

# Monoaxial distraction of ulna to second metacarpal followed by single bone forearm in massive post infective radial bone loss

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## ABSTRACT

**Introduction:** Radial bone loss associated with gross manus valgus deformity can be managed by open reduction internal fixation using intervening strut bone graft, callus distraction using ring or monoaxial fixator, and achieving union by distraction histogenesis. These methods are particularly suitable when bone loss is small. Single or staged procedure is described for congenital as well as in acquired extensive bone loss of radius. Distraction through radial proximal to distal segments, to achieve reduction of distal radio-ulnar joint (DRUJ), is also described in acquired cases. In the present series, functional results of distraction through ulna to 2<sup>nd</sup> metacarpal is studied alongwith, functional status of hand, stability of wrist, level of patient's satisfaction are also studied.

**Materials and Methods:** 7 unilateral cases of radial loss (M = 5, F = 2) affecting 4 right hands of mean age 17 years (range 9 to 24 years) were included in this study. They were treated by distracting through ulna to 2<sup>nd</sup> metacarpal to achieve DRUJ alignment in first stage. Subsequently ulna was osteotomised and translated to distal stump of radius. It was then fixed to the distal radial remnant in 30° pronation in dominant and 30° supination non dominant hands.

**Results:** Union was achieved in all cases associated with beneficial cross union of distal ulna. Hand functions improved near to normal, with fully corrected stable wrist joint, hypertrophied ulna and without recurrence. All of them had practically complete loss of forearm rotations, however patients were fully satisfied.

**Conclusion:** This method is particularly suitable when associated with 6 cm or more radial bone loss. But when loss is small, sacrifice of one bone may not be justifiable.

**Key words:** Massive radial shaft loss, monoaxial distractor, single bone forearm, ulna to metacarpal distraction

## INTRODUCTION

Distal radial longitudinal bone deficiency described as paraxial hemimelia is a rare congenital teratogenic malformation of the upper limb which is associated with various skeletal and soft tissue anomalies.<sup>1</sup> Acquired form of such deficiency, following acute hematogenous osteomyelitis or open osteomyelitis after fracture, is though rare but not uncommon in developing countries.<sup>2-4</sup>

Occasionally, this results in varying degree of bone defect. In congenital club hand teratogenic changes of soft tissues or absence/hypoplastic thumb are added problems.<sup>1</sup> These features are absent in all acquired club hand-like deformities.<sup>5</sup> Thus management is less complicated in acquired variety. In any such condition, severe form of manus valgus deformity develops with gross dislocation of distal radio ulnar joint (DRUJ). Deficiency of radial shaft may be small to very large.<sup>6</sup>

Available options of treatment of such conditions include open reduction and internal fixation combined with shortening of ulna, with or without strut bone graft.<sup>2,3,7</sup> Staged procedures consisting of gradual correction of the DRUJ using ring fixator followed by strut bone graft fixed suitably when the defect is relatively greater.<sup>8</sup> The restoration of the length of the radius can be achieved by callus distraction using ring or monoaxial fixator.<sup>7,8</sup> Sometimes, the remaining proximal or distal or both segments may be so small or attenuated that these procedures become practically impossible. After distraction ulnar osteotomy, as second stage, its translation and fixation with distal radial remnant results in good cosmetic forearm, improves function of wrist and hand, and bring patients' satisfaction.<sup>3,9</sup>

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In such a situation, use of monoaxial distraction between shaft of ulna and 2<sup>nd</sup> ± 3<sup>rd</sup> metacarpals is also effective to achieve DRUJ alignment and subsequently, osteotomy of distal ulna at suitable level and fusing it with rudimentary distal radial segment is a viable option. Single bone forearm when is done in younger children, small amount of compensatory movements are expected to develop at humero-ulnar joint as well as at joints of the wrist permitting critical forearm rotation required for eating or maintenance of personal hygiene and writing.

We conducted the study to elicit the effectiveness of ulna to 2<sup>nd</sup> metacarpal distraction to achieve DRUJ alignment to improve cosmesis, wrist abduction, and stability and forearm length.

