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HIP FRACTURES IN ADULTS

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REVIEW ARTICLE

Challenges And Treatment Principles in Osteosynthesis of Subtrochanteric Femur Fractures

Abstract

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Subtrochanteric fractures involve the proximal femur just below the lesser trochanter and are uniquely challenging due to the dense cortical bone and powerful muscle forces acting across the region, which produce predictable deformity patterns. These injuries typically result from high-energy trauma in younger individuals or low-energy falls in elderly patients with osteoporotic bone. A wide spectrum of fracture morphologies adds further complexity, necessitating individualized surgical planning. A sound understanding of the injury mechanism and fracture configuration is essential to formulate an effective reduction and fixation strategy. The difficulty in managing these fractures lies in the high physiological forces across the subtrochanteric region, frequent medial comminution, and the inherent instability caused by muscle pull. These factors contribute to reported malunion rates of 10% to 15% and nonunion rates that may reach up to 15% in some series. Reduction is often difficult with traction alone, as muscle forces exacerbate deformity. The wide and sometimes deformed proximal medullary canal limits the role of the nail as a reduction aid, often necessitating adjunctive reduction techniques such as Steinmann pin joysticks, provisional plating, or percutaneous clamps. Implant selection should be guided by fracture pattern, bone quality, and patient-specific considerations. Intramedullary nails are generally preferred for their biomechanical advantage, particularly in comminuted fractures, while extramedullary devices remain valuable in selected scenarios. Ultimately, careful preoperative planning and adherence to sound biomechanical principles are key to optimizing outcomes in this complex and technically demanding fracture pattern. This article provides a comprehensive overview of the anatomy, injury mechanisms, surgical challenges, and current strategies in the management of subtrochanteric femur fractures, with particular focus on reduction techniques and decision-making in implant selection to achieve durable fixation and early mobilization

KEYWORDS

Biomechanics of fixation; Extramedullary fixation; Fracture reduction techniques; Intramedullary nailing; Medial cortical support; Osteosynthesis principles; Proximal femur fractures; Subtrochanteric fractures

Introduction

Subtrochanteric femoral fractures, defined as those occurring within 5 cm distal to the lesser trochanter, account for approximately 5–20% of all proximal femoral fractures.[1,2] Their management is particularly challenging due to several anatomical and biomechanical factors. Powerful muscular attachments generate substantial deforming forces at the fracture site, while the region endures high stresses during weight bearing.[3] In addition, the predominance of dense cortical bone with relatively limited vascularity predisposes these fractures to delayed union and nonunion.[4] The broad medullary canal, short proximal fragment, and strong muscle forces further contribute to difficulties in achieving and maintaining reduction. From a surgical standpoint, the quality of reduction and stability of fixation remain the most critical determinants of outcome.[5,6] Despite advances in imaging, surgical techniques, and implant design, subtrochanteric fractures remain among the most technically demanding injuries to treat, with reported complication rates ranging from 21% to 52.5%, most commonly due to nonunion, delayed union, malunion, or implant failure.[7,8] However, when anatomical challenges are carefully considered and appropriate technical strategies applied, favorable outcomes can be achieved while minimizing complications.[9] This review summarizes the current understanding of subtrochanteric fractures, with emphasis on anatomy, biomechanics, classification, fixation challenges, surgical principles, outcomes, and recent innovations that aim to improve their management.

Anatomy & Biomechanics

Anatomy

The subtrochanteric region refers to the segment of the femur extending from the lesser trochanter to approximately 5 cm distally.[10] This zone is predominantly composed of dense cortical bone, which provides substantial mechanical strength but is relatively avascular, posing a biological challenge to fracture healing. Additionally, the medullary canal in this region is narrower than the diaphyseal shaft, making intramedullary implant passage and alignment more technically demanding. A defining feature of subtrochanteric fractures is the characteristic deforming muscular forces exerted by the surrounding musculature. The iliopsoas, inserting on the lesser trochanter, causes flexion and external rotation of the proximal fragment. The gluteus medius and minimus, acting on the greater trochanter, result in abduction. Conversely, the adductors, inserting distally, pull the distal fragment into adduction and shorten.[5,11] These opposing forces contribute to a predictable and complex displacement pattern that complicates both closed and open reduction. Effective management of these deforming forces is critical to achieving and maintaining proper reduction during fixation. (Figure 1)

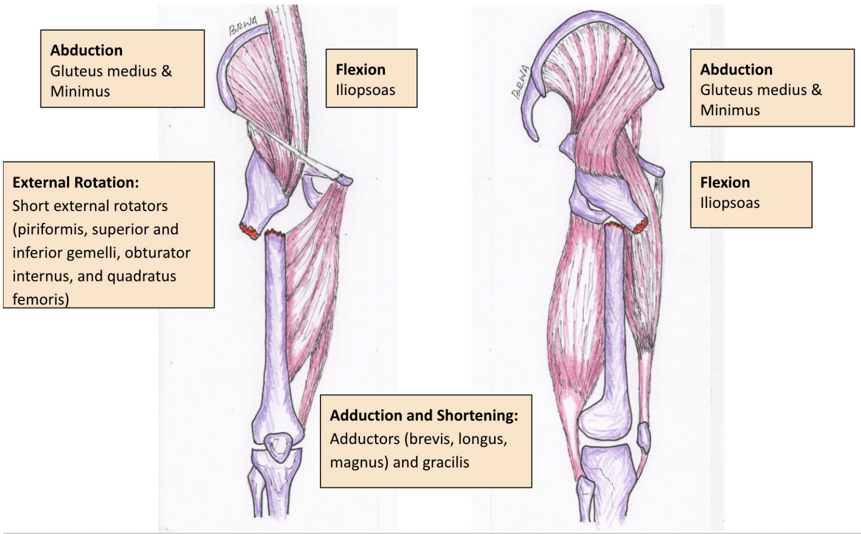

Figure 1 Anatomical illustration showing muscle forces acting on subtrochanteric fracture fragments

Biomechanics

The subtrochanteric region is biomechanically unique as it acts like a cantilever beam, transmitting forces from the femoral head and neck to the shaft. This creates high bending moments, particularly in the coronal plane, making the area vulnerable to failure if fixation is suboptimal. The posteromedial cortex, 1–3 inches below the lesser trochanter, is a critical high-stress zone: in a 200-pound individual, compressive forces may exceed 1200 lb/in^2 (~8.27 MPa), while the proximal lateral cortex simultaneously endures tensile stresses of ~900 lb/in^2 (~6.21 MPa).[11–13] This opposing stress pattern, compression medially and tension laterally, must be neutralized by the fixation construct to avoid varus collapse or implant fatigue. The dense cortical bone adds structural stiffness but limits vascularity, reducing biological healing potential and placing even greater reliance on achieving sound mechanical stability for successful union.

