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Review Article

Open or closed reduction and percutaneous pinning for pediatric displaced supracondylar humerus fractures: a meta-analysis and system review

Bo Gou*, Xiao-Tao Wang*, Qing-Song Zhang, Quan-Bing Wang

*Department of Orthopedics, Renmin Hospital, Hubei University of Medicine, Shiyan, Hubei, P. R. China. *Equal contributors.*

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Abstract: Objective: A meta-analysis was conducted to compare the effectiveness and safety of open or closed reduction and percutaneous pinning for pediatric displaced supracondylar humerus fractures. Methods: Embase, Medline and Cochrane Library were searched to identify the relevant studies published from the year of 1992 to 2015. All the controlled clinical trials and random controlled trails published to compare the open and closed reduction and percutaneous pinning (CRPP, ORPP) for pediatric displaced supracondylar humerus fractures were enrolled in the study. The study included randomized controlled trials (RCTs) and controlled clinical trial (CCT) to compare the effectiveness and safety of CRPP and ORPP for pediatric displaced supracondylar humerus fractures. Two investigators independently searched articles, extracted data, and assessed the quality of included studies. Cochrane RevMan software version 5.3 was utilized to perform the meta-analysis. Meta-analysis was performed using random-effect model. Results: 1 RCTs and 6 CCTs involving a total number of 502 patients were enrolled in the study, while 273 subjects adopted CRPP and 229 cases adopted ORPP. No significant differences were detected for the results of carrying angel, Bauman angel and complication rate [MD=-1.62, 95% CI (-3.35, 0.10), P=0.07, I^2=0%; MD=-1.17, (-5.50, 3.15), P=0.6, I^2=87%; OR=1.23, 95% CI (0.67, 2.28), P=0.5, I^2=31%]. Less mean hospital stay and union time were found when CRPP was compared with ORPP [MD=-0.58, 95% CI (-1.03, -0.12), P=0.01, I^2=36%; MD=-2.03, (-3.76, -0.29), P=0.02, I^2=83%]. The patients that accepted CRPP seem to had more satisfaction rate when compared with the patients who accepted ORPP [OR=1.12, 95% CI (1.01, 1.24), P=0.03, I^2=38%]. Conclusion: No significant differences were detected between the patients which adopted the two methods (CRPP and ORPP) for the results of carrying angel, Bauman angel and complication rate. However, the paediatric patients who adopted CRPP owned less mean hospital stay, union time and more satisfaction rate when compared with the cases, which adopted the method of ORPP.

Keywords: Closed reduction and percutaneous pinning, open reduction and percutaneous pinning, displaced supracondylar humerus fractures, controlled clinical trial, random controlled trail

Introduction

Pediatric displaced Supracondylar Humerus Fracture (SHF) is a common elbow injury among young children, which represents about 7.5% of all the children fractures [1-3]. The year between 5 to 7 has been considered to be the peak incidence age for the pediatric patients suffering from SHF, as the skeletal maturity is approached for the children more than 8 years [4, 5]. In the management of pediatric displaced SHF, different treatments have been implemented including conservative and surgical approaches, achieving the goal of minimal tissue injury, proper induction, the shortest bone union time and the lowest complication rate [6, 7]. Closed reduction and percutaneous pinning (CRPP) has been considered to be the best approach due to avoidance of high expense during the hospital stay, delayed bone union and some complications caused by the open reduction [8]. While, open reduction and percutaneous pinning (ORPP) has been also deemed to be the preferred modality for the patients with displaced or unstable fracture, open fracture with vascular or nerve injury and Volkmann's ischemic symptoms [9, 10]. If an adequate reduction could not be obtained by closed manipulation, open

Table 1. Characteristics of the eight studies included in the meta-analysis

Study	Country	Mean age (years) C/O	No. of Patients C/O	Study design	Gartland classification (I, II, III, IV) C/O	Flow-up (months)
Kathryn 1992 [13]	USA	5.4/6.2	15/14	CCT	0, 3, 12, 0/0, 1, 13, 0	Not mentioned
Chang 2003 [14]	Korea	6.7/6.1	21/14	CCT	Not mentioned	Not mentioned
Cem 2008 [15]	Turkey	8.1/8.3	32/23	CCT	Not mentioned	22.0/21.6
Egemen 2008 [16]	Turkey	7.6/7.3	76/68	CCT	Not mentioned	Not mentioned
Yaokreh 2012 [17]	France	7.9/7.0	33/25	CCT	0, 0, 9, 24/0, 0, 5, 20	Not mentioned
Keskin 2014 [18]	Turkey	Not mentioned	50/50	RCT	0, 0, 50, 0/0, 0, 50, 0	49.2/14.2
Phillip 2015 [19]	USA	Not mentioned	46/35	CCT	Not mentioned	5.2/6.0

C: close reduction. O: open reduction.

reduction of SHF is usually required and could be performed by a lateral, anterior, medial, or posterior approach [11, 12].

