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Surgical fixation of ipsilateral femoral neck and shaft fractures: a matter of debate?

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- Segmental femoral fractures represent a rare but complex clinical challenge. They mostly result from high-energy mechanisms, dictate a careful initial assessment and are managed with various techniques. These often include an initial phase of damage control orthopaedics while the initial manoeuvres of patient and soft tissue resuscitation are employed.
- Definitive fixation consists of either single-implant (reconstruction femoral nails) or dual-implant constructs. There is no consensus in favour of one of these two strategies.
- At present, there is no high-quality comparative evidence between the various methods of treatment. The development of advanced design nailing and plating systems has offered fixation constructs with improved characteristics.
- A comprehensive review of the existing evidence with a step-by-step description of these different definitive fixation strategies based on three case examples was conducted. Furthermore, the rationale for using single vs dual-implant strategy in its case is presented with supportive references.
- The prevention of complications relies mainly on the strict adherence to basic principles of fracture fixation with an emphasis on careful preoperative planning, the quality of the reduction, and the application of soft tissue-friendly surgical methods.

Keywords
- femur
- segmental fractures
- trauma

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Introduction

Segmental femoral fractures represent a rare clinical entity and are most commonly the result of high-energy trauma. They are defined as fractures of the femur with at least two main fracture lines at different levels, leaving an intact segment of the femur between them (1).

A relatively common subgroup of segmental femoral fractures consists of femoral neck/trochanteric fractures and of the ipsilateral diaphysis (FN-FD fractures). They are reported to represent 2–10% of all femoral fractures and are a result of road traffic accidents, industrial injuries, falls from height, or high-velocity trauma of mostly young patients (2, 3, 4, 5). Rarely, they have also been reported to occur intraoperatively during the preparation of a piriformis fossa entry point for a femoral nail (6).

The femoral shaft fracture is comminuted and mid-diaphyseal in 47–70% (7, 8), whilst the neck fracture is commonly vertical (unstable – Pauwels III (9)) in 70% and non-displaced in 25–60%. Most likely, this is explained as, at the time of the injury, the majority of forces are absorbed at the level of the diaphysis, whilst decreased axial and abduction loads are transferred to the femoral neck. In a few cases, the proximal segment includes neck fractures that extend to the basicervical or trochanteric region, which are mostly comminuted and displaced.

One of the critical aspects of the management of FN-FD fractures is their prompt diagnosis. A high level of suspicion should exist, especially when the clinician faces a high-energy comminuted diaphyseal fracture with associated knee and/or patella fractures or with some other distracting severe injuries in the polytrauma setting. In the literature, up to 57% of FN-FD fractures are diagnosed with a delay (intra- or even post- operatively) (10, 11). Dedicated imaging protocol includes an anteroposterior hip x-ray with the leg in internal rotation, fluoroscopic screening on a true lateral, and meticulous study of the trauma CT scan (2 mm fine cuts) (11). As previously reported, 19–55% of non-displaced neck fractures can be missed, and 5–22% can be missed even from thin-cut high-resolution CT scans. Rapid limited sequence MRI scan of the pelvis has been recently suggested to be able to identify occult femoral neck fractures and was reported to be feasible even in the clinical setting of a polytraumatised patient (12, 13).

This type (FN-FD) of segmental femoral fractures does not have a specific classification system. In the literature and routine clinical practice, they are described based on the topography, and the two different fracture levels are classified separately. For the femoral neck fracture, we usually use the Pauwels or the Garden classification systems or refer to them descriptively (i.e., subcapital/transcervical/basicervical fractures) (14, 15). The diaphyseal component of an FN-FD fracture is usually classified with the AO/OTA system (16).

When the diagnosis is attained promptly, the surgeon can choose from a large number of operative methods (i.e. antegrade nail and screws around the nail (17, 18, 19), cephalomedullary reconstruction nails – 'single-implant' strategy (20, 21, 22), free lag screws or plate screw fixations with or without a retrograde nail – 'dual-implant' strategy (8, 23, 24, 25)), which have been advocated previously. Prompt and accurate reduction, especially for the neck fracture, and stable fixation are essential irrespectively to the chosen operative strategy. Delays of more than 24 hours have been associated with a three-fold increase in neck fracture non-union and avascular necrosis of the femoral head (26).

