The following is a reprint from Operat Orthop Traumatol 2003;15:363–86 and continues the new series of articles at providing continuing education on operative techniques to the European trauma community.

Corrective Osteotomy of the Distal Femur by Retrograde Nailing

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Abstract

Objective: Correction of deformities of distal femur by a supracondylar dome or drill hole osteotomy in combination with a retrograde intramedullary nailing as an alternative to the classic technique of osteotomizing with an oscillating saw and internally fixating with a blade plate. In addition, leg length discrepancies can be corrected by the use of a unilateral distraction fixator after correction of axial and torsional deformities.

Indications: Multidimensional deformities of the distal femur. Deformities of the distal femur with shortening > 1.5 cm. Deformities of the distal femur in the presence of length discrepancy and torsional deformity of the lower leg. Distal femoral deformities that may later need to be treated with a total knee replacement.

Contraindications: State after local bone or soft tissue infections. A condylar bone stock insufficient for purchase of screws for intramedullary locking.

Surgical Technique: Knee arthroscopy. Determination of the entry point and direction of insertion of the intramedullary nail in the frontal and sagittal plane. Insertion of the nail up to the level of osteotomy, placement of Schanz screws proximal and distal to the planned osteotomy for later assessment of the degree of correction. Either dome os teotomy or drill hole osteotomy. Correction of axial and torsional malalignments. Advancing of nail and static locking.

Optional: for intended callus distraction, mounting of a unilateral distraction fixator.

Results: Follow-up after 29 (4–45) months of 18 patients, seven with callus distraction. The goal of correction was reached in 17 patients. Three nonunions and one osteomyelitis healed after surgical revision.

Key Words

Supracondylar femoral deformity · Supracondylar osteotomy · Femoral lengthening · Callus distraction Retrograde nailing

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Introductory Remarks

Deformities of the distal femur are preferably corrected at the metaphyseal (supracondylar) level. Classically, the corrective osteotomies are performed with an oscillating saw and followed by an internal fixation with a blade plate. The disadvantages of this technique include the extensive surgical trauma and the limitation of a three-dimensional correction.

The dome osteotomy or the drill hole osteotomy followed by retrograde nailing represents a viable, minimally invasive alternative [2, 11]. Besides the reduced-surgical trauma, the possibility of a three-dimensional correction at one sitting is a definite advantage. Moreover, femoral lengthening through callus distraction can be performed after surgical correction. This requires mounting of a unilateral distraction fixator.

The clinical use of retrograde nailing for the stabilization of bi- and supracondylar femoral fractures gained wide acceptance after the publications of Green [3] and Henry et al. [4].

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The author first published the described surgical technique in 2001 [14]. Paley et al. [10] developed independently the technique of fixator-assisted retrograde nailing in 1997.

Surgical Principles and Objective

Correction of one- or multimensional deformities of the distal femur. Supracondylar dome or multiple drill hole osteotomy, internal fixation with a retrograde locked nail, and, in instances of shortening, callus distraction using a unilateral distraction fixator.

Advantages

- Minimally invasive, biologically advantageous osteotomy.
- Minimally invasive internal fixation.
- One-dimensional correction without lengthening through a dome osteotomy possible.
- Multidimensional correction including lengthening possible.
- Simultaneous correction of tibial deformities by antegrade nailing performed through the same incision possible.
- The surgical approach and the retrograde nailing will not interfere with a later total knee replacement.

Disadvantages

- Demanding surgical planning.
- Removal of nail sometimes difficult.
- Risk of osteomyelitis when osteotomy combined with distraction.
- Need for a second intervention in instances of callus distraction necessary for static locking and removal of fixator.

Indications

- Multidimensional congenital or posttraumatic deformities of distal femur.
- Distal femoral deformity with shortening > 1.5 cm.
- Distal femoral deformity with ipsilateral tibial deformity.
- Distal femoral deformities that may later need to be treated with a total knee replacement.
- Uni- or, at the most, bicompartmental osteoarthritis, the second being the patellofemoral compartment.
- Age range 18–65 years.

Contraindications

- State after deep soft tissue or bone infection.
- Osteoarthritis of all three compartments III/IV.
- Age > 65 years.
- Unreliable patient.
- Callus distraction in smokers.

Patient Information

- Usual surgical risks such as thromboembolic complications, wound healing disturbances, and infection.
- Injury to vessels and nerves during osteotomy.
- Damage to articular cartilage during insertion and removal of nail.
- Risk of deep infection: for simple osteotomy up to 1%, when combined with distraction up to 5%: early removal of nail and possible change for external fixator.
- Risk of nonunion at osteotomy site, particularly in smokers.
- Too early full weight bearing: loss of correction and need for revision surgery.
- Partial weight bearing for 3 months after simple osteotomy. In instances of callus distraction, the duration depends on the extent of distraction and the maturation of the callus.
- Strict postoperative physiotherapy, until normal knee function and satisfactory muscle power have been reached.
- Duration of hospitalization for standard osteotomy 10 days, when combined with distraction 20 days and for second intervention (static locking and removal of fixator) 2 days.
- Resumption of work 2 weeks after full weight bearing.
- Implant removal: optional after standard osteotomy; removal of fixator obligatory at the end of callus distraction.

Preoperative Work-up

- Clinical assessment of lower limb geometry [13] including gait pattern, static and dynamic aspects of spinal column, function of hip, knee and ankle, axial alignment in frontal and sagittal plane, assessment of leg length and torsion of thigh and leg of both limbs.
- Standing radiographs of both lower limbs including thighs and legs and anteroposterior (AP) and lateral radiographs of both knees on long films.
- CT and ultrasound of both thighs and legs to determine length and torsion [7, 16].
- Determination of apex of deformity.
- Exact recording of deformity in frontal, sagittal and longitudinal planes as well as of length and torsion of lower limb [9].
- Definition of goal of correction.
- Drawing showing the level of osteotomy, the angle of correction in the frontal and sagittal plane, the entry point, and the direction of the nail (Figure 1).
- Selection of the appropriate nail.

- For added callus distraction over retrograde nail: selection of the proper distraction fixator and determination of sites for insertion of Schanz screws.
- Photographic documentation of deformity and knee function desirable.
- Shaving of the surgical field immediately before surgery.
- In patients with previous surgery of the affected knee or thigh: one dose of 1.5 g of cefuroxime at the time of induction of anesthetic.

Surgical Instruments and Implants

(Figures 2a and 2b)

- Intramedullary supracondylar stainless steel (IMSC) nail developed by Green, Seligson and Henry (GSH) [4] having multiple options for locking as well as corresponding instruments such as guide wire, aiming device, etc. (Smith + Nephew, Osterbrooksweg 71, 22869 Hamburg, Germany).
- Small wound spreader.
- 4.5-mm stainless steel Schanz screws.
- Plastic goniometer, gas-sterilized.
- Drill.
- Drill guide for dome osteotomy with an external diameter of 6.2 mm for insertion of drill sleeve 6.0/4.5 mm for the 4.5-mm Schanz screw. Additional holes of 5.1 mm in diameter for insertion of a drill sleeve 5.0/3.5 for introduction of a 3.5-mm drill bit.
- Soft tissue sleeves for 4.5-mm Schanz screws and 3.5-mm drill bit.
- 3.5- and 4.5-mm drill bits.
- Chisel with one prong.