Classification

Classification of subtrochanteric fractures is central to understanding fracture morphology, anticipating instability, selecting appropriate fixation, and facilitating standardized communication. Over the years, multiple systems have been proposed, though none has consistently predicted outcomes or achieved universal acceptance. The Fielding classification is one of the earliest and organizes fractures by their location in relation to the lesser trochanter, providing a simple anatomical perspective that correlates with deforming muscular forces acting on the proximal fragment.[14] The Seinsheimer classification, based on the number and configuration of fragments, attempts to capture fracture complexity and comminution, yet suffers from limited interobserver reliability in clinical use.[15] The Russel and Taylor system highlights the structural importance of the piriformis fossa and medial calcar, helping guide implant selection and optimal nail entry. It is particularly useful in identifying unstable patterns where loss of posteromedial support increases the risk of fixation failure.[16] The AO/OTA system (32A–C), though not specific to subtrochanteric biomechanics, remains the most widely adopted due to its comprehensiveness, simplicity, and applicability in research registries. Simple (A), wedge (B), and complex (C) patterns with defined subgroups allow uniform reporting, but it does not directly guide surgical strategy.[17] Despite these efforts, no classification system perfectly combines prognostic value, treatment guidance, and reproducibility. In practice, the AO/OTA system remains the standard reference, supplemented by Russel and Taylor when implant selection and surgical planning are considered critical.[18]

Management Challenges

Anatomical & Mechanical

Subtrochanteric fractures occur in a high-stress region of the proximal femur that is subjected to significant compressive and tensile forces during weight bearing. Management is further complicated by powerful deforming muscle forces: the proximal fragment is flexed by the iliopsoas, abducted by the gluteus medius and minimus, and externally rotated by the short external rotators, while the distal fragment is displaced medially and proximally by the adductors. These unbalanced forces make anatomic reduction difficult and predisposes to malalignment. The challenge is even greater in high subtrochanteric fractures (0–2.5 cm distal to the lesser trochanter), where the short proximal fragment compromises reduction and implant purchase. Extension of fracture lines into the trochanteric region, often propagating in multiple planes, increases the risk of trochanteric blowout during implant insertion. In addition, posteromedial comminution of the calcar and lesser trochanter region eliminates the critical medial buttress required to resist varus collapse. Loss of this support directs all functional stresses onto the implant, concentrating load during the early healing phase and predisposing to early mechanical failure. Conversely, fractures with an intact medial cortex allow partial load sharing, reducing implant strain and enhancing construct durability.

Biological

Healing in the subtrochanteric region is intrinsically challenging due to its limited biological potential. The dense cortical bone in this area has relatively poor vascularity compared to cancellous regions, predisposing to delayed union and nonunion. Healing is further compromised in comminuted fractures, particularly those resulting from high-energy trauma or occurring in osteoporotic bone, where both the bony architecture and the surrounding soft tissue envelope are disrupted, reducing local blood flow. In addition, surgical factors can exacerbate these problems: excessive periosteal stripping, thermal necrosis from aggressive reaming, or fixation performed under distraction all diminish the already tenuous healing capacity. These combined anatomical, biological, and iatrogenic challenges explain the higher risk of delayed consolidation and mechanical failure in subtrochanteric fractures compared with other femoral injuries.

Patient Related

Obesity poses unique challenges in the management of subtrochanteric fractures due to difficulties in positioning, reduction, and fixation. Excess soft tissue hampers proper setup, obscures landmarks, and limits fluoroscopic visualization, often necessitating open reduction with longer operative times, greater blood loss, and higher risk of wound complications. Establishing an accurate entry point is particularly demanding, as abducted limb positioning frequently results in an excessively lateral start, leading to medial cortex comminution and varus malalignment. (Figure 2) Biomechanically, the increased load from higher BMI places additional stress on fixation constructs,

Figure 2 Technical challenges in obese patients often lead to a lateral entry point during intramedullary nailing. This results in iatrogenic medial comminution, and subsequent abduction of the proximal fragment produces a varus deformity

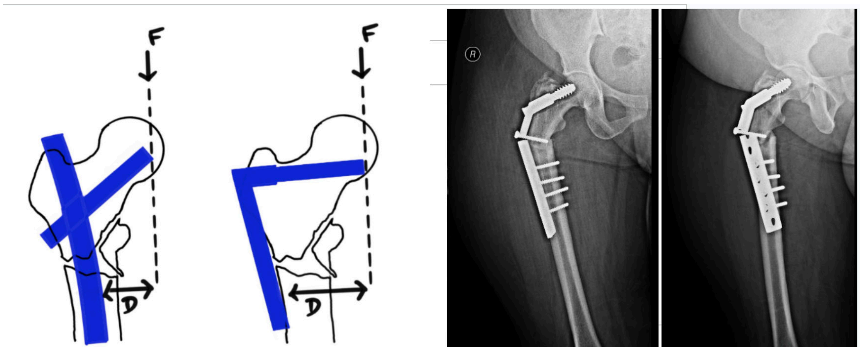

Figure 3 In medial comminution, extramedullary fixation behaves as a cantilever construct, concentrating bending forces on the implant and predisposing to varus collapse and failure. In contrast, intramedullary nailing, by virtue of its load-sharing central position, better resists these forces and provides superior biomechanical stability.

predisposing to implant failure or nonunion if reduction is suboptimal or fixation inadequate. While supine positioning on a fracture table is standard, the lateral position may be advantageous in obese patients, as it facilitates visualization, improves alignment in both coronal and sagittal planes, and reduces traction-related issues. To mitigate risks, liberal proximal exposure for accurate reduction, a slightly medialized trochanteric entry point, and augmentation with plate fixation in cases of medial comminution or high body weight are recommended to reduce nail strain and enhance stability.

