Nonunions of the Proximal Femur

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Introduction

Although elderly patients may do well functionally with nonunions of long bones in the upper extremity (clavicle, Humerus and ulna), nonunited fractures of the proximal femur are not well tolerated in active individuals [1, 2]. Femoral nonunions, however, are more frequently painful and may preclude weightbearing on the affected extremity. If, however, pain is minimal or nonexistent and occurring within a nonambulatory individual, nonoperative management is the treatment of choice.

Anatomic Considerations

The hip is a ball-and-socket joint formed by the femoral head and the acetabulum. The *femoral head*, an imperfect sphere of cancellous bone sheathed in articular cartilage, is characterized by a relatively dense meshwork of trabecular bone that facilitates the absorption and distribution of weightbearing stresses to the dense cortical bone of the femoral neck and proximal femur. The size of the femoral head varies, more or less, in proportion to body mass, ranging from roughly 40 to 60 mm in diameter [3]. The thickness of the articular cartilage covering the femoral head averages 4 mm superiorly and tapers to 3 mm at the periphery [4].

The *femoral neck* comprises the region between the base of the femoral head and the intertrochanteric line anteriorly and the intertrochanteric crest posteriorly. The femoral neck forms an angle with the femoral shaft ranging from 125 to 140° in the coronal plane and 10–15° (anteversion) in the transverse plane [5]. The cancellous bone of the femoral neck is characterized by trabeculae organized into medial and lateral systems [6]. The medial trabecular system forms in response to the joint reaction force on the femoral head; the epiphyseal plates are perpendicular to the medial trabecular system. The lateral trabecular system resists the compressive force on the femoral head resulting from contraction of the abductor muscles.

The *intertrochanteric region* of the hip, consisting of the greater and lesser trochanters, represents a zone of transition from the femoral neck to the femoral shaft. This area is characterized primarily by dense trabecular bone that serves to transmit and distribute stress, similar to the cancellous bone of the femoral neck. The greater and lesser trochanters are the sites of insertion of the major muscles of the gluteal region: the gluteus

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medius and minimus, the iliopsoas, and the short external rotators. The calcar femorale, a vertical wall of dense bone extending from the posteromedial aspect of the femoral shaft to the posterior portion of the femoral neck, forms an internal trabecular strut within the inferior portion of the femoral neck and intertrochanteric region and acts as a strong conduit for stress transfer [7, 8].

The *subtrochanteric region*, which extends from the lesser trochanter to an area 5 cm distal, consists primarily of thick, dense cortical bone. This is an area of high stress concentration, with large compressive forces medially and tensile forces laterally. The dense cortical bone permits efficient transmission of both axial and torsional loads.

The *hip capsule* is attached to the labrum and transverse acetabular ligament of the acetabulum, the medial side of the greater trochanter, the intertrochanteric line anteriorly, a site immediately superior and medial to the lesser trochanter, and the femoral neck posteriorly [9]. The entire anterior aspect of the femoral neck and the proximal half of its posterior portion lie within the capsule of the hip joint. Fractures within this area are thus termed *intracapsular*.

The musculature of the hip region can be grouped according to function and location [9]. The abductors of the gluteal region, the *gluteus medius* and *gluteus minimus* that originate from the outer table of the ilium and insert onto the greater trochanter, function to control pelvic tilt in the frontal plane. The *gluteus medius* and *gluteus minimus*, along with the *tensor fascia lata*, are also external rotators of the hip. The hip flexors are located within the anterior aspect of the thigh and include the sartorius, iliopsoas, and rectus femoris. The pectineus is a hip flexor located within the medial thigh but shares its function and innervation with the anterior compartment hip flexor group. The *iliopsoas*, *comprised of the iliacus and psoas major*, inserts upon the lesser trochanter. The *gracilis* and the *adductor* muscles (longus, brevis, and magnus) are located in the medial aspect of the thigh. The short external rotators, the *piriformis*, *obturator internus*, *obturator externus*, *superior* and *inferior gemelli,* and *quadratus femoris*, all insert onto the posterior aspect of the greater trochanter. The *gluteus maximus*, originating from the ilium, sacrum, and coccyx, inserts onto the gluteal tuberosity along the linea aspera in the subtrochanteric region of the femur and the iliotibial tract. The gluteus maximus serves as an extensor and external rotator of the hip. The *semitendinosus*, *semimembranosus*, and *biceps femoris*, which originate from the ischium to form the hamstring muscles of the thigh, are responsible for knee flexion as well as hip extension.

The two largest tributaries of the profunda femoral artery are the *medial* and *lateral femoral circumflex arteries*. The latter originates from the anterolateral aspect of the profunda femoral artery. It then proceeds laterally across the iliopsoas muscle, passes horizontally between the divisions of the femoral nerve, and then runs deep to the sartorius and rectus femoris, where it divides into ascending, descending, and transverse branches. The *medial femoral circumflex artery*, which originates from the medial or posteromedial side of the profunda femoral artery, runs posteriorly between the iliopsoas and pectineus muscles. A key structure responsible for ensuring blood flow to the distal extremity when a blockage occurs between the proximal femoral and external arteries is the cruciate anastomosis. It is located within the upper thigh at the inferior margin of the quadratus femoris muscle. This circulatory anastomosis is comprised of a descending branch of the inferior gluteal artery, the first perforating branch of the profunda femoral artery, the medial and lateral circumflex arteries, and often a posterior branch of the obturator artery. The *superficial femoral artery* continues in the thigh within the adductor canal, separated from the profunda femoral vessel by the adductor longus muscle. The femoral artery then passes from medial to posterior in the thigh through a tendinous hiatus in the adductor magnus (*Hunter's canal*), becoming the *popliteal artery*.

