Surgical correction of Madelung's deformity by combined corrective radioulnar osteotomy: 14 cases with four-year minimum follow-up

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Abstract Fourteen wrists in 11 girls, mean age 13.3 years (range 9–16) at surgery, were treated for Madelung's deformity. The presenting complaint was incapacitating pain. All were treated by radial closing wedge osteotomy and ulnar shortening osteotomy. The dorsal retinaculum was also surgically repaired in six cases. At a mean follow-up of 5.1 years (range 4–8.75), we observed improved range of motion in both flexion/extension and pronation/supination and absence of pain during daily activity. Radiographically, positioning of the distal radial articular surface and lunate subsidence were improved. Union was obtained after all osteotomies without secondary procedures. Posterior displacement of the ulnar head persisted in two wrists. Combined radioulnar osteotomy restored the anatomy to as near normal as possible. This technique provides satisfactory and encouraging results and does not compromise the surgical future of the wrist. However, longer follow-up is required to assess recurrence or possible long-term degenerative consequences.

Resumé Quatorze poignets chez 11 filles d'âge moyen 13,3 ans (9–16) à la chirurgie, ont été traités pour une

déformation de Madelung. La douleur était la plainte principale. Tous les patients ont bénéficié d'une ostéotomie cunéiforme radiale de fermeture associée à un raccourcissement de l'ulna. Une plastie du retinaculum dorsal a été associée dans 6 cas. Au recul moyen de 5,1 ans (4–8,75), nous avons observé une amélioration des amplitudes articulaires aussi bien en flexion/extension qu'en pronation/supination avec absence de douleur lors des activités quotidiennes. Radiographiquement, l'orientation de la glène radiale ainsi que la subsidence du lunatum ont été améliorées. Toutes les ostéotomies ont consolidé en première intention dans des délais normaux. Un déplacement postérieur de la tête ulnaire persistait dans 2 cas. L'ostéotomie combinée radio-ulnaire permet de restaurer une anatomie le plus proche de la normale. Cette technique offre des resultants satisfaisants et encourageants et ne compromet pas le devenir chirurgical de ces poignets. Cependant, des études avec un plus long recul sont nécessaires afin de rechercher d'éventuelles récidives ou de possibles conséquences dégénératives à plus long terme.

Introduction

Madelung's deformity of the wrist is caused by premature partial closure of the ventromedial part of the distal growth plate of the radius. The frequency is estimated at 1.7% of wrist deformities [9] with a sex-ratio of four girls to one boy. The diagnosis is made during periods of bone growth; the deformity is frequently bilateral but asymmetrical [10]. The aetiology is unknown but Madelung's deformity can be encountered in a variety of contexts [4, 8, 10, 13, 20, 22]. Volar and medial epiphysiodesis of the distal radius causes exaggerated inclination and forward tilt of the articular

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surface and a shortened, bowed radius. The ulna appears rectilinear and comparatively longer, with ulnolunar impingement. The forward tilt of the radius combined with posterior displacement of the ulna produces anterior displacement of the wrist. These deformities lead to pain in the ulnar compartment and decreased grip strength and range of movement [14]. In the long term, impingement and instability lead to the onset of radiocarpal arthrosis [18].

The treatment for Madelung's deformity is surgical. Several techniques have been described. Conservative surgical treatment aims to correct the position of the distal radial articular surface and to restore satisfactory radial and ulnar anatomy. However, there are, as yet, not enough reports [3, 7, 11, 16, 18, 19] to allow assessment of the outcomes of the various surgical techniques proposed.

We report our clinical and radiographic results in a continuous, consistent, single-centre series of patients all treated by combined osteotomy consisting of metaphyseal closing wedge osteotomy of the radius and ulnar shortening osteotomy, combined with realignment of the dorsal extensor retinaculum. Minimum follow-up was four years.

