Original Article

Treatment of Femoral Neck Fractures with Intramedullary Fixation with Integrated Interlocking Lag and Compression Screws

Bradley Lezak, Roberto Hernandez-Irizarry[1], Stephen Quinnan[2]

NYU Langone Orthopedics, NYU Langone Health, New York, NY, [1]Emory School of Medicine, Atlanta, GA, [2]Paley Institute, West Palm Beach, FL, USA

Abstract

Objectives: (1) To describe our operative technique for femoral neck fractures using an intramedullary device with integrated compression screws. (2) Retrospective analysis of patients treated with intramedullary fixation with interlocking lag and compression screws for femoral neck fracture (3). To compare our results to published literature on more classic fixation techniques. **Design:** Single-center retrospective cohort. **Setting:** Level 1 trauma center. **Patients/Participants:** Thirty-eight patients with 39 femoral neck fractures were treated with internal fixation. Only patients treated with intramedullary fixation with integrated interlocking lag and compression screws were included; patients treated for femoral neck fractures with a sliding hip screw, screw fixation alone, or intramedullary devices without integrated interlocking screws were excluded. Our final cohort consisted of 19 patients (47% female) with an average age of 50 (27–82) who had 15 (79%) isolated femoral neck fractures and 4 (21%) femoral neck-shaft combined fractures. **Intervention:** Internal fixation with intramedullary fixation using interlocking lag and compression screws for femoral neck fracture. **Outcome Measurements:** Quality of reduction, radiographic healing, and radiographic assessment of nonunion/avascular necrosis (AVN). **Results:** Follow-up time was on average 50 months (range: 34–84), with a median of 50 months (interquartile range: 42–56). Nineteen patients (100%) had successful healing without further intervention. There were no nonunions, and 2 (10%) patients developed AVN leading to conversion to total hip arthroplasty. **Conclusion:** Femoral neck fractures are challenging to manage due to their intracapsular location and the tenuous blood supply to the femoral head. The use of intramedullary devices with integrated lag and compression screws is an effective method for the operative fixation of femoral neck fractures. Level of evidence: Level IV therapeutic.

Keywords: *Compression screw, femoral neck fracture, hip fracture, intramedullary nail, lag screw*

Introduction

Fractures of the proximal femur are a major burden to communities worldwide. More than 300,000 femoral neck fractures occur annually in the United States,[1] and this number is expected to increase substantially in the coming years given the aging of the overall population. These fractures occur in a bimodal distribution, with more high-energy trauma resulting in high-risk fracture patterns in the younger population and low-energy fractures associated with poor bone quality in the older population. Unfortunately, treatment of these injuries has proven challenging in both groups with high complication rates. This is especially true for completely displaced fractures where complication rates include 10%–30% nonunion and 20% avascular necrosis (AVN).[2,3]

Given the difficulties of treating femoral neck fractures, there have been many investigations into the optimal treatment strategy of these fractures. Several studies favor arthroplasty for the treatment of many geriatric patients with completely displaced fractures.[4,5] There are also investigations regarding the optimal method to repair these fractures, especially in younger and more active patient populations.[6,7] These studies have mainly focused on comparing the two most commonly used strategies of either percutaneous screws or a sliding hip screw. These two fixation strategies offer contrasting advantages and disadvantages, but both have suboptimal rotational stability to facilitate the healing of these fractures.[8,9] In recognition of the shortcomings of traditional implants in controlling rotation in the treatment of femoral neck fractures, several manufacturers have more recently released plating systems designed to improve rotational control.

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Address for correspondence:
Dr. Bradley Lezak, Nyu Langone Health, New York, NY, USA.
E-mail: bradley.lezak@nyulangone.org

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Recent studies have demonstrated that implants containing integrated interlocking lag and compression screws are superior to standard cephalomedullary nail constructs with a single lag screw in the treatment of intertrochanteric fractures of the hip.[10,11] The two major differences observed with these devices are the rotational stability provided by the integrated implant design and the increased amount of compression that can be achieved, both of which favor the interlocking screw construct. Implants with integrated interlocking lag and compression screws, which have both the superior mechanics of an intramedullary device and excellent control of rotational forces, have not previously been reported for the treatment of femoral neck fractures.

