Sliding hip screw vs intramedullary nail for AO/OTA31A1-A3: a systematic review and meta-analysis

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Objective: to conduct a systematic review with consequent meta-analysis evaluating the best treatment for Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) 31A1-A3 trochanteric fractures when comparing the sliding hip screw (SHS) to the intramedullary nail (IMN). The outcomes used for comparison are major complications (in total, as well as nonunion and infection specifically), mortality rates, functional outcomes and patient-reported outcome measures (PROM).

Methods: Search strings for the Cochrane Library, CINAHL, Medline and Embase databases were developed with the help of a scientific librarian. Two authors screened the studies from the search string independently using Covidence.org and data extraction was performed similarly. Quality assessment was performed using the Cochrane Risk of Bias tool for randomised trials (ROB2) for RCT studies, and Cochrane Risk of Bias in Non-Randomised Studies – of Interventions (ROBINS-I) for non-RCT studies. Meta-analyses were performed using Log Risk Ratio as the primary effect estimate.

Results: Of the 2,051 studies screened by the two authors, six RCTs and six non-RCTs were included in this meta-analysis, with a total of 10,402 patients. The results indicated no significant differences in total major complications, nonunion, infection or mortality between SHS and IMN treatments for AO/OTA 31A1, 31A2 and 31A3 trochanteric fractures. Due to a lack of comparable data, we were unable to perform a meta-analysis on function scores and PROM. However, there are trends that favour IMN for 31A1 and 31A2 fractures.

Conclusion: No significant difference between SHS and IMN was found in the meta-analysis in any of the examined AO/OTA fracture subtypes in terms of primary and secondary outcomes. When assessing function scores and PROM, we found trends favouring IMN for 31A1 and 31A2 fractures that should be explored further.

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Introduction

Trochanteric fractures are usually treated surgically and the two predominant choices for internal fixation are the sliding hip screw (SHS) and the intramedullary nail (IMN) [1,2]. Numerous studies have demonstrated no difference in outcome between SHS and IMN, but this finding may be due to the pooling of results from all types of trochanteric fractures. Contemporary research tends to categorise stable or unstable fractures without distinguishing between the different Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) subtypes (31A1, 31A2, and 31A3), and such a differentiation could be more helpful in applying the results to the clinical reality [3-7].

The NICE guidelines [1] recommend SHS as the surgical treatment for A1 and A2 and IMN for A3 fractures. The AAOS guidelines [8] furthermore, recommend either SHS or IMN for stable fractures and IMN for unstable fractures. The difference in the guidelines is not evidence-based, as most meta-analyses have demonstrated no notable advantage to choosing one treatment over the other [2,9-12].

Subgrouping has previously only been applied to a limited extent due to insufficient data on specific AO/OTA-fracture types. Few meta-analyses have been performed on the AO/OTA subgroups, and they did not present convincing results as to the preferred implant [13,14]. Furthermore, these meta-analyses include only a...
few studies, and those studies focused on prior generations of intramedullary nails.

This study aims to assess whether the prevalence of major complications (in total, as well as nonunion and infection specifically) in AO/OTA 31A1, 31A2 and 31A3 hip fractures is lower when using the sliding hip screw over the intramedullary nail (or vice versa) as the fracture fixation. Additionally, the study examines whether there are any differences in the one-year mortality rate and in functional measurements assessed using function scores and Patient Reported Outcome Measures (PROM).

Methods

Protocol and registration

This meta-analysis was conducted using the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines [15]. The study protocol was registered in the international prospective register of systematic reviews, PROSPERO (CRD42020208249), prior to data extraction.