## MATERIALS AND METHODS

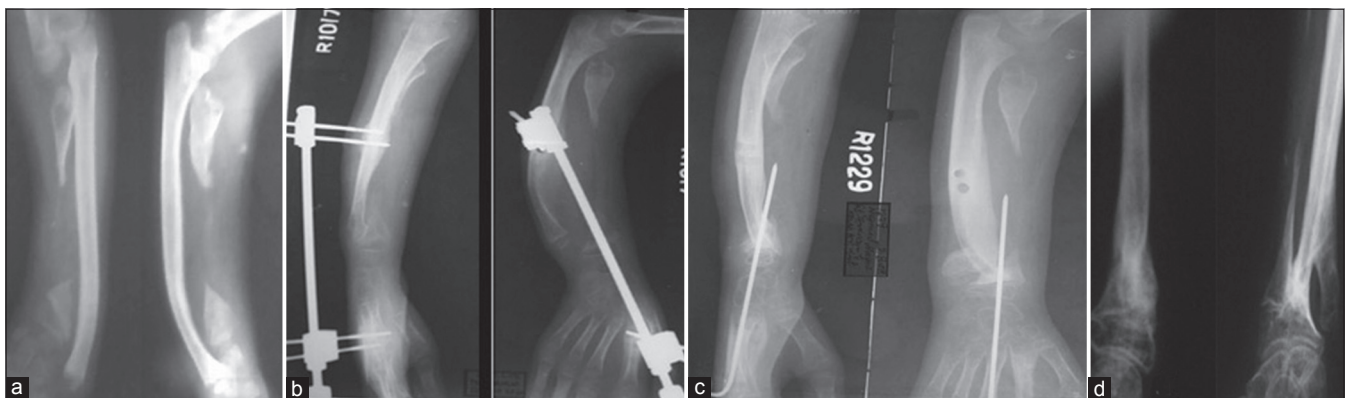
This prospective study was done August 2007 and January 2012. Seven limbs (right side-4, left side-3) of seven patients, 5 males and 2 females with mean age 17 years, (range 9-24 years) were included in this study. The cause of radial loss was chronic osteomyelitis due to acute haematogenous osteomyelitis ( $n=2$ ) or open fractures ( $n=5$ ). The fulminating infection resulted in extensive diaphyseal bone loss was [Figures 1a, 2a, and b]. Mean shortening of length of fore arm (FA) was 7.7 cm (range 6 to 11 cm). Radiologically calculated mean radial bone loss was 7.6 cm (range 6-13 cm). The cases with less than 6 cm bone loss were excluded. Bone loss was calculated by measuring the actual bone gap plus amount of ulnar dislocation in magnification adjusted preoperative X-rays. All were having radiological DRUJ dislocation, gross wrist joint instability, reduction of pinch and grip strength. Grip strength is measured using dynamometer and average of three readings was compared with sound side in percentage. Radial deviation and flexion at wrist joints was increased where as extension and ulnar deviations were restricted in all cases. The wounds were non-discharging with normal ESR

and total count at least for 6 months before considering for the procedure. Ulnae were found hypertrophied in all cases. 15° ulnar bowing (angle between longitudinal axes of proximal and distal ulna) was found in one case only (case-1). The mean forearm angles (manus valgus) are 67.1° (range 60° - 80°) [Table 1]. It is measured by the method which is followed by Shariatzadeh *et al.*<sup>10</sup> It was calculated as angle between long axes (vertical line on distal ulnar physis) of ulna and 3<sup>rd</sup> metacarpal. Exclusion criteria were congenital deformity, active (discharging sinus) infection, and major co-morbidities.

## Operative procedure

Monoplaner distractor was applied between shaft of ulna just proximal to the apex of bowing and 2<sup>nd</sup> metacarpal. 3.5 mm pin for ulna and 2.5 mm pins for 2<sup>nd</sup> metacarpal are used. Pins are directed anterolateral to posteromedially in ulna and lateral to medial in 2<sup>nd</sup> metacarpal [Figure 1b]. Distraction was started on 3<sup>rd</sup> postoperative day onwards at the rate of 1 mm per day in 4 fractions for 30 to 45 days till DRUJ alignment was restored. Additional 2 weeks distractor was kept in static mode for stabilization of stretched soft tissues. After 50 days, distractor was removed and an above elbow plaster cast was put for 2 weeks to heal pin tracks and further stabilization of soft tissue balance.

