Double joystick technique – a modified method facilitates operation of Gartlend type-Ⅲ supracondylar humeral fractures in children

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Gartland type-Ⅲ supracondylar humerus fracture (SCHF) is a severe lesion with the feature of difficult reduction. Due to the high failure rate of traditional reduction, a more practical and safer method is needed. This retrospective study aimed to explore the effectiveness of the double joystick technique during the closed reduction of children with type-III fractures. Forty-one children with Gartland type-Ⅲ SCHF underwent closed reduction and percutaneous fixation using the double joystick technique at our hospital between June 2020 and June 2022, and 36 (87.80%) patients were successfully followed up. The affected elbow was evaluated by the joint motion, radiographs, and Flynn's criteria then contrasted with the contralateral elbow at the last follow-up. A group of 29 boys and seven girls with an average age of 6.33 ± 2.68 years. The mean time of surgery and hospital stay was 26.61 ± 7.51 min and 4.64 ± 1.23 days, respectively. After a mean follow-up of 12.85 months, the average Baumann angle was 73.43 ± 3.78°, although the average carrying angle (11.33 ± 2.17°), flexion angle (143.03 ± 5.15°), and extension angle (0.89 ± 3.23°) of the affected elbow were less than those of the contralateral elbow ($P < 0.05$), the mean range of motion difference between two sides is only 3.39 ± 1.59°, with no complications. Furthermore, 100% of patients recovered satisfactorily, with excellent outcomes (91.67%) and good outcomes (8.33%). The double joystick technique is a safe and effective method that facilitates the closed reduction of Gartland type-Ⅲ SCHF in children without raising the risk of complications. *J Pediatr Orthop B* 33: 147–153

Journal of Pediatric Orthopaedics B 2024, **33**:147–153

Keywords: children, closed reduction, fracture, joystick technique, supracondylar humerus

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Received 14 August 2022 **Accepted** 16 February 2023.

Supracondylar humerus fractures (SCHFs) account for 27% of all pediatric fracture types and 55–75% of elbow fractures in children, which are classified into two types: extension (98%) and flexion (2%) [1–3]. It has a risk of complex complications including neurovascular injury, compartment syndrome, reduction loss, and cubitus varus, some of which require repeated operations, greatly causing patients suffering. Fortunately, the incidence of many complications has been dramatically reduced by modern techniques, whereas the rate of cubitus varus leading to poor prognosis is still as high as 30% [4]. Therefore, more attention should be paid to SCHF in children.

According to the Gartland classification: type-Ⅲ fracture ends are completely separated without periosteal hinge, which is characterized by difficult reduction and severe instability, and easily results in elbow dysfunction [4,5]. These features might prompt surgeons to select open surgery for better reduction; however, numerous studies comparing closed Kirschner wiring to open reduction for the treatment of type-Ⅲ fractures have found that closed reduction has better outcomes with fewer complications [6–8]. Hence, closed reduction and percutaneous pinning (CRPP) is a preferred treatment for type-Ⅲ SCHF, and satisfactory reduction is the key to an excellent outcome [9].

Currently, various approaches have been developed to enhance the quality and efficiency of closed reduction for type-Ⅲ SCHF, among which joystick technology using Kirschner wire is a focal point [10–14]. Pei *et al.* [11] corrected anteroposterior (AP) angulation displacement using single leverage assistance for 27 children, with a rate of excellent and good outcomes was 96.3%. According to Dong *et al.* [12], a single Kirschner wire can be utilized to rotate the distal fragment in the sagittal plane until a satisfactory reduction of fracture ends, which can significantly improve the efficiency of operation. Interestingly, Wei *et al.* [13] improved the stability of the distal fragment for better alignment by applying a single trans-olecranon pin and obtained great results in 22 kids with multidirectionally unstable SCHF; however, we found that the rotational displacement of fracture ends is hardly corrected by using a single joystick in practice. Consequently, we attempted to improve this technique and found that two joysticks could be more

DOI: 10.1097/BPB.0000000000001083

efficient for operation. In this research, we evaluated the effectiveness of the double joystick technique during closed reduction of children with type-III SCHF through follow-up, and expect to conclude a more practical approach.