Seven articles have been published to compare the function outcomes including carrying angel, Bauman angle, as well as satisfactory and complication rate between CRPP and ORPP [13-19]. However, the number of enrolled patients in each group is limited and the conclusion is difficult to draw. Thus, a meta-analysis and systematic review which adopts the standards of the international Cochrane Collaboration is urgently required to assess the efficacy and safety between CRPP and ORPP for patients suffering from pediatric displaced SHF. The meta-analysis and system review is carried out to help those patients with such kind of fractures to choose the best treatments.

Patients and methods

Search strategy

Medline, EMBASE, and Cochrane Library databases were used to carry out the literature research from their inception to April of 2017. Relevant studies reporting CRPP and ORPP for pediatric displaced SHF were identified and analyzed. In addition, the references of relevant articles and proceedings were examined for additional relevant references. Closed reduction and percutaneous pinning, open reduction and percutaneous pinning, displaced supracondylar humerus fractures, controlled clinical trial and random controlled trail were chosen to be the search terms.

Selection criteria

The enrolled studies should meet the following criteria: (1) randomized controlled trials or controlled clinical trial comparing CRPP and ORPP; (2) pediatric patients suffering from displaced SHF; (3) the ages of the enrolled patients are no more than 10 years old; (4) no others therapies were adopted for the enrolled patients before the treatments of CRPP or ORPP; (5) no other congenital diseases were found in the enrolled pediatric patients; (6) all the included articles in the study should provide data that compare the results between the CRPP and ORPP; (7) the results of the study include at least one of the carrying angel, Bauman angel, mean hospital stay, union time, satisfaction and complication rate. Articles without a clear description of data regarding intervention details (CRPP or ORPP) were excluded; article with non English were excluded; article without the included results were excluded. Two investigators independently retrieved all the included citations to confirm inclusion or exclusion of the studies. The views from the third investigator should be adopted if disagreements exist between the two investigators.

Data extraction and quality assessment

The primary radiographic and clinical outcomes include carrying angel, Bauman angel, mean hospital stay and union time, while the last safety profile includes satisfactory rate and complication related to the two therapies, such as superficial pin track infection, iatrogenic ulnar nerve injuries, wound dehiscence and myositis ossificans. Two investigators independently extracted the following information from the enrolled studies by using a standardized collection: author name, publication year, country of the enrolled study, mean age of the enrolled patients, article type, mean following-up and Gartland classification of the fracture (**Table 1**). Quality *ASSESSMENT* of the enrolled random-

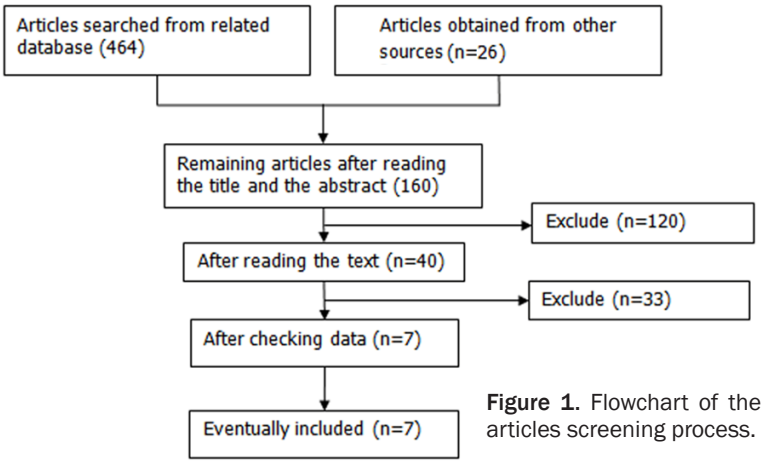

Figure 1. Flowchart of the articles screening process.