The blood supply to the femoral head and neck is complex and has important orthopedic implications [10–12]. The medial and lateral circumflex arteries send branches that anastomose to form an extracapsular arterial ring at the base of the femoral neck. Coming off this arterial ring are the ascending cervical arteries, also known as the *capsular* or *retinacular arteries*, which pierce the joint capsule and traverse the neck of the femur deep to the synovial membrane. There are four major retinacular arteries—*anterior*, *medial*, *posterior*, and *lateral*—named for their position relative to the femoral neck. The lateral retinacular artery is the most important blood supply to the femoral head and neck. The retinacular vessels anastomose at the base of the femoral head to form the subsynovial intra-articular ring. Small epiphyseal arterial branches then pierce and supply blood to the femoral head. The artery of the ligamentum teres is either a branch of the posterior division of the obturator artery or a branch from the medial circumflex artery.

This artery, which supplies blood to small, variable area of bone adjacent to the fovea of the femoral head, appears to be of limited clinical importance following physeal closure.

Definitions

Fractures heal at different rates depending on various factors (i.e., comminution, anatomical site, blood supply, etc.). Most fractures, however, will unite by 4–6 months or at a minimum show progressive healing on serial radiographs. If a fracture fails to heal in that time frame or in the average or usual time for similar fractures, it is defined as a delayed union. A nonunion is an arrest of the fracture repair process; there is no further potential for fracture union (REF).

Etiology

In general, fracture nonunion results from a combination of host, injury-specific, initial treatment, and complicating factors. The most commonly observed contributors include excessive fracture motion, continued fracture gap, avascularity, and ongoing infection. Fracture gap can result from soft tissue interposition, fracture distraction, fracture malposition, or bone loss. Avascularity results from damaged nutrient vessels, excessive soft tissue stripping, or severe fracture comminution. General patient factors which predispose to nonunion include nicotine, older age, poor nutritional status, corticosteroid use, anticoagulation medication, radiation therapy, and burns.

General Principles

Nonunion of the proximal femur must be divided into three separate regions with specific anatomical consideration: the femoral neck, the intertrochanteric region, and the subtrochanteric region. Although femoral neck and intertrochanteric fractures occur with a similar incidence, fractures of the femoral neck are more likely to progress to nonunion due to their intracapsular nature. The lower incidence of subtrochanteric femur fractures and their extracapsular location make them less commonly observed.

In most cases treatment of proximal femoral nonunion requires operative intervention if a patient is to regain functional use of their lower extremity. Surgical options vary based upon factors including preinjury functional status, age, and the condition of the articular cartilage.

When treating the patient with proximal femoral nonunion, correction of any regional deformity must be addressed in addition to obtaining union. The goal of joint mobilization should be met to return function to the extremity. When present, resolution of infection may require staged surgical intervention. When the history of infection is remote, union may be achieved. Suppressive antibiotics are required in the occurrence of infectious recrudescence following fracture union.

Furthermore, there is potential for autogenous or allogenic graft requirement if significant bone loss is present or previous infection has resulted in significant bone resorption. Active, draining infection suggests the presence of necrotic material at the nonunion site. These cases will require extensive debridement with concomitant bacterial culture for appropriate antibiotic selection [13–15].

Diagnosis

The diagnosis of proximal femoral nonunion can be difficult to make, especially within the femoral neck. The diagnosis should always be considered in the patient who has undergone fixation and complains of hip or groin pain 4–6 months after surgery [16]. In many cases, failure of fixation will herald the presence of fracture nonunion [17].

If an ununited fracture is suspected clinically, a standard radiographic series of the hip including anteroposterior and lateral views may elucidate a persistent fracture line or a subtle change in the neck-shaft angle. An internal rotation view of the hip that brings the femoral neck into profile can assist the treating physician if there is any question. Computed tomography has virtually replaced plain tomography for the diagnosis of fracture nonunion. CT reconstruction views are good for detailing fracture margin sclerosis, and multiplanar reformatted images can evaluate fracture fixation for breakage or loosening by reducing metallic artifact [18] (Fig. 10.1).

In the case of femoral neck nonunions, it is important to clearly establish the presence of osteonecrosis within the femoral head prior to surgery, as greater than 50% involvement of the head may herald eventual collapse and therefore preclude repair of the nonunion [19]. Diagnosis of AVN may be difficult with implants in place. If titanium implants are within the femoral neck and head, an MRI can be utilized to evaluate the hip for AVN. Otherwise a Tc99 bone scan or intraoperative laser Doppler flowmetry can be obtained [20, 21].

The presence of infection should be ruled out in any patient with a nonunion and history of previous surgery. Laboratory values including an erythrocyte sedimentation rate and C-reactive protein should be obtained preoperatively. Gallium scanning has been shown to be of limited value in these cases [22].

Lifestyle factors such as tobacco use have a risk of nonunion associated with it [23]. Patients should be counseled as to this risk, and all attempts to cease smoking should be made in the pretreatment phase.

Preoperative Planning

Preoperative planning should include the use of templates of the hardware to be used, superimposed on preoperative radiographs (Fig. 10.2). The normal side may be used as a template for the prospective end result of the surgery. Special implants or prostheses that may be used should be ordered well in advance of the planned surgery. Special tests such as a bone scan, arteriogram, or

