

Corrective Osteotomy After Damage of the Distal Radial Physis in Children: Surgical Technique and Results

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Abstract: Distal radial physis closure in children can develop severe wrist deformity (radial shortening). These patients can be treated using a single-step surgery. It was carried out in the form of a corrective osteotomy adopting the volar approach, with fixed-angle volar plate fixation and bone grafting from the iliac crest. There have been few descriptions of the use of this technique in the management of deformities related to early epiphysiodesis in distal radius. The use of fixation systems for the radius, using fixed-angle locking plates, allows radius lengthening adjusted to demand after osteotomy, using the combination of the plate and distal locking pins as spacer—with customized tricortical iliac crest grafting within the defect. The freeing of soft parts such as the dorsal periosteum and brachioradialis muscle tendon allows adequate bone lengthening in a single-surgical step.

Key Words: epiphysiodesis, distal radius, osteotomy

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HISTORICAL PERSPECTIVE

Wrist deformities because of early epiphysial closure (epiphysiodesis) of the distal radius can be produced by trauma, infections, congenital disorders (Madelung disease), and metabolic pathologies. Regarding traumatic causes, between 1% and 7% of epiphysiolysis present deformities caused by epiphysiodesis, as a consequence of the trauma or the treatment, due to Kirschner wire multiple perforations. Wrist pain has also been described in adolescent gymnastics athletes, with an ulnar plus variant secondary to early physal closure of distal radius, as a consequence of repeated traumatism to the heel of hand.¹

Clinical and radiologic diagnosis can only be made after a minimum of 6 months after the initial lesion. However, earlier changes can be appreciated with magnetic resonance imaging. The risk of growth disturbances is increased in cases of severe initial deformity, open wounds either with repeated or late manipulations, although severe physal lesions have also been described after nondisplaced fractures.

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The treatment depends on the physal compromise, the child's growth potential, and the deformity. Near-complete physal closure creates distal radius shortening and angulation that can compromise joint function, and create pain and instability. Surgical treatment with different techniques, either alone or combined, such as 1 or 2-staged bone lengthening osteotomy, external fixation, and ulnar shortening with or without epiphysiodesis, is indicated to correct the deformity.²

INDICATIONS

The authors propose a novel, not earlier described in the literature, surgical technique for the treatment of deformities caused by physal closure of the distal radius, using 1-staged radius lengthening with an addition osteotomy through a volar approach, fixated by a fixed-angle volar plate with added iliac crest bone grafting.

TECHNIQUE

An addition corrective osteotomy with contralateral iliac crest bone graft is performed through a volar approach, extended to the flexor carpi radialis (FCR) muscle.³ A 10-cm incision is placed between the distal radius metaphysis and the scaphoid bone tuberosity. Parona's space is approached through an opening of the FCR deep fascia. This approach protects important structures that are located here, thus radially displacing the radial artery and ulnarly displacing the median nerve.

Next, an L-shaped flap is created with the pronator quadratus muscle, and the radius volar periosteum is elevated. As the children's periosteum is lax, the elevated flap can be later easily reattached, thus covering all osteosynthesis hardware. It is very important to avoid damaging volar radiocarpal ligaments that originate from the radius volar lip, which are strong joint stabilizers. Then, the tendon from the brachioradialis muscle is released with a zigzag technique, and the first extensor compartment is released using the technique of Orbay et al.⁴

The osteotomy is performed proximally to the distal radius physis, so that the bone fixation system does not impinge the growth zone. After the osteotomy, the proximal fragment is pronated, giving access to the distal portion of the wrist. It is very important to resect a dorsal periosteal rectangle, along with the deep portion of the extensor compartment. Without this, it is impossible to perform radius lengthening in case of severe deformities.

Once all tissue is released from the volar, radial, and dorsal aspects of the distal radius, the proximal fragment is allowed to rotate. Care must be taken to avoid injury to the tissues from the ulnar aspect, so that there is no interference to the radius vasculature from interosseous blood vessels.

