28 Return to Sport After Patellofemoral Realignment and Stabilization Procedures

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28.1 Introduction

Injuries and disorders of the patellofemoral joint are some of the most common causes of knee pain and frequently include inflammation of the parapatellar soft tissues, damage to the articular cartilage of the patella and/or femoral sulcus, and instability (subluxation or dislocation) [1]. The terminology used to describe patellofemoral disorders can be confusing. *Patellar malalignment* is a translational or rotational deviation of the patella relative to any axis caused by an abnormal relationship between the patella, the soft tissues surrounding the patella, and the femoral and tibial osseous structures. The abnormalities may be caused by congenital issues, such as peripatellar tissue tightness or laxity, a shallow or convex trochlear groove, bony abnormalities of the patella, rotational malalignment of the femur and tibia, patella alta, or patella baja, and may be exacerbated by inflexibility or weakness of the lower extremity musculature. Patellar malalignment may also arise from an injury that disrupts soft tissue stabilizers, especially the medial tissues restraints, including the medial patellofemoral ligament (MPFL). Patellar dislocations and patellofemoral instability are common problems in young athletic individuals. In a study that analyzed factors associated with patellar dislocations in 40,544 injured knees in the United States, Waterman et al. [2] reported that 52% of the injuries occurred during athletics. The peak incidence of dislocations occurred between 15 and 19 years of age. Redislocation rates of first-time patella dislocations treated conservatively range from 36% to 71% in pediatric populations [3, 4] and from 14% to 57% in adult populations [5, 6].

While many patients who sustain patellar dislocations may be successfully treated with conservative measures, surgery is required to prevent recurrent dislocations and the subsequent patellofemoral cartilage damage that occurs. Patients with distinct anatomical abnormalities described in detail elsewhere are more likely to undergo repetitive dislocations unless there is surgical intervention. Many surgical procedures have been described for realignment or stabilization of the patellofemoral mechanism including proximal realignment, distal realignment, or a combination of both (Fig. 28.1). Proximal realignment procedures alter the medial-lateral position of the patella through balancing of soft tissue restraints proximal to its inferior pole and include MPFL repair or reconstruction (Fig. 28.2), medial retinacular capsular and medial patellomeniscal plication, vastus medialis obliquus advancement, and lateral retinacular release. Distal realignment

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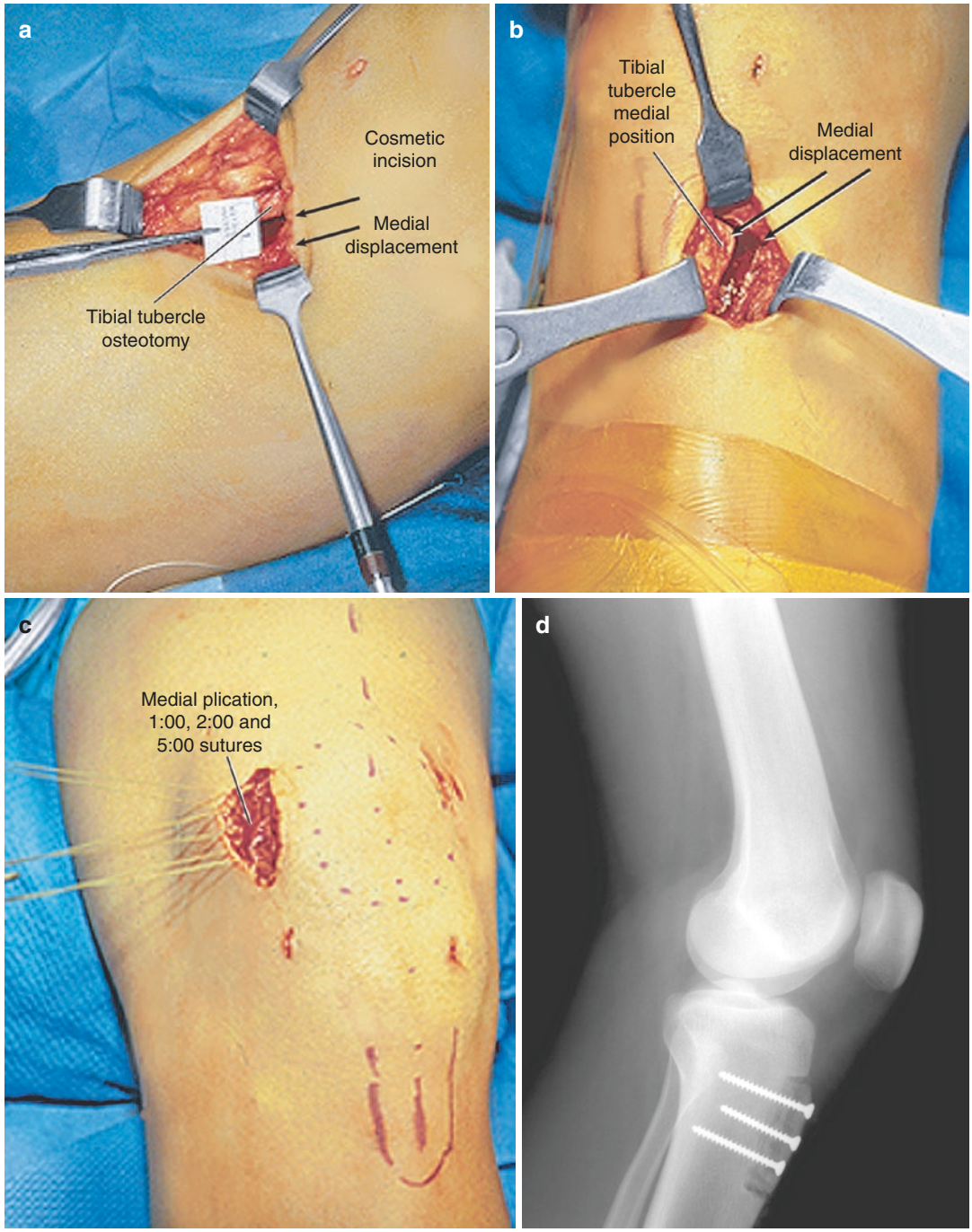

