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Local osteopenia associated with management of intra-articular distal radial fractures by insertion of external fixation pins in the distal fragment: prospective study

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ABSTRACT

Purpose. To assess the restoration of the bone mass of the distal radius following the use of implants in the distal radial fragment. Highly comminuted Frykman type 7 and 8 fractures were studied to determine whether the use of fixation pins in the comminuted distal radial fragment leads to osteopenia in the distal radial fragment after healing of the fracture.
Methods. As part of a clinical trial, 30 patients with comminuted intra-articular fractures of the distal radius were treated with closed reduction, external non-bridging fixation, and early postoperative mobilisation. To detect local osteopenia, bone density measurements were taken at the distal metaphysis and mid-diaphysis following healing of the fractured radius and the contralateral unaffected radius in 12 patients.
Results. The mean age of the 12 patients for whom bone density measurements were recorded was 52.5 years (range, 39–87 years). There were 9 females and 3 males included in the study. Seven patients had a Frykman type 8 fracture and 5 patients had a Frykman type 7 fracture. Significant osteopenia was absent despite the use of four 2.5-mm fixation pins in the distal fragments of the healed distal radial fracture. The median value of the maximal step was 2.8 mm (range, 0–9.1 mm). The median value of the intra-articular interfragmentary gap was 1.8 mm (range, 0–13.4 mm).
Conclusion. The findings of this study do not suggest long-term osteopenia following the use of four 2.5-mm pins in the distal fragments. The non-bridging fixator, by allowing early physical activity, possibly led to satisfactory functional and structural results.

Key words: *distal radial fractures; external fixation; post traumatic osteopenia*

INTRODUCTION

The use of external fixation in the treatment of comminuted intra-articular distal radial fractures has

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been established.[1–3] Most of the systems that are used span the wrist (bridging fixators) and usually immobilise the joint. A non-bridging fixator has also been used to provide stable fixation while permitting early mobilisation of the wrist.[4] Fixation involves the use of 2 pairs of threaded pins in the distal fragments that are then linked with a central dorsal pin in the proximal radial diaphysis. This procedure, however, potentially leads to residual voids at the pin sites in the bone, thereby compromising structural integrity. If local osteopenia is present, there may be increased risk of refracture and collapse.

The objective of this study was to assess the restoration of the bone mass of the distal radius following the use of implants in the distal radial fragment. We studied highly comminuted Frykman type 7 and 8 fractures to determine whether the use of fixation pins in the comminuted distal radial fragment leads to osteopenia in the distal radial fragment after healing of the fracture.

MATERIALS AND METHODS

30 patients were treated with the Delta Frame External Fixator (Mathys Medical Ltd, Bettlach, Switzerland) as part of a clinical trial.[4] Formal approval from the Ethics Committee of our institution was obtained. Informed written consent was obtained from each patient.

For each patient, four 2.5-mm self-tapping pins were used to fix the distal radial fragments. The 4 distal pins were placed in the distal fragments within one cm of the distal articular surface of the radius. One 2.5-mm self-tapping pin was used in the radial diaphysis of the proximal fragment. Following reduction of the fracture under fluoroscopic control, the pins were linked with connecting rods through universal joints creating a delta configuration, which stabilised the fracture. The wrist was mobilised after one week postoperatively. The clinical outcomes of these patients were published in 1998.[4]

12 patients were available for determination of bone density indices and assessment of radiological parameters of the healed distal radial fracture. All had highly comminuted intra-articular fractures. Seven patients had a Frykman type 8 fracture and 5 patients had a Frykman type 7 fracture (Knirk and Jupiter 1986, Frykman 1967). The average time of in situ use of the external fixator was 33 days. The average duration between application of the external fixator and the measurement of bone density was 27 months (range, 18–30 months).

