SCIENTIFIC ARTICLE

Treatment of Madelung Deformity With Vicker Ligament Release and Radial Physiolyses: A Case Series

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Purpose To evaluate the surgical outcomes in a series of Madelung wrists treated with a Vicker ligament release at a young age. We hypothesize that early treatment of Madelung deformity with Vicker ligament release is safe and may minimize progression of deformity.

Methods A retrospective review was performed at a single large pediatric institution from 2013 to 2016 of patients with a diagnosis of Madelung deformity treated with Vicker ligament release and radial physiolysis. Exclusion criteria included patients who were skeletally mature, who underwent osteotomy procedures, or who had incomplete follow-up. Patient demographics were collected, concomitant surgeries were recorded, and outcomes including range of motion and pain were documented. Measurements of standard anteroposterior and lateral radiographs were calculated before and after surgery to monitor radiographic deformity and progression.

Results Six girls with bilateral Madelung deformity who underwent bilateral Vicker ligament resection and radial physiolysis (12 total wrists) were included. The average age at presentation was 7.5 years (range, 7–9 years), with an average follow-up of 30 months. Reasons for presentation included sports injuries (2), ulnar-sided wrist pain (2), and mild deformity (2). Additional radial and ulnar epiphysiodeses were performed in 2 wrists each. There were no intraoperative complications. Although pain resolved within the first month after surgery for all patients, 2 patients had intermittent unilateral ulnar-sided wrist pain at final follow-up. All patients returned to their presurgery activities. There was no loss of range of motion, and 4 wrists with preoperative supination deficits improved by an average of 17°. Radiographic measurements demonstrated improvement in the radial physeal angle in 10 out of 12 wrists (83%). No patients displayed worsening deformity after surgery. Two patients underwent subsequent procedures.

Conclusions In patients with early Madelung deformity, Vicker ligament release with radial physiolysis is a safe treatment option that theoretically has the potential to minimize the progression of radiographic deformity. *(J Hand Surg Am. 2019;44(2):158.e1-e9. Copyright © 2019 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic V.

Key words Madelung deformity, physiolysis, Vicker ligament.

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Madelung deformity is a relatively uncommon condition of the wrist characterized by partial to complete arrest of the volar ulnar distal radial physis.[1] The initial most complete description of the condition was presented by the German surgeon, Otto Wilhelm Madelung in 1878.[2] Although he was not the first to describe the deformity, the condition bears his name because he was the first to fully define the

wrist condition and propose an etiology and treatment.[3]

Madelung deformity is most commonly observed in girls in late childhood or early adolescence and is typically bilateral.[2,4] It can be secondary to haploinsufficiency of the *SHOX* gene, observed as part of Turner syndrome, associated with dyschondrosteosis, a form of mesomelic dysplasia, or may be idiopathic.[5–8] The hereditary form is thought to be inherited as an autosomal dominant trait, with variable expressivity and penetrance.[8]

Characteristic radiographic changes are present in the radius, ulna, and carpus,[9–11] These include increased dorsal and radial bowing of the distal radius, a widened distal radioulnar joint, a triangular arrangement of the carpal bones with lunate subsidence, increased volar tilt of the distal radial articular surface, and an exaggerated ulnar tilt of the distal radius.[3,12] Patients may develop pain, decreased motion (particularly in supination and extension), and instability owing to incongruence of the joint surfaces.[2,13–15] Despite the clinical appearance and loss of mobility, patients usually function with minimal deficit.

The treatment is determined by function, pain, and stage of presentation. Vickers and Nielsen[16] reported on the first case series of Madelung patients who underwent removal or release of the thickened radiolunate ligament (Vicker ligament). The average age of their patients was 12 years, with a range of 11 to 14 years. We present a case series of younger patients with a diagnosis of Madelung deformity treated with Vicker ligament resection and radial physiolysis. We hypothesize that early treatment of Madelung deformity with Vicker ligament release and radial physiolysis is a safe surgery with the potential to reduce deformity.

