Optimal surgical methods to treat intertrochanteric fracture: a Bayesian network meta-analysis based on 36 randomized controlled trials

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Abstract

Background: There are several surgical methods to treat intertrochanteric fracture: dynamic hip screw (DHS), compression hip screw (CHS), percutaneous compression plate (PCCP), Medoff sliding plate, less invasive stabilization system (LISS), Gamma nail, proximal femoral nail (PFN), and proximal femoral nail anti-rotating (PFNA). We therefore conducted a network meta-analysis to compare eight surgical interventions, including DHS, CHS, PCCP, Medoff sliding plate, LISS, Gamma nail, PFN, and PFNA, to provide the optimal surgical intervention for intertrochanteric fracture.

Methods: An electronic search of 4 databases (PubMed, Embase, Cochrane library, and Web of Science) from inception to July 2020. Two or more of the eight surgical interventions, including the DHS, CHS, PCCP, Medoff sliding plate, LISS, Gamma nail, PFN, and PFNA, for intertrochanteric fracture were included. The methodological quality of the included studies was assessed using the Cochrane Collaboration risk of bias (ROB) tool. Network meta-analysis was conducted by using R-3.5.1 software with the help of package “gemtc”. The odd ratios (ORs) with 95% credibility interval (CrI) were used to assess complications and standard mean difference (SMD) with 95% CrI to calculate the continuous outcomes (operative time, intraoperative blood loss, and Harris hip score). Surfaces under the cumulative ranking curves (SUCRA) were used to rank the intervention.

Results: A total of 36 RCTs were included in this study. The results of this network meta-analysis showed that, compared with the CHS and DHS group, PFNA exhibited a beneficial role in reducing the blood loss (SMD, 152.50; 95% CrI, 72.93 to 232.45; and SMD, 184.40; 95% CrI, 132.99 to 235.90, respectively). PFNA achieved the lowest value for the surface under the cumulative ranking curve (SUCRA) for the blood loss (SUCRA = 0.072) and highest of Harris hip score (SUCRA = 0.912). PCCP may have the lowest probability of the operative time (SURCA = 0.095). There were no significant differences among the eight surgical procedures in complications.

Conclusion: PFNA technique is the optimal treatment method for intertrochanteric fracture. Larger, longitudinal RCTs addressing current limitations, including sources of bias, inconsistency, and imprecision, are needed to provide more robust and consistent evidence.

Keywords: Intertrochanteric fracture, Surgical interventions, Harris hip scores, Network meta-analysis

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Background
Intertrochanteric fractures are common injuries in elderly, with estimated prevalence of intertrochanteric fractures greater than 150,000 cases in the USA annually [1, 2]. Patients with intertrochanteric fractures always have a history of falls or bone disease, which might be due to a low-energy mechanism including fall from standing [3, 4]. Further, the typical clinical manifestations include pain and difficulty walking. The aging was associated with a greater risk of intertrochanteric fractures, and the mortality rate from intertrochanteric fractures ranged from 12 to 41% within 6 months [5]. The goal of treatment of patients with intertrochanteric fractures was to reduce the morbidity, mortality, re-operation, and early mobility [6].

Several surgical methods have already been demonstrated to be effective for patients with intertrochanteric fractures, mainly including extramedullary fixation (dynamic hip screw (DHS), compression hip screw (CHS), percutaneous compression plate (PCCP), Medoff sliding plate, and less invasive stabilization system (LISS)) and intramedullary fixation (Gamma nail, proximal femoral nail (PFN), and proximal femoral nail anti-rotation (PFNA)) [7–14]. Generally, intramedullary fixation is a valuable alternative method for patients with intertrochanteric fractures, which could be associated with lower levels of operation time, blood loss, and tissue damage.

The percutaneous compression plate (PCCP) was developed in the late 1990s by Gotfried for fixation in patients with intertrochanteric fractures [15]. This method could minimize operative trauma using two small percutaneous portals and small-diameter drilling, which could lower additional bone damage in the remaining lateral trochanteric wall. Previous studies illustrated that PFNA was associated with a lower risk of implant-related complications and could provide angular and rotational stability [16]. These characteristics, with early mobilization and weight-bearing, were suitable for patients with osteoporotic bone and unstable intertrochanteric fractures. LISS has some advantages in the treatment of complex proximal femoral fractures in a more stable construct with higher pullout resistance [17].

