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# Minimally invasive double-plating osteosynthesis of the distal femur

## Electronic supplementary material

The online version of this article (https://doi.org/10.1007/s00064-020-00664-w) includes supplemental figures and videos (case examples). Article and supplementary material are available at www.springermedizin.de. Please enter the title of the article in the search field, the supplementary material can be found under "Ergänzende Inhalte".

## Introductory remarks

Peri- and interprosthetic distal femur fractures are becoming increasingly common as life expectancy rises and the incidence of joint replacements increase [2, 3]. As these fractures often occur in elderly, or even frail patients, the morbidity and mortality rates are high [4]. In addition, advanced age or history of arthroplasty is commonly associated with both quantitative and qualitative loss of bone stock, contributing to the high number of implant failures and loss of reduction [5]. Due to these unfavorable conditions, peri- and interprosthetic fractures are a major clinical challenge.

It has been shown that peri- and interprosthetic femur fractures can be effectively treated with locking plates using a minimally invasive approach [1, 6, 7]. To minimalize the stress riser zone, the fixation device in interprosthetic fractures must also overlap both the prosthesis by at least twice the diameter of the femoral diaphysis [7]. Moreover, in osteoporotic bone the mechanical stress at the end of a plate might result in secondary fractures as well [8]. Therefore, spanning the entire femur is advised to avoid these stress riser zones and to concurrently prevent secondary fractures [9]. Modern locking plates are perfectly suited for spanning the total femur, with the option of fixation with (variable angle) locking screws beside the prosthesis, cerclages around the stem of the hip prosthesis, or locking attachment plates [10]. In addition, minimally invasive plate osteosynthesis (MIPO) of the femur has been shown to maintain local fracture biology and preserve local vascularity which promotes bone healing [11–13].

Weight bearing in distal periprosthetic femur fractures has been limited postoperatively due to concerns of high fixation failure rates, up to 26% with open reduction and lateral locking plate fixation [8, 14]. For interprosthetic femur fractures, treated with lateral locking plate fixation, no fixation failure rates are described in the literature and there are no case series that describe direct postoperative weight bearing after fixation. At present, postoperative weight bearing is therefore restricted until radiologic evidence of osseous consolidation occurs [7, 10, 15, 16]. In the first 6–8 weeks after surgery, patients are usually restricted to nonweight bearing [7, 10, 15, 16]. The restrictions in weight bearing are primarily due to concerns of implant failure and loss of reduction, as these geriatric patients have poor bone quality and lack the ability to comply with partial weight bearing [17, 18]. Limiting weight bearing status after surgery has been associated with a prolonged recovery period and an increased risk of postoperative complications [8]. In analogy to insights from geriatric patients with acute hip fractures, early mobilization without restrictions and full weight bearing appears to improve the functional postoperative outcome and decreases mortality [19, 20].

In the past, an additional medial plate has been added in complex fractures (segmental comminution or non-unions) of the distal femur to obviate implant failure and loss of reduction [21–23]. These parallel placed plates improved the stiffness and strength but were later abandoned due to the increased risk of refractures when both plates were removed simultaneously. The refracture risk was due to the vascular damage, contact necrosis, and bone loss caused by the compression plates [24]. Locking plates have resolved this problem, but placing a second