Given the potential improvement in mechanical stability over either a sliding hip screw or cannulated screws and the clinical success in the treatment of intertrochanteric fractures, we began using an intramedullary device with integrated interlocking lag and compression screws for the treatment of femoral neck fractures at our institution. The goal of this study was to describe our operative technique, perform a retrospective analysis of patients treated with this technique, and compare our results to those published regarding more classic fixation techniques for the treatment of displaced femoral neck fractures.

Materials and Methods

After approval from our institutional review board, all adult patients treated for a femoral neck fracture with a short INTERTAN® nail (Smith and Nephew, Memphis, TN) or either a long INTERTAN® or META-TAN® nail (Smith and Nephew, Memphis, TN) for all combined neck-shaft fractures at our level 1 trauma center by a single surgeon (SQ) from January 1, 2011, to March 1, 2020, were reviewed. Inclusion criteria included patients who: (1) were older than 18 years of age at the time of injury, (2) presented with a femoral neck fracture (OTA/AO 31-B), (3) underwent operative fixation by SQ, and (4) had at least 3 months of follow-up. Patients with combined femoral neck and shaft fractures were also included. Exclusion criteria included: (1) patients <18 years of age and (2) vulnerable subjects (pregnant, prisoners, etc.). The institutional radiographic database was used to classify fractures. Fractures were classified using preoperative anteroposterior plain radiographs of the hip, as well as computed tomography (CT) scans performed in the emergency room. Demographic characteristics and clinical profiles including age, gender, smoking status, comorbidities, and follow-up were recorded. The choice of fixation device, the operative approach, and the need for capsulotomy were determined by the senior author on a case-by-case basis. The quality of the reduction was evaluated as previously described by Haidukewych *et al.*; the quality of reduction was graded as (1) excellent (<2 mm of displacement and <5° of angulation), (2) good (2–5 mm of displacement and/or 5–10° of angulation), (3) fair (>5–10 mm displacement and/or >10–20° of angulation), or (4) poor (>10 mm of displacement and/or >20° of angulation or any varus). Two independent reviewers evaluated the quality of the reduction (RH and BL), and inter-reliability was measured and found to be excellent at 0.86. Data were analyzed using the R statistical package (R version 3.6.1, Vienna, Austria).

A total of 38 patients with 39 femoral neck fractures were treated with internal fixation by a single surgeon (SQ) at our institution. Our final cohort consisted of 19 patients (47% of females) with an average age of 50 (27–82) who had 15 (79%) isolated femoral neck fractures and 4 (21%) femoral neck-shaft combined fractures. Demographic data are summarized in Table 1.

Surgical technique

Patients are administered general endotracheal anesthesia and positioned on a fracture table or supine on a flattop table on a case-by-case basis. Most frequently a fracture table is employed with the specific protocol that follows. An attempt at closed reduction of the fracture is first performed.

Table 1: Baseline demographic data

	Patient cohort
	***n* (%)**
Age	50 (27–82)
Sex	
Male	10 (52.6)
Female	9 (47.4)
Fracture classification (AO-OTA)	
31B1	7 (36.8)
31B2	11 (57.9)
31B3	2 (5.3)
Combined neck-shaft fracture	
Yes	4 (21.1)
No	15 (78.9)
ASA score	
1	3 (15.8)
2	10 (52.6)
3	4 (21.1)
4	0
5	2 (10.5)
Smoker	
Yes	1 (5.3)
No	18 (94.7)
Diabetes	
Yes	0
No	19 (100)
Renal disease	
Yes	1 (5.3)
No	18 (94.7)
Time to surgery (days)	1.5 (0–6)
Follow-up time (months)	50 (34–84)

Summarized data are represented as median (IQR). ASA: American Society of Anesthesiologists, IQR: Interquartile range, AO-OTA: 31-B

If closed reduction is successful at achieving anatomic reduction, then prepping and draping proceeds with the leg in the position of optimal reduction. If the reduction is not anatomical, then the surgeon can plan for an open reduction. In this scenario, all traction is released, and the injured leg is placed in a somewhat adducted position before prepping and draping. This positioning allows for optimal relaxation of the anterior thigh muscles to perform a standard Smith–Peterson anterior approach to the hip. The approach is performed, and the fracture is exposed.

