ORIGINAL ARTICLE

Long-term Outcomes Following Vickers Ligament Release and Growth Modulation for the Treatment of Madelung Deformity

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Background: Madelung deformity arises from a partial distal radial growth disturbance in combination with an abnormal hypertrophic ligament spanning the volar radius and carpus, termed, the Vickers ligament. The purpose of this study is to report long-term clinical and radiographic outcomes following Vickers ligament release and distal radial physiolysis in a population of skeletally immature patients with symptomatic Madelung deformity.

Methods: Medical records were retrospectively reviewed of patients with Madelung deformity surgically treated between 1994 and 2005. All eligible patients who underwent a Vickers ligament release and distal radial physiolysis were contacted and invited to return to the clinic for follow-up.

Results: Six patients (8 wrists) with Madelung deformity underwent Vickers ligament release and distal radial physiolysis. All were white females with a mean age at initial presentation of 11.4 years (10 to 12.8 y). Mean age at the time of initial surgery was 12.0 years (10.0 to 14.5 y). The median follow-up time was 10.6 years (5.8 to 21.9 y) and the average age at last follow-up was 23.1 years (17.5 to 32.2 y). Pain alone or in combination with concerns for deformity was the chief complaint in 6 of 8 of the wrists. At 1 year of clinical follow-up, 7 of 8 wrists were reported to be pain-free, and 6 of the 8 were noted to be completely pain-free at last follow-up. Motion in flexion, extension, pronation, supination, radial, or ulnar deviation was similar between the preoperative status and long-term follow-up. The average preoperative ulnar tilt was 35.1 degrees (SD: 8.5 degrees), average preoperative lunate subsidence was 1.9 degrees (SD: 1.8 degrees), and average preoperative palmar carpal displacement was 21.9 degrees (SD: 2.9 degrees). At the final follow-up, there was a large progression in lunate subsidence, but minimal change in ulnar tilt and palmar carpal displacement. At last clinical follow-up, 2 of the 6 patients had undergone a subsequent procedure including 1 radial dome osteotomy and 1 ulnar shortening osteotomy.

Conclusion: In the skeletally immature patient population with Madelung deformity with growth potential remaining, distal radial physiolysis and Vickers ligament release is associated with relief of pain, preservation of motion, and, a reasonable rate of reoperation.

Type of Study: This was a therapeutic study.

Level of Evidence: Level II.

Key Words: Madelung, growth modulation, pediatric orthopaedics, Vickers ligament release

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Described by the German surgeon Otto Madelung in 1878, Madelung deformity is characterized by radial bowing, ulnar head prominence, and volar carpal subsidence.[1] The deformity arises from the combination of a partial distal radial physeal arrest and an abnormal hypertrophic ligament spanning the volar radius to the carpus. This anomalous ligament, termed the Vickers ligament, prevents volar distal radial growth through both a tethering and a compressive effect on the affected physis.[2] A similar wrist deformity can be seen in the setting of trauma or infection, but it is the presence of the Vickers ligament that defines the true Madelung deformity.

The deformity typically presents bilaterally and has a female predominance.[3] It is often seen in association with genetic conditions, most frequently, Leri-Weill dyschondrosteosis. If a patient becomes symptomatic, it is typically during their period of peak skeletal growth and they present with complaints of wrist pain, cosmetic deformity, or loss of mobility. Treatment depends on the patient's age and severity of the deformity. By the time most patients present to a surgeon they have little growth potential remaining and thus surgery is directed at correcting the existing deformity via corrective osteotomy of the radius and/or ulnar shortening osteotomies. Infrequently, a patient will present with growth potential remaining and it has been postulated that performing a distal radial physiolysis and Vickers

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FIGURE 1. Radiographic parameters. A, Ulnar tilt (posteroanterior x-ray) is measured as the complement of the angle formed by the longitudinal axis of the ulna and the proximal surface of the scaphoid and lunate. B, Lunate subsidence (posteroanterior x-ray) is measured as the distance (mm) between the proximal surface of the lunate and a line through the distal articular surface of the ulna perpendicular to its longitudinal axis. C, Palmar carpal displacement (lateral x-ray) is measured as the distance (mm) between the most volar aspect of the lunate or capitate and the longitudinal axis of the ulnar.

ligament release will prevent the need for future radial and ulnar osteotomies.