MATERIALS AND METHODS

After institutional review board approval, a retrospective chart review was performed for all patients at a single institution with a diagnosis of Madelung deformity. The inclusion criteria for patients in this study were skeletally immature patients with a diagnosis of Madelung deformity who underwent a Vicker ligament release and radial physiolysis between the years 2013 and 2016 by 1 of 2 hand fellowship–trained orthopedic surgeons (J.E.P. or J.B.S.) and who had a minimum follow-up of 16 months. Exclusion criteria included skeletal maturity at the time of intervention, patients treated with osteotomy procedures, and patients lost to follow-up or with insufficient follow-up. All patients were evaluated with a thorough history, physical examination, and radiographic imaging. Plain radiographs were obtained on all 12 wrists, and magnetic resonance imaging (MRI) was obtained in 11 of 12 wrists. At each presentation, pain, deformity, and range of motion (ROM) were assessed. Standard anteroposterior and lateral radiographs were obtained before surgery and at final follow-up after surgery. Changes in deformity were measured on radiographs (Fig. 1) according to Vickers and Nielsen.[16]

Operative technique

Under tourniquet control, a volar approach to the wrist was made either just radial to the flexor carpi ulnaris or just ulnar to the flexor carpi radialis, depending on surgeon preference. The pronator quadratus muscle was identified and elevated from the radius in an ulnar direction. The abnormally thickened radiolunate (Vicker) ligament was then identified (Fig. 2). The ligament was resected from proximal to distal. The radial physis was evaluated both with direct visualization as well as with fluoroscopy. A physiolysis was performed at the site of pathology. We were careful not to perform an overly aggressive release of the ulnar side of the distal radial physis because there is potential risk of lunate collapse. Careful fluoroscopic and intraoperative dissection minimizes this complication, which could potentially lead to worsening of the metaphyseal growth disturbance. If an ulnar epiphysiodesis was performed, as was the case in 2 wrists, a direct ulnar approach between the flexor carpi ulnaris and extensor carpi ulnaris was utilized at the level of the physis. Fat graft was obtained in this approach. The fat graft was placed at the site of the radial physiolysis (at the volar ulnar radial physis). Under fluoroscopic guidance, an epiphysiodesis of the ulna was performed utilizing a combination of curettes, K-wires, and a Freer elevator. A short-arm orthosis was applied at the end of the case. Patients were transitioned to casts at the first postoperative visit, for a total of 4 weeks of immobilization to protect the subchondral region after the physiolysis of the radius was performed.

RESULTS

Retrospective review identified 6 patients with bilateral Madelung deformity who underwent Vicker ligament release between January 2013 and June 2016 (Table 1). A total of 10 patients were excluded due to either insufficient follow-up (1 patient with $<$ 1 year follow-up) or advanced age (9 patients aged $\geq$ 15 years). All of the included patients were girls and all presented with asymmetrical but bilateral deformities, for a total of 12 wrists. The average age of

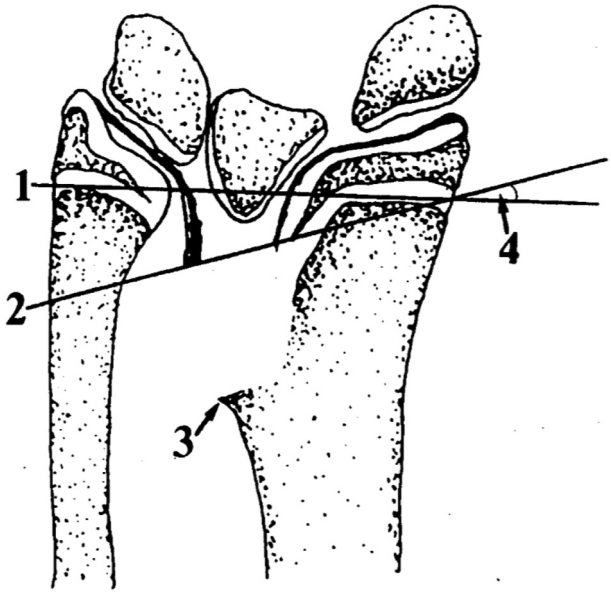

FIGURE 1: Radiographic measurements were utilized to monitor changes in deformity as described by Vickers and Nielsen. The transverse line (1) represents a line perpendicular to the longitudinal axis of the ulna passing through the most radial extent of the radial physis. The physeal line (2) joins the most radial and most ulnar extents of the radial physis. The angle subtended by the transverse line and the physeal line represents the physeal angle (4). The surgical spike (3) is a radiographic feature that allows for measuring metaphyseal growth on follow-up imaging. (Reproduced with permission from Vickers D, Nielsen G. Madelung deformity: surgical prophylaxis [physiolysis] during the late growth period by resection of the dyschondrosteosis lesion. *J Hand Surg Br.* 1992;17[4]:401–407[16]).