Shared first authorship: F.J.P. Beeres and B.L. Emmink

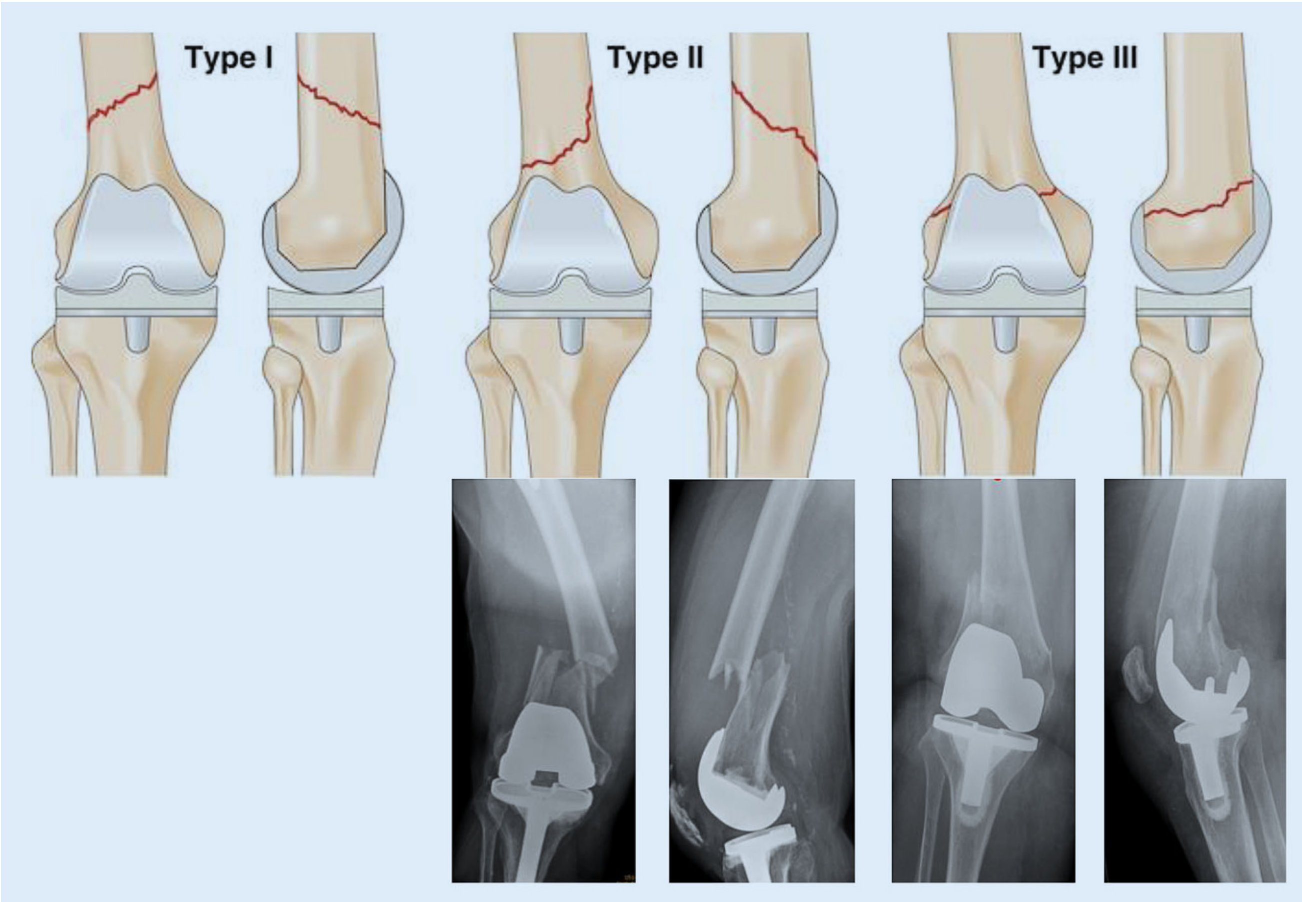


**Fig. 1** ▲ Indication(s) for minimally invasive double-plating of distal peri- and interprosthetic femur fractures: type I, II, and III supraconylar periposthetic femoral fractures, based on the Su et al. classification. (*Type I*: fracture proximal to the femoral component. *Type II*: fracture originating at the proximal end of femoral component and extending proximally. *Type III*: fracture in which any part of the fracture line can be seen distal to the anterior flange of the femoral component). (Schematic drawings from [38])

plate on the medial side via subvastus approach of distal femur still requires soft tissue dissection and fracture exposure with loss of hematoma and periosteum [23]. Moreover, a direct medial approach is limited to the distal 60% of the femur due to the risk of injury to the femoral artery [25].

Recently, a helical shaped locking plate has been introduced for the ventromedial side of the distal femur [26, 27]. This helical shaped plate can be inserted in a minimally invasive technique, without any additional exposure of the fracture site. The distal part of the helical plate fits the medial condyle and the proximal part the ventral or ventrolateral side of the femur. As the plate has a helical shape and the proximal part of plate fits the ventral or ventrolateral side of femur, it can be safely introduced without risking injury to the femoral artery [25]. Biomechanically, the helical plate replaces the missing remote cortical support by acting as a kind of tension/compression band with a large leverage arm lowering the axial loading on the plate and reducing pullout forces on screws [28–30]. The application of a helical shaped plate has been shown to add the required rigidity and strength to make direct unrestricted weight bearing possible after reoperations and primary fixation of femur fractures with segmental comminution [27, 31].

To date, no paper has addressed the technical aspects of double helical plating for distal femur fractures, its indications and advantages with respect to after treatment. In this technical paper we describe the indications, technical tips and tricks, postoperative management, and our results of patients who have undergone double-plating of the distal femur.

## Surgical principle and objective

**Minimally invasive double-plating of the distal femur in patients with limited bone stock and poor bone quality in order to reduce the risk of secondary displacement and to allow unrestricted postoperative weight bearing.**

## Advantages

- Double-plating:
  - Improves fixation in the condylar region which has limited bone stock and is of poor quality. It enhances the stability of the distal

## Abstract · Zusammenfassung

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## Minimally invasive double-plating osteosynthesis of the distal femur

### Abstract

**Objective.** Technical description of minimally invasive double-plating of the distal femur.
**Indications.** Peri- and interprosthetic distal femur fractures with limited (periprosthetic) bone stock in geriatric patients. Re-operations (delayed and non-unions; infected non-unions) of the distal femur. Distal femoral fractures or femoral shaft fractures that do not qualify for femoral nailing and where the patient is unable to comply with weight-bearing restrictions.
**Contraindications.** Peri- and interprosthetic femoral fractures with unstable knee prosthesis and local soft tissue infection. Peri- and interprosthetic fractures of the proximal femur.
**Surgical technique.** Supine position on a radiolucent table with both legs draped free. Support the knee to release traction on the distal fragment by the gastrocnemius muscle. Reduction and fixation of the fracture using a minimally invasive lateral approach. To reduce stress riser zones in interprosthetic fractures, the fixation device should overlap both the prosthesis by at least twice the diameter of the femoral diaphysis. Control plate position and reduction with special emphasis on length, rotation and longitudinal axes, using the healthy side as a reference. After sufficient reduction and fixation of the fracture, one proceeds to the medial plate fixation of the femur. Pre- or intraoperative contouring of a narrow large fragment locking compression plate into a helical shaped plate should be performed, using bending irons and a saw bone of a standard femur. The helical shaped plate is introduced submuscular and epiperiosteal in a minimally invasive fashion and fixed with bicortical locking screws.
**Postoperative management.** Unrestricted weight bearing with walker or crutches under supervision of physiotherapist.
**Results.** Between 2015 and December 2018, minimally invasive double-plate osteosynthesis using a medial helical shaped plate was performed in 11 patients. In 6 cases it was applied in patients (81 years ± 7 SD) with a supracondylar peri- or interprosthetic femoral fracture. No implant failure or loss of reduction was seen after postoperative unrestricted weight bearing. In the additional 5 cases double-plating was used in salvage procedures ([infected] non-unions, hardware failure). One of these patients developed a fracture-related infection for which all material was removed. The fracture healed after a new attempt of antegrade nailing combined with an additional locking plate. In the remaining patients complete bone healing without hardware failure was seen.

### Keywords

Bone fractures · Peri- and interprosthetic fractures · Knee prosthesis · Geriatrics · Helical shaped plate

