Periarticular Knee Osteotomy

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6.1 High Tibial Osteotomy

6.1.1 Introduction

In valgus and varus knee malalignment in relatively young and active patients, osteotomy has long been recognized as an appropriate option in the management of knee osteoarthritis. Historically, the first high tibial osteotomy (HTO) was performed by Jackson in 1958 with a ball and socket osteotomy below the anterior tibial tuberosity and osteotomy at the middle third of the fibula [1]. Gariepy performed the osteotomy above the anterior tibial tubercle and reported good results in patients with knee osteoarthritis. Following these experiences, HTO was used by several authors. In the same period, opening wedge technique of HTO was developed in France [3, 4] with medial approach, using allograft or autograft bone and plates that allowed stable fixation. At the end of the 1970s, another technique was described by Maquet: the tibial

D.A. Parker (ed.), *Management of Knee Osteoarthritis in the Younger, Active Patient: An Evidence-Based Practical Guide for Clinicians*, DOI 10.1007/978-3-662-48530-9_6

dome osteotomy [5]. After years of popularity, between the 1960s and 1980s, HTO had a slow decline after good results were demonstrated with unicondylar and total knee arthroplasty and rising surgeon preferences for these techniques.

Currently HTO is undergoing a revival, particularly in younger more active patients, due to the desire to preserve the native knee, bone stock, and proprioception and also the possibility to allow physical activities that are not well tolerated with a unicompartmental knee arthroplasty (UKA) [6]. The preference also relates to expectations for physical activities due to the increase in life expectancy [7]. In addition, HTO has become a better option due to new hardware: plates that work like an "internal fixation" allowing a very stable osteosynthesis and periosteal vascular supply preservation. There are also new and more sophisticated bone substitutes and biomaterials that can avoid an iliac crest bone graft harvest and therefore an additional incision with related complications [3, 8, 9].

The first aim of HTO is to eliminate or reduce pain, translating loads to the contralateral femorotibial compartment by correcting deformity. Surgical indications and careful preoperative planning are important to permit long-term satisfying results [10–17]. This chapter will summarize the current knowledge about periarticular knee osteotomies.

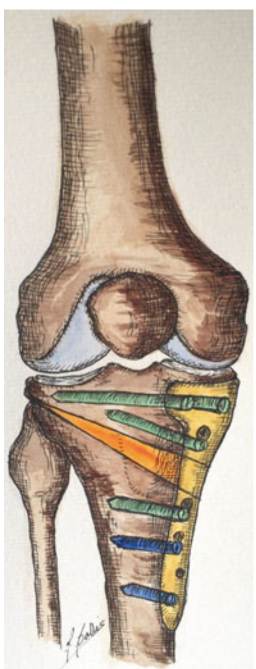


Fig. 6.1 HTO – medial opening wedge

6.1.2 Indications and Contraindications (Table 6.1)

Physical indications include: age between 30 and 70 years; well localized pain at the femorotibial joint line; flexion more than 90° and, if present, a lack of extension <10°; normal or correctable ligamentous status (but anterior cruciate ligament [ACL] or posterior cruciate ligament [PCL] insufficiency is not a contraindication); non-reducible deformity; and patients with an active lifestyle [18].

Physical contraindications include obesity, inflammatory disease, smoking, osteoarthritis or meniscectomy in the contralateral compartment, and tibial subluxation more than 1 cm.

Radiological indications include partial or complete joint space width narrowing in one compartment, no contralateral femorotibial joint space width narrowing or patellofemoral joint space width narrowing, and extra-articular deformity more than 5° [18]. MRI can also be used to more accurately assess the contralateral compartment.

Disputable contraindications include patellofemoral arthritis, flexion less than 100° or fixed flexion deformity, severe extra-articular deformity, older than 70 years, and obese female [18] (Table 6.1).

Table 6.1 Indications and contraindications in HTO

Indications	Contraindications
Age between 40 and 70	BMI >30 (disputable)
Flexion >90°, lack of extension <20°	Flexion <90°, lack of extension >20°
Medial femorotibial compartment involvement	Osteoarthritis (3–4° Outerbridge) in contralateral compartment
Non-reducible deformity	Medial meniscectomy
Metaphyseal varus	Infection
Active lifestyle	Rheumatoid arthritis
Good compliance for rehabilitation	Tibial subluxation >1 cm
	High smokers

6.1.3 Surgical Techniques

Two techniques have been used for the treatment of medial compartment arthritis: medial opening wedge high tibial osteotomy (OWHTO) (Fig. 6.1) and lateral closing wedge high tibial osteotomy (CWHTO) (Fig. 6.2).

6.1.3.1 Surgical Planning (Table 6.2)

Preoperatively, a complete radiological evaluation of the limb is mandatory for accurate planning. This is to determine the mechanical axis and calculate the amount of correction required. The standard x-ray series shows the osteoarthritis grade and the tibial slope, including x-rays done in Rosenberg view (45° of flexion). The weight-bearing anteroposterior long-leg x-ray allows measurement of the HKA angle to plan the correction. The axial patellar x-ray assesses involvement of the femoropatellar joint. A guide to the measurement of the constitutional varus is the epiphyseal axis as defined by Levigne (a line connecting the middle of the tibial joint line and the middle of the line connecting the tibial epiphysis). This axis forms a constant angle of 90° ± 2° to the lateral tibial plateau. The constitutional deformity of the tibia is defined as the angle between the epiphyseal and the tibial mechanical axis. The alignment goal of correction for osteoarthritis is usually 2–3° of mechanical valgus [18].

6.1.3.2 Opening Wedge High Tibial Osteotomy (Table 6.3)

The osteotomy is performed just proximal to the tibial tubercle, having elevated the superficial medial collateral ligament. The plane of the osteotomy is horizontal, slightly different from the medial closing wedge HTO, which is more oblique. First two Kirschner wires are introduced medially. Laterally, these guide pins should be just superior to the head of the fibula. Correct position of the guide pins is assessed using the image intensifier. The direction can be adjusted, if necessary. Using an oscillating saw, the tibial cut is made underneath these guide pins, always staying in contact with them. Firstly, the center of the tibia is cut, followed by the anterior and posterior cortices. The cuts are completed using an osteotome, especially on the anterior cortex, where the patellar tendon is at risk. It is necessary to have an intact lateral hinge for this type of osteotomy. Subsequently, a Lambotte osteotome is introduced into the osteotomy. A second osteotome is then introduced below the first. To open up the osteotomy gently, several more osteotomes are introduced between the first two. In order to maintain the tibial slope, the opening of the osteotomy at the posteromedial cortex should

Table 6.2 X-ray needed for a correct planning

Preoperative planning
Standard x-ray posteroanterior and lateral
X-ray in Rosenberg view
Weight-bearing anteroposterior long-leg x-ray
Sky view patellar x-ray

Table 6.3 HTO techniques

Approach and technical considerations
Lateral closing wedge high tibial osteotomy (using a blade plate)
Slightly oblique anterolateral skin incision, the insertion of the tibialis anterior is released as a Z-plasty; tibialis anterior and long toe extensor muscle are released from the metaphysis
Osteotomy of the fibular neck, protect the peroneal nerve
HTO is done proximal to the tibial tubercle in an oblique direction, using image intensifier
Introduce the blade plate, perform the distal cut of the osteotomy with the saw; the medial cortex is weakened with a 3.2 mm drill
Evaluate the femorotibial axis and fix the osteotomy with two bicortical screws
Medial opening wedge high tibial osteotomy
Anteromedial skin incision just proximal to the tibial tubercle, retraction of pes anserinus tendons, incision of the superficial MCL
Perform the osteotomy proximal to the tibial tubercle, first insert two Kirschner guide pins, from medial to lateral, just above the fibular head, use image intensifier; if the position is okay, perform the osteotomy with the saw; first cut the center then the anterior and finally the posterior part of the tibia. Complete the cuts with osteotome
Subsequently introduce a Lambotte osteotome to open the osteotomy and then introduce as much osteotomes as necessary to obtain the desired correction
Fix the osteotomy with a plate and screws or staples

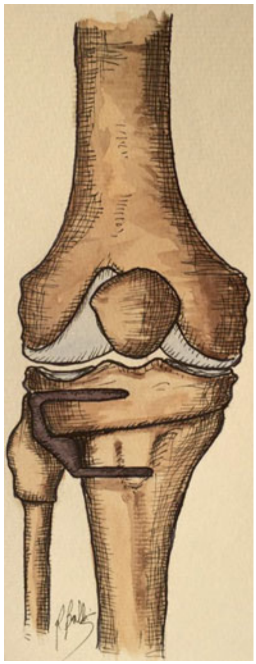


Fig. 6.2 HTO – lateral closing wedge

be approximately twice that at the tibial tubercle [19].

Due to autograft site harvest morbidity, bone substitutes have been used with more frequency, mostly of calcium and phosphate. These substitutes try to reproduce the bone structure, with their porosity, provide a structural support, and allow new vessel and osteoprogenitor cell infiltration promoting new bone formation.

Best results are seen with biomaterials like tricalcium phosphate, calcium phosphate, hydroxyapatite-tricalcium phosphate, and hydroxyapatite only. Substitutes like bioglass, coralline wedges, and combined fillers give high rate of delayed union and nonunion [8].

First treatment with HTO was performed without fixation, but this leads to a high rate of complications including loss of correction, joint stiffness, and patellar tendon contracture. The best fixation is still controversial. Options for fixation include staples, external fixators (axial and circular), and plates (conventional, blade plates, locking plates and with or without spacers). Specific plates such as Puddu plate and Tomofix have demonstrated a high rate of union and less complications [8].

6.1.3.3 Closing Wedge High Tibial Osteotomy (Table 6.3)

The fibular styloid process is first identified, and this procedure usually starts with the osteotomy of fibular head (or neck) or the release of the proximal tibiofibular joint in order to prevent any impingement with the fibula and to allow a final good correction. The surgeon can measure 60 mm distally from the fibular styloid process, in order to define the zone where the fibular osteotomy should be performed. The area between 68 and 153 mm should be avoided, to prevent peroneal nerve palsy [7].

Once the fibular osteotomy is performed, the distal cut of the closing wedge osteotomy is performed. Many surgeons use a guide pin for the distal cut of the osteotomy. The posterior surface of the tibia is protected by a large periosteal elevator, and the patellar tendon is retracted anteriorly. An oscillating saw is used to make the distal cut. An angled cutting guide (6.8 or 10°) is introduced in the distal cut of the osteotomy, and the proximal cut is then made using this angle. The cutting guide should be introduced and impacted on the medial cortex. An oscillating saw is used. The bone wedge is removed. The medial cortex is weakened with a 3.2 mm drill. The wedge is closed, and using a long metal bar positioned on the center of the femur head and in the middle of the ankle joint, the mechanical femorotibial axis is evaluated. The metal bar should pass just laterally to the lateral tibial spine. Computer-assisted surgery can also be used if available.

The osteotomy can be fixed with staples, blade plate, or locking plates.

