



Fixation of AO-OTA 31-A1 and A2 trochanteric femur fractures using a sliding hip screw system: can we trust a two-hole side plate construct? A review of the literature

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- Trochanteric femur fractures are frequently fixed with a four-hole side plate sliding hip screw device, but in recent decades two-hole side plates have been used in an attempt to minimize operative time, surgical dissection, blood loss and post-operative pain.
- The aim of this review was to determine whether two-hole sliding hip screw constructs are an acceptable option for fixation of AO-OTA 31-A1 and A2 trochanteric femur fractures.
- An electronic MEDLINE® database search was performed using PubMed®, and articles were included in this review if they were reporting historical, biomechanical, clinical or outcome data on trochanteric fracture fixation using a two-hole sliding hip screw device.
- A two-hole dynamic hip screw with a minimally invasive muscle-splitting approach is recommended for fixation of AO-OTA 31-A1 simple trochanteric fractures; this implant is biomechanically safe, and allows the use of a minimally invasive muscle-splitting approach which potentially provides better clinical outcome, such as decreased surgical trauma, shorter operative time, less blood loss, decreased analgesics use, and shorter incision length. As the majority of reviewed publications relate to the dynamic hip screw, it is not clear whether the above recommendations can be extended to any other sliding hip screw device.
- An intramedullary device is recommended for all other extra-capsular proximal femoral fractures.

Keywords: dynamic hip screw; four holes; gliding hip screw; sliding hip screw; trochanteric femur fracture; two holes

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Introduction

Sliding hip screw devices were developed in the middle of the 20th century and gained popularity for surgical fixation of proximal femoral fractures in the late 1980s.¹ The latest versions of these implants, such as the dynamic hip screw (DHS), are nowadays accepted options for surgical fixation of simple trochanteric fractures (AO-OTA 31-A1), multi-fragmentary trochanteric fractures (AO-OTA 31-A2), and some subtypes of femoral neck fractures with a rather vertical fracture line (AO-OTA 31-B, Pauwels 2 & 3).²⁻¹²

Despite the wide use of sliding hip screw devices for surgical management of trochanteric femur fractures, there is no clear consensus on the optimal number of holes and screws to fix the side plate to the femoral shaft. Traditionally, most trochanteric fractures have been fixed with four-hole side plates, but in recent decades, two-hole side plates have been used in an attempt to minimize operative time, surgical dissection, blood loss and post-operative pain.¹³ Despite the lack of strong scientific evidence, this trend is partly supported by the latest Arbeitsgemeinschaft für Osteosynthesefragen (AO) recommendations for surgical fixation of AO-OTA 31-A1 fractures (two-hole to four-hole DHS are proposed), but not for AO-OTA 31-A2 fractures (four-hole DHS are proposed).¹⁴

The aim of the present study was to review the available literature in order to determine whether two-hole sliding hip screw constructs are an acceptable option for fixation of AO-OTA 31-A1 and A2 trochanteric femur fractures.

Methods

An electronic MEDLINE® database search was performed using PubMed®. The following terms were used: trochanteric femur fracture fixation, proximal femur fracture

fixation, sliding hip screw, SHS, gliding hip screw, dynamic hip screw, DHS, two holes, four holes. Abstracts were reviewed to determine whether the publications were relevant to the topic. Articles were fully reviewed and included in the present study if they were reporting historical, biomechanical, clinical or outcome data on trochanteric fracture fixation using a two-hole sliding hip screw device. There were no study design, language, geographical or publication restrictions. Date of publication was limited to the last 15 years for clinical and outcome studies. Furthermore, reference lists from articles found during this search were checked for possibly missed relevant publications using the same criteria listed above.

