Closed Reduction and K-Wiring With the Kapandji Technique for Completely Displaced Pediatric Distal Radial Fractures

Bhava R. J. Satish, MS (Ortho), DNB (Ortho); Muniramaiah Vinodkumar, MS (Ortho); Masilamani Suresh, MS (Ortho); Prasad Y. Seetharam, DNB (Ortho); Krishnaraj Jaikumar, MS (Ortho)

abstract

Full article available online at Healio.com/Orthopedics

In completely displaced pediatric distal radial fractures, achieving satisfactory reduction with closed manipulation and maintenance of reduction with casting is difficult. Although the Kapandji technique of K-wiring is widely practiced for distal radial fracture fixation in adults, it is rarely used in pediatric acute fractures. Forty-six completely displaced distal radial fractures in children 7 to 14 years old were treated with closed reduction and K-wire fixation. One or 2 intrafocal K-wires were used to lever out and reduce the distal fragment's posterior and radial translation. One or 2 extrafocal K-wires were used to augment intrafocal fixation. Postoperative immobilization was enforced for 3 to 6 weeks (with a short arm plaster of Paris cast for the first half of the time and a removable wrist splint for the second half), after which time the K-wires were removed. Patients were followed for a minimum of 4 months. Mean patient age was 9.5 years. Near-anatomical reduction was achieved easily with the intrafocal leverage technique in all fractures. Mean procedure time for K-wiring was 7 minutes. On follow-up, there was no loss of reduction; remanipulation was not performed in any case. There were no pin-related complications. All fractures healed, and full function of the wrist and forearm was achieved in every case. The Kapandji K-wire technique consistently achieves easy and near-anatomical closed reduction by a leverage reduction method in completely displaced pediatric distal radial fractures. Reduction is maintained throughout the fracture-healing period. The casting duration can be reduced without loss of reduction, and good functional results can be obtained.

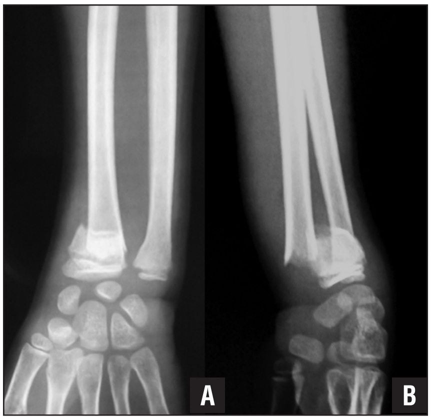

Figure: Preoperative anteroposterior (A) and lateral (B) radiographs of a completely displaced distal radius fracture in 10-year-old child.

The authors are from the Department of Orthopedic Surgery (BRJS, MS, KJ), BRJ Orthocentre, Coimbatore; the Department of Orthopedic Surgery (MV), Ganganagar Orthocentre, Bangalore; and the Department of Orthopedic Surgery (PYS), Seetharam Orthoclinic, Visakhapatnam, India.

The authors have no relevant financial relationships to disclose.

Correspondence should be addressed to: Bhava R. J. Satish, MS (Ortho), DNB (Ortho), Department of Orthopedic Surgery, BRJ Orthocentre, Koundampalayam, Mettupalayam Rd, Coimbatore 641 030, India (drbrjorthocentre@gmail.com).

Received: September 23, 2013; Accepted: January 30, 2014; Posted: September 9, 2014.
doi: 10.3928/01477447-20140825-58

The distal radius is the most common site of fracture in the pediatric age group, constituting approximately 31% of all pediatric fractures.[1] Whereas undisplaced and moderately displaced fractures are generally treated by nonsurgical methods, completely displaced and angulated fractures are treated by several methods, including molding and casting without anesthesia, closed reduction and casting under anesthesia, closed reduction and percutaneous K-wiring under anesthesia, and open reduction and K-wiring.

Achieving good reduction of the fracture may be difficult in completely displaced pediatric distal radial (PDR) fractures by a regular closed technique consisting of traction and fracture manipulation. The bayonet deformity is difficult to overcome in several cases. Traction was found to be ineffective,[2] especially in intact ulnar or greenstick ulnar fractures,[3] and completion of a greenstick ulnar fracture[4] or osteoclasis of an intact ulna[5] has been suggested to obtain radial fracture reduction. In displaced PDR fractures, loss of reduction and redisplacement after closed manipulation and casting is reported in 29% to 91% of cases.[6-10] Several authors have identified the risk factors for redisplacement in PDR fractures, which can be categorized into primary and secondary factors.[7,11-13] The primary factors include age older than 10 years, complete initial displacement, fracture translation greater than 50%, angulation greater than 20°, oblique fracture line, presence of comminution, dorsal bayonet pattern, and associated ipsilateral distal ulnar fracture. Secondary factors include failure to achieve initial perfect reduction, suboptimal casting technique with a cast index greater than 0.8, repeated reduction maneuvers, and reduction under sedation or hematoma block rather than general anesthesia.

