Poor Outcomes of Children and Adolescents with Femoral Neck Fractures: A Meta-Analysis Based on Clinical Studies

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Objective: To comprehensively assess the differences in outcome between open reduction and closed reduction for children and adolescents with femoral neck fractures.

Methods: Based on the predetermined strategies, eligible studies were obtained by searching Embase, the Cochrane Library, and PubMed databases (retrieval time: June 2018) and through manual retrieval for paper documents. The 95% confidence intervals (CI) and risk ratios (RR) were used as evaluation indexes. Moreover, the results of avascular necrosis, coxa vara, or non-union were compared between open reduction and closed reduction under random or fixed effects models. After sensitivity analysis was carried out, publication bias was evaluated for the eligible studies using Egger’s test.

Results: Six studies were included in our meta-analysis. No significant heterogeneity was found among the included studies (P ≥ 0.05) and, thus, the fixed effects model was used for merging the effect sizes of avascular necrosis (RR [95% CI] = 0.50 [0.26, 0.98], P = 0.04), coxa vara (RR [95% CI] = 0.16 [0.04, 0.70], P = 0.01), and non-union (RR [95% CI] = 0.22 [0.05, 0.93], P = 0.04). Sensitivity analysis suggested that the results of avascular necrosis were not stable (RR = 0.50, 95% CI = 0.25 1.17, P = 0.12), while those of coxa vara and non-union were stable. There was no significant publication bias among the eligible studies (t = −0.70, P = 0.522).

Conclusion: Femoral neck fractures treated by open reduction had less adverse outcomes compared with those treated by closed reduction.

Key words: Avascular necrosis; Closed reduction; Femoral neck fracture; Meta-analysis; Open reduction

Introduction

Femoral fractures are induced by serious trauma and include fractures of the neck, the head, the trochanter, the middle of the femur, and the diaphysis. Femoral fractures are often characterized by severe pain, swelling, leg shortening, deformity, soft-tissue injury, shock, and bleeding. Avascular necrosis of the femoral head and non-union of fractures are the two major complications in the therapy of femoral neck fractures. The optimal treatment method of femoral neck fractures is manual reduction and internal fixation, and the healing rate is 80% to 90%. Therefore, the treatment principle of femoral neck fractures is

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Grant Sources: This work was supported by the Natural Science Basic Research Plan in Shaanxi Province of China (Project number: 2017JM8118), the China Postdoctoral Science Foundation (Project number: 2017M613179), and the Project for Development and Clinical Application of Fracture Healing Period (Project number: S2018-YF-YBSF-0265).

Disclosure: The authors declare that they have no competing interests.

Received 26 July 2019; accepted 14 January 2020

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Orthopaedic Surgery 2020;12:639-644 • DOI: 10.1111/os.12629

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by Wang et al (2014) evaluated the correlation between avascular necrosis and open/closed reduction for femoral neck fractures, revealing that CRIF leads to a higher avascular necrosis rate compared with ORIF12. However, that meta-analysis was not focused on femoral neck fractures in children and adolescents. Therefore, it is necessary to identify the differences in outcomes of children and adolescents treated for femoral neck fractures with open reduction and closed reduction through a more comprehensive meta-analysis.

Thus, in this study, we use a meta-analysis to comprehensively assess the differences in outcome between open reduction and closed reduction for children and adolescents with femoral neck fractures. The present study may provide direction for further correlation studies.

Methods

Search Strategy
Using “femoral neck fractures” and “open reduction” as search key words, eligible studies were extracted from Embase, the Cochrane Library, and PubMed databases based on the predetermined strategies (retrieval time 7 June 2018, without restriction on the language). Combining topic words and free words, the search was performed. The search procedure of PubMed is shown in Supplementary Table S1. Manual retrieval for paper documents was also carried out, and the references of relevant reviews and enrolled studies were further screened to include more studies into this meta-analysis.

Fig. 1 The process of selecting eligible studies. A total of 856 studies were included in this meta-analysis through a database search; 210 studies were excluded by screening the repeated articles and 612 ineligible studies were removed after scanning through the titles. From the remaining 34 studies, 25 studies were screened out after reading abstracts and 3 studies were further eliminated after reading full texts. Finally, a total of 6 studies with 198 patients were included in this meta-analysis.
Inclusion Criteria

Studies were considered for inclusion if they met the following criteria.