To the best of our knowledge, there is no conclusive study on the optimal time window nor to which fracture level should be addressed first, and with which of the different strategies. The available evidence is of low level (III–IV) (27, 28, 29). With the present review, we aim to present the specific steps of how to proceed with either of the two main fixation strategies and a comprehensive summary of their reported outcomes and complications.

Management

'Single-implant' strategy

Case example 1

A 64-year-old male patient was admitted to a level-one trauma centre after a high-energy motor vehicle accident. He sustained multiple injuries (Injury Severity Score (ISS) of 41), including a left segmental femoral fracture (FN-FD), with associated moderate brain and bilateral chest trauma, aortic transection, spleen and liver laceration, left acromion and radial shaft fractures, a left transverse acetabular fracture, and a left trimalleolar ankle fracture.

Following initial resuscitation and during the primary damage control surgical procedure, he received K-wire fixation of the undisplaced neck fracture and the application of an external fixator on the femoral shaft on the day of his admission. Subsequently, the FN-FD was managed using a single implant (closed reduction of the intracapsular fracture and mini open reduction of the diaphysis and insertion of two cerclage wires followed by reamed cephalomedullary nail fixation). Fluoroscopic views during the operation revealed good alignment of both levels of the femoral fracture. The rest of his injuries were also managed operatively. The patient was discharged to a rehabilitation institute 2 weeks later. Full weight-bearing was started 3 months postoperatively, and he completed his follow-up a year later with uneventful healing of his femoral fractures (Fig. 1).

Surgical technique and aftercare

Supine positioning of the patient on the fracture traction table, or alternatively, lateral decubitus position of the patient on a radio-lucent standard table with the leg draped and free of traction. When a bridging external fixation has been previously inserted (as in the presented case example), depending on the fracture comminution, the period in the external fixation, and the state of the pin sites, the external fixation can be removed before draping or remain to assist the reduction manoeuvres. Disinfection and draping occur in the usual way, with preoperative antibiotic prophylaxis according to the hospital protocol. Fluoroscopy is required with the C-arm from the contralateral side and the screens are positioned at the feet of the patient. It is helpful to acquire and save a true anteroposterior view of the contralateral intact proximal femoral metaphysis in neutral rotation, which can be helpful later as a reference guide for the correct rotational alignment of the fractured extremity (30).

If the diaphyseal fracture has a spiral or long oblique configuration to the subtrochanteric zone (as in this presented case example), a limited subvastus lateral approach can assist fracture reduction and the insertion of 1–2 cerclage wires/cables. This allows easier control of the subtrochanteric fragment and facilitates the subsequent acquisition of the nail entry point and instrumentation.

Prior to that, the femoral neck fracture can be reduced and stabilized with two partially threaded 2.5 mm Kirschner wires passed anteriorly to the femoral calcar, neck, and head so that they will not obstruct the subsequent insertion of the guide wire, reamers, and nail itself. If an open reduction of the femoral neck is required, this can be attained following an additional anterior (Smith Petersen, modified Hueter), anterolateral (Watson Jones), or a mini-transgluteal approach (31).

The preliminary fixation of the femoral neck prevents displacement of the femoral neck fracture during nail