Eligibility criteria

A Patient, Intervention, Comparison, and Outcome model (PICO) [16] was defined for adult patients with a pertrochanteric hip fracture of the femur treated with either extra- or intramedullary fixation with outcomes of major complications, mortality, and a return to full function postoperatively. Randomised Clinical Trials (RCT) and cohort studies were included in the analysis. Studies were excluded if they:

- Were written in a language other than English
- Included paediatric patients
- Included pathological fractures
- Compared SHS with older generations of IMNs (prior to 2000, before the introduction of 3rd generation IMNs)
- Used other fracture classification schemes (e.g., EVANS or Jensen classification)
- Were cadaver studies, biomechanical studies, case-report, editorials, reviews, guidelines and conference abstracts

Information sources and literature search

Search strings were developed for four databases: the Cochrane Library, CINAHL, Medline (Ovid) and Embase (Ovid). The searches included key terms such as ‘pertrochanteric fracture’ in combination with ‘intramedullary fracture fixation’ and ‘extramedullary fracture fixation’, as well as further variations thereof. To ensure the high sensitivity of the search strings, specific outcome measurements were not included. The complete search strings are shown in Appendix 1. The search strings were optimised in collaboration with a scientific librarian from the University Library of Southern Denmark, and the last search was performed on the 9th of July, 2020. Meta-analyses and systematic reviews found in the data string were cross-referenced for eligible studies.

Study selection

Search results were extracted into Endnote (Clarivate Analytics, Philadelphia, Pennsylvania, USA), where some duplicates were removed. The remaining studies were uploaded to Covidence (Veritas Health Innovation, Melbourne, Australia) where further duplicates were removed. Two independent reviewers (JOW and MPB) determined eligibility by reviewing the title, abstract and full text of each study. In the case of a discrepancy, the decision was debated to reach a consensus. If this was not possible, the study was brought before the lead scientist (BV), who made the final decision.

Data collection process

Data extraction was performed by two independent researchers (JOW and MPB) and plotted in an Excel spreadsheet, where the data was cross-checked. If data was found to be pooled across AO/OTA-subgroups, the lead author of the relevant paper was contacted via the corresponding email provided in the manuscript to supply data specifying the subgroup division. Primary outcome data was pooled in 38 studies, and an additional two studies (out of the 12 included) did not specify mortality details. Out of the 40 study authors [17–56] contacted, seven [17–19,28,41,43,53] replied, and only two authors were able to supply the requested data on the two devices divided into AO/OTA fracture subtypes [18,41].

Data categories

Data concerning author, title, year of publication, country of origin, study type, number of participants, mean age, sex, type of fracture fixation used, and fracture classification were extracted. The primary outcome was major complications, defined as any reoperation (except simple hardware removal) or nonoperatively treated nonunion, malunion, wound infection (deep or superficial), peri-implant fracture, cut-out, avascular necrosis, implant failure or intraoperative nerve injury. If a study counted more than one complication per patient, only the operatively treated patients were included.

Secondary outcomes were mortality, specific major complications (nonunion and infection), and any form of function measurements, both by various scoring systems (e.g., Harris Hip score, Barthel index or functional recovery score etc.) and by PROM. Deceased patients who were excluded from the studies’ final analyses were included in this study’s analysis. This was not possible for Duymus et al., [57] as the number of deceased patients excluded was unavailable.

Risk of bias in individual studies

Included studies were assessed for risk of bias using the Cochrane Risk Of Bias tool for randomised trials (ROB2) for RCT studies as well as the Cochrane Risk Of Bias In Non-Randomised Studies – of Interventions (ROBINS-I) for non-RCT studies [58,59]. The tools assessed each study against five and seven possible sources of bias, respectively. ROB2 investigates bias due to:

- Randomisation, deviations from intended intervention, missing outcome data, measurements of outcome data, and selection in reported data.

ROBINS-I evaluates based on bias due to:

- Confounding, selection of participants into the study, classification of interventions, missing data, measurements of outcome, and selection of the reported results.

Both tools summarise the results of each domain in overall risk-of-bias judgments. When using ROBINS-I, a fundamental part of the risk-of-bias assessment involves identifying and adjusting for possible confounders. Age, comorbidities and functional status were chosen to be the relevant confounding factors since they have all been found to be individual risk factors for major complications [60–64]. Both the ROB2 and ROBINS-I assessments were performed at the study level by two independent researchers (JOW and MPB) and later checked for any discrepancies in the results.