In the next step, radius bone lengthening can be performed by either 2 forms:

- The use of a laminar spreader, similar to that used in spinal surgery or in tibial opening osteotomies, placed at the

radial and posterior portions of the radius, allows plate positioning.

- The use of the distal radial fixation as a fixed-angle, blocking implant, with a radial distal metaphyseal osteotomy, and radius lengthening using the plate as a lever device, thus correcting the deformity and, once correction is attained, the plate is fixed to the radial diaphysis.

The corticocancellous bone graft is introduced through the same approach, filling the bone defect that is created. Both of those 2 proposed technical possibilities allow the use of tricortical grafting to reinforce the mounting stability.

CLINICAL CASES

Case 1

A 10-year-old girl presented with a fracture of both forearm bones and distal radius epiphysiolsis after a fall. The girl was conservatively treated, and the distal radius physis evolved to a premature closure. At 4 years postlesion, the patient presented a severe wrist deformity, with 28 mm of distal radius shortening. Computerized axial tomography scan showed that the distal radius physis had a 70% closure (Figs. 1, 2). The patient and next of kin did not accept the possibility of correction by external fixation because of cosmetic reasons and, after patient and family informed consent, an osteotomy through a volar approach with a fixed-angle volar plate was used (Fig. 3). In this case, a laminar spreader was used to perform bone lengthening. Neither bone substitutes nor any surgical gesture toward the distal ulnar epiphysis were used. Antibiotic prophylaxis with 2 g intravenous cephazolin q8 h for 24 hours, according to the institution's infection committee, was used.

The operated limb was kept elevated for 24 to 48 hours, and after this time, the patient was discharged from the hospital

for outpatient follow-up. The wrist was immobilized with a volar splint for 3 weeks, followed by physical therapy for 6 weeks.

At 40 days postoperatively, a complete bone healing of the osteotomy was observed, with total graft incorporation, showing complete, painless range of motion.

At 2 years of prospective follow-up, the patient is now 16-year-old and remains asymptomatic, with no problems regarding sports practice or daily living activities. There is no recurrence of the deformity, and the distal ulnar physis is closed. There has been no need for implant removal or any further surgical intervention (Fig. 4).

Case 2

A 13-year-old boy presents a deformity of both upper and lower limbs. He has been diagnosed of bilateral early diaphyseal closure from both distal radii and both proximal tibiae, probably because of a systemic postinfectious outcome. The left wrist was asymptomatic, and did not require any treatment, despite the deformity (Fig. 5). However, the right wrist presents a radius shortening of 26 mm in respect to the ulna, showing a dorsal distal radius angulation of 29 degrees, associated with pain for daily living activities (Fig. 6).

After preoperative planning and informed consent, a volar approach osteotomy was performed, using a fixed-angle volar plate. Differently from the first case, the plate was first fixed at the distal end, and then the osteotomy was performed. By manipulating the distal-end fixed on the plate to lengthen the radius and perform the correction, the plate was then fixed with screws on the proximal region, creating a bridge-mode osteosynthesis. Next, a tricortical iliac crest bone graft was harvested, and impacted cancellous chips filled the defect. The ulna was not operated, but the radius was preventively overcorrected in 5 mm. The operated limb was kept elevated