6.1.4 Results (Tables 6.4 and 6.5)

6.1.4.1 Outcomes

There are 25 published series of high tibial osteotomy with an average of more than 10 years of follow-up currently in the literature [3, 6, 7, 9–12, 16, 20–35]. The studies were divided into two groups: opening wedge high tibial osteotomy

Table 6.4 Systematic review HTO (closing wedge)

Author	Journal/year	Average age	Osteoarthritis classification	Cohort (operated knees)	Device used	Follow-up (years)	Preop average angle	Postop average angle	Results	Scores	Compli-cation rates	Compli-cations	Survival
Gstöttner et al. [6]	Arch Orthop Trauma (2008)	54 years (19–74)	-	134	Staple	12.4 years (1–25)	FTA varus 6–10° 57 %, 11–15° 21 %, 1–5° 18 %	FTA valgus (1 year fu) 1–5° 60 %, 0–5° 20 %, 5–10° 20 %	Survivorship: 94 % 5 years fu, 80 % 10 years fu, 65.5 % 15 years fu, 54 % 18 years fu; predictor factors: age. Not predictor factors: gender, mechanical axis	–	28 %	7 % DVT, 5 % peroneal nerve palsy, 2 % sup infection, 14 % delayed union	39 % converted to TKA
Papachristou et al. [7]	International Orthopaedics (2006)	51 years (26–60)	Ahlbäch 32 % grade I, 23% grade II, 45 % grade III	44	Staple	10 years (5–17)	FTA 177.7°	FTA 185.8°	Postop: 88 % pain relief. 10 years fu: 27.2 % excellent, 9.09 % good, 11.3 % fair-poor. 10–15 year fu: 4.5 % excellent, 15.9 % good, 15.8 % fair-poor	HSSK preop: 52 points. HSSK postop: 83.5 points excellent-good, 58.83 points fair-poor	11 %	4.5 % Sup. infection, 4.5 % tibial fracture, 1 % pulmonary embolism	–

(continued)

Table 6.4 (continued)

Author	Journal/year	Average age	Osteoarthritis classification	Cohort (operated knees)	Device used	Follow-up (years)	Preop average angle	Postop average angle	Results	Scores	Compli-cation rates	Compli-cations	Survival
Koshino et al. [8]	The Knee (2006)	59.6 years (40–73)	Ahlbäch 60 % grade II, 35 % grade III, 6 % grade IV	241	Plate + screws	68 knees included 19 years (15–28)	FTA 186° ± 6.5°	FTA 171° ± 7.5°	15–28 years fu: 98 % satisfied	HSSK preop: 21 % 60–69 points fair,78 % 59 points poor. HSSK postop: 65 % 85–100 points excellent, 25 % 70–84 points good, 10 % 60–69 points fair	6 %	4.4 % peroneal nerve palsy, 1.4 % tibial fracture	16 % converted to TKA/MUA at final fu
Aoki et al. [32]	JBJS (2006)	59.8 years (47–72)	HUGS 25 % grade II, 55 % grade III, 20 % grade IV	86	External fixator	56 knees included 11 years (10–15)	FTA 185.4° (180–198°)	FTA 170.6° (163–183°)	18 % good, 45 % fair, 37 % poor	TKSS preop: 53.2 (35–65), poor. Postop: 74.4 (50–95), fair	28 %	23 % delayed union, 3 % peroneal nerve palsy, 2 % superficial infection	3 % converted to TKA
Sprenger et al. [5]	JBJS (2003)	69 years (47–81)	Ahlbäch 57 % grade I, 54 % grade II, 3 % grade III	76	Plate + screws	10.8 years	–	–	Survivorship: 86 % 5 years fu, 74 % 10 years fu, 56 % 15 years fu. Mean patient satisfaction 9.5 years. No differences in: age, gender, weight, Ahlbäck (except grade II vs. III)	HSSK <70 points survivorship: mean 7.4 years	21 %	43 % nerve palsy, others not reported	34 % converted TKA

Aglietti et al. [17]	JKS (2003)	58 years (36–69)	–	120	32 % plaster cylinder cast 68 % screw + cylinder cast	61 knees included in 15 years (10–21)	Average varus angle 4.7° ± 5°	–	Preop pain: 66 % moderate, 33 % severe. Postop pain: 16 % mild, 21 % moderate, no severe pain reported	HSSK final fu: 46 % excellent, 25 % good, 21 % fair, 8 % poor	9 %	4 % DVT, 1 % fatal PE, 5 % delayed union	25 % converted TKA average time conversion 11 years (7–17)
Benzakour et al. [23]	International Orthopaedics (2010)	55 years (40–72)	Ahlbäch 20 % grade I, 35 % grade II, 37 % grade III, 8 % grade IV	106	Plate/ staples/ molded cast	15 years (5–27)	Average varus angle 11°	–	12 % excellent, 30 % good, 31 % fair, 27 % poor	HSSK improvement: 86 % score improvement at final fu	11 %	2 % implant removal, 2 % sup infection, 1 % hematoma, 1 % art. fracture, 2 % cortical fracture, 1 % DVT, 1 % nerve palsy, 2 % dystrophy	10 % converted TKA, 2 % re-osteotomy

(continued)

Table 6.4 (continued)

Author	Journal/year	Average age	Osteoarthritis classification	Cohort (operated knees)	Device used	Follow-up (years)	Preop average angle	Postop average angle	Results	Scores	Compli-cation rates	Compli-cations	Survival
Douglas et al. [16]	Clin Orthop Relat Res (1999)	55 years (16–76)	–	94	Staples/ external fixator	61 knees included in 14 years (10–22)	–	–	Survivorship estimate of failure: 73 % at 5 years, 51 % at 10 years, 39 % at 15 years, 30 % at 20 years. Risk factors associated: >50 years, prev arthroscopy, <120° flexion arch, high BMI, lat thrust	–	20 %	15 % delayed union, 10 % nonunion, 3 % art. fracture, 16 % sup infection, 2 % deep infection, 2 % instability, 25 % DVT, 3 % perennial nerve palsy	20 % converted TKA at latest fu
Yasuda et al. [19]	Clin Orthop Relat Res (1992)	60 years (47–72)	Sasaki 18 % stage II, 58 % stage III, 24 % stage IV	86	External fixator	51 knees included in 11 years (10–15)	FTA 185.5° (175–185°)	FTA 6 years fu: 169° ± 5.4°. 10 years fu: 170° ± 6.3°	Preop: 7 % fair, 93 % poor. 6 years fu: 63 % good, 25 % fair, 12 % poor. 10 years fu: 18 % good, 45 % fair, 37 % poor	TKSS improvement: 54 % 6 years fu, 49 % 10 years fu. WAS improvement: 2 % 6 years fu, 2 % 10 years fu. PS improvement: 4 % 6 years fu, 3 % 10 years fu	5 %	2 % peroneal nerve palsy, 1 % sup infection, 1 % delayed union	2 % converted TKR <5 years of fu

Fletcher et al. [22]	Clin Orthop Relat Res (2006)	42 years (15–76)	Ahlbäch 64 % grade I, 28 % grade II, 8 % grade III	372	Staple/ plate + screws	301 knees included in 18 years (12–28)	Average varus angle 6° (13–15°)	66 % postop varus deformity 5° (1–12°)/ 34 % postop valgus deformity 3° (1–10°)	33 % excellent, 44 % good, 7 % fair, 15 % poor protecting factors outcome: <50 year, BMI <25, Ahlbäch grade I, postop valgus angle >6°. No correlation: gender, preop varus angle	–	3 %	1 % DVT, 1 % sympathetic dystrophies, 1 % fixation failure, 0.3 % other compli-cations	7 % converted TKA/4 % converted MUA revision end point 8 years
Majima et al. [18]	Clin Orthop Relat Res (2000)	59 years (47–70)	–	48	External fixator	26 knees included in 12 years (10–15)	FTA 185.1 ± 6.3°	FTA 171° ± 6.1°	–	TKSS preop: 7 % fair, 93 % poor. Postop: 1 year 49 % good, 51 % fair, 1 % poor. 10 years 17 % good, 44 % fair, 39 % poor	4 %	4 % skin necrosis. No serious compli-cations observed	4 % converted TKA <7 years fu
Yasuda et al. [20]	Bulletin HJDOT (1991)	59 years (37–76)	HUGS 14 % grade II, 58 % grade III, 27 % grade IV	86	External fixator	55 knees included in 12 years (10–15)	FTA 186° (175–195°)	FTA 170.6° (10 years fu)	Preop: 11 % fair, 89 % poor. 6 year fu: 62 % good, 23 % fair, 15 % poor. 10 year fu: 25 % good, 36 % fair, 38 % poor	TKSS preop: 60.2 points, poor. Postop: (6/10 years fu) 89.7 points, fair; 81.4 points, fair. WAS preop: 11.2. Postop: (6/10 years fu) 17.3, 14.1. PS preop: 13.5. Postop: (6/10 years fu) 27.4, 23.3	7 %	4 % peroneal nerve palsy, 1.5 % delayed union, 1.5 % sup infection	4 % converted TKA <5 years fu

(continued)

Table 6.4 (continued)

Author	Journal/year	Average age	Osteoarthritis classification	Cohort (operated knees)	Device used	Follow-up (years)	Preop average angle	Postop average angle	Results	Scores	Compli-cation rates	Compli-cations	Survival
Ivarson et al. [21]	JBJS (1999)	73 years (52–87)	–	99	Staple	65 knees included in 11.9 years (11–13)	–	–	Satisfaction: 5.7 years fu; 57 % good/78 % acceptable/11, 9 years fu; 43 % good 60 % acceptable pain at rest: prep 65 %/5.7 years fu: 38 %/ 11.9 years fu: 30 %	LST: 11.9 years fu; 64 ± 21; fair	12 %	9 % sup infection, 2 % DVT, 1 % peroneal nerve palsy	6 % converted TKA and 1 % converted MUA <5.7 years fu
Van Raaij et al. [33]	Acta Orthopaedica (2008)	49 years (24–67)	Ahlbäch 5 % grade 0, 43 % grade I, 44 % grade II, 8 % grade III	100	Staple	12 years (10–16)	FTA 6.5°	-	Regression model, high risk to conversion to TKA: woman, Ahlbäch >2. No risk associated with BMI and preop HKA angle	–	4 %	1 % over-correction (varus HTO), 1 % symptomatic exostosis, 3 % peroneal nerve palsy	25 % converted TKA < average of 6 years. Probability of surviving HTO 75 % at 10 years fu

Schallberger et al. [27]	Knee Surg Sports Traumatol Arthrosc (2011)	40 years (15–68)	–	71	OWHTO: plate + screws. Iliac crest CWHTO: plate + screws	54 knees included in 13.5 years (13–21)	FTA 178° (171–184°)	FTA 190° (184–190°) median correction 10°	Osteotomy survival was of 98 % after 5 years, 92 % after 10 years, and 71 % after 15 years	Average VAS at final fu: 0, range 0–4 (0–10). MSI: 80 %, range 30–100 (0–100) at final fu. Medial KOOS score: 71, range 9–100. Median WOMAC score: 84, range 9–100, both at final fu	–	–	24 % converted TKA, 76 % survivor HTO at final fu OWHTO vs. CWHTO no significant difference in survival and score outcome
Babis et al. [29]	J Orthop Sci (2008)	53 years (19–71)	–	54	Plate + screws	36 knees included in 10 years (7–14)	FTA 186.6° ± 3°	FTA 177.2 ± 3.61° (2 months fu)	Satisfaction 35 % excellent, 16 % good, 11 % fair, 19 % poor result or had failed. No risk factors: age, BMI, preop medial load, preop/postop medial line obliquity	HSSK preop: 49 points, poor. At final fu: 77 points, good	–	–	31 % converted to TKA <7.6 years fu osteotomy survival rate 89 % at 5 years/76 % at 10 years
Omori et al. [30]	J Orthop Sci (2008)	59 years (40–69)	KLC 16 % grade II, 73 % grade III, 10 % grade IV	68	Plate + screws	48 knees included in 17.1 years (14–24)	FTA 185.4 ± 4.4	FTA 169.1 ± 4.5 (6.5 years fu)/169.8 ± 5.2 (17.1 years fu)	77 % satisfied, 33 % unsatisfied	JOA score 48 knees. Preop: 59.1 points, poor. 6.5 years fu: 86.3 points, good. >10 years fu: 83.1 points, good	4 %	2 % peroneal nerve palsy, 2 % delayed union	–

(continued)

Table 6.4 (continued)

Author	Journal/year	Average age	Osteoarthritis classification	Cohort (operated knees)	Device used	Follow-up (years)	Preop average angle	Postop average angle	Results	Scores	Compli-cation rates	Compli-cations	Survival
Akizuki et al. [28]	JBJS (2008)	63 years (45–76)	KLC 6 % grade II, 33 % grade III, 61 % grade IV	132	Plate+screws	94 knees included in 16.4 years (16–20)	FTA 183.7° (177–195)	–	74 % excellent/good at final fu	HSSK preop: 60.7 points, fair. 5 years fu: 90 points, excellent. Final fu: 84 points. Good risk factors: BMI, prep range of movement	13 %	4.2 % peroneal nerve palsy, 0.8 % DVT, 2.5 % skin necrosis, 0.8 % sup infection, 1.6 % nonunion, 1.6 % early loss correction	7.4 % converted to TKA. Survivorship 97.6 % at 10 years fu/90.4 % at 15 years fu
Hoells et al. [31]	JBJS (2014)	50 years (26–66)	1 % mild, 10 % moderate, 89 % severe	164	Plate+screws	95 knees included in 10 years	–	–	Improved survival rates: age <50 year, BMI <30, WOMAC >45	WOMAC: preop, 61/ 5 years fu; 88 /10 years fu: 84 TKSS: prep 130/5 years fu; 181/10 years fu; 168	7 %	1 % PE, 2 % sup infection. 3 % delayed union, 1 % nonunion	Survivorship 87 % at 5 years of fu/79 % at 10 years fu

Fu follow-up

Table 6.5 High tibial osteotomy (opening wedge)