Previous studies have tested different internal fixation techniques for the surgical treatment to provide insight into the option for treating intertrochanteric fractures. However, there is no consensus about the optimal surgical method for intertrochanteric fractures [18, 19]. More important, traditional meta-analyses only compare two treatments, while network meta-analysis allows for the simultaneous comparison of multiple interventions through combination of direct and indirect evidences from RCTs.

Therefore, a Bayesian network meta-analysis was performed to compare eight common surgical methods, including DHS, CHS, PCCP, Medoff sliding plate, LISS, Gamma nail, PFN, and PFNA, to provide the optimum treatment method for intertrochanteric fracture.

Material and methods
This systematic review was written according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Extension Statement for Meta-analysis. Ethical approval was not required as the work was collected data from published literatures.

Search strategy
PubMed, Embase, Cochrane library, and Web of Science were searched for potentially relevant studies from the time of the inception to July 2020. The terms used for the literature search were as follows: “percutaneous compression plate” OR “proximal femoral nail anti-rotation” OR “proximal femoral nail” OR “less invasive stabilization system” OR “dynamic hip screw” OR “compression hip screw” OR “Medoff sliding plate” AND “intertrochanteric fractures”. In addition, we performed a manual search according to the references of eligible studies to prevent any omissions. Study topic, design, intervention, control, and investigated outcomes were employed to identify any included studies. The literature search and study selection were conducted by two authors independently using a standardized approach. Any inconsistency was resolved by group discussion until a consensus was reached.

Inclusion and exclusion criteria
Studies were pooled for meta-analysis if they met the following criteria: (1) the study with RCTs; (2) the head to head RCT that compares any of the following two comparisons: DHS, CHS, PCCP, Medoff sliding plate, LISS, Gamma nail, PFN, and PFNA; (3) the study presenting the relevant outcomes, including blood loss, Harris hip score, operation time, and complications; and (4) intertrochanteric fractures were confirmed via X-ray imaging.

Data extraction
Two reviewers (Yan-xiao Cheng and Xia Sheng) independently extracted data in pre-designed proforma and managed using Microsoft Excel 2010 (Microsoft Corp, Redmond, WA). Any discrepancy was resolved by a consensus meeting between the two reviewers. Following information including first author’s name, publication year, study design, sample size, mean age, percentage of
males, Orthopaedic Trauma Association (OTA) fracture classification, and investigated outcomes (blood loss, Harris hip scores, operation time, and postoperative complications) were extracted.

Quality assessment
The methodological quality of each randomized controlled trials (RCTs) was assessed according to the Cochrane Collaboration tool for assessing the risk of bias (ROB). A total of seven items were included for assessment: random sequence generation, allocation concealment, blinding of participant and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and other bias.

Statistical analysis
Network meta-analysis was conducted using a Bayesian approach using R version 3.5.1 (R Project for Statistical Computing) through the library gemtc. Node splitting method will be used to evaluate the inconsistency between direct and indirect comparisons. There was no significant inconsistency when 95% CIs of inconsistency factors include zero or $P$ value > 0.05 for the comparison between direct and indirect effects. Heterogeneity of study results was assessed using $I^2$ test, and significant heterogeneity was considered at $I^2 > 50%$. The clinical outcome (operation time, intraoperative blood loss, and Harris hip scores) was evaluated by the standard mean difference (SMD) with 95% credibility interval (CrI). Postoperative complications were expressed as odds ratios (ORs) with 95% CIs. Comparison-adjusted funnel plots were performed by Stata 14.2 (Stata Corp, College Station, TX) to assess publication bias for network meta-analyses.

Result
Study characteristics
A total of 3524 studies were identified from the electronic search, and additional 15 records were identified through other sources. Using Endnote software (Clarivate Analytics), a total of 1182 duplicated articles were excluded. A total of 2223 obviously irrelevant studies were excluded after reading the title and the abstract; another 83 studies were excluded due to various reasons after reading the full text. Finally, a total of 36 studies were included in this meta-analysis [20–52]. A flow chart diagram of the search strategy and study selection is provided in Fig. 1, and the general characteristics of the included studies are presented in Table 1.

