Closed Treatment of Overriding Distal Radial Fractures without Reduction in Children

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Background: Traditionally, distal radial fractures with marked displacement and angulation have been treated with closed or open reduction techniques. Reduction maneuvers generally require analgesia and sedation, which increase hospital time, cost, patient risk, and the surgeon's time. In our study, a treatment protocol for pediatric distal radial fractures was used in which the fracture was left shortened in an overriding position and a cast was applied without an attempt at anatomic fracture reduction.

Methods: Consecutive patients three to ten years of age presenting between 2004 and 2009 with a closed overriding fracture of the distal radial metaphysis were followed prospectively. Our protocol consisted of no analgesia, no sedation, and a short arm fiberglass cast gently molded to correct only angulation. Patients were followed for at least one year. All parents or guardians were given a questionnaire assessing their satisfaction with the treatment. Financial analysis was performed with use of Current Procedural Terminology codes and the average total cost of care.

Results: Fifty-one children with an average age of 6.9 years were included in the study. Initial radial shortening averaged 5.0 mm. Initial sagittal and coronal angulation averaged 4.0° and 3.2°, respectively. The average duration of casting was forty-two days. Residual sagittal and coronal angulation at the time of final follow-up averaged 2.2° and 0.8°, respectively. All fifty-one patients achieved clinical and radiographic union with a full range of wrist motion. All parents and guardians answered the questionnaire and were satisfied with the treatment. Cost analysis demonstrated that closed reduction with the patient under conscious sedation or general anesthesia is nearly five to six times more expensive than the treatment used in this study. Adding percutaneous pin fixation increases costs nearly ninefold.

Conclusions: This treatment protocol presents an alternative approach to overriding distal radial fractures in children and provides the orthopaedic surgeon a simple, effective, and cost and time-efficient method of treatment.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Forearm fractures represent 45% of all fractures in children and are the most common traumatic injuries seen in pediatric orthopaedic private practice[1]. Of these fractures, 75% to 84% occur in the distal third of the forearm[2,3]. Distal forearm fractures therefore have substantial medical and financial impacts on the health-care system. An effective and cost-efficient approach to managing these patients is needed. Nonoperative treatment should be considered if it leads to a good functional and cosmetic outcome.

Displaced distal radial fractures with complete dorsal translation and radial shortening, or with the radius in an overriding position, have traditionally been treated with closed reduction with the patient under conscious sedation or general anesthesia, followed by percutaneous pin fixation in some cases. A common justification for internal fixation is the need to avoid the high frequency of redisplacement following closed reduction and casting. Redisplacement is a substantial concern, and there are several articles favoring percutaneous pinning to maintain post-reduction alignment[4-8]. Redisplacement rates following reduction of metaphyseal radial fractures have been reported to be as high as 91%[4]. In a recent prospective study, complete displacement at

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the fracture site was the most significant risk factor for redisplacement[9].

Although overriding distal radial fractures have traditionally been reduced to restore normal alignment, there are data to suggest that this is not necessary. Plánka et al.[10] studied the outcomes of closed treatment of overriding distal radial fractures and found that 86% had nearly anatomic remodeling at the time of final follow-up. In that study, angulation was not corrected at the time of casting. A similar study evaluated the results of treatment of thirty-four overriding distal radial fractures[11]. All patients in that study had redisplacement following closed reduction, and the fractures were allowed to heal in a shortened position with <15° of angulation and <1 cm of shortening. All patients returned to normal levels of activity without restrictions, pain, or stiffness.

Closed reduction of pediatric fractures commonly requires sedation and analgesia to achieve an anatomic reduction and to alleviate the child's reaction to and recall of a painful and stressful situation. Complications associated with procedural anesthesia include respiratory depression, hypoxia, hypotension, vomiting, and aspiration[12-15]. In addition to these health risks, procedural anesthesia increases physician and nurse staffing requirements, the length of time spent in the hospital, and the total cost of treatment. Internal fixation risks may include pain, infection, neurovascular damage, implant breakage/migration, and possible physeal injury.

Our hypothesis is that closed treatment of overriding distal radial fractures without manipulation results in excellent radiographic and functional outcomes in children.