In 1992, Vickers and Nielsen[2] reported encouraging results after distal radial physiolysis and Vickers ligament release in a skeletally immature patient population. In addition, in 2018, Otte et al[4] published positive results in 6 patients undergoing this procedure on bilateral wrists. To the best of our knowledge, these are the only published literature detailing the results of this procedure. Therefore, the purpose of this study was to report long-term clinical and radiographic outcomes following Vickers ligament release and distal radial physiolysis in a sample of skeletally immature patients with symptomatic Madelung deformity.

METHODS

After obtaining Institutional Review Board approval, a retrospective review of medical records and radiographs was performed for all patients with Madelung deformity surgically treated at a tertiary institution between the dates of January 1, 1994, to December 31, 2005. The inclusion criteria were skeletally immature patients with growth potential remaining, as evidenced by open physes, and a diagnosis of Madelung deformity who underwent distal radial growth modulation and release of the Vickers ligament. Subjects were excluded if the deformity was acquired secondary to trauma or infection or if they lacked sufficient clinical or radiographic follow-up. All eligible patients were contacted by research staff and invited to return to the clinic for the recording of clinical details, range of motion measurements, and radiographs.

Medical records review was conducted for all eligible patients and included demographic information, clinical examination findings, radiographic studies, and surgical details. The range of motion data was collected using a goniometer. The radiographic assessment included a posteroanterior and lateral view of the wrist or forearm. The severity of the deformity was characterized using ulnar tilt, lunate subsidence, and palmar carpal displacement as seen in Figure 1.[5,6] Measurements were made on Synapse PACS software (FUJIFILM Medical Systems USA Inc., Stamford, CT). Preoperatively the radiographs obtained closest to the surgical date were used for assessment. Postoperatively, the posteroanterior and lateral radiograph closest to their 1-year follow-up as well as the last clinical visit were used for assessment.

All patients underwent a Vickers ligament release and distal radial physiolysis by 1 of 2 pediatric orthopaedic hand surgeons. The typical technique included a volar longitudinal approach with dissection to the distal radius. The pronator quadratus was reflected from its radial origin. The Vickers ligament was reflected from its origin distally and the abnormal distal radial ulnar physis was resected until normal physis was encountered. Local fat was then placed into the defect and the incision was closed and the patient placed into a long-arm cast.

Given the small sample size, no statistical analysis was performed. We presented scatterplots with means to describe measurements at different timepoints.

RESULTS

A total of 6 patients with 8 wrists and Madelung deformity met inclusion criteria and were treated at our

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institution with Vickers ligament release and distal radial physiolysis. One patient had been excluded due to insufficient clinical documentation. All patients were white females and had a mean age at initial presentation of 11.4 years (range: 10 to 12.8 y). Bilateral wrist involvement was seen in 4 of the 6 patients, 2 of whom had a surgical intervention on both wrists. Two of the 6 patients had the deformity in association with Leri-Weill syndrome and 1 of these patients with Leri-Weill syndrome had a surgical intervention on both wrists. Three of the 6 patients had a family member with Madelung deformity.

The pain was the chief complaint in 4 of the 8 wrists and was located at the distal ulna in all of these patients. The average duration of pain before the presentation was 5 months. The deformity was the chief complaint in 2 of the 8 wrists and was characterized as ulnar prominence in both patients. Two patients presented with a chief complaint of both pain and deformity. The mean age at the time of the initial surgery was 12.0 years (range: 10.0 to 14.5 y). The median follow-up time was 10.6 years (range: 5.8 to 21.9 y) and the average age at last follow-up was 23.1 years (range: 17.5 to 32.2 y).

Clinical details were reviewed for all patients. In regard to pain, 7 of the 8 wrists were reported to be pain-free at 1 year of clinical follow-up. Four of 8 had complete resolution by 3 months postoperatively. At last follow-up, 6 of the 8 wrists were noted to be completely pain-free. The 2 with pain rated it as occasional, 1 after prolonged typing and 1 after prolonged writing.

The average wrist range of motion was documented before surgical correction and at subsequent postoperative visits. Motion in flexion, extension, pronation, supination, radial or ulnar deviation was similar between the preoperative status and long-term follow-up (Supplemental Fig. 1, Supplemental Digital Content 1, http://links.lww.com/BPO/A265).