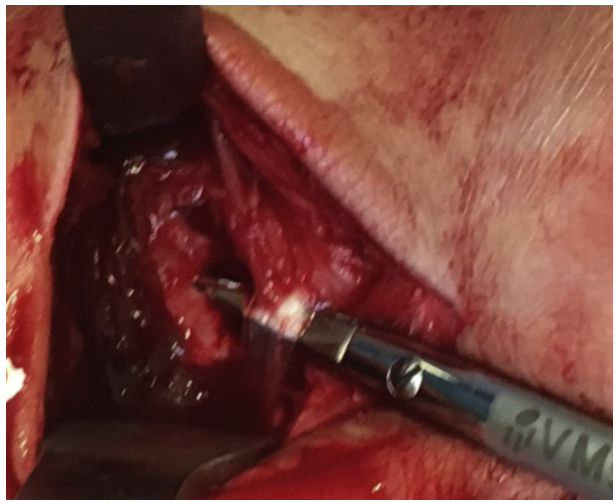

FIGURE 2: Intraoperative clinical photograph of Vicker ligament before release.

presentation was 7.5 years (range, 7–9 years). Pain, deformity, or injury was the presenting feature in all patients. The average follow-up was 30 months (range, 17–51 months). All patients were skeletally immature at the time of surgery. All but 1 case were idiopathic and primary. One patient had a family history of Madelung deformity in her mother and maternal grandmother.

Two patients initially presented after wrist injuries: 1 patient had a unilateral wrist sprain from gymnastics and 1 patient sustained a unilateral distal radius buckle fracture from a trampoline-related incident. Two patients presented initially with complaints of atraumatic ulnar-sided wrist pain: 1 patient with a family history of Madelung who presented with bilateral complaints and 1 with unilateral pain. Two patients initially presented with concerns over clinical deformity: 1 patient with bilateral wrist deformities and 1 patient with a missing knuckle; radiographs revealed a physeal arrest of the fourth metacarpal in addition to Madelung deformity.

All 6 patients underwent bilateral Vicker ligament release and radial physiolysis with fat interposition for a total of 12 wrists (Table 1). Two wrists (both in patient 2) underwent concomitant radial epiphysiodeses and 2 wrists (both in patient 1) underwent concomitant ulnar epiphysiodeses. There were no intraoperative complications. One patient had an early postoperative superficial wound infection on 1 wrist that resolved with local wound care and oral antibiotics. No patient treated with Vicker ligament release, physiolysis, epiphysiodesis, or a combination of these procedures required radial osteotomy or ulnar shortening after the initial procedure within the follow-up period, which averaged 30 months. However, none of the patients are yet fully skeletally mature. Two patients underwent additional surgery at 3 years and at 16 months after the initial procedure, respectively. The first patient, with a family history of Madelung deformity, underwent her initial procedure at age 7, which did not include bilateral ulnar epiphysiodeses (patient 2; Tables 1, 2). At her 3-year follow-up, she was doing very well clinically; however, she was still skeletally immature with open ulnar physes and positive ulnar variance. The recommendation was made for bilateral ulnar epiphysiodeses, which were performed uneventfully just over 3 years from the initial procedure. The second patient that underwent a subsequent procedure was also age 7 at the time of her initial procedure, which only included bilateral Vicker ligament resection and radial physiolysis (patient 6; Tables 1, 2). She remained skeletally immature at her 16-month follow-up, at which time her right wrist had shown an acceptable response to treatment but her left wrist