Materials and Methods

This was a retrospective case series of fifty-four consecutive patients seen between 2004 and 2009. All patients presented to either the emergency room or the treating surgeon's office within seventy-two hours after injury. All orthopaedic care was provided by the senior author (B.H.I.), a fellowship-trained pediatric orthopaedic surgeon. We obtained institutional review board approval for this study. Inclusion criteria were an age of ten years old or younger and a closed overriding fracture of the distal radial metaphysis with or without an associated fracture of the ulna (AO 23-M/3.1). Exclusion criteria were open fractures, physeal involvement by the fracture, metabolic bone disease, neurovascular injuries, or the presence of another skeletal injury. An overriding position was defined as 100% dorsal translation and shortening of the distal radial segment. There was no limitation on the amount of fracture shortening allowed for inclusion of a patient in the study.

On initial evaluation by the treating surgeon, informed consent regarding our treatment protocol was obtained from the patient's parent(s) or legal guardian(s). The protocol consisted of the application of a short arm fiberglass cast gently molded to correct angulation (which was not always fully corrected) with no attempt to correct shortening. Casts were applied in the outpatient clinic and, in accordance with the senior author's preference, no sedation or analgesia was administered during their application. Radiographs at the time of injury and fluoroscopic images were used to assess the fracture before and after casting. The treating surgeon examined and applied the cast for all patients within seventy-two hours after the injury. Follow-up was carried out at one week, two weeks, six weeks, and one year. During the course of treatment, the majority of the patients had at least one cast change after the soft-tissue swelling subsided. Some patients returned for a second cast change at the senior author's discretion. Cast immobilization was discontinued when the fracture site was nontender and there was radiographic evidence of callus formation. Sagittal and coronal angulation was measured on fluoroscopic images obtained immediately after the initial casting and at the time of final follow-up. The amount of initial distal radial shortening was assessed immediately after the initial cast was applied. Patients were assessed for the presence of gross deformity, wrist motion and strength, and fracture site tenderness. Wrist motion and strength were determined with gross visual and manual examination, respectively. If the injured wrist had 90° each of flexion and extension motion that was symmetrical with that of the uninjured wrist, it was noted as "full." If the injured wrist had 5/5 flexion and extension strength that was symmetrical with the uninjured wrist, it was noted as "good." Finally, the patient's parent(s) or guardian(s) were asked two questions about their satisfaction with the treatment: (1) Are you happy or satisfied with the way things have turned out? (2) If given the chance to treat the fracture again, would you choose the same treatment?

A financial analysis comparing four different methods of treatment of displaced pediatric distal radial fractures was done. Current Procedural Terminology (CPT) codes were used to scan the database of the largest local private insurance company and, with use of information from actual patient encounters, the average total cost of care for each of the following scenarios was determined:

1. An office-based visit with application of a short arm cast with correction of angulation but without fracture reduction (the treatment provided in this study)
2. Closed reduction in the emergency room with conscious sedation
3. Closed reduction in the operating room with general anesthesia without pin fixation
4. Closed reduction in the operating room with general anesthesia with pin fixation

Stastistical Methods

Raw radiographic data were used to calculate the mean and standard deviation of each category.

Source of Funding

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Results

Fifty-four patients met the inclusion criteria for enrollment. The parents of one patient desired reduction of their child's injury and sought treatment elsewhere. Two patients moved out of the state prior to completing one year of follow-up. This left fifty-one patients, all of whom completed at least one year of follow-up. There were twenty-eight boys and twenty-three girls. The average age was 6.9 years (Fig. 1). The left extremity was involved in twenty-four patients. Six patients had an isolated distal radial fracture, and all other patients had an associated ulnar fracture. The ulnar fracture was complete in sixteen patients and incomplete or plastically deformed in twenty-nine patients. The mechanism of injury included a fall from a height such as from a tree, a bed, or monkey bars (thirty-nine patients), a skateboard accident (six), a sports injury (four), a fall while wearing "heely shoes" (a shoe that has a wheel built into the sole that allows the wearer to roll in a fashion similar to rollerskating) (one), and a bicycle accident (one) (see Appendix). The average time spent in a cast (and standard deviation) was 42 ± 6.7 days (range, thirty to eighty-nine days).