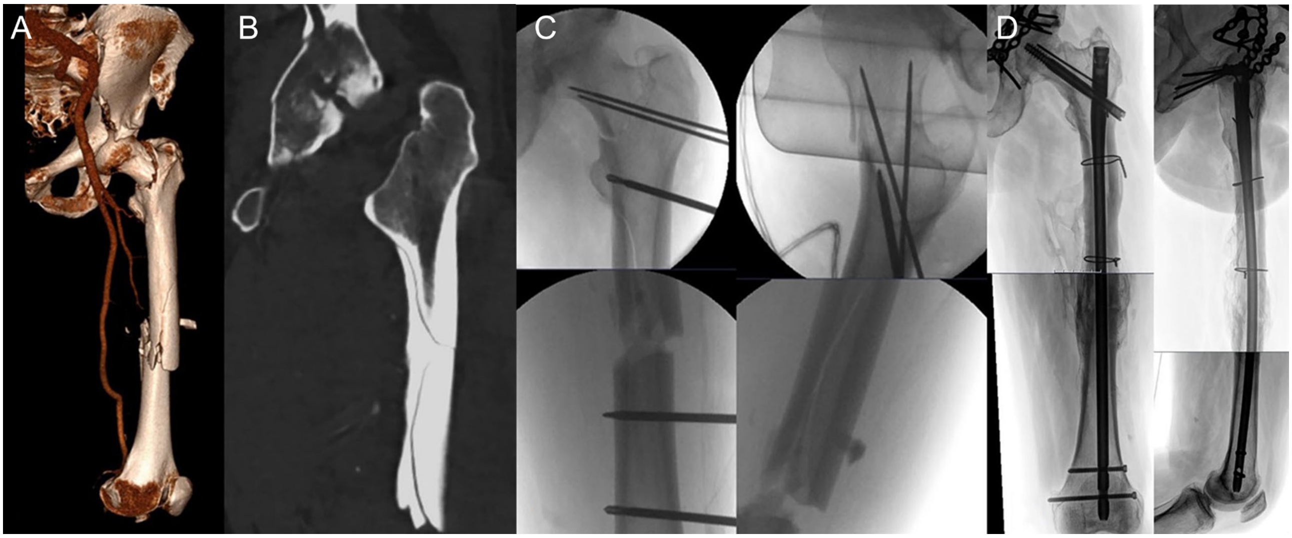

Figure 1

Case example 1. A 64-year-old male patient presented with multiple injuries following a high-energy motorcycle traffic accident. (A) A 3D CT scan of the left femur shows a transverse acetabular fracture with ipsilateral neck and femoral shaft fractures (FN-FD). (B) Coronal reconstruction of the CT scan shows non-displaced fracture extensions at the subtrochanteric area. (C) Image intensifier views showing the intraoperative preliminary fixation as part of the damage control surgery using K-wire fixation of the femoral neck and application of an external fixator at the femur. (D) Radiographs at 6 months show evident fracture healing at all levels after the definitive management of the FN-FD using a cephalomedullary nail (Long Gamma3® – Stryker®) following the 'single-implant strategy' for stabilization of these fractures.

insertion and shaft fixation. To avoid malreduction, the preoperative CT scan can be utilized to measure the anteversion of the intact contralateral femur. To determine the correct anteversion intraoperatively, a guide wire is placed anterior to the femoral neck and head. Axial traction allows the reduction of the femoral shaft fracture. In the presence of residual displacement after traction, a bone hook or pointed reduction clamps, Schanz pins with a T-handle, or two wires inserted in the unicortical bone might be helpful for gentle manipulation of the floating femoral fragment as recommended previously (32, 33). The correct rotational alignment of the femoral shaft is ensured when the cortical thickness of the proximal and distal femur fragments is comparable and no 'cortical step sign' is observed at the fracture level. In addition, the shape of the lesser trochanter at the fractured femur can be compared to the shape of the lesser trochanter of the uninjured limb ('lesser trochanter shape sign').

Following the identification and development of the nail entry point at the tip of the greater trochanter and the insertion of the long guide wire to the centre of the distal femoral metaphysis, the medullary canal is slightly over-reamed (+2 mm of the nail diameter in a stepwise fashion with flexible reamers) to facilitate nail insertion without displacing the femoral neck fracture (34, 35). The insertion of the nail is followed by the two proximal (cephalomedullary screws) and subsequent distal locking screws (36). Layered wound closure and sterile wound cover are offered in a standard fashion. Postoperatively, weight bearing is restricted to partial for 6–8 weeks.

Advantages, rationale, and outcome

There are certain advantages of using an antegrade nail with simultaneous fixation of the femoral neck and shaft in these case scenarios, as long as re-alignment of the neck/shaft angle is restored and protected during reaming and nail instrumentation. As presented in this case, the use of free K-wires at the anterior neck is employed to achieve this or an open reduction via a separate anterior approach may be required.