Table 2. Quality score for CCT (MINORS Score)

Study	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	MINORS Score
Kathryn 1992 [13]	2	2	2	2	2	0	2	2	2	1	2	2	21
Chang 2013 [14]	2	2	2	2	2	0	2	1	2	2	2	2	21
Cem 2008 [15]	2	2	2	2	2	2	2	1	2	1	2	2	22
Egemen 2008 [16]	2	2	2	2	2	0	2	1	2	1	2	2	20
Yaokreh 2012 [17]	2	2	2	2	2	2	2	0	2	2	2	1	21
Phillip 2015 [19]	2	2	2	2	2	2	2	0	1	1	2	1	19

① Providing the clear research purpose; ② Coherence of the enrolled patients; ③ Collection of the expected data; ④ Reflection of the research purpose; ⑤ Objectivity of the results; ⑥ Adequacy of the following-up time; ⑦ Default rate is below 5%; ⑧ Estimation of the sample size; ⑨ Appropriateness of the control group; ⑩ Synchronization of the control group; ⑪ Comparability of base line between groups; ⑫ Appropriateness of the statistical analysis. 0 point: no reporting; 1 point: Reporting with insufficient information; 2 points: Reporting with sufficient information.

ized controlled trials (RCTs) and controlled clinical trial (CCT) were carried out by two independent investigators. RCTs were assessed by using the tool of Cochrane Risk of Bias, while CCT was *ASSESSED* by MINORS score [20, 21]. Discussions and consensus should be adopted from the senior author if conflicts exist regarding literature search, study selection, and data extraction between the two investigators.

Data synthesis and analysis

The software of RevMan 5.2 was used to perform the statistical analysis. Two-sided tests were used to conduct the data analyses, with a significant level of $P<0.05$. Heterogeneity of the results was checked by the I^2, with the values less than 50% being considered as no significant heterogeneity. The fixed effects model was used in cases of no heterogeneity, while random effects model was applied if heterogeneity were detected. The odds risk (OR) and 95 percent confidence intervals were calculated for dichotomous variables, while mean difference and 95 percent confidence intervals were used for those data, which involved quantitative measurement. Publication bias was checked by using the funnel plot produced by RevMan 5.2 software. The strength of outcomes was checked and the methods on the effect size were explored by conducting the sensitivity analyses.

Results

Literature search and evaluation

A flowchart was drawn to show the articles screening process (**Figure 1**). 7 articles published from the year of 1992 to 2015 were left finally, including six CCTs and one random controlled trail. All the left seven articles met the inclusion and exclusion criteria [13-19].

The enrolled seven articles included a total number of 502 patients, 273 cases adopted CRPP while 229 cases adopted ORPP. All the pediatric displaced SHFs were characterized by using Gartland classification [22]. The clinical characteristics of the studies are presented below (**Table 1**).

Quality ASSESSMENT and overall estimations of the meta-analysis

The quality of the seven articles was evaluated by using Cochrane Risk of Bias tool and MINORS score [20, 21]. The results are shown in **Tables 2** and **3**. 6 CCTs provide the clear research purpose, the coherent patients, objective results and collection of the expected data, while the results of the six articles can also reflect purpose of the research [13-17, 19]. 3 CCTs provide adequate following-up time [15, 17, 19]. The default rate of the six CCTs is below 5% [13-17, 19]. 1 CCT estimated the sample size [13]. 5 CCTs provide the appropriate control group [13-17]. 2 CCTs provided synchronous control

Table 3. Quality assessment of the included RCT

Study	Random sequence generation	Allocation concealment	Blind	Incomplete outcome data	Selective reporting	Other bias
			Participants and personnel/ outcome assessment			
Keskin 2014 [18]	Unclear	Unclear	Low/Low	Low	High	Unclear

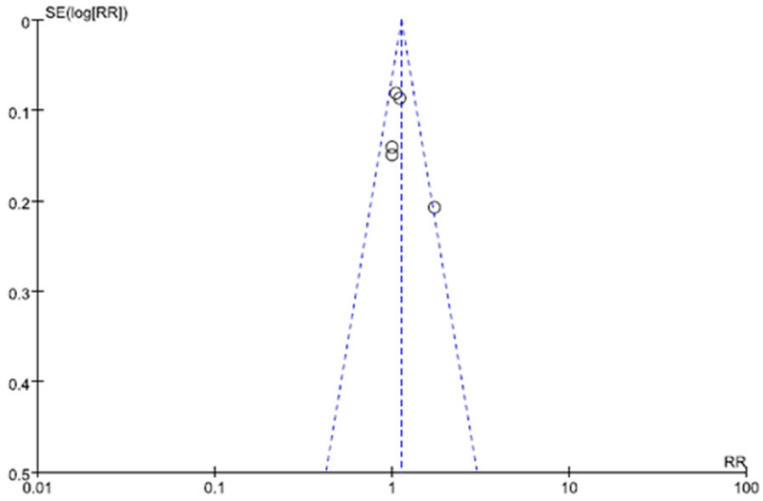

Figure 2. Funnel plot of the publication bias.