Review results

Brief history of sliding hip screw devices

The first sliding hip screw device was designed by Robert Danis in 1934, but was never clinically used.¹ Ernst Pohl patented a two-hole side plate with a barrel angled at 135° in 1951, and encouraging clinical results in the first 28 patients (24 fresh fractures and four osteotomies for femoral neck non-union) were reported in 1955.^{1,15} During the same period, other devices were also used for internal fixation of proximal femoral fractures, such as proximal femoral intramedullary nails and blade plates.¹ Over the next decades, sliding hip screw devices with longer side plates and more screw holes were developed, and the latest versions of these implants finally gained popularity for surgical fixation of proximal femoral fractures in the late 1980s.^{16,17}

Indications for sliding hip screw devices in trochanteric femur fracture treatment

Nowadays, modern sliding hip screw devices such as the DHS are accepted options for surgical fixation of simple trochanteric fractures (AO-OTA 31-A1) and multi-fragmentary trochanteric fractures (AO-OTA 31-A2). Saudan et al performed a randomized controlled trial (RCT) comparing 106 DHS to 100 proximal femoral nails (PFN) in the treatment of low-energy AO-OTA 31-A1 and A2 fractures in patients aged 55 years or over.¹¹ They concluded that there was no advantage to using intramedullary implants, specifically with increased costs and lack of evidence of decreased complication rate or improved outcome. Barton et al reported on an RCT including 210 patients aged 18 years or over with an AO-OTA 31-A2 fracture, treated with either a long Gamma nail or a 100 Omega 2 sliding hip screw.⁴ They concluded that the sliding hip screw should remain the implant of choice for the treatment of these fractures, because it was associated with similar outcomes and less expense. Verettas et al performed an RCT of 118 consecutive patients over 70 years of age with an AO-OTA 31-A2 fracture, treated either with a DHS or with

an intramedullary nail (Gamma nail or Endovis BA nail).¹² They also concluded that sliding hip screws could preserve their position as a safe and effective solution for treatment of AO-OTA 31-A2 fractures. In a review of the literature including 43 trials containing predominantly older people with mainly trochanteric fractures, Parker and Handoll concluded that sliding hip screw devices appeared superior for the treatment of AO-OTA 31-A1 and A2 fractures, in comparison with intramedullary nails.¹⁰ However, Jacob et al mitigated this recommendation and stated in their recent review that some AO-OTA 31-A2 fractures should not be treated with a sliding hip screw.¹⁸ Some reports showed that fractures involving intermediate or multiple fragments of the lateral wall of the greater trochanter were inherently prone to collapse and should be fixed with an intramedullary device rather than with a sliding hip screw implant,^{19–21} despite good results previously reported in this instance with a trochanter stabilizing plate, which is a modular extension of a four-hole DHS.^{22,23} Published data also showed that fractures with a large posteromedial fragment implying loss of the calcar buttress were too unstable to be fixed with a sliding hip screw device and deserved intramedullary nailing.²⁴ Finally, Socci et al published a review on the choice of implants for the treatment of intertrochanteric fractures and recommended the use of a sliding hip screw device for stable trochanteric fractures (AO-OTA 31-A), and the use of an intramedullary device for all others.²⁵

Concerning surgical treatment of inherently highly unstable intertrochanteric fractures, such as those involving the lateral cortex of the proximal femur (transverse or reverse obliquity) or those classified as subtrochanteric (AO-OTA 31-A3 and some AO-OTA 32), available scientific evidence does not support the use of sliding hip screw devices and recommends intramedullary nails.^{10,26–29}

Quantification of surgical trauma

Trochanteric fracture patients are mainly elderly with multiple comorbidities, and the aim of fracture fixation is to add minimal second hit aggression to the initial first hit of trauma, in order to improve and accelerate post-operative recovery.³⁰ However, publications on quantification of surgical trauma related to hip fracture surgery are scarce.

Wagman et al noted in a retrospective study of 349 trochanteric fractures that serum creatine phosphokinase (CPK) levels as a biochemical marker of soft tissue injury were higher in DHS patients than in PFN patients on post-operative day one, that post-operative haemoglobin decrease was greater in PFN patients probably due to the reaming process (this difference did not reach statistical significance) and that post-operative C-reactive protein (CRP) levels were not statistically significantly different between patient groups.³¹ The surgical technique used for DHS implantation involved a 7 to 10 cm long approach;

this implies that a DHS with more than two holes was used, presumably a four-hole DHS, and that a muscle-reflecting approach rather than a minimally invasive muscle-splitting approach was used.

