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ORIGINAL ARTICLE

Locked wires fixator for fractures of the distal third of the radius and ulna in children

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Abstract

Background Prevention of redisplacement is an issue after the treatment of fractures of the distal third of the radius in children. In this study, we used a locked wires fixator for this type of fracture and achieved favorable treatment outcomes.
Methods The subjects were 8 children with fractures of the distal third of the radius (male: 7, female: 1, mean age: 9.0 years old) who underwent surgery with locked wires fixators and were able to be evaluated 12 months after surgery. Immobilization was not applied after surgery. The locked wires fixator or K-wire was removed when the bridging callus was observed on plain radiography 4–6 (mean 5.5) weeks after surgery in all patients. The presence of bone union, functional outcomes, and complications were investigated postoperatively.
Results All patients achieved bone union without redisplacement excellent function. The pin site infection was observed in two patients.
Conclusions The locked wires fixator may be a new useful treatment method for fractures likely to cause postoperative redisplacement.

Keywords Fractures of the distal third of the radius in children · Locked wires fixator · Redisplacement · Minimally invasive technique

Introduction

Fractures of the distal third of the radius are one of the most common fractures of the upper limb of children [1]. In general, bone union can be acquired by manual reduction and casting, and favorable functional recovery is expected [2]. The incidence of redisplacement after reduction which was associated with the position of forearm in the cast or loss of cast fixation is approximately 34% [3, 4], and prevention of redisplacement after treatment remains an issue. Based on this background, plate fixation was recommended for this type of fracture [5], but it is not the standard treatment because of its high invasiveness.

Percutaneous pinning for fractures of the distal third of the radius in children can obtain higher stability than cast immobilization alone [6]. However, percutaneous pinning is complicated and unlikely to result in stable fixation because the pin insertion angle is small and the lever arm length of the inserted pin shortens [7]. Thus, we used a locked wires fixator, which exhibits stronger fixation than percutaneous pinning, for this fracture and achieved favorable treatment outcomes.

Methods

This study was approved by the ethics committee for medical research of our university (No. 19-084), and informed consent was received from the parents of all patients.

The subjects were 8 children with fractures of the distal third of the radius [male: 7, female: 1, mean age: 9.0 (range: 5–13) years old] who underwent surgery at our hospital

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between September 2017 and October 2018 and were able to be evaluated 12 months after surgery. Surgery was performed within 4 days (1–4 days) after injury on all patients under general anesthesia. Manual reduction was first tried and when it was not possible, reduction was applied using the intrafocal pin technique with Kirschner wire (K-wire) in the fracture region. Then, intramedullary nail fixation with K-wire was applied retrogradely from the distal bone fragment. A burr hole was prepared in the radial dorsal bone cortex proximal to the epiphyseal line of the distal bone fragment using 1.6-mm K-wire, and it was inserted into the medullary cavity of the proximal bone fragment through this burr hole as an intramedullary nail, followed by insertion of a threaded mini fixator pin (ARATA Co., Ltd., Tokyo, Japan) into the proximal bone fragment. Lastly, the K-wire and mini fixator pin were connected and fixed using the locked wires fixator "JuNction" (ARATA Co., Ltd., Tokyo, Japan) (Video 1). No immobilization was applied after surgery, and the locked wires fixator was removed when the bridging callus formed.

Data collection included the presence of concomitant distal ulna fracture at the time of injury, bone union 12 months after surgery, wrist range of motion, grasp (% of the healthy side), visual analog scale (VAS), quick disabilities of the arm, shoulder and hand (Q-DASH) score, modified mayo wrist (Mayo) score, and complications.