group [14, 17]. 6 articles have comparable base line between the groups [13-17, 19]. Four CCTs provided appropriate statistical analysis [13-16]. As for the RCT, no clear random sequence generation is provided, and the method of concealment is not described or not described in sufficient details to allow definite judgment [18]. It was believed that outcomes and measurements of the RCT were not likely to be influenced by lack of blinding, and the risks of performance and detection bias did not exist [18]. The enrolled RCT provided complete outcome data [18]. Selective reporting existed and no other bias were found in this article [18].

Publication bias and sensitivity analysis

Funnel plot produced by RevMan5.2 software was used to assess the publication bias. The funnel plot is symmetrical, which means no significant publication bias existed among the enrolled studies (**Figure 2**).

Carrying angel

Carrying angle was formed when the pivots of the humerus and ulna intersect and is also measured by X-ray, and the average value of the angel ranges from 10 to 20 degree, depending on the sex and body shape [17]. Two articles were enrolled to evaluate the result of carrying angel [13, 15]. Fixed effect was adopted for the meta-analysis as non-heterogeneity was detected among the enrolled studies (I^2= 0%). No significant difference was found between CRPP and ORPP for the result of carrying angel [MD=-1.62, 95% CI (-3.35, 0.10), P=0.07] (**Figure 3**; **Table 4**).

Bauman angel

Bauman angel, which was also known as the humeral-capitellar angle, is measured on an antero-posterior radiographs of the elbow between the long axis of the humerus and the growth plate of the lateral condyle by X-ray, and the average value of such angel ranges from 10 to 15 degree [17]. Three articles were included to evaluate the result of Bauman angel [14, 15, 17]. Random effect was adopted for the meta-analysis as significant heterogeneity was found among the included studies (I^2=87%). There was no significant difference between CRPP and ORPP for the result of Bauman angel [MD=-1.17, (-5.50, 3.15), P=0.6] (**Figure 4**; **Table 4**).

Mean hospital stay

Mean hospital stay was measured from the day the patients got into the hospital to the day the patients left the hospital. Two articles were enrolled to evaluate the mean hospital stay [17, 18]. Fixed effect was used for the meta-analysis, as there was no significant heterogeneity found among the enrolled articles (I^2=36%). The paediatric patients adopting CRPP owned shorter mean hospital stay when compared with the patients adopting ORPP [MD=-0.58, 95% CI (-1.03, -0.12), P=0.01] (**Figure 5**; **Table 4**).

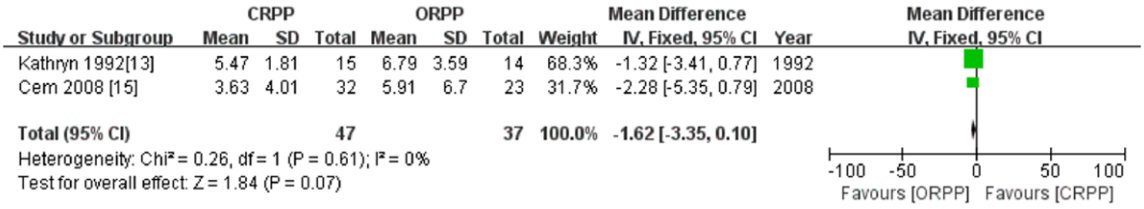

Figure 3. Forest plot of the Carrying angel for CRPP and ORPP.