In an RCT on AO-OTA 31-A1 and A2 fracture fixation, Hong et al compared 10 patients operated using a minimally invasive muscle-splitting approach (4 to 5 cm long skin incision) to implant a three-hole DHS, and 10 patients who received a PFN.³² There was no statistically significant difference in the absolute values and temporal changes of potential soft tissue damage marker serum levels (CPK, CRP, myoglobin).

Three publications compared the conventional muscle-reflecting DHS technique and the minimally invasive muscle-splitting DHS technique for trochanteric fracture fixation in terms of potential surgical trauma to the soft tissues.^{33–35} These reports found significantly decreased operative time, haemoglobin drop, wound drain duration, post-operative interleukin-6 levels (inflammatory response marker), blood transfusion needs and oral analgesics consumption in the minimally invasive group, a trend towards less morphine use, but no statistically significant difference for pain. As two-hole and four-hole DHS were used in both standard approach and minimally invasive approach groups, the authors concluded that the approach had more influence on these results than the length of the plate. In one of these studies, Alobaid et al also demonstrated with an angiogram review that the distance from the lower edge of the trochanteric flare to the first significant perforator artery averaged 9.3 cm (8.0 to 10.1 cm), thus allowing sufficient safe surgical field for a standard two-hole DHS (5.2 cm long) to be inserted using a minimally invasive muscle-splitting technique without active search and control of perforator branches.³³

Biomechanical studies

Failure mechanism in sliding hip screw implants is mostly represented by fracture collapse, cut-out and plastic deformation of the implant.³⁶ Rarely, pull-off of the side plate from the femoral shaft, breakage of the implant or disengagement of the cervico-cephalic compression screw from the barrel of the side plate may occur.³⁷

When a two-hole sliding hip screw device is used to fix a trochanteric fracture, the surgeon must be confident that the four cortices fixation of the side plate to the femoral shaft is sufficient to prevent pull-off of the screws from the bone. Three biomechanical studies help answering this question. Yian et al used saw bone models and cadaveric femora to show that three screws provided an optimal distribution of tensile forces to prevent side plate pull-off from the femoral shaft when surgically treating unstable trochanteric fractures (equivalent to an AO-OTA 31-A2 fracture).³⁸ However, in this study, the sliding cervico-cephalic compression screw was prevented from telescoping, which produced continuous

fracture instability and maximized the role of the side plate screws. The authors mitigated their conclusions by stating that if telescoping had been allowed, all screw tension values would have been lower, and probably two screws would have been sufficient for side plate stability.

McLoughlin et al compared the biomechanical strength and stiffness of two-hole and four-hole DHS constructs used for the fixation of unstable trochanteric fractures (equivalent to AO-OTA 31-A2 fractures) created in cadaveric femora.³⁹ They found that the two-hole DHS was biomechanically as stable as the four-hole DHS, and that there was no side plate pull-off from the femoral shaft.

Rog et al also demonstrated in a biomechanical study using a recreated AO-OTA 31-A1 fracture in an osteoporotic saw bone, that DHS constructs with a two-hole or a four-hole side plate were comparable with regard to axial and torsional stiffness and load to failure, and that there was no side plate pull-off from the femoral shaft.⁴⁰

Case series on the use of two-hole sliding hip screws in trochanteric femur fracture treatment

In 2004, Verhofstad and van der Werken conducted a retrospective case series including 148 AO-OTA 31-A1 fractures treated with a two-hole 135° DHS.⁴¹ They noted favourable healing and complication rates, two cut-outs and one side plate breakage after a fall from the bed, but no side plate pull-off. They concluded that the use of a two-hole DHS was safe for the treatment of stable trochanteric fractures, and that any further prospective, randomized study design should aim at investigating secondary outcomes, such as operative time, blood loss, length of incision, use of analgesics etc.

