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Osteotomy of the radius and ulna for the Madelung deformity

F. B. dos Reis, M. V. Katchburian, F. Faloppa, W. M. Albertoni, J. Laredo Filho, Jr

From the Federal University of São Paulo, Brazil

The Madelung deformity can result in pain and decreased function of the wrist and hand. None of the surgical techniques available has been shown consistently to improve grip strength, range of movement or relieve pain. In this prospective study we have treated 18 patients with the Madelung deformity (25 wrists) by wedge subtraction osteotomy of the radius and shortening of the ulna.

Our results show statistically significant improvement in grip strength and range of movement of the wrist and forearm. Pain improved in 80% of the patients and 88% were satisfied with the appearance. One patient had a wound infection and another developed reflex sympathetic dystrophy. Two had some recurrence due to continued growth of the ulna and it is recommended that the procedure be delayed until skeletal maturity, or else combined with epiphysiodesis of the ulna.

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The Madelung deformity of the wrist is due to partial closure of the palmar and ulnar portion of the distal growth plate of the radius.[1] Continued growth of the radial portion of the physis leads to dorsal and radial bowing of the radius, and the plane of the distal radial articular surface develops an exaggerated palmar and ulnar tilt, attaining values of up to 35° and 60°, respectively. The ulnar portion of the distal radius may fail to ossify.[1] There is palmar and ulnar subluxation of the carpus which, as the deformity becomes more advanced, becomes pyramidal in shape with a distal base and the lunate at the apex. This wedge-shaped carpus gradually embeds itself between the distal radius and ulna leading to increased separation of their distal ends and possible deformity of the lunate. Subluxation of the distal radioulnar joint occurs due to continued growth of the ulna; the head of the ulna becomes prominent dorsally and may come to lie dorsal to the carpal bones.

These anatomical changes alter the biomechanics of the wrist and associated structures giving a decreased range of movement, particularly ulnar deviation and extension, decreased grip strength and often pain.

The deformity usually presents in late childhood or adolescence, is more common in females and is often bilateral. In many cases there is a hereditary component with autosomal dominant inheritance of variable penetrance.[1-4] Several authors have reported the Madelung deformity as being one of the predominant features of dyschondrosteosis,[5-10] but this does not account for all cases and other bone dysplasias have also been associated with the condition.[1,11]

The aetiology of the premature fusion of the growth plate is unclear and various causes have been suggested including the occupation or nutrition of the patient,[12-16] vascular insufficiency affecting the interosseous pedicle of the distal radial growth plate,[17] muscular disorders[1,18,19] and fibrous bands tethering the distal radial epiphysis.[1,20] Vickers and Nielsen[20] also observed disorganised columns of cells in the affected areas of the growth plate. Trauma and infection are also recognised causes in some cases.[2]

Conservative methods of treatment are often ineffective and do not prevent progression of the deformity. A number of surgical techniques have been developed.[2,17,21-25] Dobyns et al[2] divided these into three broad groups: first, those applied to the radius such as epiphysiodesis, corrective osteotomy and physiolysis; secondly, those applied to the ulna such as epiphysiodesis, excision of the head, shortening osteotomy and creation of a pseudarthrosis with or without fusion to the radius; and thirdly, combined techniques in which both bones are dealt with usually by one or other of the above methods. Some of the more ablative procedures, however, have given rise to long-term problems.[26]

F. B. dos Reis, MD, Head of Traumatology
Department of Orthopaedics and Traumatology, Federal University of San Paulo, R. Borges Lagoa 786, São Paulo, Brazil.

M. V. Katchburian, FRCS, Specialist Registrar in Orthopaedics
St Thomas' Hospital, Lambeth Palace Road, London SE1 7E4, UK.

F. Faloppa, MD, Associate Professor, Discipline of Hand Surgery
W. M. Albertoni, MD, Titular Professor, Discipline of Hand Surgery
J. Laredo Filho Jr, MD, Titular Professor and Head
Department of Orthopaedics and Traumatology, Federal University of San Paulo, R. Borges Lagoa 786, São Paulo, Brazil.

Correspondence should be sent to Mr M. V. Katchburian at 129 Old Dover Road, London SE3 8SY, UK.