## Minimal-invasive Doppelplattenosteosynthese des distalen Femurs

### Zusammenfassung

**Operationsziel.** Technische Beschreibung der minimal-invasiven Doppelplattenosteosynthese des distalen Femurs.
**Indikationen.** Peri- und interprothetische distale Femurfrakturen mit limitiertem (periprothetischem) Knochensubstrat bei geriatrischen Patienten. Revisionseingriffe (verzögerte Frakturheilung, Pseudarthrose und infizierte Pseudarthrose) am distalen Femur. Distale Femurfrakturen und Femurschaftfrakturen bei Patienten, die eine Teilbelastung nicht einhalten können und bei denen keine Versorgung mittels Marknagelung möglich ist.
**Kontraindikationen.** Peri- und interprothetische Femurfrakturen mit instabiler Knietotalendoprothese und lokaler Weichteilinfektion. Peri- und interprothetische proximale Femurfrakturen.
**Operationstechnik.** Rückenlagerung des Patienten auf röntgenstrahlendurchlässigem Tisch; beiden Beine frei gelagert; Rolle unter distalem Femur des frakturierten Beines. Primäre Reposition und Fixation der Fraktur erfolgt über minimal-invasiven lateralen Zugang. Um die Zone erhöhter mechanischer Beanspruchung möglichst zu minimieren muss das Osteosynthesematerial das Prothesenmaterial um mindestens den doppelten Durchmesser der Femurdiaphyse überragen. Kontrolle von Plattenlage und Reposition mit besonderem Augenmerk auf Länge, Rotation und Achse anhand des gesunden Beins. Nach suffizienter Reposition und Fixation der Fraktur erfolgt die mediale Plattenosteosynthese. Prä- oder intraoperatives Vorbiegen einer schmalen winkelstabilen Großfragmentkompressionsplatte in eine Helixform unter Zuhilfenahme von Schränkeisen und eines Standardfemurs aus Kunstknochen. Nun minimal-invasives submuskuläres epiperiostales Einschieben der Helixplatte mit anschließender bikortikaler winkelstabiler Verschraubung.
**Weiterbehandlung.** Uneingeschränkte Vollbelastung an Unterarmgehhilfen oder am Rollator unter physiotherapeutischer Instruktion.
**Ergebnisse.** Zwischen 2015 und Dezember 2018 wurde bei 11 Patienten eine minimal-invasive Doppelplattenosteosynthese unter Verwendung einer Helixplatte durchgeführt. In 6 Fällen wurde sie bei Patienten (81 Jahre ± 7 SD) mit einer suprakondylären peri- oder interprothetischen Femurfraktur angewendet. Es trat kein Implantatversagen und kein sekundärer Repositionsverlust bei postoperativer Vollbelastung auf. In 5 weiteren Fällen wurde die Doppelplattenosteosynthese als Revisionseingriff ([infizierte]) Pseudarthrose und Implantatversagen) durchgeführt. Einer dieser Patienten erlitt eine postoperative Infektion mit konsekutiver vollständiger Osteosynthesematerialentfernung. Nach Ausheilung des Infektes erfolgte eine erneute Osteosynthese mittels antegrader Marknagelung und Zusatzplatte, durch welche die Heilung erzielt werden konnte. In den restlichen Fällen konnte die Fraktur komplikationslos ausheilen.

### Schlüsselwörter

Knochenfrakturen · Peri- und interprothetische Frakturen · Knieendoprothese · Geriatrie · Helikal geformte Platte

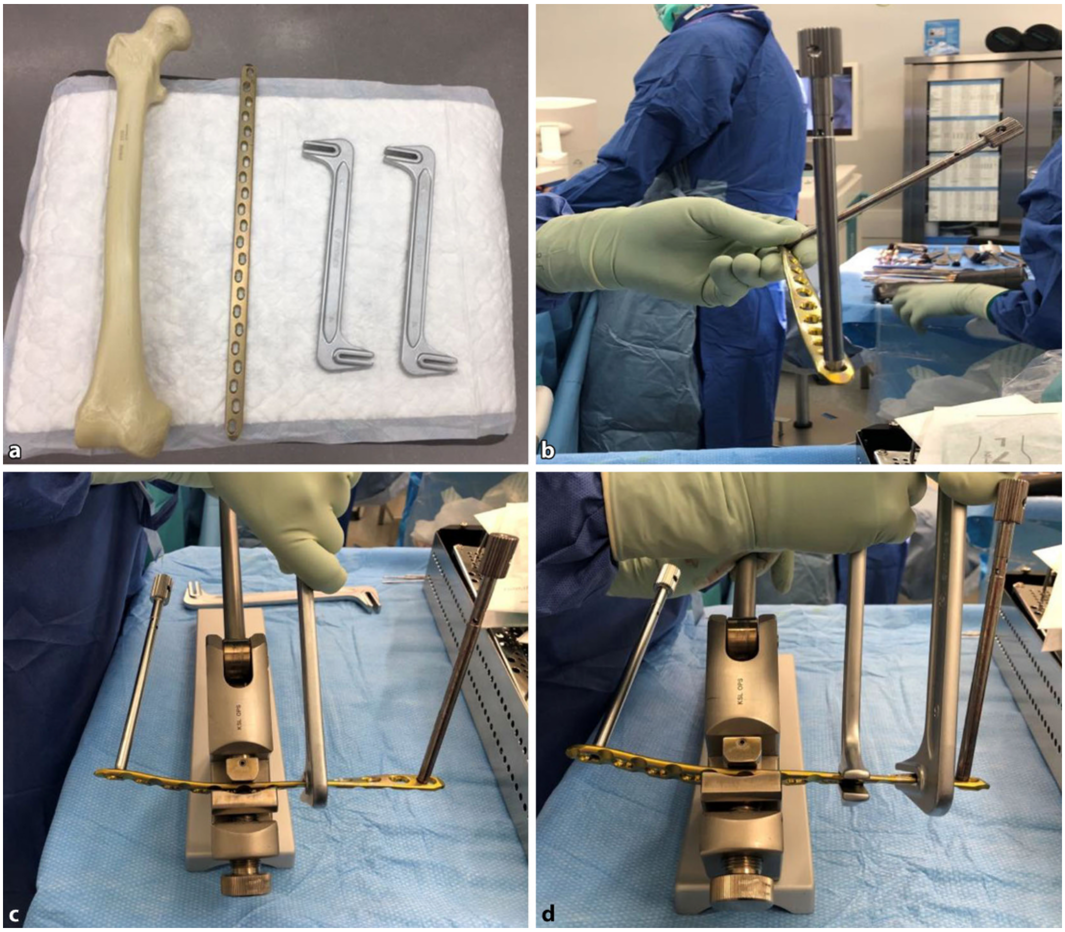

**Fig. 2** ◂ Materials and steps needed for precontouring a narrow large fragment locking compression plate (LCP) into a helical shaped plate; **a** bending irons and standard femur saw bone. **b** Manual helical contouring is done by inserting two drill sleeves at both ends of plate. Bending can be started from distal or proximal. Bend plate in small steps. **c, d** Additional contouring to fit (saw-bone) femur is done by using bending irons in combination with bending press. Precontouring can be performed preoperatively if time permits, alternatively intraoperatively, using a saw bone packed in a sterile bag

articular block, preventing possible varus collapse and loss of reduction.
  - Adds the required rigidity and strength to allow direct unrestricted weight bearing. This improves the functional postoperative outcome and will most probably decrease postoperative complications.
- Minimally invasive approach causes less soft tissue trauma, preservation of the hematoma and periosteum compared to conventional plate osteosynthesis. Placing a helical plate on the ventromedial aspect of the femur needs minimal additional exposure and it requires no additional exposure of the fracture site.
- Use of locking plates (LCP) creates greater biomechanical stability compared to dynamic compression plate systems (DCP) or intramedullary nail osteosynthesis.