Osteoporosis diminishes bone quality and compromises the mechanical integrity of the proximal femur. It can lead to comminution either at the time of injury or during fracture reduction. Poor bone mineral density reduces screw purchase, limiting the stability of fixation and increasing the risk of hardware failure, such as cut-out or implant loosening. In osteoporotic bone, even small technical errors in implant placement or fracture reduction can result in suboptimal construct stability.[9]

Osteosynthesis Principles

Importance of Medial Cortical Support in Implant Stability

The integrity of the medial cortex is a critical factor in achieving successful union and avoiding mechanical failure in subtrochanteric femur fractures. The presence of a medial void, commonly resulting from comminution, significantly compromises the structural stability of the construct and is a well-recognized risk factor for nonunion and implant failure. When extramedullary fixation devices, such as the dynamic condylar screw (DCS) or 95° angled blade plate, are used in the absence of medial cortical support, they are subjected to a biomechanical phenomenon known as the cantilever loading effect.[11,19] This can be visualized as a beam anchored at one end and free at the other, bearing the entire applied load. In such scenarios, the implant acts as the unsupported beam, while the medial void becomes a fulcrum, concentrating stress at the site of the defect. Instead of distributing load between the implant and the bone, the construct places a disproportionate burden on the implant, significantly increasing the risk of bending, fatigue, and ultimate mechanical failure. (Figure 3)

Finite element analysis has demonstrated that the absence of medial cortical contact markedly increases implant stress due to cantilever loading, thereby elevating the risk of mechanical failure. In alignment with this, evidence from a systematic review and meta-analysis showed significantly higher failure rates in fractures treated with extramedullary devices when medial voids were present, whereas intramedullary fixation provided better resistance against such biomechanical challenges.[6,20] Collectively, these observations emphasize the crucial importance of restoring medial cortical continuity to maintain reduction and facilitate successful healing.

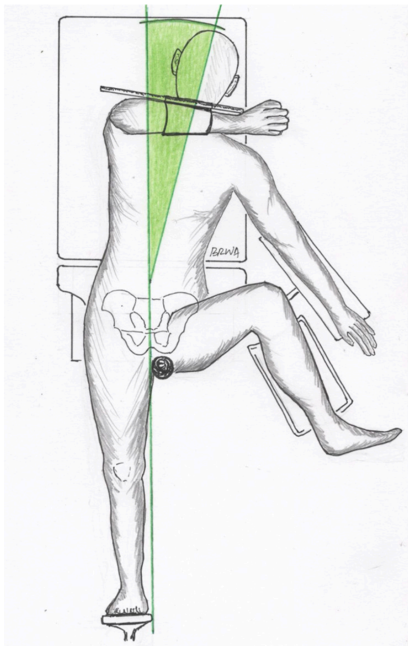

Figure 4 Diagram showing supine positioning on a fracture table with the contralateral limb in lithotomy position. Sustained traction is applied with a perineal post against the opposite ischial tuberosity, and ipsilateral hip adduction is facilitated by shifting the torso 10°–15° contralaterally for nail insertion.

Patient Positioning

The patient may be positioned either supine or lateral, on a radiolucent or fracture table, depending on the surgeon's preference and training.[21] A supine position on a radiolucent table is often preferred in cases of bilateral femur fractures, as it enables access to both femurs without the need to reposition the patient. This setup is also advantageous in polytrauma patients, allowing simultaneous assessment and management of associated injuries. However, it requires skilled assistants to provide traction and maintain reduction throughout the procedure.

When the patient is placed supine on a fracture table, sustained traction can be achieved effectively. The

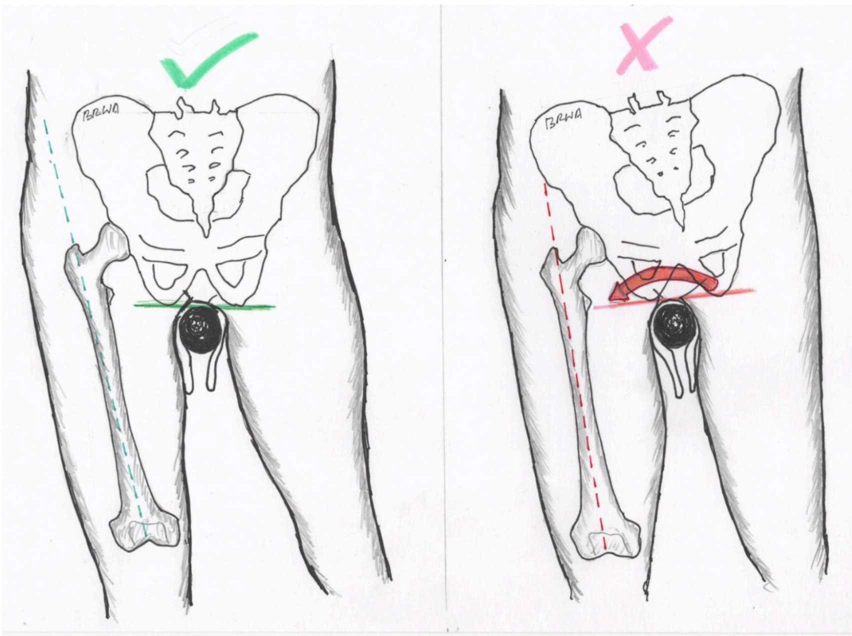

Figure 5 Excessive traction during reduction may cause pelvic rotation around the perineal post, leading to relative hip abduction and obstructed access to the proximal femoral entry point.

Figure 6 Armamentarium for reduction in subtrochanteric femur fractures.

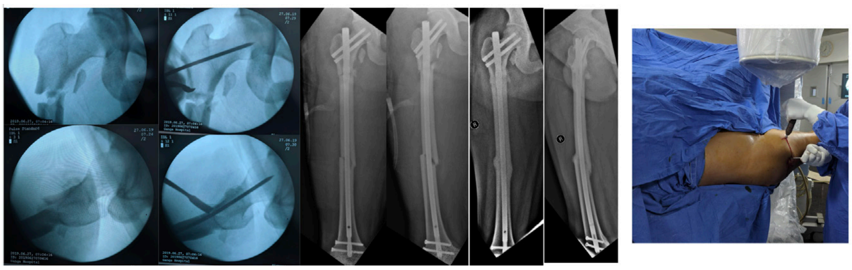

Figure 7 Joystick technique for reduction in subtrochanteric femur fractures.

contralateral limb may be positioned either beneath the injured limb in a scissoring configuration or supported on a lithotomy holder. If the uninjured leg is placed in a lithotomy holder, it is essential to achieve adequate ipsilateral hip adduction to facilitate nail insertion. To aid this, the torso may be shifted approximately 10°–15° toward the contralateral side. Excessive traction applied in an attempt to reduce the fracture may inadvertently cause pelvic rotation around the perineal post, resulting in relative abduction of the hip and obstructing access to the proximal femoral entry point. (Figure 4 and 5)

Using a scissoring position, where both legs are in traction, helps minimize pelvic tilt and avoids unintended hip abduction. Slight flexion and adduction of the injured hip allows easier nail entry, while extension and abduction of the uninjured hip facilitate lateral imaging. While the fracture table provides sustained traction, excessive force should be avoided, as soft tissue tension may hinder reduction. Moreover, prolonged traction carries a risk of pudendal nerve palsy.