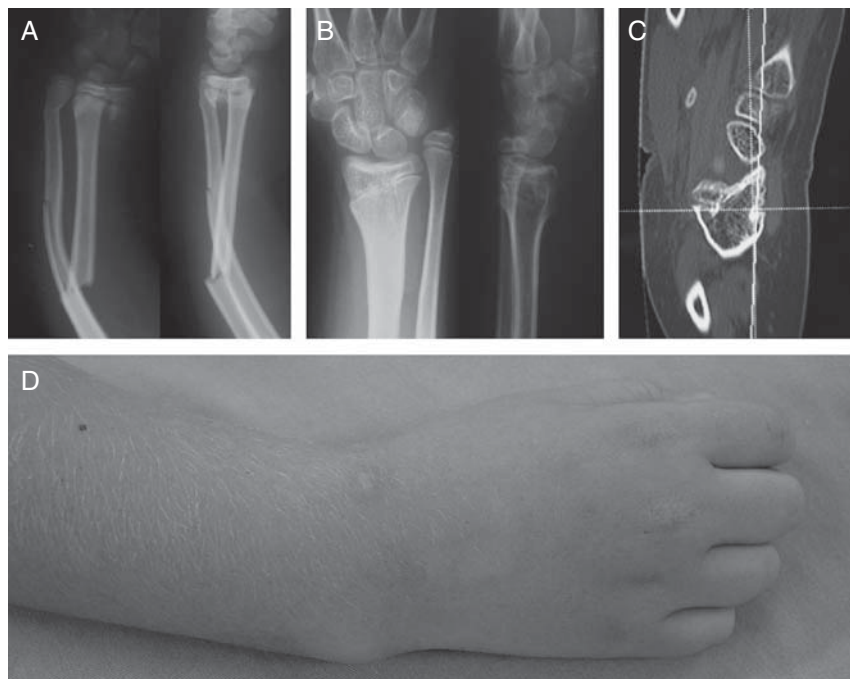


FIGURE 1. Case 1. A, Displaced fracture of both right forearm bones, plus a distal epiphysiolsis from the distal radius of a 10-year-old girl. B and D, After 3 years of evolution, a severe radius shortening is seen due to early epiphysiodesis. C, The computerized axial tomography scan confirms severe physal compromise.

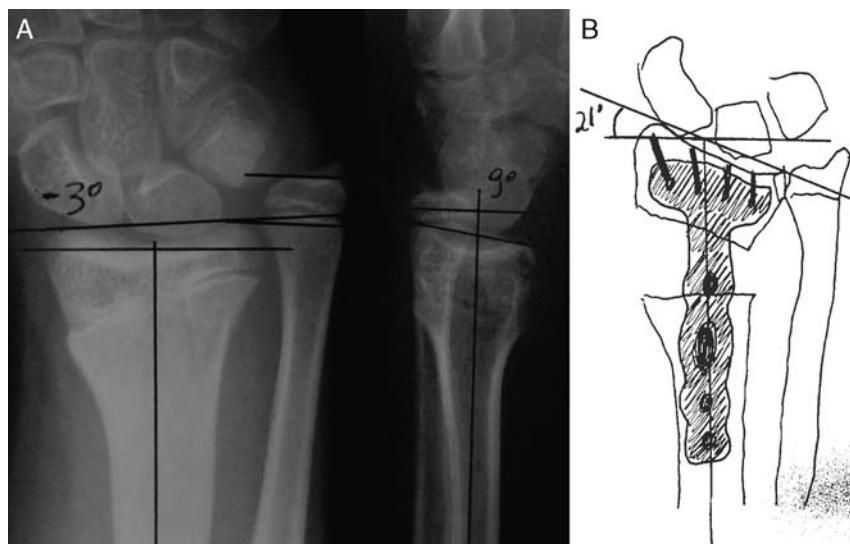


FIGURE 2. A, Radiographs with distal radius angle measurements. A, A severe radius shortening (28 mm) is observed, along with the ulnar angulation of the radius. B, Preoperative planning and intended appearance of the osteotomy.

for 48 hours, using the same antibiotic prophylaxis protocol of the other case.

The evolution was excellent, and no complications were observed. No neurovascular signs or symptoms related to radius lengthening were observed. A complete radiographic bone healing was achieved at 45 days. At 2 years postoperatively, the patient is 15-year-old and is symptomatic. The radiographic study shows complete radius physal closure, whereas the ulnar physis is still open. Despite the intentionally created slope during the surgery, there is a distal radioulnar index of +4 mm because of distal ulnar growth (Fig. 7). At the present moment, the need of a new intervention is rejected, and the patient remains under clinical follow-up.