Six comparisons evaluated the effect of Gamma nail and CHS, 10 comparisons evaluated the effect of Gamma nail and DHS, 5 comparisons evaluated the effect of PFNA and DHS, 2 comparisons evaluated the PCCP and CHS, 2 comparisons evaluated the effect of PCCP and CHS, 2 comparisons evaluated the Gamma nail and PFNA, 1 comparison evaluated the Gamma nail and PFN, 1 study evaluated LISS and PFNA, 1 study evaluated DHS and Medoff sliding plate, 1 study evaluated PCCP and PFNA, and 1 study evaluated PCCP and DHS. Follow-up duration ranged from 3 to 19 months (mean follow-up duration = 10.06 months). Figure 2 graphically represents the network of eligible comparisons for the blood loss, Harris hip score, operative time, and complications of the network meta-analysis.

Methodological quality
All included studies in the meta-analysis were judged to be at high/unclear risk of bias. High/unclear risk of bias was assessed because all included studies had not described adequate blind method and sample calculation. Random sequence generation was adequate in only 12 studies. The details regarding the risk of bias for each included study are shown in Fig. 3.

Results from network meta-analysis
Blood loss
A total of 35 studies reported the intraoperative blood loss. Pooled results revealed that Gamma nail could significantly decrease blood loss than CHS (SMD, 76.16; 95% CrI, 17.78 to 134.71, Table 2) and DHS (SMD, 108.05; 95% CrI, 67.16 to 149.07, Table 2). Moreover, Gamma nail could decrease blood loss than LISS (SMD, −197.87; 95% CrI, −349.78 to −45.44, Table 2) and Medoff sliding plate (SMD, −150.74; 95% CrI, −232.93 to −68.17, Table 2).

PCCP could significantly decrease the blood loss than CHS (SMD, 111.14; 95% CrI, 32.73 to 189.61, Table 2), DHS (SMD, 143.12; 95% CrI, 88.36 to 197.79, Table 2), LISS (SMD, 232.87; 95% CrI, 75.76 to 389.37), and Medoff sliding plate (SMD, 185.81; 95% CrI, 86.09 to 285.40, Table 2).

PFN could also decrease blood loss than CHS (SMD, 192.01; 95% CrI, 39.72 to 344.08, Table 2), DHS (SMD, 224.03; 95% CrI, 76.76 to 370.03, Table 2), LISS (SMD, 313.46; 95% CrI, 106.62 to 520.79, Table 2), and Medoff sliding plate (SMD, 266.76; 95% CrI, 103.64 to 428.84, Table 2).

The results of this network meta-analysis showed that, compared with the CHS and DHS group, PFNA exhibited a beneficial role in reducing the blood loss (SMD, 152.50; 95% CrI, 72.93 to 232.45; and SMD, 184.40; 95% CrI, 132.99 to 235.90, respectively, Table 2). Compared with Gamma nail, PFNA was associated with a reduction of the blood loss (SMD, 76.32; 95% CrI, 18.32 to 134.70, Table 2).
Harris hip score
Thirty studies were available to assess the effect of eight treatment methods on postoperative Harris hip score. We observed that CHS has a higher Harris hip score than PCCP (SMD = 6.65, 95% CrI 2.15–11.13, Table 2). Gamma nail could also increase the Harris hip score than PCCP (SMD = 9.46, 95% CrI 5.04–13.81, Table 2).

The results of this network meta-analysis showed that, compared with the CHS, DHS, Medoff sliding plate, and PCCP group, PFNA exhibited a beneficial role in increasing the Harris hip score (SMD, –5.88; 95% CrI, –10.70, –1.05; SMD, –5.72; 95% CrI, –9.37 to –2.06; SMD, –8.28; 95% CrI, –14.29 to –2.34; SMD, –12.53; 95% CrI, –17.28 to –7.72, respectively, Table 2).