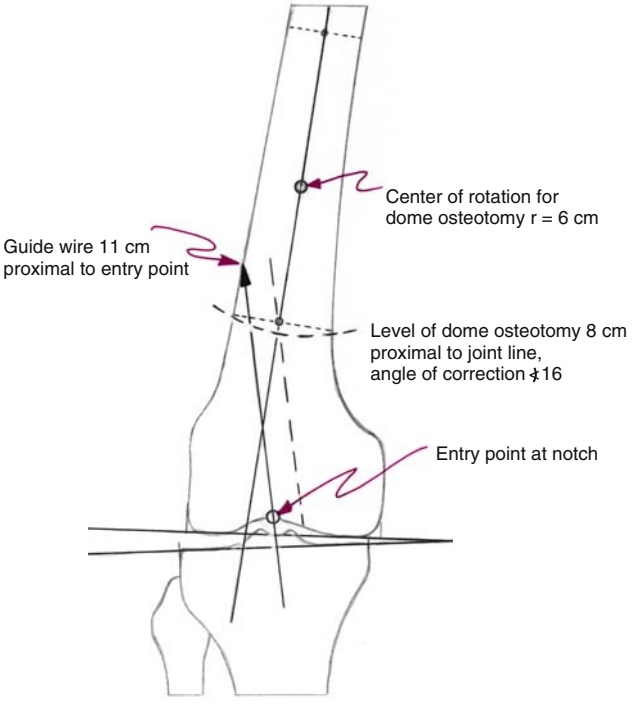
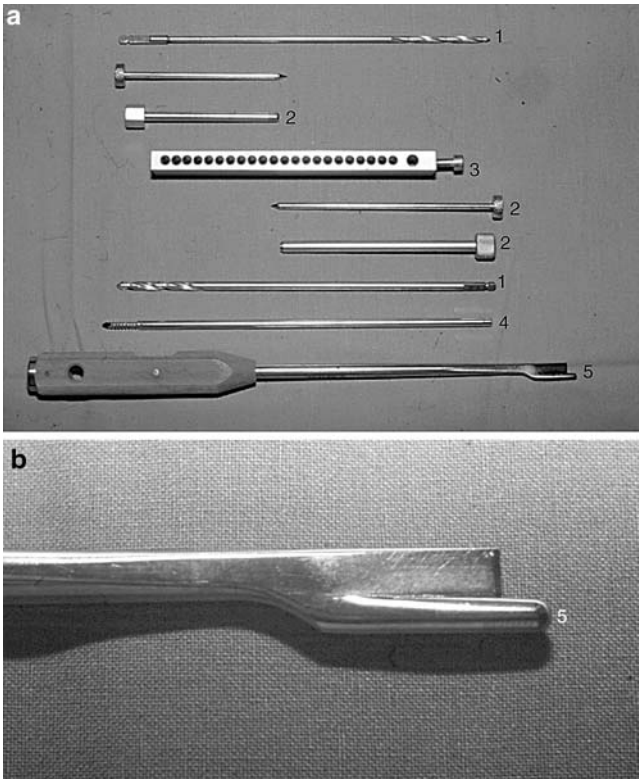


Figure 1.



Figures 2a and 2b.
a) Instruments.
1: 3.5- and 4.5-mm drill bits.
2: soft tissue sleeves for 4.5-mm Schanz screws and 3.5-mm drill bit.
3: drill guide for dome osteotomy.
4: 4.5-mm stainless steel Schanz screw.
5: chisel with prong.
b) Detail of chisel with prong.

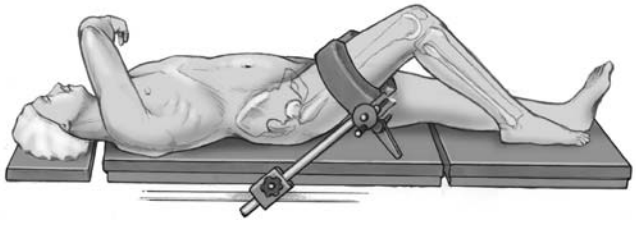


Figure 3.

Surgical Technique

Figures 4 to 13

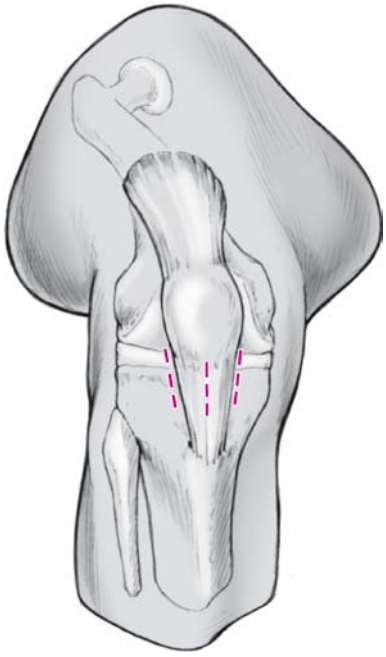
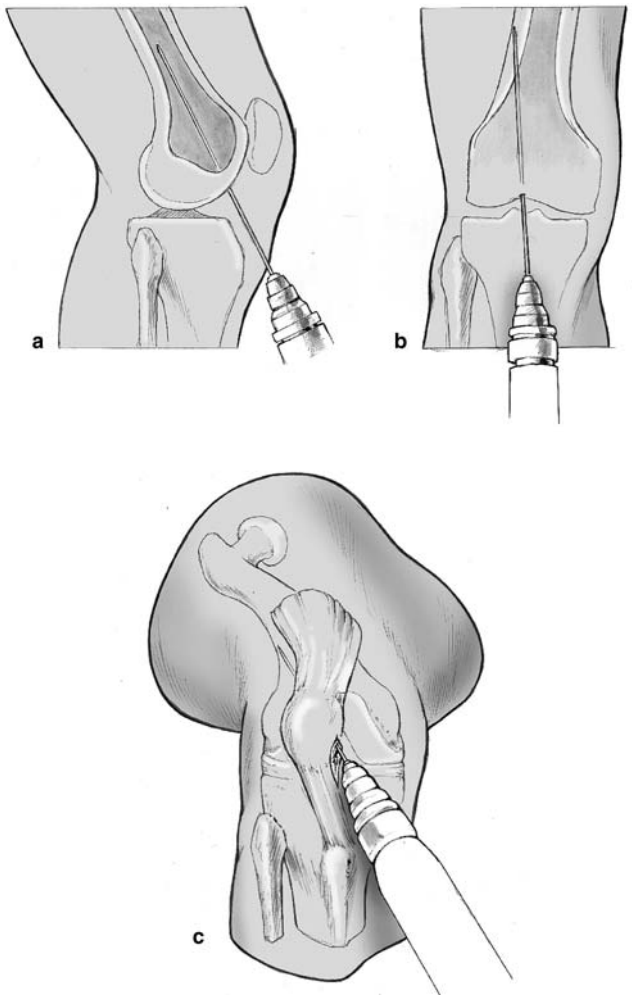
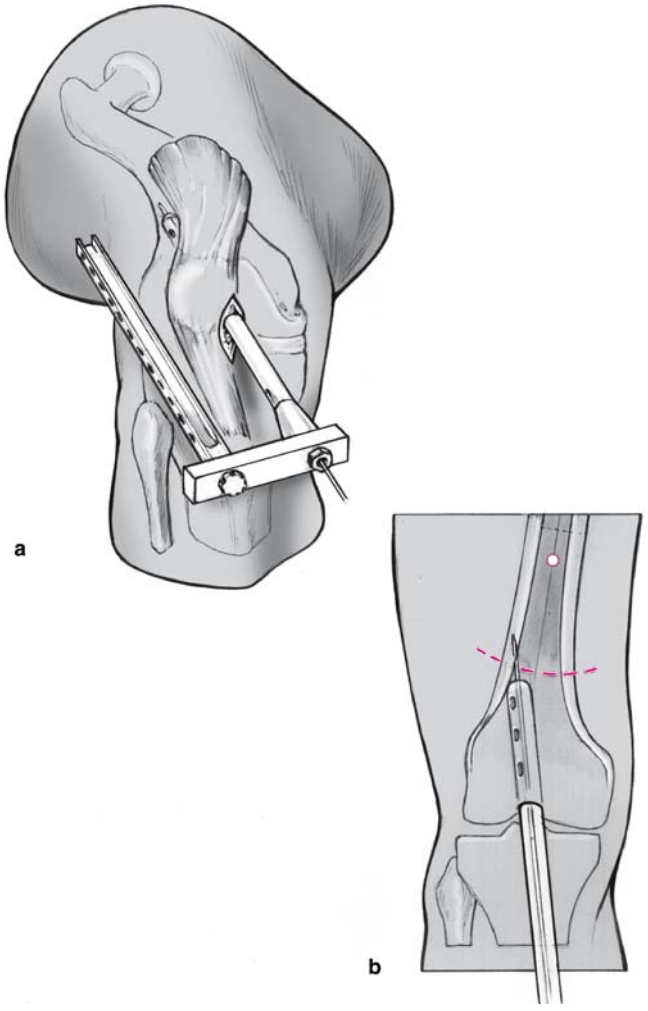