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Table I. Classification of the Madelung deformity according to Nielsen[10]

I)	Idiopathic Madelung deformity
	a) Classic Madelung deformity
	b) Dysplasia of bone + Madelung deformity
II)	Symptomatic Madelung deformity (pseudoMadelung deformity)

In 1987 we began a prospective study to assess the results of using dorsolateral wedge subtraction osteotomy of the radius together with an ulnar shortening osteotomy to treat this condition. The rationale is that by restoration of the distal radial and ulnar anatomy to as nearly normal as possible, biomechanical improvements will result leading to improved function in the wrist and hand.

Patients and Methods

Between 1987 and 1993, 18 patients with a Madelung deformity who were dissatisfied with conservative treatment were seen at a tertiary referral centre. All had the classical deformity according to Nielsen's classification[11] (Table I). Twelve (66.6%) were affected bilaterally and in seven of these we performed the operation on both sides. Thus, a total of 25 wrists was treated surgically.

Details of the patients are given in Table II. Their mean age was 22.8 years (16 to 35). They were all female and right-handed. The mean follow-up was 53.4 months (22 to 76). All had reached skeletal maturity by the final follow-up.

In six patients surgical correction was undertaken for pain. In three, functional impairment interfered with daily activities and in the remainder the main indication was deformity.

Assessment. Pain, grip strength and goniometry of the wrist and forearm were assessed before and after operation. The range of movement of the wrist was measured with the patient seated, the elbow flexed to 90° and the forearm pronated. Pronation and supination were measured with the elbow at 90° and the shoulder in the neutral position.[25,27,28] The angle of the distal radial articular surface in relation to the long axis of the radius, ulnar variance, and the degree of dorsal ulnar subluxation were measured radiologically before and after operation.

The patients were also asked whether the pain and appearance had improved.

Operative technique. Before operation we measured the size of the wedge to be excised from the radius from the radiographs. This was calculated in order to restore the inclination of the distal articular surface of the radius to within normal limits, i.e., 22 to 23° on the anteroposterior view and 10 to 11° on the lateral projection.[29] The amount of bone to be resected from the ulna was calculated in a similar manner to restore ulnar variance to zero (Fig. 1).

Through a dorsoulnar incision in the distal third of the forearm a segment of the ulna was excised and the bone stabilised with a six-hole 3.5 mm dynamic compression plate. The radius was approached through a V-shaped incision with a radial apex on the dorsal aspect of the distal third of the forearm (Fig. 2). The osteotomy was performed and the bone fixed with a seven-hole 3.5 mm AO T-

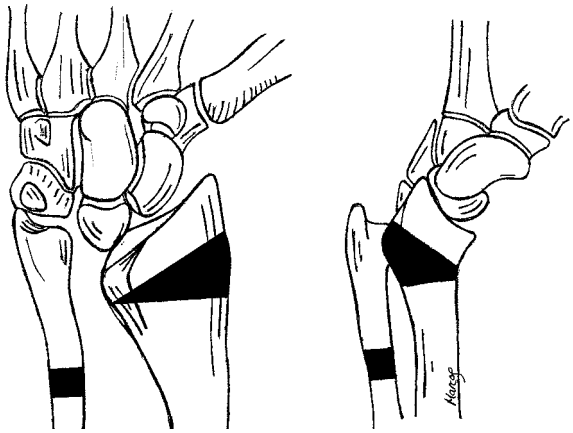

Fig. 1

Diagram showing the site of the radial and ulnar osteotomies (shaded areas).

Table II. Details of the 18 patients with the Madelung deformity

Case	Age (yr)	Occupation	Affected hand(s)	Operated hand	Main complaint	Follow-up (mth)
1	30	Maid	Left	Left	Pain	50
2	17	Student	Bilateral	Left and right	Deformity	76
3	21	Bank clerk	Bilateral	Left and right	Deformity	36
4	30	Maid	Bilateral	Right	Pain	72
5	19	Student	Left	Left	Deformity and limitation of function	70
6	35	Maid	Bilateral	Right	Pain	22
7	26	Secretary	Right	Right	Deformity and pain	73
8	21	Saleswoman	Bilateral	Right	Deformity and limitation of function	59
9	28	Maid	Right	Right	Deformity and pain	71
10	33	Maid	Bilateral	Left and right	Pain	66
11	17	Student	Bilateral	Left and right	Deformity	51
12	16	Student	Bilateral	Left and right	Deformity	67
13	23	Saleswoman	Bilateral	Left	Deformity	31
14	22	Maid	Right	Right	Deformity	46
15	18	Student	Bilateral	Right	Deformity	64
16	21	Telephone operator	Bilateral	Left and right	Deformity	34
17	16	Student	Right	Right	Deformity	43
18	19	Student	Bilateral	Left and right	Deformity and limitation of function	29