In 2004, DiPaola et al reported on the use of a two-hole DHS with a minimally invasive muscle-splitting approach in 13 patients.⁴² There were three AO-OTA 31-A1 fractures, seven AO-OTA 31-A2 fractures, and three femoral neck fractures. Along with operative time, healing time and outcome measure comparing favourably with historical four-hole sliding hip screw devices reports, the authors noted no cut-out and no side plate pull-off.

In 2005, Laohapoonrungrassee et al published the results of a retrospective case series of 83 AO-OTA 31-A1 and A2 fractures treated with a two-hole DHS.⁴³ They observed two cut-outs and two side plate pull-offs at seven and 13 weeks post-operatively (both pull-offs occurred in AO-OTA 31-A2 fractures). They concluded that despite these two episodes of pull-off, a two-hole DHS was adequate for fixation of simple and multi-fragmentary trochanteric femur fractures.

In 2010, Riha and Bartoníček conducted a retrospective case series including 30 patients with an AO-OTA 31-A1 fracture, and two patients with an AO-OTA 31-A2 fracture, all treated with a two-hole DHS.⁴⁴ In their protocol, the standard fixation device for AO-OTA 31-A1 fractures was a two-hole DHS, whereas this implant was only exceptionally

used for AO-OTA 31-A2 fractures, making any conclusions on the latter type very weak. They found operative time, healing time and complication rates comparing favourably with previously published results on four-hole DHS, no cut-out, and one pull-off of a side plate following a fall four weeks after fixation of an AO-OTA 31-A2 fracture. They concluded that the use of a two-hole DHS was safe in the treatment of AO-OTA 31-A1 fractures.

Randomized controlled trials on the use of two-hole sliding hip screws in trochanteric femur fracture treatment

We did not find any RCT specifically comparing the results of a two-hole versus a four-hole DHS in the treatment of AO-OTA 31-A1 and/or A2 fractures.

Literature review summary

A summary of the above findings is presented in Table 1.

Conclusion

Authors' recommendations

As summarized in Table 2, the authors recommend the use of a two-hole DHS with a minimally invasive muscle-splitting approach only for fixation of AO-OTA 31-A1 simple trochanteric fractures (Fig. 1). Using a short side plate

for these fractures is biomechanically safe. Performing a minimally invasive muscle-splitting approach also potentially provides better clinical outcome, such as decreased surgical trauma, shorter operative time, less blood loss, decreased analgesics use, and shorter incision length. This last statement would need a prospective randomized trial to be definitively scientifically proved.

The authors advocate the use of an intra-medullary device for all other extra-capsular proximal femoral fractures (AO-OTA 31-A2 and A3; Fig. 2 and Fig. 3).

The use of a side plate with more than two holes for the fixation of trochanteric fractures must be justified in all cases and should be restricted to very specific situations, as a longer plate does not provide any mechanical advantage and is potentially detrimental for the patient in terms of increased surgical trauma and second hit aggression. These specific situations are: (1) the need to use a trochanter stabilizing plate to fix an AO-OTA 31-A2 fracture involving intermediate or multiple fragments of the lateral wall of the greater trochanter – this extension plate is only usable with a four-hole DHS; (2) associated trochanteric (AO-OTA 31-A1 or A2) and diaphyseal fractures, where a retrograde intramedullary nail is used to stabilize the diaphyseal fracture and a sliding hip screw to fix the trochanteric fracture; a longer side plate with more screws overlapping the proximal end of the nail would