Lateral positioning offers several benefits, especially in subtrochanteric fractures. It helps reduce the fracture by relaxing the abductors and counteracts the posterior sag frequently seen with the supine position. It also provides better access to the nail entry point, especially in obese individuals. However, assessing rotational alignment and limb length intraoperatively becomes more difficult in this position. For radiographic imaging, the shoot-through posteroanterior (PA) projection is used to obtain an anteroposterior (AP) view of the hip and femur. A lateral view requires a 25° caudal angulation to visualize the femoral neck and a 10° posterior angulation to compensate for femoral anteversion. It is crucial to rehearse imaging positions prior to draping. Studies have shown that the lateral position can reduce setup time, operative duration, intraoperative blood loss, and radiation exposure. However, other comparative studies report no significant differences in reduction quality, fixation parameters, or postoperative outcomes between supine and lateral positions.[22]

Reduction Strategies

Subtrochanteric fractures, unlike trochanteric fractures, rarely achieve satisfactory alignment with traction alone. In fact, excessive traction may worsen the deformity. Unlike diaphyseal fractures, where the nail itself often aids in achieving alignment due to the relatively wide medullary canal of the proximal fragment, the proximal segment in subtrochanteric fractures does not permit the nail to serve as a primary reduction tool. As a result, once an undesirable intramedullary track is created, the nail will continue to follow it, even if an assistant maintains reduction. Therefore, it is essential to restore proper alignment before determining the nail entry point or proceeding with plate fixation. (Figure 6)

Reduction techniques

Achieving and maintaining accurate reduction in subtrochanteric fractures is technically demanding, and a stepwise approach, progressing from closed to progressively more invasive techniques, helps preserve soft tissue while optimizing alignment.

Percutaneous techniques are the first line when closed reduction fails. The joystick technique using Steinmann pins is highly effective in correcting multidirectional deformities. A 4 mm Steinmann pin is inserted into the femoral neck from the lateral wall, approximately 1 cm below the innominate tubercle, and directed along the anterior cortex of the femoral neck. This pin corrects abduction and external rotation deformities. A second pin placed anteroposteriorly at the level of the lesser trochanter corrects flexion. Controlled manipulation of these pins aligns the proximal fragment, allowing a true AP view for nail entry, with minimal soft tissue disruption. (Figure 7 and 8)

The ball spike pusher technique allows targeted force application on the proximal fragment. Through a small lateral incision, a ball spike is introduced to correct abduction and flexion, offering improved control while maintaining minimally invasive access.

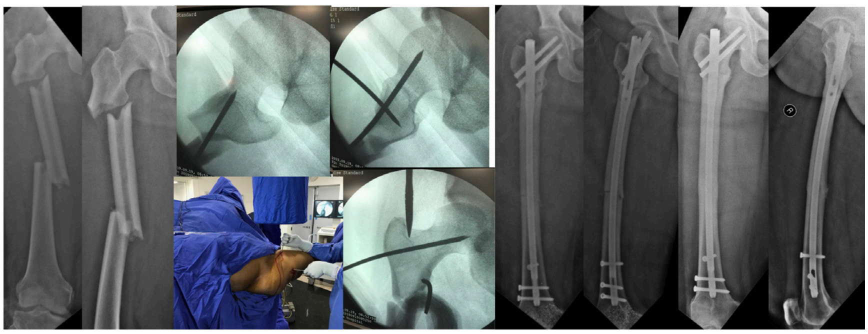

Figure 8 Joystick technique for reduction in subtrochanteric femur fractures.

In reverse oblique fractures, a push-and-pull technique may be required. The distal fragment, typically displaced medially, is pulled laterally using a bone hook or collinear clamp, while the proximal fragment is pushed medially with a ball spike or clamp. This simultaneous traction and counter-pressure restore alignment effectively.

Long curved haemostatic forceps can be used to address flexion, external rotation, and abduction deformities in a simple and reproducible manner. Through a 2 cm lateral incision posterior to the femoral axis, the haemostat is guided to the lesser trochanter. Elevating it anteriorly increases tension in the surrounding soft tissues, indirectly correcting the deformity through a soft-tissue tensioning mechanism. (Figure 9)

Blocking-assisted reduction is a reliable adjunct to optimize alignment during intramedullary nail fixation. Blocking can be achieved using screws, drill bits, or wires; however, blocking wires offer greater versatility as they can be easily repositioned to fine-tune reduction.[23,24] Strategically placed percutaneous wires guide reaming of the intact cortex in the proximal femoral segment, preventing the reamer and nail from following the path of least resistance. For example, in a fracture with intact lateral and anterior cortices, a medial and a posterior blocking wire can ensure adequate reaming of these areas. The wires can also serve as joysticks to intentionally manipulate fragment position during reaming, effectively allowing the implant to reduce the fracture by constraining the nail within the desired metaphyseal trajectory rather than relying solely on manual reduction.[25,26] Compared to screws, wires require smaller cortical perforations, are easily adjustable, and can be replaced with screws for additional stability if needed. Larger-diameter wires (>2.5 mm) reduce the risk of breakage.[27] Blocking wires also create a static reduction environment

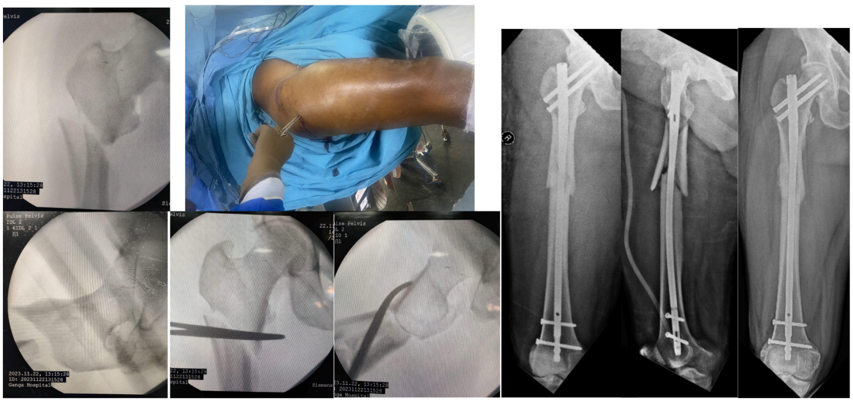

Figure 9 Joystick technique for reduction in subtrochanteric femur fractures.

for interlocking without continuous manual holding. In osteoporotic bone with wide medullary canals, replacing wires with screws after final fixation can prevent postoperative displacement. A potential pitfall is the wire migration when contacted by the reamer; this can be avoided by engaging the far cortex without penetrating it and maintaining manual control during reaming. Even in cases with near-cortex comminution, a unicortical far-cortex–seated wire can function effectively as a reduction aid.[28] (Figure 10 and 11)

When percutaneous techniques are insufficient, a mini-open reduction may be performed. A small incision over the fracture site allows the placement of reduction forceps to achieve anatomical alignment. This approach is useful in short oblique or spiral fractures with interposed soft tissue and provides a controlled setup for accurate nail insertion.

