EXTERNAL FIXATION FOR COMMINUTED INTRA-ARTICULAR WRIST FRACTURES

by E. VERHAVEN, H. DE BOECK, P. HAENTJENS and P. OPDECAM

We treated 101 consecutive patients with Frykman type III, IV, VII and VIII fractures of the distal radius and ulna with the small Hoffman external fixator between 1986 and 1989.
All patients were reviewed after a mean follow-up period of 22 months (range : 12 to 45 months). At follow-up, 88 wrists (87%) were rated good or excellent, according to the demerit point system, and 13 wrists (13%) were rated fair or poor according to the same system.
A highly significant correlation ($p < 0.01$) was found between the overall scores at follow-up and the grade of postoperative articular incongruity, between the overall scores and the grade of osteoarthritis at follow-up, between the grade of postoperative articular incongruity and the grade of osteoarthritis at follow-up, as well as between the overall scores and the grip strength at follow-up. A significant correlation ($p < 0.05$) was found between the length of follow-up and the grade of osteoarthritis at follow-up. Although the complication rate was rather high (40%), most of these problems were minor, transient and pin-related.

Keywords : external fixation ; wrist ; fractures.
Mots-clés : fixateur externe ; poignet ; fractures.

RÉSUMÉ

E. VERHAVEN, H. DE BOECK, P. HAENTJENS et P. OPDECAM. Traitement des fractures intra-articulaires du poignet par fixation externe.

Les auteurs analysent les résultats cliniques et radiographiques de 101 fractures articulaires comminutives du poignet traitées par fixateur externe. Dans ces cas leur préférence va à l'utilisation du fixateur externe de Hoffman, complété par un brochage avec incision cutanée en présence d'un fragment postéro-interne. Après distraction et mise en place du fixateur externe, l'analyse des clichés peropératoires doit être attentive : en présence d'une dénivellation de plus de 2 millimètres au niveau de la surface articulaire, les auteurs préconisent le traitement sanglant associé au fixateur externe qui remplit alors une fonction de neutralisation.

SAMENVATTING

E. VERHAVEN, H. DE BOECK, P. HAENTJENS en P. OPDECAM. Externe fixatie bij intra-articulaire comminutieve polsfrakturen.

Honderd-en-één patiënten met een intra-articulaire comminutieve polsfraktuur werden behandeld met een externe fixator.
We menen dat de voorkeursbehandeling van intra-articulaire comminutieve polsfrakturen een externe fixator is. Bij aanwezigheid van een "die-punch" fragment kan een additionele Kirschner-verpenning uitgevoerd worden.
Zo er een incongruentie van meer dan twee millimeter blijft bestaan ter hoogte van de gewrichtsoppervlakte van de pols, bevelen wij een open reduktie aan, waarbij de externe fixator als neutralisatie-apparaat kan behouden blijven.

INTRODUCTION

The optimal treatment of comminuted intra-articular fractures of the distal radius still remains controversial (2, 5, 6, 9, 10, 19, 21, 22). Specific

Department of Orthopaedics and Traumatology, Vrije Universiteit Brussel (Belgium).

problems in terms of stability and immobilization due to comminution of the dorsal cortex and the intra-articular involvement itself are encountered (3, 4, 5, 6, 9, 10, 11, 12, 18, 19, 21, 22). For intra-articular fractures, restoration of the articular congruity seems more critical than the restoration of radial length and the reduction of the dorsal tilt of the articular surface of the distal radius (13). Improved joint congruity would provide protection against future degenerative changes (2, 11, 13).
The aim of this paper is to evaluate the usefulness of the external fixator as a treatment modality for comminuted intra-articular wrist fractures, with emphasis on the restoration of articular congruity.

MATERIALS AND METHODS

Between 1986 and 1989, all patients with comminuted intra-articular fractures of the distal radius were treated with the small Hoffman external fixator. Patients with Barton or Smith fractures were not included in this study.