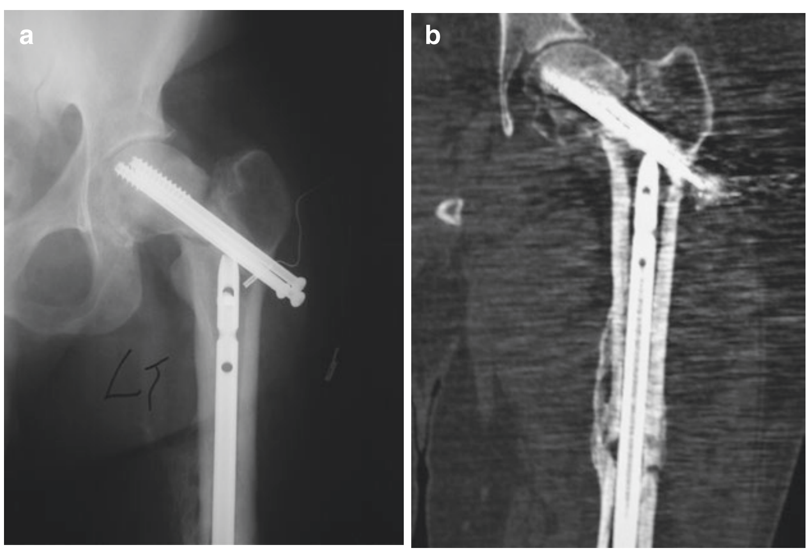

Fig. 10.1 A 38-year-old male who sustained an ipsilateral femoral neck and shaft fracture. (**a**) Anteroposterior (AP) radiograph at 4 months suggests nonunion. (**b**) A reconstructed CT image demonstrating a clear femoral neck nonunion

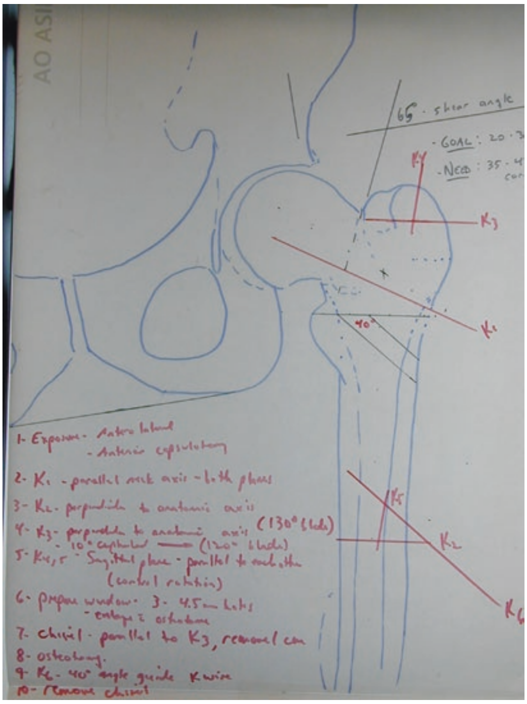

Fig. 10.2 The preoperative template for the patient in Fig. 10.1. All aspects of the surgical tact are accounted for

Doppler ultrasound for vascularity should be performed as part of the preoperative plan.

Consultations with anesthesia, vascular surgery, plastic surgery, internal medicine, cardiology, neurology, urology, psychiatry, and any other services necessary for diagnosis or treatment should be obtained well in advance of surgery.

Overall, preoperative planning should be thorough, thoughtful, and complete. It should include social services with consideration of financial and family concerns, in addition to the medical and surgical consultations listed previously. Only with proper preoperative planning can a successful result be obtained in a high percentage of elderly patients who have a nonunion.

Incidence

The reported incidence of nonunion following fracture of the femoral neck varies from less than 5% to greater than one third of observed cases within the literature [24]. Its clinical significance is highlighted by the high rates of reoperation for cases of nonunion. In two randomized controlled trials, the rates of nonunion were 34.5% and 36%, with avascular necrosis occurring in 4.9% and 6%, respectively [25, 26]. In these trials, the reoperation rate after internal fixation was 40% and 42%, respectively, with 75% of those progressing to nonunion requiring surgery [25, 26].

In comparison, avascular necrosis of the femoral head following femoral neck fracture requires reoperation in one third of patients [24]. Certain factors have been repeatedly shown to be associated with nonunion of a femoral neck fracture. To date, these factors have yet to reliably demonstrate robust predictive capacity. The association between osteonecrosis of the femoral head and femoral neck fracture nonunion is important to discuss.

Development of osteonecrosis does not preclude the ability to heal a femoral neck nonunion. Prior studies have shown union in the face of established osteonecrosis of the femoral head as well as osteonecrosis that develops following surgical treatment of the nonunion [27, 28].

Certainly, the amount of initial fracture displacement has some bearing on the development of nonunion. There is a clear relationship with fracture nonunion and displaced femoral neck fractures compared to non-displaced fractures [29]. Fracture comminution, particularly of the posterior cortex, has been linked to decrease fixation stability and increased incidence of nonunion [30]. Timing of surgery and adequacy of the reduction may be more important for the development of osteonecrosis but may also contribute to the development of nonunion [27]. Furthermore, the type of implant utilized may have some bearing on the incidence of nonunion [31, 32].

The orthopedic literature is replete with studies that look at treatment of femoral neck fractures. In a systematic review of the literature and a meta-analysis of 106 studies, the incidence of femoral neck nonunion in displaced femoral neck fractures was reported to be as high as 33% [33]. Factors felt to be associated with development of fracture nonunion included inadequate reduction, poor internal fixation, premature weightbearing, and infection [34]. Individual studies of femoral neck fractures observed varied results. Banks reported on the 20-year experience in Boston. He reported on 301 femoral neck fractures, of which 296 were displaced. There were 34 nonunions in this series [35]. In their study of over 1500 femoral neck fractures, Barnes et al. found no correlation with length of time to reduction and the development of nonunion, but the adequacy of reduction was an important factor with regard to development of nonunion [36]. In a prospective, randomized study comparing sliding hip screw and divergent cannulated pins for the treatment of displaced femoral neck fractures, the authors reported an overall incidence of nonunion of 28%, with the sliding hip screw group significantly higher. Interestingly, no correlation between adequacy of reduction and development of nonunion could be made [31].

Yang, Lin, and Chao et al. reported a series of 202 femoral neck fractures treated with three cannulated screws. Their nonunion rate was 21.7% with significant differences in nonunion rate among fracture type, reduction quality, and screw tip subchondral purchase [24]. Their study also reported a significant difference in rate of fracture nonunion based upon cannulated screw configuration. In a similar series reported by Cobb and Gibson, comprised of 65 femoral neck fractures with adequate reduction and technically sound fracture repair, the nonunion incidence was only 4.7% [37]. Garden reported the incidence of nonunion to be 16.6% in his series of 500 patients with subcapital femoral neck fractures [38]. Another report on 76 patients out of an initial 179 showed an incidence of nonunion with and without osteonecrosis of 21% [39].