Results

Concomitant distal ulna fracture occurred at the time of injury in all patients. Surgical treatment using the locked wires fixator was applied only to the radius. Intramedullary nail fixation with K-wire was applied to the olecranon over the ulna in 1 of the 8 patients, and the ulna was not treated in the other 7 patients. The locked wires fixator or K-wire was removed when the bridging callus was observed on plain radiography 4–6 (mean 5.5) weeks after surgery in all patients. The pin insertion site became infected in two of the 8 patients, but it was resolved by removal of the pin and oral antibiotic treatment. At 12 months after surgery, bone union of the radius/ulna was noted without redisplacement of the fracture region in all patients. The wrist range of motion was 88.8° ± 2.3° on flexion and 88.8° ± 2.3° on extension, forearm pronation was 88.1° ± 2.6°, forearm supination was 89.4° ± 4.2°, and the grip strength relative to that on the healthy side was 89.3 ± 5.9%. The VAS, Q-DASH score, and Mayo score were 0/10, 0/100, and 100/100, respectively (Table 1).

Case presentation

A 13-year-old boy fell and was injured while playing soccer, and visited our hospital for swelling, deformation, and pain of the right wrist joint over the forearm. On plain radiography, fractures of the distal third of both the radius and ulna were noted (Fig. 1a, b). Using the procedure introduced in Materials and Methods, only the radius was fixed using the locked wires fixator (Fig. 2a–d). Postoperative immobilization was not necessary, and movement of the wrist joint and forearm was permitted according to pain. No postoperative complications developed, bone union was acquired on the final follow-up, and the patient returned to playing soccer without issue (Fig. 3a, b).

Discussion

The acceptable range of reduction of distal forearm fractures in children depends on age. A displacement angle of 20° or smaller is acceptable in 10-year-old or younger

Table 1 Treatment outcomes of fractures of the distal third of the radius in children

Age	F/U				Wrist ROM				Grasp (% of healthy side)	VAS	Q-DASH	Mayo	Complications
	Sex	Ulnar Fx	(Mo)	Bone Union	F	E	P	S					
7	M	+	12	+	85	85	85	85	83	0	0	100	–
9	M	+	12	+	90	90	85	85	86	0	0	100	Pin-track infection
11	M	+	12	+	90	90	90	90	80	0	0	100	–
13	M	+	12	+	85	85	85	85	95	0	0	100	–
12	M	+	12	+	90	90	90	95	95	0	0	100	Pin-track infection
9	M	+	12	+	90	90	90	90	92	0	0	100	
6	F	+	12	+	90	90	90	95	88	0	0	100	
5	M	+	12	+	90	90	90	90	95	0	0	100	

Fx fracture, *F/U* follow up period, *Mo* months, *M* male, *F* female, *ROM* ranges of motion, *F* flexion, *E* extension, *P* pronation, *S* supination, *VAS* visual analog scale, *Q-DASH*: quick disabilities of the arm, shoulder and hand (Q-DASH) score, *Mayo* modified Mayo score

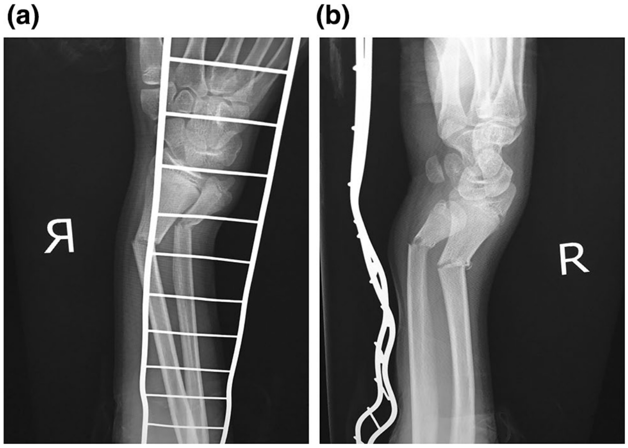

Fig. 1 Plain radiography at the time of injury. Fracture of the distal third of both the radius and ulna was noted (**a**: A-P view, **b**: lateral view)

patients, but the target of reduction should be a 10° or smaller displacement angle in those 10 years old or older because the self-correction ability of bone decreases [7]. Redisplacement of the fracture region readily occurs even if it was previously reduced in children with fractures of the distal third of the radius [3, 7]. An entirely displaced fracture suggesting periosteal injury and 11° or larger displacement of the coronal plane are known risks for redisplacement [8, 9]. Khosla et al. epidemiologically surveyed the incidence of distal forearm fracture and found the highest incidence of this fracture in 10–14 years old of both sexes, which was approximately 800–1300 in 100,000 persons in males and 500–800 in 100,000 persons in females [1]. Therefore, this fracture commonly occurs at 10 years old or older when the self-correction ability of bone decreases, suggesting that this trauma requires stronger fixation.