Table 4. Overall estimations of meta-analysis

Results	No. study	No. patient		MD or OR (95% CI)	*P* value	Heterogeneity
		C	O			
Carrying angel	2 [13, 15]	47	37	-1.62 [-3.35, 0.10]	0.07	I^2=0%
Bauman angel	3 [14, 15, 17]	86	62	-1.17 [-5.50, 3.15]	0.6	I^2=87%
Mean hospital stay	2 [17, 18]	83	75	-0.58 [-1.03, -0.12]	0.01	I^2=36%
Union time	2 [15, 19]	78	58	-2.03 [-3.76, -0.29]	0.02	I^2=83%
Satisfaction rate	5 [14-18]	179	136	1.12 [1.01, 1.24]	0.03	I^2=38%
Complication rate	4 [13, 15, 17, 18]	130	112	1.23 [0.67, 2.28]	0.50	I^2=31%

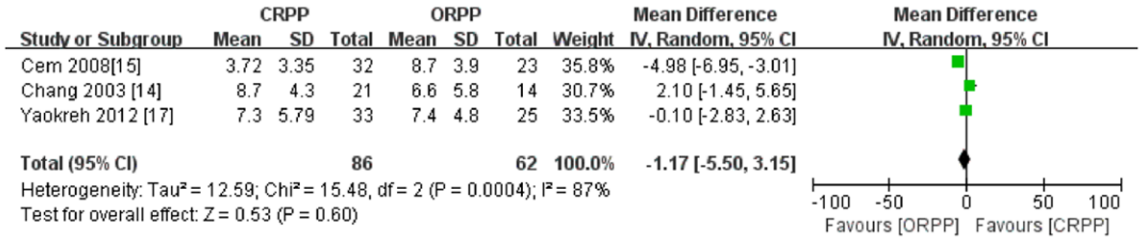

Figure 4. Forest plot of the Bauman angel for CRPP and ORPP.

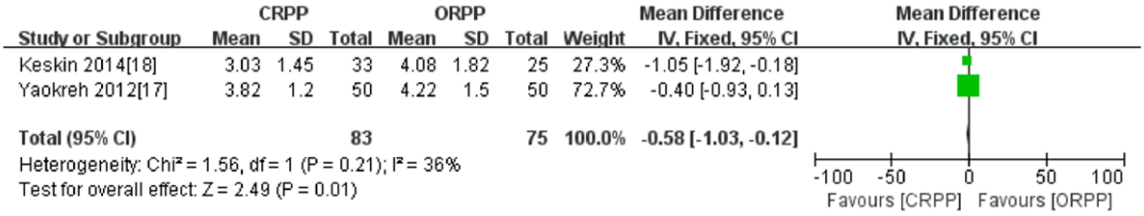

Figure 5. Forest plot of the mean hospital stay for CRPP and ORPP.

Union time

Union time was measured from the first day after the operation to the day of the bone union. The author enrolled two articles to estimate the result of union time [15, 19]. Random effect was adopted for the meta-analysis, as significant heterogeneity was detected between the studies (I^2=83%). The paediatric patients adopting ORPP owned longer union time when compared with the patients adopting CRPP [MD=-2.03, (-3.76, -0.29), P=0.02] (**Figure 6**; **Table 4**).

Satisfaction rate

The final clinical results are evaluated according to Flynn criteria, and the patients attitude towards the results included excellent, good, fair and poor [17]. The author counted the number of the cases choosing the attitudes of excellent and good, and satisfaction rate is the ratio when the obtained number was divided by the total number of the patients. Five studies were included to evaluate the result of satisfaction rate [14-18]. Fixed effect was used for the

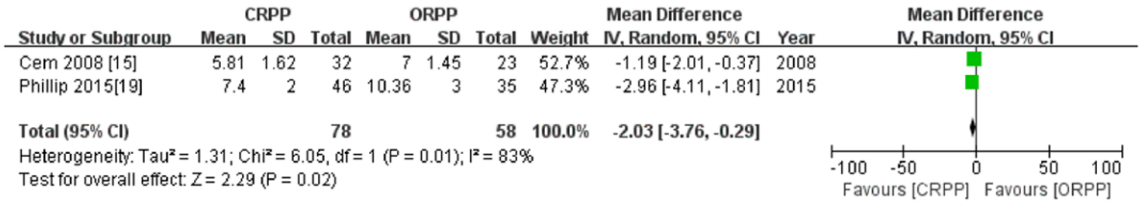

Figure 6. Forest plot of the union time for CRPP and ORPP.