In a prospective, randomized study looking at internal fixation of femoral neck fractures, 128 patients were treated with a sliding compression screw and 127 with a nail plate. Eleven percent of Garden 3 and 4 fractures went on to nonunion with the compression screw and 25% with the nail plate device [40]. These authors confirmed results of previous studies in which the presence of a varus malunion was associated with development of nonunion. Stromqvist et al. had 22 healing complications in 68 displaced femoral neck fractures. The rate was higher in the flanged nail group [41]. In a second report, Stromqvist et al. reported on 300 femoral neck fractures treated with “Hook Pins.” Of these 215 fractures were displaced, Garden 3 or 4. The incidence of nonunion was 25% overall and 35% in surviving patients [41]. Finally, Skinner and Pauwels reported that in a series of 107 displaced femoral neck fractures, 15 developed a nonunion by 1 year in fractures treated with a sliding hip screw [42].

The incidence of nonunion following surgical repair of an intertrochanteric hip fracture is rare, given the excellent blood supply and cancellous bone stock within the segment. Literature regarding intertrochanteric fracture nonunion and its treatment is limited. Limited case series regarding revision internal fixation and bone grafting following fixation failure have shown encouraging results [35, 43]. Most intertrochanteric fractures treated by conservative methods or internal fixation heal. In a large prospective study performed on over 500 intertrochanteric hip fractures, Kyle et al. reported a 2% incidence of nonunion. All of these occurred in the unstable type 4 fracture patterns treated with a variety of implants [44]. However, nonunion rates may approach 10% when excessive stripping of comminuted fractures disturbs bone nutrition [45]. Mariani and Rand reported on the treatment of ununited intertrochanteric hip fractures. Upon reviewing the initial postoperative radiographs, the authors noted an association with failed ORIF and poor reduction as well as medial displacement osteotomy [46]. Bogoch et al. reported a 6.5% incidence of nonunion following intertrochanteric hip fracture in patients with rheumatoid arthritis [47]. The authors felt the condition of rheumatoid bone was a contributing factor in healing complications.

Subtrochanteric nonunion is more common than intertrochanteric nonunion, most likely owing to its high-stress region in the femur. The incidence of nonunion reported in the literature range from 0.5 to 5% [48–50]. Nonunion of subtrochanteric fractures may be related to poor fracture reduction, unfavorable fracture pattern, poor bone quality, loss of medial column support, and early weightbearing [51–53].

Seinsheimer reported the results of 56 patients treated for subtrochanteric fracture treated with a variety of methods and implants. There were eight failures of fixation and three persistent nonunions reported [49]. The authors associated failures and nonunions with fractures that had extensive comminution in the posteromedial cortex; thus, the lateral plate is subjected to excessive medial bending forces as well as a fracture length greater than 8 cm.

Zickel reported on 84 subtrochanteric femur fractures treated by one surgeon with a cephalomedullary device. He had only one nonunion in his series [54]. Wiss et al. reported on 95 subtrochanteric femur fractures. There was only one nonunion in his series (1%) of fractures all treated with an interlocking intramedullary nail [50]. The authors performed their surgery without exposing the fracture site, and thus there was no stripping of medial soft tissues.

In their series of 50 patients with subtrochanteric femur fractures, Velasco and Comfort reported a complication rate of 21%. However, only one patient (2%) developed nonunion of their fracture [55].

Treatment Options

Femoral Neck Nonunions

In most cases, a femoral neck nonunion requires operative treatment if a patient is to regain functional use of their lower extremity. However, if the patient experiences minimal discomfort and has a sedentary lifestyle, one should treat the patient nonoperatively with mobilization out of bed and ambulation using assistive devices as needed. Surgical options vary based on several factors, including preinjury functional status, patient age, condition of the articular cartilage, and the presence or absence of osteonecrosis.

Pauwels Osteotomy

The concept behind the intertrochanteric osteotomy in the treatment of femoral neck nonunion is the conversion of principally shear forces acting on the fractured femoral neck to compressive forces. At no time is the nonunion site exposed. Healing of the nonunion is purely due to alteration in the biomechanical forces at the femoral neck. The technique relies on careful preoperative planning and meticulous attention to surgical detail. Good-quality biplanar radiographs are essential. Classically, the amount of the wedge resection is based on the angle the fracture line makes with the femoral shaft. The operation is performed at the intertrochanteric level. A 30–60° wedge is removed from the lateral cortex, and the osteotomy site fixed with a 95–120° blade plate for fixation depending on the size of the wedge is removed. The blade should enter the proximal fragment 2 cm proximal to the osteotomy site, and its tip should lie in the inferior quadrant of the femoral head [56] (Fig. 10.3). Patients should be kept partial weightbearing for 6–12 weeks until fracture and osteotomy site union has occurred.

Raaymakers and Marti reported on their experience with 66 patients treated with intertrochanteric abduction osteotomy of Pauwels performed in the setting of femoral neck nonunion [32]. Union of the femoral neck was achieved in 58 (88%) of the cohort and union of the osteotomy achieved in 65 (99%). Overall, a good or excellent result was achieved in 62% of patients. Of 30 cases requiring further intervention, 21 underwent subsequent total hip replacement for osteonecrosis. Healing occurred in the setting of femoral head osteonecrosis without the need for further treatment in 13 cases. Eight persistent nonunions following osteotomy required additional intervention, with only one final treatment failure.

