

Original Research Article

Functional and radiological outcomes of Madelung and Madelung-like deformities corrected with corrective osteotomies of radius with or without ulnar shortening

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ABSTRACT

Background: Madelung deformity results from a bony and ligamentous dysplasia at the wrist, leading to palmar displacement of the hand on a shortened, bowed forearm. It is commonly associated with dorsal subluxation and prominence of the ulnar head, which collectively contribute to restricted wrist range of motion.

Methods: This study included 15 patients diagnosed with Madelung and Madelung-like deformity, with a mean age of 15 years (range: 10–21 years). All patients underwent clinical and radiographic evaluations. Various surgical techniques were employed, including dorsolateral closed-wedge osteotomy, open-wedge osteotomy, and dome osteotomy. Functional outcomes were assessed using the Modified Mayo wrist score, both pre- and post-operatively.

Results: Postoperative analysis revealed statistically significant improvements in wrist range of motion, pain relief, grip strength, radial inclination, and carpal slip. The modified Mayo wrist scores also demonstrated significant postoperative improvement.

Conclusions: Our findings suggest that surgical intervention plays a pivotal role in restoring wrist function by enhancing range of motion, increasing grip strength, and alleviating pain, ultimately contributing to improved functional outcomes and patient quality of life.

Keywords: Madelung deformity, Wrist, Early outcome, Adolescent group

INTRODUCTION

Madelung deformity is a clinical condition resulting from abnormal development of the wrist's osseous and ligamentous structures. It leads to palmar displacement of the hand on a shortened, bowed forearm and is frequently accompanied by dorsal subluxation and prominence of the ulnar head, contributing to restricted wrist mobility.¹

Madelung-like deformity refers to an acquired form of the condition, often arising due to trauma, infections, or neoplasms. These acquired deformities can typically be distinguished from congenital or dysplastic causes based

on unilateral presentation, absence of associated skeletal anomalies, and a relevant medical history.²

This deformity most commonly affects adolescent females, who often seek medical attention due to pain or visible wrist deformity. The condition is believed to be associated with X-chromosome mutations, and many hereditary cases are linked to mesomelic dysplasia. Bilateral involvement is observed in nearly 50% of affected individuals. Clinical symptoms of Madelung deformity usually become evident during adolescence, between the ages of 10 and 14. It is exceedingly rare for symptoms to manifest before age 10. The deformity arises

due to partial closure of the distal radial physis, resulting in radial shortening and progressive dislocation at the wrist joint.³

Although various classification systems have been proposed, none have gained universal acceptance. When this visually apparent deformity presents in a hand surgery setting, it poses significant challenges regarding optimal correction using contemporary techniques. There remains ongoing debate concerning the best treatment strategy for adolescents presenting with pain or deformity. Many surgeons now acknowledge that individuals with a history of wrist trauma often endure persistent discomfort extending into adulthood, in addition to the visible deformity.

The condition presents a substantial cosmetic concern for both male and female patients. The dilemma persists—should the deformity be observed conservatively, or should surgical correction be pursued? If surgery is indicated, what is the optimal age and technique? With these considerations in mind, this study aims to evaluate the clinical presentation, surgical interventions, and their outcomes in affected patients.

The primary objective of this study was to evaluate the early clinical and radiological outcomes of patients with Madelung and Madelung-like deformities who underwent surgical correction using dorsolateral closing wedge, open wedge, or dome osteotomy techniques. The study aimed to assess improvements in wrist function through postoperative evaluation of grip strength, range of motion, pain relief, and cosmetic appearance, using the modified Mayo wrist score and radiological criteria as assessment tools.

METHODS

This prospective interventional study was conducted at Sawai Man Singh Medical College and its affiliated hospital in Jaipur, Rajasthan. A total of 15 patients involving 20 wrists were included, with 5 patients presenting bilateral wrist deformities. Surgical procedures were performed between 2022 and 2025, following ethical clearance from the institutional review board. In our study cohort, the incidence of deformity was higher in females compared to males. All cases of true Madelung deformity were identified in female patients, with bilateral wrist involvement seen in the majority. In contrast, all male participants exhibited Madelung-like deformities, with no confirmed cases of true Madelung deformity.