Ulna was osteotomized at a level 6 mm distal to that of the proximal end of the distal segment of the radius. It was translated to the radius to align in the line of 3<sup>rd</sup> metacarpal, so that ulnar shaft, remnant of radius and 3<sup>rd</sup> metacarpal remained in straight line. Distal radius is aligned to the ulna in 30° pronation and 30° supination respectively in dominant and nondominant hands. Dorsal inverted L fashion incision was used and fixed by a longitudinally placed 2 mm Kirshner wire (K-wire) passed through 3<sup>rd</sup> metacarpal to carpals then into radial remnant and finally to ulnar shaft. Another crossed 2 mm K-wire was also placed through ulnar shaft to distal radius to achieve rotational stability except case 1; where longitudinal K wire pierced the cortex of ulna for its bowing [Figure 1c]. Long arm cast was



**Figure 1:** X rays images (a) showing gap between segments and amount of DRUJ dislocation (b) showing after applying distractor (c) Post fusion X-ray image when longitudinal K-wire in position (d) Post operated X-ray after complete fusion

applied for 2 weeks which was changed during removal of stitches. It was continued for another 4 weeks. Longitudinal K wire removed at 6 weeks when cast is discarded but crossed one was retained for another one month usually. They were put for active mobilization of elbow, wrist, and hand joints at 6 weeks post fusion. Crossed K-wire was removed after evidence of union.

The patients were called for followup at 2 weeks [Table 2], and then regularly at interval of one month for 6 months. Subsequent followup was once in six months. The FU period ranges from 12 months to 52 months (mean – 29.7 months).



**Figure 2:** Clinical photographs (a) showing radial deviation (b) with attempted ulnar deviation (c) during writing at final followup (d) during eating at final followup

A Mayo Modified Wrist Score (MMWS) was used for assessment of hand function on the basis of pain, ability to be employed, forearm rotation and grip strength.<sup>11</sup> A score of 95 to 100 points indicate an excellent result, 80 to 90 is good, 65 to 79 is fair, and <65 points is poor.

**RESULTS**

At final FU, none had any pain, grip strength improved almost to normal level, all are able to be employed, but forearm rotations were virtually absent in all cases. Hence, MMWS were calculated to be 75 points in first 5 cases and 70 points in last two cases. Thus, results are as follows: excellent – nil, good – nil, fair – 7 (100%), poor – nil.

Other features like shape of forearm and wrist looked normal, wrist dorsiflexion improved, wrist stability improved. Mean shortening of FA was 2.1 cm (range 1-6 cm). So mean improvement of FA length in final follow up was 5 cm (range 4.5-5.5). In two younger patient (case 1 and 2), functional rotations of FA developed about 15° to 10°. In two cases, pin tract infection developed which healed with removal of pins. In final followup [Table 3] ulna hypertrophied further and patients were able to perform activities of daily living [Figures 1d, 2c and d].

**DISCUSSION**

The management of congenital radial club hand is more complicated in view of Morphological changes of congenital radial club hand like soft tissue structural deficiency and contracture, hypoplastic or absent thumb, muscle

**Table 1: Clinical details of patients**

Case	Side	Stability of wrist	SOFA (cm)	LOR (cm)	Hand-FA angle	BOU	Wrist motion (degree)	GS (%)	PS (%)	AL (%)	MMWS (points)
9 yr M	R	Unstable	11	13	80°	15°	Flexion-0-120 Ext-0-10	40	50	20	40
15 yr F	L	Unstable	7	8	70°	0°	Flexion-0-120 Ext-0-20	30	60	30	45
24 yr F	L	Unstable	6	6	65°	0°	Flexion-0-100 Ext-0-15	50	30	30	30
19 yr M	R	Unstable	6	6	70°	0°	Flexion-0-100 Ext-0-10	40	50	30	40
18 yr M	R	Unstable	6	6	60°	0°	Flexion-0-90 Ext-0-30	40	50	40	40
18 yr M	L	Unstable	7	7	65°	0°	Flexion-0-110 Ext-0-25	40	50	40	45
16 yr M	R	Unstable	7	7	60°	0°	Flexion-0-100 Ext-0-20	30	50	20	50

R=Right, L=Left, M=Male, F=Female, DOP=Date of presentation, SOFA=Shortening of forearm LOR=Loss of radius, FA=Forearm, BOU=Bowing of ulna, Ext=Extension, GS=Grip strength, PS=Pinch strength, AL=Activity level, MMWS=Mayo modified wrist score