Fig. 28.1 Proximal-distal realignment procedure. (**a**) The medial retinaculum and vastus medialis obliquus 2 cm above the patella are advanced in line of their insertions to restore patellar stability. (**b**) The millimeters of tibial tubercle medial displacement requires are measured at surgery. (**c**) A dovetail tibial tubercle osteotomy has been performed, maintaining the distal and medial soft tissues. (**d**) Postoperative radiograph (From Noyes and Barber-Westin [1])

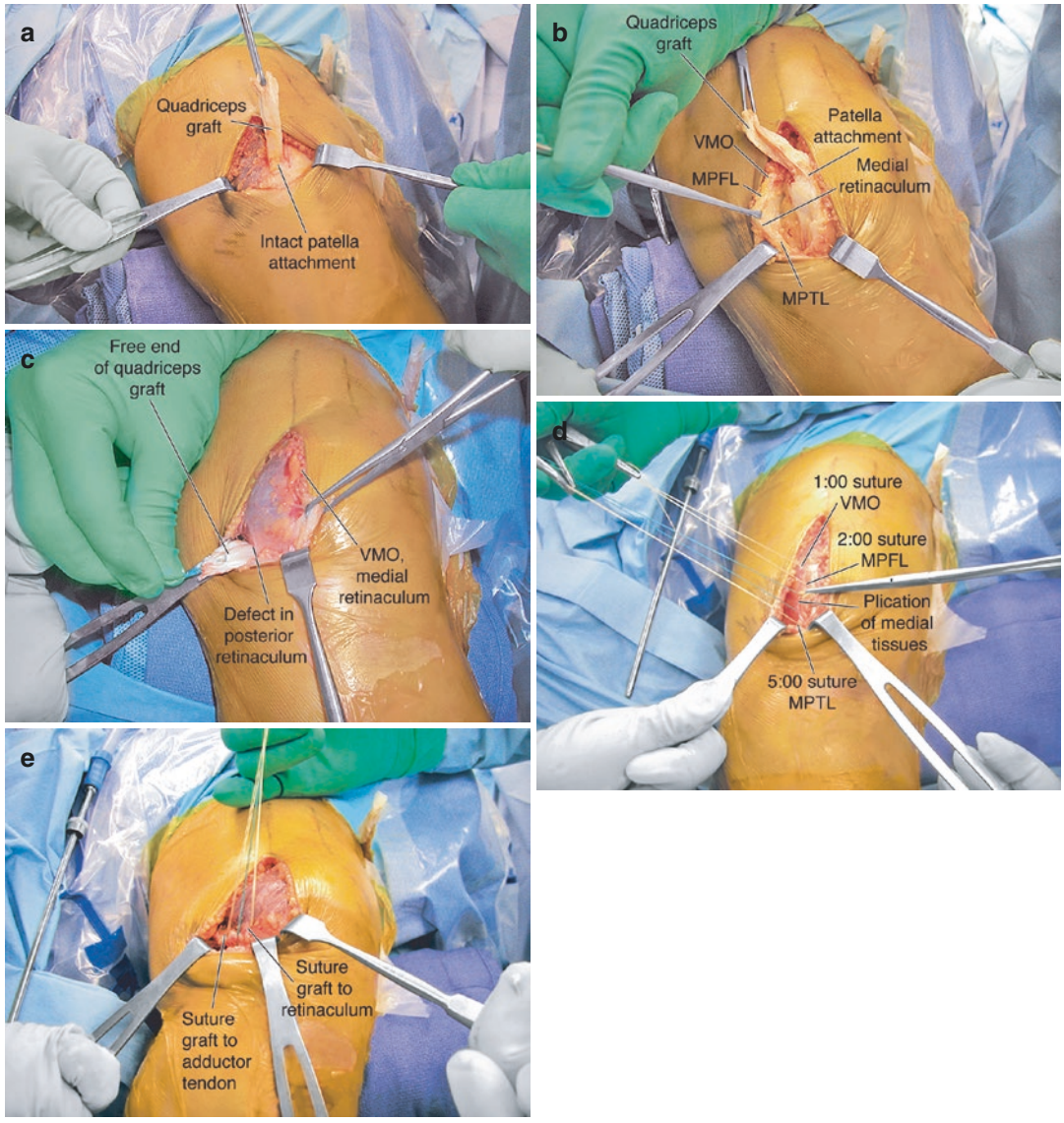

Fig. 28.2 Medial patellofemoral ligament (MPFL) reconstruction with quadriceps tendon. (**a**) A medial full-thickness quadriceps tendon graft, 60 mm × 8 mm wide (measured to the superior edge of the patella) is harvested with the patellar attachment retained. In some knees, a partial-thickness autograft provides a suitably sized graft. Two to 3 mm of the remaining quadriceps tendon is left attached to the vastus medialis obliquus (VMO) for later closure. (**b**) Dissection deep to the medial retinaculum and above synovial pouch and MPFL, medial patellomeniscal ligament (MPML). (**c**) Puncture of the medial retinaculum, posterior to the medial femoral epicondyle at the native MPFL attachment just anterior to the adductor tendon, with the passage of graft beneath the retinaculum. Setting of the normal tension of the medial soft tissues. (**d**) Imbrication of the VMO, medial retinaculum, MPFL, and MPML. (**e**) Suturing of the quadriceps graft to the MPFL native femoral attachment, with a backup suture to the adductor tendon. The graft and medial tissues are not overtensioned and should allow a normal lateral translation (glide) of 25% patellar width (From Noyes and Barber-Westin [1])

procedures modify the medial-lateral, anterior-posterior, rotations, and proximal-distal positions of the patella by transfer of the tibial tubercle. Included in this category are anterior (Maquet [7]), medial (Elmslie-Trillat [8]), and anteromedial (Fulkerson [9]) transfer of the tibial tubercle. Literally, hundreds of articles have been written on these operative procedures regarding their indications, technique, and clinical outcomes [4, 10–20]. However, information regarding the ability of patients to return to sports (RTS) and previous activity levels after these operations is more difficult to determine and, as of the time of writing, no formal systematic review had been conducted on this topic.

Few detailed postoperative rehabilitation guidelines specific for RTS after patellofemoral realignment operations are available. In 2018, Zaman et al. [21] reviewed 53 studies to determine criteria for RTS after MPFL reconstruction. The authors reported that although 35 studies (66%) provided an expected timeline for RTS, only eight included objective criteria in the rehabilitation protocol, such as sufficient quadriceps or general muscle strength, range of motion (ROM), and patellar stability. However, none of the eight studies provided numerical values for these criteria. Fisher et al. [18] reviewed the literature to determine the ability of an MPFL reconstruction to return patients to sports activities. Of 21 studies included in the investigation, only six provided sports activity level ratings (Tegner scores) and the authors concluded that there was very limited RTS information available.