TABLE 1. Patient Features*

Patient	Sex	Age	Bilateral Deformity	Family History	Presenting Complaint	Initial Surgery	Additional Surgery	Final Follow-Up (mo)
1	Female	9	Yes	No	Injury	VR, RP, UE	None	23
2	Female	7	Yes	Yes	Pain	VR, RP, RE	UE	36
3	Female	8	Yes	No	Pain	VR, RP	None	17
4	Female	7	Yes	No	Injury	VR, RP	None	26
5	Female	7	Yes	No	Deformity	VR, RP	None	51
6	Female	7	Yes	No	Deformity	VR, RP	RE (left only)	24

RE, radial epiphysiodesis; RP, radial physiolysis; UE, ulnar epiphysiodesis; VR, Vicker release.
*Six patients fulfilled the study's inclusion criteria.

TABLE 2. Six Patients Representing 12 Wrists (Left and Right) Were Available for Objective Deformity Monitoring After Surgery Using Radiographic Parameters as Demonstrated in Figure 1

Patient	Wrist	Metaphyseal Growth (mm)	Lunate Advancement (mm)	Initial Angle of Physis (°)	Improvement in Angle of Physis at Final Follow-Up (°)	Preoperative Supination (°)	Postoperative Supination (°)
1	Left	9	−7	9	5	80	80
	Right	9	−4	17	12	80	80
2	Left	8	−2	35	18	80	80
	Right	Static	5	24	20	80	80
3	Left	5	−2	7	5	80	80
	Right	6	−3	11	Static	80	80
4	Left	9	−1	3	Static	80	80
	Right	3	2	22	11	80	80
5	Left	18	−3	12	4	60	70
	Right	1	3	4	3	60	80
6	Left	1	1	29	7	60	80
	Right	8	−4	34	5	60	80

had minimal improvement in the physeal angle. The recommendation was made for a unilateral left radial epiphysiodesis to slow the growth of the radial portion of the distal radius. This was performed uneventfully just over 16 months after the initial procedure.

Pain

All patients reported a reduction in pain within the first month after surgery. This was recorded as a qualitative pain assessment: pain improved or not improved since surgery. Patients were able to resume full activities following surgical recovery without limitation with little or no pain. One patient returned to rock climbing, one to gymnastics, and another to volleyball without pain or limitations. Four of 6 patients reported being pain free at final follow-up. In the 2 patients with pain, it was described as intermittent unilateral ulnar-sided wrist pain that was not activity limiting.

Range of motion

Before surgery, all patients had full flexion, extension, and pronation. The most common ROM deficit before surgery was supination. Four wrists with supination limitation before surgery improved clinically an average of 17° at the final postoperative evaluation (Table 2). Those who had full ROM prior to surgical intervention maintained full ROM at the final postoperative assessment. No patient lost ROM in any direction.