Marti et al. reported on 50 patients treated with intertrochanteric abduction osteotomy of Pauwels [28]. The authors treated all patients less than age 70 with this operation regardless of the presence of femoral head necrosis. Eighty-six percent of their patients healed their femoral neck

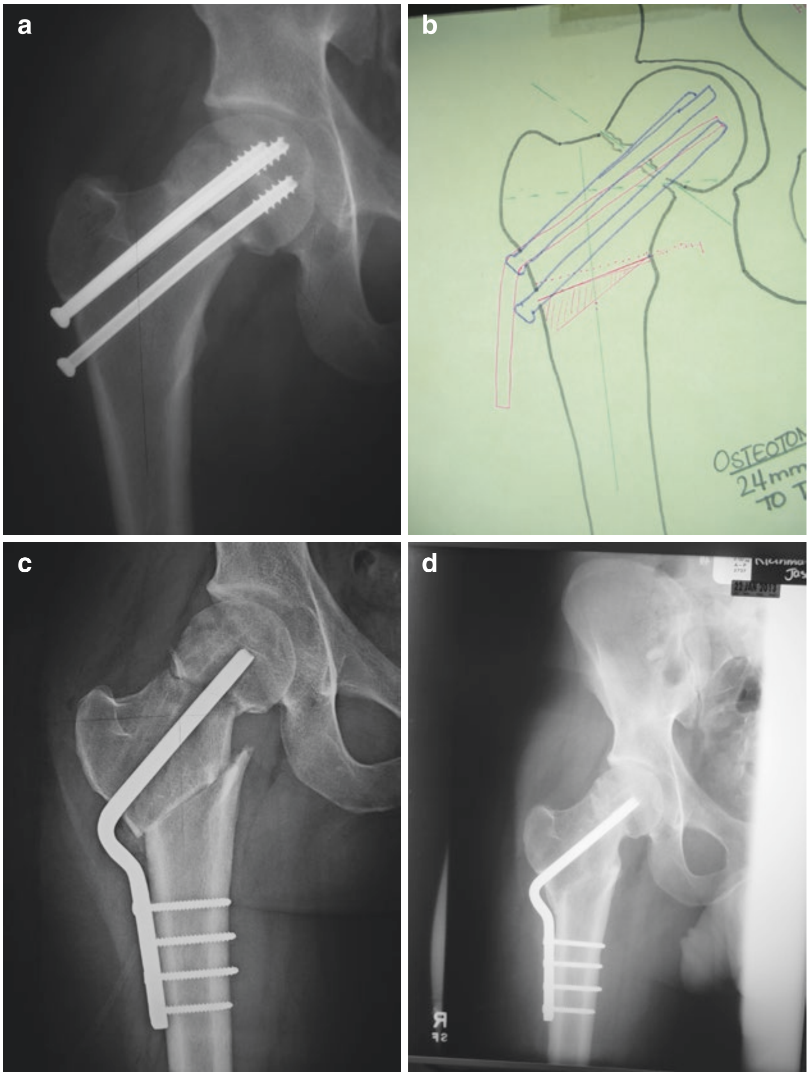

Fig. 10.3 A 21-year-old male is 6 months following ORIF of a displaced femoral neck fracture. He has developed a nonunion. (**a**) AP radiograph at 6 months. (**b**) Preoperative plan. (**c**) Immediate postoperative following osteotomy. D0 AP radiograph at 1 year following surgery, the osteotomy site and femoral neck have healed with no signs of AVN of the femoral head

fractures. Seven patients went on to hip arthroplasty, but only three of these were for persistent nonunion.

Open Reduction and Internal Fixation

The concern with open/closed reduction of the femoral neck following femoral neck nonunion is the creation of osteonecrosis, secondary to disruption of the blood supply during the surgical exposure and nonunion reduction. These procedures have been reported in small series mostly for neglected femoral neck fractures that have gone on to nonunion but also following failed internal fixation. Although neglected femoral neck fractures are rarely observed in Western society, the phenomenon persists in nations with limited medical resources. The technique involves an anterior approach to the hip (Watson-Jones) with removal of fibrous tissue from the nonunion site and placement cancellous bone graft. This is followed by screw fixation of the femoral neck under fluoroscopic control.

Elgafy, Nabil, and Gregory reported their experience with 17 cases of aseptic symptomatic femoral neck nonunions following open reduction and internal fixation [57]. These patients underwent revision internal fixation with nonvascularized fibular bone graft. Fibular autograft had a 69.2% success rate with a mean time to union of 4.8 months. Those receiving allograft had a 33.3% success rate with mean time to union of 13.3 months.

A meta-analysis by Jain, Mukunth, and Srivastava identified seven studies with a total of 406 patients undergoing internal fixation and nonvascularized fibular grafting for neglected femoral neck fracture [58]. The average time to union was 22.5 weeks (n = 170). There were 33 persistent nonunions and 11 incidences of avascular necrosis reported among 374 patients for an 11.3% complication rate.

Nagi et al. reported on 40 cases of neglected femoral neck fractures treated by open reduction and internal fixation and free fibular grafting to act as a biological implant [59]. They had 38/40 patients healed. Seven of the eight patients who had preoperative evidence of AVN revascularized without collapse. Seven patients had radiologic evidence of AVN following surgery, four of which went on to complete collapse.

Vascularized Pedicle Grafts

The theory behind vascularized pedicle grafting is that the graft will bring blood supply to the region and promote nonunion healing. Sheng-Mou et al. described this approach with the utilization of a vascularized iliac crest bone graft based on the deep circumflex iliac vessels rotated into the nonunion site. All of their five cases healed and were without aseptic necrosis of the femoral head at 2 years. This technique achieves good final functional results, but requires greater operative expertise.

Leung et al. also reported on the use of a vascularized pedicle graft in 15 patients, 6 with established nonunion of the femoral neck and 9 acute fractures with delays in treatment [60]. Their patients mean age was 38 years. Technique involved laying the vascularized iliac crest pedicle graft in a trough perpendicular to the fracture site. The tightening of the screws locks the graft into place. All nonunion sites eventually united.