Seven patients underwent at least one failed attempt at a closed reduction prior to our treatment. Six of these attempts

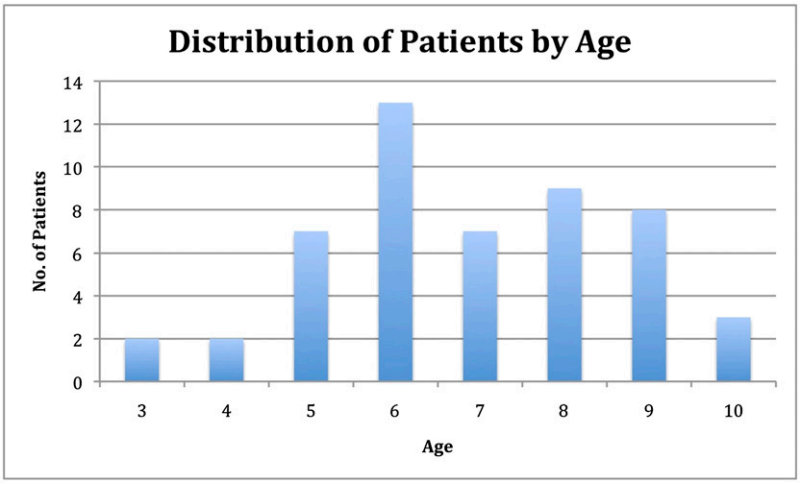


Fig. 1

Distribution of patients by age.

were performed by an emergency room physician and three (including one in the operating room), by a board-certified orthopaedic surgeon. One of these patients underwent three unsuccessful reduction attempts—twice under conscious sedation in the emergency room (once each by an emergency room physician and an orthopaedic surgeon) and once under general anesthesia in the operating room by an orthopaedic surgeon.

Radial shortening on radiographs made immediately after the initial cast was applied measured an average of 5 ± 2.5 mm; range, 1 to 14 mm). Table I illustrates the angulation measurements obtained before and after treatment.

At the time of final follow-up, all patients had a full range of wrist motion and good grip strength. There were no reports of pain or tenderness at the fracture site. All patients had returned to normal activities without restrictions. There were no instances of malunion, nonunion, cross-union, refracture, physeal injury, or neurovascular injury. The parents/guardians of all fifty-one children answered "yes" to both questions related to satisfaction with treatment.

At the time of cast removal, only a few patients had a minimally noticeable clinical deformity; thus, no objective measurements of radial shortening deformity were made. Although patients often demonstrated a "dinner fork" deformity at the time of the initial presentation, this often was no longer appreciable at the time of cast removal. Two patients had initial shortening of >1 cm (1.2 and 1.4 cm); both had remodeling to neutral ulnar variance and 0° of coronal/sagittal angulation. After the initial casting, the angulation in our study was corrected to an average of 4.0° ± 4.1° (range, 0° to 13°) in the sagittal plane and 3.2° ± 3.1° (range, 0° to 10°) in the coronal plane. These numbers improved at the time of final follow-up, with sagittal angulation of 2.2° ± 2.7° (range, 0° to 10°) and coronal angulation of 0.75° ± 1.4° (range, 0° to 5°).

The financial analysis demonstrated the potential for substantial cost savings with our treatment protocol (Table II). Closed reduction in the emergency room with the patient under conscious sedation is 4.7 times more costly, closed reduction in the operating room with the patient under general anesthesia is 6.2 times more costly, and closed reduction in the operating room with pin fixation is 8.5 times more costly than our treatment method.

TABLE I Radiographic Measurements After Initial Cast Application and at Final Follow-up

	Mean and Stand. Dev. *(deg)*	Range *(deg)*
Initial radiographs		
Sagittal angulation	4.0 ± 4.1	0-13
Coronal angulation	3.2 ± 3.1	0-10
Final radiographs		
Sagittal angulation	2.2 ± 2.7	0-10
Coronal angulation	0.75 ± 1.4	0-5

Discussion

Overriding distal radial fractures in children ten years of age or younger have remarkable remodeling potential and do not require anatomic reduction to achieve an excellent result. Do et al.[11] reported uniformly excellent results in a series of patients treated without remanipulation after redisplacement. All patients were able to return to normal activities without pain, stiffness, or restrictions. Plánka et al.[10] also treated a series of patients without reduction and had good results. In that series, the angulation was not corrected at the time of casting and patients had up to 30° of angulation; however, 86% had complete remodeling of the radius to a nearly anatomic position at the time of follow-up. Our treatment method attempted to gently correct angulation at the time of casting and was successful in reducing the angulation to 10° in the coronal and sagittal planes. Given the obvious clinical and radiographic appearances of this injury, obtaining acceptance of a primarily nonmanipulative approach presents a unique challenge to the surgeon. The decision to leave the overriding deformity