Table 1. Literature review key points

Literature findings

1. Available scientific evidence unconditionally supports the use of sliding hip screw devices for surgical fixation of simple trochanteric fractures (AO-OTA 31-A1); these devices are associated with similar outcomes and less expense when compared to intramedullary implants.
2. Available scientific evidence is equivocal concerning fractures involving intermediate or multiple fragments of the lateral wall of the greater trochanter and fractures involving a large posteromedial fragment, which are inherently prone to collapse (AO-OTA 31-A2); intramedullary nails might possibly be better implants than sliding hip screw devices for surgical fixation of these fractures.
3. Available scientific evidence does not recommend the use of sliding hip screw devices for surgical fixation of inherently highly unstable intertrochanteric fractures, such as those involving the lateral cortex of the proximal femur (transverse or reverse obliquity; AO-OTA 31-A3) or those with a subtrochanteric extension; in these instances, intramedullary implants are preferred.
4. Minimally invasive muscle-splitting DHS and PFN produce similar levels of soft tissue damage when performed for AO-OTA 31-A1 and A2 fractures.
5. Minimally invasive muscle-splitting DHS produces less soft tissue damage than conventional muscle-reflecting DHS when performed for AO-OTA 31-A1 and A2 fractures.
6. Minimally invasive muscle-splitting approach allows a sufficiently safe surgical exposition for a two-hole DHS to be inserted without active search and control of perforator branches.
7. Biomechanical studies support the use of a two-hole DHS in the treatment of AO-OTA 31-A1 and A2 fractures.
8. Clinical case series support the use of a two-hole DHS as a safe implant for fixation of AO-OTA 31-A1 fractures, and also possibly for fixation of AO-OTA 31-A2 fractures.
9. There are no RCT specifically comparing the results of a two-hole versus a four-hole sliding hip screw device in the treatment of AO-OTA 31-A1 and/or A2 fractures.

Note. DHS, dynamic hip screw; PFN, proximal femoral nail; RCT, randomized controlled trial.

Table 2. Authors' recommendations

	Recommendations	Justification
AO-OTA 31-A1	Two-hole DHS and minimally invasive approach	Biomechanical, clinical and biological evidence No scientific justification for four-hole DHS
AO-OTA 31-A2	Intramedullary implants	Equivocal scientific evidence with possible advantage of intramedullary implants
AO-OTA 31-A3 & subtrochanteric extension	Intramedullary implants	Definitive advantage of intramedullary implants

Note. DHS, dynamic hip screw.