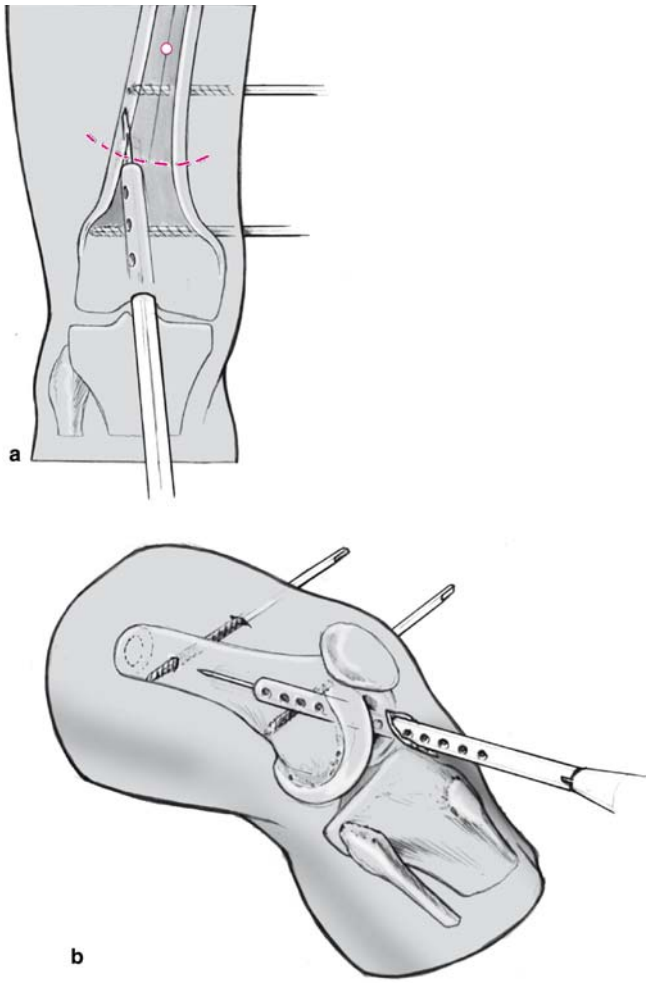
Figure 4. Marking of the infrapatellar skin incision with a felt pen. An incision of 2–3 cm in length is sufficient; it lies in the midline between inferior patellar pole and anterior rim of the proximal tibia. If an approach to the knee joint medial to the patellar ligament is chosen, the retinaculum is incised longitudinally. The approach is modified, if the transligamentous incision or an incision lateral to the ligament is chosen. Blunt spreading with scissors of Hoffa's fat pad and deepening through the intercondylar notch.



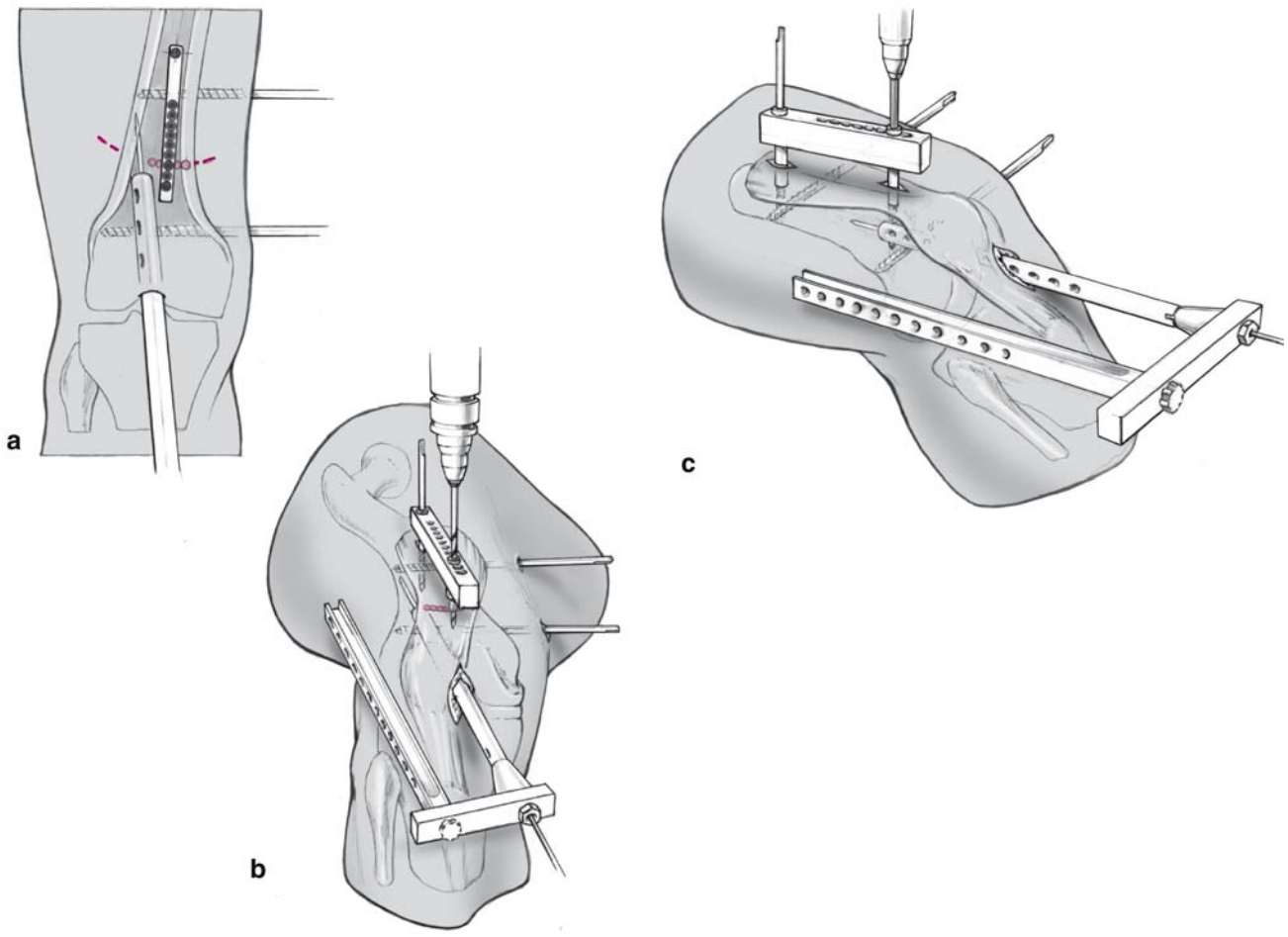
Figures 5a to 5c. Determination in two planes of the entry point for the 3.2-mm guide wire under image intensification. This point lies in the lateral plane at the anterior border of the Blumensaat line (anterior border of intercondylar notch; a) and in the AP plane usually intercondylar (b). The AP entry point can be considerably different depending on the preoperative drawing. The guide wire is advanced up to lateral femoral cortex (c). The image on the image intensifier is compared to the preoperative planning. Of importance is to check the entry point in both planes, to measure the distance between the joint line and the site of cortical perforation of the guide wire as well as to determine the angle between guide wire and diaphyseal cortex. All three points are checked under image intensification with a goniometer and a ruler.
If no additional correction in the sagittal plane is needed, which means no correction of flexion or extension, the guide wire is placed in the center of the sagittal plane as recommended by the manufacturer.