**Table 2: Followup assessment at two weeks of treatment**

Case	Stability of wrist	SOFA (cm)	Hand-FA angle	BOU	Wrist motion (degree)	GS (%)	PS (%)	AL (%)	FR	MMWS (points)
1	Stable	6	0°	10°	Flexion-0-60 Extension-0-20	80	70	70	0°	60
2	Stable	2	0°	0°	Flexion-0-70 Extension-0-30	80	80	80	0°	65
3	Stable	1	0°	0°	Flexion-0-75 Extension-0-40	70	70	85	0°	60
4	Stable	1	0°	0°	Flexion-0-50 Extension-0-30	80	75	90	0°	65
5	Stable	1.5	0°	0°	Flexion-0-60 Extension-0-20	70	70	90	0°	65
6	Stable	1.5	0°	0°	Flexion-0-60 Extension-0-40	80	75	90	0°	65
7	Stable	2	0°	0°	Flexion-0-60 Extension-0-20	75	70	90	0°	60

SOFA=Shortening of forearm, FA=Forearm, BOU=Bowing of ulna, GS=Grip strength, PS=Pinch strength, AL=Activity level, FR=Forearm rotation, MMWS=Mayo modified wrist Score



imbalance of hand and wrist post infective massive bone loss secondary to chronic hematogenous osteomyelitis and open fractures also present an therapeutic challenge.

All the reported cases are as consequences of chronic osteomyelitis (OM). The deformities finally appeared clinically are similar to that of congenital radial club hand Brayne type III or IV.<sup>12</sup> Distal remnant of radius was present in all cases. However, hand-forearm angle remains similar in both situations though ulnar bowing was present in one cases only.<sup>10</sup> Scarring, due to previous disease and operations, brought some difficulties during ulnar osteotomy and its translation.

Netrawichien suggested radial club hand-like deformity resulting from osteomyelitis of the distal radius which can be corrected by single-stage procedure and centralization of ulna.<sup>7</sup> This procedure required considerable resection of ulna produce further shortening of forearm and loss of tension of tendons. Hence we felt such procedure is inappropriate in our case. Jain and Sinha (2005) recommended that up to 4 cm bone loss can be reconstructed with intervening bone graft in infected long bone defects.<sup>3</sup> However, Gupta and Kumar (2010) believed that up to 7.5 cm gap can be treated by tricorticocancellous bone graft under compression in infected gap NU of FA.<sup>2</sup> But status of the DRUJ was not discussed in their study particularly when loss was in the radius. The arbitrary value of 6 cm was taken in this study as tricortical bone of that length is difficult to harvest in young individuals. More over this value is not a percentage of total length of radius; as a result it is likely to produce different implications in shorter and taller individuals. In present study subjects are of lower age group. Sabharwal *et al.* described staged protocol for congenital club hands by distraction with ring fixator followed by centralization and obtained good result in all four affected hands.<sup>13</sup> With similar procedure Sabharwal reported good result in two cases of atrophic nonunion also.<sup>8</sup> In current series distraction is achieved by monoaxial distractor. Malki *et al.* reported a case of infected nonunion with extensive bone loss which was treated by modified Hey-Grove procedure and obtained similar result.<sup>9</sup> Whereas Azhar-Ul-Haque reported opined it as a salvage procedure after treating one such case

of hematogenous OM treated by single bone FA.<sup>14</sup> Jain and Sinha considered one bone forearm a good option in special situation similar to our cases.<sup>3</sup> By callus distraction, it allows gain in length and can be utilized to achieve union at the docking site. But complexities of instrumentation, its cost, neurovascular damage, duration of treatment, pin track infection are important issues.<sup>6,15</sup> Callus distraction using monolateral fixator by Zhang *et al.*<sup>15</sup> in 13 patients gained length up to 8.2 cm with mean healing index 43 days/cm. They reported good functional and cosmetic results in all of their cases. In present series, time required is much shorter.

In previously reported cases, distraction was done between segments of radius to gain length of the FA as well to achieve reduction of DRUJ.<sup>7,9,14</sup> The pin negotiation may be difficult and chance of injury to nerve or vessel is a potential risk in these cases where proximal segment of radius is very short and thin and is placed with in scar tissues. We achieved DRUJ reduction using monoaxial distractor where two threaded pins are placed just proximal to apex of the ulnar bowing and two distal pins are put through second and third metacarpals. It is very simple day care procedure and cost of instrumentation is also considerable low. Distraction period is considerable less in comparison to callus distraction procedure. Pins are not interfering with the fusion area. Some amount of ulnar bowing is also corrected during distraction process as the bones are relatively plastic. This particular advantage may not be available in adult individual. Ligamentotaxis of wrist provides early restoration of movement.