Before reduction attempts, a guidewire is placed into the greater trochanter in the appropriate position for placement of a cephalomedullary nail. Intraoperative fluoroscopy is used to calculate an exact entry point [Figure 1]. Following nail placement, an unscrubbed assistant applied traction and assists with manipulation through the fracture table. This method provides the benefits of traction from the table while minimizing the difficulty and soft-tissue damage caused by having the leg reduced and in traction during the approach.

The fracture is further manipulated into an anatomic reduction using a mix of reduction techniques such as joy stick wires, tenaculum bone clamps, a Jungbluth clamp, and/or a ball spike pusher. When an anatomic reduction is achieved, a guidewire is placed through the jig for the intramedullary nail and into a center–center position within the femoral head. An additional guidewire is then placed away from the nail and outside of the path of the lag and compression screws, usually superior to the lag screw, until it traverses the fracture. The initial guidewire which will be used for placement of the lag screw is then advanced across the hip joint into the acetabular fovea. A properly placed guidewire should end up caudal to the weight-bearing dome in an essentially nonarticulating part of the joint so that this does not cause hip damage. This method assists in improving control of the head fragment during placement of the screws. However, once the wire is advanced across the joint no further manipulation of the fracture or hip joint should be performed to eliminate the possibility of bending the wire and causing it to shear during off during the remainder of the procedure.

The compression screw hole is drilled next and the antirotation rod is placed through the jig providing another point of fixation across the fracture site during lag screw placement. The lag screw is then drilled and advanced. If the patient has very dense bone, it may be necessary to tap the bone ahead of placing the screw to prevent rotation of the head during lag screw placement. Once the lag screw is in place, the compression screw can be applied to achieve compression. It should be noted that the amount of compression with a femoral neck fracture will be less than what is expected with an intertrochanteric fracture. For this reason, compression should be performed cautiously, and if at any point the lag screw begins to pull out, it may be necessary to advance it deeper into the subchondral bone. This happened twice in our series and both times additional advancement of the lag screw was possible and sufficient to restore optimal compression and fixation positioning.

For neck-shaft fractures, treatment of the shaft fracture proceeds as if it was an isolated injury before approaching the femoral neck. This allows the surgeon to focus on the reduction of the shaft without juggling two reductions and greatly improves the ability to perform a manipulative reduction of the femoral neck before fixation. Multiple blocking wires are often used to ensure concentric reaming and a nail path that is centered in the femoral shaft [Figure 2]. Femoral rotation can be challenging to gauge in neck-shaft fractures. In these cases, the femoral bow can be an additional clue that the rotation is appropriate. A perfect lateral of the knee should be