For complex fracture, especially with medial wedge fragments, open reduction with cerclage wiring offers better control. Through a lateral approach, the vastus lateralis is elevated with minimal periosteal stripping, allowing fracture exposure. Cerclage wires can then be passed to stabilize fragments, particularly near the lesser trochanter, to redirect the guidewire if it exits medially. Though concerns exist about vascular compromise, evidence supports that when applied judiciously, one or two cerclage wires do not significantly disrupt periosteal blood flow. Key principles include open visualization, limited dissection, and avoidance of excessive tension. Risks such as blood loss, prolonged surgery, or wire migration can be mitigated with modern cables and careful technique. (Figure 12)

Unicortical plating may be used as a temporary reduction tool or definitive adjunct. A short precontoured plate applied through a lateral window allows controlled manipulation and stabilization of the proximal fragment. This technique is particularly useful in obese patients or nonunions where fragment control is otherwise difficult. Care must be taken to avoid excessive cortical breach, screw protrusion, or interference with the nail. When used correctly, it improves alignment, enhances construct stability. (Figure 13) Together, these reduction strategies, from minimally invasive percutaneous methods to open cerclage and unicortical plating, offer a

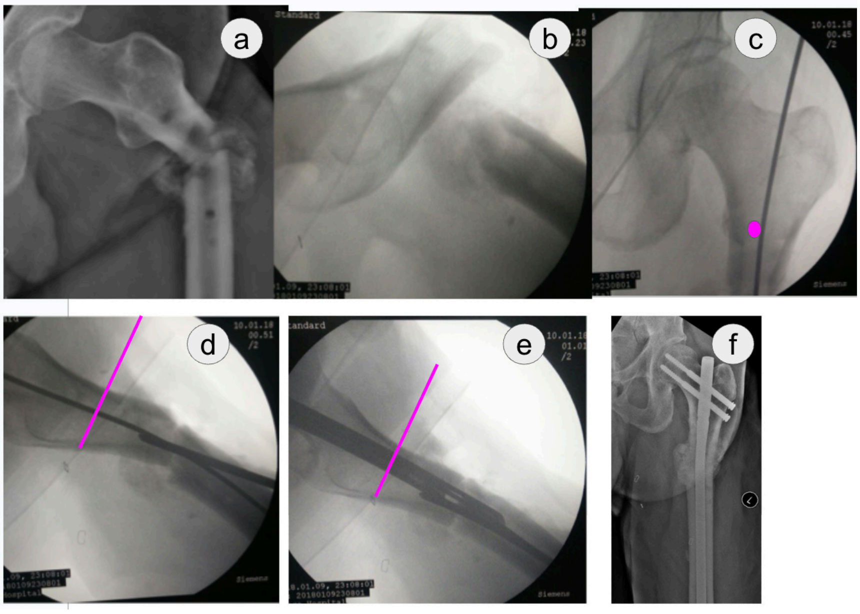

Figure 10 Blocking-assisted reduction using medial and posterior blocking wires. These wires ensure adequate reaming, act as joysticks for controlled fragment manipulation, and allow the nail to reduce the fracture by constraining it within the desired metaphyseal trajectory rather than relying solely on manual reduction.

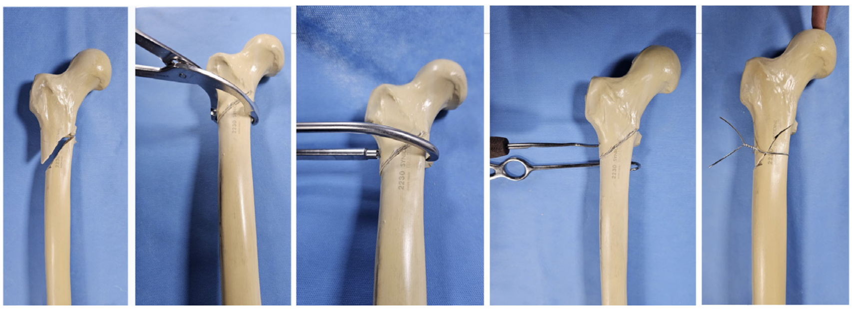

Figure 11 Bone model showing reduction techniques using instruments such as reduction clamps, collinear clamps, and push–pull devices. Assisted reduction is followed by cerclage wiring, particularly useful in reverse oblique fracture patterns.

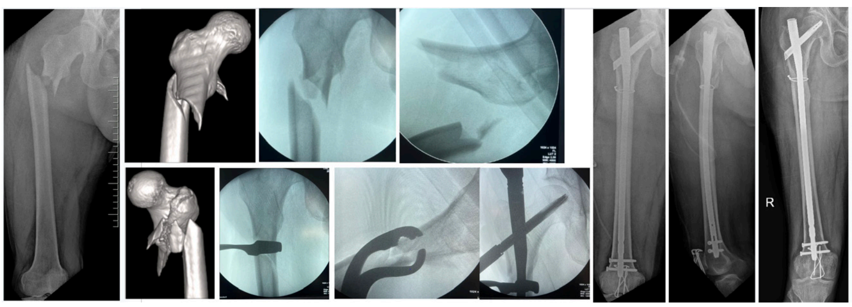

Figure 12 Case example of a spiral subtrochanteric fracture reduced with a reduction clamp and augmented with cerclage wiring, which subsequently united without secondary displacement.