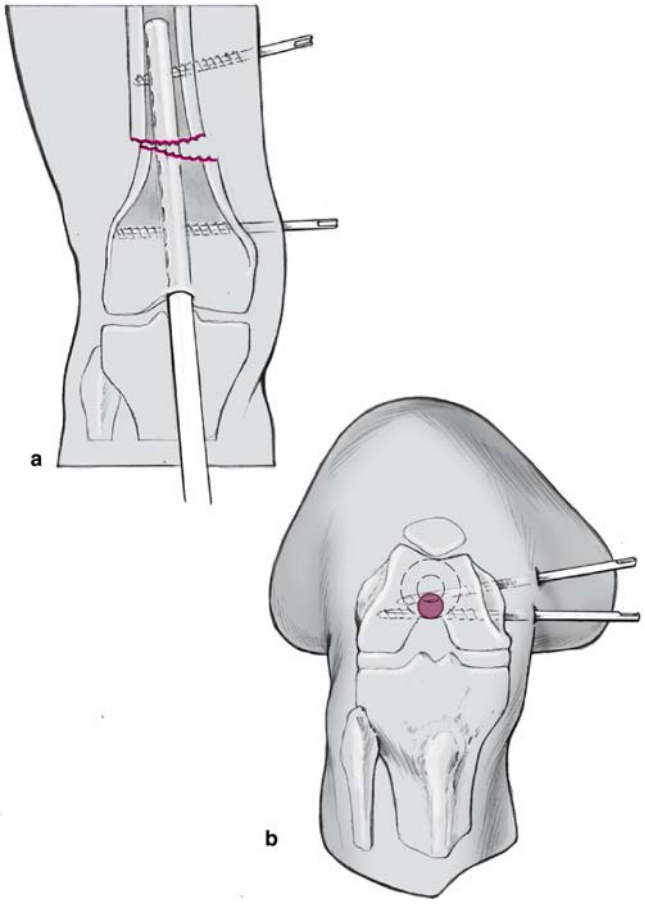
Figures 6a and 6b. Progressive enlargement of the medullary canal (a) and advancement of the selected intramedullary nail (b) up to the level of the planned osteotomy. The latter can be marked with a Kirschner wire. During these steps, the nail is attached to the aiming device.



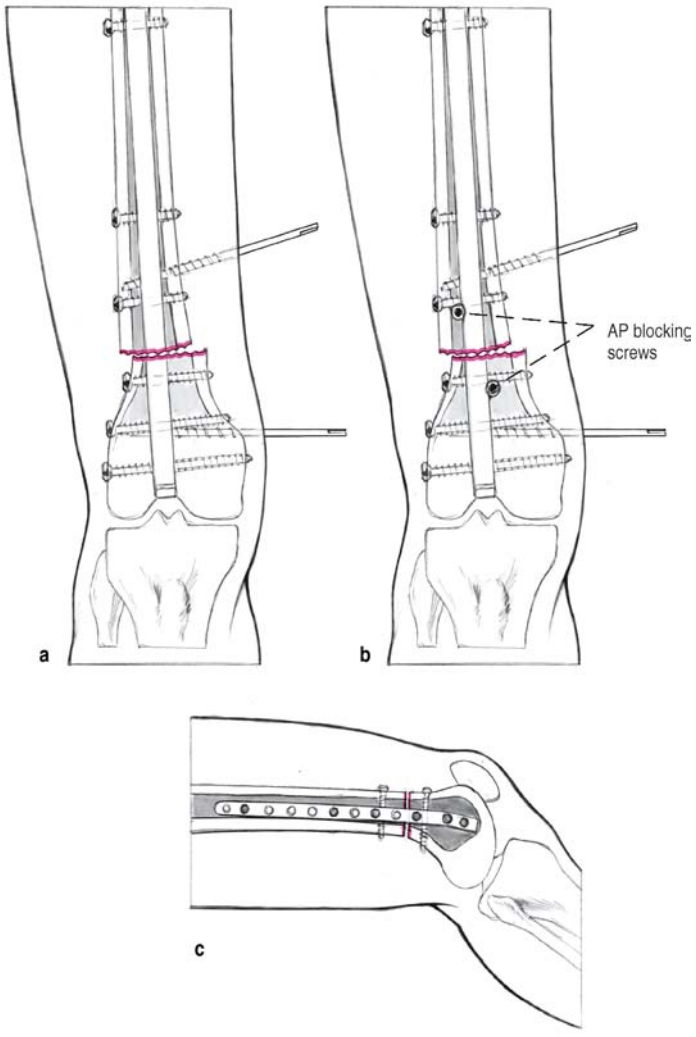
Figures 7a and 7b. Insertion of 4.5-mm Schanz screws used for indicating the extent of correction achieved, once the osteotomy has been performed: medial stab incisions 3 cm proximal and 3 cm distal to the planned site of osteotomy. Blunt spreading of tissues down to bone medioposteriorly. Insertion of 5.0/3.5-mm soft tissue sleeves and drilling with a 3.5-mm bit into the mediposterior femoral cortex (linea aspera), thus avoiding the future nail site. Insertion of both Schanz screws. They must lie parallel to each other in the frontal and axial plane. The view from anterior helps to assess the amount of correction of varus and that of the axial plane the degree of torsional correction.