Author	Journal/year	Average age	Side	Osteoarthritis classification	Cohort (operated knees)	Device used	Graft	Follow-up (years)	Preop average angle	Postop average angle	Results	Scores	Compli-cation rates	Complications	Survival
Hernigou et al. [13]	The knee (2001)	59 years (35–73)	Medial opening wedge	–	245	Plate + screws	Cement block	87 knees included in 10 years (6–15)	–	75 % desired correction (3–6° valgus), 5 % over-corrected, 20 % under-corrected	Survivorship (Kaplan-Meier): 94 % (5 years), 85 % (10 years), 68 % (15 years)	–	4 %	1.6 % postoperative infection, 0.4 % vascular injury, 0.4 % DVT, 0.4 % non-union, 0.8 % delayed union	87 patients (10 years fu): 26.4 % converted TKR, 73.5 % satisfied
Hernigou et al. [11]	International Orthopaedics (2010)	60 years (43–67)	Medial opening wedge	–	53	Plate + screws	Resorbable tricalcium phosphate	10 years (8–12)	FTA 162° (158–165°)	FTA 180° (173–190°) 10–12 years	10 years fu: 81 % excellent-good/1.3 % fair/ 11.3 % poor	–	4 %	3.7 % fixation system complain (before 4 years after OWTO)	9.4 % converted TKA, 1.8 % converted MUA (before 7 years after OWTO)
Marti et al. [14]	JBJS (2001)	43 years (17–66)	Lateral opening wedge	Ahlbäck 41 % grade I, 53 % grade II, 5.8 % grade III	36	Plate 53 % Screw 8.8 % Ext. fix. 3 % Staple 5.8 % None 30 %	Iliac crest	11 years (5–21)	FTA 11.6° (4–22)	FTA 5.1° (–5–13)	0 % progression OA, 0 % loss ROM after follow up	LGS 26 % excellent 62 % good 9 % fair 3 % poor	15 %	9 % nerve palsy, 3 % superficial infection, 3 % thrombo-phlebitis	3 % converted to arthrodesis because severe pain (before 6 years after OWTO)
Benzakour et al. [23]	International Orthopaedics (2010)	55 years (40–72)	Medial opening wedge	Ahlbäch 20 % grade I, 35 % grade II, 37 % grade III, 8 % grade IV	118	Plate/ staples/ molded cast	Iliac crest	15 years (5–27)	FTA 133°	–	12 % excellent/ 30 % good/31 % fair/27 % poor	KSS improvement: 67 % score improvement at final fu	11 %	2 % re-osteotomy, 2 % implant removal, 2 % sup. infection, 1 % hematoma, 1 % art. fracture, 2 % cortical fracture, 1 % DVT, 1 % nerve palsy, 2 % dystrophy	10 % converted TKA

(continued)

Table 6.5 (continued)

Author	Journal/year	Average age	Side	Osteoarthritis classification	Cohort (operated knees)	Device used	Graft	Follow-up (years)	Preop average angle	Postop average angle	Results	Scores	Compli-cation rates	Complications	Survival
Hernigou et al. [10]	JBJS (1987)	60 years (43–77)	Medial opening wedge	Ahlbäch 37 % grade I, 48 % grade II, 11 % grade III, 2 % grade IV, 1 % grade V	89	Plate + screws	Iliac crest	76 knees included in 11.5 years (10–30)	FTA 172° (158–179)	FTA 182° (173–190°)	Final follow up preop pain: 55 % severe/49 % moderate/ 5 % mild postop pain: 13 % severe/16 % moderate/ 16 % mild/55 % none	–	–	–	18 % knees required revision at 5–10 years: 5 % MUA, 4 % bicompart-mental,10%re-osteotomy
Saragaglia et al. [15]	International Orthopaedics (2011)	53 years (32–74)	Medial opening wedge	Ahlbäch 22 % grade I, 34 % grade II, 35 % grade III, 9 % grade IV	124	Plate + screws	Tricalcium phosphate	107 knees included in 10 years (8–14)	FTA 172° (162–179°)	FTA 182° (178–186°)	HTO survivorship: 89 % in 5 years/74 % in 10 years 88 % satisfaction at final fu	LS: preop 65.4 ± 13.3 points/postop 88 ± 12.7 points (51–100) KOOS score 86 ± 4.6 points (25–100)	22 %	8 % tibial plateau fracture, 2 % DVT, 3 % PE, 6 % delayed union, 3 % screw breakages	12 % converted TKA at 8 ± 3 years

(OWHTO) and closing wedge high tibial osteotomy (CWHTO).

CWHTO

The CWHTO results included 2091 operated knees. The mean follow-up range is from 10 to 18 years. There are different kinds of devices that have been used to fix the osteotomy: plate and screws 42 %, staples 31 %, external fixture 26 %, and cylinder plaster 1 %. In literature, the average femorotibial angle pre- and post-operation is 177°–186° and 169°–190°, respectively.

Good results have been reported regarding survival rates, >survivorship at 5 years of follow-up from 73 to 98 %, at 10 years of follow-up from 51 to 92 %, and more than 15 years of follow-up from 39 to 71 % [7, 20, 25]. Koshino et al. reported a satisfaction rate at final follow-up for excellent/good results of 98 % at 15–28 years of follow-up [22]. Sprenger et al. reported excellent/good patient satisfaction of 9.5 years after HTO [7].

Risk factors that have been associated with poor outcomes are age more than 50 years at time of surgery, less than 120° of flexion, high BMI, lateral thrust, more than Ahlbäck grade I articular degeneration in contralateral compartment, and excess postoperative valgus angle [10, 22, 25, 30, 31, 35].

Survival rates are influenced by preoperative mechanical axis, gender, and WOMAC >45 [7, 10, 20, 31, 33, 35]. Van Raaij et al. associated low grades of survival rates in women [35]. Conversion rates included for conversion to total knee arthroplasty or unicompartmental arthroplasty are from 3 to 39 % [2, 6, 7, 10, 20, 25, 27–29, 31, 35].

OWHTO

The OWHTO results included 665 operated knees. Literature shows the prevalence of the medial opening osteotomy technique except Marti et al. who perform a lateral opening osteotomy [26]. Mean follow-up range is from 10 to 15 years.

The fixation devices used were plate and screws, staples, screws, external fixator, and modulated cast. Tricortical iliac crest was used in 50 % of the articles, tricalcium phosphate was used in 33 % of the studies, and 16 % used cement block. Average femorotibial angle pre- and post-operation is 133°–172° and 180°–182°, respectively.

Good results have been reported regarding survival rates, survivorship at 5 years of follow-up from 89 to 94 %, at 10 years of follow-up from 74 to 85 %, and more than 15 years of follow-up around 68 %, reported by Hernigou et al. [9, 24]. Hernigou et al. mentioned a satisfaction rate at 10 years follow-up for excellent/good results of 81 % and Saragaglia et al. 88 % excellent/good results at final follow-up [9, 22].

At 10 years, conversion rates included for conversion to total knee arthroplasty are 10–26 % with 73 % excellent/good satisfaction at the final follow-up [9, 11, 23, 24]. Conversion to unicompartmental arthroplasty ranges from 2 to 35 % [3, 23].

6.1.4.2 Complications (Tables 6.4, 6.5, 6.6 and 6.7)

For CWHTO complication rates, the average is from 3.3 to 28 %. The most frequent complication reported in this group is peroneal nerve palsy with rates from 2 to 43 % [7, 20, 22, 26, 34], followed by delayed union with an average of 2–23 % [6, 20, 25,

Table 6.6 Advantages and disadvantages of the two different techniques

Surgical techniques: advantages and disadvantages
Closing wedge high tibial osteotomy
Lateral
Peroneal nerve palsy
Potentially less accurate
Potential changes in patellar height (patella alta)
Opening wedge high tibial osteotomy
Medial
Fracture of the lateral hinge or the tibial plateau
Creates less deformity than CW in tibial metadiaphysis
Potential increase in tibial posterior tibial slope
Potential changes in patellar height (patella infera)

Table 6.7 Complications in HTO

Complications
Malunion
Nonunion
Patella infera or patella alta
Stiffness
Loss of correction
Hardware failure
Compartmental syndrome
Neurologic injury (peroneal nerve palsy)
Vascular injury
Infection
Proximal tibial fracture

32, 34]. Other important complications are deep vein thrombosis, pulmonary embolism, superficial infection, skin necrosis, and sympathetic dystrophies. OWHTO complication rates are 3 to 22 %, mainly due to tibial plateau fracture in 10 %, nerve palsy in 10 %, and delayed union in 10 %. Other important complications are superficial infection and vascular problems [3, 9, 11, 16, 23, 25].

6.1.5 Discussion

Knee joint realignment is intended to redistribute knee joint forces from the affected area to the unaffected side to interrupt the vicious cycle of destruction and malalignment described by Coventry who postulated arbitrarily that varus knees should be overcorrected by osteotomy to 5° of valgus [31]. The majority of authors have reported satisfactory results in the short to mid-term, but these results gradually deteriorated over time, especially at more than 10 years after surgery. The most important finding of this review is the high survival rate of HTO which after 5 years of follow-up is over 95 %, after 10 years of follow-up is around 80 %, and more than 15 years of follow-up is more than 50 % for both techniques.

The percentage of satisfactory results (excellent/good) after HTO was over 80 % after long-term follow-up for both techniques. Looking at patients converted to TKA, most operations were performed more than 10 years after HTO. Generally, osteoarthritis progressed, and increasing symptoms became the indication for further surgery. Total knee arthroplasty should be reserved for unicompartmental or bicompartmental diseases in older and/or lower demand patients [29]. The success of osteotomies depends primarily on correct indication. Patients should have good pain tolerance because a low pain threshold is often a negative factor in the outcome of the treatment of musculoskeletal disease. Precise planning and appropriate surgical technique achieving the desired correction are fundamental [29]. Aglietti et al. reported that opening wedge technique creates less deformity than the closing with tibial metadiaphyseal mismatch that might interfere with a subsequent revision to TKA [6]. But hinge position can affect the change in posterior tibial slope. Medial OWHTO, in particular, is associated with an increased posterior slope (PTS) compared to CWHTO, due to an increased anterior positioning of the wedge. Anterior and superior translation of tibial plateau is followed by an earlier contact with femoral condyle. CWHTO is more commonly associated with a decrease in PTS. El-Azab et al. described PTS in OWHTO preop/postop with locking and no locking plate, 7.7°/9.1° and 5°/8.1°, respectively, and PTS in CWHTO preop/postop of 5.7°/2.4° [36]. Understanding of anatomy, and careful surgical technique can avoid unintentional changes in tibial slope.

Regarding the patellar height CWHTO is associated with an increased patellar height due to lowering the joint line, and in OWHTO descent of the patella is constant. Tigiani et al. observed a patella elevation in 57 % of CWHTO (Caton-Deschamps index), associated with a post-operation correction of knee axis less than 10°. OWHTO postoperation knee axis correction more than 15° is associated with a patella baja [37].

Regarding the filler used Lash et al. detailed that allograft is used in 25.9 %, autograft 29.5 %, tricalcium phosphate 12.6 %, calcium phosphate 7.2 %, hydroxyapatite-tricalcium phosphate 3.4 % (which is associated with higher rates of loss of correction), bioglass 1.7 %, combined fillers 0.9 %, coralline wedge 0.9 %, hydroxyapatite 0.4 %, and no filler 17.3 % [8].

For Benzakour et al. opening technique did not give significantly better clinical outcome than closing technique [11]. Opening and closing wedge HTO have similar results in functional outcome and survival. Literature comparing clinical outcome after opening versus closing wedge HTO is very limited and long-term comparisons are lacking, with only two authors reporting the comparison [11, 29]. Our results not only confirm the long-term effectiveness of valgisation high tibial osteotomy as treatment for medial compartment osteoarthritis, but there is also evidence that the opening wedge technique can have a long-lasting effect similar to the traditional closing wedge high tibial osteotomy. This has a high clinical relevance currently, as an increasing percentage of HTO are done using the opening wedge technique, and long-term experiences are very limited [29]. The main reason for the good clinical outcome is the good alignment which has been described as the most important factor for good long-term clinical results [22].

There is still considerable discussion about which factors affect the long-term outcome of HTO. Two of the most important factors are the correction angle at surgery and the preoperative severity of knee osteoarthritis. Regarding the correction angle, previous studies have reported that the optimum clinical outcomes were associated with a correction of 6–16° valgus, and an undercorrection less than 5° was strongly related to a high failure rate [6, 7, 22].

Douglas et al. showed that preoperative knee flexion of less than 120 was related to significantly lower survival, but Aglietti et al. did not relate failure to either flexion contracture or lack of extension. We found that the preoperative range of movement of <100 was significantly associated with early failure [6, 25].

6.1.6 Conclusions

In summary, opening and closing wedge high tibial osteotomies are successful and durable methods of treatment for unicompartmental degenerative diseases with associated varus in active patients. Survival of both techniques is comparable in most series and is associated with low complication rates, high satisfaction, and high activity levels of the survivors.

6.2 Distal Femoral Osteotomy

6.2.1 Introduction

Historically, the first treatment for genu valgum was osteotomy, but with the advent of TKA and UKA, they have been used less commonly. Today, osteotomy represents a valid option which allows postponing TKA and thereby preserving the native knee.