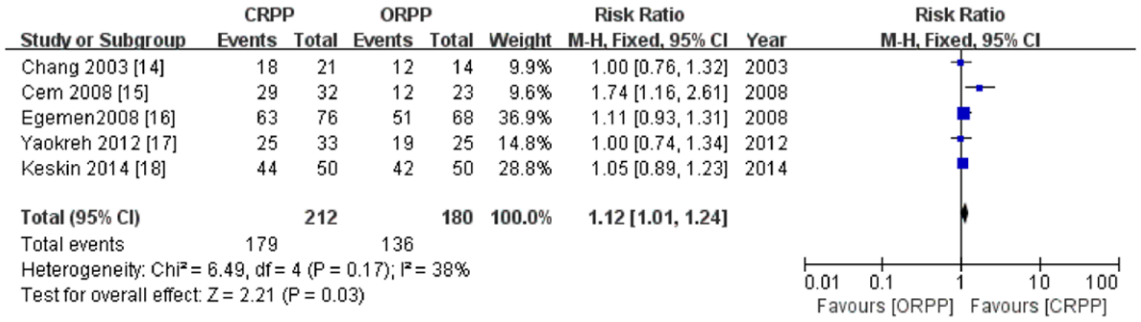

Figure 7. Forest plot of Satisfaction rate for CRPP and ORPP.

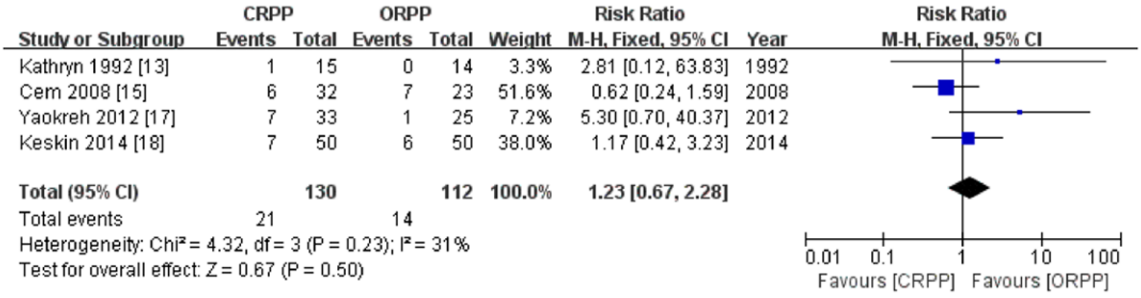

Figure 8. Forest plot o Complication rate for CRPP and ORPP.

meta-analysis, as non-heterogeneity was found among the enrolled articles (I^2=38%). The paediatric patients adopting CRPP had higher satisfaction rate when compared with patients adopting ORPP [OR=1.12, 95% CI (1.01, 1.24), P=0.03] (**Figure 7**; **Table 4**).

Complication rate

There are several complications resulted from the two methods, including pin tract infection, nerve injuries, compartment syndrome and cubitus varus [16, 17]. The author counted the number of the cases with complications while the complication rate is the ratio when the obtained number of patients with at least one complication was divided by the total number of the patients. Four articles were enrolled to assess the result of complication rate [13, 15, 17, 18]. Fixed effect was adopted for the meta-analysis, as there was no significant heterogeneity was found between the enrolled studies (I^2=38%). There was no significant difference between the methods of CRPP and ORPP for the result of complication rate [OR=1.23, 95% CI (0.67, 2.28), P=0.5] (**Figure 8**; **Table 4**).

Discussion

Extention-type Supracondylar Fracture of Humerus in Children happened when force was conducted to the junction between humerus disphysis and condyle. Such kind of fracture accounts for 98% of the paediatric SHF, while bending- type fracture accounts for 2% of the SHF in Children [23]. Obese children are more

likely to have SHF, while the incidence rate is 1.7 times higher than the children with the normal body weight [24]. The incidence rate of paediatric SHF in boys is two times than that in the girls, especially for the non-dominant hands [24]. Gartland classification has been widely used for such kind of fracture, including extra-articular and intra-articular fracture of the elbow joint [23, 24].