Menetrey et al. [22] reviewed the literature to devise a RTS protocol after patellar dislocation or surgery for patellofemoral instability. These authors also concluded that available evidence regarding the functional capacity of patients, including rehabilitation and testing protocols, that allowed for a safe RTS was sparse. They provided the following criteria from a consensus meeting from the ISAKOS Sports Medicine Committee held in 2013 on RTS after patellofemoral instability: (1) postoperative complete radiographic healing of bone, (2) no knee pain, effusion, or instability, (3) full or nearly full ROM, (4) completion of neuromuscular training and proprioception, (5) satisfactory core strength and endurance, (6) acceptable dynamic control (Star Excursion Balance Test, SEBT), (7) limb symmetry index >85% on hop tests, (8) adequate performance with physiotherapist during sport-specific drills simulating the intensity and movement patterns of the athlete's sport, and (9) psychological readiness to RTS (Single Assessment Numerical Evaluation [SANE] score > 80/100). The authors recommended consideration of several videotaped tests to determine dynamic control, including the single-leg squat, the drop-jump, the side-hop, and the SEBT.

We have published elsewhere a complete description of the management of active patients with patellofemoral malalignment and instability, including a review of the biomechanics of patellofemoral restraints, indications, and contraindications for surgery, and postoperative management [1]. This chapter summarizes data from 52 studies regarding RTS after MPFL reconstruction and proximal/distal realignment procedures that did not involve MPFL reconstruction (Table 28.1). Data regarding return to

Table 28.1 Summary of studies reviewed

	All studies reviewed		RTS incidence rate		Tegner scores only	
	No. of studies	No. of patients	No. of studies	No. of patients	No. of studies	No. of patients
MPFL reconstruction	36	1408	16	677	20	731
Patellar realignment procedures	16	484	5	173	11	311
Total	52	1892	21	850	31	1042

All data are numbers
MPFL medial patellofemoral ligament, *RTS* return to sports

preinjury sport and return to any type of sport, as well as Tegner activity scores and failure rates are provided. An analysis of the postoperative rehabilitation criteria for RTS described by each study is presented. Our postoperative rehabilitation protocol is detailed, along with our criteria to initiate sports training and for final RTS release.

28.2 Return to Sport After MPFL Reconstruction

Our review located 36 studies that provided RTS percentages (Table 28.2) and/or Tegner activity scores (Table 28.3) after MPFL reconstruction in 1408 patients [23–58]. The mean age was approximately 22.8 years (range, 10.3–56) and the gender breakdown, provided in 31 studies, was 717 females and 481 males. The mean follow-up was 3.2 years (range, 0.3–13 years).

The MPFL was reconstructed in all patients in 30 studies and hamstring tendon autografts were used in the majority (23 studies). MPFL reconstruction or repair was selected based on indications in one investigation [38] or in a randomized trial design in two studies [46, 52]. MPFL suture repair was used in acute ruptures in two studies [26, 28] and for chronic recurrent dislocations in one [29]. Associated procedures were described in 12 studies, with the most common including tibial tuberosity transfer, lateral release, and trochleoplasty.

Return to preinjury sports activity levels, provided in 14 studies encompassing 387 patients, averaged 70% (range, 22–100%, Fig. 28.3). Data regarding return to any sport, found in 15 studies, averaged 83% (range, 43–100%). The mean postoperative Tegner score, calculated from 29 studies (Fig. 28.4), was 5.2 points.

The mean time patients were usually allowed to RTS was found in 21 studies (Table 28.4). Almost no criteria were provided to determine when patients could be released safely to either sports-specific training or unrestricted activities. Carnesecchi et al. [23] allowed RTS "depending on the analytical and functional recovery" of the patient. Drez et al. [25] allowed RTS when full ROM and normal quadriceps strength had been achieved. Tompkins et al. [38] released patients to full sports once they passed a "functional assessment"; however, no information regarding tests used or passing criteria was provided.

Ambrozic et al. [35] described sports activity levels in 29 patients (14 females, 15 males, mean age, 26.2 years) who underwent isolated MPFL gracilis autograft reconstruction for recurrent dislocation. RTS was permitted 6 months postoperatively. Twenty-six patients were active in sports before surgery and three never participated. An average of 6.4 years postoperatively, 23 patients had RTS, with 16 obtaining their preinjury level. The most common sports patients returned to were soccer, cycling, and skiing. There were no complications or failures.

Lippacher et al. [28] also focused on the ability of a MPFL reconstruction to return patients to sports activities. These authors followed 68 patients (44 females, 24 males, mean age, 18.3 years) a mean of 2 years postoperatively. Sixty-two patients participated in sports before surgery and all were able to return; 53% at the same or higher level and 47% at lower levels. Common sports patients returned to included soccer, volleyball/handball, cycling, and swimming. Recurrent dislocations occurred in two patients and five patients had 1–2 episodes of subluxation. All of these individuals underwent further rehabilitation and none required revision surgery.

28.3 Return to Sport After Patellar Realignment Procedures

We found 16 studies that provided RTS data after patellar realignment procedures (that did not include MPFL repair or reconstruction) in 484 patients [39, 58–72]. The mean age was approximately 22.2 (range, 5–56) and the gender numbers, provided in 13 studies, were 264 females and 116 males. The mean follow-up was approximately 7 years (range, 0.5–46 years). The operative procedures included Elmslie-Trillat in four