TABLE II Treatment Cost by Common Procedural Terminology (CPT) Code

Treatment by CPT Code	Cost ($)
Office visit with application of short arm cast	1027
Emergency room with sedation, closed reduction, and casting	4846
Operating room with general anesthesia, closed reduction, and casting	6415
Operating room with general anesthesia, closed reduction with percutaneous pinning, and casting	8742

unreduced in a child may not be easily understood by the patient, family, or hospital staff. This may drive the surgeon to pursue more aggressive treatment than is needed. A technique used in our study involved showing the hospital staff, patient, and patient's family sequential radiographs of a similar fracture as it remodeled over time (Figs. 2-A through 2-D). In our study, all parents were satisfied with the treatment protocol and the clinical results of treatment (Figs. 3-A through 3-J).

The distal radial and ulnar physes are responsible for 80% of the total forearm length and 40% of the upper-extremity length[16]. Healing of distal radial fractures directly correlates with the remodeling potential left in the distal radial and ulnar physes. Children less than ten years of age have substantial advantages in terms of remodeling potential and angulation correction[17]. Angulation disappears more completely "the younger the child" and when the fracture is closer to the distal radial physis[18]. The goal of

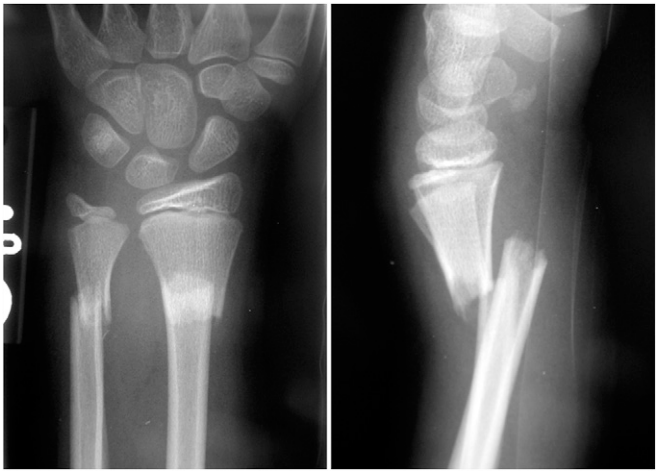
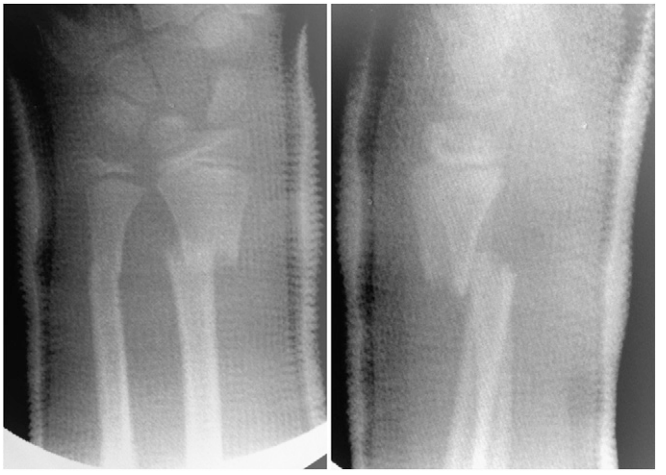


Fig. 2-A



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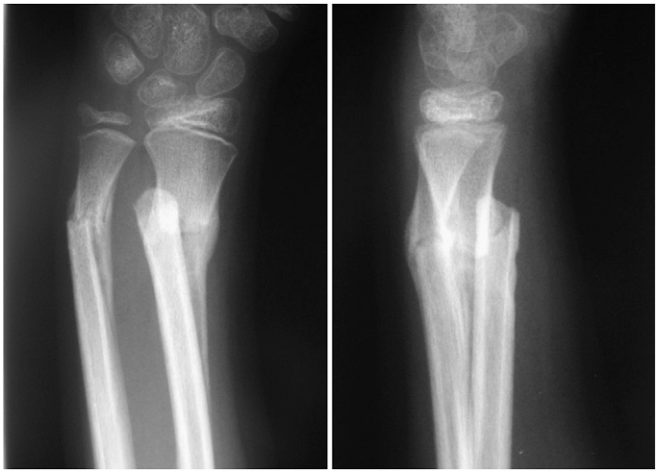