Methods

Patient information

From June 2020 to June 2022, 41 children with Gartland type-Ⅲ SCHF underwent CRPP at our hospital. Inclusion criteria: fresh closed injury of type-Ⅲ SCHF; aged 14 or less; affected limb had an intact function before trauma; complete clinical and radiographic data. Exclusion criteria: pathological fractures; with surgical contraindications or refusal of surgery. Finally, five (12.20%) cases were excluded due to incomplete data or loss to follow-up.

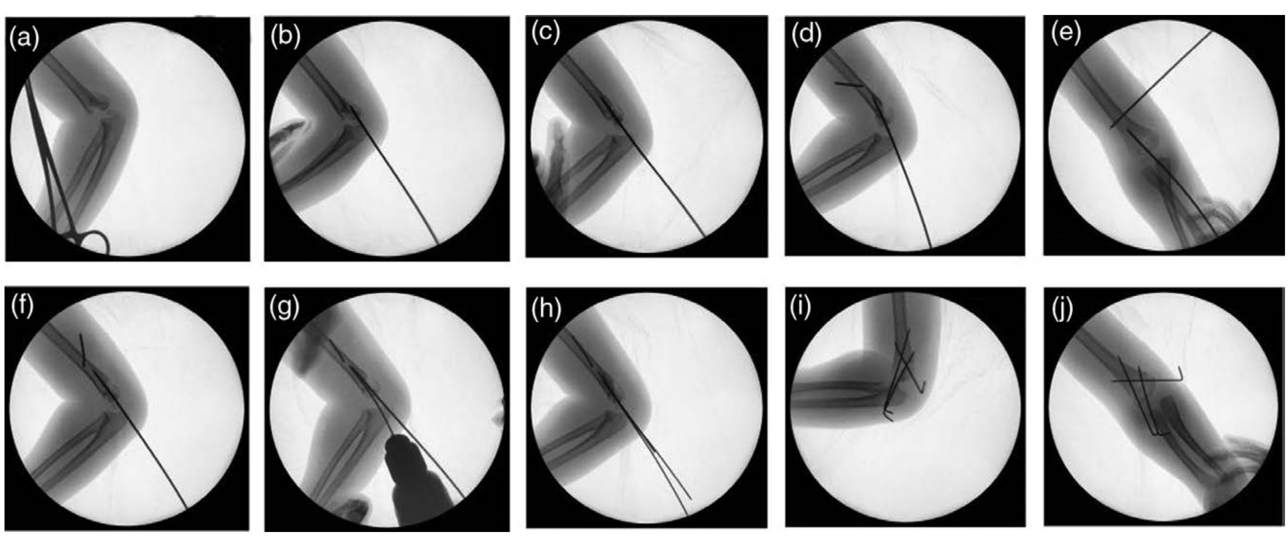
The data of 36 (87.80%) patients were collected from the electrical medical record system, including general information (age, sex, weight, etc), clinical information (injury history, operation time, complications, etc), and follow-up information (elbow motion, Baumann angle, carrying angle, etc). At each follow-up, X-ray examination and the Flynn criterion [15] were required to evaluate the outcome. All data were recorded by special personnel, and angle variables were independently measured three times by two senior orthopedists who did not participate in this study, and the average values of three times were recorded. This investigation was approved by the Affiliated Hospital of Jiujiang University Clinical Research Ethics Committee.

Double joystick technique

The patient was placed in a supine position with the affected shoulder and the C-arm extremity near the edge of the operating table after general anesthesia. Then, routine safeguarding, disinfection, and sheet laying were performed. A 2.0 mm Kirschner wire can provide enough strength for holding the fracture fragment and is often chosen [12].

First, the stability of the fracture ends was tested by image C-arm. Next, the manual reduction was attempted by finger extrusion during continuous axial traction at 40° elbow (Fig. 1a). After the initial reduction, a 2.0 mm Kirschner wire (main joystick) was inserted into the distal fragment through the olecranon (Fig. 1b). The main joystick was pushed up or down to correct angulation displacement in the sagittal plane, then was drilled into the medullary cavity of the distal humerus for temporary fixation after confirming rough reduction (Fig. 1c). Later, another 2.0 mm Kirschner wire (auxiliary joystick) was introduced laterally through the distal third of the humerus to penetrate the contralateral cortex (Fig. 1d),