Another approach involves a pedicled graft of part of the greater trochanter and quadratus muscle. This technique is utilized via a posterolateral approach to the hip and involves meticulous dissection of the quadratus femoris from the hip capsule and transection from the greater trochanter with attached bone. The capsule is incised and the graft is fashioned to fit in a trough along the posterior femoral neck. Meyers et al. reported on 32 patients who were treated with internal fixation and quadratus muscle pedicle grafting for neglected hip fracture (more than 30 but less than 90 days following their injuries) and failed ORIF [61]. Eighteen patients had supplemental autogenous cancellous grafting to the posterior femoral neck. Seventy-two percent of cases achieved union. This procedure has received good results when a true synovial pseudarthrosis exists [13]. Nair, Patro, and Babu reported similar outcomes with their experience of 17 similar patients [62]. They encountered two cases of persistent nonunion and no cases of osteonecrosis. Their series supported the utility of quadratus femoris muscle pedicle bone grafting as adjunctive therapy, demonstrating good functional results comparable to other methods.

Bhuyan retrospectively reported on 48 patients treated for neglected femoral neck fracture by internal fixation and tensor fasciae latae-based muscle pedicle bone grafting [63]. Union was achieved in 41 (85.4%) patients who were followed postoperatively for an average period of 4.4 years. Three nonunions persisted and two patients experienced avascular necrosis.

Arthroplasty

Most authors agree that in young active patients, all attempts should be made to save the hip joint. In elderly, more debilitated individuals, the option of arthroplasty is a viable one. The decision to perform hemiarthroplasty vs. total hip arthroplasty is based on several factors, including the presence of preexisting acetabular arthrosis and patient life expectancy (Fig. 10.4).

In one study of 84 total hip replacements performed for failed osteosynthesis of a femoral neck fracture, the authors reported early failure

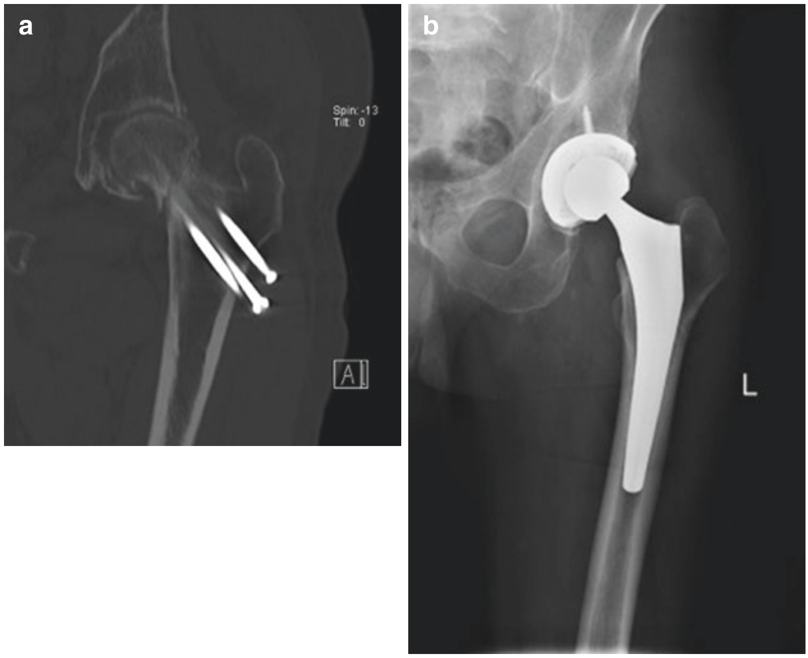

Fig. 10.4 A 68-year-old active male presents 6 months following in situ pinning of a valgus impacted femoral neck fracture. (**a**) A CT scan demonstrates nonunion. (**b**) Following non-cemented total hip arthroplasty

of 9 hips. At latest follow-up 35 hips were available for follow-up. The age and sex adjusted complication rate for total hip arthroplasty for failed femoral neck fracture was 2.5 times higher compared to arthroplasty for osteoarthritis [64]. Mabry, Prpa, and Berry et al. investigated long-term outcomes for total hip arthroplasty for femoral neck fracture nonunion [65]. Ten-year rate of component survival free of revision or removal for any reason was 93%. Ninety-six patients were pain-free or reported only mild pain at final follow-up.

If an arthroplasty is to follow a failed internal fixation, planning must include removal of all implants. In addition, the use of a stem at least two cortical diameters past the most distal screw hole should be considered.

Hip Arthrodesis

The advent of arthroplasty techniques over the past 25 years has made this operation virtually obsolete. It should be reserved for very limited indications such as failed revision osteosynthesis who are not candidates for arthroplasty, such as in the case of severe infection.

Intertrochanteric Nonunions

Patients with an intertrochanteric nonunion are more likely to be symptomatic than those who have developed a nonunion after femoral neck fracture. Therefore, most intertrochanteric nonunions require operative treatment. Osteonecrosis is not present given the lack of interruption to the intracapsular blood supply, and one is more likely to try to preserve the femoral head than with femoral neck nonunion.

Repeat ORIF with Bone Grafting

The richly vascularized, large bony surfaces associated with the intertrochanteric region lead to the low incidence of nonunion with intertrochanteric hip fractures. Implant choices for these nonunions include a sliding hip screw, intramedullary hip screw, variable angle screw, and multi-axial sliding plate (Fig. 10.5). While autogenous iliac crest bone graft remains the gold standard, newer biologics such as demineralized bone matrix, calcium phosphate, and a variety of synthetic bone morphogenic proteins are being used in concert with allograft cancellous chips.