(i) Participants: Children and adolescents (<18 years old) who suffered from femoral neck fractures.

(ii) Interventions and comparisons: The study explored the differences in poor outcomes between open reduction and closed reduction.

(iii) Outcomes: Avascular necrosis, coxa vara, or non-union.

(iv) Study design: The study was a randomized controlled trial (RCT) or a non-randomized clinical study.

Exclusion Criteria

The exclusion criteria were: (i) the studies were reviews, comments, letters, et al; and (ii) the studies were republished papers or studies using data involved in several publications.

Data Extraction

Two investigators independently completed document screening according to the above inclusion and exclusion criteria. After determining the studies to include, the investigators independently performed data extraction in accordance with the predesigned standardized form. The information that needed to be extracted included: the name of the first author, the publication year, the study area, the ages and sexes of the subjects, the sample sizes, the study types, and the research outcomes. After the above data extraction was finished, the two investigators exchanged the extraction tables. If there were any inconsistencies, they discussed these together to resolve disagreements.

Statistical Analysis

The 95% confidence intervals (CI) and risk ratios (RR) were selected as the evaluation indexes. Cochran’s Q test and the $I^2$ test were used for performing heterogeneity tests for the included studies. When the studies had significant heterogeneity ($P < 0.05$ and/or $I^2 > 50$%), the random effects model was used for merging the effect sizes. When there were homogeneous outcomes ($P \geq 0.05$ and $I^2 \leq 50$%), the fixed effects model was used. Egger’s test was used to evaluate whether there was publication bias among the included studies. If significant publication bias was found, the effect of publication bias on the results would be assessed with the trim and fill method. Using the transform merge model, a sensitivity analysis was conducted to evaluate the stability of the results. All statistical analysis was performed using RevMan 5.3 software and STATA 11.0 software.

Results

Eligible Studies

As shown in Fig. 1, a total of 277, 524, and 55 studies were selected from PubMed, Embase, and Cochrane Library databases. Repeated articles were filtered out, and 646 studies remained. Then, 612 ineligible studies were removed after...
scanning through the titles. From the remaining 34 studies, 25 studies were screened out following reading the abstracts and 3 studies were further eliminated after reading full texts. Finally, a total of 6 studies were included in this meta-analysis13,16–20. As shown in Table 1, there were 198 patients in these 6 studies13,16–20, including 118 males and 80 females. The fracture type of the study by Bali et al. included 16 type II, 11 type III, and 9 type IV16. The fracture type of the study by Dendane et al. included 9 type II, 10 type III, and 2 type IV17. The fracture type of the study by Ju et al. included 30 type II, 21 type III, and 7 type IV13. The fracture type of the study by Lin et al. included 25 type II and 9 type III18. The fracture type of the study by Song included 15 type II and 12 type III19. The fracture type of the study by Stone et al. included 13 type II, 8 type III, and 1 type IV20.

### Study Characteristics

All of the 6 included studies were retrospective clinical studies13,16–20. The publication years of the included studies were from 2010 to 2016, and their study areas included China13,18, India16, Korea19, the USA20 and Morocco17. Except for the study of Bali et al. (involving 28 displaced fracture cases and 8 undisplaced fracture cases16), the studies only included displaced fracture cases13,17–20. The characteristics and the outcomes of the eligible studies are presented in Tables 1 and 2, respectively.

### Meta-analysis

The results of the meta-analysis for avascular necrosis showed that there was no significant heterogeneity among the 6 included studies13,16–20 (I² = 9%, P = 0.36), and thus, the fixed effects model was used (RR [95% CI] = 0.50 [0.26, 0.98], P = 0.04) (Fig. 2). The meta-analysis for coxa vara suggested that there were homogeneous outcomes among 4 eligible studies (I² = 0%, P = 0.9513,16,18,19), and the fixed effects model was selected (RR [95% CI] = 0.16 [0.04, 0.70], P = 0.01) (Fig. 3). Moreover, the meta-analysis results for non-union indicated that there was no significant heterogeneity in 4 studies (I² = 0%, P = 0.9413,16,18,19), and the fixed effects model was also used (RR [95% CI] = 0.22 [0.05, 0.93], P = 0.04) (Fig. 4).