Pector et al. [3] identified a factor which increases the chance of redisplacement and the failure to achieve a perfect reduction, the presence of initial complete displacement. A perfect anatomical reduction was the most important favorable prognostic factor [10]. This is because completely displaced fractures are usually associated with severe injury to the periosteum and the surrounding soft tissues [6]. The lack of a periosteal hinge affects stability and increases the incidence of redisplacement [6]. Severe soft issue injury causes more initial swelling which usually subsides in about a week resulting in a loose cast and increasing the chance of redisplacement [6]. Surgical treatment is recommended for these high-risk cases of redisplacement.

There are several surgical procedures for this fracture in children such as percutaneous pinning, intramedullary nailing, and plate fixation. Percutaneous pinning is low cost and minimally invasive, but it is complicated and unlikely to result in stable fixation because the pin insertion angle against the fracture line is small and the lever arm length of the inserted pin shortens [7]. Intramedullary nailing overcomes the disadvantage of percutaneous pinning, i.e., weak fixation, to some extent, but postoperative immobilization is necessary and initiation of joint movement is delayed [7]. However, these fixation techniques can obtain not high stability. Single-bone intramedullary nailing of unstable both-bone forearm fractures in children leads to increased redisplacement (redisplacement rate is approximately 31%) [11]. On the other hand, reliable fixation can be acquired by plate fixation and it has almost no risk of redisplacement [5]. However, there are risks of deep infection and refracture after removal the plate with this method, and these complications actually occurred in 2 case of all 43 cases (deep

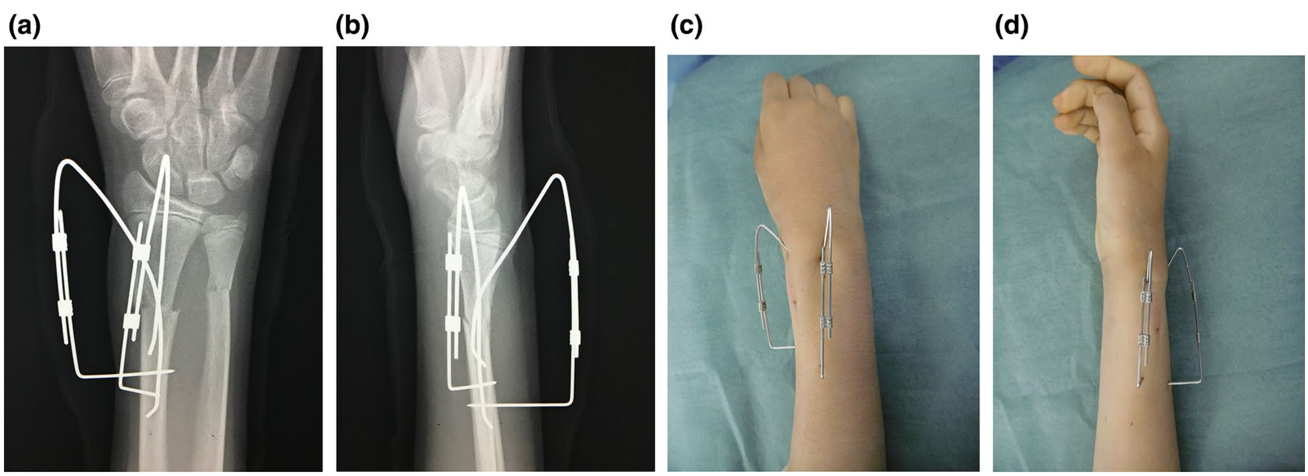

Fig. 2 Postoperative plain radiography and locked wires fixator. Both the radius and ulna were reduced. In the radius, the K-wire intramedullary nail inserted from the radial dorsal side and mini fixator pin inserted into the proximal bone fragment were fixed using the locked wires fixator "JuNction" (plain radiography: **a**, A-P view; **b**, lateral view; macroscopic findings: **c**, A-P view; **d**, lateral view)