REHABILITATION

The operated limb was kept elevated for 24 to 48 hours, and after this time, the patient was discharged from the hospital for outpatient follow-up.

The wrist was immobilized with a volar splint for 3 weeks, followed by physical therapy for 6 weeks. The patient is encouraged to continue light activities for the next few weeks, but heavy strain should be avoided until satisfactory healing of the osteotomy.

COMPLICATION

The technique that we presented can correct severe distal radius deformities in 1 surgical stage, with no associated procedure on the ulna, allowing more than necessary radius lengthening, and creating a sufficiently high radioulnar index—between 5 and 10 mm—so that there is no interference on the rotation arc, and allowing a further normal ulnar growth. However, the case 2 patient was 13-year-old at the time of intervention. Despite a satisfactory 2-year postoperative result, the radiographic examination showed an elongated ulna in comparison with the radius. Perhaps, in these cases, owing to the growth potential up to 21 years of age in boys, the possibility of an associated distal ulnar epiphysiodesis at the same surgical stage should be considered.

DISCUSSION

Physal closures can be divided in partial and total. The best method to define the grade of physal compromise is by computerized axial tomography as radiographs, usually because of image superposition, may simulate more severe lesions. Those lesions with less than 40% of physal area closure, those with more than 2 years of potential growth, and those with an angular tilt of less than 20 degrees can be treated by bone bar resection and fat tissue interposition.^{5,6}

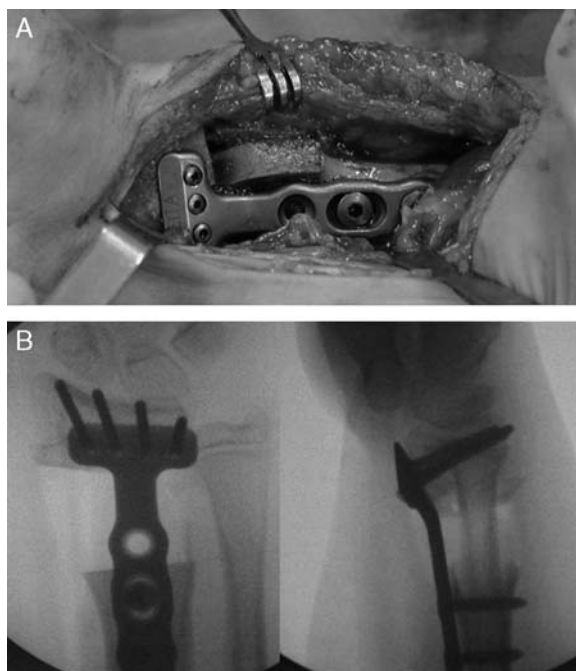


FIGURE 3. A, Perioperative view after fixed-angle volar plate fixation for the distal radius, and the use of tricortical bone graft from iliac crest. B, Perioperative radiographs showing corrected angulation and length of distal radius, kept in position with the osteosynthesis system.