Degeneration of the tibiofemoral compartment leads to a valgus deformity that is frequently a consequence of partial or total lateral meniscectomy. Other causes are post-traumatic, partial epiphysiodesis and growth disorders. The purpose of osteotomies around the valgus knee is to relieve the lateral knee compartment and to displace the loads medially.

Proximal tibial varus osteotomy can be used for minor genu valgum deformities, but not for major angulations, or if the projected obliquity of the joint is more than 10°. Distal femoral osteotomy (DFO) is a good option because tibial osteotomies for large deformities produce medial tilt of the joint line, which may increase lateral shear forces and lateral subluxation during gait [5]. The most commonly performed techniques are the lateral opening or the medial closing, with dome osteotomy rarely used [38–40].

The aim of this section is to analyze the literature about DFO regarding indications, results, functional outcomes, and survivorship.

6.2.2 Indications and Contraindications (Table 6.8)

Appropriate indications for DFO are critical for final stability and good outcomes [40, 41]. Painful valgus deformity with related osteoarthritis in the lateral compartment is the absolute indication for

Table 6.8 List of indications and contraindications of DFO

Indications	Contraindications
Age <60 male, age <55 female	BMI >30 (disputable)
Flexion >90°, lack of extension <20°	Flexion <90°, lack of extension >20°
Lateral femorotibial compartment involvement	Osteoarthritis (3–4° Outerbridge) in medial compartment
Mechanical angle deformity localized in the femur	Medial meniscectomy
Genu valgum	Infection
Active lifestyle	Rheumatoid arthritis
Good compliance for rehabilitation	Tibial subluxation >1 cm
	Valgus deformity >20° (disputable)
	High smoking

DFO [42–46]. Better results have been seen in patients with mild osteoarthritis [47] and in valgus deformity not more than 20° due to the significant ligamentous laxity [48]. McDermott et al. stated that arthritis of the medial knee compartment is not an absolute contraindication, as long as it is minor compared to the lateral compartment. In addition, there must be good bone stock, normal circulation, a stable joint, and knee flexion >90° [15]. A small lack of extension may be tolerated and corrected during surgery [49].

Absolute contraindications include severe osteoarthritis of the medial compartment of the knee, severe tricompartmental osteoarthritis, and tibiofemoral subluxation [44, 46]. Osteoporosis is a relative contraindication because, despite a rigid femoral fixation, the cortical bone of the proximal segment can often subside into the cancellous bone of the distal segment when the patient weight-bears, resulting in unwanted axial deviation [45].

For Stahelin et al. contraindications are also valgus deformity due to obliquity of the tibial plateau, inflammatory arthritis, instability due to laxity of the medial collateral ligament, lack of extension >15°, and severe osteoporosis [45]. Puddu et al. included BMI >30 and severe bone loss (more than a few millimeters) of the lateral tibia or femur, since after intervention congruent weight-bearing on both tibial plateaus is not possible [48].

Femoropatellar involvement for Stahelin et al. is an absolute contraindication [45], but Zarrouck et al. and Wang et al. treated, respectively, nine patients and eight patients with DFO associated with patellofemoral osteoarthritis in which they performed a lateral release in 15 patients, distal realignment in one, and combined proximal and distal realignment in one patient. The final results at last follow-up were satisfactory [43, 46]. The proposed reason is because distal varus osteotomy decreases the Q angle between the quadriceps tendon and the patellar tendon, which reduces the magnitude of the patella's lateral traction forces [5].

6.2.3 **Surgical Technique** (Table 6.9)

Tibial medial closing wedge osteotomy was the first technique performed, but results have been reported not to be as good as those of proximal tibial valgus osteotomy for varus deformity. For corrections more than 12° of valgus, HTO is not recommended because the joint line, after bone removal, will be oblique medially inducing an increase in femorotibial shear stress. DFO will give much better results at long follow-up. Actually, the most commonly performed is the medial closing DFO as reported in multiple studies [42, 45, 46, 48–63].

All authors agree with regard to preoperative assessment: standard x-ray posteroanterior and lateral in which the tibial slope can be assessed, AP x-ray in Rosenberg view to quantify the compartmental involvement of osteoarthritis, weight-bearing anteroposterior long-leg x-ray to measure the angle deformity between the femur and tibia (mechanical or anatomic axis) and calculate the desired correction, and axial view of the patella to evaluate any osteoarthritis in the femoropatellar joint (Table 6.8). MRI scan is also a useful supplement to more accurately assess articular cartilage pathology.

Table 6.9 DFO surgical techniques

Approach and technical considerations
Medial closing wedge distal femoral osteotomy
Approach medial side, proximal to the adductor tubercle and the anterior side of the femoral articular surface
Osteotomy technique osteotomy trait parallel to the joint line. Do x-ray to ascertain that the chisel has not penetrated the intercondylar notch or the anterior femoral surface. Important to leave untouched the lateral cortex. Removal of a 5–10 mm bone wedge from the distal femur. Fixation with different hardware mostly a 90°degree offset dynamic compression blade plate or Tomofix
Lateral opening wedge distal femoral osteotomy
Approach lateral side, distal third of the femur 15 cm proximal to the joint line until the Gerdy's tubercle, carried down from the vastus lateralis muscle
Osteotomy technique If deformity is metaphyseal, osteotomy cut must be parallel and 30 mm proximal to the joint line; if diaphyseal it must be oblique to the joint line. Opening wedge filled up with auto-allograft, PRP, and bone cement and fixed with different hardware mostly the 95° blade plate, Puddu plate, or Tomofix

6.2.3.1 Technique: Medial Closing Wedge DFO (Fig. 6.3)

With the knee joint in the extended position, an anteromedial longitudinal incision is made starting 10 cm above the patella and ending at the upper third of the patella. This incision has the advantage that it can be used again for any subsequent surgery. Incise the subcutaneous tissue and dissect the fascia of the vastus medialis muscle. Elevate the muscle and dissect as far as necessary from the intermuscular septum. Expose the medial patellofemoral ligament at the distal end of the incision. Incise the ligament and the distal insertion of the vastus medialis muscle in order to facilitate mobilization of the muscle. Now expose the intermuscular septum near the condyles and incise the septum carefully, close to the bone and parallel to the femoral shaft. Separate the soft tissue of the back of the knee from the distal femur, to allow the use of a wide, blunt-tipped Hohmann retractor behind the femoral shaft. Use a Hohmann retractor to expose the anteromedial aspect of the supracondylar region of the femur. Expose the shaft proximally so that the plate can be positioned safely.

The position of the osteotomy is best determined by placing the plate directly on the anteromedial distal femur. It is not necessary to achieve a distal fit due to the angular stability. However, it is important to ensure that the distal screws do not penetrate the condyles dorsally.

The distal osteotomy cut should be placed approximately 5 mm above the patella groove descending laterally, ending 10 mm from the lateral cortical bone in the lateral condyle of the femur (Table 6.10). The proximal osteotomy starts higher in the medial supracondylar region. It is advisable to mark the planned osteotomy site with an electric cautery.

Perform the osteotomies by marking the planned wedge removal with Kirschner wires (check the Kirschner wire placement with the image intensifier before cutting). The wires will then act as a guide for the saw. The osteotomy ends 10 mm before the lateral cortical bone, leaving a lateral hinge and removing a medially based wedge. Perform the osteotomies with an oscillating saw, protecting the soft tissue with a Hohmann retractor and constantly cooling the saw blade. Remove the wedge; check that any residual bone fragments have been removed from the osteotomy. If the bone is very hard, weaken the lateral cortical bone with the 2.5 mm drill bit.

Close the osteotomy carefully by applying continuous pressure to the lateral lower limb while stabilizing the knee joint region. This may take several minutes. The osteotomy gap can then either be held closed by manual compression or with two crossed Kirschner wires considering the later plate position. Check the corrected mechanical axis with the image intensifier by positioning a long metal rod between the center of the femoral head and the center of the ankle joint. The projected axis line passes either centrally or just medial to the center of

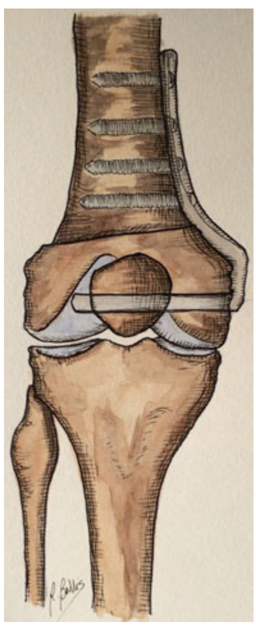


Fig. 6.3 DFO – medial closing wedge

Table 6.10 X-ray pool for preoperative planning

Preoperative planning
Standard x-ray posteroanterior and lateral
X-ray in Rosenberg view
Weight-bearing anteroposterior long-leg x-ray
Sky view patellar x-ray

the knee joint, depending on the preoperative plan.

Position the plate anteromedially on the distal femur. The screws should be aimed in a slightly proximal, lateral direction to achieve good interfragmentary compression. This is particularly important if the lateral femoral cortical bone fractures when closing the osteotomy. Close the arthrotomy and reattach the medial patellofemoral ligament and the partially released distal insertion of the vastus medialis muscle on the patella. Close the wound layer by layer. Although nonunion is uncommon with good surgical technique, even using a locking plate cannot completely eliminate bone healing complications [53].

6.2.3.2 Lateral Opening Wedge Distal Femoral Osteotomy (Using Blade Plate) (Fig. 6.4)

With the knee in 90° of flexion, a lateral skin incision starts 15 cm proximal to the joint line and ends at the level of Gerdy's tubercle. The fascia lata is incised slightly anteriorly in the direction of its fibers, and the lateral vastus muscle is elevated. The perforating arteries of the vastus lateralis are carefully coagulated or ligated. Subsequently, the vastus lateralis is elevated from the lateral border of the femoral diaphysis using a periosteal elevator. The patellar tendon is identified and a limited lateral arthrotomy is performed; this exposes the orientation of the trochlea and condyles. Two guide pins are inserted into the joint, one at the femorotibial joint line and the other in the patellofemoral joint. The guide pins help guide the blade plate and reduce the radiation caused by image intensifier.

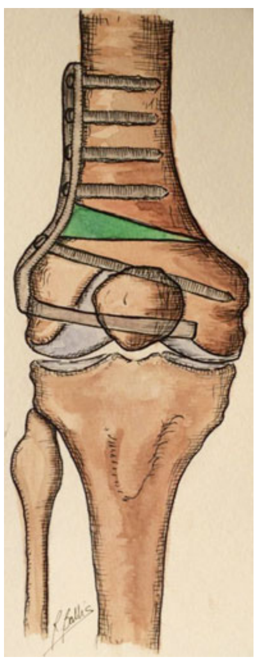


Fig. 6.4 DFO – lateral opening wedge

The osteotomy is horizontal, just proximal to the lateral part of the trochlea. With the knee in extension, the suprapatellar pouch is elevated, and, with the knee at 90° of flexion, the posterior side of the metaphyseal region is elevated. A landmark is made on the lateral side of the femur with the oscillating saw, perpendicular to the horizontal osteotomy. This will serve as a guide to determine the rotation.

The blade should be introduced into the epiphyseal region, 30 mm proximal to the joint line. The blade plate is 5.6 mm thick and 16 mm wide, and the distance between the screw holes is 16 mm. The guide for the blade plate should be introduced ventrally and proximally to the femoral insertion of the lateral collateral ligament. The angle of insertion depends on the level of the deformation. If the deformation is located at the diaphyseal level, the blade should be introduced oblique to the joint line. To obtain a varisation of 10°, the angle should be set at 75° (85–10°) at a complementary angle to the anatomic distal femoral angle (95°, angle of correction). If the deformation is situated at the metaphyseal level, the blade should be introduced parallel to the joint line (this is the most common situation). When introducing the blade parallel to the joint line, a correction to a normal anatomic femoral valgus of 5° is automatically obtained by introducing a 95° angled blade plate. In other words, if the femur were normal, no correction would be obtained if the blade plate is introduced parallel to the joint line. If we are confronted with a combined deformation or with a mixed metaphyseal component (lateral condyle hypoplasia or diaphyseal malunion), the angle of introduction should be even smaller, and the blade plate should be introduced at a smaller angle. Preoperative planning is essential to evaluate the correction needed.

The position of the blade can be checked using the image intensifier. The angle of correction can now be measured on a printout by drawing a line tangent to the medial and lateral condyles and another line tangent to the blade. The femoral osteotomy is performed with an oscillating saw. The medial cortex should not be cut. Once the blade plate is introduced, the medial cortex is fragmented using a drill bit. Two or more osteotomes are then introduced into the osteotomy, but it is the impaction of the blade plate that will progressively open up the osteotomy once in contact with the diaphysis. A screw is temporarily placed in the distal oval screw hole, in the proximal zone of the hole.