Materials and methods

The research protocol was approved by the local ethical committee. Clinical and radiological data were collected prospectively during the preoperative and postoperative period until the last follow-up. All 11 patients (14 wrists) operated upon for Madelung's deformity were female. In two of the patients (three wrists), the deformity was associated with dyschondrosteosis of the Leri-Weill type. Nine patients presented a bilateral form and two patients a unilateral form. Three patients had operations on both wrists. In seven cases, the procedure involved the dominant wrist. Madelung's deformity was symptomatic in all cases. Surgery was motivated by permanent pain or pain during minimal everyday activity, affecting the ulnar side of the wrist or occurring during dorsal flexion. Mean age at the time of surgery was 13.3 years (range 9–16). Mean clinical follow-up was 5.1 years (range 4–8.75). Range of movement (pronation/supination, flexion/extension) was measured in a standard fashion preoperatively and at the last follow-up after hardware removal. Anatomical results were evaluated by comparing anteroposterior and lateral radiographs of the treated wrist taken before the procedure and at follow-up (Figs. 1–4). Radial inclination was measured according to Harley et al. [11] on anteroposterior radiographs and compared with the axis of the ulnar diaphysis (Fig. 5). Forward tilt of the distal radial articular surface and volar displacement of the wrist were compared with the axis of the ulnar diaphysis on lateral radiographs (Fig. 6),

Fig. 1 Preoperative anteroposterior view

and lunate subsidence was measured on anteroposterior radiographs as described by McCarroll et al. [15] (Fig. 7). The angle of the lunate fossa was not assessed as this measurement is not reproducible [15].

Surgical technique

The procedure was carried out using an upper-arm tourniquet. It consisted of metaphyseal osteotomy using the dorsal radial approach to reposition the distal radial articular surface closed with a posterolateral wedge, combined with ulnar shortening osteotomy. The radial osteotomy was internally fixed with wires in eight wrists and with plates (lateral or posterior) in six. The ulnar shortening osteotomy was adjusted under intra-operative radiographic monitoring to restore satisfactory ulnar subsidence [15] and internal fixation was carried out using a compression plate. Mean ulnar shortening was 8.4 mm (range 5–10). In six wrists, the dorsal extensor retinaculum was realigned to reduce and stabilise the extensor carpi ulnaris tendon. The wrist was immobilised postoperatively with an arm–forearm–palm cast for six weeks followed by patient rehabilitation. K-wires were removed six to eight weeks after surgery and plates were removed after one year.

Fig. 2 Same patient as Fig. 1: anteroposterior view at last follow-up showing significant improvement of lunate subsidence and radial inclination, and lunate remodelling

Statistical analysis

A non-parametric Wilcoxon rank sum test was used to compare pre- and postoperative values. *P* values <0.05 were considered significant.

Results

At the last follow-up (mean 5.1 years, range 4–8.75), we observed a significant clinical improvement, with only two patients experiencing pain during sustained activity (carrying heavy loads or keyboard use for long periods). There

was significant improvement in postoperative range of movement, notably in supination and extension which increased from 57.3 ± 9.6 to 86.2 ± 2.4 ($p=0.004$) and from 46.7 ± 23.8 to 72.2 ± 17.2 , respectively ($p=0.02$). The values of pre- and postoperative joint mobility are given in Table 1.

Radiographically, we noted a very significant improvement in radial inclination, lunate subsidence, ulnocarpal displacement, and ulnar variance (Table 2). The procedure did not modify the forward tilt of the distal radial articular surface. At the last follow-up, the ulnar head showed posterior displacement in two wrists. In one wrist, pain persisted on the ulnar side during sustained activity. In two other wrists, anterior subluxation of the lunate bone persisted without clinical significance except for limited dorsal flexion.

Union was obtained in all cases and no repeat surgery was required. The two complications were neurological—one case of compression of the median nerve by an haematoma which required surgical evacuation and one

Fig. 3 Preoperative mediolateral view

Fig. 4 Same patient as Fig. 3: mediolateral view at last follow-up

case of irritation of the superficial branch of the radial nerve which completely resolved after one year. There was no problem related to hardware.