## Disadvantages

- At present there is no precontoured locking compression plate available for spanning of the ventromedial side of the distal femur.
- Learning curve to precontour standard large fragment locking compression plate to a helical shaped plate. In addition, precontouring is done on a standard femur saw bone which may vary from patient's anatomy, frequently requiring additional intraoperative contouring.
- Prolonged operation time

## Indications

- Supracondylar peri- and interprosthetic femur fractures in geriatric patients with a stable primary knee prosthesis (Lewis and Rorabeck, type I and II [32]; Su et al., type I, II, and III [33]; ◘ **Fig. 1**). Depending on the anchorage possibility and the bone quality Su type I can be seen as a relative indication. The additional operative effort of augmenting the construct to allow full weight bearing should be taken into account.
- Distal femur fractures with limited bone stock in patients with total hip prosthesis
- Revision operations (non-unions, delayed-unions and infections) of the distal femur [31]
- Inability to comply with restricted weight bearing

## Contraindications

- Supracondylar peri- or interprosthetic femoral fractures with unstable primary knee prosthesis, type III based on Lewis and Rorabeck classification [32, 33]
- Peri- and interprosthetic fractures of the proximal femur
- Local soft tissue infection

**Fig. 3** ▲ Narrow large fragment locking compression plate is precontoured so that distal part of plate fits the shape of medial condyle and proximal part the ventromedial side of femur

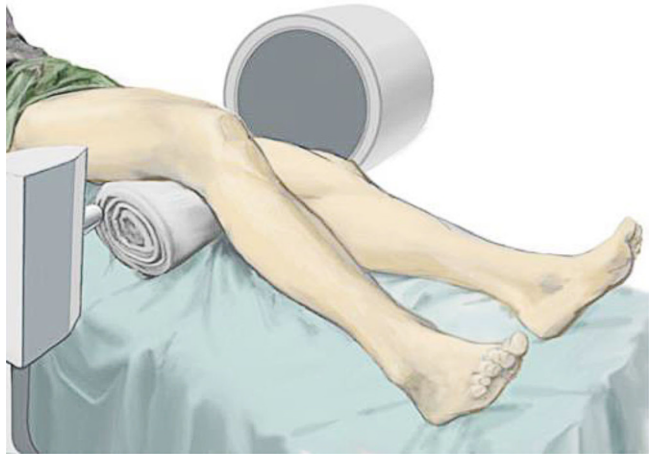

**Fig. 4** ◀ Patient in supine position on a radiolucent table with both legs draped free. Knee in slight flexion to relieve the strain of gastrocnemius muscle on distal part of femur. (From [1])

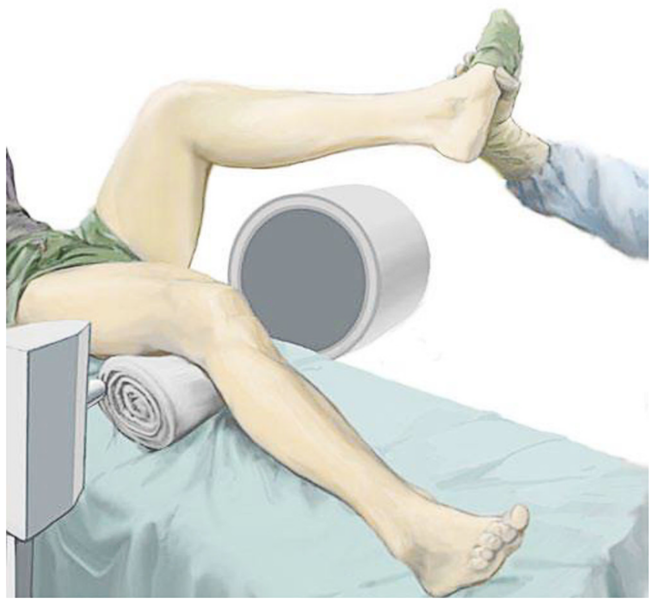

**Fig. 5** ◀ Operating table with x-ray permeable leg plates. Lateral x-rays can be made by raising or lowering the contralateral leg plate. (From [1])

## Patients information

- General operation risks
- Restrictions in extremity movement, particularly the knee joint
- Delayed bone healing, pseudoarthrosis, and non-union
- Secondary mechanical complications (e.g., loss of fixation) and reoperation
- Implant removal after bone healing only necessary in case of complaints

## Preoperative work-up

- X-ray diagnostics of the entire femur and the adjacent joints in two levels. In case of revision operation additional standing long leg radiographs of both legs. An additional CT scan is advocated for preoperative planning and to evaluate the stability of the total knee prosthesis according to the Lewis and Rorabeck classification [32].
- Examination of the patient with documentation of the status of the sensorimotor functions and blood circulation of the affected extremity.
- Precontouring a narrow large fragment locking compression plate (narrow 4.5 mm LCP) into a helical plate, using bending irons, bending press and standard femur saw bone (**Fig. 2**). The plate is precontoured so that the distal part of plate fits the shape of the medial condyle and the proximal part of plate onto the ventral side of femur (**Fig. 3**). Precontouring can be performed preoperatively if time permits, alternatively intraoperatively.
- Sterilization of precontoured helical plate if contouring is performed preoperatively
- One dose of intravenous 2000 mg Cefazolin, 30 min prior to the skin incision
- Documentation of the contour of the trochanter minor when patella is positioned ventrally on the healthy side

## Instruments and implants

- Helical (precontoured) narrow 4.5 mm large fragment LCP plate (Synthes, Oberdorf, Switzerland)

- Instruments and aiming device for lateral plating (VA-LCP 4.5/5.0 or LISS-plate, Synthes)
- Large fragment LCP instrument and implant set
- Kirschner wires (1.6 mm)
- Schanz screws
- Large distractor (AO Synthes) or external fixator.
- Reposition clamps and collinear reposition clamp (Synthes)
- Minimally invasive cerclage passer (Synthes)
- Whirley Birds (Synthes)
- Locking attachment plates

## Anesthesia and positioning

- Patient in supine position
- General or regional anesthesia
- Surgical skin disinfection of both legs. This is done to assess the rotation intraoperatively, using the uninjured leg [34].
- Knee in slight flexion to relieve the strain of gastrocnemius muscle on distal part of femur (**Fig. 4**).
- Operating table with x-ray permeable leg plates. Lateral x-rays can be made by raising or lowering the contralateral leg plate (**Fig. 5**).