Table 28.2 RTS after MPFL reconstruction

Study	Cohort			MPFL graft, associated procedures[a]	Sports scale	RTS data				% Failed
	No. of men, women	Mean age (range)	Mean follow-up year			RTS % preinjury	RTS % any sport	Mean time RTS allowed (months)	Comments	
Carnesecchi et al. [23]	14/16	21.9 (NP)	1	Gracilis	None	100%	100%	4	RTS allowed "depending on the analytical and functional recovery"	0%
Nelitz et al. [24]	15/6	12.1 (10.3–13.9)	2.8	Gracilis. All open growth plates	Tegner	81%	100%	3	Tegner preop 6.0, FU 5.8; mean time RTS 5.3 months (4–12); 19% returned lower level	0%
Drez et al. [25]	10/5	22 (14–52)	2.6	Semitendinosus or gracilis	Tegner	80%	100%	6	Tegner preop 6.8, FU 6.7. Full activity allowed full ROM and normal quadriceps strength achieved	7%
Nelitz et al. [26]	14, 9	19.2 (15.4–23.6)	2.5	Gracilis and trochleoplasty	Tegner	74%	100%	3	Tegner preop 5.5, FU 5.0. Patients advised to avoid high-risk pivoting activities	0%
Panni et al. [27]	11/37	28 (16–50)	2.7	Semitendinosus	None	64%	100%	6	20% returned to lower level sports for knee-related reasons, 16% returned to lower level for non-knee-related reasons. Gentle jogging on trampoline begun at 8 weeks, controlled sports-specific rehabilitation begun at 12 weeks	0%
Lippacher et al. [28]	24/44	18.3 (14–43)	2	Gracilis	Tegner	53%	91%	3	Tegner preop 4.5, FU 4.0. 47% returned lower level. Common sports: soccer, volleyball, handball, cycling, swimming, skiing. Patients advised of risks of high-pivot sports	0%

Camp et al. [29]	14/13	19 (11–32)	4	MPFL repair (chronic), microfracture 21%, lateral release 3%	Tegner	88%	88%	NP	Tegner preop 6.9, FU 6.6	28%
Ahmad et al. [30]	4/4	32 (16–56)	3	MPFL repair (acute)	None	86%	86%	4	None	12.5%
Ronga et al. [31]	21/7	32.5 (19–40)	3.1	Gracilis	Authors' own	32%	86%	Sports-specific rehab 3, full sports 6	54% returned lower level; mean time RTS 7.5 months (6–16); isokinetic testing 60° and 120°/s involved side significantly weaker than noninvolved	3.5%
Mariani et al. [32]	11/6	21 (14–42)	2.2	MPFL repair (acute)	None	82%	82%	NP	None	0%
Feller et al. [33]	15/21	NP (14–44)	3.1	Semitendinosus or gracilis; transfer tibial tuberosity 25%	Authors' own	NP	81% isolated MPFL, 70% combined	NP	Highest level of sports activities: isolated MPFL 81% strenuous, 19% moderate. Combined 57% strenuous, 20% moderate, 14% light. Frequency of sport: isolated MPFL 47% 4–7 day/week, 43% 1–3 day/week, 5% 1–3 ×/month Combined 43% 4–7 day/week, 57% 1–2 day/week	0%
Wagner et al. [34]	17/33	19 (NP)	1–2	Gracilis	Tegner	80%	80%	NP	Tegner scores NP	6%
Ambrozic and Novak [35]	15/14	26.2 (17–40)	6.4	Gracilis	Tegner	70%	79%	6	Tegner preop 4.4, FU 5.7. Cycling and jogging allowed after 3 months. Common sports soccer, cycling, skiing	3%
Howells et al. [36]	84/109	26 (16–49)	1.3	Semitendinosus	Tegner	NP	76%	NP	Tegner preop NP, FU 5.3. 13% sports with symptoms	0%

(continued)

Table 28.2 (continued)

Study	Cohort			MPFL graft, associated procedures[a]	Sports scale	RTS data				% Failed
	No. of men, women	Mean age (range)	Mean follow-up year			RTS % preinjury	RTS % any sport	Mean time RTS allowed (months)	Comments	
Hopper et al. [37]	Total 61	23.9 (14–46)	2.6	Semitendinosus or gracilis; transfer tibial tuberosity 31%	Tegner	NP	56% (54) mild trochlear dysplasia; 43% (7) severe trochlear dysplasia	NP	Tegner preop NP, FU mild trochlear dysplasia 3.9, severe trochlear dysplasia 2.3	9% mild trochlear dysplasia; 100% severe trochlear dysplasia
Tompkins et al. [38]	7/16	20 (NP)	2–6.2	MPFL repair (14) or hamstring reconstruction (9)	Tegner	64% repair, 22% reconstruction	NP	5–6	Tegner preop repair 5.5, reconstruction 8; FU repair 6.5, reconstruction 5. Patients allowed to RTS once they passed a functional assessment	0%

FU follow-up, *MPFL* medial patellofemoral ligament, *NP* not provided, *ROM* range of motion, *RTS* return to sport

[a]All autografts

Table 28.3 Studies reporting Tegner scores only after MPFL reconstruction

Study	Cohort			MPFL graft, associated procedures[a]	RTS data			% Failed
	No. of men, women	Mean age (range)	Mean follow-up year		Mean time RTS allowed (months)	Tegner preop[b]	Tegner FU[b]	
Lim et al. [39]	6/3	20.2 (14–23)	1	Gracilis	NP	5	6.8	0%
Xie et al. [40]	Total 85	NP	5	Semitendinosus; suture augmentation 49%, transfer tibial tubercle 87%	4	3.3 ± 1.7 augmentation, 3.5 ± 1.8 no augmentation	6.8 ± 1.3 augmentation, 5.5 ± 1.9 no augmentation	2.4% augmentation, 23% no augmentation
Blond and Haugegaard [41]	Total 29	19 (12–39)	2.4	Gracilis and trochleoplasty	NP	4 (1–6)	6 (4–9)	17%
Banke et al. [42]	6/11	22.2 (NP)	2.5	Gracilis and trochleoplasty	NP	2 (0–4)	6 (3–8)	0%
Li et al. [43]	28/37	29.4 (NP)	6.5	Allograft	6	3.1 ± 0.6	5.8 ± 0.9	0%
Berruto et al. [44]	9/7	19 (15–43)	3.3	Synthetic ligament	6	3.9 (3–5)	5.7 (3–7)	0%
Calanna et al. [45]	12/7	25.5 (NP)	1.8	Semitendinosus	5–6	6.1 ± 1.1	5.7 ± 0.8	0%
Zhao et al. [46]	15/73	24 (16–43)	5	Semitendinosus or medial retinaculum repair + lateral release; transfer tibial tubercle 89%	4	3.1 ± 1.9 reconstruction, 2.9 ± 1.6 repair	5.7 ± 1.7 reconstruction, 4.0 ± 1.4 repair	9% reconstruction, 26% repair
Ahmad et al. [47]	Total 20	23 (11–43)	2.6	Semitendinosus autograft or allograft. Lateral release 60%	Running and agility training 3, full sports 4	3.6	5.6	0%
Csintalan et al. [48]	12/37	24 (13–49)	4.3	Semitendinosus	NP	6.1 ± 2.7	5.6 ± 2.5	0%
Becher et al. [49]	10/20	22 (NP)	2.2	Gacilis	NP	NP	Dynamic technique 5.2 ± 1.9, static technique 4.4 ± 1.8	3%
Steiner et al. [50]	12/22	27 (NP)	5.5	Variety graft options	NP	3.1 ± 1.6	5.1 ± 1.6	0%
Hinterwimmer et al. [51]	6/13	23 (16–47)	1.3	Gracilis	NP	NP	5 (3–7)	0%