Fig. 1



Closed reduction and percutaneous pinning through the double joystick technique for Gartland type-Ⅲ SCHF in a 3-year-old girl. (a) The broken ends of the fracture were separated and rotated, which were unstable. (b) Continuous axial traction was performed, and a 2.0 mm Kirschner wire (main joystick) was inserted into the distal fragment through the olecranon. (c) Pushing up or down the main joystick to correct the displacement in the sagittal plane and then drilled into the medullary cavity of the distal humerus for temporary fixation. (d) Another 2.0 mm Kirschner wire (auxiliary joystick) was introduced laterally through 1/3 of the distal humerus to penetrate the contralateral cortex. (e) The C-arm is rotated to an anteroposterior (AP) view showing the reduction of the distal fragment in the coronal plane. (f) The C-arm is rotated again to the lateral view. The sagittal displacement, angulation, and rotation of the two fracture ends are corrected by manipulation of two Kirschner wires. (g) Fixation of the distal fragment using one 2.0 mm Kirschner wire inserted laterally through the capitellum. (h) A second 2.0 mm Kirschner wire was introduced through the medial epicondyle of the humerus for further fixation. (i) A third 2.0 mm Kirschner wire was introduced laterally through the capitellum to complete the fixation, then two joysticks were removed to test elbow function. (j) Final C-arm AP and lateral views confirm the anatomic reduction of SCHF. SCHF, supracondylar humerus fracture.

and fine reduction in the coronal plane was achieved by rotating or pushing the auxiliary joystick combined with a careful manipulation of another fragment.

When reduction in the image C-arm was basically satisfactory (Fig. 1e and f), a 2.0 mm Kirschner wire should be percutaneously inserted from the capitellum across the fracture line to engage the contralateral cortex (Fig. 1g). It should be noted that minor adjustment by two joysticks could still be made at this time, especially the rotational deformity. When the positive and lateral reduction was satisfactory, a second 2.0 mm Kirschner wire was inserted through the medial epicondyle of the humerus to fix the fracture ends (Fig. 1h). Finally, a third 2.0 mm Kirschner wire was introduced laterally through the capitellum to complete the fixation. After removing the two joysticks, the elbow motion and the stability of fracture ends were tested again (Fig. 1i and j). Three pin tails posited outside were cut and bent, and then the affected elbow was fixed at less than 70° flexion with a cast.

X-ray examination was performed 4 weeks after the operation to observe fracture healing. Once the fracture line is blurred, the three pins and cast should be removed and elbow exercises should be started. The recovery of elbow function was reviewed every 3–6 months in the outpatient department, which was evaluated by the range of motion (ROM), radiographs, and Flynn's criteria and compared with the contralateral elbow at the last follow-up.

Statistical analysis

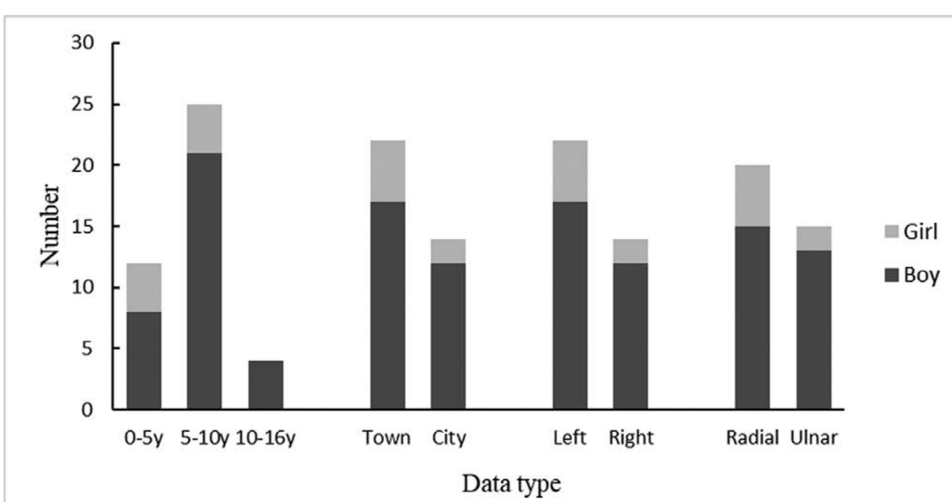
The statistical analysis was conducted by using SPSS software (version 22.0; Chicago, Illinois, USA). The measurement data were expressed as the means ± SD. Paired-sample *T*-test was used to compare differences. When $P < 0.05$, the difference was considered statistically significant.