## Surgical technique

(**Figs. 6, 7, 8, 9, 10, 11, 12**)

For the complete technical comments and figures on the lateral minimally invasive approach, reduction, and fixation of distal femur fractures we refer to Link and Rosenkranz et al. [1, 35, 36]. Only after sufficient reduction and fixation of the fracture can one proceed to medial plate fixation of the femur.

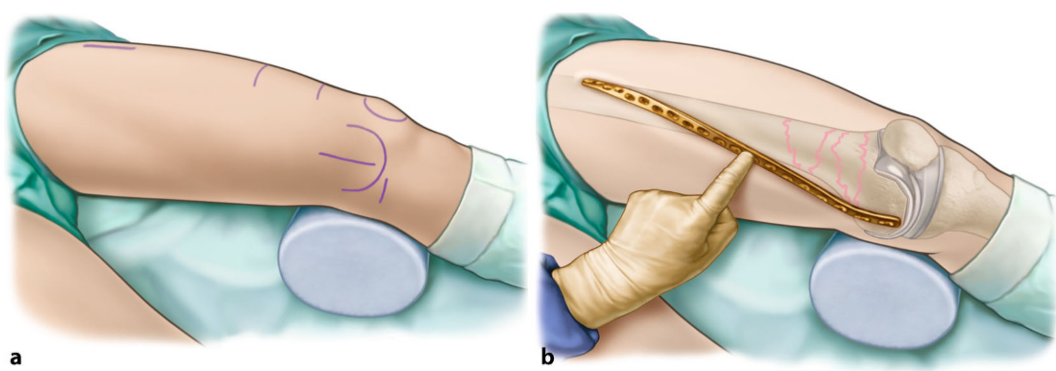


**Fig. 6** ◀ Minimally invasive approach to the ventromedial side of femur. **a** Anatomical landmarks of distal femur are drawn. **b** With use of the precontoured helical plate the distal and proximal incision sites can be marked on the ventromedial side of the femur

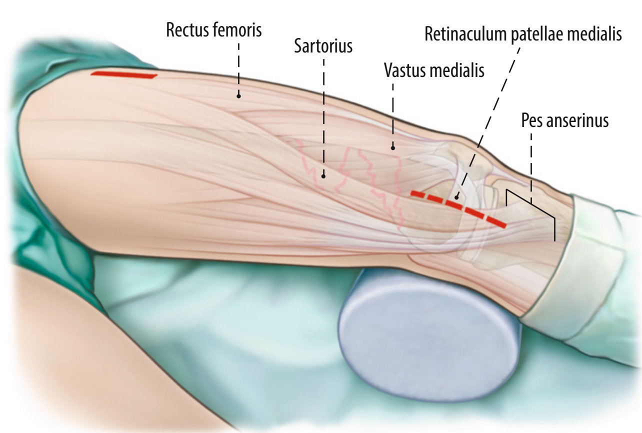


**Fig. 7** ▲ Minimally invasive approach to medial side of distal femur; skin incision over center of condyle in line with femur, after which the vastus medialis is retracted to open the submuscular area

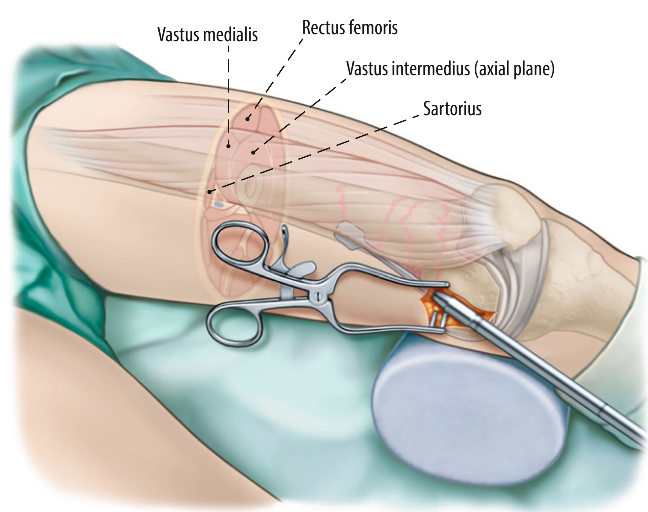


**Fig. 8** ▲ Before introduction of the plate, a submuscular epiperiosteal tunnel is created from distal to proximal and from medial to ventral by carefully inserting the long periosteal elevator under vastus medialis and vastus intermedius muscles. The periosteal elevator must be directed to the ventral part of proximal femur. Alternatively the plate itself may be used to slide over the medial aspect of the femur to create its own tunnel

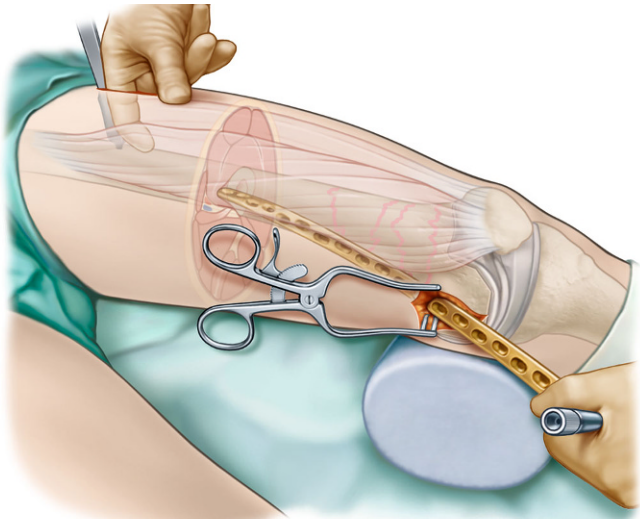

**Fig. 9** ▲ Introduction of the precontoured helical plate over the medial condyle while directing the plate to the ventral part of proximal femur