Although mild angulations remodel well, especially in smaller children, remodeling may take several months and may be incomplete in older children, bayonet displacements, severe angulations, and rotational malreductions.[14] Deviations (dorsal angulation or radial deviation) more than 30° after age 8 years, more than 20° after age 10 years, and more than 15° after age 13 years may not achieve spontaneous remodeling through the growth process.[15] De Courtivron[16] observed that correction of angulation is not always complete with nonsurgical treatment of PDR fractures. In his series of 602 distal radius fractures, malunion (5° difference compared with the opposite side) at the time of healing was noticed in 86 (14.2%) patients. Of these malunions, only 53% corrected fully in the sagittal plane and 78% corrected in the frontal plane; 37% had a measurable loss of forearm rotation, and 20% had a decrease in radiocarpal motion.[16] It was also found that residual dorsal angulation and radial deviation of the distal fragment were significantly associated with a decrease in the range of forearm rotation and with unsatisfactory end results.[12,17]

Loss of fracture reduction may necessitate remanipulation, open reduction, calloclasis or osteoclasis, and fixation with K-wire or plate and screws, depending on the timing of the procedure after initial injury and the age of the patient. Several authors consider initial complete displacement a major risk factor for redisplacement.[18,19] Choi et al[20] proposed percutaneous K-wiring for high-risk PDR fractures with translation greater than 50%. To avoid redisplacement, Zamzam and Khoshhal[7] advised primary percutaneous K-wiring even after satisfactory closed reduction in completely displaced PDR fractures. Proctor et al[8] suggested percutaneous K-wiring in all cases in which a perfect reduction could not be achieved. Ozcan[21] recommended K-wiring for PDR fractures with ipsilateral ulnar fracture. According to Mostafa et al,[12] primary percutaneous K-wiring should be the preferred procedure for PDR fractures with high risk of redisplacement.

The Kapandji intrafocal K-wire technique is a well-established method of reduction and fixation for distal radial fractures in adults, and the current authors have performed it routinely at their institution for many years. Because of its simplicity and effectiveness, the authors extended the same technique to completely displaced PDR fractures. Although likely used by several surgeons, this technique in acute PDR fractures has been reported infrequently.[22]

Materials and Methods

From January 2011 to January 2013, patients younger than 15 years who sustained completely displaced, closed, nonphyseal distal radial fractures with or without ulnar fracture were prospectively enrolled in the study. Preoperative anteroposterior (AP) and lateral radiographs were obtained. Informed consent for the surgical procedure was obtained from the parents or caregivers.

Surgical Technique

After suitable anesthesia, the limb was placed on a radiolucent side table (**Figures 1-2**). Gentle traction and countertraction were applied to achieve the radial length. In all cases, the distal fragment was posteriorly displaced. With the forearm in the lateral position and under image intensifier control, a K-wire was introduced by hand into the fracture site from the posterior aspect (**Figure 3**). A 1.5-mm K-wire was used in smaller children, and a 2-mm K-wire was used in larger children.

The K-wire was passed across the distal fragment into the fracture area of the proximal fragment. The posterior cortex of the proximal fragment was levered out posteriorly with the handheld K-wire, reducing it to the posterior cortex of the distal fragment (**Figure 4**). Once the posterior cortices were aligned, the K-wire was pushed through the fracture obliquely to touch the anterior cortex of the proximal fragment. A drill was attached to the

Figure 1: Preoperative anteroposterior (A) and lateral (B) radiographs of a completely displaced distal radius fracture in 10-year-old child.