(continued)

Table 28.3 (continued)

Study	Cohort			MPFL graft, associated procedures[a]	RTS data			% Failed
	No. of men, women	Mean age (range)	Mean follow-up year		Mean time RTS allowed (months)	Tegner preop[b]	Tegner FU[b]	
Ma et al. [52]	22/41	28 (NP)	3.3	Semitendinosus or medial retinaculum plasty and lateral release	3	3 (1–5)	5 (2–8)	0%
Song et al. [53]	10/10	21 (13–34)	2.8	Semitendinosus	3–6	3 (1–4)	5 (4–7)	0%
Kohn et al. [54]	14/28	22 (13–46)	2	Revision gracilis; variety associated procedures in 64%	NP	2.4 (0–7)	4.9 (3–8)	0%
Suganuma et al. [55]	16/30	20 (14–34)	4	Synthetic ligament	3	4.6 (3–7)	4.6 (3–7)	0%
Matthews et al. [56]	12/9	24 (17–44)	2.6	Semitendinosus or gracilis	3–6	3 (0–6)	4.4 (1–7)	0%
Christiansen et al. [57]	15/29	22 (12–47)	1.8	Gracilis; transfer tibial tuberosity 27%	Controlled sports 3, contact sports 6	NP	4 (1–9)	2%
Sillanpaa et al. [58]	Total 15	20.2 (19–22)	10.1	Adductor magnus tenodesis	NP	NP	4 (2–8)	7%

FU follow-up, *MPFL* medial patellofemoral ligament, *NP* not provided, *RTS* return to sport

[a]Autografts unless otherwise indicated

[b]All data given as provided in study

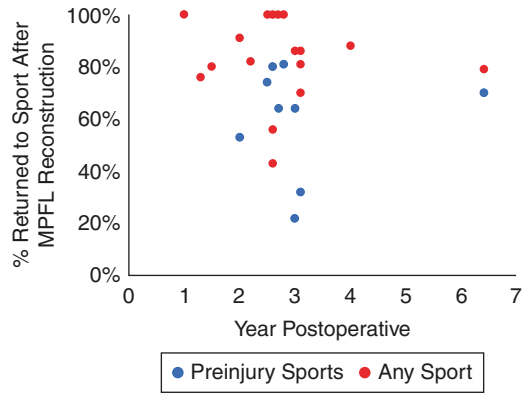

Fig. 28.3 Percentages of athletes who returned to either preinjury sports activities and/or any sport after MPFL reconstruction. A mean of 70% returned to preinjury activity levels and a mean of 83% returned to any sport

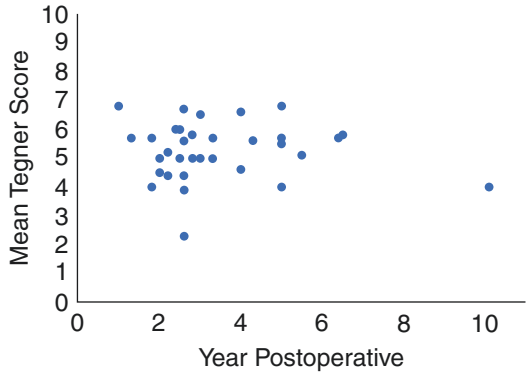

Fig. 28.4 Mean Tegner scores at follow-up after MPFL reconstruction in 29 studies

studies, Elmslie-Trillat-Roux in two studies, Fulkerson in two studies, Roux-Goldthwait in one study, Grammont in one study, and a variety of procedures offered in six studies. Associated procedures were described in nine studies and most frequently included lateral release. Trochleoplasty was done in two studies in select patients.

Return to preinjury sports activity levels was provided in only five studies involving 173 patients (Table 28.5). Percentages ranged from 22% to 97%. Postoperative Tegner activity scores were found in 13 studies (Table 28.6) and averaged 4.1 points (Fig. 28.5).

The mean time patients were usually allowed to RTS was provided in seven studies (Table 28.4). Criteria for RTS was sparse. Tjoumakaris et al. [71] required "adequate" quadriceps strength and ROM. Luhmann et al. [67], in a study involving 27 children (aged 8.8–18.3 years), cited adequate radiographic healing, knee ROM, and near normal leg strength as criteria. Barber and McGarry [59] had similar requirements for RTS.

Liu et al. [66] specifically analyzed RTS after a Fulkerson tibial tubercle anteromedialization for a primary diagnosis of patellofemoral pain or osteoarthritis. A total of 57 patients (48 females, 9 males, mean age, 29.6 years) were followed a mean of 4.6 years postoperatively. Patients were typically allowed to RTS between 6 and 8 months but had to demonstrate "quality movement strate-

Table 28.4 Mean times postoperative sports participation allowed

Operation	Months RTS postoperatively	Qualifications	Number of studies
MPFL reconstruction or repair	3	Running, agility training only	1
	3	Controlled sports only	1
	3	None	5
	4	None	5
	6	None	7
	3–6	None	2
	5–6	None	2
Proximal and/or distal realignment, no MPFL reconstruction or repair	2–3	None	1
	3	None	1
	4–5	None	3
	6	None	1
	6-8	Except contact sports with cutting/pivoting	1
	9	Contact sports with cutting, pivoting	1

