Comparison and analysis of reoperations in two different treatment protocols for trochanteric hip fractures – postoperative technical complications with dynamic hip screw, intramedullary nail and Medoff sliding plate

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Abstract

Background: In treatment of unstable trochanteric fractures dynamic hip screw and Medoff sliding plate devices are designed to allow secondary fracture impaction, whereas intramedullary nails aim to maintain fracture alignment. Different treatment protocols are used by two similar Swedish regional emergency care hospitals. Dynamic hip screw is used for fractures considered as stable within the respective treatment protocol, whereas one treatment protocol (Medoff sliding plate/dynamic hip screw) uses biaxial Medoff sliding plate for unstable pertrochanteric fractures and uniaxial Medoff sliding plate for subtrochanteric fractures, the second (intramedullary nail/dynamic hip screw) uses intramedullary nail for subtrochanteric fractures and for pertrochanteric fractures with intertrochanteric comminution or subtrochanteric extension. All orthopedic surgeries are registered in a regional database.

Methods: All consecutive trochanteric fracture operations during 2011–2012 (n = 856) and subsequent technical reoperations (n = 40) were derived from the database. Reoperations were analysed and classified into the categories adjustment (percutaneous removal of the locking screw of the Medoff sliding plate or the intramedullary nail, followed by fracture healing) or minor, intermediate (reosteosynthesis) or major (hip joint replacement, Girdlestone or persistent nonunion) technical complications.

Results: The relative risk of intermediate or major technical complications was 4.2 (1.2–14) times higher in unstable pertrochanteric fractures and 4.6 (1.1–19) times higher in subtrochanteric fractures with treatment protocol: intramedullary nail/dynamic hip screw, compared to treatment protocol: Medoff sliding plate/dynamic hip screw. Overall rates of intermediate and major technical complications in unstable pertrochanteric and subtrochanteric fractures were with biaxial Medoff sliding plate 0.68%, with uniaxial Medoff sliding plate 1.4%, with dynamic hip screw 3.4% and with intramedullary nail 7.2%.

Conclusions: The treatment protocol based on use of biaxial Medoff sliding plate for unstable pertrochanteric and uniaxial Medoff sliding plate for subtrochanteric fractures reduced the risk of severe technical complications compared to using the treatment protocol based on dynamic hip screw and intramedullary nail.

Keywords: Pertrochanteric, Subtrochanteric, Fracture, Reoperation, Intramedullary nail, Medoff sliding plate, Dynamic hip screw

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Background

Stable two-fragment pertrochanteric fractures are treated with good result with dynamic hip screw (DHS) devices [1, 2], but controversy remains regarding treatment of unstable pertrochanteric and subtrochanteric fractures. Dynamic fixation methods are designed to allow secondary fracture impaction to improve interfragmentary stress transfer, thereby facilitating fracture healing and unloading the implant. DHS allows dynamic compression along the axis of the femoral neck, which, depending on fracture geometry, may be more or less appropriate or effective [3, 4].

The Medoff sliding plate [5] (MSP) adds compression along the axis of the femoral shaft, thus allowing biaxial dynamisation. Lag screw sliding is optional and may be blocked by a locking screw to prevent medialisation of the femoral shaft, thereby creating uniaxial dynamisation.

Intramedullary nail (IMN) fixation is most commonly used worldwide for unstable pertrochanteric and subtrochanteric fractures and provides a strong and rigid fixation [6]. However, poor load transfer may subject the implant to high loads with increased risk of non-union, implant failure or fracture due to stress concentration [2, 7].

In Skåne, Sweden, two similar regional emergency care hospitals use different treatment protocols for trochanteric fractures. For pertrochanteric fractures considered as stable both hospitals use DHS, whereas for fractures considered as unstable within the respective treatment protocol, Helsingborg Hospital uses MSP, and Kristianstad Hospital uses IMN. All orthopedic operations performed are consecutively registered in a mutual regional database and both hospitals cover similar population based catchment areas.

The aim of this consecutive retrospective study was to analyse and compare all performed reoperations and related technical complications in all pertrochanteric and subtrochanteric fractures, treated during two years according to two different treatment protocols in two parallel consecutive case series.