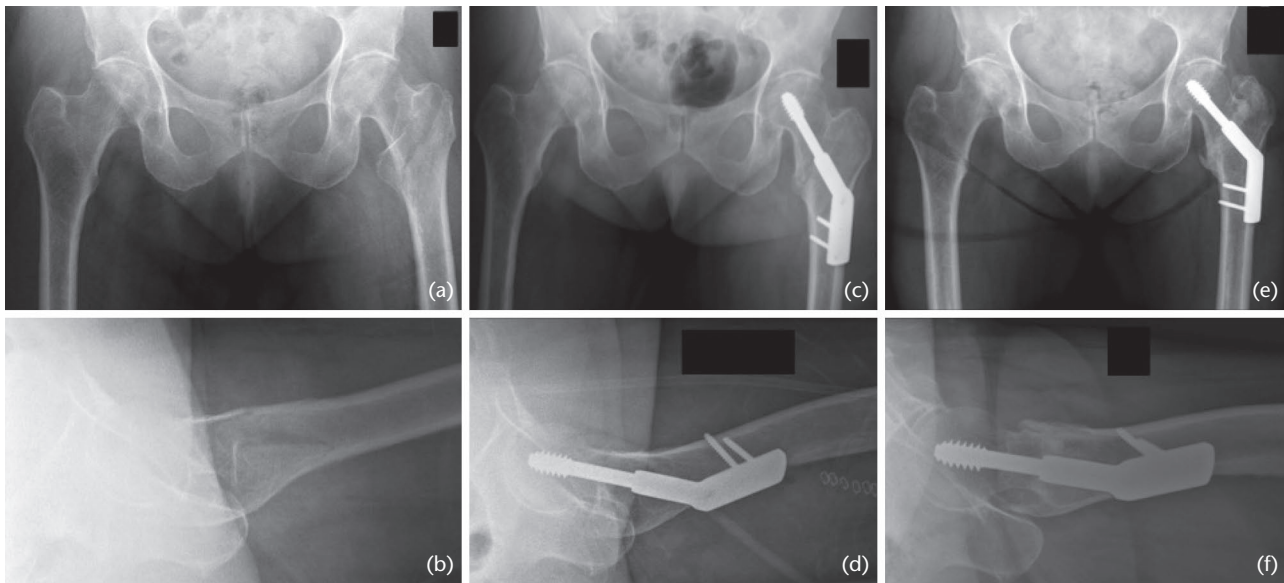


Fig. 1 Radiographs of an 82-year-old female with a left AO-OTA 31-A1 simple trochanteric fracture. (A) and (B) antero-posterior and axial views prior to fixation. (C) and (D) antero-posterior and axial views on day 0 after surgical fixation with a two-hole DHS. (E) and (F) final follow-up antero-posterior and axial views six months after surgery; the patient was able to walk with one crutch and minimal discomfort from three months after surgery. At six months, the crutch was used only for security reasons, as the patient was afraid of falling again.

Note. DHS, dynamic hip screw.

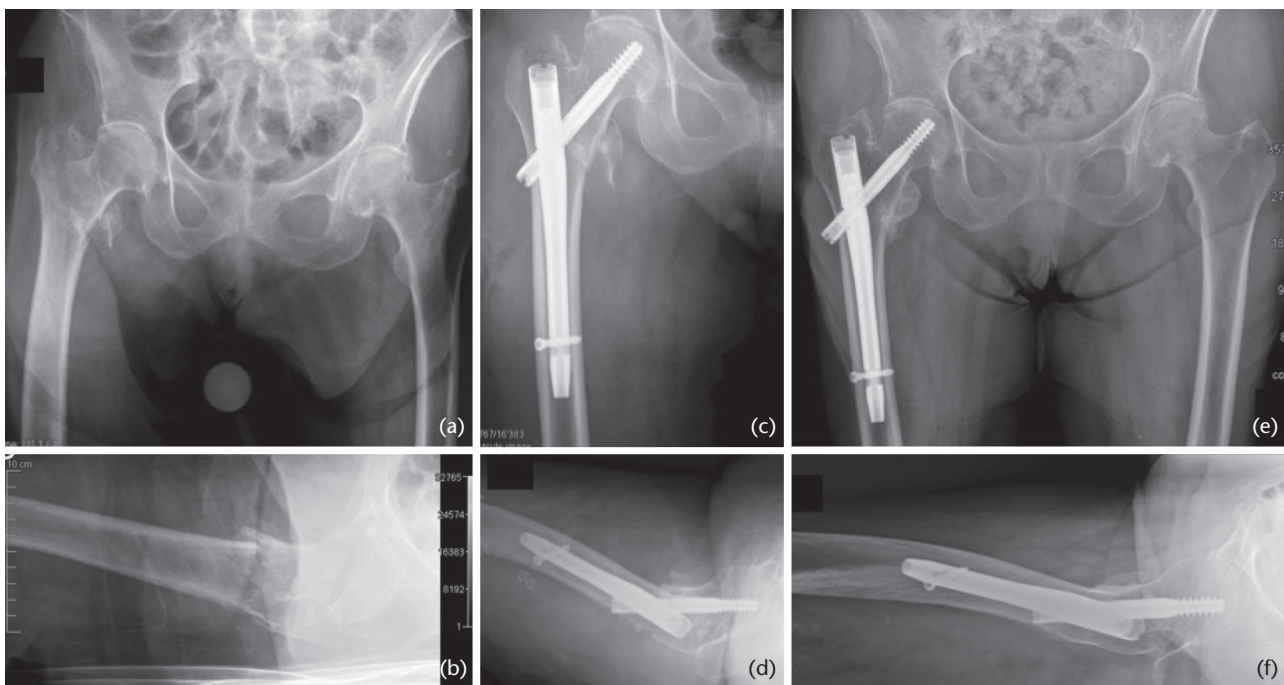


Fig. 2 Radiographs of a 94-year-old female with a right AO-OTA 31-A2 multi-fragmentary trochanteric fracture. (A) and (B) antero-posterior and axial views prior to fixation. (C) and (D) antero-posterior and axial views on day 0 after surgical fixation with a cephalo-medullary nail (Gamma nail). (E) and (F) final follow-up antero-posterior and axial views one year after surgery; the patient was able to walk with one crutch and no pain or discomfort from three months after surgery, and kept the crutch from then only for security reasons.

