *Am J Sports Med* 2009;37:1684-1691.
2. Vavken P, Murray M. Treating Anterior cruciate ligament tears in skeletally immature patients. *Arthroscopy* 2011;27: 704-716.
3. Colvin AC, West RV. Patellar instability. *J Bone Joint Surg Am* 2008;90:2751-2762.
4. 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;171:131-136.
5. Woods GW, O'Connor DP. Delayed anterior cruciate ligament reconstruction in adolescents with open physes. *Am J Sports Med* 2004;32:201-210.
6. DeJour H, Walch G, Nove-Josserand L, Guler C. Factors of patellar instability: An anatomic radiographic study. *Knee Surg Sports Traumatol Arthrosc* 1994;2:19-26.
7. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *PLoS Med* 2009;6:e1000100.
8. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *BMJ* 2009;339: 2535.
9. Moher D, Cook DJ, Eastwood S, Olkin I, Rennie D, Stroup DF. Improving the quality of reports of meta-analyses of randomised controlled trials: The QUOROM statement. Quality of reporting of meta-analyses. *Lancet* 1999;354:1896-1900.

10. Calfee RP, Sutter M, Steffen JA, Goldfarb CA. Skeletal and chronological ages in American adolescents: Current findings in skeletal maturation. *J Child Orthop* 2011;4: 467-470.
11. O'Connor JE, Bogue C, Spence LD, Last J. A method to establish the relationship between chronological age and stage of union from radiographic assessment of epiphyseal fusion at the knee: An Irish population study. *J Anat* 2008;212:198-209.
12. O'Connor JE, Coyle J, Spence LD, Last J. Epiphyseal maturity indicators at the knee and their relationship to chronological age: Results of an Irish population study. *Clin Anat.* 2012 Jun 22. [Epub ahead of print.]
13. Nomura E, Inoue M, Kobayashi S. Long-term follow-up and knee osteoarthritis change after medial patellofemoral ligament reconstruction for recurrent patellar dislocation. *Am J Sports Med* 2007;35:1851-1858.
14. Shah JN, Howard JS, Flanigan DC, Brophy RH, Carey JL, Lattermann C. A systematic review of complications and failures associated with medial patellofemoral ligament reconstruction for recurrent patellar dislocation. *Am J Sports Med* 2012;40:1916-1923.
15. Emerson J, Burdick E, Hoaglin D, Mosteller F, Chalmers T. An empirical study of the possible relation of treatment differences to quality scores in controlled randomized clinical trials. *Control Clin Trial* 1990;11:339-352.
16. Vavken P, Culen G, Dorotka R. Clinical applicability of evidence-based orthopaedics—A cross-sectional study of the quality of orthopaedic evidence [in German]. *Z Orthop Unfall* 2008;146:21-25.
17. Apostolovic M, Vukomanovic B, Slavkovic N, et al. Acute patellar dislocation in adolescents: Operative versus nonoperative treatment. *Int Orthop* 2011;35:1482-1487.
18. Palmu S, Kallio P, Donell S, Helenius I, Nietosvaara Y. Acute patellar dislocation in children and adolescents: A randomized clinical trial. *J Bone Joint Surg Am* 2008;90: 463-470.
19. Kwon OS, Kelly JT. Arthroscopic repair of medial patellofemoral ligament avulsion in acute patellar dislocation in skeletally immature patient—A case report. *Knee* 2012;19:713-715.
20. Ma LF, Wang CH, Chen BC, et al. Medial patellar retinaculum plasty versus medial capsule reefing for patellar dislocation in children and adolescents. *Arch Orthop Trauma Surg* 2012;132:1773-1780.
21. Zhao J, Huangfu X, He Y, Liu W. Recurrent patellar dislocation in adolescents: Medial retinaculum plication versus vastus medialis plasty. *Am J Sports Med* 2012;40: 123-132.
22. Ji G, Wang F, Zhang Y, Chen B, Ma L, Dong J. Medial patella retinaculum plasty for treatment of habitual patellar dislocation in adolescents. *Int Orthop* 2012;36: 1819-1825.
23. Camp CL, Krych AJ, Dahm DL, Levy BA, Stuart MJ. Medial patellofemoral ligament repair for recurrent patellar dislocation. *Am J Sports Med* 2010;38:2248-2254.
24. Drez D Jr, Edwards TB, Williams CS. Results of medial patellofemoral ligament reconstruction in the treatment of patellar dislocation. *Arthroscopy* 2001;17:298-306.