Operative time
Twenty-eight studies reported different treatment methods for the operative time. We found that PCCP could significantly decrease the operative time than CHS (SMD, 36.94, 95% CrI, 6.62 to 67.30, Table 2), DHS (SMD, 30.68; 95% CrI, 8.18 to 53.29, Table 2), LISS (SMD, 88.49; 95% CrI, 22.88 to 154.23, Table 2), and
Table 1 General characteristic of the included studies. NA not available, RCT randomized controlled trial, DHS dynamic hip screw, CHS compression hip screw, PCCP percutaneous compression plate, Medoff sliding plate, LISS less invasive stabilization system, PFN proximal femoral nail, PFNA proximal femoral nail anti-rotating

| Authors            | Intervention          | Comparator  | Follow-up (months) | Type of fracture | Age (mean, year) | Study | BMI (kg/m²) | Outcomes |
|--------------------|-----------------------|------------|--------------------|------------------|------------------|-------|-------------|----------|
| Leung et al. [20]  | Gamma nail            | CHS        | 7.2                | 31-A1–A3         | 83.35            | RCT   | NA          | 1,2,3,4  |
| Goldhagen et al. [21]| Gamma nail            | DHS        | 6                  | 31-A1–A3         | 80.6             | RCT   | NA          | 1,2,3,4  |
| Butt et al. [22]   | Gamma nail            | DHS        | 6                  | 31-A2–A3         | 79               | RCT   | NA          | 1,2,3,4  |
| O'Brien et al. [23]| Gamma nail            | DHS        | 13                 | 31-A1–A2         | 81.2             | RCT   | NA          | 1,2,3,4  |
| Hoffman and Lynskey [24]| Gamma nail        | DHS        | 12                 | 31-A1–A3         | 62.25            | RCT   | NA          | 1,3,4    |
| Kukla et al. [25]  | Gamma nail            | DHS        | 6                  | 31-A1–A3         | 81.9             | RCT   | NA          | 1,2,3,4  |
| Ahrengart et al. [26]| Gamma nail            | CHS        | 6                  | 31-A1–A3         | 79.6             | RCT   | NA          | 1,2,3,4  |
| Kosygan et al. [27]| PCCP                  | CHS        | 19                 | 31-A1–A3         | 72.95            | RCT   | NA          | 1,2,3,4  |
| Utrilla et al. [28]| Gamma nail            | CHS        | 12                 | 31-A1–A3         | 80.2             | RCT   | NA          | 1,2,3,4  |
| Ekström et al. [29]| Gamma nail            | Medoff sliding plate | 6 | 31-A2                        | 83.2 | RCT | NA          | 1,2,3,4  |
| Peyser et al. [30] | PCCP                  | CHS        | 12                 | 31-A1–A3         | 80.85            | RCT   | NA          | 1,2,3,4  |
| Romero et al. [31] | DHS                   | PCCP       | 12                 | 31-A1–A3         | 82.9             | RCT   | NA          | 1,2,3,4  |
| Zou et al. [32]    | DHS                   | PFNA       | 12                 | 31-A1–A3         | 82.5             | RCT   | NA          | 1,2,3,4  |
| Xu et al. [33]     | DHS                   | PFNA       | 12                 | 31-A1–A3         | 62.25            | RCT   | NA          | 1,2,3,4  |
| Yaozeng et al. [34]| Gamma nail            | PFNA       | 6                  | 31-A1–A3         | 75               | RCT   | NA          | 1,3,4    |
| Yang et al. [35]   | PCCP                  | DHS        | 15                 | 31-A1–A3         | 71.2             | RCT   | NA          | 1,2,3,4  |
| Guo et al. [36]    | PCCP                  | PFNA       | 12                 | 31-A1–A2         | 83.55            | RCT   | NA          | 1,2,3,4  |
| Sharma et al. [37] | PFNA                  | DHS        | 6                  | 31-A1–A3         | 81               | RCT   | NA          | 1,2,3,4  |
| Singh et al. [38]  | PFNA                  | DHS        | 5                  | 31-A1–A3         | 83.3             | RCT   | NA          | 1,2,3,4  |
| Adeel et al. [39]  | PFNA                  | DHS        | 12                 | 31-A1–A3         | 82.5             | RCT   | NA          | 1,2,3,4  |
| Brandt et al. [40] | PCCP                  | DHS        | 3                  | 31-A1–A3         | 71.4             | RCT   | NA          | 1,2,3,4  |
| Bridle et al. [41] | Gamma nail            | DHS        | 6                  | 31-A1–A3         | 75               | RCT   | NA          | 1,2,3,4  |
| Janzing et al. [42]| PCCP                  | DHS        | 12                 | 31-A1–A3         | 76.2             | RCT   | NA          | 1,2,3,4  |
| Kosygan et al. [27]| PCCP                  | DHS        | 19                 | 31-A1–A3         | 83               | RCT   | 23.2        | 1,2,3,4  |
| Madsen et al. [43] | Gamma nail            | DHS        | 6                  | 31-A1–A3         | 82.9             | RCT   | NA          | 1,2,3,4  |
| McCormack et al. [44]| DHS                  | Medoff sliding plate | 6 | 31-A1–A3                  | 81             | RCT   | NA          | 1,3,4    |
| Miedel et al. [45] | Gamma nail            | Medoff sliding plate | 12 | 31-A1–A3                  | 68.9            | RCT   | NA          | 1,2,3,4  |
| O'Brien et al. [23]| Gamma nail            | DHS        | 13                 | 31-A1–A3         | 70.4             | RCT   | NA          | 1,2,3,4  |
| Pajarinen et al. [46]| DHS                  | Gamma nail | 4 | 31-A1–A2                  | 80.2            | RCT   | 21.8        | 1,2,3,4  |
| Park et al. [47]   | Gamma nail            | CHS        | 12                 | 31-A1–A3         | 76.2             | RCT   | NA          | 1,2,3,4  |
| Parker et al. [48] | Gamma nail            | CHS        | 12                 | 31-A1–A2         | 72.9             | RCT   | NA          | 1,2,3,4  |
| Radford et al. [49]| DHS                   | Gamma nail | 12 | 31-A1–A3                  | 75.7            | RCT   | NA          | 1,2,3,4  |
| Schipper et al. [50]| Gamma nail            | PFN        | 12                 | 31-A1–A3         | 72.85            | RCT   | NA          | 1,2,3,4  |
| Utrilla et al. [28]| Gamma nail            | CHS        | 12                 | 31-A1–A3         | 72.85            | RCT   | NA          | 1,2,3,4  |
| Vaquero et al. [51]| PFNA                  | Gamma nail | 12 | 31-A1–A3                  | 75.7            | RCT   | NA          | 1,2,3,4  |
| Zhou et al. [52]   | LISS                  | PFNA       | 12                 | 31-A1–A3         | 75.7             | RCT   | NA          | 1,2,3,4  |
Medoff sliding plate (SMD, 53.29; 95% CrI, 12.48 to 95.58, Table 2). Moreover, PCCP could significantly decrease the operative time than that of PFNA group (SMD, −38.50; 95% CrI, −67.14 to −10.11, Table 2).