Results

A group of 36 (36/41) patients, including 29 (80.56%) boys and seven (19.44%) girls, most of whom were 5–10 years old (Fig. 2). Their average age was 6.33 ± 2.68 years (range, 1–12 years), and their mean BMI was 18.63 kg/m^2. There were more injuries on the left (61.11%) than right (38.89%). All fractures were of the extension type, with the most distal fragments radially displaced (55.56%) according to the radiograph. In addition, 22 (61.11%) children lived in the town, and the average interval between injury and operation was 23.46 ± 13.26 h (range, 4–54 h). The average time of surgery and hospital stay were 26.61 ± 7.51 min (range, 17–50 min) and 4.64 ± 1.23 days (range, 3–7 days), respectively.

There were no complications regarding tissue infection, iatrogenic nerve damage, reduction loss, or cubitus varus during the follow-up (12.85 ± 6.13 months). Fractures healed in all patients, with a mean time of 5.53 weeks. In addition, the average Baumann angle of the affected elbow was 73.43 ± 3.78° (range, 66–85°) (Table 1). Although the average carrying angle (11.33 ± 2.17°), flexion angle (0.89 ± 3.23°), and extension angle (143.03 ± 5.15°) of the injured elbow were less than those of the contralateral elbow ($P < 0.05$), the mean ROM difference between the two sides was only 3.39 ± 1.59° (range, 0–9°). Furthermore, all patients obtained satisfactory recovery (36, 100%), with excellent (33, 91.67%) and good (3, 8.33%) outcomes at the last follow-up (Table 2).

Fig. 2



Categorical statistics of the general information of patients.

Discussion

SCHF is one of the most common fracture types in children, which is not hard to be diagnosed by clinical evaluation and radiographic examination; however, the physician must take note of vascular and neurologic examinations, especially the skin puckering combined with ecchymosis, which is a sign of considerable soft tissue injury. X-ray is a routine examination, but initial radiographs sometime show no evidence of a fracture except for a posterior fat-pad sign that is easily misdiagnosed. It is essential to identify the comminution of the medial column through the Baumann angle. In 1959, Gartland first classified SCHF into three types [5]: Type-I is non-displaced or slightly displaced (<2 mm); Type-II is displaced (>2 mm) with anterior cortex fracture; and Type-III is severely displaced with fracture ends completely separated and rotated, often accompanied by complex complications, challenging treatment, and poor prognosis.

Cubitus varus is the most common complication following SCHF [16], which often leads to poor recovery with tardy posterolateral instability, particularly in type-III fractures [17]. A previous study described that cubitus varus deformity was caused by unequal growth in the distal part of the humerus [18]; however, the most recognized reason for cubitus varus in children with SCHF is malunion rather than growth arrest [19–21]. Therefore, satisfactory reduction is crucial for an excellent outcome, which should be as close to the normal state as possible. In 1948, Swenson used percutaneous pinning during closed reduction to treat SCHF and obtained great clinical outcomes [19]. Then, CRPP has been widely applied and numerous studies further developed various methods that can effectively enhance its reduction quality [10–14], but the overall outcome is not ideal due to the limited remodeling ability of the elbow [4]. In this study, we have achieved better reduction using the double joystick technique, with 100% of patients obtaining satisfactory results.

Similar to other reports [1–4], 36 patients were mainly boys (80.56%), most of whom were 5–10 years old. It is worth noting that although obesity's effect on long-term outcomes after CRPP of SCHF is uncertain [22], two of three boys who rated good were found to have a BMI > 28 kg/m^2 in this group. Therefore, more follow-up research is required to deeply explore this matter and find a more accurate index of childhood obesity. In addition, the average interval between injuries (23.46 ± 13.26 h) in our study is more than other reports [13,14], possibly because most patients lived in the town and required multiple referrals. This situation indicated that the awareness and treatment of type-III SCHF in primary hospitals is inadequate, and a more practical approach is urgently needed. Besides, the reason why our hospital stay (4.64 ± 1.23 days) is longer than in other studies is that anxious parents mostly ask for postoperative observation for a few days in the hospital.