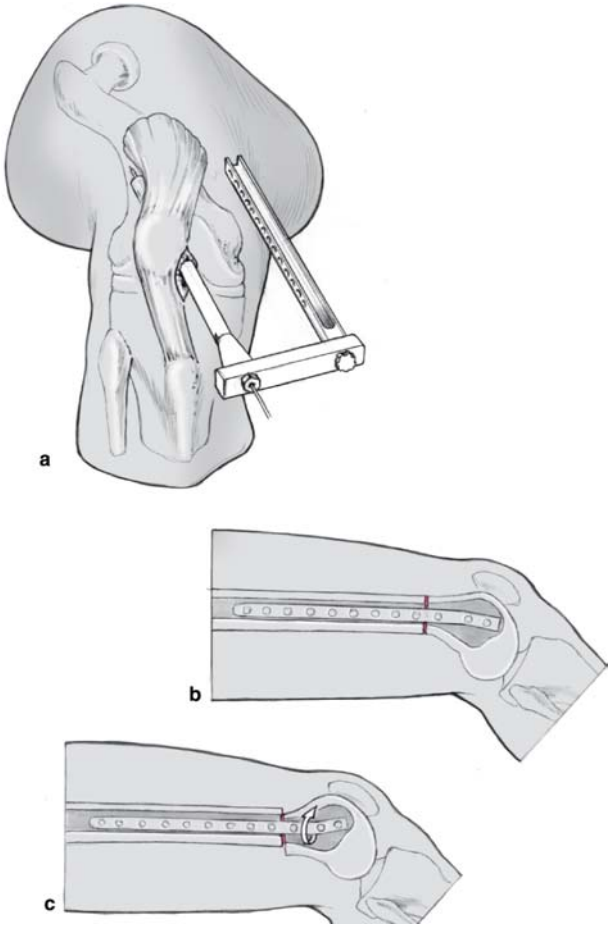
Figures 8a to 8c. Osteotomy: a dome-shaped osteotomy is performed only if correction in one plane without lengthening is indicated, particularly in instances of frontal plane deformities. For the osteotomy, the femur is approached through a 1–2 cm longitudinal splitting of the quadriceps tendon. Through a separate incision, the drill guide is fastened to bone with a 4.5-mm Schanz screw proximal to the planned site of osteotomy (a). The drill guide can pivot around the screw. Through one hole of the drill guide and using a 5.0/3.5-mm soft tissue sleeve put in contact with bone, an arc-shaped series of 3.5-mm holes are drilled into the femur (b, c). The medial and lateral cortices are carefully divided with the special chisel after having inserted its prong into the last (medial or lateral) drill hole. The anterior and posterior cortices are stepwise divided with a Lambotte osteotome under image intensification in the lateral plane. A transverse drill hole osteotomy is adequate for torsional corrections. It is also the procedure of choice for multiplane corrections or instances of callus distraction. For this osteotomy, the anterior cortex is perforated at one or several sites with a 4.5-mm drill bit inserted into a 6.0/4.5-mm soft tissue sleeve. A 3.5-mm drill bit passed through a 5.0/3.5-mm soft tissue sleeve is now inserted into the anterior drill hole. It is used to perforate the posterior cortex at several places made possible through a change in the drill bit's angle of advancement (fan-like). Tangential contact of the drill bit with the posterior cortex may cause a breakage of the bit. The cortices are further weakened by careful chiseling as done for the dome osteotomy. Before completion of the osteotomy, the intramedullary nail is advanced into the proximal fragment by 1–2 cm. Removal of the guide wire. Completion of the osteotomy with well-controlled chiseling. For the correction of axial and torsional malalignments, the leg is used as a lever arm. Neither the intramedullary nail nor the Schanz screws should be used to obtain the correction. The latter only serve as indicators!



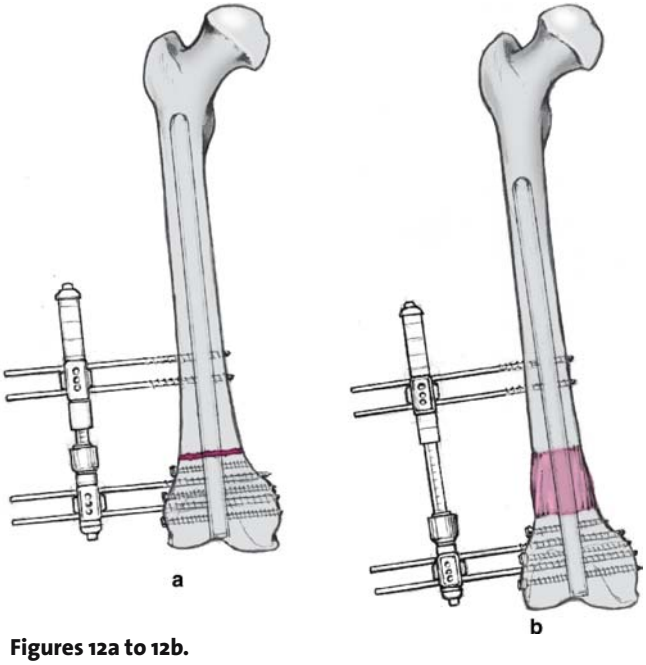
Figures 9a and 9b. Once the desired amount of correction has been achieved, the nail is advanced under constant control in the frontal (a) and torsional (b) correction. Distal locking with the help of the aiming device, impaction of the osteotomy with well-controlled hammer blows. Removal of the aiming device. The screw cap is inserted into the end of the nail. Checking of knee function, particularly of extension. Renewed control of axial and torsional correction relying on the Schanz screws, the goniometer as well as the image intensifier.



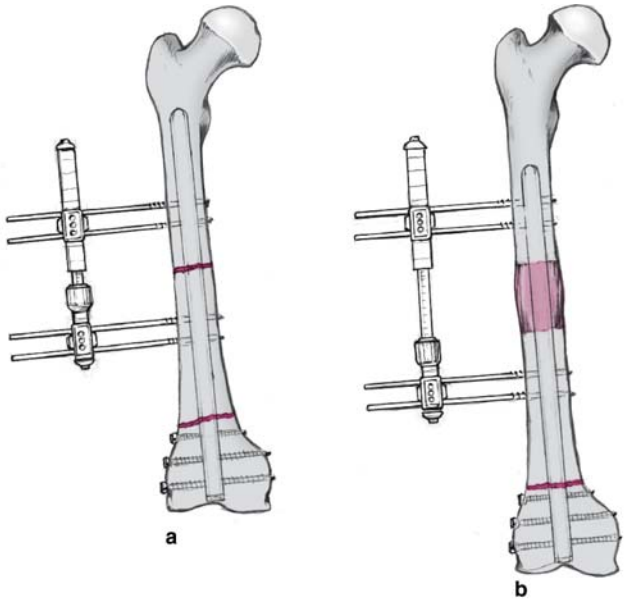
Figures 10a to 10c. Insertion of one locking screw proximally with the help of the aiming device or freehand. Renewed control of torsion and of external and internal rotation of hip. Placement of the second locking screw (a). Insertion of additional locking screws as well as of blocking bolt close to the site of osteotomy in instances of a wide femoral canal to ensure maintenance of axial alignment and stability of fixation (b, c).
Having checked again the correction in all planes and found it satisfactory, the Schanz screws are removed.
Copious irrigation of the knee joint with the arthroscopy cannula. Suture of the patellar ligament with interrupted, resorbable stitches, continuous suture of the peritendinous tissue with monofilament resorbable 4-0 thread. If an approach medial or lateral to the patellar ligament has been used, a reconstruction of the retinaculum is done. Subcutaneous suture, intracutaneous skin closure with resorbable thread. Closure of the stab incisions. Gauze dressing, elastic bandage from base of toes to proximal thigh. Positioning on a foam splint with the knee in 30° flexion.