Follow-up radiographs were available for all patients. The average time from the preoperative radiograph until the surgery was 7 months. The average 1-year postoperative radiograph was taken at 15 months. The average preoperative ulnar tilt was 35.1 degrees (SD: 8.5 degrees), average preoperative lunate subsidence was 1.9 degrees (SD: 1.8 degrees), and average preoperative palmar carpal displacement was 21.9 degrees (SD: 2.9 degrees). At the final follow-up, there was a progression in lunate subsidence but only minimal changes were seen in ulnar tilt and palmar carpal displacement. Figure 2 shows preoperative radiographs and postoperative radiographs nearly 6 years later of our patient who demonstrated the greatest increase in lunate subsidence. Supplemental Figure 2 (Supplemental Digital Content 1, http://links.lww.com/BPO/A265) shows similar radiographs in a patient who demonstrated minimal progression in lunate subsidence. Preoperative, 1-year postoperative, and long-term follow-up values for radiographic parameters can be seen in Figure 3.

FIGURE 2. Increased lunate subsidence. Patient #2: Age at surgery 11+11. A, Preoperative lunate subsidence (posteroanterior x-ray). B, Postoperative (6 y later) lunate subsidence (posteroanterior x-ray).

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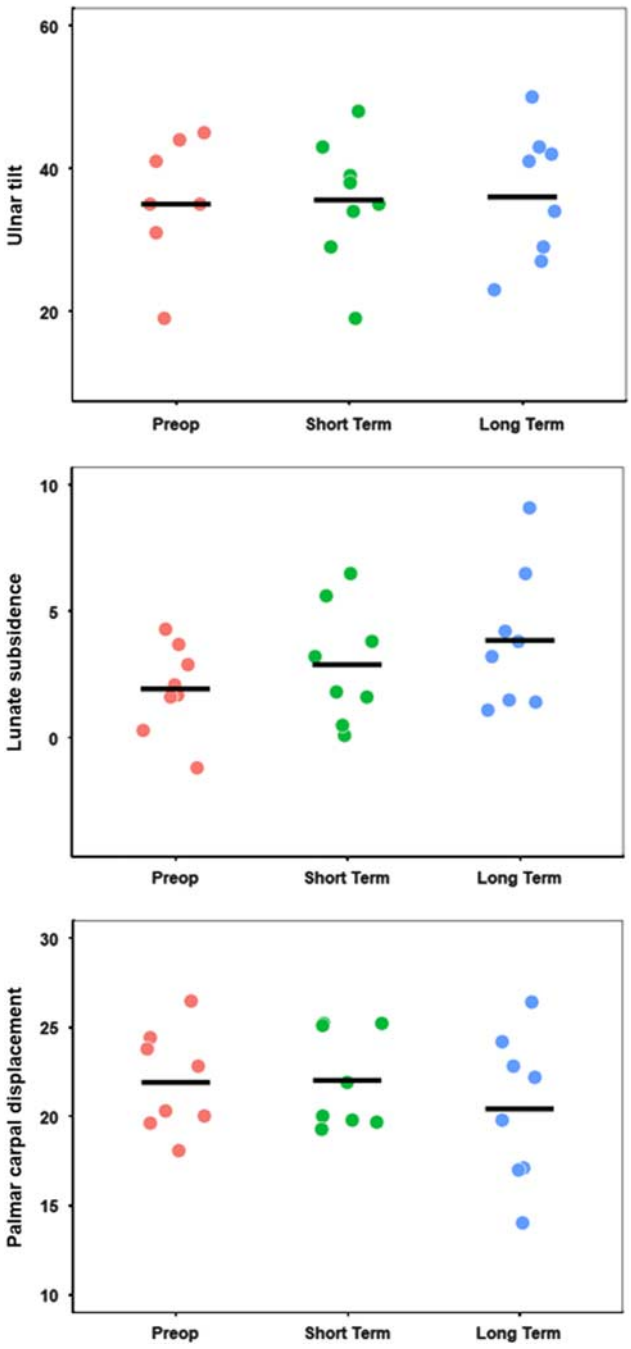

FIGURE 3. Radiographic parameters. Pink: preoperative posteroanterior/lateral radiographic data. Green: 1-year postoperative posteroanterior/lateral radiographic data. Blue: last clinical follow-up posteroanterior/lateral radiographic data. Black bars: average value.