Discussion

Many surgical techniques have been suggested for the treatment of Madelung's deformity. These procedures belong in general to three broad groups: first, surgery to correct the radius (epiphysiodesis, desepiphysiodesis, corrective osteotomy [5, 6, 13, 14] or progressive lengthening [12]); second, surgery to correct the ulna (ulna reduction osteotomy [3, 18], resection-stabilisation of the ulnar head using a Darrach procedure [6, 18], radioulnar arthrodesis using the Sauvé-Kapandji procedure [2, 6]); and third, the combined techniques comprising surgery on both radius and ulna [6, 7, 13, 18, 19, 23]. There are too few consistent series with sufficient follow-up in the literature to allow assessment of the results of these techniques [3, 7, 16, 18, 19]. Some authors [20] prefer to wait for skeletal maturity so as to not make existing anomalies worse and to avoid the risk of recurrence [7]. Other authors suggest operating early to benefit from the remodelling and adaptation potential of

the immature skeleton [21] and to prevent the development of irreversible degenerative consequences. Vickers and Nielsen [22] advocate early preventive epiphysiodesis with fat interposition combined with release of the Vickers ligament.

In our series, we used a combined radio-ulnar osteotomy with a realignment of the extensor retinaculum tendon in six out of 14 wrists. This technique showed good medium-term results (mean follow-up 5.1 years) even if longer-term analysis is necessary to assess the stability of clinical results at some distance from completion of growth and to screen for possible degenerative lesions. Our method has several advantages. The distal radial articular surface can be correctly repositioned in all three planes to improve range of motion. The pain due to excessive pressure in the ulnar compartment and ulnar head subluxation is significantly reduced thanks to a planned shortening osteotomy. Moreover, this procedure both reduces and stabilises the extensor carpi ulnaris tendon that undergoes volar luxation in pronation and corrects the ulnar head subluxation in pronation. If comparison of clinical data seems easy, the radiographic data are difficult to analyse. It would be preferable to use radiological criteria which are more reproducible [11, 15], such as lunate subsidence, measurement of orientation of the distal radial articular surface in

Fig. 5 Radial inclination is measured on the anteroposterior radiograph and compared with the axis of the ulnar diaphysis

Fig. 6 Mediolateral view: forward tilt of the distal radial articular surface is measured as the complement of the acute angle (A) between the longitudinal axis of the ulna and a line across the distal articular surface of the radius. Volar displacement of the wrist is the distance (D) between the longitudinal axis of the ulna and the most volar point of the lunate

Fig. 7 Mediolateral view: lunate subsidence is the distance (D) between the most proximal point of the lunate and a line perpendicular to the longitudinal axis of the ulna and through its distal articular surface

relation to the ulnar diaphysis, and anterior displacement of the wrist. This would offer a more reliable tool to compare the radiographic results of the various techniques.

Salon et al. [19] and Dos Reis et al. [7] reported satisfactory clinical results after double distal radioulnar osteotomy in a series of 11 wrists with a mean follow-up of 9.7 years (range 1.5 – 22) and in 18 adult patients with a mean follow-up of 4.45 years (range 1.8 – 6.3), respectively. Pain during daily activities decreased significantly and joint mobility improved, with a satisfactory cosmetic appearance. However, Salon et al. [19] noted three wrists with persistent subluxation of the ulnar head in pronation. In the series of Dos Reis et al. [7], 80% of patients were free of pain. These authors used a procedure identical to ours, but they did not combine osteotomy with surgical release of the extensor retinaculum. Harley et al. [11] have suggested a combination of release of the Vicker's ligament and dome osteotomy of the distal radius. Using this technique, positioning of the distal radial articular surface can be corrected in all three planes simultaneously. At a mean follow-up of 1.9 years, despite satisfactory results for pain and joint mobility, three of their 26 wrists required ulnar shortening osteotomy due to recurring pain. Pain relief was obtained in two of these patients, but the third required a Darrach-type resection-stabilisation before a

satisfactory result could be achieved. These results show the importance of restoring a satisfactory position of the ulnar head, because while the pain is partly due to excessive pressure in the ulna and wrist, it is also caused by ulnar head subluxation. Ulnar shortening osteotomy relieves pressure in this compartment while tightening up the internal ligament structure. This osteotomy can be combined with volar flexion to help reduce the displacement of the ulnar head and to stabilise the distal radioulnar joint [19].