25. Deie M, Ochi M, Sumen Y, Yasumoto M, Kobayashi K, Kimura H. Reconstruction of the medial patellofemoral ligament for the treatment of habitual or recurrent dislocation of the patella in children. *J Bone Joint Surg Br* 2003;85:887-890.
26. Kumahashi N, Kuwata S, Tadenuma T, Kadowaki M, Uchio Y. A "sandwich" method of reconstruction of the medial patellofemoral ligament using a titanium interference screw for patellar instability in skeletally immature patients. *Arch Orthop Trauma Surg* 2012;132:1077-1083.
27. Yercan HS, Erkan S, Okcu G, Ozalp RT. A novel technique for reconstruction of the medial patellofemoral ligament in skeletally immature patients. *Arch Orthop Trauma Surg* 2011;131:1059-1065.
28. Nelitz M, Dreyhaupt J, Reichel H, Woelfle J, Lippacher S. Anatomic reconstruction of the medial patellofemoral ligament in children and adolescents with open growth plates: Surgical technique and clinical outcome. *Am J Sports Med* 2012;41:58-63.
29. Savarese E, Bisicchia S, Carotenuto F, Ippolito E. A technique for treating patello-femoral instability in immature patients: The tibial tubercle periosteum transfer. *Musculoskelet Surg* 2011;95:89-94.
30. Benoit B, Laflamme GY, Laflamme GH, Rouleau D, Delisle J, Morin B. Long-term outcome of surgically-treated habitual patellar dislocation in children with coexistent patella alta. Minimum follow-up of 11 years. *J Bone Joint Surg Br* 2007;89:1172-1177.
31. Joo SY, Park KB, Kim BR, Park HW, Kim HW. The 'four-in-one' procedure for habitual dislocation of the patella in children: Early results in patients with severe generalised ligamentous laxity and aplasis of the trochlear groove. *J Bone Joint Surg Br* 2007;89:1645-1649.
32. Aulisa A, Falciglia F, Giordano M, Savignoni P, Guzzanti V. Galeazzi's modified technique for recurrent patella dislocation in skeletally immature patients. *J Orthop Sci* 2012;17:148-155.
33. Grannatt K, Heyworth B, Ogunwole O, Micheli L, Kocher M. Galeazzi semitendinosus tenodesis for patellofemoral instability in skeletally immature patients. *J Pediatr Orthop* 2012;32:621-625.
34. Letts R, Davidson D, Beaule P. Semitendinosus tenodesis for repair of recurrent dislocation of the patella in children. *J Pediatr Orthop* 1999;19:742-748.
35. Luhmann S, O'Donnell J, Fuhrhop S. Outcomes after patellar realignment surgery for recurrent patellar instability dislocations: A minimum 3-year follow-up study of children and adolescents. *J Pediatr Orthop* 2011;31:65-71.
36. Ramaswamy R, Kosashvili Y, Murnaghan JJ, Cameron K, Cameron J. Bilateral rotational osteotomies of the proximal tibiae and tibial tuberosity distal transfers for the treatment of congenital lateral dislocations of patellae: A case report and literature review. *Knee* 2009;16:507-511.
37. Maenpaa H, Lehto MU. Patellar dislocation. The long-term results of nonoperative management in 100 patients. *Am J Sports Med* 1997;25:213-217.
38. Wright RW, Fetzer GB. Bracing after ACL reconstruction: A systematic review. *Clin Orthop Relat Res* 2007;455:162-168.
39. Hubbard JK, Sampson HW, Elledge JR. The vastus medialis oblique muscle and its relationship to

patellofemoral joint deterioration in human cadavers. *J Orthop Sports Phys Ther* 1998;28:384-391.
40. Laprade J, Culham E, Brouwer B. Comparison of five isometric exercises in the recruitment of the vastus medialis oblique in persons with and without patellofemoral pain syndrome. *J Orthop Sports Phys Ther* 1998;27:197-204.
41. Lin YF, Lin JJ, Cheng CK, Lin DH, Jan MH. Association between sonographic morphology of vastus medialis obliquus and patellar alignment in patients with patellofemoral pain syndrome. *J Orthop Sports Phys Ther* 2008;38:196-202.
42. Irish SE, Millward AJ, Wride J, Haas BM, Shum GL. The effect of closed-kinetic chain exercises and open-kinetic chain exercise on the muscle activity of vastus medialis oblique and vastus lateralis. *J Strength Cond Res* 2010;24:1256-1262.