A single implant in the form of a reconstruction nail is less invasive, decreases the surgical trauma, reduces the intraoperative blood loss, offers a biological fixation of both fractures with a single implant, and clears biomechanical benefits for the diaphyseal segment. Furthermore, it avoids the creation of stress risers between dual-implant constructs (37), has a better cosmetic appearance with less scars, and has lower direct medical costs (27, 38, 39).

The progress to the union for this particular patient in all parts of this segmental femoral fracture was uneventful and good functional recovery was documented at the follow-up a year later (Fig. 1D).

'Dual-Implant' strategy

Case example 2

A 40-year-old male jumper was admitted with an ISS 32, abdominal bleeding, and a type 2 open right segmental femoral fracture in the form of an intertrochanteric fracture AO/OTA 31A1 and a multifragmentary distal diaphyseal–metaphyseal fracture AO/OTA 32C3. After initial resuscitation following ATLS protocol, the abdominal bleeding was controlled by general surgeons, and the femur was fixed using an external fixator. The open fracture wound located laterally at the distal third of the femur was irrigated and debrided, local antibiotics were delivered using as a carrier a synthetic bone cement (CeramentG®-BONESUPPORT), and the wound was closed. Definitive fixation was performed 4 days later using two implants (Fig. 2).

Surgical technique and aftercare

In this case, the 'dual-implant' strategy referred to a short proximal femoral nail for the intertrochanteric segment and a long distal femoral plate addressing the distal segment. Preoperative planning was facilitated using the 2D and 3D reconstruction images of the trauma CT scan. Implant templating indicated that a 13-hole distal femoral periarticular plate (NCB DF plate®-ZimmerBiomet) would allow adequate overlap to a 13 mm proximal femoral nail (INTERTAN®-Smith&Nephew).

Figure 2
Case example 2. (A) 40-year-old male with an open right segmental femoral fracture in the form of an intertrochanteric fracture AO/OTA 31A1 and a multifragmentary distal diaphyseal-metaphyseal fracture AO/OTA 32C3. (A) Sagittal 2D CT reconstruction capture demonstrating the comminuted distal diaphyseal fracture and the ipsilateral proximal femoral fracture. (B) Sagittal and coronal 2D CT reconstruction captures following the initial damage control with external fixation of the femur. (C) Anterior-Posterior (AP) femoral x-ray post definitive fixation.

The patient was positioned in a lateral decubitus on a radiolucent table. Prior to draping, verification of unobstructed fluoroscopy images was performed, especially for the lateral projections of the proximal femur (40, 41). After removing the external fixator and debridement of the pin sites, the distal segment was addressed first.

A lateral approach of the distal femur was used, finishing about 2 cm above the Gerdy's tubercle. The former open fracture wound was excised again and used partially as an extension of the approach. The iliotibial band was split longitudinally, and the vastus lateralis muscle was elevated. The multifragmentary femur fracture was exposed, and each main fragment was cleaned from reduction inhibiting debris, and sequentially reduced using pointed reduction clamps. Two main butterflies were fixed using small fragment 3.5 mm cortical lag screws. Following that, a 13-hole NCB DF plate was positioned carefully over the lateral femoral condyle and centred proximally over the femoral diaphysis, using anchoring K-wires through the plate K-wire holes. After verification of plate position and alignment of the femoral shaft, several 5.0 mm cortical screws were inserted proximally and distally to stabilize the diaphyseal fracture segments. The most proximal screw holes were left free to allow the unobstructed insertion of the proximal nail and the overlap of the two implants.