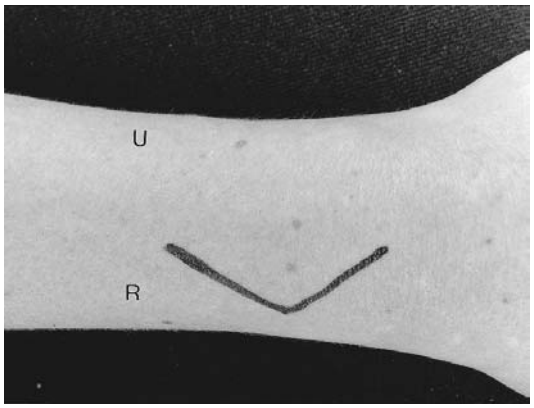

Fig. 2

The site of the radial incision.

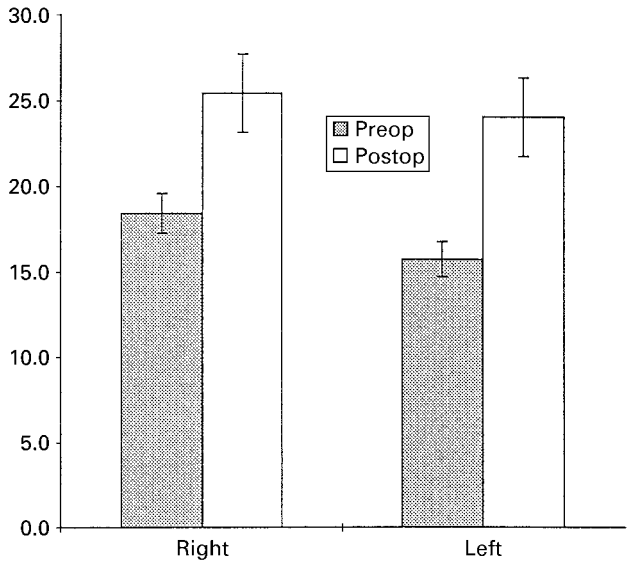

Fig. 3

Mean pre- and postoperative grip strength for right and left hands. Error lines show the SD.

plate.[30-32] The extensor tendons were realigned and in some cases a flap of extensor retinaculum was interposed between the plate and tendons. The plates and screws were removed 20 months after operation.

Statistical analysis. We used the Wilcoxon non-parametric test[33] to compare the information obtained before and after operation, and the left and right wrists in patients who had bilateral surgery. The level for rejection of the null hypothesis was set at 5% ($p \leq 0.05$).

Results

In order to determine whether right and left wrists needed to be considered independently both wrists of the seven patients (38.9%) who had bilateral procedures were compared with each other. A significant difference between the two sides was observed preoperatively with regard to grip strength (R>L), pronation (L>R) and radial inclination (R>L). Postoperatively, a statistically significant difference was seen for grip strength (R>L), adduction (R>L), ulnar variance (R>L) and dorsal subluxation of the ulna (L>R).

Although the sample size in this case was small, as a result of these differences the right and left wrists were then studied independently when comparing data before and after operation. There were 14 right wrists (56%) and 11 left (44%).

Pain was present in nine patients (ten wrists) and was the principal complaint in six. After operation, two patients (cases 6 and 10) continued to have pain, and in case 6 this was worse than before surgery. Thus, eight wrists (80%) with preoperative pain improved.

Table III and Figure 3 give the results of the pre- and postoperative assessment of grip strength before and after operation, and Table IV and Figure 4 give the range of movement of right wrists. Table V and Figure 5 show the same observations for the left wrists. Statistically significant improvement was observed in all measurements.