Summary measures and synthesis of results

Outcomes were reported across studies and were meta-analysed using forest plots (statistical software: Stata IC 16.0). The
intervention effect was expressed as log risk ratio (log RR), with a 95% confidence interval included. Statistical significance was defined as p ≤ 0.05. Pooled data was assessed for heterogeneity using chi-squared and I-squared tests. Heterogeneity was defined as ‘absent’ (0–25%), ‘low’ (26–50%), ‘moderate’ (51–75%) or ‘high’ (76–100%). Fixed-effect meta-analysis was performed when the I-squared was less than 50% [65].

Results

Study selection and characteristics

After the preliminary search and removal of duplicates, 2,051 studies were screened for eligibility (Fig. 1). The inclusion criteria were initially met by 50 studies; however, upon further assessment, 38 studies were excluded as they did not classify study results in accordance with the AO/OTA-classification. Ultimately, 12 studies were included in the final analyses [18,41,57,66–74]. A total of 10,402 patients were included from six RCTs and six non-RCTs; their demographics are shown in Table 1. Across the 12 studies, 7,827 patients were treated with SHS and 2,575 were treated with IMN.

Risk-of-bias assessment

Overall, the studies were judged to have a moderate or greater risk of bias (Fig. 2 and Fig. 3). The 6 RCT studies all scored poorly due to their lack of a study protocol in addition to generally insufficient methods sections, risking possible bias in outcome measurements and selection of the reported results. These same concerns were present in the non-RCT studies as well, with possible additional biases due to missing data. Furthermore, all non-RCT studies scored ‘moderate’ or worse for bias due to confounding. One study did not adjust for any of the relevant confounders, leading to a critical bias assessment; two studies did adjust for age but not function or comorbidities, leading to a serious judgment; the three remaining studies were adjusted for all three confounding factors, but received a moderate judgment due to expected possible confounding [75] (Fig. 2).

Primary outcome: Major complications

The meta-analysis performed on the pooled data (regardless of fracture subtype) revealed no significant change in risk between SHS and IMN, with a Log RR of 0.22 and 95% CI: [-0.17, 0.61], as seen in Fig. 4. Extending the analysis to the subgroup level, no sig-
Fig. 2. Results of Cochrane Risk Of Bias tool for randomized trials (ROB 2) visualized in traffic light plots for each individual domain assessed using Robvis Tool of visualization.

Fig. 3. Results of Cochrane Risk Of Bias In Non-Randomized Studies – of Interventions (ROBINS-I) visualized in traffic light plots for each individual domain assessed, using Robvis Tool of visualization.
nificant difference could be found in the 31A1 subgroup, with a Log RR of 0.55 [-0.35, 1.45] (Fig. 5). Concerning the subgroup 31A2, no significant change in risk was found, with a Log RR of 0.21 [-0.14, 0.56] (Fig. 6). Due to a lack of studies concerning 31A3 – only Parker et al.[41] included this particular subgroup in their results – there is no analysis of outcomes for this fracture type for either primary or secondary outcomes. Thus, this study found no difference between SHS and IMN in terms of the likelihood of major complications.

Secondary outcomes: Nonunion, infection, mortality, and functional outcome

No significant change in risk of nonunion was found in analysing the results of the comparison of SHS to IMN in the 31A1 and 31A2 subgroups, with Log RR values of 0.41 [-0.57, 1.38] and 1.07 [-0.52, 2.65], respectively (Figs. 7 and 8). The study on the 31A3 subgroup reported one incidence of nonunion in both the SHS and IMN subgroups (out of 42 and 47 patients in each group, respectively), but we were unable to make a statistical analysis on this subgroup.