Methods

The two treatment protocols for choice of fixation methods (MSP/DHS or IMN/DHS) are described in Table 1. In short, DHS was used in fractures considered as stable, whereas treatment protocol: MSP/DHS aimed to use MSP in all pertrochanteric fractures with 3 or more fragments and treatment protocol: IMN/DHS aimed to use IMN in fractures with intertrochanteric comminution or fracture extension below the trochanters. In subtrochanteric fractures treatment protocol: MSP/DHS used locked MSP and treatment protocol: IMN/DHS used IMN. The implants used were the Medoff sliding plate (MSP) or Hansson plate (DHS) (Swemac Orthopaedics, Linköping, Sweden), or IM nails (Gamma Nail (Stryker, Kalamazoo, MI, USA), Intertan and Trochanteric Anterior Nail (Smith&Nephew, Memphis, TN, USA). The DHS and MSP were combined with either a Twin hook [8] (n = 697) (Swemac, Orthopaedics, Linköping, Sweden) or a lag screw (n = 5). The Twin hook wings may be retracted, which allowed percutaneous technique with the plate left in situ when adjustment, replacement or removal of the Twin hook was needed. The MSP was used in biaxial or uniaxial mode (locking screw for the Twin hook/ lag screw). In treatment protocol: MSP/DHS repeat radiographs were obtained 10 days postoperatively when MSP was used in uniaxial mode. If axial sliding capacity of the plate was consumed (25 mm), or migration of the Twin

| Fracture type                     | Fixation method          | Treatment protocol: MSP/DHS | Treatment protocol: IMN/DHS |
|-----------------------------------|---------------------------|-----------------------------|-----------------------------|
| Pertrochanteric                   |                           |                             |                             |
| Stable - 2 fragments              | DHS                       |                             |                             |
| Unstable - 3 or more fragments   | MSP biaxial               |                             |                             |
| Unstable - no lateral and/or no posterior support | MSP uniaxial (locked) |                             |                             |
| Stable                           | DHS                       |                             |                             |
| Intertrochanteric comminution and/or subtrochanteric extension | DHS |                             |                             |
| Subtrochanteric                   |                           |                             |                             |
| Fracture extension below >2 of MSP plate screws | IMN or long DHS |                             |                             |

*Medoff sliding plate (MSP) / dynamic hip screw (DHS)
*Intramedullary nail (IMN) / dynamic hip screw (DHS)
*Choice of treatment based on Jensen Michaelesen and Seinsheimer classifications including analysis of lateral and posterior support
*Choice of treatment based on intertrochanteric fracture comminution or subtrochanteric fracture extension
*Approximately 10 cm below the lesser trochanter
hook/lag screw was observed, the locking screw was routinely removed to allow biaxial dynamisation.

From the mutual regional orthopedic surgery database all orthopedic operations performed in the two Skåne regional hospitals during 2011 and 2012 were assessed. Data on all operations with a surgical procedure code for plate or intramedullary nail, and any of the International Code of Disease (ICD-10) codes S7200/01 (femoral neck fracture), S7210/11 (pertrochanteric fracture) or S7220/21 (subtrochanteric fracture), were retrieved ($n = 892$). The total number of previously performed trochanteric hip fracture surgeries was also derived from the database for each individual non-specialist surgeon.

All fractures were classified by evaluation of available pre-, intra- and postoperative radiographs. Following exclusion of femoral neck and basicervical fractures, a final study group of 856 patients was set (Fig. 1).

Pertrochanteric fractures were classified according to Jensen Michaelsen (JM) [9], and subtrochanteric fractures according to Seinsheimer (SH) [10]. In the study analysis JM types 1–2 (2 fragments) were considered as stable and JM types 3–4–5 (3 or more fragments) and all subtrochanteric fractures as unstable.

Fractures were also classified regarding lateral and/or posterior support, defined as the presence of intact cortical bone of the femoral shaft at the level of or above the center of the lag screw entry hole.

Fracture classification was performed by a single examiner. To assess interobserver variability 75 randomly selected fractures were also classified by a second independent observer.

To find relevant reoperations all additional orthopedic operations performed in any Skåne regional hospital after the index operation on the 856 study patients between

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**Fig. 1** Flow chart depicting the collection of the final study cohort ($n = 856$) and all technical reoperations ($n = 40$) with numbers given in brackets for treatment protocol: Medoff sliding plate/dynamic hip screw (MSP/DHS) followed by treatment protocol: intramedullary nail/dynamic hip screw (IMN/DHS).
January 2011 and April 2014, thus with a follow-up time span from 16 to 40 months, were derived from the regional database. After exclusion of other orthopedic surgical procedures and of reoperations other than technical, a final total of 40 technical reoperations was set (Fig. 1). For these cases, technical reoperations and the postoperative course of events were analysed in detail using all available postoperative radiographs and medical charts. Quality of fracture reduction and implant positioning was classified as good, acceptable or poor [11–13] and definitions were set to analyse reoperations, final outcome and related technical complications in the four categories adjustment (removal of locking screw, no technical complication) or minor (percutaneous withdrawal, replacement or removal of Twin Hook/lag screw due to penetration, followed by fracture healing), intermediate (reosteosynthesis due to non-union, femoral shaft stress fracture or varisation/cut-out) or major (loss of hip joint integrity with Girdlestone procedure or hip joint replacement, or persistent nonunion).