### Table 2 Outcomes of the studies included in the meta-analysis

| Study          | Area    | Group | n, M/F | Fracture type (Delbet’s criteria) | Age, years | Delay (days) | AVN | Coxa vara | Non-union |
|----------------|---------|-------|--------|-----------------------------------|------------|--------------|-----|-----------|-----------|
| Bali, 2011     | India   | ORIF  | 18, NR | NR                                | NR         | NR           | 3   | 0         | 0         |
| CRIF           | NR      |       |        |                                    |            |              | 1   | 2         |           |
| Dendane, 2010  | Maroc   | ORIF  | 13, 8/5| 5 type II, 6 type III, 2 type IV  | 9–16       | 1–21         | 5   | NR        | NR        |
| CRIF           | 8, 6/2  | 4 type II, 4 type III, 0 type IV | 5–14 | 0.5–15 | 1 | NR | NR |
| Ju, 2016       | China   | ORIF  | 37, 26/11| 19 type II, 14 type III, 4 type IV | 9.21 ± 3.14 | 4.89 ± 2.47 | 5   | 0         | 0         |
| CRIF           | 21, 14/7| 11 type II, 7 type III, 3 type IV | 8.85 ± 3.79 | 4.29 ± 2.10 | 6 | 3 | 1         |
| Lin, 2012      | China   | ORIF  | 19, 11/8| 14 type II, 5 type III          | 8.1 ± 1.3 | 7.3 ± 2.6 hours | 0   | 0         | NR        |
| CRIF           | 15, 9/6 | 11 type II, 4 type III | 7.9 ± 1.5 | 8.5 ± 1.8 hours | 2 | 1 | NR |
| Song, 2010     | Korea   | ORIF  | 15     | 8 type II, 7 type III            | 9.7 (5.0–15.0) | 12 cases <1 | 0   | 0         | 0         |
| CRIF           | 12      | 7 type II, 5 type III | 10.1 (5.0–16.0) | 12 cases <1 | 2 | 2 | 2         |
| Stone, 2015    | USA     | ORIF  | 6, 6/0 | 2 type II, 4 type III, 0 type IV | 12.2 (10.7–12.6) | 3 cases ≤1, 3 cases >1 | 0   | NR        | 0         |
| CRIF           | 16, 7/9 | 11 type II, 4 type III, 1 type IV | 10.7 (9.3–14) | 15 cases ≤1, 1 cases >1 | 8 | NR | 2         |

AVN, avascular necrosis; CRIF, closed reduction and internal fixation; F, female; M, male; NR, not report; ORIF, open reduction and internal fixation.

**Fig. 2** The results of the meta-analysis for avascular necrosis for open reduction and internal fixation (ORIF) and closed reduction and internal fixation (CRIF). The results of the meta-analysis for avascular necrosis showed that there was no significant heterogeneity among the 6 included studies (I² = 9%, P = 0.36), and the data were pooled using fixed effects model analysis. P < 0.05, difference was statistically significant.
Due to the low heterogeneity among the included studies, the fixed effects model was used for merging the effect sizes of avascular necrosis, coxa vara, and non-union. The merged results for avascular necrosis changed significantly (RR = 0.50, 95% CI = 0.25–1.17, P = 0.12), indicating that the results were not stable. Although the combined results of coxa vara and non-union were changed, they were still statistically significant. Therefore, the results for coxa vara and non-union were stable (Table 3).

All 6 eligible studies had the outcome of avascular necrosis and, thus, publication bias was based on avascular necrosis. Egger’s test showed that there was no significant publication bias among the included studies (t = −0.70, P = 0.522).

**Sensitivity Analysis and Publication Bias**

Due to the low heterogeneity among the included studies, the fixed effects model was used for merging the effect sizes of avascular necrosis, coxa vara, and non-union. The merged results for avascular necrosis changed significantly (RR = 0.50, 95% CI = 0.25–1.17, P = 0.12), indicating that the results were not stable. Although the combined results of coxa vara and non-union were changed, they were still statistically significant. Therefore, the results for coxa vara and non-union were stable (Table 3).

All 6 eligible studies had the outcome of avascular necrosis and, thus, publication bias was based on avascular necrosis. Egger’s test showed that there was no significant publication bias among the included studies (t = −0.70, P = 0.522).