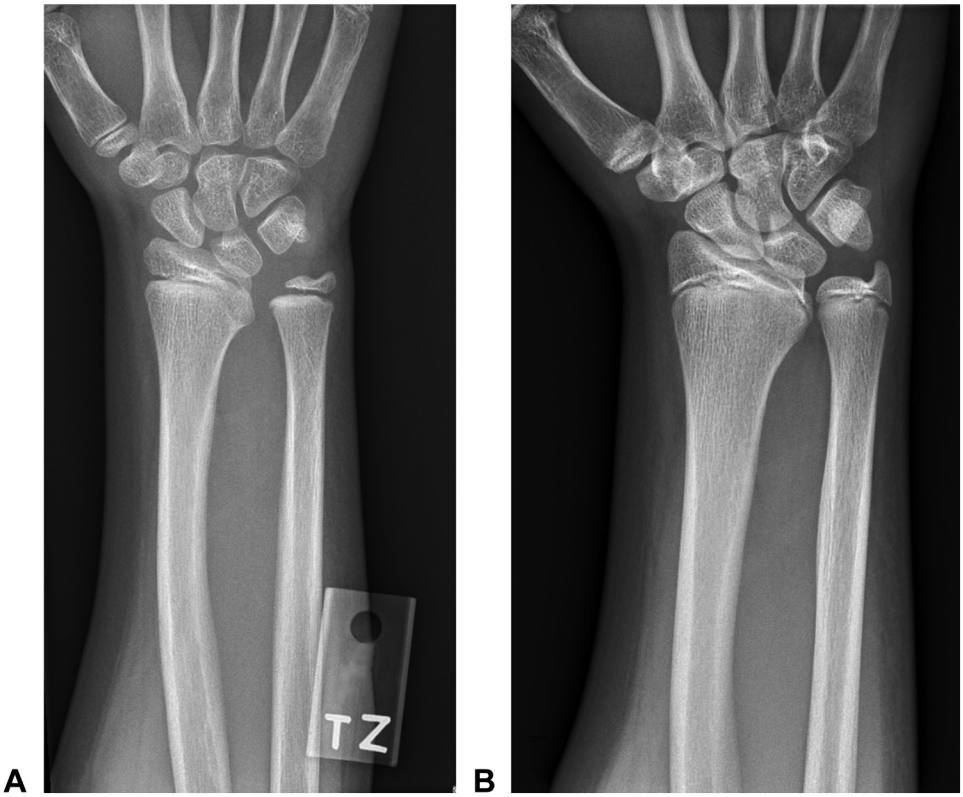

FIGURE 3: A Preoperative radiograph of patient 5 at 7 years of age and **B** follow-up radiograph 4½ years later demonstrate improvement of lunate subsidence and radial physeal angle.

Deformity

No patient displayed worsening deformity following surgery. Pre- and postoperative radiographic measurements were performed (Table 2). Positive metaphyseal growth was seen in 92% of cases. The maximal metaphyseal growth was 18 mm, with a minimum of 0 mm (static growth). Static growth was evident in 1 wrist (patient 2, right wrist), which demonstrated no measurable metaphyseal growth by the final 35-month follow-up. The average growth in the 12 wrists was 6.4 mm. The initial angle of the radial physis was measured before surgery and compared with the final postoperative physeal angle to monitor radiographic deformity. Improvement in deformity, as demonstrated by an improvement of the radial inclination (ie, less radial inclination), was apparent in 10 out of 12 wrists (83%). The physeal angle was unchanged, or remained static, in 2 wrists. No patients demonstrated worsening deformity as represented by the radial physeal angle. The maximum improvement in the physeal angle was 20° with a minimum of 0°, producing an average of 7.5° of improvement. Lunate subsidence had mixed results (Table 2), but some patients demonstrated a more acceptable position of the lunate as demonstrated by positive lunate advancement (Table 2 and Fig. 3).

One case example is seen in Figures 4 and 5. Patient 1 initially presented with a wrist injury, at which time she was diagnosed with bilateral Madelung deformity (patient 1; Tables 1, 2). She presented early enough for a physiolysis procedure to allow some correction of the distal radius pathology. At her latest follow-up, she was completely pain free and she resumed full activities including volleyball, and displayed full ROM.

DISCUSSION

Management of Madelung deformity of the wrist can be a challenging problem, and there is a lack of consensus on treatment. Patients with mild deformities can function quite well without any surgical intervention.[4] More significant deformities, however, can lead to ulnocarpal impingement, limited motion, and pain.[13] Late-stage presentation with radial and ulnar deformities requires a more extensive surgical undertaking and can include corrective radial osteotomies, bone lengthening, distal ulna resection, and ulnar shortening osteotomies.[13,17–20]

FIGURE 4: **A** Anteroposterior and **B** lateral radiographs of patient 1, a 9-year-old girl who presented with a mild clinical deformity and ulnar-sided wrist pain. **C, D** She demonstrated an improvement of 12° in the physeal angle.

We present data on a unique cohort of patients that were diagnosed at a very young age with Madelung disease. Vickers and Nielsen (1992)[16] presented a series of 17 patients treated with prophylactic Vicker ligament resection and radial physiolysis with encouraging results. Our cohort was much younger than theirs, with an average age of 7.5 years (range, 7−9 years) compared with 12 years (range, 11−14 years). Most of the patients presented after injuries and this diagnosis was made incidentally and fortuitously at an earlier age than is customary. We offered a Vicker ligament release and radial physiolysis as soon as we would diagnose these young patients and found this surgery to be minimally intrusive and safe.