Fig. 2-C

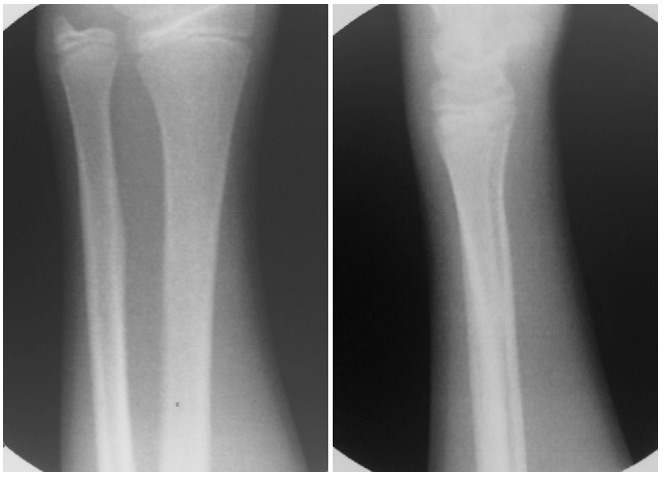

Fig. 2-D

Figs. 2-A through 2-D Radiographs of a nine-year-old patient with an overriding distal radial fracture and an ulnar metaphyseal fracture. **Fig. 2-A** Injury radiographs. **Fig. 2-B** Radiographs after application of a short arm cast. Note that the overriding alignment has not been corrected but the dorsal angulation is improved. **Fig. 2-C** Radiographs after forty-two days of cast immobilization. Note the callus formation and early remodeling. **Fig. 2-D** Follow-up radiographs two years after injury.


Fig. 3-A


Fig. 3-B


Fig. 3-C


Fig. 3-D


Fig. 3-E


Fig. 3-F

Figs. 3-A through 3-J A seven-year-old patient after treatment with our protocol for an overriding right distal radial fracture. The initial clinical deformity was less than the radiographs suggest; this increased parental acceptance of this treatment protocol. **Figs. 3-A and 3-B** Anteroposterior (**Fig. 3-A**) and lateral (**Fig. 3-B**) radiographs of the right wrist on the day of injury. **Figs. 3-C and 3-D** Anteroposterior (**Fig. 3-C**) and lateral (**Fig. 3-D**) radiographs of the right wrist on the day of cast application. **Figs. 3-E and 3-F** Anteroposterior (**Fig. 3-E**) and lateral (**Fig. 3-F**) radiographs of the right wrist on day of cast removal seven weeks after the fracture.

treatment is achieving an acceptable fracture alignment that will not result in a functional or cosmetic malunion. Acceptable limits regarding fracture alignment vary. Noonan and Price[17], in a review article, stated that bayonet apposition is acceptable provided there is <20° of angulation and the patient has more than two years of growth remaining. Our study supports this guideline and provides the largest series of patients of which we are aware as evidence of its validity. We did not have difficulty in achieving gentle angulation correction to within 20° of normal without analgesia. Do et al.[11] showed a 50% increase in the cost of the emergency department visit for patients who underwent closed reduction with manipulation, as compared with splinting and referral for outpatient orthopaedic treatment, of a moderately displaced distal radial fracture. In our study, the average total cost of care for various forms of treatment was determined from the database of the dominant local private insurance company. This analysis demonstrated a large cost savings with conservative treatment. Our treatment protocol had an average total cost of care of $1027 as compared with $4846 for closed reduction under sedation in the emergency room and $6415 for closed reduction under general anesthesia in the operating room. The addition of percutaneous pinning to a closed reduction increased costs to $8742 (Table II).

Traditionally, regional blocks and intravenous sedation have been used for closed reductions of pediatric fractures, with advantages including pain reduction, muscle relaxation, and rapid onset of action. However, procedural anesthesia is not without risks. There are multiple drugs available for conscious sedation, each with its own advantages and disadvantages, and some are also used in combination. Despite the relative safety of conscious sedation, rates of adverse events during sedation have been reported to be from 2.3% to 17%, and these events have ranged from respiratory depression and vomiting to cardiovascular instability and death[12-14]. Newman et al.[19] determined that adverse events occurred in 13.7% of their patients, with 11.9% having serious events (hypoxia, stridor, and hypotension). Also, the risk of adverse events may increase when higher dosages or combinations of drugs are used to produce the desired analgesic effect[12].