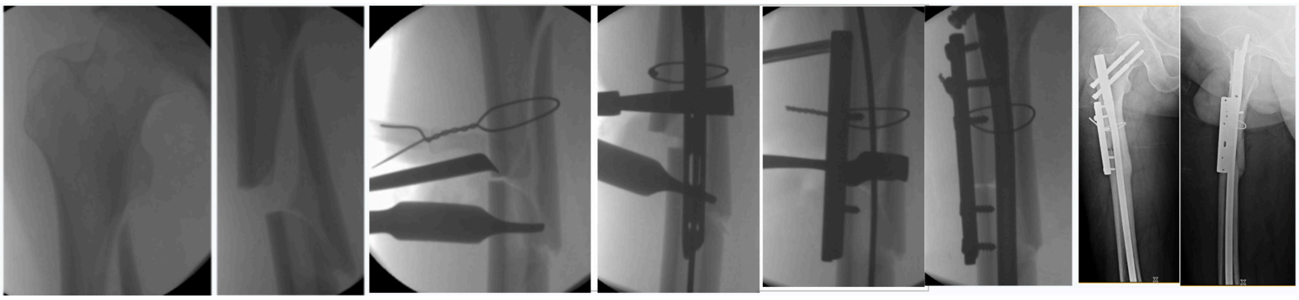

Figure 13 Intraoperative fluoroscopic image showing abduction of the proximal fragment following nail entry, reduced using plate assistance with unicortical screws, which subsequently united uneventfully.

toolkit for surgeons to tailor treatment according to fracture morphology, soft tissue status, and intraoperative reduction quality.

Choice of Implant

Subtrochanteric fractures can be managed with both extramedullary and intramedullary devices. While traditional fixation required extensive exposure with risk of soft-tissue compromise, current biological fixation techniques emphasize indirect reduction and alignment, thereby minimizing surgical insult and lowering complication rates.

Plate fixation

Extramedullary implants, including the dynamic hip screw (DHS), dynamic condylar screw (DCS), angle blade plates, and proximal femur locking plates, have historically been used in the management of subtrochanteric fractures.[29] The DHS was once widely used but has largely fallen out of favor due to its high risk of complications, including medialization of the femoral shaft and poor outcomes reported in up to 70% of cases.[9] Its use is now largely restricted to very distal subtrochanteric fractures, where multiple screws can be securely anchored into the proximal fragment, effectively functioning as a conventional plate rather than a sliding device. Fixed-angle devices, such as the DCS and angle blade plates, developed by the AO group, have demonstrated more reliable results, particularly when the medial buttress is restored. In these situations, the lateral plate functions as a tension band, converting tensile forces into compressive forces across the fracture site.[19] In the absence of medial continuity, however, the entire stress is transferred to the lateral plate, increasing the risk of implant bending and fatigue failure. Proximal femur locking plates, which lock screws rigidly to the plate and minimize periosteal disruption, initially showed promise in biomechanical studies.[5,29] Clinically, however, outcomes have been less favorable, with Collinge et al. reporting high complication rates, including fixation failure, malalignment, deep infection, and revision surgery in over 40% of cases. At present, plating techniques are best reserved for highly specific indications, such as extremely short proximal fragments or as a salvage option following failed nailing, malreduction, delayed union, or nonunion. [20] (Figure 3)

Intramedullary nails

Intramedullary nailing is considered the gold standard for stabilizing subtrochanteric femur fractures, owing to its biomechanical superiority over extramedullary devices. By positioning the implant close to the mechanical axis, intramedullary nails reduce the lever arm, provide load sharing, and preserve periosteal blood supply through minimally invasive insertion, thereby promoting secondary bone healing.[30–32] Compared with extramedullary implants, several studies have shown that intramedullary devices are associated with shorter operative time, reduced transfusion requirements, decreased length of hospital stay, and lower risk of implant failure. [19,31,33] Kuzyk et al. reported a reoperation rate of 6% with long intramedullary nails versus 20% with plate fixation, highlighting the reduced risk of failure.[31] Similarly, Borens et al. observed that intramedullary nailing resulted in fewer complications (12% vs 32%) and faster functional recovery compared to extramedullary devices.[34] Long intramedullary nails are the preferred fixation for subtrochanteric fractures, offering superior stability and fewer complications than short nails. Studies show higher union rates and lower reoperation rates (4.0% vs. 8.4%) with long PFNs. Their biomechanical advantage is most evident in osteoporotic and comminuted fractures. Optimal outcomes require advancing the nail distally into the metaphysis, ideally to the epiphyseal scar, which enhances anchorage and reduces migration or bending.[35–37] Overall, long nails consistently ensure reliable union and improved functional recovery. Considering these biomechanical and clinical advantages, the authors prefer intramedullary nailing for the management of subtrochanteric femur fractures.

Entry Point in Intramedullary Nailing

The selection and execution of the entry point are critical steps in the intramedullary nailing of subtrochanteric femur fractures. Achieving and maintaining an accurate reduction, either by closed or open methods, is essential before initiating the nail entry. An ideal starting point facilitates a correct nail trajectory, helps correct angular deformities, and minimizes the risk of malreduction. Current evidence supports a medialized start point, typically just medial to the tip of the greater trochanter in the coronal plane, which aligns with most contemporary nail designs and provides favorable biomechanical outcomes. (Figure 10)

Improper entry point selection can compromise reduction and fixation. A starting point that is too lateral can cause varus malreduction, while an excessively anterior starting point can lead to malreduction in flexion. Trochanteric entry nails, particularly those with a proximal lateral bend, can assist in coronal plane reduction when combined with a medialized start, but care must be taken to avoid anterior malposition. Piriformis entry nails, by contrast, are naturally medial and posterior, aligning well with the intramedullary canal but can be technically demanding and carry a higher risk of malrotation, especially if there is comminution of the piriformis fossa. (Figure 2)

Preparation of the proximal femoral segment should be tailored to the fracture pattern. The reaming trajectory is generally planned from medial to lateral in the coronal plane and posterior to anterior in the sagittal plane, ensuring the nail follows the optimal path.

Retrograde entry preparation through the fracture site is a valuable technique in select subtrochanteric femur fractures where achieving the ideal medialized start point is difficult with conventional antegrade methods. This approach is particularly useful in obese patients, cases with previous failed nailing, atypical fractures with varus remodeling, or when the medullary canal is blocked by sclerotic bone. Retrograde drilling offers several advantages, it allows an unobstructed distal–lateral to proximal–medial trajectory, avoids interference from gluteal musculature or the iliac crest, and reliably reams the thickened lateral cortex or endosteal beak under direct vision. This prevents reamer-induced drift toward the medial cortex, which can cause varus malalignment, and helps maintain the correct nail trajectory. Since the proximal fragment is prepared before fracture reduction, the time spent holding and maintaining reduction during nailing is minimized.[38]

Cerclage wiring, when used with intramedullary nailing, is a useful adjunct for subtrochanteric fractures where closed reduction fails, helping restore alignment, define the entry point, and reduce fluoroscopy time. Performed through limited incisions with minimal periosteal disruption, it maintains blood supply while improving reduction, stability, and early weight-bearing, thereby reducing risks of varus malunion and secondary displacement. Complications such as infection, wire breakage, iatrogenic fracture, or vascular injury are rare with meticulous technique, though excessive wiring should be avoided.[39] In appropriately selected fractures, particularly long oblique or spiral patterns, cerclage wiring offers a reproducible, minimally invasive method to achieve stable anatomical reduction prior to nailing.(Figure 12)