Subsequently, a standard proximal approach was performed for nail insertion, and the fracture was reduced using manual axial traction of the fixed femoral diaphysis. A guide wire technique was used to acquire a standard trochanteric entry point for the nail. Following the insertion of the guide wire, reaming was performed to the proximal metaphysis, and a short INTERTAN® nail was inserted. Then, the femoral neck interlocking screws were inserted, allowing for intraoperative fracture compression using the features of this nailing system. Finally, distal nail locking was performed through the most proximal hole of the NCB plate with a single 5.0 mm cortical screw. Further local antibiotics (gentamycin) were inserted at the shaft comminution area, using as a carrier the same synthetic cement (10 mL of CERAMENTG®). The wound was closed in layers in a standard fashion, thromboprophylaxis continued for the first 4 weeks, and mobilization, as tolerated, was allowed to the affected leg using walking aids from the next day (Fig. 3).

Advantages, rationale, and outcome

In this situation, a 'dual-implant' strategy was employed to allow the optimal treatment for both segments of this high-energy injury. Alternatively, this strategy could be

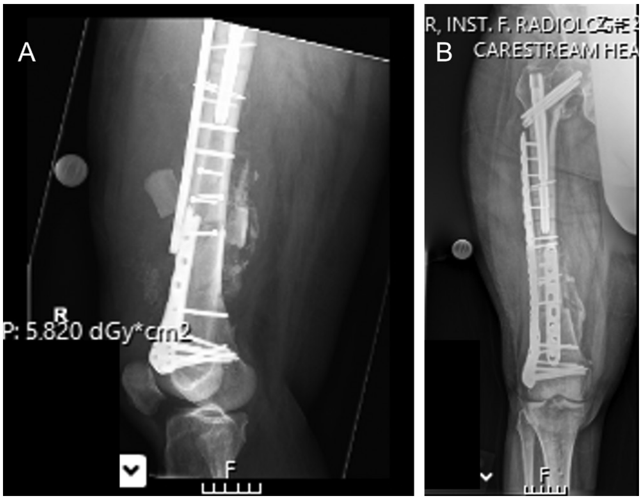

Figure 3

Case example 2. (A) Fatigue failure of the plate fixation of the distal femoral diaphysis at 6 weeks after definitive fixation following open reduction, lag screw fixation and neutralizing plate fixation of the diaphyseal segment. (B) Follow-up AP femoral x-ray 6 months after the revision fixation with an orthogonal plating construct.

delivered using a proximal plate/screw construct and simultaneous retrograde femoral nail. However, the presence of a contaminated open wound at the diaphysis and the increased risk of septic knee arthritis led the surgeon to choose the former combination of implants and techniques.

The same fracture could also be addressed via a single implant (antegrade reconstruction long femoral nail), as previously presented in this paper. Again, the presence of an open wound that had to be debrided, the sacrifice of the fracture hematoma during the irrigation phase, and the degree of comminution at the distal diaphysis, as well as the limited anchorage to the distal metaphysis contemporary reconstruction nails offer, led the surgeon to provide the presented 'dual-implant' solution.

This patient returned 6 weeks later with an early fatigue failure of the plate over the comminuted diaphyseal fracture. There was no clinical, biochemical, microbiology culture, or histological evidence of infection following tissue biopsies. The distal plate fixation was revised to orthogonal dual plating using a 90–90 construct with an anterior large fragment LCP® of Depuy Synthes and a distal femoral NCB-PP®-ZimmerBiomet. After 6 months, good callus formation and pain-free functional recovery was recorded (Fig. 3).

Expected complications and their management

Case example 3

A 44-year-old female patient was admitted to a level-one trauma centre after a fall from 5 m. She sustained multiple injuries with an ISS of 35. She had a traumatic brain injury with intracranial temporal lobe hematoma and a left open GII femoral fracture with a fragmented wedge (AO/OTA33-B3) distal to the shaft isthmus, an associated displaced basicervical femoral neck fracture 31-B2-1 (Fig. 4), and a comminuted ipsilateral open patella fracture. On the day of admission, the patient received a craniotomy to evacuate the cranial hematoma and an external fixator bridging the hip and stabilizing the distal femoral segment without attempting fixation of the femoral neck.