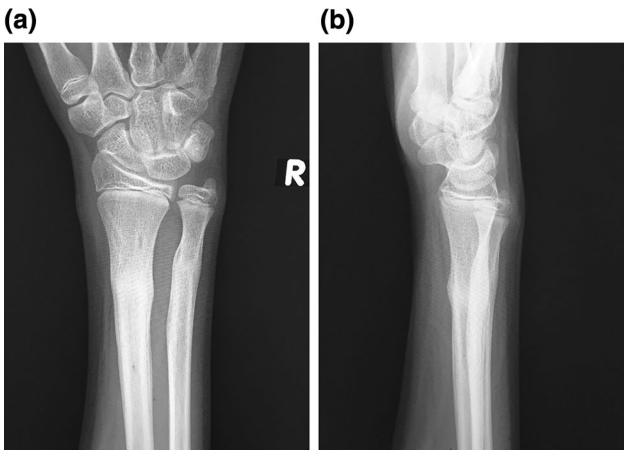

Fig. 3 Plain radiography on the final follow-up. Bone union of the radius and ulna was acquired without postoperative redisplacement (**a**: A-P view, **b**: lateral view)

infection: 1, refracture: 1) [5]. Realistically, many surgeons want to avoid the invasiveness of plate placement and skin incision in the forearm in children for esthetic and emotional reasons.

Surgical treatment with the locked wires fixator can reduce the risk of postoperative redisplacement, which is a disadvantage of conventional percutaneous pinning and intramedullary nail fixation, while retaining the advantage of plate fixation, i.e., no postoperative external fixation. The entire procedure can be applied percutaneously, being a minimally invasive treatment method. A biomechanical study on the fixing force of intramedullary rods suggested that rotational stability is improved by the insertion of several intramedullary rods [12]. It is also well known that external fixation can provide much higher stability at the fracture site than K-wire fixation [13]. In external fixation, the connection between the external fixation device and its screws or wires is outside the body. Therefore, because the lever arms are much longer than the internal fixation devices, a large moment of force is generated around them [14]. According to these biomechanical studies, our technique which is not only intramedullary pinning using two K-wires but also external fixation using locked wires fixator can connect and fix wires can obtain much higher stability compared to other techniques except plates.

Miyamoto et al. used the locked wires fixator HK2 (AREX™, Palaoseaus, France) for 5th carpometacarpal joint dislocation fractures and achieved favorable outcomes without postoperative immobilization [15]. Several studies reported that application of a locked wires fixator to fractures previously treated by percutaneous pinning enabled range of motion training early after surgery without postoperative immobilization, leading to a favorable treatment outcome [16, 17]. This technique was initially applied to fractures of the distal third of the radius in children in our study. Surgical treatment of this fracture using the locked wires fixator is minimally invasive and provides strong fixation sufficient to permit range of motion training early after surgery. All 8 patients acquired favorable final outcomes without postoperative redisplacement, suggesting that this surgical procedure overcomes the problem of postoperative redisplacement, which may develop at a high rate. Locked wire fixator system can be available worldwide. For example, the JuNction (ARATA Co., Ltd., Tokyo, Japan) used in this study was developed by Japan; Meta-HUS® and HK2® (AREX™, Palaoseaus, France) were developed by France, previously described as locked wire fixator system [15–17].

One of the limitations of this study is the small number of patients. In our institution, patients who need surgical treatment are referred from our satellite hospitals. Many of these fractures undergo conservative treatment at these satellite hospitals, resulting in a small number of cases due to selection bias. Next, about cost, one JuNction to connect wires is about 2000 yen. Although the cost is higher than percutaneous pinning, the cost is low for external fixator.

Author contributions KN (first and corresponding author) mainly wrote this manuscript and performed medical examinations and surgery for these patients. SK, NN, YS, HO, KG, and AK were assistant of operative procedure. NN, YS, HO, and KK discussed and advised about the treatment for these patients. All authors read and approved the final manuscript.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Ethical approval This study was approved by the ethics committee for medical research of our university (No. 19-084), and informed consent was received from the parents of all patients.

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