Postoperative computed tomography (CT) was performed with a CTi Hi-Speed Advantage scanner (GE; Milwaukee, Wisconsin, United States). Helical scans were acquired in the coronal plane with one-mm collimation and a pitch of 1.0 mm. Coronal and sagittal reformations were obtained and an Advantage workstation (version 3.1; GE; Milwaukee, Wisconsin, United States) was utilised to perform measurements of maximal intra-articular step and gap according to the longitudinal axis method of Cole et al.[5] However CT was not used to assess bone density or bony architecture, because the technique provided limited information in that regard. The functional assessment of these patients had been conducted earlier.

Bone density measurements were performed using the Lunar DPX-L (Dexa, Wisconsin, United States). Density measurements were obtained in the distal radius within one cm of the articular surface (which is where the distal radial external fixation pins were placed) in order to assess the quantity of subchondral bone. The sample size was 0.6 mm $\times$ 1.2 mm and the collimation size was 0.84 mm. Measurements were also obtained from the mid-diaphysis of the radius at a site remote from the fracture. This site varied from 240 mm to 290 mm, from the distal radial articular surface, depending on the length of the individual radius. Similar measurements were performed on the contralateral (uninjured) side.

The bone density was considered normal if it was within 2 standard deviations of age-, sex-, and weight-matched reference values that had been derived from a control population provided by software on the Lunar DPX-L bone densitometer. Bone density was defined as low or high when values were more than 2 standard deviations below or above reference measurements, respectively.

RESULTS

There were 9 females and 3 males included in the study. The mean age of the 12 patients for whom bone density measurements were recorded was 52.5 years (range, 39–87 years). None of the 12 patients, who were all right hand dominant, reported any deviation of their functional status from earlier assessments,[4] and all were satisfied with the outcome. Distal radial fractures involved the right and left forearms in 5 and 7 patients, respectively.

Seven patients had a Frykman type 8 fracture and 5 patients had a Frykman type 7 fracture (Knirk and Jupiter 1986, Frykman 1967). According to the Arbeitsgemainschaft fur Osteosynthesefragen (AO)

Table
Characteristics of patients with intra-articular distal radial fractures

Patient No.	Extremity	Fracture	Dominance	Age (years)	Bone mineral density (g/cm^2)	Dist Rad*	Mid Rad†	Follow-up since injury (months)	Frykman classification	A.O.‡ classification
1	RT§	—	RT	87	0.206	N¶	L**	28	8	C3.2
1	LT‖	LT	—	87	0.25	L‡	L	28	8	C3.2
2	RT	RT	RT	76	0.364	N	L	30	8	C3.1
2	LT	—	—	76	0.496	H††	L	30	8	C3.1
3	RT	—	RT	51	0.352	N	N	18	7	C3.2
3	LT	LT	—	51	0.352	N	N	18	7	C3.2
4	RT	—	RT	58	0.383	N	N	18	8	C3.2
4	LT	LT	—	58	0.368	N	N	18	8	C3.2
5	RT	—	RT	64	0.29	L	L	27	8	C2.2
5	LT	LT	—	64	0.263	N	N	27	8	C2.2
6	RT	—	RT	73	0.196	L	L	32	8	C3.2
6	LT	LT	—	73	0.244	L	L	32	8	C3.2
7	RT	RT	RT	40	0.404	N	N	29	7	C2.2
7	LT	—	—	40	0.363	N	N	29	7	C2.2
8	RT	RT	RT	77	0.31	N	L	33	7	C2.2
8	LT	—	—	77	0.237	L	L	33	7	C2.2
9	RT	—	RT	55	0.327	L	L	31	8	C2.1
9	LT	LT	—	55	0.424	N	L	31	8	C2.1
10	RT	—	RT	54	0.353	L	N	18	7	C2.2
10	LT	LT	—	54	0.388	N	N	18	7	C2.2
11	RT	RT	RT	39	0.433	H	N	30	8	C3.1
11	LT	—	—	39	0.467	H	N	30	8	C3.1
12	RT	RT	RT	82	0.32	H	H	30	7	C2.1
12	LT	—	—	82	0.26	N	H	30	7	C2.1

* Dist Rad bone density of the distal radial metaphysis
† Mid Rad Bone density of the mid radial diaphysis
‡ A.O. Arbeitsgemainschaft fur Osteosynthesefragen
§ RT right
‖ LT left
¶ N normal bone density
** L low bone density
†† H High bone density

classification (Muller et al 1990), all the fractures were within the C class for distal radial fractures—namely, C2.1 (n=2), C2.2 (n=4), C3.1 (n=2), and C3.2 (n=4).