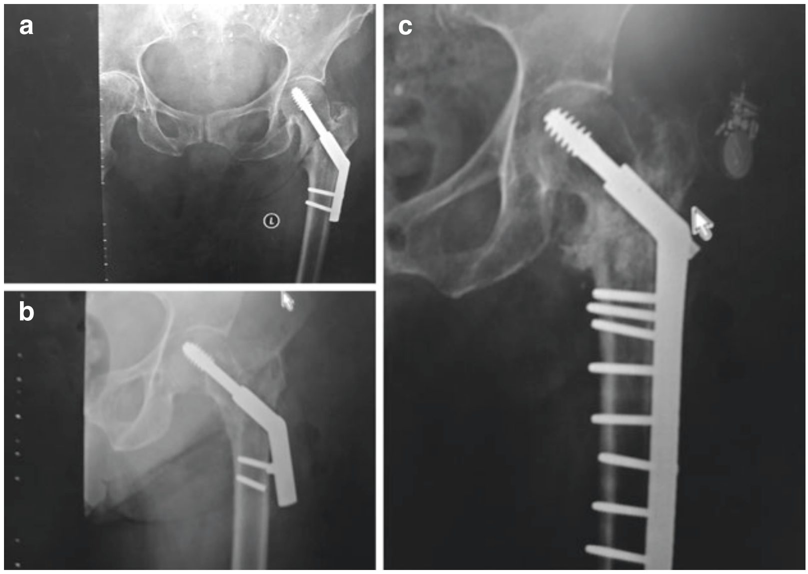

Fig. 10.5 A 73-year-old female sustained a left stable intertrochanteric hip fracture. (**a**) Immediate postoperative films. (**b**) At 4 months the fracture is ununited and the hardware has failed. (**c**) Three months following revision ORIF with a longer side plate, autogenous bone graft, and an implanted electric bone stimulator. The fracture has healed

Because there is a high association between a varus neck-shaft angle and nonunion, an attempt to alter the neck-shaft angle into a more valgus position should be made. In their series of 20 intertrochanteric nonunions treated over a 20-year period, 11 patients underwent repeat ORIF with a variety of implants and 6 receiving a bone graft. Nine of the 11 (82%) achieved union at an average of 6 months. The mean neck-shaft angle preoperatively in this series was 1120; postoperatively it increased to only 1160 [46]. Haidukewych and Berry reported similar findings in a series of 20 patients undergoing revision internal reduction and bone grafting with 19 (95%) fractures healing [66]. One persistent nonunion treated with an angled blade plate and autograft failed to heal and required revision hemiarthroplasty at 12 months postoperation. At follow-up 16 of 19 healed nonunions reported freedom from pain.

If the nonunion site is mobile, a more valgus position can be achieved by utilizing a fixed-angle device and inserting the proximal fixation point (blade or lag screw) into an inferior neck position and utilize the side plate to add valgus when brought into contact with the shaft. Implants that can be utilized include a 95–120° blade plate, 95° dynamic condylar screw or a sliding hip screw.

Osteotomy

Medial displacement osteotomy similar to that of Demon and Hughson has been described for the treatment of intertrochanteric nonunions [48]. The concept behind the operation is to medialize the shaft and achieve a valgus position of the proximal fragment which should reduce shear at the site of the nonunion. The procedure is performed via an anterolateral approach, direct visualization of the nonunion site occurs, and the wedge removed from the intertrochanteric region is a good source of bone graft. The osteotomy is fixed with a 130° blade plate. The trochanteric fracture is wired back to the plate and shaft.

Sarathy et al. reported on six patients with intertrochanteric nonunions treated with this procedure [48]. The authors reported healing in all cases. Potential complications associated with this treatment method include AVN of the femoral head, risk of future lateral compartment knee arthritis, difficult conversion to total hip if needed, and failure of trochanteric union.

Arthroplasty

There are few series of arthroplasty, either hemi or total, reported for intertrochanteric hip fracture nonunions. While treatment to preserve the femoral head is usually preferred for young patients, salvage treatment with hip arthroplasty may be considered for older patients with poor bone quality, bone loss, or articular cartilage damage. Haidukewych and Berry reported 60 patients with hip arthroplasty for failed treatment of intertrochanteric hip fractures [67]. Thirty-two patients underwent total arthroplasty, while 28 were treated with hemiarthroplasty. All patients reported improvement in pain and functioning with 87.5% of patients free from any implant revision at 10-year follow-up. Salvage arthroplasty presents increased operative challenges and risk of medical complication within the older patient but can provide good pain relief and functional improvement.

Patients with systemic diseases such as rheumatoid arthritis, Parkinson's disease, or AVN should undergo total hip arthroplasty [47, 68]. Elderly less functional patients with good acetabular cartilage can be considered for endoprosthetic replacement.

Implant choice is dependent on the amount of bone loss following resection of the proximal fragment. A significant amount of proximal femoral bone loss may require the use of a calcar replacing stem. Newer stem designs and improved metallurgy with superior alloys may obviate the need for such implants.

The biggest pitfall in the use of prosthetic replacement for these fractures is unsecured greater trochanteric fixation if a separate fragment. With failure of trochanteric union following arthroplasty, the patient is at higher risk for postoperative dislocation.

Subtrochanteric Nonunions

Nonunion following subtrochanteric fracture is more common than either femoral neck or intertrochanteric fracture. To date there have been no large clinical series to guide the clinician treating a subtrochanteric nonunion. Deformity, bone loss from prior hardware, and the high stresses of the subtrochanteric region of the femur pose challenges to achieving union. Similar to intertrochanteric nonunions, osteonecrosis is rarely present. Furthermore, the large size of the femoral head and neck segment makes repeat internal fixation a better treatment option and prosthetic replacement. Haidukewych and Berry described their institution's experience with 21 patients with subtrochanteric nonunion [51]. Implants used for revision internal fixation included cephalomedullary nail, standard antegrade femoral nail, fixed-angle blade, sliding hip screw, dynamic condylar screw, and dual large fragment plates. Eighteen of twenty-one patients had bone grafting. Twenty of twenty-one nonunions healed. Overall the series demonstrated high rate of union and functional improvement with multiple fixation techniques.