Table VI and Figure 6 show the radiological measure-

Table III. Pre- and postoperative grip strength (kgf) of left and right hands

Right			**Left**		
Pre	**Post**	**Increase**	**Pre**	**Post**	**Increase**
18	24	6	16	21	5
19	25	6	16	22	6
20	29	9	15	25	10
18.5	22.5	4	16.5	26	9.5
19	23	4	15.5	25	9.5
18.5	24.5	6	15	26	11
18	26	8	16	24	8
17	29	12	16	22	6
19	26	7	18	21	3
20	24	4	14	28	14
19.5	26	6.5	15	25	10
16	30	14			
17	27	10			
18	27	9			
Mean 18.4 ± 1.2	25.9 ± 2.3	7.5 ± 3.0	15.7 ± 1.0	24.1 ± 2.3	8.4 ± 3.1
Percentage increase in mean grip strength		*41*			*53*

Table IV. Pre- and postoperative range of movement (degrees) for right wrists

Flexion		Extension		Abduction		Adduction		Pronation		Supination	
Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
80	85	40	65	5	8	20	30	60	60	80	70
75	80	35	75	0	9	22	33	55	80	40	75
60	75	30	50	0	7	15	31	50	80	60	70
60	55	40	45	0	4	10	10	60	30	40	35
75	60	45	60	4	5	23	27	30	70	60	60
55	60	35	50	5	6	18	30	60	60	40	50
60	65	40	60	0	6	15	28	60	80	45	80
80	80	40	60	4	9	22	30	70	75	45	75
70	80	40	70	0	6	20	28	40	75	60	80
70	75	40	55	4	10	20	25	45	70	50	65
60	70	35	60	3	9	18	28	50	80	50	80
75	80	40	65	3	8	16	30	40	80	60	65
80	80	45	60	2	8	20	28	60	80	65	80
70	75	45	45	0	8	18	30	60	75	45	70
Mean											
69.3 ± 8.7	72.8 ± 9.3	39.3 ± 4.3	58.6 ± 8.9	2.1 ± 2.1	7.3 ± 1.7	18.3 ± 3.5	27.7 ± 5.5	52.8 ± 10.9	71.0 ± 13.8	52.8 ± 11.7	68.2 ± 13.0
Increase in mean											
	3.6		19.3		5.2		9.4		18.2		15.4
Percentage increase in mean											
	5		*49*		*248*		*51*		*34*		*29*

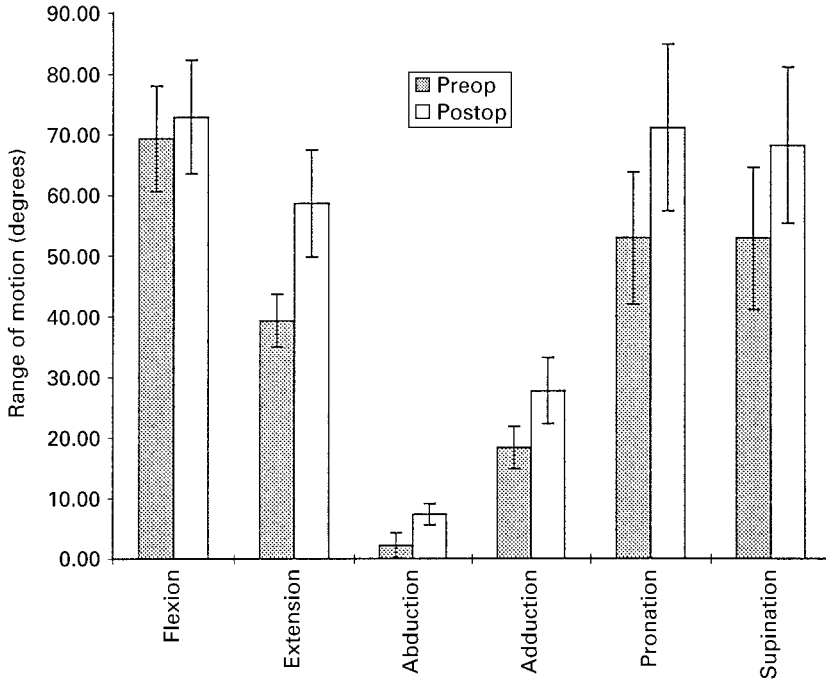

Fig. 4

Mean pre- and postoperative range of movement for right wrists. Error lines show the SD.

ments for the right wrists and Table VII and Figure 7 for the left. All the measurements were closer to the accepted normal range after operation. This change was statistically significant for all values measured.