After 8 days, definitive fracture fixation followed, according to the 'dual-implant' strategy. First, an 11 mm/300 mm retrograde nail was inserted, and the patella fracture was fixed with a cerclage wire. Subsequently,

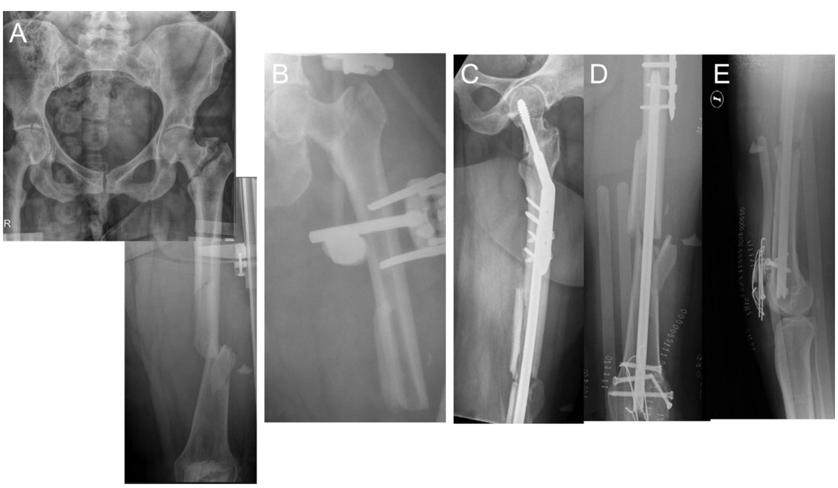

Figure 4

Case example 3. A 44-year-old female patient with a left open femoral fracture with a fragmented wedge AO/OTA 33-B3 distal to the shaft isthmus and an associated displaced basicervical femoral neck fracture AO/OTA 31-B2-1. (A) Preoperative AP x-ray of this segmental femoral fracture case. (B) AP x-ray of the proximal femur with the bridging hip external fixator as part of the damage control orthopaedic at the early admission phase of this patient. (C) Lateral x-ray of the proximal femur following definitive fixation with two implants (sliding hip screw and retrograde femoral nail). (D) AP x-ray of the distal femur following definitive fixation with two implants (sliding hip screw and retrograde femoral nail). (E) Lateral x-ray of the distal femur following definitive fixation with two implants (sliding hip screw and retrograde femoral nail).

closed reduction and internal fixation of the proximal fracture with a sliding hip screw were applied. No attempt to reduce the diaphyseal wedge fragment was made. Due to the fracture pattern and the presence of the proximal plate and its screws, the tip of the nail was only 4 cm proximal to the diaphyseal fracture zone. The patient was discharged to a rehabilitation institute 3 weeks later. Full weight-bearing was permitted after the first 6 weeks. The follow-up x-rays at 3 and 5 months showed consolidation of the proximal fracture, but the diaphyseal fracture did not show any signs of a union. After 8 months, an oligotrophic non-union was recorded without any evidence of surgical site infection. The patient underwent exchange nailing with a 13 mm/320 mm retrograde nail after debridement of the fibrous tissue at the non-union site and autologous bone grafting (contralateral femur harvest with the RIA®-DepuySynthes). After 4 months, the fracture showed radiological signs of circumferential callus formation (Fig. 5).

Discussion

The treatment goals of FN-FD fractures are accurate reduction and restoration of the length, alignment, and rotation of the fractures and ensuring adequate fixation (42). Accordingly, the importance of reduction for the long-term outcome of both neck and shaft fractures if managed as single injuries is consistently reported by various studies (23, 27, 43). The available data on the success in treating FN-FD fractures is limited and mostly derives from relatively small series. As previously published, fracture union is observed within 28 weeks at the level of the neck and within 39 weeks at the femoral shaft (36, 37, 44, 45, 46, 47, 48). The incidence of avascular necrosis (AVN) of the femoral head is reported to be up to 14% using a single implant in contrast to up to 26% if two implants were used. The surgical site infection rate was independent of the technique used by up to 10% (45, 46, 48).