The blade plate is now impacted. Subsequently, a screw is introduced into another screw hole while the former screw is taken out. The impaction of the blade plate is continued, and the osteotomy will progressively open up until the blade plate is in full contact with the lateral side of the femoral diaphysis. Progressive impaction allows opening of the osteotomy. Provisional fixation with one screw helps control the correction and provides additional stability. By playing with the impaction and positioning of the screws, one can increase or decrease the amount of opening. If the blade plate is impacted with the screw left in place, the correction will be halted. Conversely, if an additional screw is again placed in the distal part of the screw hole and the former screw is taken out, the correction can be increased.

Final fixation of the blade plate is achieved by four 4.5 mm cortical screws. In lateral opening DFO it is important to graft the osteotomy gap. Different authors have suggested using bone filler for defects greater than 7.5 mm [47], while the gold standard is represented by tricortical iliac crest bone graft. There are different ways to fill the defect as seen in literature with no major complications and substantially good results: allograft, synthetic bone substitutes (hydroxyapatite, β-tricalcium phosphate, bone cement) filled with or without PRP, and growth factors or bone marrow stem cells [13]. Some authors did not use any graft [42]. The soft tissues and skins are closed over a drain, which is introduced underneath the fascia lata.

6.2.3.3 Hardware Selection

Hardware choice may have an important role because it allows stability of the osteotomy and reliable healing. Blade plate is the hardware mostly utilized and usually demonstrates good results in DFO at long-term follow-up and in the immediate postoperative period and early rehabilitation. For lateral opening osteotomy, plate with less volume leads to better results in terms of iliotibial tract irritation [72].

Edgerton et al. tried different ways of fixation with staples but with poor results and high complication rates. In the recent times, healing will occur reliably also with angle-stabilized locking plate [52]. Van Heerwaarden et al. performed an incomplete medial closing osteotomy with lateral cortical intact to improve final stability of the construct [49].

6.2.3.4 Angle Correction

This remains controversial, and the majority of authors recommend correction of the mechanical axis to 0° + −2 – the amount of the neutral tibiofemoral angle [14, 16, 42, 46, 48, 49, 51–53, 55, 57–64, 67, 69, 73]. In the average person, the hip-knee-shaft angle is between 5°and 7°. The mechanical axis, on the other hand, is 90° to the same condylar line. Thus, if the anatomic angle is brought to an angle of 90° with the condylar line, the leg will be moved out to the natural valgus approximately 5–7°, and the lateral compartment will be unloaded [59, 73].

McDermott et al. and Cameron et al. found no correlation between alignment and outcome and both aim for an angle of correction of 0° [16, 42]. Some authors, on the basis of Maquet indications, recommend a femoral supracondylar osteotomy with slight overcorrection (in varus) with the object of diminishing considerably the pressure on the joint and distributing the loads uniformly and neutralize the force of medial muscles [6, 47, 50, 54].

Some authors recommend undercorrection retaining a 2–4° of valgus [43, 45, 56, 66]. Some authors did the correction of the mechanical axis to a line passing the knee joint just medial to the deepest point of the trochlea [49, 61, 74].

Marin Morales et al. found, in line with the study of Sharma et al. [75] about the role of knee alignment in OA disease progression and functional decline, that malalignment greater than 5° (varus or valgus) was associated with a significantly greater functional deterioration over the period of follow-up.

6.2.4 **Results** (Tables 6.11, 6.12, 6.13, and 6.14)

6.2.4.1 Outcomes

Medial femoral closing wedge is the most commonly used technique for the correction of valgus alignment, since McDermott et al. described this technique. They removed a wedge between 5 and 10 mm, showing good results in 92 % of 24 patients treated with DFO [16]. With a similar technique, Healy et al. reported good results in 86 % of 23 patients, with a mean correction of ±2° of valgus [56].

Learmonth, using a special jig for tibial anatomic axis alignment, achieved good results in 20 osteotomies after a mean of 4 years with no complications [60]. Finkelstein et al. showed good results in 64 % at 11 years follow-up, with complications attributed to poor selection of patients [53].

Wang et al. reported survivorship in 30 osteotomies of 87 % at 10 years follow-up and did not recommend articular debridement associated with DFO as it increased the risk of postoperative arthrofibrosis [46]. Backstein et al. described a DFO survivorship of 82 % at 10 years follow-up and 45 % at 15 years follow-up of 38 knees [6]. Similar results were reported by Gross et al. who found good results at 10 years follow-up with survivorship of about 64 % [62].

Koshashvili et al. reported at 1 year follow-up excellent/good results in 84.4 % of patients. Failure rate at 15.8 years follow-up was about 48.5 % [55]. Sternheim et al. reported results at long follow-ups: 89.9 % survival at 10 years, 78.9 % survival at 15 years, and 21.5 % at 20 years of 45 osteotomies done with blade plate [58].

Edgerton et al., in a study of 24 knees, reported a 71 % rate of satisfactory results after an average duration of follow-up of 8.3 years [52]. Mathews et al., in a study of 21 patients who underwent DFO followed by stabilization with a plaster cast, staples, or a blade plate, reported only a 33 % rate of satisfactory results, but he did report high rate of complications after 1–8 years follow-up [47]. Stahelin et al., using a semitubular AO plate, reported improving HSS score in a mean follow-up of 5 years in 21 osteotomies [45]. Similar results were retrieved by Omidi-Kashani et al. at 1.5 years mean follow-up [57].

Freiling et al. reported good results between 3 months and 4 years follow-up using Tomofix in 60 patients. They had three delayed union/nonunion, one deep infection, one superficial infection, one hematoma, and one fracture [61]. Similar results were reported by Petersen et al. [62]. Recently, Forkel et al. evaluated 23 patients after surgery with the Tomofix plate, reporting better results than Edgerton but comparable with the results reported by Freiling. He had no major complications and only reported one complication: a loss of correction with the possible reason being breach of the lateral cortex of the femur. Finally he stated that using a locking plate (Tomofix) cannot eliminate completely the bone healing complications [54].

There is less literature available for *lateral opening wedge osteotomy*. However, good results were reported by Madelaine et al. at mean follow-up of 6.7 years using a 95° blade plate; they also found that the osteotomy has no impact on the final leg length [64]. Similar results were reported by Dewilde et al. with a survivorship of 82 % at 7 years follow-up, using bioresorbable calcium phosphate cement to fill the defect [65]. Thein et al. also reported good results in six patients at 6.5 years mean follow-up using tricortical iliac crest bone graft [66]. Das et al., in 16 patients at 3 years follow-up, had the same results using bone allograft to fill the osteotomy gap [67]. Saithna et al. reported a survivorship of 79 % at 5 years follow-up [68]. All authors performed surgery as described by Puddu et al. with a Puddu

Table 6.11 Complications of DFO

Complications (from the most frequent)
Malunion
Nonunion
Stiffness
Loss of correction
Hardware failure
Iliotibial band pain (lateral opening DFO)
Neurologic injury
Vascular injury
Infection
Fracture

Table 6.12 Comparison between the two techniques

Surgical techniques: advantages and disadvantages
Closing wedge distal femoral osteotomy
Medial historically the most performed; shorter bone healing; well tolerated by the patient, complex surgical technique
Opening wedge distal femoral osteotomy
Lateral easier to perform instead of the medial closing; bone correction precise; iliotibial tract plate irritation; longer bone healing

plate. Zarrouck et al. reported good results in 23 patients at mean follow-up of 4.5 years using a 95° blade plate with no grafting [43].

Jacobi et al. used a Tomofix plate in 16 patients, with a mean follow-up of 3.75 years. They ultimately abandoned the opening DFO because of high grade of postoperative complications, in particular iliotibial band irritation and slow healing of osteotomy; however, postoperative outcomes appeared to be satisfactory [69].

Nicolaides et al. performed surgery with insertion of a coralline wedge in the osteotomy site [70]. Cameron I. et al. divided the patients into two groups: osteoarthritis group and joint preservation group. The survivorship was 74 % in the first group and 92 % in the second one, after a follow-up of 5 years using different devices: locking plate Dynafix in 22 patients, Puddu plates in six, and Tomofix in one patient. He reported only one nonunion in the arthritic group [71].

There are some probable *prognostic factors* related to the success of this osteotomy. Cameron et al. reported results of 46 patients with a mean follow-up of 3.5 years and attempted to identify these prognostic factors but did not find any correlation between patient age, sex, time after the intervention, final femorotibial angle or number of degrees of correction, and the final good outcome. Patients with delayed union did not differ significantly from those who did not have a delayed union [42]. Other authors believe that good results may be reached with a rigid fixation, adequate correction, and less advanced osteoarthritis [47]. Under- or overcorrection may contribute to failure [50], and good results are predictable with a correction between 0° and 6° of anatomic valgus [43].

6.2.4.2 Complications (Table 6.11)

Complications involving the two techniques are not infrequent, and they are represented mostly by delayed union and nonunion, stiffness, and hardware failure that are frequently associated with lateral opening wedge osteotomy. In addition in lateral DFO the majority of patients complained about iliotibial band pain because of plate irritation (21–86 % in the literature) [69, 71]. Lateral opening osteotomies theoretically elongate the peroneal nerve at the level of a tight trajectory around the fibular head, but in the follow-up there were no nerve injuries [67]. This technique is simpler than the closing DFO since the lateral approach avoids risk of neurovascular complications and is easier to do and the correction will be more accurate [64].

Edgerton demonstrated 63 % failure related to staple fixation that is therefore thought to be an inadequate fixation technique for femoral osteotomies [52]. Less commonly reported are deep and superficial infections, hematoma, and fractures. The main variable that allows for a drastic reduction of complications is patient selection.

6.2.5 Discussion (Table 6.12)

Studies about DFO are all represented by small patient cohorts and low level of evidence, but all report agreement in improvements in arthritic pain. Other results are not well defined. Distal femoral osteotomy may allow an easier future knee replacement. The most performed v is the medial closing

Table 6.13 Opening wedge DFO

References	Year	Cases	Average age (years)	Mean follow-up	Fixation	Results	Complications	Range of motion	Angle HKS
Nicolaides et al. [70]	2000 Knee	2	20/44	1.3/1.1	Coralline wedge Cast	Good	None	Not reported	Preop 16° and 14° valgus Postop not reported
Puddu et al. [44]	2007 Sports Med Arthrosc Rev	21	54	from 4 to 14	Puddu plate	Improving in IKDC HSS from 60 to 87 points	Not reported	Not reported	Not reported
Das et al. [67]	2008 Open Acces Surg	12	34 (11–49)	6.1 (4.25–7.4)	Puddu plate	Lysholm from 64 to 76 Clinical HSS from 42 to 64 Functional HSS from 58 to 67	Not major complications reported	Not reported	Preop 16° valgus (10–21° valgus) Postop 5° valgus (1–8° valgus)
Jacobi et al. [69]	2011 Arch Orthop Trauma	14	46 (28–63)	3.8 (2.2–5.3)	Tomofix	50 % of osteotomies healed at 3 months, 14 % at 6 months and the others at 9 months. Mean satisfaction index was 78 %. KOOS from 31 to 69	9 including 2 nonunion 1 fracture 86 % of patients complain about plate intolerance	Not reported	Not reported
Zarrouck et al. [43]	2010 Orthop Traumatol Surg Res	22	53 (27–66)	4.5 (3–11)	90° blade plate	IKSS from 49.28 to 74.23 Functional score from 50.68 to 72.85	None	Not reported	Preop: 14.5° valgus (8–18° valgus) Postop: 5.5° valgus (3° varus–6° valgus)
Thein et al. [66]	2012 J Ortho	6	46.7	6.5	Puddu plate	Mean Oxford Knee Score from 13.1 to 26 Average subjective satisfaction rate 6.6 (at last fu on a scale of 0–10)	No major complications	Not reported	Preop 13.5° valgus mean Last fu 1.6° valgus mean

Dewilde et al. [65]	2013 Knee Surg Sports Traumatol Arthrosc	16	47 (30–51)	5.6 (2.5–10.5)	Puddu plate	Average knee score from 43 preoperatively to 78 at last fu. Kellgreen-Lawrence osteoarthritis remained unchanged. Survivorship at 7 years fu 82 %	1 fracture	Not reported	Preop 6.5 valgus (3–10° valgus) Last fu 1.2° varus mean
Saithna et al. [68]	2014 Knee	21	41 (8–58)	4.5 (1.6–9.2)	Puddu plate Tomofix	The cumulative survival rate of 79 % at 5 years, with a significant improvement in all the outcomes evaluated (KOOS; IKDC; Lysholm-Tegner)	6 including 1 nonunion 2 losses of correction 1 infection	Not reported	% from medial to lateral Preop 75 % Last fu 37 %
Madelaine et al. [64]	2014 Knee Surg Sports Traumatol Arthrosc	29	44.4	6.66	95° blade plate	KSS from 80.5 to 65.8 Functional score from 50.4 to 68.5 Survivorship 91.4 % at 60 months	4 including 1 nonunion and 1 fracture	From 128.9° to 127.7°	Preop 7.8 valgus Last fu 0.4 valgus
Cameron et al. [71]	2014 Clin Orthop Relat Res	38 Arthritis group (61 %) Joint preservation group (39 %)	Not reported	5 (2–12)	22 Dynafix 6 Puddu plate 1 Tomofix	Joint preservation group: IKDC from 36 to 62. Survivorship at 5 years 92 % Arthritis group: IKDC from 47 to 67. Survivorship at 5 years 74 %	1 nonunion	Not reported	Joint preservation group: from 5° valgus to 2° varus Arthritis group: from 7° valgus to 2° varus