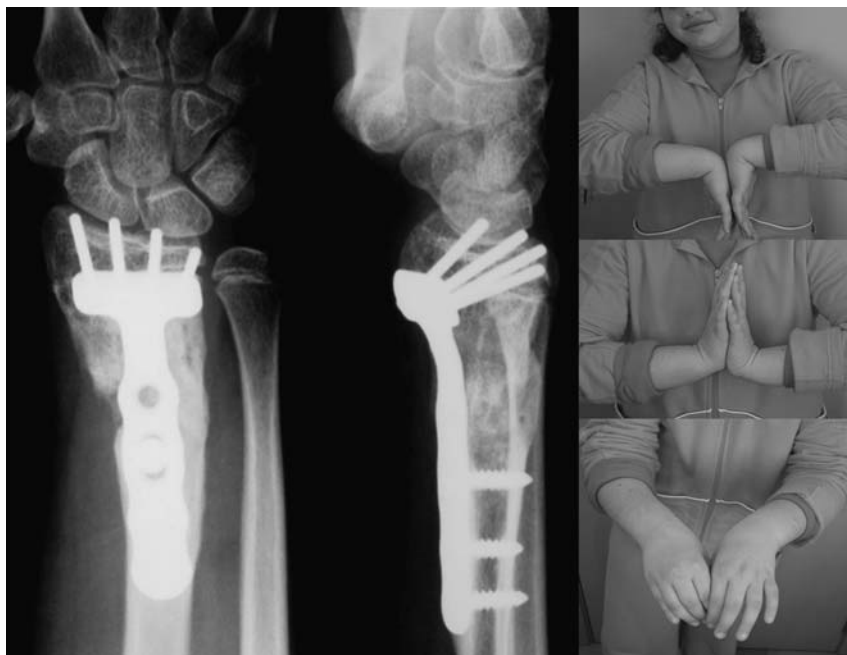


FIGURE 4. Clinical, radiologic, cosmetic, and functional appearance at 24 months of evolution, showing complete mobility recovery and deformity correction.

Severe deformities because of distal radial physal closure have been classically treated by surgical means, without the correction of the normal bone anatomy, by correcting radius, ulna, or both (Fig. 8). There have derotatory, oblique radius osteotomies, zetaplastic-shaped lengthening osteotomies,⁷ or addition osteotomies using iliac crest bone grafting⁸ all been described. Those techniques were originally stated to treat adult deformities, and were stabilized with either the use of Kirschner wires or interfragmentary screws. The correction from the deformity can be achieved by using a ring, Illizarov-type external fixator.⁹ This technique had been earlier proposed as a treatment for case 1 in another service, but was turned down by the girls' parents, as she had previous emotional problems caused by the deformity, which could

become worse with the use of such ostentatious external fixation system. Hence, we decided to offer an internal fixation system option.

Zehntner et al¹⁰ described the treatment of partial physal closure from the distal radius (so-called pseudo-Madelung deformity) using addition osteotomies with iliac crest grafting and dorsal plate fixation on an 8-year-old boy. There has also been described a technique to perform corrections of dorsal radius deformity as a result of distal radius malunion in adults by using an osteotomy performed through the approach.^{4,11,12} After encouraging results in adults, the authors decided to use the technique in children, and to correct severe distal radius deformities in 1 surgical stage, performed with a conventional volar approach or extended to the FCR.



FIGURE 5. Case 2: severe bilateral deformity from both wrists of a 13-year-old boy, after the early physal closure from both distal radii. Despite adequate range of motion, the patient presented pain and left wrist functional disability.