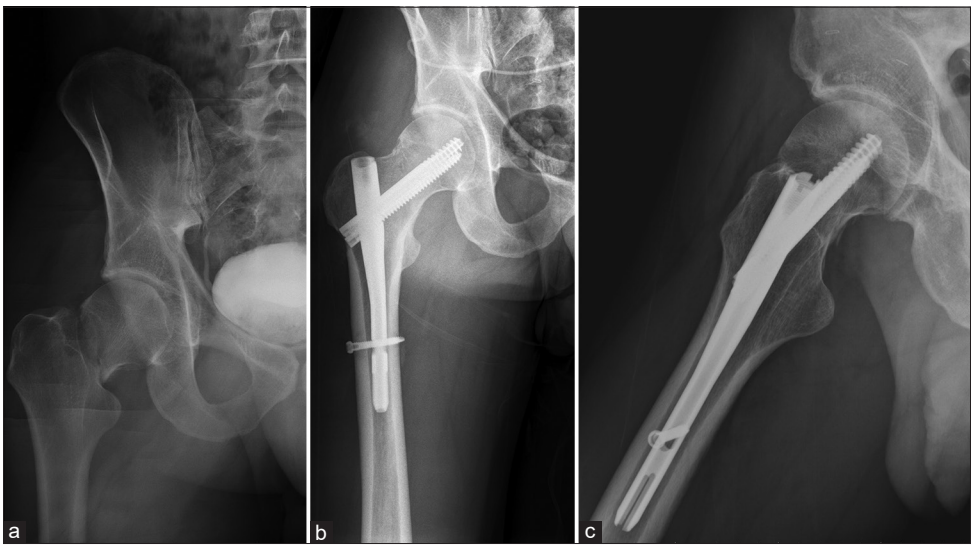

Figure 1: Clinical example of a 41-year-old male patient who sustained an isolated femoral neck fracture after a motor vehicle accident: (a) Injury film, (b and c) Postoperative films for the same patient