At the last clinical follow-up, 2 of the 6 patients had undergone a subsequent procedure including one of the patients with Leri-Weill syndrome. One patient began developing daily unremitting pain along her wrist 35 months postoperatively. Radiographs showed increases in ulnar tilt, lunate subsidence, and palmar carpal displacement. The patient elected to undergo a radial dome osteotomy 39 months after the initial procedure. Another patient developed ulnar-sided pain wrist pain ~12 years postoperatively and elected to undergo an ulnar shortening osteotomy performed 14 years after the index procedure. The ulnar-sided wrist pain resolved after undergoing the ulnar shortening osteotomy. A summary of patients' age at presentation, initial surgery, and subsequent procedure can be seen in Table 1.

DISCUSSION

Madelung deformity remains a perplexing problem with a variety of treatment options available. As most patients present at or very near to skeletal maturity, surgery is usually directed at correcting the existing deformity. Long-term outcomes data is scarce but a few studies have shown positive results after corrective osteotomies. Steinman and colleagues published their long-term results after distal radial dome osteotomy and Vickers ligament release. At an average follow-up of 11 years, they reported no loss in average wrist range of motion from initial postoperative to last clinical visit. In addition, they reported no difference in radial inclination and patient-reported functional outcome scores [Disabilities of the Arm, Shoulder, and Hand (DASH)] were equivalent to normative data.[7] The literature is even scarcer regarding the treatment of patients who present with symptomatic Madelung deformity with growth potential remaining.

Vickers and Nielsen advocated for distal radial physiolysis and Vickers ligament release to treat patients with symptomatic Madelung deformity and remaining growth potential. Recently, Otte et al[4] performed a retrospective review of 6 patients (12 wrists) with a mean age of presentation of 7.5 years, who underwent this procedure. Given these studies are the only published literature on this procedure, it is important to directly compare our results. Pain is one of the most common presenting complaints and a common indication for operation in patients with Madelung deformity.[3,8–11] Vickers and Nielsen reported 14 of 17 (82%) of their patients requested surgery mainly for pain. Otte and colleagues found that 4 of 6 of their patients presented with pain, 2 resulting from sports injuries, and 2 presenting with atraumatic etiologies. In our series, 6 of 8 patients listed pain as one of their chief complaints. Regarding short-term outcomes, Vickers and Nielsen reported a substantial reduction of pain in all their patients within the first 6 months of surgery. Otte and colleagues reported that within 1 month postoperatively, all patients had a reduction in pain. Our cohort found 7 of 8 operatively treated wrists had no complaints of pain at 1-year follow-up. Of the 15 wrists available for longer term analysis by Vickers and Nielsen, 4 were reported to be "totally pain-free and able to do all physical activities." Otte and colleagues found that, at an average follow-up time of 30 months, 4 of 6 patients were pain-free. Our study found that at long-term follow-up 6 of 8 of our wrists were pain-free, while 2 rated their pain as occasional. However, our long-term pain results need to be interpreted with the understanding that before the final follow-up, 2 of our patients required additional procedures secondary to pain. The etiology of the pain relief after distal radial physiolysis and Vickers ligament release is likely multifactorial. One possible

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TABLE 1. Patient Ages and Subsequent Surgeries

Patient and Laterality	Leri-Weill Syndrome	Age at Presentation (Years+Months)	Age at Surgery (Years+Months)	Age at Subsequent Procedures (Years+Months)	Subsequent Procedure
1—Right	Yes	12+9	14+6		
2—Right		11+8	11+11		
3—Right		11+0	11+11	25+11	Ulnar shortening osteotomy
3—Left		11+0	11+11		
4—Left		11+8	11+10		
5—Right		10+0	10+0		
6—Right	Yes	11+1	12+4	15+7	Radial dome osteotomy
6—Left	Yes	11+1	11+7		

explanation is the restoration of more normal carpal mechanics following the surgical procedure. It is also reasonable to postulate that, as our radiographic variables did not greatly improve, the pain relief may arise from the release of the Vickers ligament which might cause a compressive and possibly a painful effect on the distal radial physis. In addition, a majority of our population had relief of pain within the first 3 to 6 months postoperatively. This seems to support the notion of the Vickers tether as the etiology of the pain as the effects of the physiolysis are likely to require many months of bony growth before improvement in deformity and relief of pain.

