

# LIGAMENTOTAXIS AND BONE GRAFTING FOR COMMINUTED FRACTURES OF THE DISTAL RADIUS

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The conventional treatment of comminuted fractures in the distal radius has been unsatisfactory. We therefore made a prospective study using the principle of ligamentotaxis and primary cancellous bone grafting as the uniform method of treatment. Ligamentotaxis was maintained by using an external fixator for three weeks only, after which a carefully monitored programme of rehabilitation was given.

We have reviewed 72 consecutive distal radial fractures after a follow-up of 7 to 40 months (average 11 months). Reduction had been maintained during healing and over 80% of patients regained full range of movement in hands, wrists and forearms with strong and pain-free wrist function. Complications were infrequent and gave no real problems. We conclude that distraction, external fixation and bone grafting appears to be an excellent method of treating comminuted fractures of the distal radius.

The conventional treatment of comminuted fractures of the distal radius has been disappointing. Closed reduction and plaster often allows early redisplacement with angulation or late collapse. Open reduction is possible but there is no effective means of internal fixation. The use of external fixators has shown promising results, but, because of the severe displacement and comminution, the impaction of metaphyseal bone still results in some loss of length. In addition, even though fractures can be reduced and held adequately, an external fixator has to remain on for a long period to achieve satisfactory union.

To avoid collapse of the fracture and to shorten the period of external fixation, we used primary cancellous bone grafting as an adjunct to external fixation in a prospective study.

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**Table I.** Classification of 72 comminuted fractures of the distal radius (Frykman 1967)

	Number	Per cent
I Extra-articular, no fracture of ulna	1	1.4
II Extra-articular, fracture of ulna	3	4.2
III Intra-articular radiocarpal, no fracture of ulna	6	8.3
IV Intra-articular radiocarpal, fracture of ulna	13	18.0
V Intra-articular radio-ulnar, no fracture of ulna	8	11.1
VI Intra-articular radio-ulnar, fracture of ulna	7	9.7
VII Intra-articular radiocarpal and radio-ulnar, no fracture of ulna	15	20.8
VIII Intra-articular radiocarpal and radio-ulnar, fracture of ulna	19	26.4

## PATIENTS AND METHODS

Of 72 consecutive patients with comminuted fractures of the distal radius 53 were men and 19 women. Their ages ranged from 18 to 65 years (average 35.6 years); 44 fractures were right-sided. The original radiographs showed that 73.6% of the fractures were moderately to severely comminuted, with marked or severe displacement in 81.9%. Over 90% were intra-articular. According to Frykman's classification (1967), 26.4% of the fractures were type III and IV, 20.8% were type V and VI, and

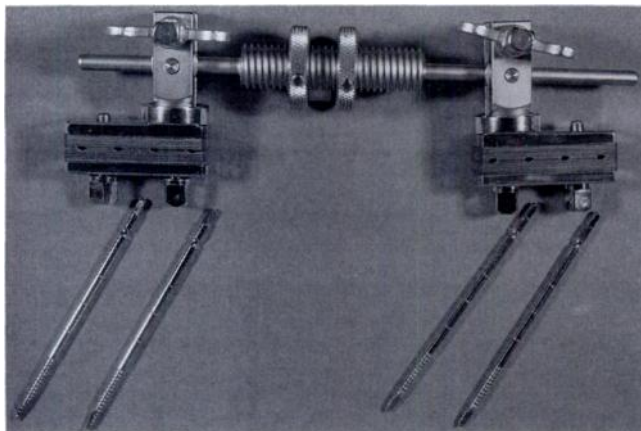


Fig. 1

The small 'C' model Hoffmann external fixator which is used to distract the wrist joint.

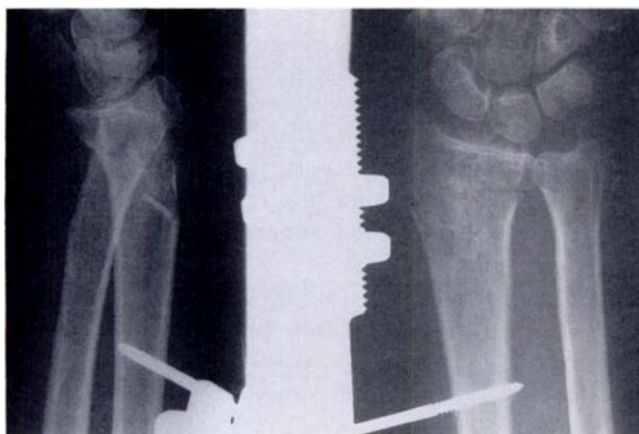


Fig. 2

Radiograph with cancellous grafts in place.