Figures 11a to 11c.



Figures 12a to 12b.



Figures 13a to 13b.

For Additional Callus Distraction

- Distraction fixator (Triax Monotube red, Stryker Howmedica, Gewerbeallee, 45478 Mülheim, Germany).
- 6.0-mm Schanz screws, 20–25 cm long.

Anesthesia and Positioning

- Endotracheal anesthesia preferably combined with a continuous paravascular inguinal femoral nerve block, or epidural or spinal anesthesia.
- Supine on radiolucent table with leg support that can be lowered (Figure 3).
- Free draping, knee holder at thigh, if needed.
- Neither tourniquet nor exsanguination.

Correction of a Supracondylar Varus Deformity Serving as an Example

Initially, a knee arthroscopy is performed. This step is obligatory for all corrective osteotomies close to the knee joint. The arthroscopy serves the following purposes:

- assessment of the articular cartilage of medial, lateral and patellofemoral compartments; the findings may call for a modification of the extent of the planned correction or, in the presence of severe osteoarthritis, preclude an osteotomy;
- assessment of the patellofemoral congruence;

- treatment of meniscal lesions;
- treatment of articular cartilage defects due to procedures such as abrasion, microfracturing, etc.;
- possible extension lag is treated by dissection of soft tissue or bony (osteophytes) structure responsible for this lag.

The preoperative drawing (Figure 1) shows the intercondylar point of entry as well as the direction of the guide wire in the frontal and sagittal plane. The latter is not shown in this figure. The approach to the knee joint depends on the entry point that can be either medial or lateral to the patellar ligament or transligamentous. We recommend placing the guide wire on the anterior surface of the distal thigh and align it under image intensification according to the drawing.

Special Considerations

Correction in a Sagittal Plane

- An extension lag can be corrected by proper orientation of guide wire and nail. After osteotomy, the nail is advanced, thus causing the desired correction in the sagittal plane.
- Another worthwhile possibility to correct extension lags of 10–15° is the use of an IMSC nail with a distal anterior bow of 8°. In this case, the aiming device is mounted medially (Figure 11a), the nail is advanced as usual (Figure 11b), and, finally, nail and aiming device are turned by 180° (Figure 11c). Locking from lateral is performed in the usual way.

Lengthening

- If a concomitant femoral lengthening is indicated, we recommend a callus distraction over a long, retrograde-inserted nail. In general, a supracondylar distraction is done (Figures 12a and 12b)
- Should the bone quality at the level of the supracondylar osteotomy be doubtful, we recommend an additional diaphyseal osteotomy and segmental transport in a distal direction with compression of the supracondylar osteotomy and simultaneous, continuous gain in length at the diaphysis (Figures 13a and 13b).
- If a callus distraction is planned, the reaming of the medullary canal must exceed the nail diameter by 1.5–2.0 mm.
- In general, 6-mm Schanz screws of sufficient length should be used for the distraction fixator. Their length must allow the placement of two parallel distraction fixators. The Schanz screws are inserted into the posterolateral part of the femur ensuring that their threaded part does not touch the nail. The axial view must show that the screws are parallel to each other. The minimum distance between screws and osteotomy must be 3 cm. All other distances are dictated by the design of the fixator. To reduce later soft tissue irritation, screws close to the knee must be inserted with the knee in 90° of flexion.
- Mounting of the fixator parallel to the femur and to the nail, respectively. Trial distraction by 0.5–1 cm under image intensification followed by compression of the osteotomy.

Postoperative Management

- Change of dressing on day 1 and thereafter every 2–3 days. Elastic bandage or compression stocking for 6–8 weeks.
- Independent of the surgical procedure, the following limitation of active and passive motion must be respected: weeks 1 and 2: 0-0-50°; weeks 3 and 4: 0-0-70°; weeks 5 and 6: 0-0-90°. Thereafter, unlimited range of motion.
- In instances of a standard procedure, weight bearing is limited during the first 4–6 weeks to 20 kg, depending on the bone quality. Thereafter, increase of weight bearing by 10 kg/week.
- Callus distraction is started on day 1 with an alignment of the system. The patient turns the distraction screw four times daily by a quarter turn, corresponding to a lengthening of 0.25 mm. In young patients, the speed of distraction can be increased to 2 mm/day.
- Weight bearing during distraction is limited to 10 kg. After proximal static locking, the aftercare is identical to that of the standard technique.
- Radiographic control in two planes including knee and distal half of thigh on day 1 or 2, and after 6 and 12 weeks.
- Having used the standard technique, clinical observation daily during the first 2 weeks and then after 6 and 12 weeks. During callus distraction weekly controls, and this depending on the patient's reliability.
- Bony consolidation should be expected after 9–13 weeks, when the standard technique has been used. The speed of consolidation depends on factors such as bone quality, body weight, and whether patient is a smoker or not. Bony maturation after callus distraction will take 2–3 weeks per centimeter of distraction.
- Implant removal after standard technique at the earliest after 9 months, and after additional callus distraction after 24 months. Nail removal should be done under arthroscopic control [1]. There is no absolute need for implant removal. In elderly patients,

in whom a later knee replacement is anticipated, the nail can be removed at that time.

Errors, Hazards, Complications

Standard Technique

- Displacement of the Schanz screws used as indicators: always follow strictly the preoperative drawing; it is possible to achieve a secondary correction with blocking screws; control of torsion through testing of full external and internal rotation of hip.
- Accidental creation of large bony fragments during osteotomy: screw fixation, use of blocking screws; increase number of locking screws.
- Malpositioning of locking screws: leave screws either temporarily or permanently in place. To avoid this complication, locking screws have to be placed properly.
- Deep infection: immediate determination of systemic parameters of infection (sedimentation rate, C-reactive protein, white blood count); prompt surgical revision, swab for culture and sensitivity from knee joint, surgical wound, and medullary canal; administration of systemic antibiotics such as levofloxacin 2 × 500 mg and rifampicin 600 mg daily while waiting for result of culture, then specific antibiotic therapy. In the presence of sensitive germs, continue levofloxacin 2 × 250 mg and rifampicin 600 mg per day orally. Arthroscopic lavage and, if necessary, synovectomy; removal of locking screws and extraction of nail. Debridement of medullary canal through drilling and jet lavage; setup of suction irrigation or intramedullary insertion of Septopal® chains and intraarticular placement of Sulmycin® collagen fleece with gentamicin (Essex Pharma Co, P.O. Box 830347, 81703 Munich, Germany). If stability is in doubt: external fixator, preferably ring fixator. Depending on the course of local and systemic parameters of infection, repeat arthroscopic revision after 2–5 days as well as debridement, irrigation and removal of Septopal® chains.
- Nonunion: proximal dynamization of nail; if unsuccessful: freshening of nonunion and apposition of autogenous cancellous bone.