The etiology of the physeal arrest in Madelung deformity is unclear, but theories include trauma, malnutrition, infection, vascular insufficiency, disorganized cells, muscular disorders, and a fibrous tether

FIGURE 5: A–D Patient 1 had complete elimination of her pain and demonstrated full range of motion at 23 months after surgery.

of the distal radial epiphysis by Vicker ligament.[16,21,22] The presence of a physeal bar and the anomalous Vicker ligament extending from the distal radius to the lunate, triquetrum, or ulna can be seen on MRI[23] and is present in 91% of cases in adolescent patients with Madelung deformity.[18] Although not necessary for preoperative planning, we did evaluate 11 of the 12 wrists with MRI, and Vicker ligament was present in all 11 wrists, with various trajectories that correlated with the intraoperative findings (Fig. 6).

We found that, after Vicker ligament resection and physiolysis in skeletally immature children with Madelung deformity, there was improvement in pain within the first month in all patients and all patients returned to their presurgery activities. There were 2 patients, however, who continued to have intermittent unilateral ulnar-sided wrist pain, which did not correspond to their radiographic parameters. Range of motion improved or was maintained in all wrists. There was also an improvement in radiographic deformity parameters with improvement in the radial physeal angle in 83% of the cases without worsening deformity in any wrists. This decrease in inclination of the radial physis was seen in the presence of positive radial metaphyseal growth in all but 1 wrist following our surgical intervention. In the absence of a control group, we cannot directly compare expected metaphyseal growth in a Madelung wrist without surgery. Furthermore, there was

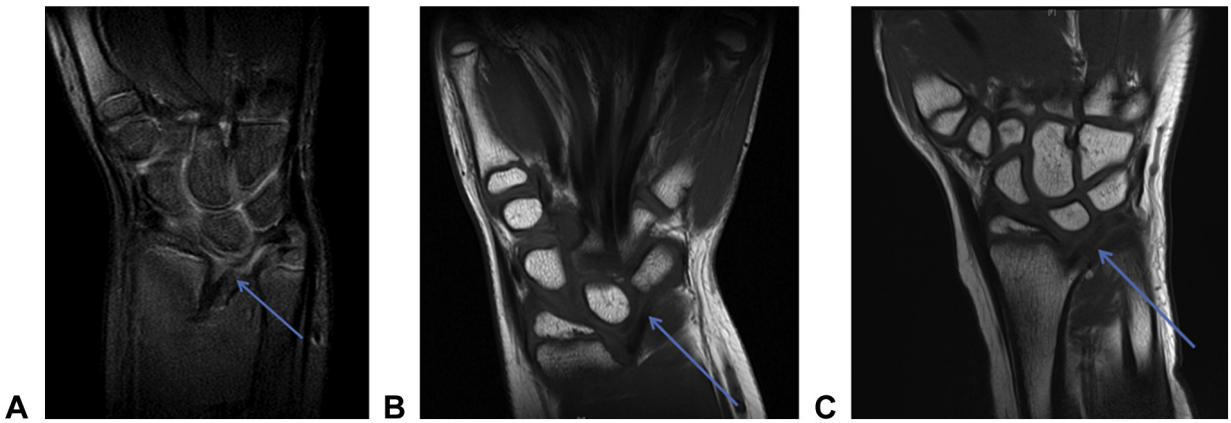

FIGURE 6: Representative MRIs of Vicker ligament. It can be seen in various trajectories: spanning from **A** the radius to the lunate, **B** the radius to the triquetrum, and **C** the radius to the ulna.