Statistical analysis
Statistical analyses were made using Analyse-it Standard Edition 3.20 ( Analyse-it Software, Ltd. Leeds, UK). Median was given with 25th and 75th percentiles. Comparisons between groups were made using the chi-squared test or by calculation of relative risk (RR) with 95% C.I. Results with a p < 0.05 were considered as significant.

Results
Study group
The treatment protocol: MSP/DHS (n = 492) and treatment protocol: IMN/DHS (n = 364) groups were similar regarding age, gender, distribution of different fracture subtypes, number of surgeons and surgeons experience. Median age was 85 (79–89) years and two thirds of the patients were female. The operations were made by a surgeon having performed 25 or more previous trochanteric hip fracture surgeries in 68% of the patients in treatment protocol MSP/DHS and in 87% in treatment protocol IMN/DHS, respectively. 16% of all fractures were classified as stable pertrochanteric, 70% unstable pertrochanteric and 14% subtrochanteric. Lack of lateral support was noted in 19% and of posterior support in 48% of all fractures.

In assessment of interobserver variability, classification agreement was 75% (56/75) for specific JM/SH fracture subtypes, whereas 97% (73/75) were uniformly classified as stable or unstable.

Fixation methods
A vast majority of stable pertrochanteric fractures were treated using DHS in both treatment groups. Unstable pertrochanteric fractures, according to study fracture classification, were operated with MSP in biaxial mode (82%) or in uniaxial mode (9%) in treatment protocol: MSP/DHS. In 9% DHS was used, not compliant with the treatment protocol. In treatment protocol: IMN/DHS 35% were operated with IMN and 65% with DHS, but of all fractures JM types 3–4–5 only 2% (6/251) had lack of lateral support and were treated with DHS, contradicting the treatment protocol. Subtrochanteric fractures were treated using IMN (92%) or DHS (8%) in treatment protocol: IMN/DHS, and with MSP in uniaxial (61%) or biaxial mode (7%), with IMN (23%) or with DHS (9%) in treatment protocol: MSP/DHS (Table 2).

Treatment groups and reoperations
There was a total of 40 technical reoperations in 856 patients, 20 in treatment protocol: MSP/DHS (4.1%, Table 3) and 20 (5.5%) in treatment protocol: IMN/DHS (p = 0.33, Table 4). Quality of fracture reduction and of implant positioning in the 40 reoperated patients appeared to be similar in the 2 treatment groups (Tables 3 and 4). 13 technical complications (2.6%) occurred in treatment protocol: MSP/DHS and 19 (5.2%) in treatment protocol: IMN/DHS (p = 0.049). The rate of intermediate and major complications was more than 3 times higher (RR 3.6, 1.5–8.9) in treatment protocol: IMN/DHS (16/364, 4.4%) than in treatment protocol: MSP/DHS (6/492, 1.2%) (p = 0.0037). Documented absence of fracture healing (joint replacement, Girdlestone procedure or persisting nonunion) occurred in 10 cases in treatment protocol: IMN/DHS (2.7%) and in 3 cases (0.61%) in treatment protocol: MSP/DHS (p = 0.011, RR = 4.5, 1.3–15) (Fig. 2).

Stable pertrochanteric fractures had a total reoperation rate of 0.75%, unstable pertrochanteric 3.2% and subtrochanteric 16%. Intermediate and major technical complications were more than 4 times more frequent in treatment protocol: IMN/DHS than in treatment protocol: MSP/DHS in both unstable pertrochanteric fractures (p = 0.018) and in subtrochanteric fractures (p = 0.031, Table 5).