Table 6.14 Closing wedge DFO

References	Year	Cases	Average age (years old)	Mean follow-up (years)	Fixation	Results	Complications	Range of motion	Angle HKS
Johnson and Bodell [59]	1981 Mayo Clinic Proc	46	49 (17–76)	3.6	V blade plate or Steinmann pins or Harris splint or Kirschner wires or staple	22 good 15 fair 16 poor	Plate: 1 infection, 4 nonunions, 2 failure fixation Staples: 2 nonunion 2 failure fixation Pins: 1 nonunion	Not reported	Not reported
McDermott et al. [15]	1988 JBJS Am	24	53 (22–74)	4 (2–11.5)	90° blade plate	20/22 good results Improvement of 28 points in knee rating scale	1 failure fixation 1 superficial wound infection	Not reported	Not reported
Healy et al. [56]	1988 JBJS Am	23	56 (19–70)	4 (2–9)	90° blade plate	86 % were rated as good or excellent HSS score, from 65 to 86	2 nonunions 1 fracture	Not reported	Preop: 18° valgus mean Postop: 2° varus to 6° valgus
Learmonth [60]	1990 JBJS Br	12	40	3.5	90° blade plate	Good improving of pain	None	Not reported	Not reported
Edgerton et al. [52]	1993 Clin Orthop Rel Res	23	55	8.3	90° blade plate	Satisfactory results 71 %	17 including 7 delayed-nonunion	Not reported	Preop 18° valgus mean Postop 1° valgus mean
Finkelstein et al. [53]	1996 JBJS Am	21	56.3 (27–77)	11.1 (8.1–20)	90° blade plate	Average improvement in score of 30 points Survival rate 83 % at 40 months and 64 % at the final fu Survivorship at 10 years 64 %	7 including 1 femoral fracture and 1 loss of correction	Not reported	Last fu: 2° valgus mean
Cameron et al. [42]	1997 Can J Surg	49	60 (23–84)	3.5 (1–7)	90° blade plate	KSS postoperatively 84.8	1 loss of fixation 1 fracture	Not reported	Preop 13° valgus (7–23° valgus) Postop not reported

Mathews et al. [47]	1998 Orthopedics	21	53 (21–77)	3 (1–8)	10 cast 5 staple 6 AO blade plate	33 % of patients had a satisfactory result. HSS score from 61 to 64	57 % percent had significant complications including 1 wound infection 1 infected nonunion 4 nonunions and 11 implant failure	Not reported	Preop 14.7° valgus (6–32° valgus) Postop 5.1° valgus (0–20° valgus)
Stahelin et al. [45]	2000 JBJS AM	21	57 (39–71)	5 (2–12)	Semitubular AO plate	Average HSS score increased from 65 to 84 11 knees rated as excellent, 88 knees good	1 nonunion	No loss of ROM	Preop: 12° valgus (10–16° valgus) Last fu: 1.2° valgus (0–4° valgus)
Gross and Hutcjison [63]	2000 Oper Tech Sports Med	24	56 (27–77)	11.16 (5–20)	90° blade plate	Survivorship at 4 years 83 % and good functional results in 92 % Survivorship at 10 years 64 %	7 complications including 1 failure fixation 1 infection	Not reported	Not reported
Aglietti et al. [59]	2003 Am J Knee Surg	18	54 (38–75)	9	90° blade plate	77 % of good or excellent results	No patients had nonunion or infection. 3 loss of correction	Postop: 119° (95–135°)	Preop 11.5° valgus (5–18° valgus) Postop 1° valgus (5° varus–10° valgus)

(continued)

Table 6.14 (continued)

References	Year	Cases	Average age (years old)	Mean follow-up (years)	Fixation	Results	Complications	Range of motion	Angle HKS
Marin Morales et al. [50]	2000 Acta Orthop Belg	17	55 (50–72)	6.5 (2–15)	95° AO blade plate and straight blade plate	26.4 % excellent results 47.22 % good results HSS from 47.5 to 83.3	1 deep infection	Not reported	Preop 16° valgus (10–27° valgus) Last fu 1° valgus (10° varus–8° valgus)
Wang and Hsu [46]	2005 JBJS AM	30	53 (31–64)	8.3 (5.1–14.1)	90° blade plate	83 % satisfactory result KSS improved from 46 points to 88 points Survival rate at 10 years was 87 %	1 nonunion 1 fracture 2 losses of correction	From 121° (80–130°) to 124° (100–135°)	Preop 18.2° (12–27°) Last fu 1.2° valgus (6°-varus to 10° valgus)
Backstein et al. [38]	2007 J Arthroplast	38	44.1(20–67)	10.3 (3.3–20.4)	90° blade plate	60 % good or excellent results 10-year survival rate was 82 % Mean function HSS from 54 to 85.6	Not reported	Not reported	Preop 11.6° valgus (4–15 valgus) Postop 1.2° varus (0–5° varus)
Van Heerwaarden et al. [49]	2007 Oper Techn Orthop	59	37.5 (17–79.6)	Not reported	Tomofix	Not reported	2 losses of correction 1 infection	Not reported	Not reported
Omidi-Kashani et al. [57]	2009 J Orthop Surg Res	23	23.3(17–41)	1.3 (0.6–2.08)	90° blade plate	Mean knee score from 90.7 preoperatively to 98.13 at last fu	2 nonunions 1 wound infection	Referred no loss of knee motion	From 18° valgus to 2° valgus
Kosashvili et al. [55]	2010 Int Orthop	33	45.5 (24–63)	15.1 (10–25)	90° blade plate	58.8 % had good or excellent results in function score. Modified KSS from 36.8 to 60.2 (at last fu) Failure rate 48.5 % at 15.6 years	Not reported	Not reported	Not reported

Freiling et al. [61]	2010 Oper Orthop Traumatol	60	39.7 (17–79)	1.8 (0.2–3.8)	Tomofix	Tegner activity score from 2.8 to 5.6	3 delayed or nonunion	Preop 126° (95–140°) Postop 128° (105–140°)	Not reported
Sternheim et al. [58]	2011 Orthopedics	45	46.2 (24–67)	13.3 (3–25)	90° blade plate	Survivorship at 10-15-20 years was 90–79 %-21.5 % respectively Modified KSS from 36.1 to 60.5	Not reported	Not reported	Not reported
Petersen and Forkel [62]	2013 Oper Orthop Traumatol	23	Not reported	3.5	Angle-stable locking plate (LOQTEQ)	KOOS from 48.4 to 84.9	1 loss of correction	Not reported	Not reported
Forkel et al. [54]	2014 Knee Surg Sports Traumatol Arthrosc	22	47 (25–55)	1.13 (1–1.5)	Angle-stable locking plate	Increasing in all KOOS scores subgroups No difference in the two subgroup analysis: patients with and without microfracture and age (<50 vs. >50 years) Tegner from 3.5 to 4.2	1 loss of correction	Not reported	Not reported

wedge osteotomy which shows variable results from a 92 % of survivorship at 4 years follow-up to a 45 % of survivorship at 15 years follow-up. Technically, it is more difficult to perform than lateral opening wedge, which is probably why the lateral opening is preferred by some surgeons. Advantages are a more precise correction due to the gradual opening and the easier surgical approach. But it is associated with plate irritation that gives discomfort to the majority of patients and may be associated with slow bone healing. Perpendicular cuts give less stability than oblique cuts. For this reason, Jacobi et al. does not recommend lateral opening DFO even if patients were satisfied. It is important to perform thorough preoperative planning. There are some studies that compare medial closing to lateral opening DFO, and these studies reported good results with both techniques [73, 74, 76].

6.2.6 Conclusions

As reported in the literature, DFO provides an effective surgical treatment for unicompartmental arthritis associated with a valgus deformity in long-term follow-up. In addition, performing a DFO might provide easier terrain for a future TKA. Both techniques (medial closing or lateral opening) are valid and are effective in selected patients who wish to remain active.

6.3 Osteotomy around the Patellofemoral Joint

6.3.1 Introduction

Patellofemoral pain syndrome (PFPS), also described as an anterior knee pain, is a common reason for presentation to orthopedic surgeons. Trauma, overuse, and patellofemoral malalignment are more common causes of anterior knee pain in young adults and middle-aged patients [77, 78]. Chondromalacia patellae (Aleman 1917) is a softening of the articular cartilage, with an abnormal stress secondary to shear forces [79]. Isolated patellofemoral osteoarthritis (IPFOA) is a common disorder of multifactorial etiology but in many cases related to trochlear dysplasia and disorders of patellar tilt and shift [80]. The optimum treatment for anterior knee pain associated with patellofemoral osteoarthritis remains controversial, and various surgical options have been proposed when there is a failure of conservative management which is up to 35 %, and relief of articular contact stress in the patellofemoral joint may be desirable when patellar articular surface is degenerating [79–82]. Different surgical treatments have been described for IPFOA: arthroscopic lavage and debridement, drilling or microfracture of the damaged surface, anterior elevation (Maquet) or anteromedialization of the tibial tubercle (Fulkerson), lateral retinacular release, partial lateral facetectomy of the patella, patellofemoral joint replacement, arthroplasty, and patellectomy [83].

1. The Maquet osteotomy (Maquet, 1976) aims to elevate the tibial tubercle 20–25 mm in one plane in order to increase the lever arm of the extensor mechanism (quadriceps tendon) and reduce the patellofemoral contact stresses [79, 82, 85–87]. Though attaining satisfactory clinical results with improvements in function and pain relief between 63 and 97 % of patients [87, 88], Maquet osteotomy is associated with major complications, and up to 40 % of patients were reported to have problems with delayed wound healing, tibial tubercle and proximal tibial fractures, and nonunion at the osteotomy sites [82, 85, 89]. This procedure has now generally been abandoned.
2. The origins of the “Fulkerson osteotomy” can be traced to Bandi [90] and Maquet [91] who demonstrated pain reduction in patients with painful patellofemoral arthrosis when the tibial tubercle was placed in a more anterior position. The Bandi-Maquet procedure decreases patellofemoral contact force and increases the patella moment arm by opening the angle between the quadriceps and patellar tendon. Thus patellofemoral joint reaction force is reduced on the diseased joint surface (typically distal patella), thereby reducing pain. John Fulkerson (1983) described a multiplane anteromedializing modification of the Elmslie-Trillat procedure that aims to decrease

the lateral facet contact pressures and realign the joint without the need for bone graft [92]. The indication for this operation is painful patellofemoral arthrosis, particularly when it is unipolar on the inferolateral patella facet [93]. This technique has reported good/excellent short-term clinical results in 60–90 % and an 84 % overall subjective improvement in symptoms. This technique also reported lower complication rates compared to the Maquet technique, although nonunion, loss of fixation, and tibial fractures have still occurred [82, 88, 89].

3. Partial lateral facetectomy is a simple, cost-effective surgical method that requires a short period of time for postoperative rehabilitation and allows a quick recovery with encouraging results. Its goal is to relieve symptoms but not to eliminate predisposing factors [83, 84].

The purpose of this section is to summarize the most common surgical techniques used for the treatment of IPFOA, highlighting surgical techniques, outcome, predictive factors, and complications of the most popular surgical techniques, Fulkerson and Maquet.

6.3.2 Surgical Techniques

6.3.2.1 Maquet Surgical Procedure

The skin is incised medial and parallel to the tibial crest below the anterior tuberosity. Using a Kirschner wire a series of parallel holes is drilled transversely 7–8 mm posterior to the tibial crest for a distance of 15 mm. The cleft outlined with the holes is completed by thin osteotome. The tibial crest is then lifted with the tibial tuberosity and the insertion of the patella tendon. A piece of iliac bone, 20–30 mm thick, is located proximally as possible, just beneath the anterior tuberosity. The skin suture may require two lateral relieving incisions when the forward displacement exceeds 2 cm [94]. The modified Maquet elevates the tibial tubercle 15–20 mm. Ferguson biomechanically analyzed anterior tibial tubercle advancement and reported that the first 10–15 mm of patellar tendon elevation reduced the average stress in the joint by more than 80 %, lowering the complication rates [85, 95, 96].