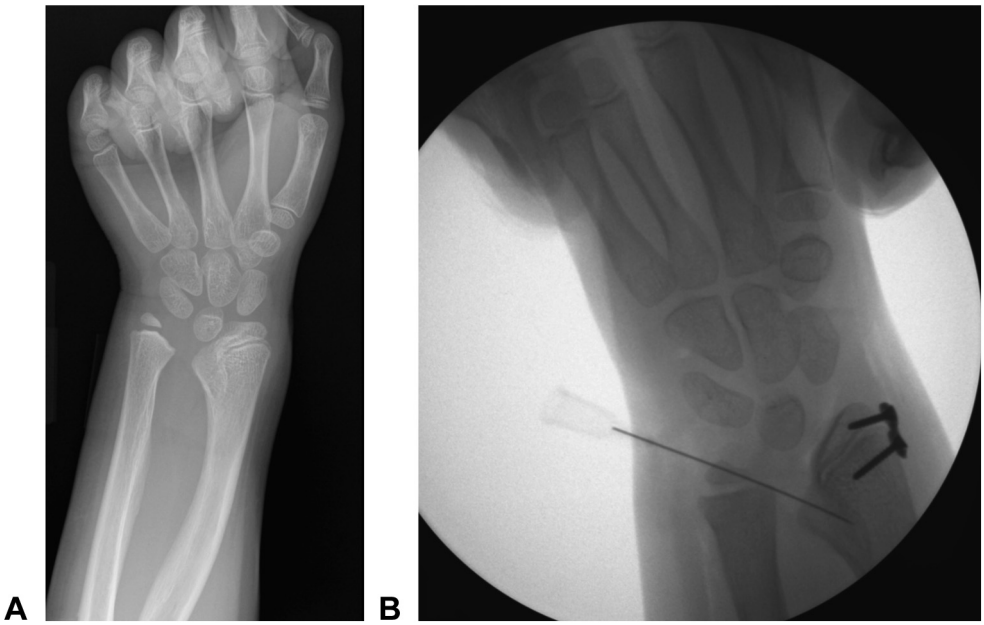

FIGURE 7: **A** Initial anteroposterior radiograph of the left wrist of patient 2, who presented at age 7 already with radial bowing. **B** Owing to her deformity, the decision was made specifically in her case to perform a guided growth procedure (radial-sided radius epiphysiodesis) in addition to the Vicker release and ulnar-sided radial physiolysis.

not consistent improvement of the lunate subsidence. The reason for this is unclear. Although there was a trend of greater initial deformity progressing to greater subsidence, the sample was too small to allow any conclusions in this regard. We can speculate that the physis may not have been sufficiently immature to respond to the ligament resection, or possibly there was an inadequate physiolysis performed.

Although all patients underwent Vicker ligament excision and radial physiolysis, one patient underwent concomitant bilateral ulnar epiphysiodeses and another patient underwent bilateral radial epiphysiodeses. Although we do not have a standard protocol for utilizing these additional procedures, in general, the older the presenting bone age or the greater the deformity, the more aggressive the treatment. Although patient 2 was only 7 years of age when she presented, she already had a fairly impressive radial bow (exceeding 10% of the total length based on the method of Schemitsch and Richards[24]), and therefore, a radial epiphysiodesis was performed in addition to the physiolysis and Vicker ligament resection (Fig. 7). Patient 1 underwent bilateral ulnar epiphysiodeses because she was nearly 10 years old, and this decision was made to prevent the need for an ulnar shortening osteotomy

(USO) in the future. Farr et al[9] recommended that an ulnar epiphysiodesis may be considered in skeletally immature children older than 10 years to prevent recurrent deformity, pain, and need for a USO. Their case series was performed to determine radiographic criteria for undergoing a USO, and no patients who had later required a USO had undergone an ulna epiphysiodesis at the index procedure (radial dome osteotomy). In our series, 2 patients did undergo subsequent surgery: 1 patient underwent bilateral ulnar epiphysiodeses at age 11 and 1 patient underwent a unilateral radial epiphysiodesis at age 10. The goal was to supplement the benefit of the initial procedures in the setting of maintained open physes and potential for deformity progression.

The main limitation of this study is the small sample size. Furthermore, without a nonoperative control group, we cannot know what the natural history would have been had we not intervened early surgically. Although we clearly outline objective radiographic data, we did not include objective clinical outcomes other than ROM and a subjective pain assessment. Finally, 1 patient had limited follow-up of 17 months, narrowing the time to monitor deformity progression. However, even within 17 months, this patient was pain free and had demonstrated improvement in the radial physeal angle in one extremity and no change in the other extremity.

In this small case series of skeletally immature patients with Madelung deformity, Vicker ligament excision was a safe option that theoretically has the potential to minimize the progression of radiographic deformity. However, it remains impossible to know what the natural history might be without this procedure, and therefore, we recommend a thorough discussion with patients and their families about the shortcomings of this option before proceeding.

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