Overall, 88% of the patients were satisfied with the improvement in the appearance of their wrist (Figs 8 and 9). The mean time for union was 4.6 weeks for right radii and 4.4 for left, and for right ulnae 7.6 weeks and left 7.3 weeks.

Complications. One patient (case 3) developed a wound infection. The wound healed leaving a hypertrophic scar which ruined the cosmetic result. In another (case 6) reflex sympathetic dystrophy occurred and although this was treated with injection of local anaesthetic and physiotherapy, considerable pain and functional limitation persisted at the last follow-up, 71 months after operation.

Discussion

A number of anatomical changes occur in the Madelung deformity which result in biomechanical alterations leading to a decreased range of movement, decreased grip strength and often pain. The technique which we describe[17,34] aims at restoring the anatomy of the wrist to as near normal as possible by repositioning the radioulnar and radiocarpal joints and thereby reversing some of these biomechanical changes.[1]

Table V. Pre- and postoperative range of movement (degrees) for left wrists

Flexion		Extension		Abduction		Adduction		Pronation		Supination	
Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
60	70	35	50	0	6	15	25	60	65	45	60
70	70	40	55	5	8	18	30	70	75	40	60
70	80	30	60	4	8	10	29	60	80	35	80
70	70	35	55	5	6	20	32	65	65	45	60
65	65	30	55	0	6	12	28	55	65	35	60
55	80	35	65	5	8	20	25	60	75	50	70
80	80	45	70	3	8	18	26	70	75	45	70
65	70	40	60	0	6	15	28	45	70	40	75
75	75	35	55	4	5	22	30	50	60	45	65
70	70	40	60	0	9	15	28	45	80	60	75
75	85	45	50	3	8	15	28	65	75	40	70
Mean											
68.6 ± 7.1	74 ± 6.3	37.2 ± 5.2	57.7 ± 6.1	2.6 ± 2.2	7 ± 1.3	16.3 ± 3.6	28 ± 2.2	58.6 ± 9.0	71.3 ± 6.7	43.6 ± 7.1	67.7 ± 7.2
Increase in mean											
	5.5		20.5		4.5		11.7		12.7		24.1
Percentage increase in mean											
	8		*55*		*171*		*72*		*22*		*55*

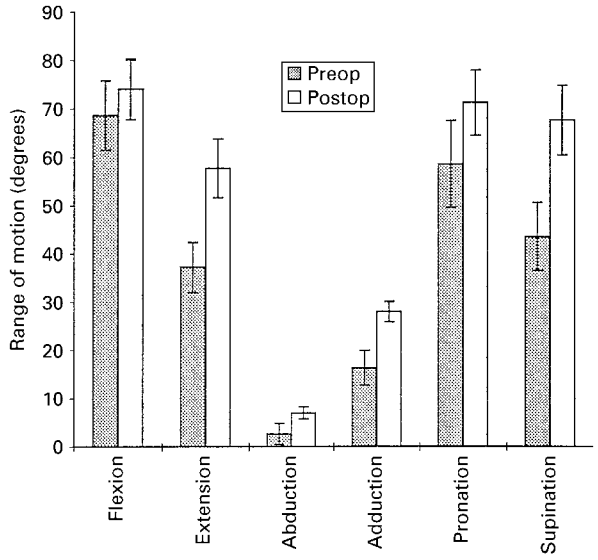

Fig. 5

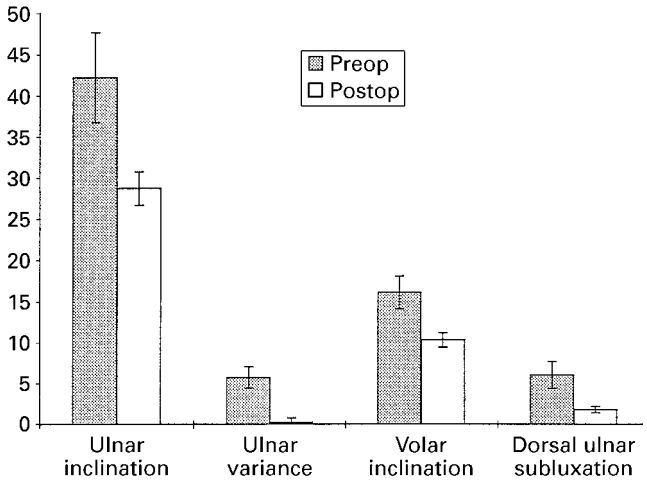

Fig. 6

Figure 5 – Mean pre- and postoperative range of movement for left wrists. Error lines show the SD. Figure 6 – Pre- and postoperative measurements of ulnar and volar inclination of the radial articular surface (degrees), ulnar variance and dorsal subluxation (mm) for right wrists. Error lines show the SD.