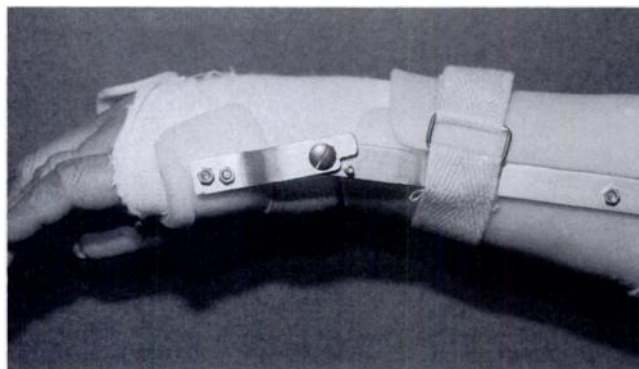


Fig. 3

Short-arm hinge brace, which allows free flexion but limits extension.

47.2% of the fractures were type VII and VIII. The remaining 5.6% of fractures were extra-articular with severe comminution and displacement (Table I).

A half-frame Hoffmann external fixator (the small 'C' model), consisting of two ball-joint clamps linked by an adjustable connecting rod, is applied (Fig. 1). In the distal clamp the proximal pin is inserted into the bases of the second and third metacarpals to ensure good anchorage. Through the proximal clamp the pins are inserted at least 50 mm proximal to the joint line to avoid injury to the superficial sensory branch of the radial nerve (Schuind, Donkerwolcke and Burny 1984), and care is taken that the tips do not interfere with rotation of the forearm.

Once the pins and external fixator are aligned, the fracture is reduced by distraction and manipulation, under fluoroscopic control. Reduction is maintained by tightening the proximal and distal ball joints, and distraction is provided at the final stage by adjusting the connecting rod. While the fixator is being applied, another surgeon harvests cancellous bone from the iliac crest.

After satisfactory reduction and distraction have been achieved, a short longitudinal incision is made on the dorsum of the wrist and blunt dissection exposes the fracture site without damaging important structures. Cancellous bone chips are then packed into the fracture cavity, particularly distally towards the radial joint surface. In most cases a substantial volume is needed to fill the large cavity created by comminution (Fig. 2). The wound is then closed and the limb bandaged. No drainage is used.

Mobilisation is started the day after the operation, with emphasis on finger movements and rotation of the forearm. Flexion and extension of the wrist is not possible with the external fixator in position. Daily pin-track care includes antiseptic washing.

At the end of the third week, the pins and external fixator are removed without anaesthesia and the wrist placed in a short-arm brace which allows full flexion but no extension (Fig. 3). At six weeks, the brace is removed and full wrist mobilisation allowed.

Two occupational therapists made serial assessments of pain, range of movement at forearm, wrist and hand, and power of grip. Clinical and radiological assessments were all made by one of the authors (KSL).

## RESULTS

**Clinical.** The 72 patients were followed up for 7 to 40 months, averaging 11 months.

**Pain.** Movement gave some pain in the initial stages of mobilisation, but its intensity gradually decreased and at six months, only six patients had mild pain in the wrist and 11 had some local pain at the ulnar styloid.

**Range of movement.** All patients retained a full range of movement in the hands and fingers. There was some

limitation of forearm rotation in the early phase, before removal of the fixator, but effective rotation (mean 146.5°) was regained in over 95% of patients at the end of six months.

All wrist movement was blocked during the first three weeks, and extension was not allowed for an additional three weeks. At seven weeks, flexion and extension were encouraged and recovery was rapid. All but two patients regained a good range with a mean total of 137.5° at six months.

**Grip.** The power of hand grip gradually improved during rehabilitation and at six months the average was 70% of the uninjured side.

**Radiology.** The angles of volar tilt and of the radial articulation were measured on the radiographs.

**Volar tilt.** Using the opposite sides as standards for comparison, nearly normal angles of volar tilt were achieved after reduction, and this was maintained in all but three patients. Mild collapse in three cases was due to graft displacement in one patient and to premature mobilisation in extension in the other two.