The bone density of the injured distal radius was normal in 8 cases, below normal in 2 cases, and above normal in 2 cases (Table). The bone density of the injured radius was normal or high in all 5 patients with Frykman type 7 fracture as well as 5 of the 7 patients with Frykman type 8 fracture. The bone density of the 6 injured radii with a C2 pattern was normal in 5 cases and high for one. Of the 6 injured radii with a C3 pattern, the bone density was normal for 4 patients and low for 2.

The bone density was normal or high in 5 of the 7 injured radii of the non-dominant upper limb (left distal radius) and all 5 of the injured radii of the dominant upper limb (right distal radius). Low bone density was noted in 2 of the injured radii of the non-dominant upper limb (left distal radius). Low bone density of the uninjured distal radius was recorded in one patient who had a Frykman 8-AO C3.2 fracture with a low reading of the injured distal radius. A low bone density measurement was recorded of the uninjured distal radius of the single patient with a Frykman type 7 fracture, as well as a normal reading of the injured distal radius. The bone density of the injured radius proximal to the fracture was normal in 6 cases, below normal in 5 cases, and high in one case.

An intra-articular step of less than one mm was noted at the distal radius (radiocarpal joint) in one case and more than one mm in 11 cases. The median value of the maximal step was 2.8 mm (range, 0–9.1 mm). The median value of the intra-articular interfragmentary gap was noted to be 1.8 mm (range, 0–13.4 mm).

DISCUSSION

A recent randomised study has demonstrated that non-bridging external fixation for distal radial fractures is superior to bridging external fixation.[6] The superiority has been attributed to early mobilisation of the wrist. Functional results of the current series also confirm a satisfactory outcome with the non-bridging external fixator—Delta frame.[4] None of the patients in the current series required bone grafting despite the comminute nature of the fractures. The fixation pins engaging the distal radial fragment were used to restore and preserve volar angulation and radial height.

There has, however, been concern with the technique. The introduction of four 2.5-mm diameter pins in the already comminute fragment of the radius is likely to predispose or cause osteopenia by displacing an equivalent volume of bone (according to the law of conservation of mass). Following removal of these pins, a volume of space occupied by these pins remains as a void. This space, if not replaced by osteoid (and subsequent mineralisation), could lead to extra- and intra-articular collapse of the healing intra-articular distal radial fracture. It could also predispose to a refracture of the distal radius.

Total restoration of bone loss related to distal radial fractures should be completed by approximately 26 months after the injury.[7] The findings of the current series comply with this guideline, despite the use of fixation pins in the comminute fragments of the distal radius. Nilsson and Westlin's study[8] also demonstrated that Colles fracture (distal radial fracture) is associated with restoration of the lost mineral. Our study is limited by the fact that bone density measurements were taken neither at the time of injury or surgery, nor in the early postoperative and rehabilitative phase. The bone mineral content following distal radial fractures is known to be at its minimum of 4 months following injury.[8] Thus, early measurements would have helped in determining the bone mineral loss after the fracture and its subsequent restoration.

The bone density of the distal radius was normal in all 5 patients with Frykman 7-AO C2 fractures and in 5 of the 7 patients with Frykman 8-AO C3 fractures. Fracture classification with the AO system revealed normal-to-high bone density in all 6 patients in the C2 category. Four of the 6 patients in the C3 category had normal bone density. Less comminution of the fracture fragments of the distal radius in Frykman 7-AO C2 fractures (and consequently less disruption of the soft tissue–vascularity of the bone) may possibly explain this observation.