Implants and reoperations
Total reoperation rate with biaxial MSP was 1.3%, with DHS 3.1% and with IMN 8.4% (Fig. 3). With MSP in uniaxial mode 13 of 74 (18%) were reoperated, 92% of these were adjustments (n = 7) or minor technical complications (n = 5). Overall rate of intermediate and major technical complications in all unstable pertrochanteric and subtrochanteric fractures was with uniaxial MSP 1.4% and was lower with biaxial MSP (0.68%) than with IMN (7.2%, p = 0.0001) and with DHS (3.4%, p = 0.023). For unstable pertrochanteric fractures separately rate of intermediate and major technical complications was lower with biaxial MSP (0.69%) than with IMN (4.5%, p = 0.011), and was...
with DHS 3.1% and with uniaxial MSP none (Table 5). In 42 subtrochanteric fractures operated with uniaxial MSP one intermediate technical complication (2.4%) occurred and in 65 operated with IMN 7 intermediate or major technical complications occurred (11%, \(p = 0.11\)).

**Lateral/posterior support**

In total, 5 reoperations (1.6%) were performed in 308 unstable pertrochanteric fractures with intact lateral and posterior support. Of the 4 technical complications 3 were minor and only one (0.32%) was major. In the 293 unstable pertrochanteric fractures with lack of lateral or posterior support 14 (4.8%) reoperations and technical complications occurred, 11 (3.8%) of these intermediate \((n = 3)\) or major \((n = 8, 2.7%)\). Lack of posterior support was more frequent than lack of lateral support, but only one of the 14 reoperations had intact posterior support compared to 10 with intact lateral support.

**Implants and lateral/posterior support**

In unstable pertrochanteric fractures with intact lateral and posterior support, reoperation rates were with DHS 2/136 (1.5%), with biaxial MSP 1/143 (0.70%) and none of the 24 fractures operated with IM. If either lateral or posterior support also was lacking, 6 (11%) technical complications occurred with DHS, 5 of these intermediate \((n = 1)\) or major \((n = 4, 7.0%)\) and with biaxial MSP 2.1% \((3/145, p = 0.0063)\), one intermediate and one (0.70%) major. All reoperations with IMN in unstable pertrochanteric fractures \((4/88, 4.5%)\) lacked lateral or posterior support.

**Discussion**

The major finding in this study was the more than 4 times higher rate of technical complications with loss of hip integrity, persistent non-union or need for revision osteosynthesis, following treatment of both unstable pertrochanteric and subtrochanteric fractures according to treatment protocol: IMN/DHS compared to treatment protocol: MSP/DHS. The low technical complication rate with MSP in both unstable pertrochanteric and subtrochanteric fractures is in line with results reported in previous studies [4, 12, 14–16]. The main mechanisms behind major technical complications were malalignment with varus dislocation and cut-out due to antero-medialisation of the femoral shaft in fractures without lateral or posterior support operated with DHS or biaxial MSP, varus dislocation and cut-out in fractures treated with DHS or IMN due to insufficient load-sharing, or bone or implant stress fracture or nonunion due to load-bearing in fractures treated with IMN.

The retrospective study design was observational using post-hoc analysis of existing data, which usually provides less solid information due to limited control of systematic and consecutive study inclusion and incomplete outcome data. However, the regional orthopedic surgery database structure warranted complete consecutive inclusion of all operated patients as well as complete registration of the

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**Table 2** Number of fractures, and fraction within fracture type group, treated with each fixation method for different fracture subtypes in the 2 treatment groups

| Fracture type | Treatment protocol: MSP/DHS | Treatment protocol: IMN/DHS |
|---------------|----------------------------|-----------------------------|
|               | DHS | MSP biaxial | MSP locked uniaxial | IMN | DHS | IMN |
| Stable pertrochanteric | 56 (77%) | 17 (23%) | 0 | 0 | 59 (98%) | 1 (2%) |
| JM1           | 28 (88%) | 4 (12%) | 0 | 0 | 39 (98%) | 1 (2%) |
| JM2           | 28 (68%) | 13 (32%) | 0 | 0 | 20 (100%) | 0 |
| Unstable pertrochanteric | 30 (9%) | 288 (82%) | 32 (9%) | 0 | 163 (65%) | 88 (35%) |
| JM3           | 13 (16%) | 60 (74%) | 8 (10%) | 0 | 67 (89%) | 8 (11%) |
| JM4           | 12 (20%) | 43 (73%) | 4 (7%) | 0 | 13 (59%) | 9 (41%) |
| JM5           | 5 (2%) | 185 (88%) | 20 (10%) | 0 | 83 (54%) | 71 (46%) |
| Subtrochanteric | 6 (9%) | 5 (7%) | 42 (61%) | 16 (23%) | 4 (8%) | 49 (92%) |

Divergence from treatment protocol:

- JM1-JM2 with no lateral or no posterior support or JM3-JM4-JM5: 31 \((1\%)\)
- JM 3–4–5 with no lateral support: 6 \((2\%)\)
- JM3-JM4-JM5 with no lateral or no posterior support or subtrochanteric: 8 \((0\%)\)

*Table 2: Number of fractures, and fraction within fracture type group, treated with each fixation method for different fracture subtypes in the 2 treatment groups.*

**Notes:**
- Treatment protocol: Medoff sliding plate (MSP)/dynamic hip screw (DHS)
- Treatment protocol: Intramedullary nail (IMN)/dynamic hip screw (DHS)
- JM Jensen Michaelsen fracture classification
- The number of operations among the above with fixation methods with main divergence from the respective treatment protocol for grouped fracture subtypes.
- Among these, number of reoperations with technical complication.
| Fracture type | Fixation | Analysis of mechanism | Reflection on mechanism of complication | Reoperation | Surgeon’s experiencea | Fracture reduction | Twin hook/lag screw position | Outcomeb |
|---------------|----------|-----------------------|----------------------------------------|-------------|-----------------------|---------------------|------------------------|----------|
| JM5 SH2C SH3A | MSP uniaxial | Sliding plate consumed | In line with treatment protocol | Locking screw removed | No adjustment | 2 | Acceptable | Good | Fracture healing |
| SH5 | | | | | | | | | |
| JM5 SH3A SH5 | MSP biaxial | Intraoperative error - TH wing in hip joint | Avoidable | TH replaced | Minor | 3 | Poor | To distal | Fracture healing |
| SH5 | | | | | | | | | |
| JM5 SH2C SH5 SH3A | MSP uniaxial | TH penetration – sliding plate consumed, but locking screw not removed | Locking screw should have been removed postoperatively, since plate sliding capacity was consumed | TH replaced locking screw removed | Minor | 2 | Poor | Good | Fracture healing |
| SH3A | | | | | | | | | |
| JM3 DHS SH3A | DHS | Medialisation and varus dislocation | DHS allowed anteromedialisation due to lack of lateral/posterior support | Hip joint replacement | Major | 1 | Good | Good | Hip joint replacement |
| JM5 SH3A | MSP biaxial | TH penetration – medialisation | MSP should have been locked. Biaxial MSP allowed anteromedialisation due to lack of lateral/posterior support | MSP biaxial replaced with MSP uniaxial | Intermediate | 3 | Acceptable | Good | Fracture healing |
| JM5 SH5 | Medialisation and varus dislocation | | | Hip joint replacement | Major | 4 | Good | Hip joint replacement |
| JM2 DHS SH5 | DHS | Varus dislocation and cut-out | Fracture impaction occured - DHS load-sharing was insufficient with unloading of fracture site | Hip joint replacement | Major | 2 | Good | Posterior | Hip joint replacement |
| IMN | Nonunion with broken IMN | IMN was load-bearing with unloading of fracture site and with stress concentration | IMN replaced with uniaxial MSP | | Intermediate | 4 | Acceptable | Good | Fracture healing |

aDocumented number of previous trochanteric hip fracture surgeries performed by index operation surgeon: Less than 10, 10 to 24, 25 or more, or specialist orthopaedic surgeon

bFracture considered as healing if no documentation of diversion from fracture healing at final follow-up

|JM Jensen Michaelsen fracture classification, SH Seinsheimer fracture classification