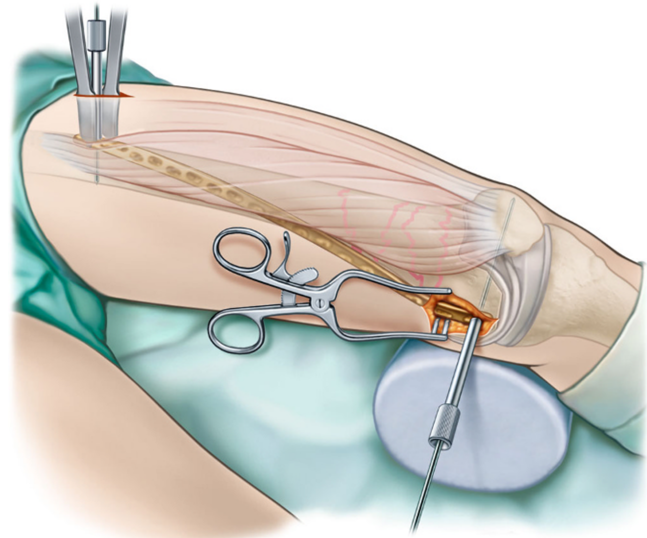

**Fig. 10** ▲ On the ventral or ventrolateral side of the proximal femur, dissection between vastus lateralis and intermedius to approach the femur, two Hohmann's are placed on either side of the shaft with the end of the plate aligned to the shaft. Confirm the proper position with the image intensifier on both the anteroposterior and the lateral view. The helical shaped plate is temporary fixed distally and proximally with Kirschner wires using drill sleeves (preferably using a threaded K-wire with a wing nut)

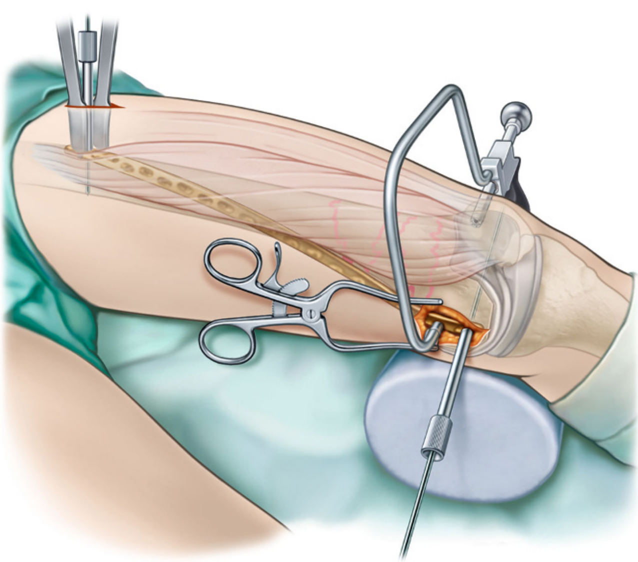

**Fig. 11** ▲ The plate should be adapted to the medial condyle using the collinear reduction clamp. Confirm the plate position with the image intensifier on both the anteroposterior and the lateral view. The helical shaped plate is fixated with fixed-angled screws both distally and proximally. It is advisable to fixate the plate with two to three fixed-angled screws on both ends of plate [31]. In some situations a conventional screw may be used first to approach the plate closer to the bone


**Fig. 12** ▲ The minimally invasive incisions on the ventromedial side of femur are closed after adequate fixation of the helical shaped plate

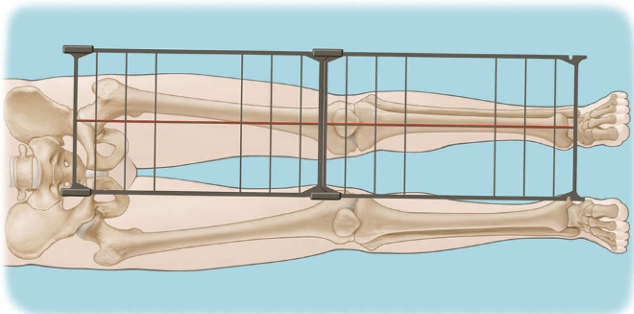

**Fig. 13** ◂ The grill-like template, which also allows intraoperative comparison with the contralateral leg, is used to control the long bone axis taking into consideration the physiologic deviation of 7–9°

## Postoperative management

- Postoperative x-ray control of entire femur including the hip and knee joint in AP and lateral view
- Unrestricted weight bearing under supervision of physiotherapist
- Outpatient clinical and radiological controls at 6, 12, 26, and 52 weeks
- Screening for osteoporosis and initiating or optimizing supportive management

## Errors, hazards, complications

- Avoid having two screws from the two plates to be exactly at the same level and make use of the advantage that the screw trajectories in the two plates have different directions, in order to distribute the stress in different sections of the proximal femur.
- Neurovascular nerve injury: any nonfully visual manipulation should be performed with the proper precautions. Extra precaution should be taken when using the minimally invasive cerclage instrument in the distal part of the femur for reduction on the lateral side of the femur; we advise constant bone contact when using this device [35]. In addition, when inserting the helical plate on the medial side of femur, be sure to insert the plate in the submuscular/epiperiosteal tunnel underneath the vastus medialis, as the adductor channel (with femoral artery and vein) runs just below the margin of the vastus medialis.
- Rotation error: intraoperatively rotation should be controlled clinically with respect to the contralateral side when applying the lateral plate. Other techniques, such as comparing the contour of the trochanter minor with the contralateral side or cortical width can also be used. In case of any postoperative uncertainty about rotation, a rotation-CT of both legs should be made [1].
- Axis deviation: a grill-like template as shown in ◘ **Fig. 13** is practical device to control the long bone axis considering the physiologic deviation of 7–9° [37]. Moreover, it allows intraoperative comparison of the contralateral side. Alternatively, the "cable technique" can be used, in which a cable passes through the femur head, knee joint, and ankle joint [1].
- Length difference: revision should be discussed and evaluated in the event of differences of more than 1.5–2 cm
- Delayed bone healing: healing can be delayed due to the rigid fixation of double-plating when full-weight bearing is not applied.
- Implant breakage during absence of fracture healing: re-osteosynthesis and possibly change of procedure

## Results

Between 2015 and December 2018, minimally invasive double-plating was performed in 11 patients. In 4 cases it was applied in patients with a peri- or interprosthetic distal femur fracture. In one case it was applied in distal femur fracture in a patient with total hip arthroplasty (THA) with limited bone stock. In addition, in 5 cases it was applied in a salvage procedure ([infected] non-union or hardware failure). In the last case, a helical plate was added to augment the construct due to loss of anchorage 6 weeks after initial only lateral plate fixation in a periprosthetic fracture (Su type II). For a complete overview see ◘ **Tables 1 and 2**.

All 4 peri- or interprosthetic fractures were supracondylar fractures, Su type II and III fractures, with stable knee prosthesis. Patients were treated with minimally invasive double-plating, consisting of a locking compression plate on the lateral side and a precontoured helical shaped locking plate on the medial side of the femur.