Table 28.5 RTS after patellar realignment procedures

Study	Cohort			Operative details, associated procedures	Sports scale (preinjury sports)	RTS data				% Failed
	No. of men, women	Mean age (range)	Mean follow-up year			RTS % preinjury	RTS % any sport	Mean time RTS allowed (months)	Comments	
Tjoumakaris et al. [71]	4/30	20 (14–54)	3.8	Fulkerson and lateral release	None	97%	97%	4–5 "adequate" quadriceps strength and ROM	All athletes; 14 high school, 12 collegiate, 8 recreational	3%
Liu et al. [66]	9/48	29.6 (NP)	4.6	Fulkerson; lateral release 68%	Authors' own	54%	70%	6–8; contact sports with cutting/ pivoting 9 months	RTS "must have shown quality movement strategies on a sport-specific RTS assessment". Most common: walking for exercise, running, cycling, weight lifting, soccer, yoga. 58% considered knee to feel normal during sports	0%
Kreuz et al. [65]	11/17	15 (5–28)	6.3	Proximal realignment, proximal-distal realignment, or proximal realignment-transfer tibial tubercle	None	36%	64%	NP	Redislocation rates: 4 (31%) proximal realignment, 2 (29%) distal realignment, 1 (12.5%) proximal realignment-transfer tibial tubercle	31% redislocation; 18% reoperation
Berruto et al. [60]	12/28	25.8 (16–44)	12.7	Elmslie-Trillat, insall, or open lateral release	Tegner	22%	NP	NP	Tegner FU 4.0 ± 1.7	<1%
Sillanpaa et al. [70]	16/1	20 (19–22)	7	Medial reefing 78%, Roux-Elmslie 22%	Tegner	76%	NP	NP	Tegner FU 5 (2–9)	0%

NP not provided, *ROM* range of motion, *RTS* return to sports

Table 28.6 Studies reporting Tegner scores only after patellar realignment procedures

Study	Cohort			Operative details, associated procedures	RTS data			% Failed
	No. of men, women	Mean age (range)	Mean follow-up year		Mean time RTS allowed (months)	Tegner preop[a]	Tegner FU[a]	
Luhmann et al. [67]	5/22	14.1 (8.8–18.3)	5	Proximal realignment, lateral release; distal realignment 78%	Light jogging 3, full sports 4.5 (adequate radiographic healing, knee ROM, near normal leg strength)	NP	5.4 (1–9)	7%
Marcacci et al. [68]	7/8	21.1 (13–37)	5	Elmslie-Trillat; trochleoplasty 22%	2–3	2 (0–3)	5 (3–7)	0%
Kraus et al. [64]	10/33	14.6 (12.7–16)	8	Grammont realignment; osteochondral fragment fixation 23%	3	6.2 (2–10)	5 (2–9)	7%
Sillanpaa et al. [58]	Total 21	20 (19–24)	7	Roux-Goldthwait	NP	NP	5 (2–7)	14%
Endres and Wilke [62]	4/14	28.2 (17–48)	9.7	Roux-Elmslie-Trillat, lateral release	NP	3.4	4.6	5%
Carney et al. [61]	12/2	NP (17–24)	2.2	Roux-Elmslie-Trillat	NP	NP	4 (1–8); 60% ≤level 3, 33% level 5–6, 7% level 8	7%
Rillmann et al. [69]	Total 32	23.2 (15–42)	5.2	Elmslie-Trillat	NP	3.1 ± 1.2	3.8 ± 0.9	8%
Barber and McGarry [59]	9/26	27.7 (13–52)	8.2	Elmslie-Trillat, lateral release	Running 3, full sports 4–5 (with radiographic healing, full ROM, good quadriceps strength)	NP	3.8	3%
Karataglis et al. [63]	8/30	31 (19–56)	3.3	Elmslie-Trillat; medial plication 18%	NP	NP	3.5 (2–8)	5%
Lim et al. [39]	9/5	21.3 (14–32)	1.3	Distal realignment	NP	1.4	3.4	0%
Vivod et al. [72]	Total 54	NP (5–48)	22.5	Proximal realignment, distal realignment, or proximal-distal realignment; proximal-distal realignment and trochleoplasty 36%	6	NP	3 for all procedures	36% proximal realignment, 20% distal realignment, 32% proximal-distal realignment and trochleoplasty

NP not provided, *ROM* range of motion, *RTS* return to sport
[a]All data are given as provided in the study

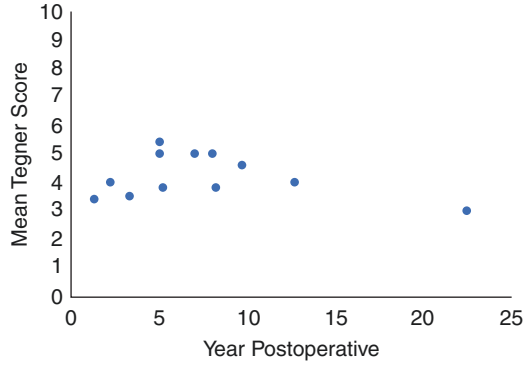

Fig. 28.5 Mean Tegner scores at follow-up after proximal and/or distal patellar realignment procedures in 13 studies

gies on a sports-specific return-to-play assessment" similar to the authors' anterior cruciate ligament patients. Contact sports involving extensive cutting and/or pivoting were prohibited until 9 months postoperatively. Overall, 70% returned to any sport and 54% returned to preinjury levels. The authors noted that 48 patients had participated in sports within 3 years of surgery and of these, 40 were able to return to at least one sport after surgery. Activities most commonly resumed included weightlifting, cycling, soccer, running, and yoga. There was no correlation between age, number of prior surgical procedures, smoking status, patellar Outerbridge grade, or the presence of trochlear lesions and the ability to RTS. There were no failures, although 47% had chronic pain and only 58% felt their knee was normal during sports.

Tjoumakaris et al. [71] followed 34 athletes (30 females, 4 males, mean age, 20 years) who underwent a Fulkerson procedure for a primary diagnosis of recurrent patellar instability. There were 14 high school, 12 collegiate, and 8 recreational athletes. Patients were allowed to RTS by 4–5 months after surgery if "adequate quadriceps strength and ROM" had been achieved. At follow-up, a mean of 3.8 years postoperatively, 97% had returned to their preinjury sport. The authors did not provide data related to any problems patients may have experienced while participating. The one patient who failed and had recurrent instability tested positive for Ehlers–Danlos syndrome.