Regarding the range of motion, none of our patients experienced a great loss of range of motion in any plane from preoperative to long-term follow-up. Otte and colleagues also reported no postoperative range of motion loss in any direction in their cohort. Vickers and Nielsen reported a net overall gain in the range of motion from preoperative to postoperative. Interestingly, our cohort showed improvement across all ranges of motion at 1-year follow-up, however, the initial improvement in range of motion present at 1 year was not sustained at long-term follow-up. Vickers and Nielsen reported similar findings with some patients losing the motion by the last follow-up, that they had initially gained postoperatively. These findings may be related to the early relief of pain, but further studies are needed to clarify these results.

Madelung deformity presents along a spectrum and can be isolated to the distal radius or involve the entire radius.[12] Different radiographic measurements have been used over time to study this deformity. Otte and colleagues and Vickers and Nielsen quantified deformity based on metaphyseal growth, lunate advancement, and improvement in the angle of the physis. Our study focused on ulnar tilt, lunate subsidence, and palmar carpal displacement as detailed by McCarroll et al[5] in 2005 to quantify the severity of the deformity. The distal deformity can, in part, be attributed to the Vickers ligament. By releasing this tethering, the carpus can assume a more anatomical position relative to the distal radius. Although likely not a material difference, our results did note a decrease in palmar carpal displacement from a mean preoperative of 22 mm to a mean long-term postoperative of 20 mm. Interestingly, our lunate subsidence showed a substantial increase from 1.9 to 3.9 cm at the last follow-up. Otte and colleagues noted in their study that no patient displayed worsening deformity postoperatively. They did note however their measured lunate advancement had mixed results. This prevention of progression may be accounted for by the younger average patient age of Otte's population. Vickers and Nielsen also noted that overall no patient had progression of deformity after surgery. The lack of significant deformity improvement, or the worsening in the case of our lunate subsidence, may be explained by the damaging effect of chronic compression on the physis along with the few years of growth potential remaining that this patient population has to correct their deformity.

Vickers ligament release and distal radial physiolysis is a relatively minor intervention compared with the more extensive radial and ulnar osteotomies frequently used to treat this condition in older patients. An important parameter of success is the ability of this surgery to prevent the need for these more invasive corrective osteotomies. Two of 6 patients required additional surgery: 1 patient required a radial dome osteotomy at long-term follow-up and 1 patient required an ulnar shortening osteotomy. Vickers and Nielsen reported that none of their patients with initially mild deformity needed a radial corrective osteotomy or ulnar shortening osteotomy. Otte and colleagues reported that 2 patients underwent subsequent surgeries, 1 patient required bilateral ulnar epiphysiodesis and 1 patient underwent unilateral radial epiphysiodesis. Farr and colleagues recently performed a retrospective review of 41 wrists focusing on the association of age and severity of deformity with the need for future ulnar shortening osteotomies. They emphasized the importance of understanding the impact of ulnar length and radioulnar incongruity on the development of pain. Their results led them to recommend considering an ulnar epiphysiodesis in the skeletally immature patient aged 10 to 14 years.[9] None of our patients received an ulnar epiphysiodesis at the index operation, however, it is reasonable to postulate that performing this procedure could have mitigated the need for the ulnar shortening osteotomy required in the 1 patient in our cohort who developed ulnar-sided wrist pain.

There are several limitations to our study. First, we have a small patient sample given the infrequency at which this population presents with skeletal growth remaining. Second, our average age of 12 years at the time of surgery

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limits the growth potential remaining of the distal radial physis. Given that these patients are nearing skeletal maturity it is reasonable to question whether surgery affords the opportunity to change the natural progression of the disease. Third, there is a lack of literature detailing the natural history of Madelung progression and it is possible that symptoms may resolve spontaneously after skeletal maturity. Along these lines, it is also possible that postoperative pain relief may be attributed to a placebo effect of surgery given there was no nonoperative control group to compare our results. Fourth, Madelung deformity is a complex 3-dimensional deformity and there is a risk of the measurement error based on the use of standard radiographic technique and projections. Last, no functional outcome data were collected on this population which would further clarify patient response to treatment.