43. Christoforakis J, Bull AM, Strachan RK, Shymkiw R, Senavongse W, Amis AA. Effects of lateral retinacular release on the lateral stability of the patella. *Knee Surg Sports Traumatol Arthrosc* 2006;14:273-277.
44. Pagenstert G, Wolf N, Bachmann M, et al. Open lateral patellar retinacular lengthening versus open retinacular release in lateral patellar hypercompression syndrome: A prospective double-blinded comparative study on complications and outcome. *Arthroscopy* 2012;28:788-797.
45. Lattermann C, Toth J, Bach BR Jr. The role of lateral retinacular release in the treatment of patellar instability. *Sports Med Arthrosc* 2007;15:57-60.
46. Zhao J, Huangfu X, He Y. The role of medial retinaculum plication versus medial patellofemoral ligament reconstruction in combined procedures for recurrent patellar instability in adults. *Am J Sports Med* 2012;40:1355-1364.
47. 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;225:736-743.
48. 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;25:957-962.
49. Elias JJ, Cosgarea AJ. Technical errors during medial patellofemoral ligament reconstruction could overload medial patellofemoral cartilage: A computational analysis. *Am J Sports Med* 2006;34:1478-1485.
50. Beck P, Brown NA, Greis PE, Burks RT. Patellofemoral contact pressures and lateral patellar translation after medial patellofemoral ligament reconstruction. *Am J Sports Med* 2007;35:1557-1563.
51. Deie M, Sumen Y, Adachi N, et al. The long-term results of meniscus transplantation for articular cartilage defects in the knee joint. *Knee Surg Sports Traumatol Arthrosc* 2007;15:61-66.
52. Panagopoulos A, van Niekerk L, Triantafillopoulos IK. MPFL reconstruction for recurrent patella dislocation: A new surgical technique and review of the literature. *Int J Sports Med* 2008;29:359-365.
53. Triantafillopoulos IK, Panagopoulos A, van Niekerk L. Isometric behavior of the reconstructed medial patellofemoral ligament using two different femoral pulleys: A cadaveric study. *Med Sci Monit* 2007;13:BR181-BR187.
54. Steiner TM, Torga-Spak R, Teitge RA. Medial patellofemoral ligament reconstruction in patients with lateral patellar instability and trochlear dysplasia. *Am J Sports Med* 2006;34:1254-1261.
55. Nomura E, Inoue M. Hybrid medial patellofemoral ligament reconstruction using the semitendinous tendon for recurrent patellar dislocation: Minimum 3 years' follow-up. *Arthroscopy* 2006;22:787-793.
56. Kepler CK, Bogner EA, Hammoud S, Malcolmson G, Potter HG, Green DW. Zone of injury of the medial patellofemoral ligament after acute patellar dislocation in children and adolescents. *Am J Sports Med* 2011;39:1444-1449.
57. Nelitz M, Dornacher D, Dreyhaupt J, Reichel H, Lippacher S. The relation of the distal femoral physis and the medial patellofemoral ligament. *Knee Surg Sports Traumatol Arthrosc* 2011;19:2067-2071.
58. Schottle PB, Schmeling A, Rosenstiel N, Weiler A. Radiographic landmarks for femoral tunnel placement in medial patellofemoral ligament reconstruction. *Am J Sports Med* 2007;35:801-804.
59. Ostermeier S, Stukenborg-Colsman C, Hurschler C, Wirth C. In vitro investigation of the effect of medial patellofemoral ligament reconstruction and medial tibial tuberosity transfer on lateral patellar stability. *Arthroscopy* 2006;22:308-319.
60. Ostermeier S, Stukenborg-Colsman C, Hurschler C, Wirth CJ. In vitro investigation of the effect of medial patellofemoral ligament reconstruction and medial tibial tuberosity transfer on lateral patellar stability. *Arthroscopy* 2006;22:308-319.
61. Bhandari M, Richards RR, Sprague S, Schemitsch EH. The quality of reporting of randomized trials in the Journal of Bone and Joint Surgery from 1988 through 2000. *J Bone Joint Surg Am* 2002;84:388-396.
62. McCulloch P, Taylor I, Sasako M, Lovett B, Griffin D. Randomised trials in surgery: Problems and possible solutions. *BMJ* 2002;324:1448-1451.