After considering infection in the 31A1 subgroup, no analysis was performed due to a lack of data. For the 31A2 subgroup, no significant reduction in risk was found in comparing SHS and IMN, with a Log RR of 0.59 [-0.13, 1.31] (Fig. 9). No infections were found in the study of the 31A3 subtype. Meta-analysis of mortality data for subgroups 31A1 and 31A3 was not possible due to insufficient data; however, the individual studies showed no difference between the implants. The analysis of the 31A2 subgroup revealed no significant difference in mortality risk between treatments, with a Log RR of -0.06 [-0.30, 0.18] (Fig. 10).

The initial aim was to then analyse measures of functional outcomes, but this was not possible due to the lack of comparable measures across the studies. The individual studies generally tended to find that IMN was superior compared to SHS. An overview of the different results can be seen in Table 2.
J.O. Wessels, M.P. Bjarnesen, J.L. Erichsen et al.

Injury xxx (xxxx) xxx

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Fig. 5. Forest plot for 31A1 major complications.

Fig. 6. Forest plot for 31A2 major complications.

Fig. 7. Forest plot for 31A1 nonunion.

Discussion

We found no statistically significant difference in the occurrence of major complications (including in subgroup analysis for nonunion and infection) or in mortality rates concerning the AO/OTA-fracture subtypes 31A1, 31A2 and 31A3 when comparing SHS to IMN. However, it is worth noting that other variables, such as function scores and PROM, could reveal a difference between SHS and IMN.

Treatment of 31A1 fractures with either SHS or IMN was accompanied by similar risks of major complications. This contrasts with the study by Jones et al., [13] whose meta-analysis concluded that IMN should not be recommended for 31A1 fractures due to a higher failure rate of fracture fixation. The discrepancy in our results can be explained by their use of outdated references (prior...
Injury xxx (xxxx) xxx

ARTICLE IN PRESS

J.O. Wessels, M.P. Bjarnesen, J.L. Erichsen et al.

Fig. 8. Forest plot for 31A2 nonunion.

Fig. 9. Forest plot for 31A2 infection.

Fig. 10. Forest plot for A2 mortality.
Table 2: Results of function outcomes from the included studies.

| A1 | Matre et al. | Parker et al.* | Zeng et al. | Weigun et al. |
|----|-------------|---------------|------------|-------------|
| Functional assessment | EQ-SD, VAS | PM | HHS | HHS |
| Result | SHS = IMN | IMN > SHS | IMN > SHS | No assessment |
| A2 | Functional assessment | Aktseis et al. | IMN > SHS | No assessment |
| PM, BI, EQ-DS | Buttl et al. | Parker et al.* | PM |
| Result | SHS = IMN | IMN > SHS | No assessment |
| A3 | Functional assessment | BI, EQ-DS: IMN > SHS (PM) | IMN = SHS | IMN > SHS |
| IMN = SHS | Parker et al.* | MS |
| Result | SHS = IMN |

to 2000), corresponding to the use of older versions of IMNs. The four studies of A1 fractures in our analysis were performed after 2013 and are therefore likely to have more relevance to the present day. When assessing functional outcomes, Jones et al. found no significant difference between the two implants. Regarding functional outcomes of 31A1 fractures in our study, Weiguang et al. [71] and Zeng et al. [74] found IMN to be superior to SHS when using the Harris Hip score; however, Matre et al. [68] and Parker et al. [41] found no differences in functional outcomes using Parker Mobility Score and EQ-SD. The latter two studies must be assumed to have a larger impact, as Matre et al. includes a total of 7,534 hip fractures, while Parker et al. performed an RCT with 1,000 patients in comparison to 225 patients with Weiguang et al. (ref.) and Zeng et al (ref.) Ultimately, we found no difference in the likelihood of major complications between SHS and IMN for 31A1 fractures. Furthermore, there is no clear advantage of either implant regarding functional outcomes.