Operative technique

Routine management of the fractures included emergency closed reduction and fixation, using a half-frame Hoffman external fixator, according to the technique described by Schuind *et al.* (18). Anesthesia consisted of an axillary nerve block, with the patient supine and the arm on a radiolucent table. Two 2.5-mm holes were drilled in the posterolateral side of the radius through small stab wounds, a few centimeters proximal to the fracture. Thereafter, two self-tapping threaded half-pins were inserted. During this procedure, great care was taken to avoid injury to subcutaneous sensory nerves, tendons or blood vessels. In a similar way, two distal pins were inserted into the shaft of the second metacarpal at an angle of 45° to the proximal pins. Thereafter, anatomical reduction was performed with fluoroscopy by longitudinal traction, as well as gentle manipulation, after which the external fixator was locked. Two plain radiographs were taken to confirm reduction. The patients were discharged from the hospital on the first postoperative day. During the first 3 weeks, the patients were seen weekly with an anteroposterior and lateral radiographic film.
After 3 weeks, distraction was discontinued by unlocking and immediately relocking the external fixator. At 6 weeks, after a last radiographic check, the external fixator was removed. Active and passive mobilization of the wrist was allowed immediately. In one patient, an additional percutaneous pinning with three Kirschner-wires was performed under fluoroscopy because of a persistent postoperative articular incongruity of 2 to 3 mm after external fixation. These wires were also removed after 6 weeks.

Evaluation criteria

In 1989, 101 patients with 101 comminuted intra-articular fractures of the distal radius were personally examined by the first author. The average age at the time of operation was 54.5 years (range : 18 to 85 years). There were 71 women and 30 men. All patients had anteroposterior and lateral radiographs of the fractured wrist at the time of injury, after operation and at follow-up in 1989 (fig. 1 a-b, fig. 2 a-b, fig. 3 a-b). The fractures were classified according to the Frykman score (table I) (2). Complete radiographic data were available for 68 fractures, and only these 68 were used for statistical analysis of radiographic data.

Table I. — Frykman's classification

Type	Fracture
I	Extra-articular, no fracture of ulna
II	Extra-articular, fracture of ulna
III	Intra-articular radiocarpal, no fracture of ulna
IV	Intra-articular radiocarpal, fracture of ulna
V	Intra-articular radio-ulnar, no fracture of ulna
VI	Intra-articular radio-ulnar, fracture of ulna
VII	Intra-articular radiocarpal and radio-ulnar, no fracture of ulna
VIII	Intra-articular radiocarpal and radio-ulnar, fracture of ulna

After reduction and external fixation, postoperative articular incongruity was graded according to Knirk and Jupiter (table II) (2).

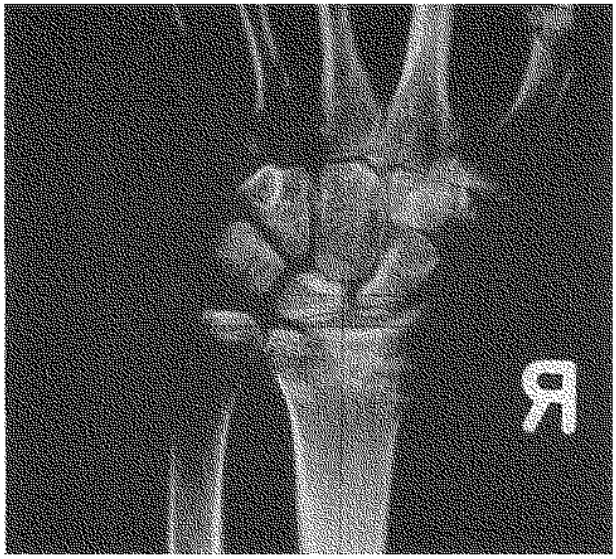
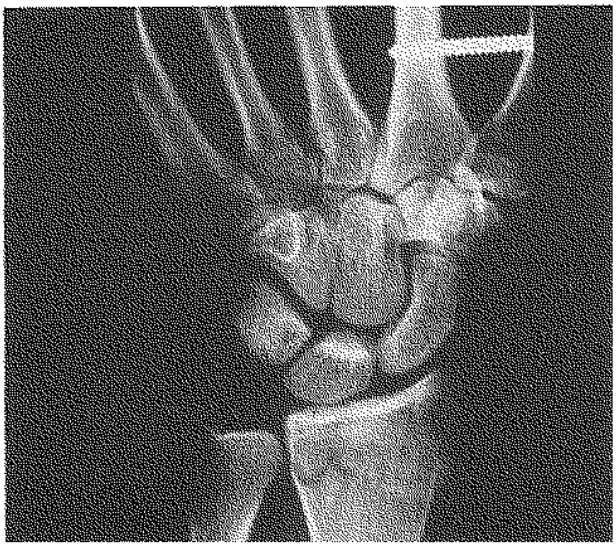


Fig. 1 a *Fig. 1 b*

Fig. 1 a-b. - AP and lateral radiographs showing a Frykman type VIII fracture.