Fig. 3-G

Fig. 3-H

Fig. 3-I

Fig. 3-J

Figs. 3-G and 3-H Clinical anteroposterior (**Fig. 3-G**) and lateral (**Fig. 3-H**) photographs of both forearms on the day of cast removal. **Figs. 3-I and 3-J** Anteroposterior (**Fig. 3-I**) and lateral (**Fig. 3-J**) radiographs of the right wrist at the time of final follow-up.

In the treatment of overriding distal radial fractures, it is often difficult to maintain a reduction without internal fixation. Redisplacement rates following closed reduction for completely displaced distal radial fractures have ranged from 29% to 91%[4,6-8,20], probably as a result of the muscular deforming forces and the inherent instability of the fracture. Our treatment strategy avoids the need to monitor and treat redisplacement. After closed or open reduction, fractures are typically followed very closely with several clinic appointments. Then, in the event of redisplacement, the surgeon is faced with a choice of whether or not to remanipulate the fracture. In the series reported by Do et al.[11], the radius was allowed to heal in the shortened position after redisplacement, with no reported complications at the time of final follow-up.

Malrotation was not directly measured in our patients. Two patients had 10° of residual dorsal angulation. No objective deficit was noted on physical examination of any of our patients. Matthews et al.[21] reported that approximately 20° of angulation in any direction was needed before important loss of forearm rotation was seen. Price et al.[22] noted that it was acceptable for patients less than ten years of age to have complete displacement, up to 15° of angulation, and up to 30° of malrotation without adverse events. Although the limits of acceptable deformity described by Matthews et al. and Price et al. refer to diaphyseal fractures, the remodeling potential of metaphyseal fractures is greater. Thus, estimating acceptable metaphyseal deformity by using the limits from these studies of diaphyseal fractures likely provides a conservative "safety buffer zone" of deformity. In patients four to nine years of age, metaphyseal deformity of up to 15° of coronal angulation and 10° to 15° of sagittal angulation is considered acceptable[23].

Our patients were treated with a short arm fiberglass cast for the duration. Traditionally, a long arm cast has been used. In a recent study, 96% of displaced distal radial fractures maintained alignment in a sugar-tong splint[24]. Additionally, treatment with a short arm cast may be sufficient if no reduction is performed. To our knowledge, our study included the largest number of children with an overriding distal radial fracture who were definitively treated without a reduction of the deformity due to this shortening. Our 94% follow-up rate (fifty-one of fifty-four patients) minimizes the risk that unsatisfactory results were missed.

Our study had limitations. We did not have a control group for comparison. Ideally, a study done prospectively with patient randomization offers the best evidence. Another limitation involves the nonobjective nature of our clinical assessment of wrist and forearm range of motion, strength, and function. Although no loss of motion or strength was noted in the records reviewed in our study, it is possible that subtle differences were not detected given the difficulty of obtaining accurate measurements in a child. Limb-length assessment was not done clinically or with radiographs.

In conclusion, the protocol presented here presents an alternative approach to the traditional treatment of overriding distal radial fractures in children, with a number of advantages. First, the patient is not exposed to the risks associated with sedation or anesthesia. Second, the surgeon expends less time and effort by evaluating and treating the patient in the office rather than in the emergency or operating room. Third, health-care payers, and the health-care system in general, realize substantial cost savings by this approach.

In our study, all patients had excellent clinical outcomes. The children's parents were unanimously satisfied with their child's care and stated that they would select the same treatment if given the chance to choose again. This study, along with the others cited in this report, provides further evidence in support of the conservative and non-manipulative management of this injury. Treating overriding distal radial fractures with this method is safe, cost-effective, and reliable. We suggest that this approach can be considered as the first-line treatment rather than simply as a secondary option for a closed, overriding, extraphyseal distal radial fracture in a child ten years of age or less.

Appendix

eA A table showing patient demographics and mechanisms of injury is available with the online version of this article as a data supplement at jbjs.org. ■

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