Intramedullary Nailing

The treatment of subtrochanteric nonunions depends in part on what initial treatment was utilized. Prior to the 1990s, implant options for the treatment of these nonunions was limited. In cases where a fixed-angle device and side plate were used to fix the fracture, conversion to a reamed, locked intramedullary nail is a very good option.

If this device is selected, a cephalomedullary-type nail should be used. The operation is performed on a radiolucent flat table. All hardware is removed utilizing previous incision. An anterolateral approach to the hip is performed if needed to correct any malpositioning. Antegrade intramedullary nailing is then performed either through the greater trochanter or a starting point just anterior to the piriformis fossa. If the nonunion site is not violated, autogenous bone grafting need not be performed.

Classically, intramedullary nailing is performed utilizing a fracture table. The table achieves fracture reduction through sustained longitudinal traction. A perineal post provides a fulcrum against which traction is applied. The design of most fracture tables allows circumferential access to the extremity for manipulation, surgical exposure, and imaging. Nailing can be performed with the patient in the lateral decubitus or supine position. The advantages of a lateral decubitus position include improved access to the piriformis fossa, especially in obese patients or those with ipsilateral hip disease with decreased hip range of motion. Disadvantages of the lateral position include respiratory compromise for patients with pulmonary injuries, valgus angulation of the fracture, difficulty in determining proper rotation, and greater difficulty inserting distal locking screws. There are several advantages to the supine position, including ease of setup, less respiratory compromise, better fracture alignment, and easier distal screw insertion. A proper entry point is critical to insure proper nail placement and fracture reduction. A 2 cm longitudinal incision is made one handsbreadth proximal to the great trochanter in line with the femoral shaft. The fascia of the maximus is incised, and the muscle bluntly splits in line with its fibers down to the piriformis fossa. A clamp is placed in the piriformis fossa, its position confirmed with fluoroscopy and spread open upon withdrawal. A guide pin is then placed into the piriformis fossa and checked on the AP and lateral views. Next, the guide pin is over-reamed to gain entry to the proximal fragment. Medial portal placement should be avoided, as this may cause a femoral neck fracture. Portal placement laterally may lead to comminution and varus alignment in proximal fractures. Alternatively, an awl may be placed in the piriformis fossa and the proximal femur opened by creating a pilot hole. If this technique is chosen, a larger skin incision will be required.

If a subtrochanteric nonunion is treated with an intramedullary nail, it should be reamed and statically locked. Supplemental bone grafting may be performed. If a subtrochanteric fracture treated with an IM nail goes on to nonunion, it can be treated with an exchange nail or converted to internal fixation (Fig. 10.4).

Revision Open Reduction and Internal Fixation

In these cases, repair of the nonunion follows more traditional approach of direct exposure of the nonunion with revision fixation and autogenous cancellous bone grafting.

The operation may be performed on or off the fracture table. Initially, all hardware is removed via the previous incision. If the nonunion is of the hypertrophic type, revision fixation with a fixed-angle device of the surgeon's choice may be sufficient to treat the nonunion. If the nonunion is of the oligo- or atrophic type (most commonly), autogenous bone grafting is required. Most agree that eight cortices of screw fixation distal to the nonunion site are required in the proximal femoral shaft for secure fixation [63] (Fig. 10.6).

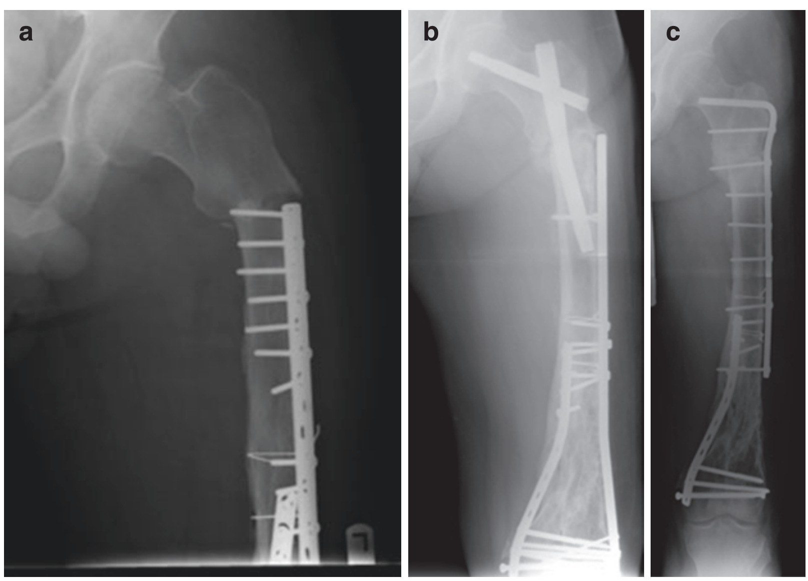

Fig. 10.6 A 52-year-old male who is 20 years s/p repair of a previous femur fracture after MVA. (**a**) Initial X-rays demonstrate a subtrochanteric fracture above the previous hardware. (**b**) At 4 months the patient has an established nonunion following IM nailing. (**c**) Six months following nonunion repair with plate and screw compression and autogenous bone graft the fracture is healed

Summary

For most nonunions encountered by orthopedists, treatment includes reversing the causative factors involved in the development of the nonunion. Thus, in cases of gap, fracture ends are compressed; in cases of avascularity, autogenous bone grafting is utilized; and in cases of excessive motion, stabile internal fixation is required to properly treat the nonunion. While all of these conditions apply to the proximal femur, the additional biomechanical factors related to the hip must be taken into account to properly treat the established nonunion of the hip.

The techniques available for the treatment of these ununited fractures are somewhat technically demanding. However, with newer implants and synthetic bone grafting at its infancy, the already relatively high success rate seen with these injuries can be expected to increase, while morbidity associated with their performance decrease.

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