Of the 2 patients with Frykman 8-AO C3.2 fractures and low bone density, a patient aged 73 years had low bone density of the uninjured distal radius. This finding indicates a generalised condition rather than regional post-traumatic osteopenia or osteoporosis. The fractures in both cases involved the non-dominant upper limb. Although this case series was heterogenous in age, all the patients included were active and functionally independent.

Some limitations of this study should be noted. Firstly, a limited portion of the bone at the fracture site was sampled for bone density (0.6 mm × 1.2 mm with 0.84-mm collimation). Secondly, sclerosis or incorporated bony fragments at the fracture site may have resulted in higher density readings than might have otherwise been the case. This factor may explain why 2 patients in our study had higher-than-expected bone density readings. Nevertheless, to the best of our knowledge, no other study has reviewed the effects of fixation pins in distal radial fracture fragments on the eventual local bone mineral density following healing of a distal radial fracture managed by a non-bridging external fixator.

Krolner et al.[7] showed that a substantial bone loss occurs from the ipsilateral forearm following a Colles fracture (bone density determined at a means of 18 months' post-fracture). They further demonstrated that the bone loss from fractured dominant forearms was substantially more than that in fractured non-dominant forearms. They concluded that the loss of the dominant forearm activity per se (because of immobilisation) is responsible for the marked bone loss in fractured dominant forearms. Karlsson et al.[9] noted that post-traumatic osteopenia was evident in lower extremity trauma cases in the injured leg decades after the injury. Their study, however, did not mention the activity levels of the patients. In our study, all the fractured distal radii of the dominant upper limbs displayed normal or high bone density. The satisfactory bone density levels could be a result of early postoperative mobilisation and enhanced use because of dominance.

The bone density of the 12 patients in our study was determined between 18 and 30 months after the application of the fixator. However, because the aim of this study was to determine the extent of restoration of the bone mass in the distal radius (and not the maturation of callus or remodelling), the range of time elapsed since the application should not be a significant factor. Both patients who had low bone density readings were assessed more than 26 months after fixator application (28 and 32 months), which was beyond the 26-month period indicated by Krolner et al.[7] By this time, the bone mass should have been restored in the distal radial fracture.

Over the past decade, considerable attention has been focused on the accuracy of reduction of the intra-articular surface of the fractured distal radius. Most authors have stressed the importance of reduction in which the intra-articular step is eliminated or less than 2 mm.[10] Given the comminution associated with intra-articular fractures, it is necessary to either replace the defect with bone graft[11] or hold the radius out to length until bony consolidation occurs.[12–14] Failure of either of these techniques can result in proximal depression of the intra-articular fragments and an intra-articular step at the distal radius. These methods usually involve immobilisation of the wrist until fracture healing.

CT scans are better than radiographs in demonstrating the extent of articular surface depression.[15] Furthermore, the interpretation of the residual intra-articular step of the distal radial articular surface on plain radiographs is subject to variation (30% underestimation or overestimation).[5] Despite an average residual step of 2.8 mm (as measured on CT scans), none of the patients in our series had any functional deficits or significant pain. This finding indicates that the 2-mm step criterion noted on radiographs in previous series could reflect an error in measurement. Alternatively, this finding may also indicate that the intra-articular step may not contribute to any early symptomatology. Radiological evidence (not necessarily clinical evidence) of osteoarthrosis had been noted in the radiocarpal joint in which the reduction failed to reduce the intra-articular step below 2 mm.[10] This result may have been because of the early mobilisation of the wrists in this series—which possibly reduced soft tissue adhesion, oedema, and osteoporosis—as well as the fact that the wrist is not a weightbearing joint like the ankle.

CONCLUSION

The use of non-bridging external fixators requires the use of fixation pins in the distal fragments.[4,6] These pins buttress the fragments of the distal radius to maintain the articular reduction and extra-articular morphometry. By enabling early mobilisation of the wrist, these precarpal fixators ensure satisfactory recovery. The findings of this study do not suggest long-term osteopenia following the use of four 2.5-mm pins in the distal fragments. The non-bridging fixator, by allowing early physical activity, possibly leads to satisfactory functional and structural results.

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