Nowadays, the preferred approach on the treatment of displaced pediatric SHF is closed reduction and percutaneous pinning; then internal fixation following an open reduction will be preferred, if not possible [25]. Controversy exists regarding treatment strategies of SHF in Children between CRPP and ORPP, especially for the extra-articular and intra-articular fracture. Someone believed that even displaced intra-articular fractures can be treated with CRPP, while others recommend that ORPP is the best choice [26, 27]. The treatment of ORPP for extra-articular fractures was associated with poorer outcomes when compared with CRPP, while the patients with intra-articular fracture preferred ORPP. Current studies showed that the number of patients adopting ORPP for failed closed treatment increases rapidly [19]. The data shows that the patients of successful closed reduction and percutaneous fixation of intra-articular fractures in skeletally mature adolescents does not own higher complication rate, such as nerve injuries, pin tract infection and cubitus varus [28]. Moreover, a concern about open reduction is prolongation of anesthesia, soft-tissue injury and radiation exposure through the repetitive closed reduction efforts. An obvious disadvantage of percutaneous pinning is the reduction loss, which may result in deformity and bone union. The choice of the best treatment for SHF in Children depends on variation in skeletal maturity and patient size relative to age as well as the variation in injury characteristics [19]. The surgeon should take several points into consideration, including the best balance of accurate reduction, stable fixation, and minimal iatrogenic injury. The treatment of ORPP can also be used for the open fracture which was associated with vascular or nerve injury, or functional reduction cannot be ensured by CRPP. An study reported that the rate of case, who had to preferred open reduction for their first choices for SHF, is no more than 46% [29].

Bauman angle, which was also known as the humeral-capitellar angle, is measured on an antero-posterior radiographs radiograph of the elbow between the long axis of the humerus and the growth plate of the lateral condyle by X-ray [17]. Carrying angel was formed when the pivots of the humeru and ulna intersect and is also measured by X-ray [17]. Bauman and carrying angel were usually measured to instruct clinical diagnosis, reduction and treatment. Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) should be used if good clinical diagnosis, reduction could not be required by X-ray. The average value of the Bauman angel is 15 to 17 degree, while the carrying angel is 10 to 20 degree, depending on the sex and body shape [17]. Such angels of uninjured side should also be measured so as to be compared with the injured side. No significant differences were found for Bauman and carrying angels between CRPP and ORPP for Pediatric SHF. The conclusion is that satisfactory reduction and treatment could also be acquired just by the method of CRPP. Less soft-tissue injury and radiation exposure were obtained for the treatment of CRPP, and patients adopting CRPP owned less mean hospital stay and union time when compared with the patients adopting ORPP. Meanwhile, less mean hospital stay and union time were obtained in the treatment of CRPP when compared with ORPP. The patients choosing CRPP own higher satisfaction rate when compared with patients choosing ORPP. Cubitus varus rate was reported to be much higher for the patients adopting ORPP, however, the rate of others complications, such as pin tract infection, nerve injuries and compartment syndrome do not show significant differences between the two methods [16, 17].

To our knowledge, 6 CCTs and 1 RCT have been carried out to evaluate the CRPP and ORPP for pediatric SFH [13-19]. However, the meta-analysis of specific comparison between the two methods, which collects high quality RCTs, still remains absent. The preferred approach on the treatment of displaced pediatric SHF is closed reduction; if not possible, then internal fixation following an open reduction will be preferred. Each method has its subject range; thus, it is hard or even impossible to carry out RCT for the research. The present meta-analysis pooled all published CCTs or RCTs to provide some evidence of treatment effectiveness and safety

between CRPP and ORPP for Pediatric Supracondylar Fracture of Humerus. However, there still exist some limitations, including the relatively small sample sizes, insufficient description of method-logic details and relatively short follow-up time. The meta-analysis is also controversial because of the critical inclusion criteria, and even small violations of those inclusion criteria can lead to misleading results.

It is difficult to weight the results of comparing open and closed reduction, because surgical indications for both techniques differ between the types of injuries in the original studies. Only seven enrolled studies could not maintain the true result of public bias, though the funnel plot did not indicate significant publication bias. Gartland classification was used to characterize the fractures only in three enrolled articles [13, 17, 18], where no relevant details about the fractures were provided in the remaining four articles [14-16, 19].

Conclusion

No significant differences were detected between the two methods (CRPP and ORPP) for the results of carrying angel, Bauman angel and complication rate. However, the children who adopted CRPP had less mean hospital stay, union time and more satisfaction rate when compared with the cases that adopted ORPP. More high quality RCTs were needed to compare the results between CRPP and ORPP regarding the related radiographic and functional results, specific complication related to each fixation.

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Disclosure of conflict of interest

None.

Address correspondence to: Qing-Song Zhang and Quan-Bing Wang, Department of Orthopedics, Renmin Hospital, Hubei University of Medicine, No. 39 Chaoyang Road, Shiyan 442000, Hubei, P. R. China. Tel: +86158-97824431; E-mail: zhangqs_1107@126.com (QSZ); wangqb2008@163.com (QBW)

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