Fixation considerations in special situation

Atypical Subtrochanteric femur fractures

Atypical femur fractures (AFFs) are insufficiency fractures strongly associated with long-term bisphosphonate use. They usually follow minimal trauma and have distinct features: a transverse fracture line starting at the lateral cortex, a medial spike in complete fractures, minimal comminution, and localized cortical thickening (“beaking”). Prodromal thigh or groin pain, bilateral involvement, and delayed healing are common. Suppressed bone remodeling from bisphosphonates reduces biological healing potential, while high mechanical stresses in this region increase the risk of nonunion. Evaluation includes history of bisphosphonate or glucocorticoid use, symptom enquiry, and imaging. Radiographs are first-line, but MRI, CT, or bone scan may be required for incomplete or contralateral lesions. Labs assess calcium, vitamin D, and bone turnover. Management begins with discontinuing bisphosphonates, correcting metabolic deficiencies, and considering anabolic therapy (e.g., PTH analogues) with endocrinology guidance[40] Surgery is recommended for both complete and incomplete AFFs because nonoperative treatment carries high risk of displacement and persistent pain. Intramedullary nailing is preferred, though plating is an option when anatomy precludes nailing. Thickened lateral cortex may deflect the nail into varus, necessitating careful reaming, partial cortical removal, or medial poller screws.[41] Bone grafting or nail–plate constructs can be considered in high-risk cases. Postoperatively, weight-bearing is protected and follow-up is close, given the high risk of delayed healing and implant complications. Despite optimal care, outcomes remain less predictable than in typical subtrochanteric fractures, underscoring the need for early recognition, multidisciplinary input, and meticulous technique.[42] (Figure 14)

Osteopetrosis

Fixation of subtrochanteric fractures in osteopetrosis is particularly demanding due to absent or extremely narrowed medullary canals, sclerotic bone, and high risk of intraoperative complications. Intramedullary nailing offers superior biomechanics, but canal preparation is often the most critical step. When no canal exists, it can be created by opening the fracture site, starting with retrograde drilling of the proximal fragment and sequential reaming, followed by antegrade preparation of the distal fragment.[43] Dense bone resists drilling; therefore, low-speed, high-torque drills with continuous saline irrigation are essential to minimize thermal necrosis. Instrument breakage is frequent, so new drill bits, multiple guidewires, reamers, and backup implants must be available. Screw fixation poses another challenge, as dense cortices generate high insertion torque. Pre-tapping and careful torque control are necessary to avoid breakage. Intraoperative imaging may not clearly define the canal, making tactile feedback and stepwise drilling with frequent fluoroscopic checks

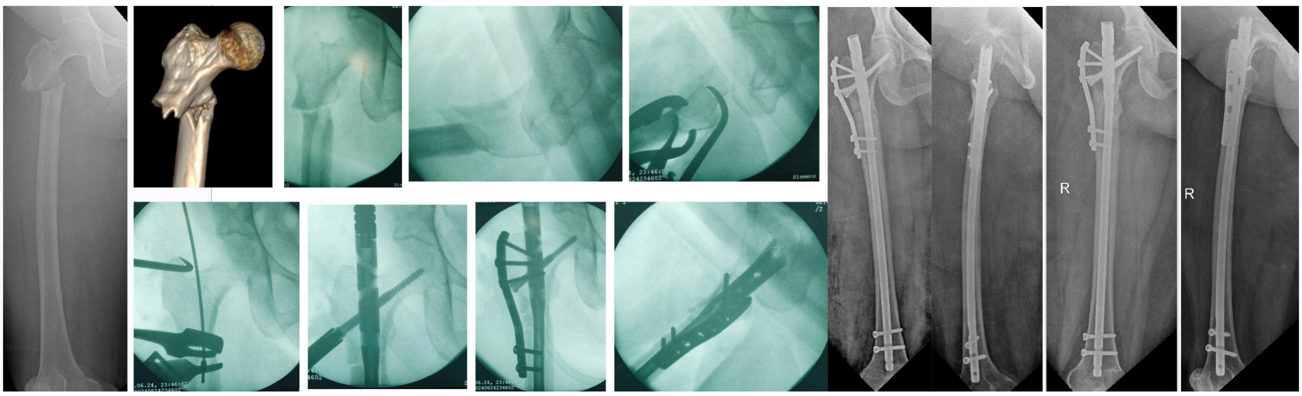

Figure 14 Atypical subtrochanteric fracture with medial beak and endosteal thickening, managed with nailing augmented by plate fixation and bone grafting, which united uneventfully.

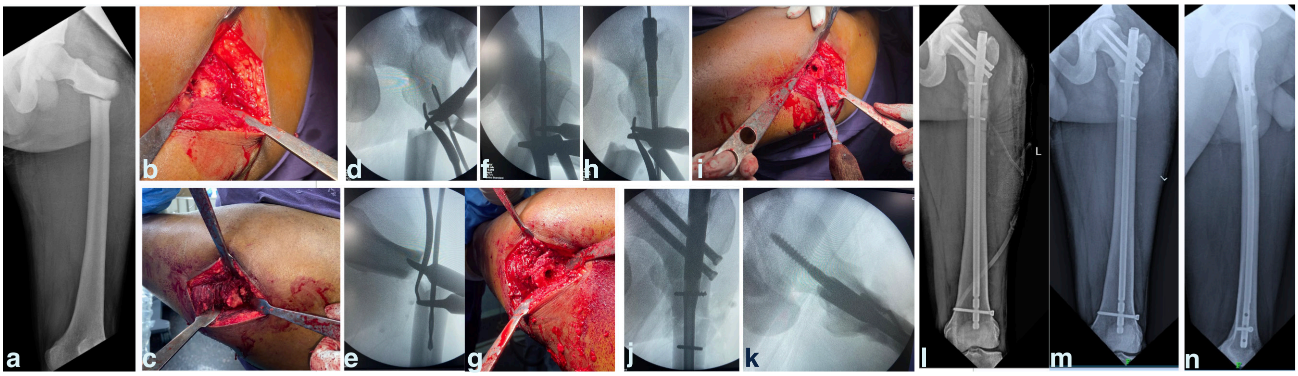

Figure 15 (a) Preoperative radiograph showing subtrochanteric fracture in osteopetrosis; (b) Exposure of fracture site revealing absence of medullary canal; (c) Retrograde entry into proximal fragment with sharp drill bit; (d, e) Sequential reaming of proximal fragment; (f) Creation of medullary path in proximal fragment; (g) Clinical image showing absence of canal in distal fragment; (h) Antegrade entry into distal fragment with drill bit; (i) Reaming of distal fragment; (j, k) Intraoperative fluoroscopy confirming nail placement; (l) Immediate postoperative radiograph; (m, n) Eighteen-month follow-up radiographs showing complete fracture union.