28.4 Failure Rates

Twenty-three studies of MPFL reconstruction or repair reported no failures or recurrent dislocations resulting in the need for further surgery (Fig. 28.6). Hopper et al. [37] reported that all seven patients who had severe trochlear dysplasia (Dejour classification C and D) failed, suffering recurrent dislocations, compared with 7.4% of 54 patients with mild dysplasia. Xie et al. [40] found that patients in whom a semitendinosus MPFL reconstruction was augmented with polyester suture ($n = 42$) had a recurrent dislocation rate of just 2.4% compared with 23.3% of patients who did not have suture augmentation ($n = 43$). Zhao et al. [46] in a level 2 randomized study reported postoperative rates of redislocation and/or multiple episodes of instability of 9% after MPFL reconstruction ($n = 45$, mean age 25.0 ± 6.6) and 26% after medial retinaculum plication ($n = 43$, mean age 23.9 ± 5.8). At the 5-year follow-up, patients in the MPFL-reconstructed group had a significantly higher mean Tegner score (5.7 ± 1.7 and 4.0 ± 1.4, respectively; $P < 0.001$).

Four studies involving other proximal and/or distal procedures reported no failures or recurrent dislocations resulting in the need for further surgery. Sillanpaa et al. [5] reported that 14% of 21 knees failed after a Roux-Goldthwait procedure. Vivod et al. [72] followed 54 patients a

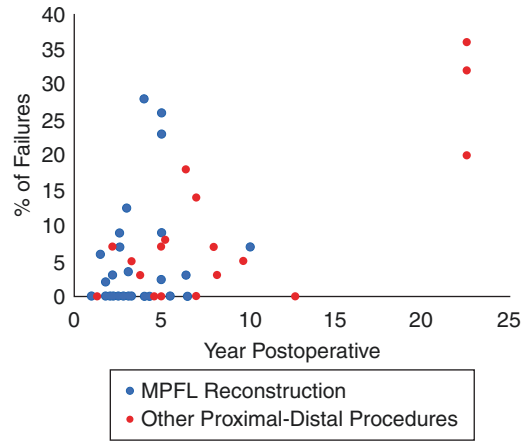

Fig. 28.6 Percentages of failures of MPFL reconstructions or repairs and other proximal-distal procedures (without MPFL reconstruction or repair) are shown

mean of 22.5 years postoperatively and reported failures (recurrent dislocations) in 36% after isolated proximal realignment, 32% after proximal-distal realignment, and 20% after isolated distal realignment. Kreuz et al. [65] followed three surgical groups in a nonrandomized study an average of 6.3 years postoperatively and found recurrent dislocations in 31% after isolated Green proximal realignment, in 29% after Green proximal and Roux-Goldthwait distal realignment, and in 12.5% after a combined proximal realignment and tubercle transfer ($P < 0.05$).

28.5 Advances in Operative Techniques for RTS

The RTS data summarized in this chapter reflect, for the most part, studies that failed to include modern objective testing of knee function, including strength and agility, as well as postoperative advanced neuromuscular retraining that is now recognized as vitally important after ACL surgery. Recent literature has demonstrated changes in surgical procedures recommended to correct patellofemoral instability that allows earlier restoration of ROM and muscle strength. These continued advances in both surgery and rehabilitation should, we believe, result in improved RTS data and lower failure rates. These include the following:

1. A better appreciation of the role of trochlear dysplasia which, when present, indicates a lack of a normal trochlear groove to provide patella stability and control patellar kinematics. Patients with trochlear dysplasia have a higher failure rate and rely to a greater extent on soft tissue ligament restraints and muscle control mechanisms. This also applies to patella alta cases, in which tibial tubercle distalization is required to position the patella within a normal patellar-trochlear relationship.
2. An understanding of the role of the MPFL in conjunction with other medial retinacular restraints (medial patellar meniscal and tibia restraints). MPFL surgery must restore a checkrein for abnormal lateral patellar translation, particularly from 0° to 20° of knee motion. The femoral attachment of the MPFL graft requires careful positioning from a proximal-to-distal direction to function at low knee flexion angles and avoid overtightening with knee flexion.
3. The indications for distal tibial tubercle medialization or elevation are now highly select and many knees do not require these procedures.
4. Proximal realignment procedures require early knee motion exercises to prevent abnormal scarring and disuse effects. For example, we reported that immediate ROM from 0° to 90° and full weight-bearing in extension is possible and encouraged immediately after surgery [73]. Previous rehabilitation protocols may have been overprotective regarding the allowance of immediate motion and weight-bearing.
5. Proximal MPFL grafts placed into the patella through drills holes risk patellar fracture. Docking of the graft at adjacent patella soft tissues avoids this complication. In the MPFL quadriceps turndown procedure advocated by the authors (Fig. 28.2) [1], the attachment of the quadriceps graft is performed entirely by soft tissue sutures at both the patella and femoral anatomic attachment sites, thereby avoiding the necessity for rigid fixation implants and their potential complications.

28.6 Postoperative Rehabilitation Concepts

Our postoperative rehabilitation protocol is summarized in Table 28.7. This protocol is used in patients undergoing proximal and distal extensor mechanism realignment procedures, with or without MPFL reconstruction. Patients are placed into a postoperative long-leg brace for the first 4 weeks. ROM exercises and patellar mobilization in superior-inferior and medial-lateral directions are begun immediately after surgery to prevent parapatellar contractures. The goal for the first week is to obtain 0–90° of motion. Knee flexion is gradually increased to 110° by the

Table 28.7 Noyes Knee Institute rehabilitation protocol for proximal-distal patellar realignment with and without MPFL reconstruction