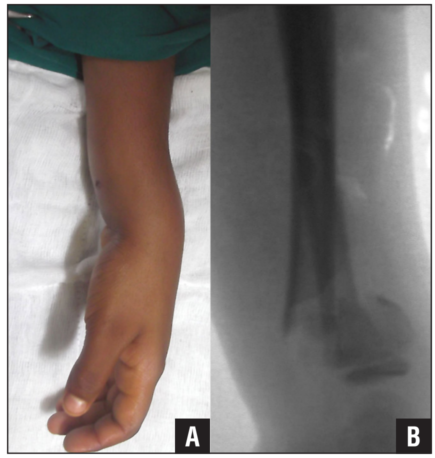

Figure 2: Photograph (A) and initial fluoroscopic image (B) of clinical deformity.

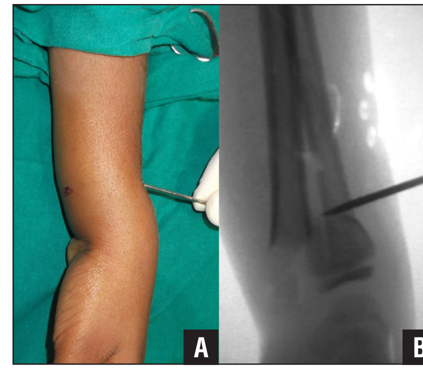

Figure 3: Clinical (A) and fluoroscopic (B) lateral views showing K-wire introduction into the radius fracture site from the posterior aspect.

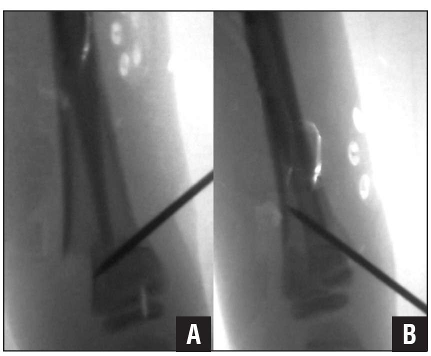

Figure 4: Fluoroscopic lateral views showing levering out of the proximal fragment (A) and reduction to the distal fragment (B) by intrafocal K-wire.

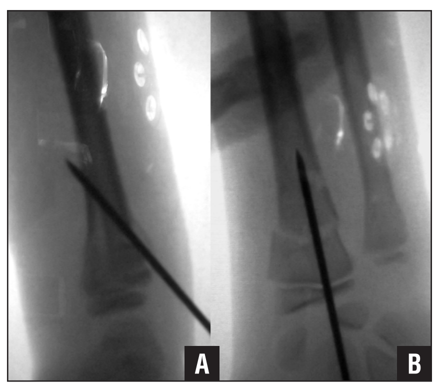

Figure 5: Fluoroscopic lateral (A) and anteroposterior (B) views showing fracture reduction after Kapandji intrafocal K-wire fixation.

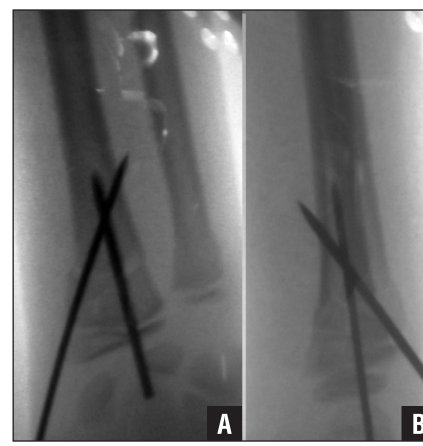

Figure 6: Fluoroscopic anteroposterior (A) and lateral (B) views after supplemental extrafocal K-wire fixation.

K-wire, and the wire was drilled through the anterior cortex, stabilizing the fracture. The forearm was fully pronated and checked on the AP view (**Figure 5**). If the fracture was reduced, as it would be in most cases, 1 extrafocal K-wire was passed on the lateral side either from distal lateral to proximal medial from the radial styloid or above the physeal line or from proximal lateral to distal medial (**Figure 6**). If there was residual lateral translation of the distal fragment on the AP view, another intrafocal K-wire was passed laterally through the fracture site. The lateral translation was reduced by a leverage method, and the wire was pushed and drilled into the medial cortex of the proximal fragment. Extrafocal K-wires were added as necessary. The K-wires were bent just outside the skin and cut (**Figure 7**). Sterile gauze dressings were positioned between the K-wire and the skin's surface.

A well-padded below-elbow plaster of Paris cast was placed in all cases after K-wiring. If the child was admitted in the morning, he or she was discharged in the evening after the procedure. If the child was admitted in the evening, he or she was discharged the next morning. Postoperative AP and lateral radiographs were obtained before discharge. An initial review was performed on postoperative day 3 or 4. Subsequent reviews were performed depending on the age of the child. The cast was worn for a minimum of 10 days to a maximum of 20 days, after which time a ready-made wrist splint was applied. The K-wire dressing was changed once when the cast was changed to a splint.