The existing comparative studies suffer from the large variation of different methodologies and the absence of randomization. The use of cephalomedullary nails (44, 47), proximal femoral nail (PFNA) (37, 45), or reconstruction nails (36, 46, 48) was compared by different authors in different decades of practice to the outcome and complication rate of dual devices in the form of compression diaphyseal plates with free lag screws for the neck (36, 37, 44, 45, 46, 47, 48), or retrograde nails with dynamic hip screws (36, 37, 45, 47, 48), or a combination of antegrade femoral nails with 'miss the nail' lag screws for the neck fracture (44, 48).

Some authors argue that in the FN-FD setting, the clear biomechanical advantages of nailing long bone fractures (49) are outweighed by the technical difficulties especially in accurately placing the proximal screws into the head and neck (36). Precise reduction and maintaining rotational stability of the head and neck fracture during nail placement is considered the priority in the treatment (48), but it is technically demanding (8, 34). The nail insertion may displace an undisplaced fracture, potentially compromising its blood supply (8, 35). However, using the technique presented in this review in the first case example (Fig. 1), these concerns can be well mitigated.

The outcome of FN-FD fractures depends on the result of treatment of the femoral shaft more than that of the proximal segment. Compared with isolated femoral shaft

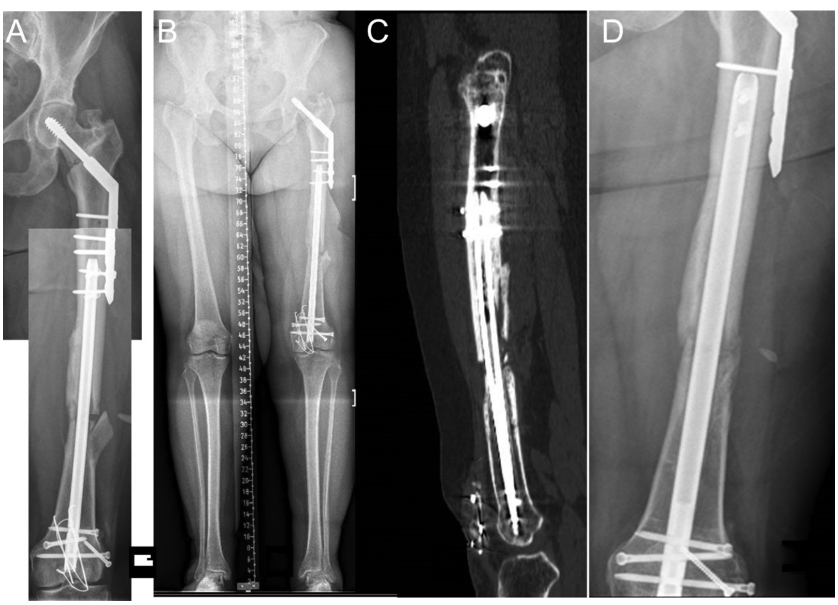

Figure 5
Case example 3. (A) Follow-up AP x-ray of the femur with the dual-implant construct. (B) Alignment views at 3 months. Slow progress of healing of the left diaphyseal femoral fracture. (C) Sagittal 2D CT reconstruction capture of the non-uniting diaphyseal fracture. (D) Follow-up AP femoral x-ray at 5 months following revision surgery to the non-union of the diaphysis with evidence of the progress of healing and pain-free function.

fractures, the segmental FN-FD fractures demonstrate longer times to union and higher rates of non-union and malunion. The complication rate for shaft fractures is higher than for the proximal fractures, as evident in two of the presented case examples. The overall rate for femoral shaft non-union is up to 20% (25, 27, 29, 42). In combined femoral fracture patterns, the diaphyseal component has severe comminution and is often open (25, 27, 43). Weight-bearing is delayed in most patients to protect the proximal fracture fixation or due to concomitant knee or pelvis injuries. This delayed mobilization hinders the callus formation that is expected following a long working length load sharing intramedullary bridging fixation. Furthermore, in most cases, the surgeon tends to prioritize the fixation of the proximal fracture, which leads them to use undersized or unreamed nails (50). In a study by Watson, 58% of all complications were associated with using non-reamed reconstruction nails (25). Some authors reported a high rate of non-union using a single implant when the fracture was at the infra-isthmus shaft. Baguel *et al.* had a 30% non-union rate with second-generation recon nail in fractures located below the isthmus (32). Wei and Lin found infra-isthmus fracture as the main factor for developing shaft non-union when antegrade fixation was used (51). In their series, all patients in the infra-isthmus group treated by reconstruction nail developed non-union, compared to 18% in the double fixation group. In a large multicentre study by Ostrum *et al.*, a 9% shaft non-union was found in 95 patients treated by retrograde nail and a separate proximal fixation (24). Femoral shaft fractures located below the isthmus, specially Winquist III and IV types, are probably best treated with a double fixation strategy to avoid this complication.