Ulnar shortening osteotomy may only be relevant when the dominant clinical picture is that of a syndrome of ulnar impaction due to a long ulna combined with moderate epiphyseal deformity of the radius [1, 3]. A Darrach

Table 1 Pre and postoperative ranges of motion of the operated wrist

Type of movement	Preoperative	Postoperative	<i>P</i>
Pronation	59.6±9.2	79.2±4.1	0.09
Supination	57.3±9.6	86.2±2.4	0.004
Flexion	74.6±23	76±15.6	NS
Extension	46.7±23.8	72.2±17.2	0.02

Values are given as the mean ± standard deviation
NS not significant

Table 2 Pre and postoperative radiographic data

Wrist	Radial inclination		Palmar tilt		Lunate subsidence		Palmar carpal displacement		Ulnar variance	
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
1	56	45	19	20	3	2	19	17	10	6
2	32	24	20	6	2	-1	16	13	15	3
3	46	40	35	31	5	-1	23	18	7	7
4	55	35	20	28	12	7	28	23	9	6
5	52	38	26	10	4	7	21	18	8	6
6	64	56	17	18	9	6	28	20	6	-3
7	58	50	18	22	5	2	21	19	10	4
8	50	32	18	2	6	3	22	19	8	1
9	48	46	24	14	5	2	15	16	5	4
10	50	38	18	28	7	3	13	12	8	2
11	55	45	9	28	4	0	17	13	10	3
12	34	28	25	5	1	-1	22	18	6	-2
13	56	40	30	34	8	2	28	24	8.5	3
14	42	32	15	20	2	-3	13	8	13	6
mean $\pm$ SD	50 $\pm$ 9 (32–64)	39 $\pm$ 9 (24 – 56)	21 $\pm$ 6.5 (9 – 35)	19 $\pm$ 10 (2 – 34)	5 $\pm$ 3 (1 – 12)	2 $\pm$ 3 (-3 – 7)	20.5 $\pm$ 5 (13 – 28)	17.5 $\pm$ 4 (10 – 24)	8.8 $\pm$ 2.7 (5 – 15)	3.3 $\pm$ 2.9 (-3 – 7)
(min–max)										
<i>p</i>	0.001		0.66		0.004		0.006		<0.001	

Values are given as the mean $\pm$ standard deviation
SD standard deviation, *min* minimum, *max* maximum

procedure can also be effective in moderate radial deformity with pain on the ulnar side [18]. However, it does not seem logical to resect the ulnar head as a first-line measure in a deformity where the anomaly is radial. Indeed, this procedure may destabilise the wrist by promoting ulnar and volar shift [6, 13, 18], even if this does not always have a clinical relevance [17]. Other authors [2, 6, 23] suggest a Sauvé-Kapandji procedure which offers good clinical results. For De Smet et al. [6], this procedure guarantees stabilisation of the distal radioulnar joint surface and prevents ulnar shift of the wrist [18] by restoring ulnar support. If there is significant inclination and forward tilt of the distal radial articular surface, osteotomy will be necessary to realign the radius. This technique seems preferable when skeletal maturity has been reached, or in cases where growth potential is limited [2].

We defend the conservative procedure of combined osteotomies to reposition the radius and to shorten the ulnar. The preoperative template must be precise to correct the bony deformation. It must be associated with a plasty of the retinaculum to stabilise the extensor carpi ulnaris tendon and correct the ulnar head subluxation in pronation.

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