After 3 to 6 weeks, radiographs were obtained. If healing was satisfactory, K-wire removal was performed as an outpatient procedure. A compression bandage was applied, and wrist mobilization was started after K-wire removal. Patients were followed for a minimum of 4 months postoperatively. In patients in whom K-wires had crossed the radial physis, a telephone interview was conducted with the parents or caregivers at 1 year postoperatively or later to ascertain the appearance and function of that wrist. When there was any complaint related to the operated

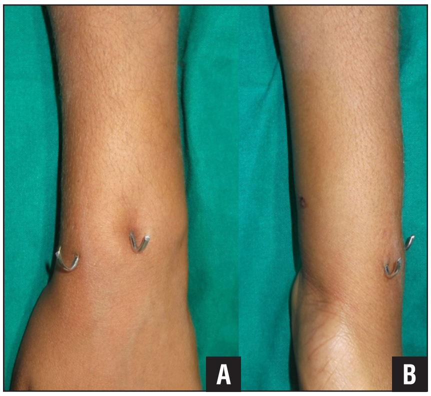

Figure 7: Dorsal (A) and lateral (B) clinical photographs showing K-wire entry sites.

Table

Intrafocal and Extrafocal K-wires Used

Total No. of K-wires	Radius: Intrafocal K-wires: Posterior	Radius: Intrafocal K-wires: Lateral	Radius: Extrafocal K-wires	Ulna	No. of Patients (N=46)
2	1		1		27
3	1	1	1		8
4	1	1	1	1	4
3	1		2		5
4	1		2	1	2

Figure 8: Four-month postoperative anteroposterior (A) and lateral (B) radiographs showing healing of a radius fracture in the anatomical position.

Figure 9: Good cosmesis of the wrist at final follow-up.

Figure 10: Good wrist and forearm function at final follow-up.

wrist, they were advised to return to the hospital for clinical and radiographic examinations.

Results

Among the 52 patients who were enrolled during the study period, 46 completed the follow-up criteria. Mean patient age was 9.5 years (range, 7-14 years). Mean procedure time for K-wiring was 7 minutes (range, 6-9 minutes). Two and 3 K-wires were used for radius fixation in 27 and 19 patients, respectively. A combination of intrafocal and extrafocal K-wires was used (**Table**). Associated ulnar fractures were seen in 16 patients, 6 of whom underwent K-wire fixation.

With the Kapandji leverage technique, anatomical or near-anatomical fracture reduction was achieved in all cases. Open reduction was not performed in any case. On immediate postoperative radiographs, there was no residual posterior angulation or translation. A residual lateral translation (mean, 1 mm) was seen in 6 cases. On final radiographs just before K-wire removal, there was no posterior or lateral translation or angulations. Eighteen patients had a total duration of 3 weeks of wrist immobilization in a short arm plaster of Paris cast. The rest of the patients were immobilized for 4 to 6 weeks, with a short arm plaster of Paris cast for the first half of the time and a removable wrist splint for the second half.

Mean follow-up was 4.5 months (range, 4-6 months). All fractures healed (**Figure 8**). Cosmesis was excellent after cast removal (**Figure 9**). All patients achieved full wrist flexion and extension and forearm rotation (**Figure 10**). Mean time to achieve full wrist range of motion after immobilization was 3 weeks (range, 2-5 weeks). There was no loss of reduction or remanipulation. No cast- or K-wire–related complications were observed.

After 1 year or more, telephone interviews were conducted with the parents or caregivers of 30 patients in whom 1 or 2 wires had crossed the physis. Except for 2 patients, the caregivers neither detected any visible difference between the injured and uninjured wrists nor reported any complaints related to the operated wrist. There was a suspicion of difference between the injured and uninjured wrists by the caregivers of 2 patients. These 2 patients were reviewed in the hospital with clinical and radiographic examination. Both patients had full range of motion of the wrist and forearm with no clinical deformity or radiographic physeal arrest.