This condition typically manifests during adolescence. The age of patients in our study ranged from 10 to 21 years, with a mean age of 15 years. The most frequent clinical complaint was wrist deformity, often reported due to cosmetic concerns, followed by pain. Pain was predominantly localized to the ulnar side of the wrist and was aggravated by loading activities, interfering with daily functions.³

Radiological evaluation was performed using the roentgenographic criteria described by Dannenberg and Ranawat. Preoperative clinical assessments included measurement of wrist range of motion, grip strength using a spring dynamometer, and pain intensity using the visual analogue scale (VAS).⁴

Following a detailed history and thorough clinical examination, eligible patients were taken up for surgical intervention under anesthesia. Distal radial corrective osteotomies were performed using one of the following techniques as described below.

Surgical techniques

Dorsolateral closed-wedge osteotomy

A wedge of bone was excised from the dorsal and radial aspects of the distal radius. The osteotomy site was closed and stabilized using Kirschner wires, typically aiming for 5–15° of volar angulation and 15–25° of radial inclination.

Palmar open-wedge osteotomy

This procedure was performed via the interval between the flexor carpi radialis and the radial artery. An osteotome was used to make a cut parallel to the distal radial articular surface. The osteotomy was gently opened using a laminar spreader, and a trapezoidal graft harvested from the iliac crest was interposed into the defect. Fixation was achieved using K-wires. Vicker's ligament was released through the same palmar approach.

Dome osteotomy

A dome-shaped osteotomy was created using an osteotome. After realigning the distal radius in the corrected position, stabilization was achieved using K-wires.

Postoperatively, all patients were placed in an above-elbow slab and discharged on the third postoperative day. Two weeks following surgery, the slab was replaced with an above-elbow cast. At six weeks, clinical and radiological assessments were conducted to evaluate union at the osteotomy site. If union was confirmed, patients were transitioned to a below-elbow splint and initiated on intermittent wrist mobilization exercises. In cases where union was incomplete, immobilization was extended for an additional two weeks.

Clinical evaluations were including grip strength, and range of motion of the wrist and elbow were conducted at 8 and 12 weeks postoperatively. Follow-up radiographs were obtained at 12 weeks. Subsequent evaluations were carried out at 6 months and again at 1 year after surgery. These follow-ups included reassessments of wrist range of motion, pain scores, grip strength, and radiological alignment. Functional outcomes were assessed using the

modified Mayo wrist score, both pre-operatively and post-operatively.⁵

At the conclusion of the study, data were compiled and analyzed using the statistical package for the social sciences (SPSS) version 11.0 statistical software. Wilcoxon signed-rank test was used to assess intraoperative differences, while Mann-Whitney U test, a non-parametric method, was used for analyzing intergroup differences.

Inclusion criteria

Patients aged between 10 and 21 years, clinically and radiologically diagnosed with Madelung or Madelung-like deformity, both male and female patients, presence of symptoms such as cosmetic deformity, wrist pain, or functional limitation, minimum 6 months of postoperative follow-up, and informed consent obtained from patient or guardian were included.

Exclusion criteria

Patients aged below 10 years or above 21 years, incomplete clinical or radiological records, refusal of surgical treatment or lost to follow-up before 6 months, history of previous wrist surgery, and contraindications to surgery or anesthesia due to medical comorbidities were excluded.

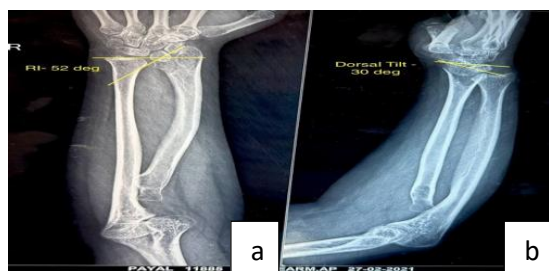


Figure 1 (a and b): Pre-operative X-ray of a 19 years/female patient with idiopathic bilateral Madelung deformity with radial inclination of 52 degrees and dorsal tilt of 30 degrees.