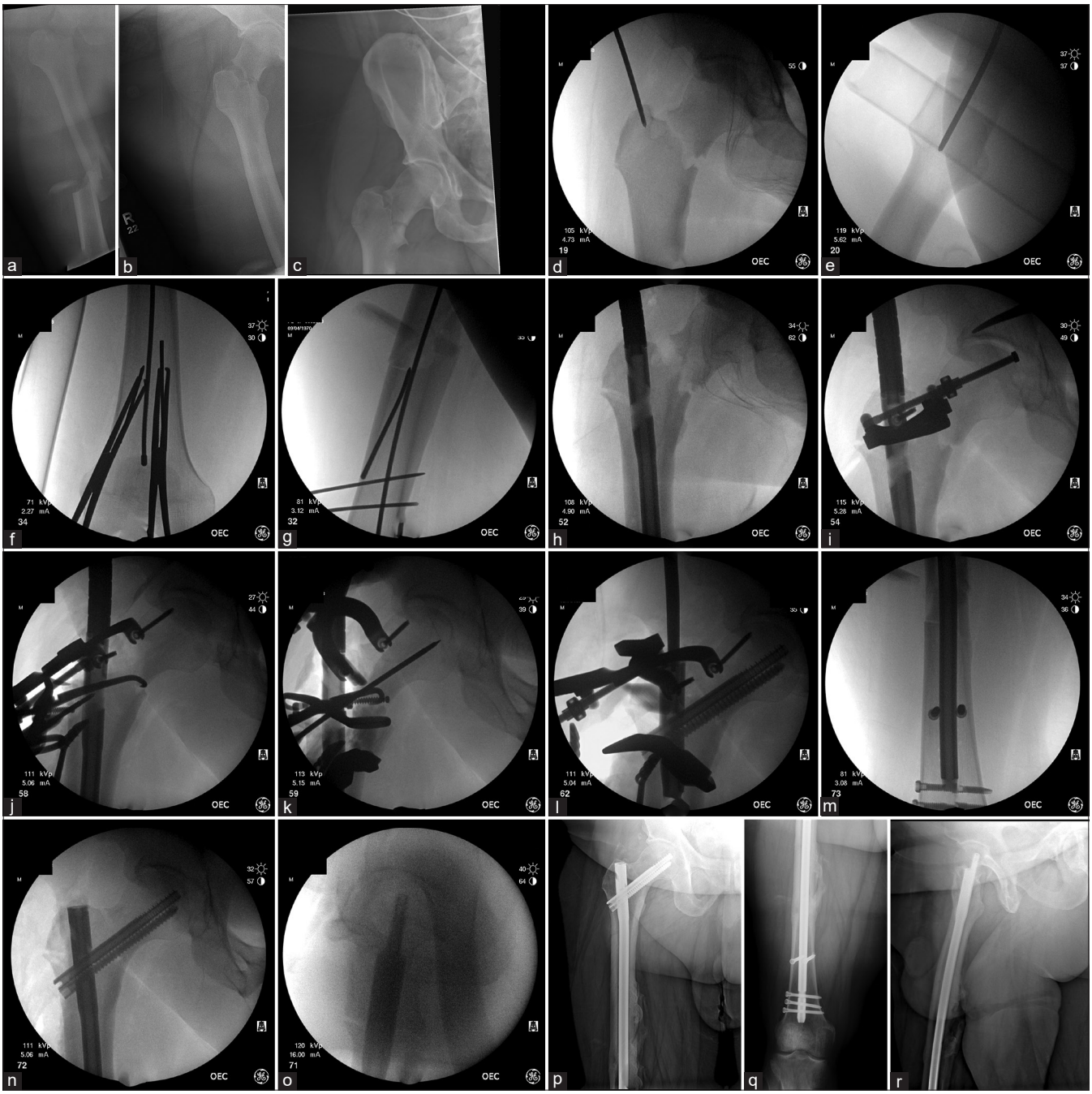

Figure 2: Technical details in a clinical example of a 47-year-old male patient with a combined femoral neck and shaft fractures: (a-c) OTA 31-B3 Femoral neck fracture combined with a femoral shaft fracture, (d-e) A proximal femur reconstruction nail with lateral offset was chosen for this case (META-TAN). The trochanteric entry point is confirmed with fluoroscopy. Of note, the femoral neck fracture is ignored at this stage of the procedure, (f-g) It is of utmost importance to ream concentrically to avoid malreduction at final implant insertion. Coronal and sagittal blocking wires are placed to control the ball tip position and the reaming path. We use clamps to hold the wires to avoid spinning while reaming, (h) The nail is inserted into the femur and is seated under fluoroscopic guidance for optimal reconstruction screw position (i-l) A direct anterior approach to the hip is used to visualize the fracture. A Jungbluth reduction clamp is used with a screw on either side of the fracture to control the fracture in multiple planes. A pointed reduction clamp is used to fine-tune the reduction. After the reduction is anatomic, the wires and finally the screws are placed with compression at the fracture site, (m) The blocking wires placed at the femoral shaft are replaced with screws, (n-o) Final images show a near anatomic reduction, (p-r) X-rays at final follow-up show healing of both fractures with clinical examination showing no deficits and full activity

obtained with fluoroscopy when the bow of the nail is located perpendicular to this view. The jig proximally should lie 15° posterior to the plane of the fluoroscopic view of the knee as the jig is built with the difference to accommodate anatomical anteversion of the hip. Making certain that the rotational profile distally is correct will both assist in reduction of the shaft fracture and also facilitate the placement of fixation in the femoral neck fracture.

After fixation of the femoral shaft is complete, it is usually possible to use the fracture table to assist in reduction of

the femoral neck fracture. Most often an open approach is required for anatomic reduction of the femoral neck in this scenario. The open reduction is performed with multiple reduction aides as described above. The wires and definitive fixation are then placed in the same manner as that described above for an isolated femoral neck fracture.

Results

There were 15 (79%) isolated femoral neck fractures and 4 (21%) femoral neck-shaft combined fractures. Because of the low number of patients and data distribution, nonparametric statistics were used. One patient (5%) was a smoker. Follow-up time was on average 50 months (range: 34–84), with a median of 50 months (interquartile range: 42.8–56.3). Nineteen patients (100%) had successful healing. There were no nonunions in our cohort, and 2 (10%) patients developed AVN [Table 2]. Of the patients who developed AVN, both had successful healing of the primary fracture but complete head collapse requiring conversion to a total hip replacement [Figure 3].