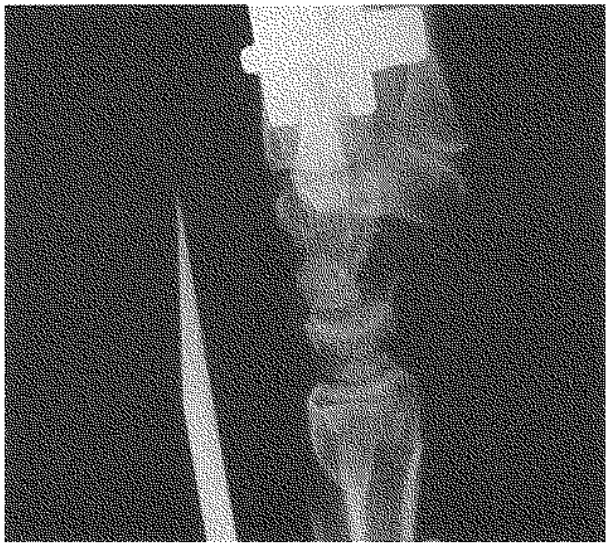


Fig. 2 a *Fig. 2 b*

Fig. 2 a-b. — After reduction and external fixation.

Fig. 3 a

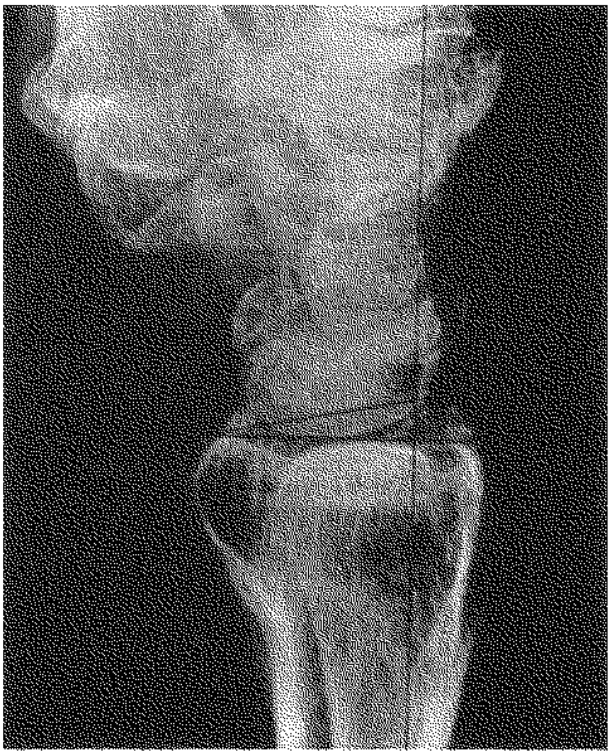


Fig. 3 b

Fig. 3 a-b. — At follow-up in 1989.

Table II. — Grading of articular incongruity*

Grade	Step-off (mm)
0	0-1
1	1-2
2	2-3
3	> 3

* Modified from Knirk and Jupiter, *J. Bone Joint Surg.*, 1988, *68-A*, 647-659.

At follow-up in 1989, the overall results were evaluated by the demerit point system of Gartland and Werley (2). This scoring system is based on clinical and radiographic data. Residual deformity accounts for 0 to 3 points. Subjective complaints such as pain, limitation of motion and disability are rated as 0 to 6 points.

Objective evaluation, which accounts for 0 to 5 points, includes loss of the different ranges of motion of the wrist, the presence of pain in the distal radio-ulnar joint, and evaluation of grip strength, Another 0 to 5 points are attributed for complications such as radiographic arthritic changes, nerve problems and poor function of the fingers. A score of 0 to 2 points is considered to be an excellent result ; 3 to 8 good ; 9 to 20 fair and more than 21 poor. The grip strength was tested with a hand-held dynamometer, with the contralateral uninjured wrist serving as a control. The grip strength was considered to be diminished when the force of the nondominant wrist did not equal at least 85% of that of the dominant side. Due to concomitant injuries of the contralateral wrist, elbow or shoulder, only 59 wrists could be tested. Osteoarthritis was also graded according to Knirk and Jupiter (table III) (2). For statistical analysis, the Chi-square test with continuity correction was used.