**Discussion**

A total of 6 studies were included into the present meta-analysis, all of which were retrospective clinical studies. The meta-analysis for all avascular necrosis, coxa vara, and non-union showed no significant heterogeneity among the included studies, and, thus, the fixed effects model was used for the three outcomes. The sensitivity analysis showed that the results for avascular necrosis were not stable, while the results for coxa vara and non-union were stable. Egger’s test suggested that there was no significant publication bias among the eligible studies.

Bali et al. analyzed the outcomes of femur neck fractures in children treated by CRIF, by ORIF, or conservatively, and found that children treated by ORIF have the lowest rate of complications. Ju et al. found that ORIF can

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**Fig. 3** The results of the meta-analysis for coxa vara between open reduction and internal fixation (ORIF) and closed reduction and internal fixation (CRIF). The meta-analysis for coxa vara suggested that there were homogeneous outcomes among four eligible studies ($I^2 = 0\%, P = 0.95$), and the data were pooled using fixed effects model analysis. $P < 0.05$, difference was statistically significant.

**Fig. 4** The results of the meta-analysis for non-union between open reduction and internal fixation (ORIF) and closed reduction and internal fixation (CRIF). The meta-analysis results of non-union indicated that there was no significant heterogeneity in 4 studies ($I^2 = 0\%, P = 0.94$), and the data were pooled using fixed effects model analysis. $P < 0.05$, difference was statistically significant.

**TABLE 3 Random-effects and fixed-effects models comparing open reduction to closed reduction**

| Outcomes   | n  | RR (95%CI), P value | Fixed-effects model | Random-effects model | Test of heterogeneity |
|------------|----|---------------------|---------------------|----------------------|----------------------|
| AVN        | 6  | 0.50 (0.26, 0.95), 0.04 | 0.54 (0.25, 1.17), 0.12 | $I^2 = 9\%, P = 0.36$ |
| Coxa vara  | 4  | 0.16 (0.04, 0.70), 0.01 | 0.17 (0.04, 0.76), 0.02 | $I^2 = 0\%, P = 0.95$ |
| Non-union  | 4  | 0.22 (0.05, 0.93), 0.04 | 0.22 (0.05, 0.98), 0.049 | $I^2 = 0\%, P = 0.94$ |

AVN, avascular necrosis; n, number of included trials.
generate better outcomes for children with displaced femoral neck fractures compared to closed reduction, which may be correlated with the higher reduction quality of open reduction. Lin et al. compared the effects of early anatomical ORIF and CRIF for children with femoral neck fractures and revealed that early ORIF can achieve better reduction and induce fewer complications. ORIF provides a higher quality of reduction and fewer complications than CRIF; therefore, ORIF is a better reduction method. Stone et al. report that children with fully displaced femoral neck fractures treated by ORIF had fewer complications (including osteonecrosis) and better reduction in comparison to those treated by CRIF. However, Dendane et al. demonstrate that open reduction, late surgery, and older age may increase the occurrence of complications in femoral neck fracture and serve as predictors of the development of avascular necrosis. These inconsistent findings of the 6 included studies might be a result of the different study areas and sample sizes.

This study is the first meta-analysis to comprehensively investigate the differences in adverse outcomes of open reduction and closed reduction in treating children and adolescents with femoral neck fractures. There was no significant heterogeneity among the included studies, and most of the demographic and clinical information, such as age and fracture types, for the two groups was not statistically different. Moreover, there was no significant publication bias among the included studies. Despite the above advantages, several limitations also existed in the current study. Only a few studies were included and the sample size was small. Sensitivity analysis showed that the stability of the merged results for avascular necrosis was poor, and the small sample size might be one of the reasons. The results of Dendane et al. were RR (95% CI) = 3.08 (0.43, 21.80). The weight increased from 5.4% to 14.2% under the random effect model, which also led to a significant change in the merger results. Because the included studies were retrospective clinical studies and there was no suitable tool for quality evaluation, this meta-analysis did not conduct a quality evaluation for the included studies. Therefore, these findings need to be supported by more researches.

In conclusion, the risk of adverse outcomes of open reduction was lower compared with closed reduction. However, more rigorous and high-quality RCT with large sample sizes are needed to confirm our results.

Supporting Information
Additional Supporting Information may be found in the online version of this article on the publisher’s web-site: Table S1 The search procedure of PubMed.

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Table S1 The search procedure of PubMed.