Table VI. Pre- and postoperative volar and ulnar inclination (degrees) of the radial articular surface, ulnar variance (mm) and ulnar subluxation (mm) for right wrists

Ulnar inclination of radial articular surface		Ulnar variance		Volar inclination of radial articular surface		Dorsal subluxation of ulna	
Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
40	29	4	0	18	11	4	1.5
47	31	6	0	16	10	6	1.5
38	27	7	0	18	10	9	2.5
38	28	6	0	19	12	5	2
45	30	5	0	17	10	6	1.5
46	29	5.5	0	16	11	4.5	1.5
40	28	5	0	15	10	5.5	2
38	26	4	0	14	10	4.5	1.5
38	26	5.5	1	15	8	6	1.5
56	33	9	0	17	11	10	2.5
45	30	7	0	19	11	6.5	2
35	26	5	0	15	10	6	1.5
45	29	5	2	12	10	6	2
40	30	6	0	15	10	5.5	1.5
Mean							
42.2 ± 5.5	28.7 ± 2.1	5.7 ± 1.3	0.2 ± 0.6	16.1 ± 2.0	10.3 ± 0.9	6 ± 1.6	1.8 ± 0.4

Table VII. Pre- and postoperative volar and ulnar inclination of the radial articular surface (degrees), ulnar variance (mm) and ulnar subluxation for left wrists (mm)

Ulnar inclination of radial articular surface		Ulnar variance		Volar inclination of radial articular surface		Dorsal subluxation of ulna	
Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
45	30	5	0	15	10	4	2
35	27	4	0	12	10	4	1.5
40	28	5	0	13	10	6.5	1.5
45	29	8	0	20	13	6.5	2
32	25	6.5	0	16	10	6	2
35	24	5	-1	13	10	5	2
40	29	6	0	14	9	4.5	1.5
46	30	3.5	1	12	10	6	2
42	29	5	-1	18	12	6	1.5
41	29	6	0	13	10	5	1.5
35	26	4	0	12	9	5.5	1.5
Mean							
39.6 ± 4.8	27.9 ± 2.0	5.3 ± 1.3	-0.1 ± 0.5	14.3 ± 2.7	10.3 ± 1.2	5.3 ± 0.9	1.7 ± 0.3

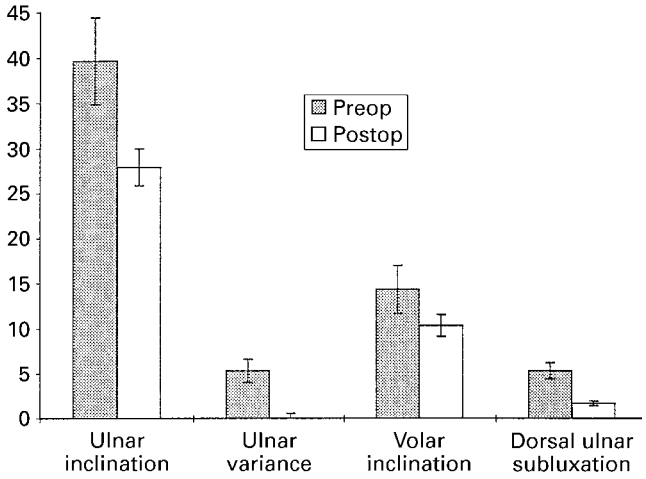

Fig. 7

Pre- and postoperative measurements of ulnar and volar inclination of the radial articular surface (degrees), ulnar variance and dorsal subluxation (mm) for left wrists. Error lines show the SD.