TH Twin hook, DHS dynamic hip screw, MSP Medoff sliding plate, IMN intramedullary nail
| Fracture type | Fixation | Analysis of mechanism | Reflection on mechanism of complication | Reoperation | Technical complication category | Surgeon’s experience | Fracture reduction | Twin hook/lag screw position | Outcome |
|---------------|----------|------------------------|----------------------------------------|------------|---------------------------------|---------------------|------------------|----------------------|---------|
| SH2A          | IMN      | No fracture impaction  | IMN was load-bearing with unloading of fracture site | Locking screw removed | No; adjustment | 4 | Acceptable | Good | Fracture healing |
| JMS           | DHS      | Intraoperative error -TH wing in hip joint | Avoidable | TH replaced | Minor | 3 | Acceptable | Posterior | Fracture healing |
| JMS           | DHS      | TH penetration –anteroanteriorisation | DHS allowed antero-medialisation due to lack of lateral/posterior support | TH replaced | Minor | 4 | Acceptable | Posterior | Fracture healing |
| JMS           | DHS      | TH penetration –medialisation | DHS/TH replaced with new DHS | No; adjustment | Intermediate | 4 | Good | Good | Fracture healing |
| JMS           | DHS      | Medialisation | DHS replaced with IMN | Hip joint replacement | Major | 4 | Acceptable | Good | Girdlestone |
| JMS           | DHS      | Nonunion – antero-medialisation | Girdlestone | Hip joint replacement | Major | 4 | Good | Good | Hip joint replacement |
| JMS           | DHS      | Varus dislocation and nonunion | Fracture impaction occurred - DHS load-sharing was insufficient with unloading of fracture site | Hip joint replacement | Major | 4 | Acceptable | Posterior | Hip joint replacement |
| JMS           | DHS      | Varus dislocation and cut-out | Hip joint replacement | Hip joint replacement | Major | 3 | Acceptable | Good | Hip joint replacement |
| JMS           | IMN      | Varus dislocation and cut-out | Hip joint replacement | IMN replaced with long DHS | Intermediate | 4 | Acceptable | Good | Fracture healing |
| JMS           | IMN      | Nonunion | IMN was load-bearing with unloading of fracture site | Hip joint replacement | Major | 4 | Good | Posterior | Nonunion |
| JMS           | IMN      | Broken locking screw | IMN was load-bearing with unloading of fracture site and with stress concentration | Hip joint replacement | Major | 4 | Poor | Proximal | Fracture healing |
| JMS           | Broken IMN | Broken IMN | IMN replaced with long IMN | IMN replaced with long DHS | Intermediate | 3 | Poor | Fracture healing |
| SH5           | Femoral shaft stress fracture | Femoral shaft stress fracture | IMN replaced with long DHS | IMN replaced with long DHS | Intermediate | 4 | Poor | Fracture healing |
| SH2C          | IMN      | IMN Nonunion | IMN was load-bearing with unloading of fracture site and with stress concentration | IMN locking screw removed | Minor | 4 | Good | Good | Fracture healing |

JM Jensen, Michaelsen fracture classification, SH Seinsheimer fracture classification
TH Twin hook, DHS dynamic hip screw, MSP Medoff sliding plate, IMN intramedullary nail
*Documented number of previous trochanteric hip fracture surgeries performed by index operation surgeon: Less than 10, 10 to 24, 25 or more, or specialist orthopaedic surgeon
*Fracture considered as healing if no documentation of diversion from fracture healing at final follow-up
*Recurrence of Twin Hook penetration left in situ
sole outcome parameter reoperation. Therefore, the study
design may actually be considered a strength, since the
objective of studying treatment protocol performance in
regular daily care was not biased by study design, or by
awareness among involved surgeons of an ongoing study.
Systematic repeat radiographs after the postoperative
examination were obtained only when uniaxial MSP was
used. Reported rates of technical complications for the
treatment protocols should therefore be considered as
lower limits of true rates.

Assumed treatment group similarity to allow group
comparisons appeared justified, since all fractures were
consecutively included and no relevant group differences
were observed regarding patient baseline data, fracture
type distribution or surgical performance. Still, in addition
to implants, existence of other group differing factors with
possible impact on outcome, such as fracture pattern
distribution or hospital specific performance, cannot be
completely ruled out. Classification reliability was assessed
by interobserver comparison and agreement was high, in
particular in the important distinction between stable and
unstable fractures.

Similar to other reports [2, 4, 14], the main technical
complications with DHS in unstable pertrochanteric
fractures were varus dislocation with lag screw cut-out
or nonunion, frequently related to femoral shaft mediali-
sation. With MSP in biaxial mode, lower rate of fixation
failure in unstable pertrochanteric fractures was repro-
duced in this study. The sliding mechanism of both the
DHS and the MSP lag screw barrel is aligned parallel to
the femoral neck. Hence, compression along this axis
will induce anteromedial translation of the femoral shaft
relative to the head and neck fragment, which may com-
promise stable contact and load transfer between the
main proximal and distal fracture fragments. A sevenfold
increase of technical fixation failures with DHS has been
reported with a medialisation of 30% or more [17]. As
with DHS, the main mechanism behind major complica-
tions with biaxial MSP is femoral shaft anteromedialisa-
tion, which however appeared to be less frequent and
less pronounced than with DHS in this study as well as
in others [4, 16], probably due to facilitated axial fracture
impaction and interdigitation of fracture fragments. Still,
as with DHS, biaxial MSP may be inappropriate if the
fracture extends below the level of the lag screw entry
hole with subsequent loss of lateral and or posterior sup-
port. Fracture malalignment has severe consequences
and the vast majority of reoperations related to femoral
shaft anteromedialisation in this study were associated with major complications. According to treatment protocol: MSP/DHS MSP should be used in uniaxial mode in the absence of lateral or posterior support. This strategy prompted some adjustment procedures to allow secondary dynamisation, or minor reoperations due to Twin hook/lag screw penetration, but no major complications occurred. The IMN maintains alignment and prevents femoral shaft anteromedialisation. Still, due to poor load transfer from implant to fracture site, varus dislocation and