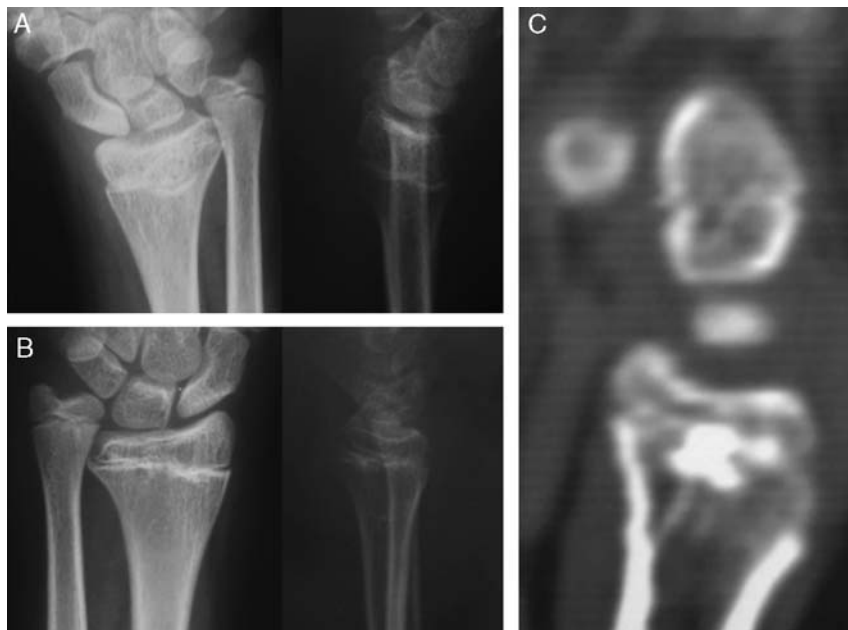


FIGURE 6. Radiologic examination of both wrists: a severe shortening and dorsal angulation of the distal radius, after early physal closure, is appreciated at the left wrist (A). The same findings are observed at the right wrist (B), albeit less severe than those from the contralateral side. Computerized axial tomography scan of the left distal radius confirming the severe epiphysiodesis (C).

The use of radius fixation systems with fixed-angle blocking plates allows the correction to be independent from the size and angulation of cut tricortical grafting, as the length is not maintained by the graft itself, but rather by the plate and screw blocking system. Small bone lengthening and angulation modifications can be thus performed during the intervention. The use of those fixation systems, where distal screws are fixed to the plate, reduce the risk of postoperative bone displacement, and need a shorter immobilization time, thus being specially indicated for the children who feature quick

healing. It is not possible to perform the presented technique with conventional, console-type fixation systems.

Some authors state this type of technique yields between 14 and 20 mm of radius lengthening.^{7,10} However, with the presented technique, the authors have gained up to 30 mm, due to the defect found, with no associated neurovascular conflicts.

Regarding the ulna, there are several treatment options to avoid ulnar overgrowth in respect to the radius, including ulnar shortening osteotomies, partial or total resection (Darrach’s) of the distal ulnar end, or epiphysiodesis with autologous grafting.¹⁰



FIGURE 7. Clinical, radiologic, cosmetic, and functional appearance after 2 years of the surgical procedure. The patient remains with a right wrist deformity, and radiologic ulnar plus at the left wrist. However, as the patient is asymptomatic and practices sports with no problems, we decided to proceed only with clinical follow-up.