**Radial articulation.** There were always mild losses in this angle when distraction was released on removal of the external fixator: the mean loss was 2.2°. This is a small amount and no further losses were seen throughout rehabilitation or at the final assessment.

**Healing pattern.** We used the classification of Uthoff and Rahn (1981) shown in Table II: 76.4% showed type Ib healing, indicating that it had occurred in the presence of inter-fragmentary stability.

An example of the radiological result is shown in a 25-year-old man with a type VIII fracture (Fig. 4). Reduction was maintained by the external fixator (Fig. 5), and the radiograph taken at the end of six months shows normal tilt and radial articular angles (Fig. 6).

**Complications.** There were no serious pin-track infections or donor site complications, though mild early pain at the donor site was inevitable. Complications such as wound haematoma, stitch abscess and paraesthesia were not seen, probably because the cancellous graft had been harvested through a 40 to 50 mm wound without periosteal stripping.

One patient sustained a fracture of the second metacarpal because the 3 mm half-pin was too large for a relatively small metacarpal shaft. The fracture united uneventfully after the distal half-pin had been re-inserted more distally, transfixing the third metacarpal to maintain position.

One patient had a neuroma of the superficial sensory branch of the radial nerve with marked hyperaesthesia while three others had similar but much milder symptoms; all recovered fully and spontaneously. Two patients had a transient carpal tunnel syndrome, and two others developed reflex sympathetic dystrophy. The latter two patients required lengthy physiotherapy but recovered completely. There were no cases of tendon rupture or of infection at the fracture sites.

Six fractures (8.8%) had not united radiologically at 6 to 8 weeks but did so after another four weeks of bracing. All the complications required a longer rehabilitation period, but the patients all regained good ranges of movement.

## DISCUSSION

Bohler first advocated the use of fixed-pin traction to maintain the reduction of comminuted fractures of the distal radius in 1929 (Bohler 1956); since then this method has been recommended and modified by many surgeons. External fixators provide good mechanical stability, and fixed traction prevents shortening due to either bone loss or later resorption of cancellous bone from the metaphysis.

Current reports reflect the growing popularity of modern external fixators for these fractures, but the recommended duration of use varies and sometimes extends to between 8 and 12 weeks (Cooney, Linscheid and Dobyns 1979; Jakob and Fernandez 1982; Vidal et al 1983; Schuind, Donkerwolcke and Burny 1984). The prolonged use of external fixators leads to pin-track infection, loosening, dislodgement, joint stiffness, osteopenia, and reflex dystrophy. In addition, intra-articular fragments are not always reduced by distraction alone. Knirk and Jupiter (1986) reported that when an external fixator was used without grafting, there was often collapse at the fracture site after prolonged distraction of a severely comminuted fracture.

In our series, there were no serious complications related to the external fixators, presumably because of the shorter period of application. Our single case of injury to a sensory branch of the radial nerve was due to a technical error.

Most patients regained good ranges of movement of the wrist and forearm, and all obtained normal active hand movements. Since the average follow-up was only 11 months, some patients could expect further improvement.

The use of cancellous bone grafts not only reduces the period of external fixation and supports the articular surface, but also promotes bone healing. Some of our cadaveric studies (see Appendix) showed that packing cancellous bone chips into these comminuted fractures increased the rigidity of reduction fourfold (Kinninmonth, Evans and Leung 1987). The very small loss of radial articular angle (mean 2.2°) seen after the removal of the external fixator at the end of the third week further demonstrates the stabilising role of the graft.

The combination of ligamentotaxis (Vidal et al 1983) and cancellous bone grafting produced excellent clinical and radiological results. As Green (1975) pointed out, good functional results usually follow good anatomical results. Our method utilises both the biological and the mechanical effects of cancellous bone grafting, enabling us to reduce the duration of external fixation to three

**Table II.** Patterns of healing (Uthoff and Rahn 1981)

	Number	Per cent
<b>I Internal trabecular healing</b>		
a Contact healing	11	15.3
b Gap healing	55	76.4
<b>II Cortical shell healing</b>		
a With external callus	6	8.3
b No bridging callus	0	0

**Table III.** Mean forces required to close the 0.5 cm fracture gap

	Force (N)	
	Dorsiflexion	Radial deviation
No treatment	20	40
Cancellous bone packing	80	100
Kirschner wires	60	90
Cancellous bone packing and Kirschner wires	130	150

weeks and to obtain a high proportion of type I healing. Routine grafting also allowed most intra-articular defects to be elevated; this prevented post-reduction shortening and should reduce the incidence of later osteoarthritis. We recommend this method of treatment for comminuted fractures of the distal radius for all except elderly patients and those in whom a perfect closed reduction can be obtained. No other method appears to be as technically simple and to give such excellent functional results.