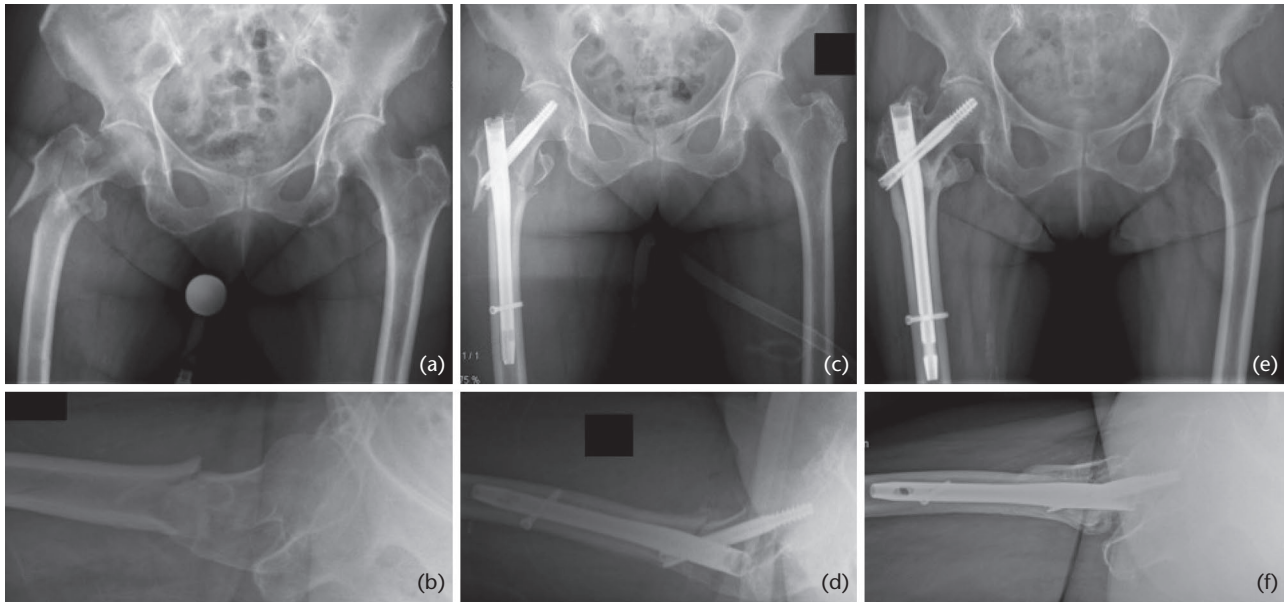


Fig. 3 Radiographs of a 90-year-old female with a right AO-OTA 31-A3 reverse obliquity trochanteric fracture. (A) and (B) antero-posterior and axial views prior to fixation. (C) and (D) antero-posterior and axial views on day 0 after surgical fixation with a cephalo-medullary nail (Gamma nail). (E) and (F) final follow-up antero-posterior and axial views 18 months after surgery; the patient was able to walk with no crutch and no pain or discomfort from two months after surgery.

theoretically be mechanically safer with lower stress risers at the interface of both implants.

The authors would like to restrict these recommendations to the use of the DHS. As the majority of reviewed publications relate to this specific implant, it is not clear whether the above recommendations can be extended to any other sliding hip screw devices. The authors would also like to point out that in addition to the right choice of implant, the main key for success in trochanteric fracture fixation is adequate fracture reduction and correct implant positioning.^{24,45,46}

Directions for future research

As stated by Verhofstad and van der Werken, any randomized controlled trial should aim at investigating secondary outcomes (operative time, blood loss, length of incision, use of analgesics), because the use of a two-hole DHS in the treatment of AO-OTA 31-A1 fractures is already known as biomechanically safe with good results in terms of fracture healing.⁴¹

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The authors declare no conflict of interest relevant to this work.

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