Regarding the complications of type-III fractures, the prevalence of absent pulse is as high as 20% [23]. Several researches have recommended angiography or duplex ultrasound to be an unnecessary test that has no bearing on treatment, and it is an emergency that the affected arm is pulseless with signs of poor perfusion [24,25]. Furthermore, Delniotis *et al.* [23] proposed that if the affected limb is pale, cold, and pulseless, urgent surgery should be conducted, and immediate exploration should be performed when the pulse cannot return or deterioration of the neurovascular status occurs. It is remarkable that excessive flexion or extension may compromise the limb's vascularity, and cast fixation at less than 70° flexion is recommended [26]. As for neurologic injuries, its rate had been reported to be 49%, but in most recent studies it has ranged between 10 and 20% [27]. Direct nerve contusion by the proximal fracture end is the most common, particularly the anterior interosseous nerve, which spontaneously recovers within 3–6 months [28,29]. Thus, closed reduction should first be attempted when nerve damage is associated with a closed SCHF. In our group, five of 36 children had finger numbness and completely recovered within 3 months after surgery. In addition, the compartment syndrome (rate from 0.1 to 0.3%) as a tricky matter is more common in type-III than others, of which early detection and intervention usually lead to good results [9]. Meanwhile, Ramachandran *et al.* [30] emphasized that ecchymosis and severe swelling should alert the compartment syndrome potential even in the situation of an intact radial pulse with a good capillary refill. More attention must be paid to children with median nerve damage, as they will not gain pain in the volar compartment.

Table 1 Clinical information and follow-up results of included patients

Parameters	Minimum	Maximum	Mean ± SD
Preoperative time (h)	4	54	23.46 ± 13.26
Operation time (min)	17	50	26.61 ± 7.51
Hospital stay (days)	3	7	4.64 ± 1.23
Follow-up time (months)	3	24	12.85 ± 6.13
Carrying angle (°)	5	15	11.33 ± 2.17*
Flexion angle (°)	129	150	143.03 ± 5.15*
Extension angle (°)	-5	8	0.89 ± 3.23*
ROM difference (°)	0	9	3.39 ± 1.59
Baumann angle (°)	66	85	73.43 ± 3.78

ROM, range of motion.
*Comparsion of the affected side and the intact side, $P < 0.05$.

Table 2 Follow-up outcome according to Flynn's criteria

Results	Rating	Functional factor: motion loss (°)	Cosmetic factor: carrying angle loss (°)
Satisfactory	Excellent	0–5 (33, 91.67%)	0–5 (33, 91.67%)
	Good	5–10 (3, 8.33%)	5–10 (3, 8.33%)
	Fair	10–15 (0)	10–15 (0)
Unsatisfactory	Poor	>15 (0)	>15 (0)

Traditionally, type-III SCHF was treated as an urgent procedure soon after admission; however, British Orthopedic Association Standards of Trauma guidelines [9] advocated that night-time operating is not necessary unless there is no pulse or signs of threatened skin viability. Moreover, Han *et al.* [31] have shown that a delay in operation, regardless of whether it is closed or open, for more than 12 h after trauma does not influence the outcomes of SCHF. Hence, it is permissible to delay such type-III fractures in the absence of trained assistants and staff, especially at night. On the other hand, the supine position as an ordinary placement in operation has the advantages of minimal time, allows for standard anesthesia management, and easily switches to an anterior approach when open reduction is needed [32]. Furthermore, Pavone *et al.* [33] proposed that the prone position could be seen as an efficient alternative, which can achieve an easier reduction with safer pin placement and more comfortable use of the C-arm, despite there being similar outcomes between the supine and prone positions. We considered that the best strategy is to perform the operation under full preparation and choose the appropriate surgical position according to the individual.

CRPP has been a gold standard treatment for type-III SCHF [1,4,9]. If there is less operation time, the less fluoroscopy and repeated manipulation would be. In this study, the period between initial reduction and final fixation with the cast was deemed as the operation time. Although our average operation time (26.61 ± 7.51 min) was similar to other reports [10–14], the lower SD indicated less fluctuation each time and the efficiency of the double joystick technique. Moreover, this difference may be caused by different inclusion criteria (including type-II and type-III fractures) and definitions of operation time (may exclude the time of plaster fixation) [10–14], so our data is still valid. On the other side, despite there being a statistical difference in carrying angle between the two elbows at the last follow-up (Table 1), all patients achieved (91.67%) and good (8.33%) results without complications, and the ROM difference was only 3.39 ± 1.59°. Novais *et al.* [10] reported an excellent outcome of the joystick technique with average differences in ROM and carrying angle between two elbows were 4.38 ± 1.65° and 11.63 ± 1.65°, respectively. Pei *et al.* [11] also obtained great results by leverage application and measured the angle varies of the affected elbow at the last follow-up: 26 (96.30%) patients had 0–10° loss of carrying angle and ROM, and one (3.70%) had 10–15° loss. Furthermore, Wang *et al.* [14] used their joystick technique to treat 36 type-II and 32 type-III fractures and found that 22 (68.75%) children had 0–5° loss of ROM and carrying angle in the type-III group. Therefore, our method is safe and useful compared to the other studies [10–14]. And this difference may be caused by the short follow-up time or small sample size.