**Complications**

Thirty-two studies were available to assess the eight surgical treatments for postoperative complications. There was no statistical significance among these groups for complications (Table 2).

**Relative ranking of eight treatment methods**

Figure 4a reveals the SUCRA probability of the blood loss for the eight surgical methods. PFNA may have the lowest probability of the blood loss (SURCA = 0.072). In Fig. 4b, we summarized the SUCRA probability of the Harris hip score for the eight treatment methods. PFNA may have the highest probability of the Harris hip score (SURCA = 0.912).

Figure 4c summarizes the SUCRA probability of the eight surgical methods for operative time. PCCP may have the lowest probability of the operative time.
We observed that LISS may have the lowest probability of the incidence of complications (SURCA = 0.280, Fig. 4d).

**Comparisons between direct and indirect evidences**

The inconsistency between direct and the indirect estimates for each comparison will be further confirmed by node-splitting method. Bayesian $P$ value more than 0.05 indicated that there was no inconsistency of our results. We could easily find that all the $P$ values of node-splitting method were above 0.05, which indicated the consistency of the direct and indirect evidence for blood loss (Fig. 5). However, significant differences were observed at the comparison between Gamma nail versus CHS and PCCP versus CHS for Harris hip score (Fig. 6). Other comparisons were all above 0.05, which indicated the consistency of the direct and indirect evidence for Harris hip score. As for operative time, $P$ values of node-splitting method were above 0.05, except for PFNA versus DHS and PFNA versus Gamma nail ($P < 0.05$, Fig. 7). Nevertheless, no significant difference between direct and indirect evidence was observed in complications (Fig. 8).

**Table 2** The comparison of eight surgical methods for blood loss, Harris hip score, operative time and complications according to the network meta-analysis using standard mean difference or odds ratios (ORs) and corresponding 95% credential intervals (Crls). Italics with red colors were with statistically significant evidence for blood loss (Fig. 5).
Discussion

In this network meta-analysis based on 36 RCTs, we systematically reviewed the DHS, CHS, PCCP, MSP, LISS, Gamma nail, PFN, and PFNA for treatment of intertrochanteric fracture. Thirty-six eligible studies were finally involved in this network meta-analysis. PFNA ranked as the most preferable surgical method with less blood loss and higher Harris hip score. As for operative time, PCCP may have the lowest probability of the operative time. However, complications did not differ among these groups. These results may help orthopedic surgeons for the selection of surgical methods for intertrochanteric fracture.