Regarding 31A2 fractures, our study found similar risks of major complications for SHS and IMN; this is in line with the conclusion of the 2017 meta-analysis by Zhu et al. [14]. Our study elaborated on that of Zhu et al. [14] by revising the inclusion of contemporary literature and incorporating four additional studies with 31A2 assessments (one RCT and three non-RCTs). When examining function measurements, Zhu et al. [14] found IMN to be superior in 31A2 fractures. However, their analysis was grounded in the results of two studies with only 154 patients in total. Despite the larger dataset used in our study, we were unable to expand on their analysis due to the heterogeneity of the function scores. Nevertheless, of the nine studies included that assessed functionality/PROM outcomes, five found significantly better outcomes in both 31A1 and 31A2 fractures when IMN was used (Table 2). This indicates that significant differences between the two treatments may exist when assessing function/PROM outcomes, a finding which could be a determining factor in the search for the superior treatment (in contrast to the current focus on occasional differences in peri- and postoperative complications). As we do not find a preferred implant, it is likely that 31A2 can be treated equally well with either SHS or IMN. However, some studies divide 31A2 further into 31A2.1, 31A2.2, and 31A2.3, as seen in Whale et al. [52] who found no difference between SHS and IMN for 31A2.1 fractures but found IMN treatment to be superior in 31A2.2 and 31A2.3 fractures as it resulted in significantly lower collapse rates compared to SHS. Overall, we found no difference in the rate of major complications between SHS and IMN when assessing 31A2 fractures. A superior treatment may be found by assessing function outcomes or by further subdividing 31A2 fractures.

A meta-analysis by Parker et al. in 2017 [76] concerning the optimal treatment for 31A3 fractures concluded that there was no difference between treating with either SHS or IMN based on data from six studies. Their methods section states that corresponding authors were contacted to obtain the needed information. We were unable to expand upon or even recreate the dataset due to a lack of responses from those same authors in attempting to provide the details needed for the analysis. Therefore, our analysis could only include one eligible study concerning 31A3 fractures. Due to the limited number of sources discussing 31A3 fractures treated with SHS or IMN, we were unable to draw relevant conclusions about the optimal treatment for this subtype.

The fact that authors of 33 studies did not respond to our attempts to acquire the information needed could have potentially affected the results for all three 31A subtype in this study – particularly for 31A1 and 31A3 fractures, for which data was limited. In a review of the results of individual studies with varying degrees of combined data for A1, A2 and A3 fractures, 15 showed no significant differences between SHS and IMN [20,24,25,34,44,46-48, 50-52, 54,56], while 18 recommended IMN mainly due to its speedier recovery and higher mobility score [21-23, 26,27,31-33, 35-40, 42,45,49,55]. This lends further support to the possibility that there exists a relevant difference between the two treatments in terms of functional scores and PROM as opposed to perioperative parameters and postoperative complications, even though the data does not take the individual 31A subtypes into account.

Furthermore, discussing the quality of implantation may also be relevant rather than simply comparing the quality of each type of implant. For example, some studies [37,40] conclude that SHS is superior because it is easier to insert by surgeons with less experience, thereby resulting in fewer postoperative complications and reduced need for reoperations. These considerations could explain part of the difference of opinion concerning the choice between the two treatments. It should be noted, however, that the last decade has seen an increase in expertise concerning the implantation of IMNs, which may explain why IMNs are preferred in some settings [66].

The following limitations of this study should be considered. First, numerous potentially eligible studies had to be excluded due to a lack of results subdivided into the distinctive AO/OTA-subtypes. Second, previous studies have suggested that the various designs of IMN may exhibit different performance levels as compared to SHS, something we did not examine further in this study [77]. Third, all studies included were adjudged to have a moderate or higher overall risk of bias, largely due to the lack of study protocols, which increases the risk of reporting and measurement biases. The included RCT-studies were at moderate or higher risk of presenting data with bias of confounding, measurement of outcomes or bias in selection of reported results. Additionally, all included non-RCTs were found to have a high risk of possible con-
founding variables. They furthermore presented some concerns or even high risk of overall risk of bias.