Generally, the CRPP is easier to correct lateral displacement or AP angulation than to repair the rotational displacement of type-III fractures, which is particularly the main cause of failure [34]. To improve the success rate of CRPP, Novais *et al.* [10] used a single joystick technique for the treatment of multidirectionally unstable SCHF in eight children, who obtained excellent outcomes meaning both the carrying angle and elbow motion were lost < 5°; however, it is difficult to laterally pin through the distal fragment in the low-position SCHF, and the stability of pin is not enough. Therefore, Wei *et al.* [13] further applied a trans-olecranon pin to improve the stability of distal fragment for multidirectionally unstable SCHF that could effectively reduce the surgical time (25.3 ± 9.1 min) and enhance reduction quality (Baumann angle: 72.4 ± 2.3°) with fewer complications. Considering that the proximal fracture fragment is also rotated, Dong *et al.* [12] recommended that a single Kirschner wire be introduced from back to front through the unilateral cortex at 1.0 cm above the proximal fracture end to correct the rotational deformity, and found that 72.22% cases obtained excellent recovery with the average Baumann angle (73.8 ± 5.7°) and frequency of fluoroscopy (4.3 ± 1.1 times) were better than traditional reduction group; however, we found it is not easy to reduce two fracture ends using a single pin in the practice. Furthermore, percutaneous pinning through the unilateral cortex may sometimes not be stable enough. Even the leverage-assisted reduction method can effectively correct AP angulation, but hardly correct the rotational displacement of type-III fractures. Therefore, we improved the joystick technique as two Kirschner wires were inserted through the olecranon and the 1/3 of the distal humerus to manipulate two fragments, respectively. Then the two fracture ends were actively aligned with each other under manipulation, just like a jigsaw puzzle, rather than a fragment passively approaching one another.

Reviewing the literature, there is no consensus on the Kirschner wire fixation for SCHF [35–38]. Although the cadaveric model study has illustrated that crossed pinning can provide better stability than lateral pinning [38], many clinical studies have shown that there is no obvious difference between the two methods in maintaining fracture reduction [35–37]. In our view, a three-wires crossed configuration is necessary when the coronal plane present on one side is high with another side collapsed. If the fracture line is flat in the coronal plane, the fixation method could be chosen according to personal proficiency. On the other hand, it has been reported that the risk of iatrogenic ulnar nerve injury is increased eightfold by cross-needle threading [39]. Interestingly, Li *et al.* [8] suggested that the incidence of nerve injury could be dramatically reduced when a microincision is assisted before medial needle threading. In our experience, touching the path of the ulnar nerve and then using the thumb to push the ulnar nerve away from the expected puncture point, while medial pinning at mild elbow flexion, can effectively protect the nerve. And there was no case of iatrogenic nerve injury in our study, which also verified the effectiveness of this method.

There are still some limitations to this research. First, we did not include previous cases that underwent manual reduction alone for comparison, owing to our proficiency and success rate of closed reduction have been improved significantly over time, and there is no special meaning for the difference. Second, we did not collect the data on the Baumann angle of the contralateral elbow because of a possible violation of the no-harm principle, and assessment of elbow motion with the carrying angle may be sufficient to evaluate the outcome. Third, the precise occurrence rate of open reduction may not be assessed because of the limitation of cases; however, this study has presented an effective method of the double joystick technique for type-Ⅲ SCHF, which could be easily popularized and applied.

Conclusion

The outcomes show that the double joystick technique is a practical method for closed reduction of Gartland type-Ⅲ SCHF in children, which has the advantages of less operation time and better reduction quality without raising the risk of complications. Furthermore, there is no complex manipulation, no high requirements, and a relatively short learning curve for beginners, which could be conducive to promotion and application in primary hospitals.

Acknowledgements

This study was supported by funds from the Science and Technology Plan of Jiangxi Health Commission, China (SKJP220210875). The funders had no role in the study design, the data collection and analysis, the decision to publish, or the preparation of the manuscript.

Conflicts of interest

There are no conflicts of interest.

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