Discussion

Three treatment methods are available for completely displaced PDR fractures: gentle molding without proper reduction and casting in casualty without anesthesia (CIC-A), closed reduction and casting under anesthesia (CRC), and closed reduction and K-wiring (CRW) under anesthesia. Open reduction is usually reserved for late presentation cases or loss of reduction with unacceptable angulations. Completely displaced PDR fractures are at risk for redisplacement after closed manipulation and casting. Redisplacement may require a second intervention or prolonged follow-up after malunion. Despite good long-term functional and radiographic outcomes in a majority of malunited PDR fractures, loss of reduction is a concern. It is not uncommon for parents or caregivers to request repeated radiographs until the disappearance of clinically visible deformity, which may take months to years. Some factors that need to be considered before selecting a particular method of treatment are the age of the child, the severity of initial angulation or redisplacement angulation that is acceptable in a given child, the duration of time that may be required for remodeling and reintervention if required, whether a second intervention could give the same result as the primary intervention, the overall duration of treatment, the overall cost involved, and parent or caregiver anxiety.

Although achieving optimal closed reduction by any technique is the essential first step, the more important step is the technique by which the reduction can be maintained throughout the fracture healing period. A good 3-point molded cast and percutaneous K-wiring are 2 options available for maintaining fracture reduction. Although perfect casting is sought, it may not be possible because of inadequate or excessive padding, too-quick or too-delayed handling of plaster of Paris, soft tissue swelling, or suboptimal anesthesia. More-than-normal swelling can be present at presentation because of high-velocity trauma, associated displaced ulnar fracture, absent first aid splinting, or after native treatment. Swelling can increase after repeated forced manipulations, especially in cases of delayed presentation. Subsidence of swelling a few days after casting can result in later fracture redisplacement.

Cast-related issues can be avoided with K-wiring. In a prospective randomized controlled trial, McLauchlan et al[9] compared 33 children treated by CRC with 35 children treated by CRW. They observed loss of reduction in 14 of 33 patients treated by CRC. Remanipulation was required in 7 patients in the CRC group and none in CRW group. They concluded that K-wire fixation maintained reduction significantly better and reduced the need for follow-up radiographs and further procedures to correct the loss of position.

In a prospective, randomized study of 100 distal radius fractures in adults treated by K-wiring, Strohm et al[23] found both the functional and radiographic outcomes of the Kapandji method to be significantly better than those of the conventional (Willenegger) technique. Conventional extrafocal K-wiring in completely displaced PDR fractures can be performed only after achieving satisfactory reduction. The Kapandji intrafocal K-wiring technique serves to achieve fracture reduction in addition to fracture fixation, which is useful in irreducible PDR fractures. With conventional K-wiring, Choi et al[20] reported an 8% incidence of open reduction and a 6.4% incidence of loss of reduction in a series of 140 patients with severely displaced PDR fractures. In the current series, closed reduction was possible in all cases with the Kapandji technique; open reduction was not necessary. There was no loss of reduction after K-wiring. Recently, Parikh et al[22] described intrafocal pinning in 10 patients with PDR fractures and compared the results with 26 patients who underwent conventional pinning. They concluded that the intrafocal pinning technique has the added advantage of being used as a reduction tool.

Closed reduction and casting under anesthesia is usually performed under image intensifier control. To avoid redisplacement, a perfect casting is attempted, and rechecks with fluoroscopy are generally performed while applying the cast. On the other hand, with the Kapandji CRW method, once intrafocal fixation is done, good casting is performed with no C-arm rechecks. Reduction is quick with the leverage technique, and with no fear of redisplacement, cast application is also quick. The overall duration of surgery, anesthesia, and radiation exposure is nearly the same for both CRC and CRW. Above- or below-elbow cast application is done at the discretion of the surgeon after CRC, but below-elbow casting is sufficient after CRW.

Crawford et al[24] observed that simple molding and CIC-A is sufficient to obtain good functional outcomes and reduces the treatment cost compared with CRC and CRW. In their study, mean patient age was only 6.9 years, and the treatment method was offered to children younger than 10 years, when good remodeling can occur. Cost calculations were done only for the initial admission and treatment, which were taken from the dominant local private insurance company. A majority of patients had at least 1 cast change after subsidence of swelling, and some had 2 cast changes at the authors' discretion. Whether the cost calculations of these subsequent castings were taken into account was not mentioned. In general, radiographic examination was performed every 7 to 10 days for the first 3 weeks to assess fracture reduction in CIC-A or to detect early unacceptable redisplacement in CRC.[9,14] In a randomized controlled trial of conservatively treated distal radius fractures with acceptable angulations, splint management was found to be cost-effective compared with casting.[25] In the current study, 18 patients (younger than 9 years) had 1 casting alone, whereas others (older than 9 years) had 1 casting initially and splinting later for wrist immobilization. The accrued costs of periodical hospital visits, cast changes, and radiological examinations with CIC-A and CRC may be equal to that of Kapandji CRW. Also, the surgeon may have to spend more time with parents or caregivers during every visit with CIC-A and CRC patients.