In patient 1 (male, age 77, American Society of Anesthesiologists [ASA] III, body mass index [BMI] 34), the distal periprosthetic femur fracture (Su type III) was treated with minimally invasive double-plating (◘ **Fig. 14**, left panel). As this was the first patient in whom double-plating was performed, partial weight bearing was prescribed. Full-weight bearing was achieved after 14 weeks. After 1 year follow-up, callus formation was seen with no implant failure or loss in reduction.

In patient 2 (female, age 71, ASA II, BMI 39), who suffered a distal periprosthetic fracture (Su type III), minimally invasive double-plating of femur was performed mainly due to her high body mass index. Double-plating made direct postoperative full weight bearing possible with a walker. After 3 months, radiographs showed no implant failure and extensive callus formation (◘ **Fig. 14**, right panel).

In patient 3 (female, age 78, ASA III, BMI 36), who in addition had a distal radius fracture, a two-step procedure was performed. At first the supracondylar interprosthetic fracture (Su type II) was stabilized by a locking compression plate on the lateral side. In a second operation, combined with the fixation of the distal radius fracture, a precontoured helical shaped locking plate was added to the medial side of the femur (◘ **Fig. 15**, left panel). Direct postoperative full-weight bearing with a single crutch was possible (see video 1 online). Postoperative radiographs showed good alignment. Complete union was documented after 7 months.

In patient 4 (female, age 95, ASA III, BMI 30), the supracondylar interprosthetic femur fracture (Su type II) was

| **Table 1** Peri- and interprosthetic femur fractures | |
|---|---|
| *N* | 6 |
| *Age (±SD)* | 81 (±7) |
| *Gender M:F* | 2:4 |
| *ASA II* | 2 (6) |
| *ASA III* | 4 (6) |
| *BMI (±SD)* | 32.1 (±4.7) |
| *Fracture type femur* | |
| Periprosthetic (*n* = 2) | Supracondylar, Su type III[a] |
| Interprosthetic (*n* = 2) | Supracondylar, Su type II[a] |
| Distal femur with THA (*n* = 1) | AO 33A3 with limited bone stock |
| Helical plate added 6 weeks after initial lateral plate fixation (*n* = 1) | Supracondylar, Su type II[a] |
| *Direct postoperative full-weight bearing* | 5 (6)[b] |
| *Radiological consolidation (±SD)* | 9 (±7) months[c] |
| *Complications* | None |
| *Follow-up (±SD)* | 13 (±8) months |

***SD*** standard deviation, ***BMI*** body mass index, ***ASA*** American Society of Anesthesiologists, ***THA*** total hip arthroplasty, ***M*** male, ***F*** female, ***AO 33A3*** AO/OTA classification to distal femur fracture-Type 33A3 (femur, distal end segment, extraarticular, wedge or multifragmentary fracture)
[a]*Type I*: Fracture proximal to femoral knee component. *Type II*: Fracture originating at the proximal aspect of the femoral knee component and extending proximally. *Type III*: Any part of the fracture line is distal to the upper edge of the anterior flange of the femoral knee component
[b]Due to intial wariness the first patient was only allowed partial weight earing
[c]*n* = 5, one patient did not attend regular follow-up, only radiological control after 30 months

| **Table 2** Reoperations (delayed and non-unions, infected non-unions) | |
|---|---|
| *N* | 5 |
| *Age (±SD)* | 39 (±12) |
| *Gender M:F* | 5:0 |
| *ASA I* | 1 (5) |
| *ASA II* | 4 (5) |
| *BMI (±SD)* | 31 (±7) |
| *Injury Severity Score (ISS) >16* | 3 (5) |
| *Open fractures* | 2 (5) |
| *Indication for double-plating* | |
| Non-union with low grade infection | 3 (5) |
| Hardware failure | 1 (5) |
| Non-union with varus deformity | 1 (5) |
| *Fracture type femur* | |
| Distal extra-articular multifragmentary (AO 33A3) | 1 (5) |
| Distal intra-articular multifragmentary (AO 33C2) | 3 (5) |
| Periprosthetic distal (Vancouver C) | 1 (5) |
| *Bone graft used* | 4 (5) |
| *Full-weight bearing reached (±SD)* | 16 (±5) weeks |
| *Radiological consolidation (±SD)* | 6.5 (±2) months |
| *Complications* | 1[a] (5) |
| *Follow-up (±SD)* | 13 (±6) months |

***SD*** standard deviation, ***BMI*** body mass index, ***ASA*** American Society of Anesthesiologists, ***THA*** total hip arthroplasty, ***M*** male, ***F*** female, ***AO 33A3*** AO/OTA classification to distal femur fracture - Type 33A3 (femur, distal end segment, extraarticular, wedge or multifragmentary fracture), ***AO 33C2*** AO/OTA classification to distal femur fracture - Type 33C2 (femur, distal end segment, complete, simple articular, wedge or multifragmentary metaphyseal fracture)
[a]Fracture related infection for which all material was removed and a retrograde femoral nail was placed

treated with combined minimally invasive lateral and medial plate osteosynthesis (**Fig. 15**, right panel). Postoperatively full-weight bearing was allowed under supervision of a physiotherapist (see video 2 online). Postoperative radiographs showed good alignment and after 6 months complete union was seen.

In the patient (male, age 86, ASA III, BMI 23) with multifragmentary distal femur fracture with THA in situ, double-plating was indicated due to limited bone stock. Direct postoperative full-weight bearing was allowed. Post-operative x-rays before showed good alignment and after full weight bearing there was no loss of reduction or implant failure.

In addition double-plating was performed in 5 patients in whom a reoperation of the distal femur was indicated due to (infected) non-union or hardware failure. The mean age of these patients was 39 (±12 SD) years, all were male, 3 were polytrauma patients (Injury Severity Score [ISS] >16) and 2 had an open fracture. The indications for double-plating as salvage procedure were as follows: non-union with low grade infection (*n* = 3), hardware failure (*n* = 1), and non-union with varus deformity (*n* = 1). In four cases bone graft was used to fill the bone defect. Postoperatively partial weight bearing was allowed; full-weight bearing in 4 patients was reached after 16 (±5 SD) weeks. Radiological consolidation was seen after 6.5 (±2 SD) months (Supplemental Fig. 1 online). There was one complication, a fracture-related infection, for which all material was removed after 14 days; this was followed by fracture stabilization with an antegrade femur nail and plate augmentation.