Figure 2 (a and b): Immediate post-operative X-ray of the patient, who underwent Vicker's ligament release and Dome osteotomy of distal radius and fixation with volar plate.



Figure 3 (a-c): X-ray at final follow up showing radial inclination of 23 degrees and palmar tilt of 14 degrees.

Figure 1 shows the pre-operative X-ray of a 19 years/female patient with idiopathic bilateral Madelung deformity; Figure 2 shows the immediate post-operative X-ray of the patient; and Figure 3 shows X-ray at final follow up.

RESULTS

A total of 15 patients involving 20 wrists were included in the study, with 5 patients presenting bilateral wrist deformities. All individuals diagnosed with true Madelung deformity were female, and the majority of these had bilateral involvement. Conversely, all male patients exhibited Madelung-like deformity, and no confirmed cases of true Madelung deformity were observed among them. These findings are consistent with previous literature.^{6,7}

Among the different types of deformities observed, the idiopathic form was the most common, whereas the genetic variant was the least frequent. The overall female predominance in the study population was notable, accounting for approximately 70% of cases. The mean follow-up duration was 18 months, with a range of 10 to 38 months. Tables 1 to 6 show different surgical options employed and their effects on the patient's well-being. A statistically significant improvement in postoperative range of motion was observed across the study cohort. Additionally, significant enhancements were noted in pain scores, grip strength, radial inclination, and carpal slip measurements.

In our study one patient developed transient tourniquet palsy, which resolved without long-term consequences. Another patient experienced delayed union of the ulna; this was successfully managed with plate fixation and bone grafting, resulting in timely union without affecting the overall outcome. In one case, persistent postoperative wrist pain necessitated a secondary Suave-Kapandji procedure, which provided satisfactory symptom relief. Functional outcomes were assessed using the modified Mayo wrist score. Postoperative scores showed a statistically significant improvement compared to preoperative values, reflecting enhanced wrist function and patient satisfaction.

Table 1: Pre-post intervention comparisons with paired samples statistics and test results (group- close wedge osteotomy).

Variables	Pre-op (mean±SD)	Post-op (mean±SD)	T value	P value
Dorsi flexion	41.11±3.33	64.44±9.82	-5.491	0.001
Palmar flexion	51.67±10.90	67.22±10.93	-3.63	0.007
Pronation	66.67±3.54	72.78±4.41	-3.773	0.005
Supination	68.89±2.20	76.11±4.86	-4.914	0.001
Radial deviation	24.44±8.08	15.00±2.00	3.51	0.003
Ulnar deviation	25.56±5.27	28.33±3.54	-3.162	0.013

Table 2: Modified Mayo wrist score (group-close wedge osteotomy).

Variables	Pre-op (mean±SD)	Post-op (mean±SD)	T value	P value
Pain (score)	21.67±5.00	27.0±1.67	5.67	0.01
Grip strength (kg)	17.78±3.63	23.33±2.50	-4.264	0.003
Range of motion	11.11±3.33	20.00±4.33	-6.4	0.001
Satisfaction (score)	11.11±3.33	25.00±0.00†	-12.5	0.001
Total function (score)	62.78±3.63	91.67±4.33	-26	0.001

Table 3: Pre-post intervention comparisons with paired samples statistics and test results (group- open wedge osteotomy).

Variables	Pre-op (mean±SD)	Post-op (mean±SD)	T value	P value
Dorsi flexion	51.00±27.70	75.00±10.84	-3.5	0.002
Palmar flexion	43.00±7.58	68.00±10.95	-4.767	0.009
Pronation	55.00±16.96	78.00±5.48	-3.8	0.001
Supination	72.00±4.47	84.00±4.47	-4.1	0.001
Radial deviation	31.00±17.46	15.00±2.00	4.2	0.001
Ulnar deviation	23.00±10.95	35.00±4.18	-3.6	0.001

Table 4: Modified Mayo wrist score (group- open wedge osteotomy).