6.3.2.2 Fulkerson Surgical Procedure

The anteromedialization osteotomy begins with an incision 5–6 cm in length, lateral to the tibial tubercle. The incision should be made large enough to limit damage to the skin and soft tissues. Dissection is continued to the level of the patella tendon insertion on the tibial tubercle. The anterior compartment musculature is exposed, then elevated from the lateral edge of the tibial crest, and retracted posteriorly to expose the posterior aspect of the tibia. Retractors are placed to expose the entire length of the planned osteotomy. The amount of medialization and anteriorization is determined by the obliquity of the osteotomy in the axial plane, with a more oblique (anterior to posterior) osteotomy producing more anteriorization for unloading of lateral and distal cartilaginous lesions. The osteotomy line is tapered to merge with the anterior tibial cortex at the most distal aspect of the osteotomy. The osteotomy cut is created using an oscillating saw from medial to lateral and anterior to posterior along the oblique axial plane. The cut should begin at the most distal aspect of the planned osteotomy and proceed proximally. An attempt should be made to leave a distal periosteal hinge along the tibial crest unless concomitant distalization is indicated. The oblique osteotomy is completed with an osteotome from lateral to medial just proximal to the patella tendon insertion on the tubercle to create a proximal bumper.

At this point, the osteotomized tubercle can be rotated anteriorly and medially along the oblique plane of the osteotomy. Temporary fixation of the tibial tubercle can be achieved. Special attention should be made to avoid overmedialization of extensor mechanism resulting in medial tracking. Typically, medialization greater than 1 cm is not recommended. Definitive fixation of the osteotomized fragment is achieved using 4.5 mm self-tapping screws. Screw placement is approximately 1 cm distal to the patella tendon insertion, and screws are spaced 2 cm apart to reduce the risk of fracture [92, 97, 98]. Some authors use a modification of Fulkerson technique with elevation of 1–1.5 cm [79] (Table 6.15).

Table 6.15 Advantages and disadvantages of anteromedialization

Advantages	Disadvantages
Preservation of the extensor mechanism	Fails to address incompetent MPFL
Large surface area for bone healing	Postoperative hardware irritation
Ability to place multiple screws	Potential neuromuscular injury
Multiplanar adjustments	Increased medial patellofemoral contact pressure
Early range of motions	Delayed union or nonunion
	Cannot be performed in skeletally immature

6.3.2.3 Partial Lateral Facetectomy Procedure

The knee is approached through a lateral parapatellar incision. A lateral retinacular release is done from the inferior to the superior pole of the patella. It is important not to injure the vastus lateralis. With the knee in extension, the patella and trochlear groove are observed for cartilage lesions and checked for patellofemoral congruency. About 1–1.5 cm of the lateral border of the patella, including osteophytes, and 1–2 mm of cartilage are resected with an oscillating saw. It has no detrimental effect on quadriceps function, but if the vastus lateralis is detached, complications such as medial patellar subluxation, patellar hypermobility, quadriceps weakness or rupture, hemarthrosis, and skin necrosis may occur. If a kissing lesion and osteophytes exist on the lateral condyle of the femur, they also are cut and trimmed. Range of motion and isometric quadriceps exercises are initiated as soon as possible, and weight-bearing is allowed in the first week postoperatively [83].

6.3.3 Results (Tables 6.16 and 6.17)

6.3.3.1 Outcomes

There are 15 published series of tibial tubercle osteotomy for patellofemoral osteoarthritis currently in the literature [77, 79, 81, 82, 86, 87, 93, 96, 99–105]. The studies were divided into two groups: the Maquet osteotomies (Table 6.16) and Fulkerson osteotomies (Table 6.17). All the studies are retrospective except two [78, 87].

Combining the Maquet osteotomy and variations (modified Maquet and Ferguson osteotomy), the studies include 457 operated knees. Mean follow-up ranges from 17 to 192 months. There is a wide margin of the reported excellent/good results, which are between 10 and 100 %. Related to the Fulkerson osteotomy combined, the studies included 179 operated knees. Mean follow-up ranges from 28 to 72 months. There is an excellent/good result between 85.7 and 93 %.

6.3.3.2 Complications

Complication rates for Maquet osteotomy are between 13 and 38 %, mainly related to tibial fracture (especially tibial tubercle fracture and metaphyseal fracture), which represents 41 % of all complications (Table 6.16). Randin performed the initial Maquet osteotomy (20–25 mm of bone graft), modified Maquet (an elevation of 15–20 mm), and the Ferguson modification (10–15 mm) in order to compare the rate of complications [95]. Related to Fulkerson osteotomy, complication rates are between 0 and 33 %, mainly related to pain when kneeling because of which 26 % of patients required hardware removal.

6.3.4 Discussion

Chondromalacia patellae and patellofemoral osteoarthritis pose a difficult treatment problem for orthopedic surgeons. The initial treatment should be a nonoperative regimen, but some patients will subsequently require operative intervention for pain relief and functional improvement. Maquet osteotomy reported good results but with a high rate of complications and therefore is now rarely used. The Fulkerson method is now more commonly used, particularly to treat inferolateral patellar wear associated with malalignment in younger patients.

Apart from surgical technique, other variables are important, including patient selection and management of the soft tissues, which have

Table 6.16 Systematic review ATT osteotomies (Maquet)

Author	Year	Average age	Cohort (operated knees)	Outerbridge grade	Performed surgery	Follow-up (months)	Results	Complication rates	Complication
Lund et al. [27]	1980	34 (33–35)	68	I 22 %, II 17 %, III 38 %, IV 22 %	M	17 months	17 months, 70 % improvement (68 % men, average age: 27 years). 30 % no improvement (75 % women, average age: 37 years)	32 %	Skin necrosis 8, nerve palsy 3, tibial fracture 4, thrombosis 2, quadriceps rupture 1, DVT 1, granuloma 2, compartmental syndrome 1
Radin [21]	1986	29 (16–56)	54	–	M 22 %, MM 59 %, FM 16 %	24 months	M 91 % S/8.3 % F, MM 93 % S/6.3 % F, FM 66 % S/33.3 % F	M 41.7 %, MM 15.6 %, FM 22.2 %	–
Bessette et al. [24]	1986	34 (15–61)	21	–	MM	29 months	Not significative for: age, patella dislocations, crepitus, and ROM	38 %	Delayed skin healing 2, tibial fracture 2, delayed union 1, transfusion required 1, manipulation required 1, re-arthroscopy 1
Radin et al. [21]	1993	31 (16–49)	42	–	MM	144 months	OAP 86 % excellent/good, OARL 75 % excellent/good, OAPP 55 % good. Results not related to age, gender, follow up, during symptoms, cartilage damage	28 %	Nonunion 2, osteomyelitis 1, tibial fracture 9
Schmid [20]	1992	34 (20–66)	35	–	M 37.1 %, MM 28.6 %, FM 34.3 %	192 months	M 100 % excellent/good, MM 80 % excellent/good, FM 58 % excellent/good	–	–

(continued)

Table 6.16 (continued)

Author	Year	Average age	Cohort (operated knees)	Outerbridge grade	Performed surgery	Follow-up (months)	Results	Complication rates	Complication
Jenny et al. [19]	1996	43 (17–64)	100	I 15 %, II 16 %, III 21 %, IV 48 %	MM	48 months (100 %), 132 (96–180) months (65 %)	48 months 62 % good, 11 months 61 % good results not related to sex, age, weight. Only PF chondral lesion has predictive value	–	–
Rozbruch et al. [29]	1979	34	30	–	M	30 months	18 % excellent/good	27 %	Wound complications 4, infections 2, tibial fracture 2
Sudmann et al. [30]	1980	30	32	–	M	22 months	30 % excellent/good	18 %	Infections 2, others 2
Heatley et al. [31]	1984	53 (10–71)	29	–	M	36 months	19 % excellent/good	13 %	Infections 1, tibial fracture 3
Engebretsen et al. [32]	1989	39 (23–55)	46	–	M	60 months	10 % excellent/good	17 %	Infections 1, tibial fracture 1, others 6

Abbreviations: M Maquet, *MM* modified Maquet, *FM* Ferguson modification, *OAP* osteoarthritis post-traumatic, *OARL* osteoarthrosis post-recurrent subluxation, *OAPP* osteoarthrosis post- patelectomy, *PF* patellofemoral, *DVT* deep venous thrombosis

Table 6.17 Systematic review ATT osteotomies (Fulkerson)

Author	Year	Average age (years)	Cohort (operated knees)	Outerbridge grade	Performed surgery	Follow-up (months)	Results	Complication rates	Complication
Jack et al. [25]	2012	34.4 (19.6–52.2)	50	–	MF	72.4 months (62–118) 92 %	Kujala score improvement 67 % VAS improvement 36 % excellent/good 72 % procedure again 86 % significant differences in age but independent for chondromalacia	6 %	Tibial fracture 1, infection 1, others 1, knee pain with screw removal 6 (12)
Fulkerson et al. [4]	1990	28 (16–56)	51	–	F	35 months (26–50)	Final follow-up: subjective, 93 % excellent/good; objective, 89 % excellent/good	29 %	Stiffness 9, tibial tubercle fracture 2, DVT 2, weakness 2
Pidoriano et al. [13]	1997	29 (16–54)	37	I 75 %, II 80 %, III 64 %, IV 72 %	F	46.8 months (12–96)	DPOA 90 % excellent/good, LFOA 84 % excellent/good, MFOA 55 % excellent/good, PDOA 20 % 92 % would have the procedure again	8 %	Tibial fracture 1, wound dehiscence 1, arthrofibrosis 1, screw removal 27 (75 %)
Karamehmetoglu et al. [1]	2007	28.6 (21–42)	21	III–IV 100 %	F	28 months (20–60)	85.7 % excellent/good, EVA improvement: 53 %	33 %	Tibial tubercle avulsion 1, DVT 1, infection 1, flexion contracture 4, screw removal 15 (71.4 %)

(continued)

Table 6.17 (continued)

Author	Year	Average age (years)	Cohort (operated knees)	Outerbridge grade	Performed surgery	Follow-up (months)	Results	Complication rates	Complication
Atkinson et al. [7]	2009	27 (18–37)	20	Mean: 3.44. 100 % chondral damage on the lateral facet and distal patella	F	62 months (26–151)	EVA improvement, 44.4 %; S&T score improvement, 45.85 %	0 %	–

Abbreviations: DVT deep venous thrombosis, *F* Fulkerson, *MF* Fulkerson modification, *DPOA* distal patellar osteoarthrosis, *LFOA* lateral facet osteoarthrosis, *MFOA* medial facet osteoarthrosis, *PDOA* proximal or diffuse osteoarthrosis, *S&T score* Shelbourne and Trumper score a role in limiting complications. Age, weight, and gender have no proven predictive values [87, 96, 106].

Some authors reported better prognosis in "end-stage" cases (Outerbridge III–IV or Iwano grades II, III, and IV). Pidoriano [93] noted an improved activity level after anteromedial tibial tubercle transfer if a lateral or distal articular lesion is present. Patients with medial or proximal lesions, however, may not achieve satisfactory improvement in physical activity. Trochlear lesions were described at the time of surgery, reporting excellent/good results for lateral lesions and worse results for central lesions which are associated with lateral and medial patella lesions, respectively.

Partial lateral facetectomy, with or without a lateral retinacular release or lengthening, is a useful operation for advanced isolated patellofemoral arthrosis. Associated tibiofemoral arthritis, even when patellofemoral arthritis is most prominent, leads to poorer outcomes [80, 83, 107–109]. Isolated lateral retinacular release (LRR) alone has been shown to improve middle-aged and elderly patients with normal tibiofemoral alignment and joint, normal Q angle (<25°), and no lateral patellar subluxation on axial view [110]. LRR is reserved for patients with abnormal patellar tilt and no arthrosis. Patients with patellofemoral arthritis associated with lateral subluxation and lateral osteophytes have satisfaction rates between 88 and 90 % when lateral facetectomy is performed, with or without a lateral release, recognizing that a lateral facetectomy alone will relax the lateral structures [80, 83, 107–109].

Parvizi added that IPFOA had an increased prevalence of extensor mechanism malalignment and an increased requirement for LRR. Wetzels and Bellemans reported that the lateral release was necessary in 78.6 % of the 168 knees undergoing lateral facetectomy [84]. Paulos reported results of lateral facetectomy associated with LRR in 66 end-stage knees, with 88 % satisfied or very satisfied in 5 years mean follow-up [107]. Martens performed isolated lateral patellectomy in 20 knees and reported 65 % of good results and 25 % of moderate results at 2 year follow-up. In long-term follow-up, Kaplan-Meier survival rates with reoperation as an end point were 85 % at 5 years, 67.2 % at 10 years, and 46.7 % at 20 years [84].