	1–4 weeks	5–8 weeks	9–12 weeks	4–6 months	7–12 months
Brace					
Soft postoperative motion	X				
Patellar (optional, symptoms)		X	X	X	X
Range of motion minimum goals					
0–90° (week 1–2)	X				
0–110° (week 3–4)	X				
0–135°		X			
Weight-bearing					
Isolated MPFL reconstruction, 100%, crutch support as needed	X				
Concurrent tibial tubercle procedure 50% (weeks 1–2)	X				
Concurrent tibial tubercle procedure 100% (weeks 3–4)	X				
Patella mobilization	X	X			
Modalities					
Electrical muscle stimulation	X	X			
Biofeedback	X	X			
Pain/edema management (cryotherapy)	X	X	X	X	X
Stretching					
Hamstring, gastrocnemius-soleus, iliotibial band, quadriceps	X	X	X	X	X
Strengthening					
Quadriceps isometrics	X	X			
Straight leg raises (isolated MPFL reconstruction)	X				
Straight leg raises (concurrent tibial tubercle procedure)		X			
Active knee extension (with secure internal fixation tubercle)	X	X	X		
Closed-chain: toe raises, wall sits, mini-squats	X	X	X	X	
Knee flexion hamstring curls (90°)	X	X	X	X	X
Knee extension quadriceps (90–30°)	X	X	X	X	X
Hip abduction-adduction, multi-hip		X	X	X	X
Leg press (70–10°)		X	X	X	X
Balance/gait/proprioceptive training					
Weight-shifting, cup walking	X	X			
Mini-trampoline, BAPS, BBS (concurrent tibial tubercle procedure delay 4–6 weeks)	X	X	X	X	X
Conditioning					
Upper body weight training, core training	X	X	X	X	X
Upper body conditioner	X				
Stationary bicycling (high seat, low resistance)				X	X
Water walking		X	X	X	X
Swimming (kicking)			X	X	X
Walking		X	X	X	X
Ski machine (short stride, level, low resistance)		X	X	X	X
Running: straight			X[a]	X	X
Cutting: lateral carioca, figure eights				X[a]	X
Plyometric training, full sports				X[a]	X

BAPS Biomechanical Ankle Platform System (Camp, Jackson, MI), *BBS* Biodex Balance System (Biodex Medical Systems, Inc., Shirley, NY), *MPFL* medial patellofemoral ligament

[a]Only for patients with normal articular cartilage in the patellofemoral joint

fourth week and then a full motion of at least 135° is allowed by the eighth week. This limitation of flexion in the first 4 weeks is designed to protect the suture lines and the repair when a proximal realignment procedure is performed. The therapist should be aware of the potential for a knee motion complication and, if 0–110° is not obtained by the end of the fourth week, the patient should undergo a local anesthetic nerve block or a gentle ranging of motion under anesthesia as previously discussed. The early treatment and avoidance of an arthrofibrotic response to surgery are critical in these cases.

After isolated MPFL reconstruction, patients are allowed to bear 100% of their body weight with the knee at full extension using crutches for support. For patients who undergo a concurrent tibial tubercle medialization procedure, 50% weight-bearing is used for 2 weeks for protection and full weight-bearing is allowed by the fourth week.

Radiographs are taken the first and the fourth postoperative weeks to ensure adequate position and healing of the osteotomy. Weight-bearing may be delayed if problems are detected in bony healing or in quadriceps control. Flexibility exercises including stretching of hamstrings, gastrocnemius-soleus, quadriceps and iliotibial band are started the first week. The strengthening program for the quadriceps mechanism is begun during the first week and gradually progressed. Straight leg raises are allowed immediately after isolated MPFL reconstruction and at the fourth week after concurrent tibial tubercle procedures. Open kinetic chain exercises are begun immediately after isolated MPFL reconstruction but are delayed until the fourth to sixth week after concurrent tibial tubercle procedures at which time the osteotomy is usually healed.

Unfortunately, the majority of patients that undergo the operative procedures described in this chapter have marked joint deterioration from chronic patellofemoral malalignment or recurrent dislocation/subluxation episodes. In these patients, the goal of surgery is to return to light, low-impact activities only. In select patients (without articular cartilage damage) wishing to resume more strenuous activities, sports training is begun with a running program when the patient demonstrates at least 70% of the strength of the noninvolved limb for quadriceps and hamstrings on isometric testing, is at least 3 months postoperative, has normal patellar stability and tracking, and has no pain or joint effusion. Our running program is described in detail in Chap. 14. The program includes agility drills, cutting, and sharp directional change movement patterns. In select patients wishing to resume sports involving pivoting and cutting, a basic plyometric training program may be initiated upon completion of the running and agility program (see also Chap. 14). Final release to unrestricted sports is based on successful completion of training and achievement of normal indices shown in Table 28.8. Testing includes quadriceps and hamstrings isokinetic [78–88], isometric [89–91], or 1-repetition maximum bench press and leg press [92, 93]; two single-leg hops [74, 78, 80, 81, 94–97]; video drop-jump [75, 98–100], single-leg squat [101–104], and plant and cut [77, 105–107] tests. Other tests to consider before the patient is released to unrestricted athletic activities include the multistage fitness test to estimate VO_2max [108] and the 60-s sit-up test or other core strength measures [109].

A trial of function is encouraged in which the patient is monitored for knee swelling, pain, overuse symptoms, and instability episodes. Upon successful return to activity, the patient is encouraged to continue with a maintenance program. During the in-season, a conditioning program of two workouts a week is recommended. In the off-season or preseason, this program should be performed three times a week to maximize gains in flexibility, strength, and cardiovascular endurance.

Table 28.8 Criteria for release to unrestricted sports activities

Test	Criteria for release to sports
Range of knee motion	IKDC normal or nearly normal
Patellar pain and instability	None
Knee joint effusion	None
Isokinetic muscle (180°/s and 300°/s)	<10% deficit quadriceps and hamstrings compared with contralateral side
Isometric muscle (use if isokinetic equipment not available: portable fixed or hand-held dynamometer, quadriceps 60° flexion, hamstrings 60° or 90° flexion, 3 reps each, use mean)	<10% deficit quadriceps and hamstrings compared with contralateral side
1-repetition maximum bench press and leg press (use if isokinetic and isometric equipment not available)	<10% deficit quadriceps and hamstrings compared with contralateral side
Single-leg hops: any 2 (single hop, triple hop, triple crossover hop, timed hop) [74]	≤15% deficit lower limb symmetry on any two tests
Video drop-jump [75]	If software available: >60% normalized knee separation distance If software not available, subjective analysis landing position: no valgus, knees flexed for controlled landing
Video single-leg squat (5 reps) [76]	Subjective analysis: no knee valgus, medial-lateral movement, or pelvic tilt
Video plant and cut (patient runs 5 m to a spot designated on the floor with tape, plants on the reconstructed leg, and then performs a 45° cut) [77]	Subjective analysis: high hip and knee flexion, upright posture, no valgus collapse

IKDC International Knee Documentation Committee

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