Table III. — Grading of arthritis*

Grade	Findings
0	None
1	Slight joint-space narrowing
2	Marked joint-space narrowing, formation of osteophytes
3	Bone on bone, formation of osteophytes and cysts

* Modified from Knirk and Jupiter, *J. Bone Joint Surg.*, 1988, *68-A*, 647-659.

RESULTS

Overall results

Fifty-five wrists (58%) had an excellent, 29 (29%) a good, 10 (10%) a fair, and 3 (3%) a poor demerit score. If we refer to the excellent and the good scores as satisfactory results, and to the fair and poor scores as unsatisfactory results, we obtain 88 (87%) satisfactory and 13 (13%) unsatisfactory results.

Overall results versus age

In 74 fractured wrists (73%), patients were more than 45 years old at the time of operation. In 27 fractures (27%), patients were 45 years old or less. Among the latter, 21 had a satisfactory and 6 an unsatisfactory demerit score. Among the patients older than 45 years, 67 had a satisfactory and 7 an unsatisfactory demerit score. No statistical correlation could be demonstrated.

Overall results versus Frykman score

Eight fractures (8%) were classified as Frykman type III, 11 (11%) as type IV, 21 (21%) as type VII and 61 (60%) as type VIII. Patients with Frykman type III and IV fractures all showed a satisfactory demerit score, while patients with a Frykman type VII fracture showed 19 satisfactory and 2 unsatisfactory demerit scores and those with a Frykman type VIII fracture 50 satisfactory and 11 unsatisfactory demerit scores. No statistical difference could be shown.

Overall results versus articular incongruity (AI)

Forty-seven wrists (69%) demonstrated grade O AI ; 15 (22%) grade 1 ; 6 (9%) grade 2 and none grade 3 AI of the radiocarpal joint after reduction and fixation. The wrists with a grade O AI obtained 41 satisfactory and 6 unsatisfactory demerit scores ; those with grade 1 AI ; 13 satisfactory and 2 unsatisfactory scores and those with grade 2 AI ; 1 satisfactory and 5 unsatisfactory demerit scores. A highly statistical difference could be demonstrated ($p < 0.01$).

Overall results versus length of follow-up

The average length of follow-up was 22 months (range 12 to 24 months). Sixty-five wrists (64%) had a followup period of 12 to 24 months ; 26 (26%) of 25 to 36 months and 10 (10%) of more than 36 months. In the follow-up group of 12 to 24 months we observed 55 satisfactory and 10 unsatisfactory demerit scores ; in the follow-up group of 25 to 36 months 24 satisfactory and 2 unsatisfactory scores, and in the group with a follow-up of more than 36 months 9 satisfactory and 1 unsatisfactory score. There was no statistically significant influence of the length of follow-up on the demerit scores.

Overall results versus grip strength

At follow-up, a diminished force was observed in 27 wrists (46%), while in 32 wrists (54%) full recovery of grip strength was obtained. All patients with normal grip strength showed satisfactory demerit scores. Patients with a diminished grip strength obtained 19 satisfactory and 8 unsatisfactory demerit scores. A statistically significant difference could be observed ($p < 0.01$).

Overall results versus osteoarthritis (OA)

Thirty-four wrists (50%) showed grade 0 of OA ; 26 (38%) grade 1 ; 5 (8%) grade 2 and 3 (4%) grade 3 of OA of the radiocarpal joint at follow-up. From the wrists with grade 0 of OA, 33 had a satisfactory and 1 an unsatisfactory demerit score ; those with grade 1 of OA showed 18 satisfactory and 8 unsatisfactory scores ; those with grade 2 of OA ; 4 satisfactory and 1 unsa-

tisfactory scores, while those with grade 3 of OA demonstrated only 3 unsatisfactory demerit scores. A highly significant difference could be shown ($p < 0.01$).