vital to maintain trajectory. Healing is slow due to impaired bone turnover, requiring absolute stability, frequent consideration of autologous grafting, and prolonged protected weight bearing. Plates may be used when nailing is not feasible, but nails remain preferable for their load-sharing advantage if technical difficulties can be overcome. Successful outcomes depend on meticulous preparation, anticipation of equipment failure, and adherence to principles of stability and biology.[44] (Figure 15)

Subtrochanteric femur fracture in Polio Limb

Management of subtrochanteric femur fractures in polio-affected limbs poses unique challenges due to a combination of osteoporosis, narrow intramedullary canals, fixed deformities, and altered anatomy.[45] These factors often make standard intramedullary nailing technically demanding or even unfeasible. A narrow canal, in particular, may preclude the use of standard-sized femoral nails, necessitating alternative fixation strategies. While intramedullary nailing remains the preferred option when feasible, preoperative planning must include contingency options for canal mismatch. In such cases, bridge plating with locking compression plates can serve as a reliable alternative, especially in osteoporotic bone or when there is severe comminution. Locking plates offer angular stability, reduced screw toggle, and preservation of periosteal blood supply, which is advantageous in compromised bone. Achieving stable fixation in this setting requires careful implant selection, possible use of smaller or anatomically contoured plates, and augmentation with bone graft when cortical purchase is poor. Ultimately, surgical success depends on maintaining flexibility in intraoperative decision-making, anticipating anatomical constraints, and having a diverse implant inventory to address the full spectrum of challenges in these complex cases.[45] (Figure 16)

Outcomes

The outcomes of intramedullary fixation for subtrochanteric femur fractures have been well documented, with union rates ranging from 77% to nearly 100%, most exceeding 95% when anatomical reduction is achieved.[7,46] Beingessner et al. (2013) treated 56 closed fractures with open reduction and reamed, locked nails, reporting union in all cases, callus formation in 91% at first follow-up,

Figure 16 Subtrochanteric fractures in a polio-affected limb: a wide canal was treated with intramedullary nailing, while a narrow canal was managed with minimally invasive plate osteosynthesis using an LCP.

and complete union by 23 weeks, with excellent alignment (<5° deformity in 98%) and minimal complications.[47] Similarly, Riehl et al. (2013) observed a 97% union rate in 35 patients, with 60% uniting within four months. Malreduction >10° was strongly predictive of delayed or absent union, while well-reduced fractures healed reliably.[48] In a larger series, Robinet et al. (2015) studied 194 patients and reported a 97% union rate (mean 18 weeks), with nonunion limited to 3%; 99% of anatomically reduced fractures united versus only 77% of poorly reduced ones.[39] Je et al. (2014) confirmed this association in 74 patients, showing overall union in 95.9% but a 22.2% nonunion rate when reduction was poor.[37]

Technical factors strongly influence outcome. Krappinger et al. (2019) reported nonunion in 23% of 74 patients, closely associated with varus malalignment (41%), loss of medial cortical support (40%), and early autodynamisation (89%).[49] Risk increased stepwise with the number of adverse factors: from 2.9% with none to 100% with all three. Panteli et al. (2022), in a multicenter series of 273 patients, found a 90.5% union rate but identified open fracture, low surgeon experience, and unfavorable locking strategies as independent predictors of nonunion (OR 3.38, 2.92, and 3.46 respectively), with rates rising to 50% when all were present.[50] More favorable outcomes were reported by Wang et al. (2021), who achieved 100% union in 31 patients at a mean of 16.5 weeks, with 87% reaching good-to-excellent Harris Hip Scores.[51]

Delayed healing remains frequent, with union times commonly extending 16–23 weeks, and delayed union rates up to 50% reported, though most progress with observation. Freigang et al. emphasized that satisfactory reduction and slight valgisation of the neck–shaft angle reduced complicated healing. Miedel et al. highlighted the link between reduction quality and reoperation: fractures with only acceptable reduction required repeat surgery, while those with good reduction did not. Varus malalignment, medial comminution, and lack of support remain the strongest risk factors for implant failure and nonunion.[52]

The fixation method also influences results. Dynamic hip screw (DHS) fixation has largely fallen out of favor, with reported poor outcomes and complication rates up to 70%. Plating techniques, including angle blade plates and locking compression plates, may shorten operative time and blood loss and remain useful in select indications such as very short proximal segments or revision after failed nailing. However, intramedullary nailing consistently provides superior biomechanical stability, earlier mobilization, and lower reoperation rates. Concerns that open reduction might increase complications have been refuted: Beingessner et al. found no excess wound or implant problems with open approaches when closed reduction was inadequate.[11,47]

Bone quality is another determinant of outcome. Osteoporotic bone predisposes to varus collapse, screw cut-out, and implant failure, requiring cautious mobilization and sometimes augmentation. Patient factors such as smoking or compliance with weight-bearing protocols may play a secondary role, but mechanical factors consistently outweigh biological ones.

Taken together, the literature demonstrates that while intramedullary fixation achieves reliable union in the majority of subtrochanteric fractures, complication rates remain higher than for other proximal femur injuries. Success depends less on implant choice than on achieving stable, anatomical reduction with restoration of medial support, avoidance of varus, and adherence to careful postoperative protocols.

Conclusion

Subtrochanteric femoral fractures remain among the most demanding injuries in orthopaedic trauma because of their complex anatomical, biomechanical, and biological challenges. Intramedullary nailing is widely regarded as the gold standard, providing superior biomechanical stability, earlier mobilization, and lower complication rates compared with extramedullary devices. Ultimately, the quality of reduction and fixation stability are the key determinants of outcome, irrespective of implant choice. Consistent evidence highlights the importance of restoring medial support, avoiding varus malalignment, and following appropriate weight-bearing protocols to achieve reliable healing. Nevertheless, complication rates remain considerable, especially in elderly, osteoporotic, and obese patients. Successful management requires a delicate balance between preserving biology and ensuring mechanical stability, and with meticulous surgical technique, most patients can achieve predictable union and satisfactory functional recovery.

Conflict of Interest

None

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