Once the ulnar osteotomy is performed and proximal end of ulna was shifted to distal radius the continuity of haematoma allowed inverted T-shaped cross union which is advantageous for DRUJ stability and prevent further development of deformity, as a result of growth contribution from distal ulnar growth plate in young individuals. The reduction of length of forearm is due to dislocation of DRUJ, combined with reduced contribution of longitudinal growth from damaged distal radial growth plate in skeletally immature patients (case 1) alongwith length loss due to bowing of ulna. Whereas radial bone loss is calculated by gap between segments of radius plus amount of ulna

**Table 3: Assessments at final followup**

Case	Stability of wrist	SOFA (cm)	Hand-FA angle	BOU	Wrist motion (degree)	GS (%)	PS (%)	AL (%)	FR	MMWS (points)
1	Stable	6	0°	10°	Flexion-0-85 Extension-0-80	100	100	>95	15°	75
2	Stable	2	0°	0°	Flexion-0-90 Extension-0-75	100	100	>95	10°	75
3	Stable	1	0°	0°	Flexion-0-90 Extension-0-80	100	95	100	0°	75
4	Stable	1	0°	0°	Flexion-0-90 Extension-0-75	100	95	100	0°	75
5	Stable	1.5	0°	0°	Flexion-0-85 Extension-0-75	100	100	100	0°	75
6	Stable	1.5	0°	0°	Flexion-0-80 Extension-0-70	100	95	100	0°	70
7	Stable	2	0°	0°	Flexion-0-75 Extension-0-70	100	90	95	0°	70

SOFA=Shortening of forearm, FA=Forearm, BOU=Bowing of ulna, GS=Grip strength, PS=Pinch strength, AL=Activity level, FR=Forearm rotation, MMWS=Mayo modified wrist score

dislocated at DRUJ. In the present series, compared FA length reduction is due to intrusion of osteotomized ulna into the distal radial stump in all cases except the first where ulnar bowing is an additional contributing factor. Length of FA in FU period is maintained by growth contribution from growth plates of both distal ulna and radius. Apprehended disproportionate over growth from distal ulna did not cause recurrence of deformity due to connection by transverse bony bar.

All three important hand functions are perfectly restored excepting marginal reduction of grip strength in two cases. During fusion rotational alignment is considered depending on the functional need of the limb. In involved dominant hands distal radius is allowed to fuse with proximal ulna in 30° pronation, where as in non dominant hand it is 30° supination. None have any problem during writing and other functions. However Sayre (1893) and Castle (1975) preferred midprone to little pronation and neutral rotation FA position.<sup>1,16</sup> The ulnar bowing is further corrected in one and hypertrophied in all as compared with sound side in before surgery and at final FU by X-rays. Thus, negate the need for corrective osteotomy. The girth increment of ulna is adequate to provide resistance to fragility.

Use of plate is technically difficult because of short attenuated distal radial stump and demands its removal subsequently. Yet it cannot eliminate POP cast immobilization to achieve beneficial ulnar distal stump cross union [Figure 1d]. Overall restoration of motion of wrist and elbow is not a problem in any of the cases.

Though all cases of this series fall in the fair result group in Mayo Modified Wrist Score criteria yet they are highly satisfied. This is because forearm rotation was allotted 25 points and which is almost completely absent in all cases.

One bone forearm though cause gross rotational limitation patients are usually satisfied. The applicability of this mode of treatment is to be investigated in some other situations like massive bone loss following graft failure in a treated case of tumor after wide margin resection. However, there is no denying that callus distraction or intervening strut bone graft is a preferred method where bone loss is relatively less.<sup>2,3,6,15</sup>

We conclude children and adolescents with massive bone loss of the radius following chronic osteomyelitis can be treated by monoaxial distractor application from ulna to 2<sup>nd</sup>

metacarpal to achieve DRUJ alignment followed by fusion of ulnar shaft with the remaining distal radius, sequentially, is a good option.

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