Isolated PFOA can also be treated by patellofemoral arthroplasty or TKA, although it is usually reserved for older patients. The success rate of patellofemoral arthroplasty varies from 44 to 90 %. Laskin reported that TKA for isolated PFOA provided excellent pain relief and improvement of function in 70–85 % [83].

6.3.5 Conclusion

Tibial tubercle anteromedialization osteotomy is an effective treatment for anterior knee pain. It can provide excellent/good long-term functional results in the majority of patients, with a very high grade of satisfaction levels and sustained improvement in pain. Knees with patellofemoral malalignment may benefit from an individualized medialization of the tibial tubercle. Lateral patellar facetectomy with or without formal LRR may also have high rates of satisfaction in longer term results.

6.4 Conclusions

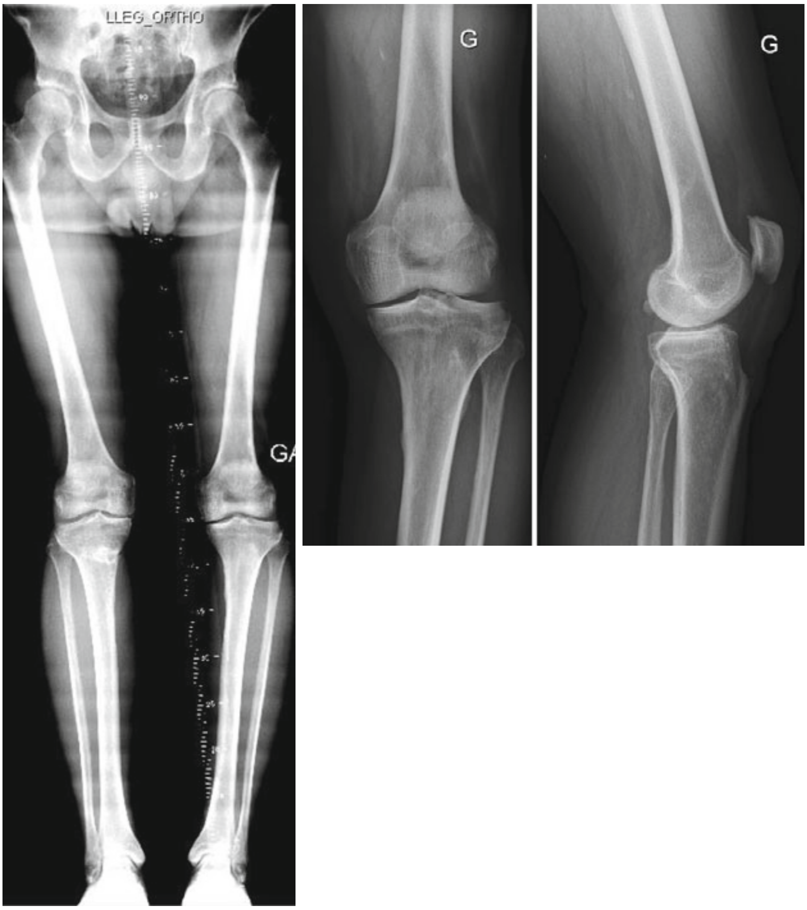
Osteotomy around the knee joint is a particularly valuable procedure for a specific group of patients, as discussed in detail in this chapter. It is especially valuable in the management of OA in the younger patient, as it allows a significant improvement in pain and function without resorting to the irreversible arthroplasty option. It has also been shown to have a positive influence on the natural history of OA. Achieving success with osteotomy relies on careful patient selection, careful and precise surgical technique, and appropriately prescribed rehabilitation. If these requirements are met, then there is usually a significant, sustained improvement, and therefore all orthopedic surgeons managing these patients should be familiar and comfortable with the techniques described in this chapter.

6.5 Case Examples

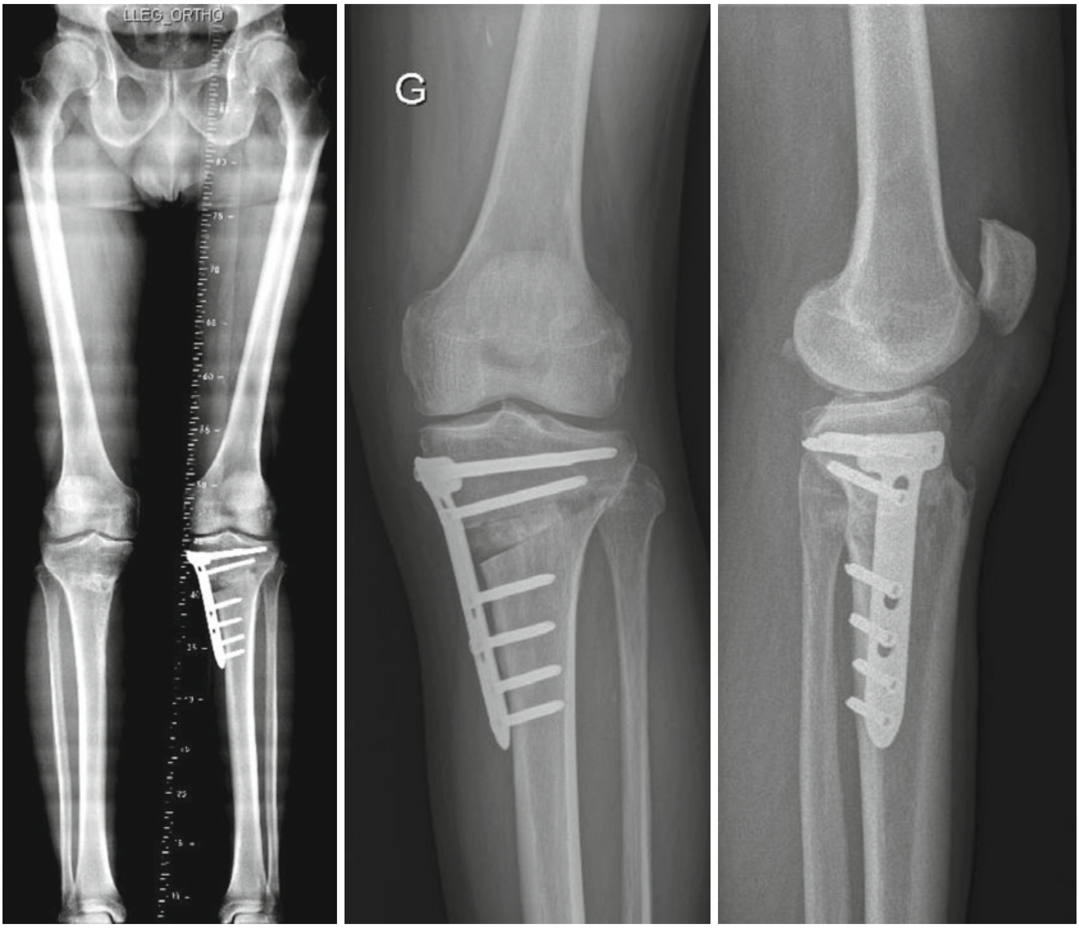
Medial Opening HTO

Young active male, 45 years old, 180 cm, 105 kg, previous medial meniscectomy 20 years ago

Suffers from medial pain during sport activities, and occasional pain when walking



Preoperative

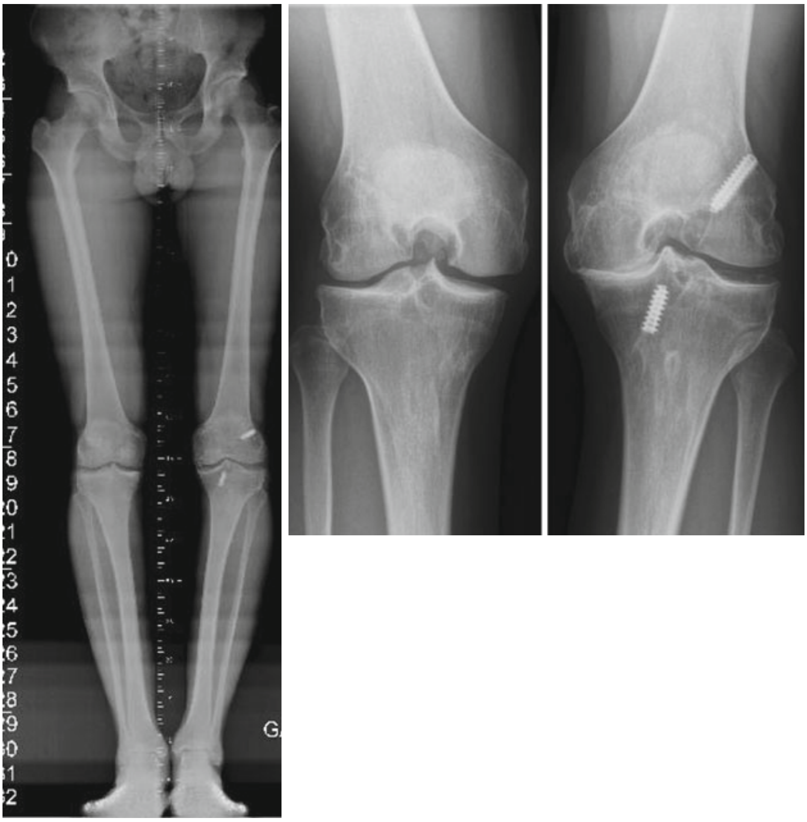


Postoperative x-rays, 2 months fu

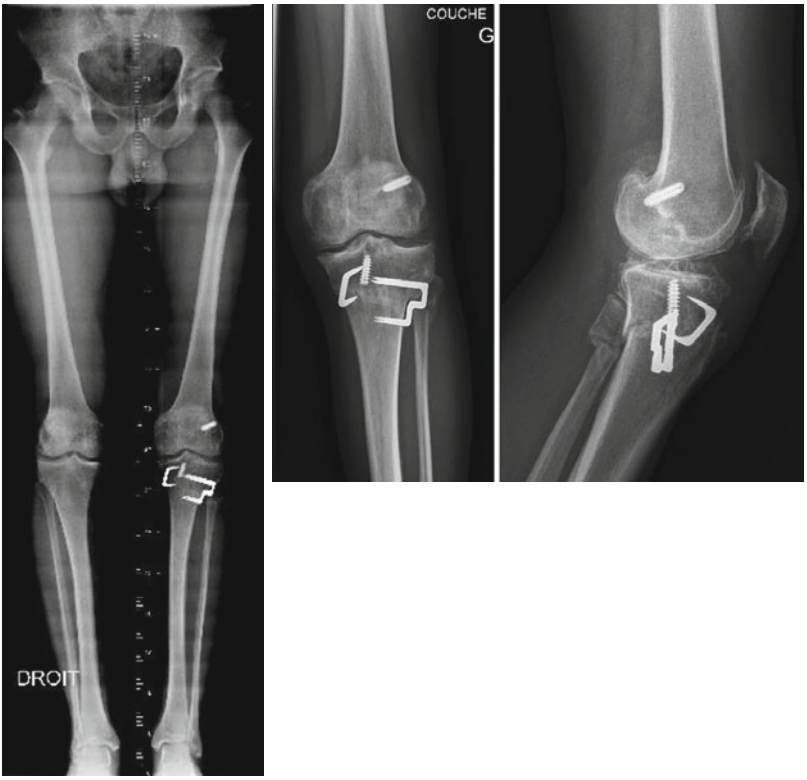
Lateral closing HTO

Young active patient, 35 years old, ACL reconstruction and medial meniscectomy 15 years ago

Suffers from medial pain during daily activities



Preoperative



Postoperative

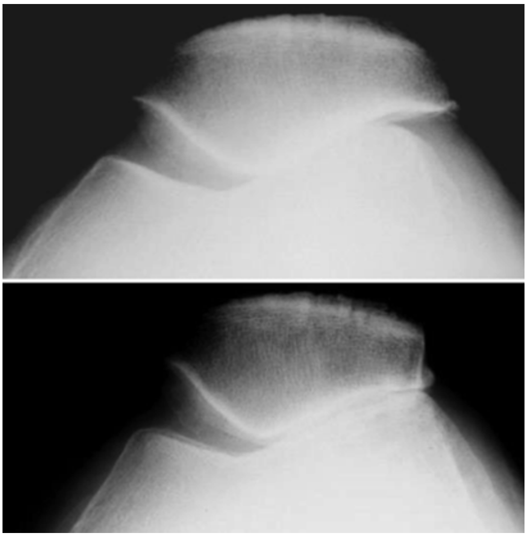
Lateral Opening DFO

Middle-aged female, 50 years old, previous lateral meniscectomy 15 years ago

Suffers from lateral knee pain, during daily activities

Preoperative

Postoperative



Lateral facetectomy

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