Accompanying Callus Distraction

- Signs of infection at pin sites such as redness, discharge, retraction: immediate determination of systemic parameters of infection; swab for culture and sensitivity; local debridement, Betaisodona® ointment (a povidone iodine ointment made by Mundipharma, P.O. Box 1350, 65533 Limburg, Germany), gauze dressing; oral antibiotic therapy with levofloxacin 2 × 500 mg daily. Continue antibiotics according to result of culture for 10–14 days.
- Septic loosening of a Schanz screw: proceed as in presence of deep infection.
- Aseptic loosening or avulsion of a Schanz screw: surgical revision; replacement of the Schanz screw distally or proximally.
- Jamming of nail: a jamming may occur during callus distraction; it may be due to pull of the adductors forcing the distal fragment into varus. Addition of a second external fixator will combat this tendency. A straightening and thus a freeing of jamming are obtained by differing the speeds of distraction, i.e., medial external fixator 1.5 mm/day and lateral fixator 1.0 mm/day.

Results

Between February 1998 and April 2002, we treated a distal femur deformity in 18 patients (six women, twelve men, average age 43 [23–58] years) with a supracondylar osteotomy and retrograde nailing. In 16 patients the deformity was posttraumatic in nature, 14 times after a fracture and twice after an intraarticular knee trauma and its sequelae. Twelve fractures could be classified retrospectively according to the AO classification [8]. One patient (WS) had suffered from a fracture of the opposite femur that healed with shortening. A determination of the original soft tissue trauma [15] was possible twelve times: an open trauma had occurred in five patients and a closed trauma in seven. Two patients (SA, SL) had suffered from a congenital femoral deformity. A concomitant posttraumatic tibia deformity was present in patients RE, SA, and SK (Table 1).

The number of previous operations, excluding arthroscopies, amounted to 1.3 (1–4). Eight patients had already undergone a supracondylar corrective osteotomy, and in two such a correction had been done three times. An arthroscopy had been performed in four patients. Patient MR had five revisions after an initial open reduction and internal fixation: two arthroscopies and three supracondylar corrections, twice with apposition of autogenous cancellous bone. Five patients (HM, LR, MR, RA, ZA) went on to a supracondylar nonunion; two of these (MR, RA) consolidated after bone grafting. At the moment of the corrective osteotomy, three patients (HM, LR, ZA) presented with a nonunion; in addition, LR had experienced a breakage of the originally introduced locked nail. A grade 3 open C3.3 fracture resulted in a nonunion in spite of three attempts at reconstruction; in addition, he suffered from an ankylosis of

Table 1. Patient data. AS: arthroscopy; C: closed; DCS: dynamic compression screw; EF: external fixator; F: female; L: left; LN: locked nailing; M: male; O: open; R: right; RN: retrograde intramedullary nailing.

Patient	Gender	Age[a] (years)	Fracture type[b]	Soft tissue trauma[c]	Side	Interval between trauma and correction (months)	Previous surgery First surgery after trauma	Corrections	Arthroscopies
BW	M	48	33 – C3.3	C II	L	48	Plate	–	2
FD	M	29	33 – C2.3	C II	L	74	Plate	–	–
GA	F	58	No fracture	–	L	564	–	2	–
HM	M	48	33 – C3.3	O III	L	17	Plate	2	–
LM	M	23	33 – C3.3	C I	R	16	RN	–	–
LR	M	35	32 – C1.3	O II	L	4	LN	–	–
MR	F	55	33 – A3.3	O I	L	53	DCS	3	2
ND	M	35	32 – B2.3	C I	L	5	EF	1	–
RA	M	36	33 – C3.2	O III	L	23	EF	3	–
RE	F	41	?	?	L	330	Extension	–	–
RH	M	48	No fracture	–	R	336	AS	2	1
SA	M	46	42 – A2.3	?	L	352	Extension	–	–
SC	F	41	33 – A3.3	?	L	244	Plate	–	–
SK	M	41	33 – A2.3	C III	L	17	Plate	1	–
SL	F	41	No fracture	–	R	Congenital	–	–	1
WS	M	56	Fracture right femur	–	L	444	Previous surgery only of right femur Osteoarthritis grade IV bilateral		
ZA	M	38	33 – A3.2 + – B3.2.1	O I C II	L	6	RN	–	–
ZH	F	54	33 – C3.3	C II	L	4	Plate	1	–

[a] age at time of corrective osteotomy
[b] fracture type according to AO classification [8]
[c] soft tissue trauma, classification according to Tscherne & Oestern [15]

Table 2. Preoperative limb geometry, range of motion of knee, and location of nonunion. Δ length: leg length discrepancy; Δ torsion: angle of torsion compared to normal side. + indicates external torsional deviation, – internal torsional deviation.

Patient	Axial malalignment Frontal	Sagittal	Longitudinal	Δ length (cm)	Δ torsion (°)	Extension/ flexion knee (°)	Nonunion
BW	Varus 5°	Anteversion 15°	0	–1.7	+28	0/15/85	–
FD	Valgus 4°	Retroversion 15°	0	–0.9	–23	20/0/110	–
GA	Varus 23°	Anteversion 10°	0	–2.5	+17	0/10/130	–
HM	Valgus 18°	Anteversion 40°	+	–8.3 (–6.4)	+19	0/30/50	Supracondylar
LM	Varus 3°	0	0	–2.6	+26	0/0/90	–
LR	0	0	0	–5.7	–2	0/0/140	Distal femur
MR	Valgus 9°	Retroversion 25°	+	–5.2 (–2.8)	–8	0/30/60	Supracondylar
ND	Valgus 6°	Anteversion 10°	+	–1.7	+24	0/10/130	–
RA	Varus 20°	Anteversion 10°	0	–0.2	0	0/10/40	Supracondylar
RE	Varus 12°	Anteversion 15°	0	–0.7	+9	0/15/140	–
RH	Varus 15°	Anteversion 10°	0	–1.2	+13	0/10/95	–
SA	Varus 3°	0	0	–0.3	+4	0/0/140	–
SC	Varus 17°	Retroversion 10°	+	–5.2	–35	10/0/35	–
SK	Varus 11°	Anteversion 10°	0	–0.7	+1	0/10/110	–
SL	Valgus 6°	0	0	–2.9	–12	0/0/150	–
WS	Varus 8°	Anteversion 10°	0	+2.0	–2	0/10/80	–
ZA	0	Anteversion 10°	0	–0.4	+32	0/10/150	Supracondylar
ZH	Varus 16°	Anteversion 5°	+	–1.3	+15	0/5/80	–

the knee and a shortening of 6.4 cm (before resection of pseudarthrosis and supracondylar correction).