The current authors obtained postoperative radiographs only twice: once in the immediate postoperative period and once at K-wire removal. They used to perform only 2 follow-up examinations after K-wire removal, the first after 2 to 3 weeks and the second 2 to 3 weeks after the first. With CRW, the caregivers were satisfied with the wrist cosmesis at the first visit after K-wire removal. By the second visit after K-wire removal, most patients achieved full wrist range of motion and were discharged from observation. McLauchlan et al[9] and Ozcan et al[21] has also observed increased follow-up intervals and decreased radiographic frequency in patients treated with K-wire fixation. The current authors' total postoperative follow-up period is normally 8 to 12 weeks, depending on the age of the child. For the purposes of this study, the authors performed a longer follow-up.

Eichinger et al[26] used the lower extremity aided fracture reduction technique as a single-provider manual reduction method in bayoneted PDR fractures. Biomechanical assessment showed the generation of 597 N of axial traction with this technique. Despite this huge force, a residual mean translation of 2 mm was noted at the end of the procedure. Acceptable reduction could not be achieved in 8% of cases, and operative intervention was needed in 12%. This much force in a pediatric wrist fracture is neither necessary nor justified: most of the force acts at the joints rather than at the fracture site. With the Kapandji technique, which is also a single-provider reduction method, necessary force is given at the necessary (fracture) site without undue stretching of normal soft tissues. The technique acts as a class I lever, with the fracture site as the fulcrum and the surgeon providing the effort to move the resistance/load provided by the displaced proximal fragment. The authors call this smooth reduction.

Many orthopedic surgeons agree that most malunited PDR fractures will remodel with minimal or acceptable cosmetic and functional impairment, especially in younger children. However, it is the authors' experience that a majority of parents or caregivers are skeptical about natural remodeling, despite being shown serial radiographs of patients who were successfully treated by nonsurgical methods. Parents or caregivers tend to obtain a second opinion from another physician who may not be aware of the remodeling potential of such fractures and who may advise for fracture reduction. The authors lost patients to follow-up after treatment by CIC-A. Because union and joint stiffness are not major problems in PDR fractures, treatment should focus on avoiding malunion, achieving range of motion quickly, and reducing the duration of treatment and follow-up. The longer the child is under observation, the more stress caregivers feel and the more money is spent. Among the 3 methods (CIC-A, CRC, and CRW), CRW seems to be more reliable in providing consistent good results with a shorter treatment period. The Kapandji method seems to be more effective in achieving easy reduction and reducing the casting period than conventional K-wiring. Thus, in all PDR fractures where the displacement is severe enough to warrant reduction under anesthesia, the authors prefer Kapandji K-wiring.

Conclusion

The Kapandji method of K-wiring is useful in achieving and maintaining reduction in completely displaced PDR fractures. Near-anatomical closed reduction can be easily achieved with minimal force by the leverage technique. With no fear of redisplacement, the casting period can be reduced. With no clinical deformity, the follow-up period can be shortened. The authors recommend this technique in all completely displaced PDR fractures that require reduction under anesthesia.