## APPENDIX

**Biomechanical study on the effect of cancellous bone grafting on the stability of comminuted fractures of the distal radius.** The skin and muscles were removed from adult cadaveric forearms but care was taken to preserve the integrity of the wrist ligaments. Two transverse, parallel saw cuts were made 1.0 cm deep and 0.5 cm apart in the distal radius, 1.5 cm from the articular surface. A longitudinal cut was then made from the midpoint of the proximal cut to the articular surface, again to a depth of 1.0 cm.

With the wrist in 45° of dorsiflexion and the palm and forearm resting against a specially designed jig, a longitudinal force was applied by blows on the olecranon. The distal radius was felt to fracture, and this fracture had a consistent pattern, being mainly transverse and comminuted, the distal fragments being separated from the proximal cut by a gap of 0.5 cm when the arm and hand were in neutral position.

Though the volar surface fractured, its periosteum remained intact,

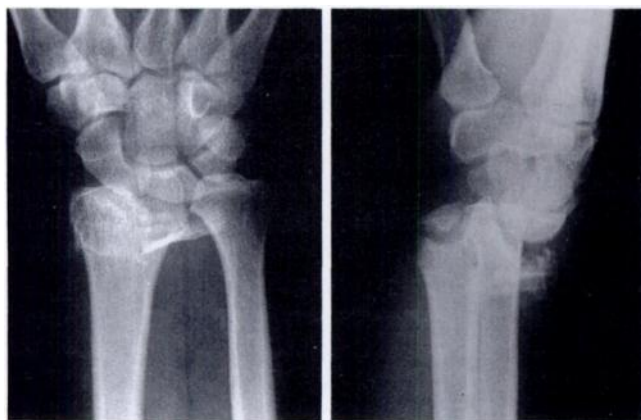


Fig. 4



Fig. 5

Radiographs of a type VIII fracture in a 25-year-old man. Figure 4 - Before operation. Figure 5 - After reduction and grafting with the external fixator in position (left) and later with the brace (right). Figure 6 - Six months later, showing normal volar and radial articular angles.



Fig. 6

as did the ligaments of the wrist. On Frykman's classification (1967) the fracture was of type VII.

The forearm was then held on a flat platform in a special jig and one screw was inserted into the dorsal surface of the proximal part of the third metacarpal and another into the radial surface of the proximal part of the second metacarpal on the radial side. These screws served as traction points for two strings passing proximally which could produce dorsiflexion and radial deviation. When this force was applied, the 0.5 cm fracture gap present in the neutral position became closed. Mechanical testing then centred on measuring the strength of pull necessary to eliminate the standard 0.5 cm fracture gap.

Testing was performed under four experimental conditions:

- 1) no treatment,
- 2) cancellous bone chips packed into the fracture site,
- 3) double Kirschner wires drilled through the radial styloid, across the fracture gap and engaging the ulnar surface of the radius proximal to the fracture, and
- 4) cancellous bone chips as well as the Kirschner wires as in method 3.

As much graft as possible was impacted into the fracture, particular attention being given to filling the cavity distally to support the articular surface.

Spring balances were used to pull on the dorsal and radial strings to close the standard 0.5 cm gap. Ten specimens were studied; each experiment was repeated three times, the grafts being re-inserted between tests. The results are given in Table III as the mean forces necessary to close the gap.

While it was impossible to reproduce the condition of a comminuted fracture completely, the general anatomical result was similar in the clinical and experimental situations. The intact periosteum could be seen to be stretched when the crumbled distal radius was packed tightly with cancellous chips, and the forces required to produce the standard 0.5 cm approximation were greatly increased. The stability achieved using Kirschner wires only was, however, slightly inferior to that of bone grafting, but both together gave an even more firm position.

Tight packing with bone graft produces better load-bearing, fills space and stretches and tightens the residual periosteum. The compressive strength of bone tissue is proportional to the square of its

apparent density (Carter and Hayes 1977) so highly compacted cancellous bone provides good support for these metaphyseal fractures.

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