The extent of the supracondylar deformity in each of the three planes in length and in torsion is listed in Table 2 for all patients as well as the preoperative range of motion of the knee.

In twelve patients we performed an arthroscopy before the corrective osteotomy (Table 3). Scoping was impossible in three patients (HM, RA, SC) on account of an arthrofibrosis. In two patients (LR, ND), an arthroscopy had already been done elsewhere. Patient WS, suffering from a grade IV osteoarthritis, had under-

Table 3. Surgical technique and duration. CO: chisel osteotomy; D: diagnostic; DHO: drill hole osteotomy; IMSC: intramedullary supracondylar stainless steel nail; OS: oscillating saw; T: therapeutic; TKR: total knee replacement.

Patient	Arthroscopy	Osteotomy	Type of nail	Distraction fixator	Duration of surgery (min)
BW	T	Dome	IMSC 200 × 13	–	180
FD	D	DHO lateral	IMSC 420 × 10	–	240
GA	T	DHO	IMSC 300 × 11	+	180
HM	–	OS/DHO	IMSC 350 × 11	+	150
LM	T	DHO/CO	ACE	+	120
LR	–	OS	IMSC 380 × 11	+	180
MR	T	OS/DHO	IMSC 340 × 11	+	210
ND	–	OS/DHO	ACE	–	120
RA	–	–	IMSC 340 × 10	–	150
RE	T	Dome	IMSC 250 × 11	–	150
RH	T	Dome	IMSC 250 × 11	–	150
SA	T	DHO	IMSC 250 × 13	–	210
SC	–	DHO	IMSC 250 × 12	+	120
SK	D	DHO	IMSC 320 × 11	–	90
SL	T	Dome	IMSC 200 × 12	+	180
WS	–	OS	IMSC 200 × 12	–	210 (with TKR)
ZA	T	DHO	IMSC 300 × 11	–	150
ZH	T	Dome	IMSC 250 × 12	–	140

gone a femoral shortening osteotomy followed by a total knee replacement.

Only two of the twelve arthroscopies were purely diagnostic to assess the quality of the articular cartilage. In the other ten patients procedures such as debridement and partial synovectomies were performed. An extension lag intraarticular in nature could be reduced or eliminated in four patients (BW, GA, RE, RH) either through resection of osteophytes of the tibial spines or at the notch, or through removal of soft tissue obstacles.

The following osteotomy techniques were used: dome osteotomy five times, drill hole osteotomy ten times, completed three times with an oscillating saw and once with a chisel. An oscillating saw only was used once (patient WS) and correction of the pseudarthrosis alone performed once (patient RA).

In addition to the corrective osteotomy, a callus distraction with a unilateral distraction fixator was done in seven patients.

The average operating time amounted to 163 (90–240) min. Included in this time are arthroscopy and implantation of a total knee prosthesis (patient WS) as well as measures to prepare a segmental transport (patient HM).

All 18 patients were followed by us. The average duration of follow-up for corrective osteotomies and completed callus distraction totaled 29 (4–45) months (Table 4). All incisions, be they infrapatellar, at the site of osteotomy or at the insertion of the indicator Schanz screws, healed primarily. One pin track infection during

Table 4. Postoperative course and results (limb geometry and range of motion of knee).

Patient	Infection	Bony consolidation (months)	Full weight bearing (weeks)	Axial malalignment Frontal	Sagittal	Longitudinal	Δ length (cm)	Δ torsion (°)	Extension/flexion knee (°)	Duration of follow-up (months)
BW	–	< 3	14	0	0	0	–0.8	.–2	0/0/130	43
FD	–	< 3	13	0	0	0	–0.7	+3	0/0/140	32
GA	–	< 3	4	0	0	0	–0.5	+6	5/0/130	30
HM	–	4–6	11	0	0	0	–1.2	+0	0/0/95	45
LM	–	< 3	6	0	0	0	+0.1	+3	0/0/140	25
LR	+	4–6	8	0	0	0	–0.5	+6	0/0/140	34
MR	–	4–6	11	0	0	0	–1.0	+15	0/0/95	24
ND	–	4–6	13	0	0	0	+0.2	+10	0/0/135	43
RA	–	> 6[a]	8	0	0	0	–0.3	0	0/0/60	16
RE	–	< 3	7	Varus 2°	0	0	–0.5	+2	5/0/150	42
RH	–	< 3	10	0	0	0	–1.4	+2	0/0/130	35
SA	–	< 3	12	0	0	0	–0.9	+1	0/0/145	26
SC	–	< 3	13	Valgus 1°	0	0	–0.1	–4	0/0/50	4
SK	–	4–6	12	0	0	0	–0.9	+8	0/0/135	17
SL	–	> 6[a]	20	Valgus 1°	0	0	–0.3	+1	5/0/140	23
WS	–	> 6[a]	8	Varus 1°	0	0	+0.5	–3	0/0/110	25
ZA	–	< 3	11	0	0	0	+0.1	+3	0/0/140	26
ZH	–	< 3	4	Varus 5°	0	0	–0.4	–3	0/0/125	37

[a] secondary autogenous cancellous bone graft

distraction led to a deep infection in spite of revision and antibiotic therapy; its outcome is described below. No other soft tissue complications, knee complications or thromboembolic events were noted. Bony consolidation at the level of the osteotomy and of the distraction callus occurred innormal time in 15 patients. It was unsatisfactory in two patients (RA, SL), both being heavy smokers [5]. A bony consolidation, although delayed, was achieved after autogenous cancellous bone grafting. Patient WS underwent a shortening osteotomy, followed by a resurfacing joint procedure. 5 months postoperatively, the retrograde nail broke at the osteotomy site. After nail change and cancellous bone grafting, the osteotomy consolidated.

The average gain in length after additional callus distraction amounted to 4.1 (2.0–7.1) cm. The average duration of external fixation was 92 (18–270) days. It took 17 (9–38) days to gain 1 cm in length. Full weight bearing was possible after 10 (4–20) weeks following a corrective osteotomy or after proximal locking at the end of callus distraction.

Whereas no infection occurred after a standard osteotomy, we observed a late pin track infection in one (LR) of the seven patients who underwent a lengthening. 6 months after removal of the fixator and proximal locking, an osteomyelitis developed in the presence of an otherwise normal course. After early implant removal, bony debridement achieved by drilling, irrigation and specific antibiotic therapy, a timely bony consolidation without further complications could be observed.

After bony consolidation, all patients had plain films radiographs on long cassettes of the lower limbs while standing as well as CT and ultrasound assessment of length and torsion, identical to the preoperative imaging. Whereas the remaining torsion and length differences remained in the normal range [12], the varus deformity in one patient decreased from 16° to 5° and was therefore not sufficiently corrected (patient ZA). The reason for this inadequate correction was the failure to properly transfer the correct preoperative planning during surgery. The preoperative average range of knee motion of 92° (0–150°) improved to an average of 122.5° (50–155°) at the time of follow-up. For patient SC, an arthrolysis with a quadriceps plasty according to Judet et al. [6] will be performed after maturation of the distraction callus.

In twelve patients the retrograde nail has already been removed under arthroscopic visualization [1].

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