Treatment of Madelung deformity requires a thorough understanding of the complex nature of this condition. The goals of treatment are to relieve pain, preserve motion, and to improve esthetic appearance. Surgeons must consider the patients' age and growth potential remaining when deciding on treatment. We feel that in the skeletally immature patient population with Madelung deformity and growth potential remaining, distal radial physiolysis and Vickers ligament release will help relieve pain and preserve the range of motion with a reasonable rate of reoperations.[13–19]

REFERENCES

1. Arora AS, Chung KC, Otto W. Madelung and the recognition of Madelung's deformity. *J Hand Surg Am*. 2006;31:177–182.
2. 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;17:401–407.
3. Nielsen JB. Madelung's deformity. A follow-up study of 26 cases and a review of the literature. *Acta Orthop Scand*. 1977;48:379–384.
4. Otte JE, Popp JE, Samora JB. Treatment of Madelung deformity with Vicker Ligament release and radial physiolyses: a case series. *J Hand Surg Am*. 2019;44:158.e1–158.e9.
5. McCarroll HR Jr, James MA, Newmeyer WL III, et al. Madelung's deformity: quantitative assessment of x-ray deformity. *J Hand Surg Am*. 2005;30:1211–1220.
6. Farr S, Bae DS. Inter- and intrarater reliability of ulna variance versus lunate subsidence measurements in Madelung deformity. *J Hand Surg Am*. 2015;40:62.e1–66.e1.
7. Steinman S, Oishi S, Mills J, et al. Volar ligament release and distal radial dome osteotomy for the correction of Madelung deformity: long-term follow-up. *J Bone Joint Surg Am*. 2013;95:1198–1204.
8. Schmidt-Rohlfing B, Schwobel B, Pauschert R, et al. Madelung deformity: clinical features, therapy and results. *J Pediatr Orthop B*. 2001;10:344–348.
9. Farr S, Kalish LA, Bae DS, et al. Radiographic criteria for undergoing an ulnar shortening osteotomy in Madelung deformity: a long-term experience from a single institution. *J Pediatr Orthop*. 2016;36:310–315.
10. Laffosse JM, Abid A, Accadbled F, et al. Surgical correction of Madelung's deformity by combined corrective radioulnar osteotomy: 14 cases with four-year minimum follow-up. *Int Orthop*. 2009;33:1655–1661.
11. Harley BJ, Brown C, Cummings K, et al. Volar ligament release and distal radius dome osteotomy for correction of Madelung's deformity. *J Hand Surg Am*. 2006;31:1499–1506.
12. Zebala LP, Manske PR, Goldfarb CA. Madelung's deformity: a spectrum of presentation. *J Hand Surg Am*. 2007;32:1393–1401.
13. Carter PR, Ezaki M. Madelung's deformity. Surgical correction through the anterior approach. *Hand Clin*. 2000;16:713–721; x–xi.
14. Harley BJ, Carter PR, Ezaki M. Volar surgical correction of Madelung's deformity. *Tech Hand Up Extrem Surg*. 2002;6:30–35.
15. Huguet S, Leheup B, Aslan M, et al. Radiological and clinical analysis of Madelung's deformity in children. *Orthop Traumatol Surg Res*. 2014;100(suppl):S349–S352.
16. McCarroll HR, James MA, Newmeyer WL III, et al. Madelung's deformity: quantitative radiographic comparison with normal wrists. *J Hand Surg Eur Vol*. 2008;33:632–635.
17. McCarroll HR Jr, James MA, Newmeyer WL III, et al. Madelung's deformity: diagnostic thresholds of radiographic measurements. *J Hand Surg Am*. 2010;35:807–812.
18. Salon A, Serra M, Pouliquen JC. Long-term follow-up of surgical correction of Madelung's deformity with conservation of the distal radioulnar joint in teenagers. *J Hand Surg Br*. 2000;25:22–25.
19. Stehling C, Langer M, Nassenstein I, et al. High resolution 3.0 Tesla MR imaging findings in patients with bilateral Madelung's deformity. *Surg Radiol Anat*. 2009;31:551–557.

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