| Fracture type                  | Implant          | Treatment protocol | Relative risk\(c\) |
|-------------------------------|------------------|--------------------|--------------------|
| Unstable pertrochanteric      | All technical complications | 7/350 (2.0%) | 11/251 (4.4%) | 2.9 (0.89–5.4) |
|                               | DHS              | 1/30               | 7/163              |
|                               | MSP biaxial      | 4/288              | -                  |
|                               | MSP uniaxial     | 2/32               | -                  |
|                               | IMN              | -                  | 4/88               |
|                               | Intermediate and major technical complications | 3/350 (0.86%) | 9/251 (3.6%) | 4.2 (1.2–14) |
|                               | DHS              | 1/30               | 5/163              |
|                               | MSP biaxial      | 2/288              | -                  |
|                               | MSP uniaxial     | 0/32               | -                  |
|                               | IMN              | -                  | 4/88               |
|                               | Major technical complications | 2/350 (0.57%) | 7/251 (2.8%) | 4.9 (1.2–21) |
|                               | DHS              | 1/30               | 4/163              |
|                               | MSP biaxial      | 1/288              | -                  |
|                               | MSP uniaxial     | 0/32               | -                  |
|                               | IMN              | -                  | 3/88               |
| Subtrochanteric               | All technical complications | 5/69 (7.2%) | 8/53 (15%) | 2.1 (0.78–5.8) |
|                               | DHS              | 0/6                | 1/4                |
|                               | MSP biaxial      | 0/5                | -                  |
|                               | MSP uniaxial     | 4/42               | -                  |
|                               | IMN              | 1/16               | 7/49               |
|                               | Intermediate and major technical complications | 2/69 (2.9%) | 7/53 (13%) | 4.6 (1.1–19) |
|                               | DHS              | 0/6                | 1/4                |
|                               | MSP biaxial      | 0/5                | -                  |
|                               | MSP uniaxial     | 1/42               | -                  |
|                               | IMN              | 1/16               | 6/49               |
|                               | Major technical complications | 0/69               | 3/53 (5.7%) | 8.6 (0.45–163) |
|                               | DHS              | 0/6                | 0/4                |
|                               | MSP biaxial      | 0/5                | 0                  |
|                               | MSP uniaxial     | 0/42               | 0                  |
|                               | IMN              | 0/16               | 3/49               |

**DHS** dynamic hip screw, **MSP** Medoff sliding plate, **IMN** intramedullary nail
*Treatment protocol: Medoff sliding plate (MSP)/dynamic hip screw (DHS)
**Treatment protocol: intramedullary nail (IMN)/dynamic hip screw (DHS)**
*95% CI*
Cut-out may occur following loss of fixation purchase in the femoral head and neck fragment [13, 18]. If purchase is maintained, nonunion, implant breakage or femoral shaft stress fracture may occur due to persistent unloading of the fracture surfaces [19–22], typical complications that were all observed in the present study.

In subtrochanteric fractures lateral and/or posterior support is by definition always absent. Miedel [23] reported reoperations in subtrochanteric fractures operated with MSP due to medialisation. However, in this study the MSP was used in biaxial mode. In subtrochanteric fractures MSP should always be used in uniaxial mode [24, 25] to achieve efficient load-sharing and prevent malalignment, at the expense of need for secondary dynamisation in a minority of patients to avoid risk of Twin hook/lag screw penetration. Nevertheless, as noted in this and in other studies [26, 27], with MSP in uniaxial mode Twin hook/lag screw penetration should not be expected to be completely avoided. With maintained axial and varus/valgus alignment this complication is however less demanding and may be resolved with a minor procedure, particularly with the Twin hook allowing percutaneous adjustments. Compared to the MSP, the IMN had a higher rate of intermediate and major technical complications, all related to load-bearing, when used in subtrochanteric fractures.