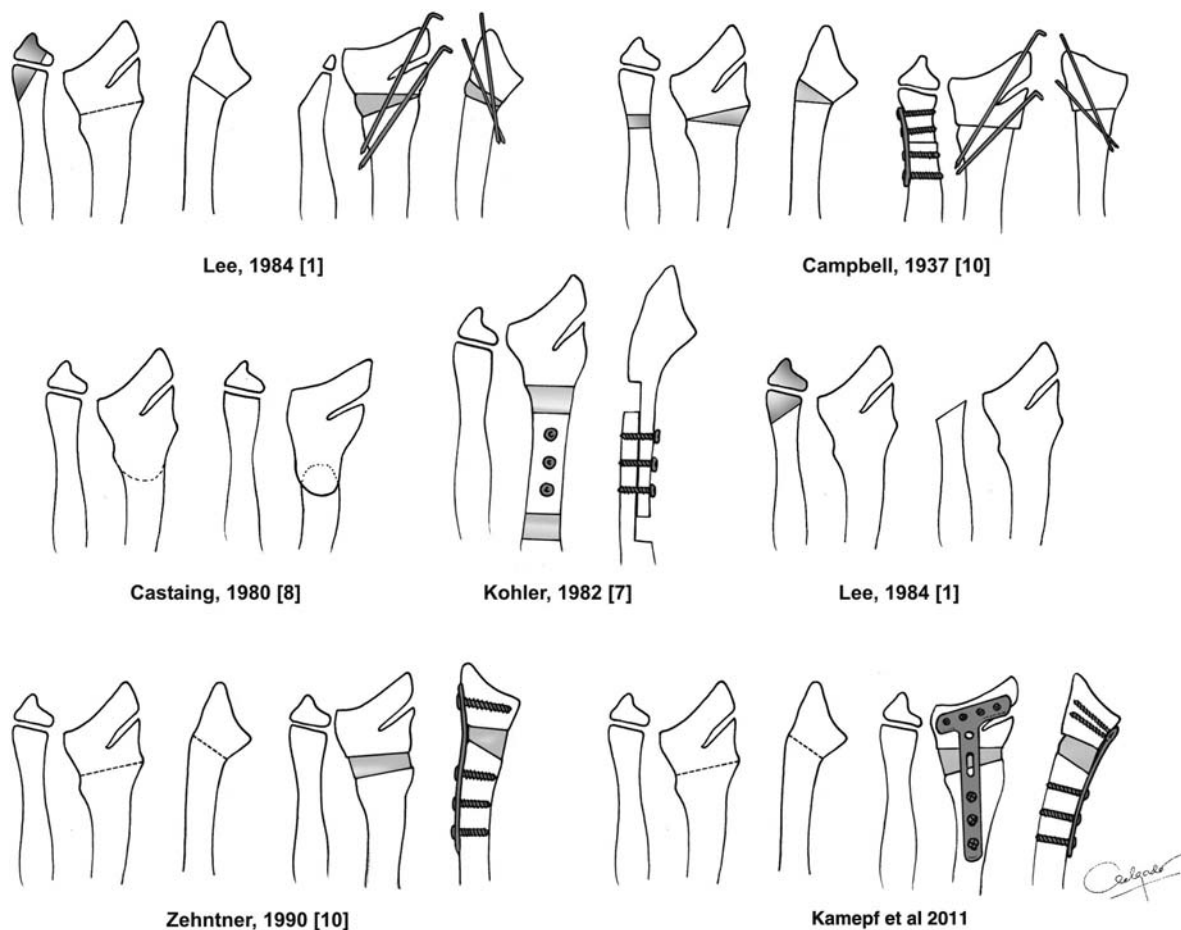


FIGURE 8. Schematics of published techniques for wrist deformity correction after distal radius early epiphysiodesis.

In cases of ulnar shortening,¹ there is a need to associate a closure radius osteotomy, which conditions a forearm shortening that originates length discrepancy between both upper limbs, potential loss of muscle power because of shortening, and possible complications derived from a second fixation system for the ulna, making such technique less than our preference.

The graft of choice comes from the iliac crest. In our experience, we found no advantages with the use of bone surrogates and, conversely to the publication from Arrington et al,¹³ there has been no increased morbidity associated to graft harvest and iliac crest incision.

Nonetheless, the decision of the best surgical technique must be made at an individual basis. Waters et al¹⁴ described the results obtained in the treatment of 32 children with a mean age of 15 years (range: 12 to 20 y), with a deformity after the early closure of the distal radius physis. A number of 13 combinations of different techniques were performed, including procedures of the radius (addition or subtraction osteotomy, and epiphysiodesis), of the ulna (epiphysiodesis, shortening osteotomy, and styloid resection), and distal radioulnar joint (triangular fibrocartilage complex repair). After 21 months of follow-up, the modified Mayo Clinic Wrist score increased preoperatively from 86 points to 98 points after the operation, with a statistically significant improvement in 24 cases that presented symptomatic wrists before the intervention.

Hove and Engesaeter¹⁵ obtained excellent results in 6 patients treated with corrective osteotomies, who presented

complete pain improvement after the intervention, and an active range of motion that corresponded to 96% of the contralateral side.

CONCLUSIONS

We can state that the treatment of distal radius deformities after an early epiphysiodesis in children, by means of lengthening osteotomies through a volar approach and fixation with blocking plate, presented satisfactory outcomes in patients with a severe deformity, such as those presented here. Nonetheless, the evolution in the long run remains uncertain, warranting longer studies with increased number of patients to confirm these results.

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