Discussion

Femoral neck fractures are challenging injuries to manage due to their intracapsular location, the tenuous blood supply to the femoral head, and the challenging mechanical environment. These injuries are usually treated operatively unless precluded by multiple medical comorbidities.[12] While there is consensus regarding operative treatment, the choice of implant and operative technique is controversial, especially in the elderly.[1,13] There is general agreement that most young patients are best treated with open reduction internal fixation to maintain their native hip joint recognizing that failure will often lead to the need for arthroplasty. However, there has been intense debate related to whether it is most optimal to perform open reduction internal fixation or an arthroplasty alternative such as hemiarthroplasty or total hip arthroplasty for older and less active patients. Nondisplaced, stable injuries are often treated with internal fixation, with the primary goal of fixation being to prevent displacement and allow safe, early motion.[14,15] Displaced injuries with comminution, however, require a more stable construct to tolerate physiologic loads immediately and in older patients are often considered an indication for arthroplasty. Internal fixation in these debates has referred to fixation strategies including multiple cannulated screws or a sliding hip screw with or without a derotational screw.

Table 2: Clinical data

Patient cohort	
	***n* (%)**
Healed	
Yes	19 (100)
No	0
AVN	
Yes	2 (10.5)
No	17 (89.5)
Nonunion	
Yes	0 (100)
No	19 (0.0)
Conversion to THR	
Yes	2 (10.5)
No	17 (89.5)
Reduction quality	
Excellent	18 (94.7)
Good	1 (5.3)
Fair	0
Poor	0
Healing time (days)	110 (64–167)

Summarized data are represented as median (IQR). Reduction quality was assessed using the clinical score developed by Haidukewych *et al*.[2] IQR: Interquartile range, AVN: Avascular necrosis, THR: Total hip replacement

Multiple studies have investigated the use of screw fixation, the dynamic hip screw, and intramedullary devices with reconstruction screws in operative fixation of femoral neck fractures.[6,9,16-19] The intramedullary device has been found to have substantial biomechanical advantages compared to screw fixation and DHS, mainly because the bending moments are transferred directly from the head and neck to the femoral shaft.[16] While previous models have shown the intramedullary implant to be more biomechanically favorable than the DHS and screw constructs, to our knowledge, there are no published clinical series documenting the results of using intramedullary implants with integrated interlocking and compression screws for the treatment of femoral neck fractures.

The results of this study showed a lower nonunion rate compared to previously published series, which is consistently about 20%.[2,3] Our rate of AVN of 10% is lower than prior reports of 19%, although still problematic. Our cohort was younger than many previous reports, which may give an advantageous healing potential with an increased risk of higher AVN rates.[20] The quality of reduction in our cohort could also contribute to a lower nonunion rate since stable anatomic reduction has been shown to be crucial for healing.[21] The results observed with the careful reduction maneuvers utilized in the study show significant promise in improving healing rates and decreasing the risk of need for conversion to total hip arthroplasty. Based on our results, more studies are warranted to better understand the role of intramedullary implants, specifically those with integrated locking and compression screws, in the treatment of femoral neck fractures.

Haidukewych *et al*. showed an 18% conversion rate of femoral neck fractures to arthroplasty at 6.6 years.[2] Our series had shorter follow-up but a significantly lower rate of conversion to arthroplasty. We understand that late

Figure 3: Clinical example of a young patient with a subcapital femoral neck who had successful healing of his fracture but developed avascular necrosis, implant cutout, and required subsequent total hip replacement (THR): (a) Femoral neck fracture upon presentation to our center, (b) Postoperative image after fixation using an intramedullary device with interlocked screws, (c-d) 6-month follow-up for the same patient with fracture healing and callus seen. Early subchondral changes of AVN can be seen, (e-f) 1-year follow-up with a healed fracture. Screw cutout can be seen with more pronounced AVN changes, (g) X-ray after implant removal. The femoral neck is well healed, however, more pronounced AVN changes can be seen, (h) Postoperative image after conversion to a THR 18 months after his trauma

development of AVN is a possibility, even after healing. We acknowledge this as a limitation of our study but note that most of our patients had >2-year follow-up and were thus at low risk of developing this complication with further follow-up. Our small sample size and retrospective nature of the study are also limitations. This appears to be relevant both for isolated femoral neck and combined with femoral neck and shaft fractures. Overall, this study shows that the use of intramedullary devices with integrated interlocking lag and compression screw fixation is an effective method for the operative fixation of femoral neck fractures.

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Conflicts of interest

There are no conflicts of interest.

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