Conclusion

We found no differences in the rate of major complications, nonunion, infection or mortality rates concerning the AO/OTA fracture subtypes 31A1 and 31A2 when comparing SHS to IMN. We were unable to make relevant statistical conclusions concerning 31A3 fractures due to lack of data. No superior treatment can be recommended based on this analysis.

In summary, our study identifies four main challenges in identifying an optimal treatment of AO-subtype fractures. First, the limited distinction between AO subdivisions (most notably 31A2 fractures) presents a substantial obstacle to any meaningful comparison between studies. Second, heterogeneity in conducting functional measurements and PROM leads to data lacking comparability. Third, investigating the influence of surgical experience on the relevant outcomes would be beneficial. Finally, most literature reviews on the topic were conducted prior to 2000, and as such should be considered somewhat outdated in that the implant types, they describe do not necessarily correspond to the types used today (e.g., Gamma 3). Future studies would benefit from taking these challenges into account.

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Appendix 1

Search strings for the different databases:

(Cochrane library

[(mh “Femoral Neck Fractures”) OR femoral neck fracture OR trochanteric OR pertrochanteric OR per-trochanteric OR intrtrochanteric OR [mh “Femur Neck”] OR [mh “Hip Fractures”]) AND [(mh “Bone Nails”) OR bone nail OR [mh “Fracture Fixation. Intramedullary”] OR fracture fixation, intramedullary OR cephalomedullary nail OR cephalo-medullary nail OR long nail OR short nail OR proximal femoral nail OR pfn OR pfna OR gamma nail OR [mh “Bone Screws”] OR dynamic screw OR sliding hip screw]

CINAHL

(MH “Femoral Fractures+” OR MH “Hips fractures+” OR pertrochanteric fracture OR trochanteric fracture OR hip fracture OR per-trochanteric fracture OR intertrochanteric fracture OR femoral fracture) AND (dynamic hip screw OR MH “Bone Screws+” OR bone screw OR sliding hip screw OR Extramedullary fracture fixation) AND (gamma nail OR PFN OR PFNA OR PTN OR InterTan OR IMHS OR HipLoc OR CHS OR DHS OR short nail OR long nail OR MH “Orthopedic Fixation Devices” OR intramedullary fracture fixation OR cephalomedullary nail OR intramedullary nail OR bone nail)

Medline (OVID)

(femoral neck fracture OR per-trochanteric OR pertrochanteric OR intertrochanteric OR trochanteric OR exp Femoral Neck Fractures/ OR exp Hip Fractures/) AND (dynamic hip screw OR sliding hip screw OR exp Bone Screws/ OR bone screw/ OR Extramedullary fracture fixation/) AND (exp Bone Nails/ OR bone nail OR exp Fracture Fixation, Intramedullary/ OR intramedullary fracture fixation OR pfn OR pfna OR gamma nail OR PTN OR InterTan OR IMHS OR HipLoc OR CHS OR DHS OR cephalomedullary nail OR cephalo-medullary nail OR intramedullary nail OR short nail OR long nail)

Embase (OVID)

(femoral neck fracture OR per-trochanteric OR pertrochanteric OR intertrochanteric OR trochanteric OR exp Femoral Neck Fractures/ OR exp Hip Fracture/) AND (exp dynamic hip screw OR dynamic hip screw OR sliding hip screw OR exp Bone Screws/ OR bone screw/ OR extramedullary fracture fixation/) AND (exp Bone Nails/ OR bone nail OR exp Fracture Fixation, Intramedullary/ OR intramedullary fracture fixation OR pfn OR pfna OR gamma nail OR PTN OR InterTan OR IMHS OR HipLoc OR CHS OR DHS OR cephalomedullary nail OR cephalo-medullary nail OR intramedullary nail OR short nail OR long nail)

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Injury (xxxx xxx) xxx

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