References

1. Randsborg PH, Gulbrandsen P, Saltyte Benth J, et al. Fractures in children: epidemiology and activity-specific fracture rates. *J Bone Joint Surg Am*. 2013; 95(7):e421-e427.
2. Fernandez DL. Conservative treatment of forearm fractures in children. In: Chapchal G, ed. *Fractures in Children*. New York, NY: Thieme-Stratton; 1981.
3. Woodbury DF, Fischer B. An overriding radius fracture in a child with intact ulna: management considerations. *Orthopaedics*. 1985; 8:763-765.
4. Skillern PG Jr. Complete fracture of the lower third of the radius in childhood with greenstick fracture of the ulna. *Ann Surg*. 1915; 61:209-225.
5. Compere CL, Carr CR, Tracy HW. Management of fractures of the distal forearm in children. *South. Med J*. 1965; 57:540-550.
6. Gibbons CL, Woods DA, Pailthorpe C, Carr AJ, Worlock P. The management of isolated distal radius fractures in children. *J Pediatr Orthop*. 1994; 14:207-210.
7. Zamzam MM, Khoshhal KI. Displaced fracture of the distal radius in children: factors responsible for redisplacement after closed reduction. *J Bone Joint Surg Br*. 2005; 87:841-843.
8. Proctor MT, Moore DJ, Paterson JM. Redisplacement after manipulation of distal radial fractures in children. *J Bone Joint Surg Br*. 1993; 75:453-454.
9. McLauchlan GJ, Cowan B, Annan IH, Robb JE. Management of completely displaced metaphyseal fractures of the distal radius in children: a prospective, randomised controlled trial. *J Bone Joint Surg Br*. 2002; 84:413-417.
10. Mani GV, Hui PW, Cheng JC. Translation of the radius as a predictor of outcome in distal radial fractures of children. *J Bone Joint Surg Br*. 1993; 75:808-811.
11. Kamat AS, Pierse N, Devane P, Mutimer J, Horne G. Redefining the cast index: the optimum technique to reduce redisplacement in pediatric distal forearm fractures. *J Pediatr Orthop*. 2012; 32(8):787-791.
12. Mostafa MF, El-Adl G, Enan A. Percutaneous Kirschner-wire fixation for displaced dis-

tal forearm fractures in children. *Acta Orthop Belg.* 2009; 75:459-466.

13. McQuinn AG, Jaarsma RL. Risk factors for redisplacement of pediatric distal forearm and distal radius fractures. *J Pediatr Orthop*. 2012; 32(7):687-692.
14. Hove LM, Brudvik C. Displaced paediatric fractures of the distal radius. *Arch Orthop Trauma Surg.* 2008; 128:55-60.
15. Lefevre Y, Laville JM, Boullet F, Salmeron F. Early correction of paediatric malunited distal metaphyseal radius fractures using percutaneous callus osteoclasis (“calloclasis”). *Orthop Traumatol Surg Res*. 2012; 98(4):450-454.
16. De Courtivron B. Spontaneous correction of the distal forearm fractures in children. Paper presented at: European Pediatric Orthopaedic Society Annual Meeting; 1995; Brussels, Belgium.
17. Roberts JA. Angulation of the radius in children’s fractures. *J Bone Joint Surg Br.* 1986; 68:751-754.
18. Hang JR, Hutchinson AF, Hau RC. Risk factors associated with loss of position after closed reduction of distal radial fractures in children. *J Pediatr Orthop*. 2011; 31(5):501-506.
19. Alemdaroglu KB, Iltar S, Cimen O, Uysal M, Alagöz E, Atlihan D. Risk factors in redisplacement of distal radial fractures in children. *J Bone Joint Surg Am*. 2008; 90(6):1224-1230.
20. Choi KY, Chan WS, Lam TP, Cheng JCY. Percutaneous Kirschner wire pinning for severely displaced distal radial fractures in children. *J Bone Joint Surg Br.* 1995; 77:797-801.
21. Ozcan M, Memisoglu S, Copuroglu C, Saridogan K. Percutaneous Kirschner wire fixation in distal radius metaphyseal fractures in children: does it change the overall outcome? *Hippokratia.* 2010; 14(4):265-270.
22. Parikh SN, Jain VV, Youngquist J. Intrafocal pinning for distal radius metaphyseal fractures in children. *Orthopedics*. 2013; 36(6):783-788.
23. Strohm PC, Müller CA, Boll T, Pfister U. Two procedures for Kirschner wire osteosynthesis of distal radial fractures: a randomized trial. *J Bone Joint Surg Am*. 2004; 86(12):2621-2628.
24. Crawford SN, Lee LS, Izuka BH. Closed treatment of overriding distal radial fractures without reduction in children. *J Bone Joint Surg Am*. 2012; 94(3):246-252.
25. Von Keyserlingk C, Boutis K, Willan AR, Hopkins RB, Goeree R. Cost-effectiveness analysis of cast versus splint in children with acceptably angulated wrist fractures. *Int J Technol Assess Health Care*. 2011; 27(2):101-107.
26. Eichinger JK, Agochukwu U, Franklin J, Arrington ED, Bluman EM. A new reduction technique for completely displaced forearm and wrist fractures in children: a biomechanical assessment and 4-year clinical evaluation. *J Pediatr Orthop*. 2011; 31(7):e73-e79.