The use of reconstruction nails ('single-implant strategy') has been related to proximal segment/neck complications. In the study of Watson *et al.* (25), 75% of neck non-unions occurred after using a reconstruction nail. They hypothesized that proximal screws in reconstruction nails are not designed to provide compression or to slide. Contemporary proximal femoral nails do offer better features allowing controlled intraoperative compression (52, 53, 54). In our experience, the use of modern reconstruction nails minimize the previously described neck-associated complications as long varus malreduction is avoided and good tip apex index is achieved (53, 55).

In FN-FD injuries, the neck fractures are more likely to be non-displaced or located in the trochanteric area. In a large meta-analysis by Ahlo, only 23% of patients had intracapsular associated femoral neck fractures. Thus, rates of AVN, malunion, and non-union are consistently low in most reports. For AVN, the overall rate is below 3%, and for non-union and malunions below 5% (24, 27, 35). Most cases occur when the neck fracture is neglected or its diagnosis occurs postoperatively (50). Open reduction is dictated when the neck fracture remains displaced following closed or other minimal invasive manoeuvres. The reported complications of the proximal segment of FN-FD fractures are associated mostly with malreduction and often lead to failure of the primary goal of hip preservation in this young patient population (56).

The use of dual implants leads equally to technical difficulties. It can certainly be more time consuming and expensive (39). It dictates different approaches, opening of more implant kits, and leads to more complex instrumentation. An important side effect of dual implants is the potential creation of stress risers between the two different fixation devices. Following recent evidence, there is no safe enough interprosthetic distance in the FN-FD scenario. The frequently mentioned safe distance of two to three femoral diameters (57) between the 'kissing implants' has been challenged in clinical and biomechanical studies (58, 59). A decreased cortical thickness, the presence of undetected fracture fissures, or the potential toggling of the intramedullary device, as well as torsional stresses or a secondary fall can lead to a new fracture and failure of the fixation in a dual device construct. The safer is to achieve an overlap of the two implants with or without crosslinking, as described in both case examples of 'dual-implant' constructs of this review (60).

Using a plating system for the diaphyseal fracture, which is usually multifragmented, can lead to early fatigue failure of the implant. In general, a bridge or neutralizing plate over femoral diaphyseal comminution, as the one in the second presented case example (Figs 2 and 3), demonstrates inferior characteristics and outcomes to nail fixation (61, 62). Fatigue failure of an axis load-sharing nail is clearly less likely to occur when compared with an off axis load bearing plate. Therefore, the most commonly described 'dual-implant' construct is a retrograde nail addressing the diaphyseal fracture segment and a plate/screw system for the proximal femur, as in case example 3 (Figs 4 and 5). However, conditions like contamination of an open diaphyseal fracture can impede an approach through the knee joint as in case example 2.

Conclusion

Due to the relative rarity of the segmental femoral fractures and the significant variance of fracture configurations, the absence of a generalized consensus to their management strategy is not a surprise. Single or dual-implant constructs can be successfully employed and are equally represented in the existing literature. At present, there is no high-quality comparative evidence between the different treatment methods presented in this review. The development of advanced design nailing and plating systems offers improved characteristics to the fixation constructs. However, the prevention of complications relies mainly on the strict adherence to basic principles of fracture fixation with an emphasis on careful preoperative planning, the quality of the reduction, and the application of soft tissue-friendly surgical methods.

ICMJE conflict of interest statement
There is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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