Variables	Pre-op (mean±SD)	Post-op (mean±SD)	T value	P value
Pain (score)	20.00±5.00	28.00±1.00	-6	0.001
Grip strength (kg)	16.00±2.24	23.00±2.74	-5.715	0.005
Range of motion	12.00±2.74	21.00±6.52	-3.674	0.021
Satisfaction (score)	11.00±2.24	23.00±2.74	-6	0.004
Total function (score)	59.00±4.18	92.00±6.71	-8.82	0.001

Table 5. Pre-post intervention comparisons with paired samples statistics and test results (group- dome wedge osteotomy).

Variables	Pre-op (mean±SD)	Post-op (mean±SD)	T value	P value
Dorsi flexion	38.75±5.83	66.88±9.98	-6.215	0.001
Palmar flexion	46.25±4.43	67.50±9.26	-8.078	0.001
Pronation	65.00±4.63	73.75±3.54	-4.249	0.004
Supination	68.13±2.59	76.88±3.72	-7	0.001
Radial deviation	21.25±9.54	15.00±0.00†	3.5	0.001
Ulnar deviation	32.50±11.65	40.00±4.43	-4	0.001

Table 6: Modified Mayo wrist score (group-dome wedge osteotomy).

Variables	Pre-op (mean±SD)	Post-op (mean±SD)	T value	P value
Pain (score)	20.00±5.35	25.00±0.00†	-2.646	0.033
Grip strength (kg)	16.88±4.58	23.75±2.32	-3.274	0.014

Continued.

Variables	Pre-op (mean±SD)	Post-op (mean±SD)	T value	P value
Range of motion	11.25±2.32	22.50±2.67	-7.18	0.001
Satisfaction (score)	11.25±2.32	23.75±2.32	-7.638	0.001
Total function (score)	60.63±4.95	93.75±5.83	-25.185	0.001

DISCUSSION

Epidemiology and presentation

Madelung deformity has been widely reported to occur four times more frequently in females than males and to present bilaterally twice as often as unilaterally. In our cohort, female patients comprised 58% of cases, while males accounted for 42%. All patients with true Madelung deformity were female, with the majority showing bilateral wrist involvement. Conversely, all male participants were diagnosed with Madelung-like deformity, and no true Madelung cases were identified among them. Due to variability in severity, unilateral presentation was common, particularly among patients with traumatic origins. In our series, all traumatic Madelung-like deformities and one idiopathic case were unilateral, which aligns with previously documented observations.^{8,9}

Classification and demographics

The Vender and Watson (1998) classification system was used for diagnostic categorization. Idiopathic Madelung deformity emerged as the most frequent type, while genetic cases were least common. The average follow-up period was 18 months (range: 10–38 months), with one patient lost to follow-up after 10 months. Most patients presented during adolescence, a period when the deformity becomes more noticeable cosmetically. Patient ages ranged from 10 to 21 years (mean: 15 years). Cosmetic deformity was the predominant presenting complaint, followed by ulnar-sided wrist pain exacerbated by loading activities.¹⁰

Importance of early intervention

Early surgical correction facilitates timely remodeling, optimizes biomechanical load distribution across the wrist, and may reduce the risk of long-term radiocarpal cartilage degeneration and secondary osteoarthritis.¹¹

Radiological findings

Plain radiographs remain the most practical and accessible diagnostic modality. The most commonly observed features included ulnar and volar angulation of the distal radial articular surface, radial shortening, triangularization of the epiphysis, and dorsal/ulnar curvature. Dorsal subluxation of the ulna and carpal wedging were also prevalent. These findings are consistent with previous literature, including those described by Douglas Lamb and Schmidt et al, who found similar patterns in their analysis of 31 patients.¹² Although MRI provides critical insights—particularly in identifying Vicker's ligament—it remains

underutilized in our setting due to financial constraints. Its a thick fibrous band originating from the ulnovolar metaphysis and inserting onto the lunate and triangular fibrocartilage. Its presence may be inferred on radiographs by a subtle radial spur and flame-shaped radiolucency.¹²