This is the very largest network meta-analysis that compared the efficacy and safety of eight common surgical methods for treatment of intertrochanteric fracture. Previously, Jiang et al. [53] conducted a meta-analysis about efficacy and safety of PFNA and LISS for intertrochanteric fracture; results suggested that PFNA could significantly reduce the hospital stay than LISS. This result is inconsistent with other observations. Arirachakaran et al. [54] suggested that PCCP was superior than DHS and PFNA in terms of intraoperative outcomes and postoperative complications. However, there were some limitations, including the retrospective study design, mixed PFN and PFNA into a group, and omitted important indicators for hip function. PFNA possesses biological advantage, minimally invasive approach, and easy manipulation. We firstly used blood loss to assess intraoperative advantage between these eight surgical methods. SURCA rank suggested that the blood loss in PFNA ranked the lowest. A major limitation of this outcome is that there is lack of hidden blood loss in these surgical treatments. It needs to be emphasized that hidden blood loss in the operation cannot be overlooked [55, 56]. Therefore, it is urgent to verify the hidden blood loss in these surgical interventions in future studies.

For hip functions, we compared Harris hip scores as the main outcome. Regarding the increase of the Harris hip score, PFNA treatment was also ranked as the top
intervention. These results suggested that PFNA could enhance the recovery of the hip function. Xie et al. [57] conducted a controlled study and suggested that PFNA had a better hip recovery than hemi-arthroplasty in intertrochanteric fractures. Ma et al. [58] conducted a meta-analysis about Gamma nail, PFNA, and DHS for intertrochanteric fracture. Results have shown that PFNA was a priority choice with minimal rate of fixation failure and shorter length of hospital stay.

We also compared operative time among the eight surgical methods. Results suggested that PCCP had the lowest probability of operative time than other treatments. However, other studies have drawn the opposite conclusion [19]. Hao et al. [19] suggested that PFNA treatment results in shortest operative time than other surgical treatments. As surgical experience might influence the operative time, thus more validation studies need to be performed. We finally compared complications between these eight treatments; network meta-analysis found that these eight treatments have no statistical significance. Concerning clinical safety, all of these treatments were comparable.

This network meta-analysis had several limitations. The number of included studies was limited and the sample size was small. Further, the quality of this network meta-analysis is limited by the quality of available data.
| Study                          | P-value | Standard Mean Difference (95% Crl) |
|-------------------------------|---------|----------------------------------|
| **Gamma_nail vs CHS**         |         |                                  |
| direct                        |         |                                 |
| indirect                      | 0.027075| 1.2 (-2.1, 4.6)                  |
| network                       |         | 2.8 (-0.57, 6.2)                 |
| **PCCP vs CHS**               |         |                                  |
| direct                        |         |                                 |
| indirect                      | 0.0281  | -2.5 (-7.9, 2.9)                 |
| network                       |         | -6.7 (-11.4, -2.1)               |
| **Gamma_nail vs DHS**         |         |                                  |
| direct                        |         |                                 |
| indirect                      | 0.358925| 3.5 (0.053, 6.9)                 |
| network                       |         | 0.75 (-4.4, 5.8)                 |
| **Medoff_sliding_plate vs DHS**|         |                                  |
| direct                        |         |                                 |
| indirect                      | 0.8941  | -3.0 (-12.5, 5.7)                |
| network                       |         | -2.6 (-7.7, 2.6)                 |

Study                          P-value | Standard Mean Difference (95% Crl)
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**PCCP vs DHS**                  |                     |
| direct                        |                     |
| indirect                      | 0.058775            | -10 (-16, -5.0)            |
| network                       |                     | -3 (-8.6, 2.7)             |
| **PFNA vs DHS**                |                     |
| direct                        |                     |
| indirect                      | 0.550325            | 6.7 (1.7, 12)              |
| network                       |                     | 4.5 (-1.2, 10)             |
| **Medoff_sliding_plate vs Gamma_nail** |          |                                  |
| direct                        |                     |
| indirect                      | 0.890375            | -5 (-11.1, 1.1)            |
| network                       |                     | -5.7 (-15.4, 3.4)          |
| **PFNA vs Gamma_nail**         |                     |
| direct                        |                     |
| indirect                      | 0.468425            | 1.5 (-4.5, 7.5)            |
| network                       |                     | 4.3 (-0.94, 9.6)           |