In the last case (female, age 74, ASA II, BMI 34), a supracondular prosthetic femur fracture (Su type II) was initially treated with a minimally invasive lateral plate osteosynthesis (**Fig. 16**). At the 6 week control, a loss of anchorage distally was noted with loosening of the locking screws. After control of the axis and length of the lower extremity an additional helical plate was inserted. Weight bearing as tolerated was continued. The patient unfortunately did not attend regular follow-up. However, due to other medical reasons a radiographic control 30 months after the initial operation showed an uncomplicated healing.

Besides our own results, there is a series of 22 cases of femur and distal femur fractures treated with double-plating by the inventor of the helix plate concept on the ICUC website, which in addition shows that this concept is reliable and promising [31].

In summary, this technical study shows that the minimally invasive addition of a helical shaped plate on the ventromedial side of the femur is safe and makes direct postoperative weight bearing possible. Based on our results we recommend using this technique in patients with peri- and interprosthetic femur fractures with limited bone stock and in reoperations ([infected] non-unions) with large bone defects. It is


**Fig. 14** ◀ Patients 1 and 2: Double plating of supracondylar periprosthetic femoral fractures. **a** Preoperative x-ray showing Su type III supracondylar periprosthetic femoral fractures. **b** Postoperative radiologic control after full weight bearing. **c** After 1 year (*left panel*) and 3 months (*right panel*) follow-up; bone healing with no implant failure or loss in reduction

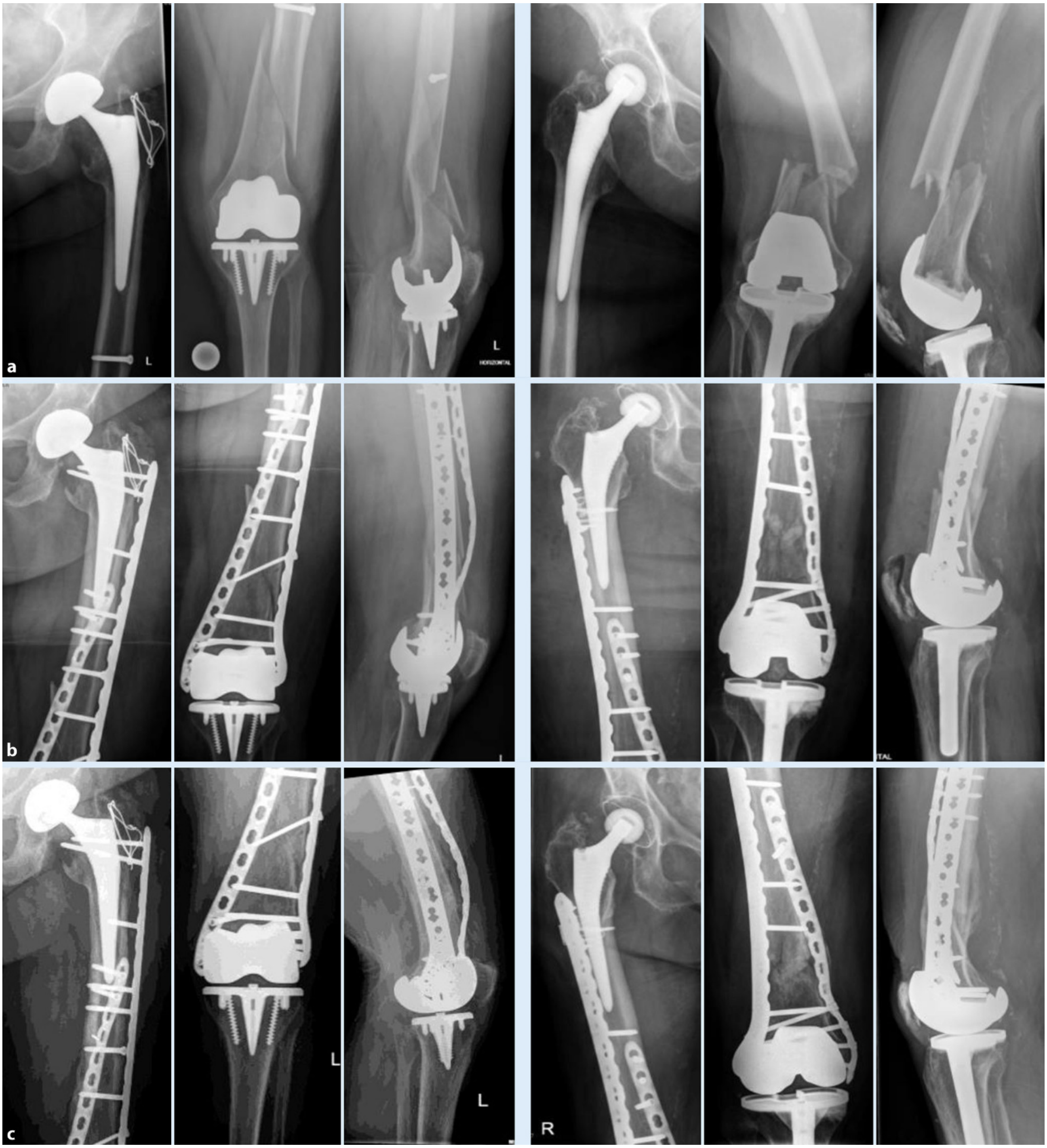


**Fig. 15** ▲ Patients 3 and 4: Double plating of supracondylar interprosthetic femoral fractures. **a** Preoperative x-rays showing Su type II supracondylar interprosthetic femoral fractures. **b** Postoperative radiologic control after full-weight bearing. **c** Radiologic control after 7 (*left panel*) and 6 months (*right panel*)


**Fig. 16** ◂ Additional double plating 6 weeks after initial lateral plate fixation. **a** Preoperative x-rays showing Su type II supracondylar prosthetic femoral fracture. **b** Postoperative radiologic control after weight bearing as tolerated. **c** Radiologic control after 6 weeks with loss of anchorage. **d** Additional helical plate and cerclage. **e** Final radiological follow-up after 30 months

an alternative tool in addition to our existing armamentarium to solve this challenging problem and to allow full weight bearing in the frail elderly. As this is a technical study with limited patient numbers, further prospective studies are needed to confirm our results.


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## Compliance with ethical guidelines

**Conflict of interest.** F.J.P. Beeres, B.L. Emmink, K. Lanter, B.-C. Link and R. Babst declare to have no commercial relations that might pose a conflict of interest in connection with the manuscript. No funding or any other support was received for this study.

Informed oral and written consent was obtained from all patients for the blinded use of their data.

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