Surgical techniques and outcomes

Among the procedures performed, dorsolateral closing wedge osteotomy was found to be technically simpler, providing excellent control of both radial fragments and avoiding the need for bone grafting. It also resulted in reduced operative time and postoperative discomfort. However, the shortening of the radius often necessitated ulnar shortening to restore balance. These outcomes are consistent with those reported by Laffosse et al, who also observed favorable functional recovery.¹³

Palmar open-wedge osteotomy required precise placement of a trapezoidal iliac crest graft and K-wire fixation, making it more technically demanding. However, it provided the advantage of releasing the anomalous ligament through the volar approach, with the added benefit of a cosmetically concealed scar. Kampa et al reported good results using this technique in 8 and 5 patients respectively.¹⁴

Dome osteotomy was also effective, combining the benefits of both techniques. Harley et al treated 26 wrists in 18 patients using this method with ligament release, achieving excellent aesthetic and functional outcomes.¹⁵

Functional and aesthetic improvements

Postoperatively, all patients, especially those with Madelung-like deformity and cosmetic concerns, showed visible improvement in wrist contour. This reinforces the dual benefit of surgery in alleviating pain and correcting deformity. Earlier studies by Ranawat and Fagg support similar indications.^{16,17}

Outcome measures

We observed statistically significant postoperative improvements in range of motion, grip strength, pain scores, radial inclination, and carpal slip. These improvements were functionally meaningful and did not compromise hand function. Enhanced grip strength likely stemmed from improved wrist mechanics and pain reduction, facilitating better tendon excursion. Comparable results were reported by Ranawat et al, who used the Darrach procedure with/without radial osteotomy.¹⁷ Our outcomes are comparable to those of

Reis, who documented similar gains in 80% of patients and aesthetic satisfaction in 88%.¹⁸

Carpal slip correction

There was a significant reduction in carpal slip (CS), decreasing from a preoperative mean of 66% to 36% postoperatively. This improvement corresponded with a reduction in radial inclination from 56° to 34°. Wrist malalignment, particularly increased ulnar inclination, alters carpal kinematics, overloads the ulnar column, and decreases lunate coverage—an early sign of pre-arthritis changes. Restoring distal radial alignment through corrective osteotomy improved wrist biomechanics, reduced pain, and reversed adaptive carpal changes.

Limitations

This study had several limitations, including a small sample size and the absence of a control group, which may restrict the generalizability of the findings. The heterogeneity in surgical techniques used across patients could introduce variability in outcomes. Additionally, the short-to-intermediate follow-up duration limits our ability to assess long-term complications or recurrence. Financial constraints also limited the routine use of advanced imaging modalities like MRI. Future studies with larger sample sizes, uniform surgical protocols, and extended follow-up periods are needed to validate these findings and optimize treatment strategies.

CONCLUSION

In our study, dorsolateral closing wedge osteotomy of the distal radius was found to be technically simpler and quicker to perform. Patients undergoing this procedure experienced reduced postoperative pain, and overall operative time was shorter. However, this technique inherently results in shortening of the forearm, which may necessitate a concurrent ulnar shortening osteotomy to restore balance.

In contrast, other osteotomy techniques—such as open wedge and dome osteotomies—do not present the same issue of forearm shortening. Open wedge osteotomy, although technically more demanding and time-consuming, allows for the excision of the anomalous Vicker's ligament through a volar approach. This approach also has the added aesthetic advantage of a more concealed scar.

Dome osteotomy offers a hybrid advantage, combining the benefits of both open and closing wedge techniques. It provides multiplanar correction without significantly affecting the forearm length and has shown promising outcomes in both cosmetic and functional parameters.

It is well established that a misaligned wrist alters carpal kinematics and increases dynamic stress on the radiocarpal joint, predisposing the joint to early osteoarthritic changes.

Our findings suggest that timely surgical correction significantly improves grip strength, range of motion, and pain relief, thereby enhancing overall wrist function. Furthermore, the cosmetic improvement following correction contributes to higher patient satisfaction and psychosocial well-being.

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