Study                          P-value | Standard Mean Difference (95% Crl)
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**PFNA vs PCCP**                 |                     |
| direct                        |                     |
| indirect                      | 0.886325            | 12.6 (2.2, 18.0)           |
| network                       |                     | 12.6 (2.2, 18.0)           |

Fig. 6 Comparison between direct and indirect evidence—Harris hip score
### Comparison between direct and indirect evidence—operative time

| Study                     | P-value | Standard Mean Difference (95% Crl) |
|---------------------------|---------|-----------------------------------|
| **Gamma_nail vs CHS**     |         |                                   |
| direct                    |         | -29. (-58, 0.20)                  |
| indirect                  | 0.1635  | 12. (-39, 64)                     |
| network                   |         | -19. (-44, 6.8)                   |
| **PCCP vs CHS**           |         |                                   |
| direct                    |         | -18. (-58, 23)                    |
| indirect                  | 0.167075| -59. (-1.0e+02, -15)              |
| network                   |         | -37. (-67, -6.7)                  |
| **Gamma_nail vs DHS**     |         |                                   |
| direct                    |         | -16. (-43, 11)                    |
| indirect                  | 0.677225| -7.4 (-41, 27)                    |
| network                   |         | -1.3 (-33, 8)                     |
| **Medoff_sliding_plate vs DHS** |     |                                   |
| direct                    |         | 3.0 (-56, 63)                     |
| indirect                  | 0.375625| 36. (-11, 83)                     |
| network                   |         | 23. (-14, 60)                     |

| Study                     | P-value | Standard Mean Difference (95% Crl) |
|---------------------------|---------|-----------------------------------|
| **PCCP vs DHS**           |         |                                   |
| direct                    |         | -38. (-64, -12)                   |
| indirect                  | 0.272725| -11. (-54, 31)                    |
| network                   |         | -31. (-53, -9.0)                  |
| **PFNA vs DHS**           |         |                                   |
| direct                    |         | 23. (-1.2, 47)                    |
| indirect                  | 0.031625| -24. (-59, 11)                    |
| network                   |         | 7.8 (-14, 30)                     |
| **Medoff_sliding_plate vs Gamma_nail** | |                                   |
| direct                    |         | 46. (4.1, 88)                     |
| indirect                  | 0.377025| 13. (-50, 76)                     |
| network                   |         | 36. (0.92, 70)                    |
| **PFNA vs Gamma_nail**    |         |                                   |
| direct                    |         | -18. (-54, 19)                    |
| indirect                  | 0.01145 | 44. (16, 73)                      |
| network                   |         | 20. (-5.4, 46)                    |

**Fig. 7** Comparison between direct and indirect evidence—operative time
literatures (high/unclear risk of bias). Additionally, the length of load time and postoperative rehabilitation strategies might be further affected by the patients’ hip functions. Finally, inconsistency was observed in places (Harris hip score and operative time); further research will be needed to verify it.

**Conclusion**

PFNA technique is the optimal treatment method for intertrochanteric fracture. Larger, longitudinal RCTs addressing current limitations, including sources of bias, inconsistency, and imprecision, are needed to provide more robust and consistent evidence.
Abbreviations
DHS: Dynamic hip screw; CHS: Compression hip screw; PCCP: Percutaneous compression plate; LSS: Less invasive stabilization system; PFN: Proximal femoral nail; PFNA: Proximal femoral nail anti-rotating; RCTs: Randomized controlled trials; ORs: Odd ratios; Crt: Credibility interval; SMD: Standard mean difference; SUCHARA: Surfaces under the cumulative ranking curves; OTA: Orthopaedic Trauma Association; ROB: Risk of bias

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Authors’ contributions
YXC and XS conceived the study design. YXC and XS performed the study, collected the data, and contributed to the study design. YXC and XS prepared the manuscript. YXC and XS edited the manuscript. All authors read and approved the final manuscript.

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