In treatment protocol: MSP/DHS the aim was to use MSP in all cases with identification of one or more separate trochanteric fragment, that is all fractures types JM 3–4–5. In treatment protocol: IMN/DHS on the other hand, most of the intermediate unstable pertrochanteric fractures, retrospectively classified as JM3–4–5, but with intact lateral and posterior support were, in accordance
with the treatment protocol, treated with DHS. Thus, as compared to the treatment protocol: MSP/DHS, almost two thirds of pertrochanteric fractures with more than 2 main fragments were operated with DHS. The remaining third operated with IMN therefore most likely represents more complex fractures within these subgroups and implant specific complication rates cannot be directly compared in fractures with the same postoperative classification in the two treatment groups. Accordingly, group comparisons in this study refer to complete fracture type groups. It should also be pointed out that the treatment protocol: IMN/DHS pattern of chosen fixation methods is representative of the overall Swedish national use of fixation methods for pertrochanteric as well as subtrochanteric fractures [28].

The complication rate with DHS was almost as high as with the IMN, suggesting that treatment of mild to moderately complex unstable pertrochanteric fractures with DHS was not optimal. A more than sevenfold increase of the technical complication rate was observed in unstable pertrochanteric fractures treated with DHS, if in addition lack of lateral or posterior support was noted. Whether the intermediate unstable pertrochanteric fracture category would do better with IMN than with DHS cannot be answered by this study. Anteromedialisation due to lack of lateral/posterior support would be controlled by the IMN, but increasing issues related to load-bearing with stress concentration and non-union should be expected. Shortcomings in fracture classification firmly defining these fracture type subgroups limit the value of available studies, as does the fact that most fractures in this subgroup are probably not treated with IMN.

In treatment protocol: MSP/DHS, a vast majority of unstable pertrochanteric fractures were operated with biaxial MSP, which in terms of minimising risk of reoperation and technical complication appears superior to both alternatives for this spectrum of fracture types. Due to surgeons' assessment of lack of lateral or posterior support, 9% of unstable pertrochanteric fractures in treatment protocol: MSP/DHS were treated with MSP in uniaxial mode. Among these, 2 lag screw penetrations occurred but no major complications, again supporting priority of alignment control over biaxial dynamisation in appropriate fracture patterns. From analysis of mechanisms of technical complications in this study as well as others [29], fractures at increased risk of reoperation can often be identified if additional parameters such as lateral and posterior support are examined.

Reoperations with minor complications had no documented divergence from final fracture healing and were by definition performed percutaneously. This type of technical complication per se should have minor consequences for most patients. Intermediate and major technical complications should be expected to have more profound consequences and these subgroups comprise the cases that should be considered true failures from a technical orthopedic surgical point of view.

**Conclusions**

In summary, in this consecutive retrospective observational study comparing two different treatment protocols, technical complications in unstable pertrochanteric and subtrochanteric fractures were less frequent and less severe with a treatment protocol based on MSP fixation, compared to a treatment protocol based on IMN fixation. In this respect, a vast majority of unstable pertrochanteric fractures are best treated with MSP in biaxial mode and stand greater risk of major complications if treated with DHS, due to loss of alignment or insufficient load-sharing, or with IMN due to load-bearing. In the most challenging unstable pertrochanteric and subtrochanteric fractures proper application of the MSP in uniaxial mode, in combining maintained alignment and effective load-sharing, will minimise the risk of major technical complications compared to DHS and IMN.

**Abbreviations**

DHS: Dynamic hip screw; IMN: Intramedullary nail; JM: Jensen & Michaelsen classification; MSP: Medoff sliding plate; SH: Seinsheimer classification; TH: Twin hook

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**Availability of data and materials**

The datasets used during the current study are not publicly available due to patient integrity, but are available from the corresponding author on reasonable request.

**Authors' contributions**

OO and JP designed the study. JCS and JP collected all data. Data analysis was performed by JCS and JP under supervision of OO. Classification of radiographs were performed by JCS under supervision of OO and interobserver variability was assessed for JCS and OO. All authors contributed in review and interpretation of data. The manuscript was drafted by JCS, reviewed by all authors and revised with contributions from all authors under supervision and final revision of OO. OO was responsible for the integrity of the work from inception to finished article. All authors read and approved the final manuscript.

**Ethics approval and consent to participate**

This study was approved by the Lund University Ethics Committee, registration number 2015/345. Patient consent to participate was not applicable due to study design, only involving retrospective review of orthopedic surgery database, radiographs and medical charts.

**Consent for publication**

Not applicable.
Competing interests
The authors declare that they have no competing interests. No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subjects of this article.

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