Overall, our results show that grip strength and the range of movement improved significantly. Pain experienced before operation was improved in 80%, and 88% of patients were satisfied with the appearance of their wrist. This compares favourably with Nielsen's results with a variety of procedures in which nine out of 13 patients felt that there had been an improvement in pain, subjective function and cosmetic appearance. In his study, however, the range of movement only improved in one patient.[11] Ranawat et al[26] used the Darrach procedure, with or without associated radial osteotomy in 13 patients, and noted improved range of movement and grip strength. More recently, Murphy et al[1] studied 12 patients who had had radial opening-wedge osteotomy and observed no change in range of movement or grip strength although pain and cosmesis improved. The increase in grip strength observed in our patients may have been due to improvement in the biomechanics of the wrist and hand as a result of better positioning of the wrist. This may also have allowed more satisfactory tendon excursion.

Fig. 8a

Fig. 8b

Fig. 8c

Fig. 8d

Radiographs showing the appearance of the wrist of a patient with the Madelung deformity before surgery (a,b) and the deformity after osteotomy of the radius and ulna with the fixation devices in place (c,d).

Fig. 9a

Fig. 9b

Anteroposterior (a) and lateral (b) radiographs showing the appearance of the wrist of a patient with Madelung's deformity after osteotomy of the radius and removal of the fixation devices.

When possible, palmar tilt of the radius should be fully corrected as this is important in restoring grip strength and improving appearance. Some radiolunate incongruity is likely as the result of correction but compressive stress across the joint may be lessened by the decrease in shear force.[1] When there is severe deformity of the carpus, however, full correction may result in instability due to articulation of a triangular carpus with the joint surfaces of the radius and ulna the orientation of which has been restored to nearly normal. In such cases full correction may not be advisable.

Realignment of the extensor tendons together with interposition of a flap of extensor retinaculum is an important part of the operation in order to avoid rupture due to impingement on the ulnar head or metal plate.[35-38]

The object in shortening the ulna is to achieve an ulnar variance of zero thus reducing the subluxed radioulnar joint and improving the anatomy of the radioulnar-carpal joint. This was difficult to achieve in two of our patients (cases 12 and 17) as they were not yet skeletally mature and resulted in some recurrence of the deformity. This was not significant clinically but may have been avoided by fusing the growth plate or delaying surgery until bone growth had ceased. The ideal age for surgical correction is not clear.[1,26,39] Techniques involving physiolysis[24] obviously require an open growth plate but with others a number of factors should be considered. Surgery before closure of the physis may lessen the development of secondary changes in the carpus and allow some remodelling. Correction after skeletal maturity or towards the end of skeletal growth, however, decreases the likelihood of recurrence of the deformity. Procedures which involve resection of the ulnar head should be avoided in young patients since ulnar deviation and carpal dislocation may result.

In previous reports the indications for surgery have been variable and many factors such as age, appearance, function and anatomical aspects have been considered,[11,20,21,24,25,35,40,41] as well as the presence of associated problems such as nerve compression[42,43] and extensor tendon rupture.[38] Fagg[44] contends that surgery is rarely indicated. In our study the principal indications for operation were deformity, pain and limitation of function. All patients were seen at a tertiary referral centre and were dissatisfied with conservative treatment.

Twelve (66%) were affected bilaterally. Of these, one (case 6) was reluctant to undergo surgery on his left wrist since he had developed reflex sympathetic dystrophy in the right wrist after operation. Three (cases 4, 8 and 13) had an operation on one side only since the symptoms and deformity on the other wrist were thought to be insufficient to warrant intervention.

The long-term effects of corrective surgery on the subsequent development of osteoarthritis of the wrist are not clear. Our technique allows further operations for arthritis such as arthrodesis or resection of the proximal row of the carpus to be performed without difficulty.[45-47] If pre-existing degenerative change is present, operation may not alleviate pain, as was the case with one of our patients (case 10). We recommend that the technique should not be used as a pain-relieving procedure in a joint with osteoarthritis.

Conclusion. Our technique produces good results for the treatment of the Madelung deformity, improving grip strength, range of movement, pain and the appearance of the wrist. These results compare favourably with those of other authors.[1,11,17,24,39] Surgery should be delayed until patients are over 16 years of age to decrease the likelihood of recurrence and prevent problems of ulnar overgrowth. Epiphysiodesis of the ulna may be an alternative in these patients.

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