Table IV. — Evaluation of the statistical correlations between the various parameters

	Age	Frykman score	AI	Folluw up	Grip strength	OA
overall score	N.S.	N.S.	$p < 0.01$	N.S.	$p < 0.01$	$p < 0.01$
OA	N.S.	N.S.	$p < 0.01$	$p < 0.05$	N.S.	/
AI	/	N.S.	/	/	/	$p < 0.01$

(AI : postoperative articular incongruity, OA : osteoarthritis at follow-up, N.S. : nonsignificant, / nondetermined).

Osteoarthritis at follow-up

Osteoarthritis versus age

Of the patients who were 45 years old or less at the time of their operation, 11 showed grade 0 ; 9 grade 1 ; 1 grade 2 and 1 grade 3 of OA of the radiocarpal joint. In the patient group older than 45 years, 23 showed grade 0 of OA ; 17 grade 1 ; 4 grade 2 and 2 grade 3 of OA. No statistical correlation between the grade of OA and age could be demonstrated.

Osteoarthritis versus Frykman score

In the Frykman type III group, we observed 5 grade 0, 1 grade 1 and no grade 2 or 3 of OA. Frykman type IV fractures demonstrated 5 grade 0 ; 1 grade 1 ; 1 grade 2 and no grade 3 of OA, Frykman type VII fractures 10 grade 0 ; 4 grade 1 ; 1 grade 2 and 1 grade 3 of OA, while Frykman type VIII fractures showed 14 grade 0 ; 20 grade 1 ; 3 grade 2 and 2 grade 3 of OA. No statistical link could be found between the intra-articular fracture types and the grade of osteoarthritis of the radiocarpal joint at follow-up.

Osteoarthritis versus articular incongruity

Evaluation of the wrists with postoperative grade 0 AI revealed 30 grade 0 of OA ; 16 grade 1 ; 1 grade 2 and no grade 3 of OA. When grade 1 AI was present, we noted 4 grade 0 ; 9 grade 1 ; 2 grade 2 and no grade 3 of OA. In the group with grade 2 AI, we observed no grade 0 ; 1 grade 1 ; 2 grade 2 and 3 grade 3 of OA. A highly significant difference at the $p < 0.01$ level could be demonstrated.

Osteoarthritis versus length of follow-up

When follow-up lasted 12 to 24 months, we noted 18 grade 0 ; 16 grade 1 and no grade 2 or 3 of OA. In the follow-up group of 25 to 36 months, we observed 11 grade 0 ; 9 grade 1 ; 3 grade 2 and 1 grade 3 of OA. When follow-up was longer than 36 months, we noted 5 grade 0 ; 1 grade 1 ; 2 grade 2 and 2 grade 3 of OA of the radiocarpal joint. A statistically significant difference at the $p < 0.05$ level could be shown.

Osteoarthritis versus grip strength

When we evaluated the grade of OA in the patient group with fully-recovered grip strength we found 18 grade 0 ; 11 grade 1 ; 3 grade 2 and no grade 3 of OA. Wrists with diminished grip strength showed 14 grade 0 ; 11 grade 1 ; 1 grade 2 and 1 grade 3 of OA. No statistical correlation was noted between the grade of OA and the grip strength at follow-up.

Postoperative articular incongruity

Articular incongruity versus Frykman score

In the Frykman type III group, 4 wrists showed grade 0 AI ; 2 grade 1 and none grade 2 AI of the radiocarpal joint. From the Frykman type IV fractures, 4 demonstrated grade 0 ; 2 grade 1 and none grade 2 AI. Frykman type VII fractures resulted in 12 grade 0 ; 2 grade 1 and 1 grade 2 AI, while Frykman type VIII fractures resulted in 27 grade 0 ; 9 grade 1 and 5 grade 2 AI of the distal radiocarpal joint. The intra-articular fracture type had no statistical influence on the grade of postoperative articular incongruity.

COMPLICATIONS

The overall complication rate was rather high (40%), although most of the complications were minor and transient. Two patients (2%) showed superficial wound problems at the pin site, which fully resolved with local wound care. Pin-tract infection was noted in one patient (1%). It responded very well to curettage and antibiotic treatment. Residual finger stiffness was found in 7 patients (7%). Neurological complications (13%) consisted of a persistent hypoesthesia of the thumb in 6%, transient paresthesias of the index in 5% and a median-nerve compression in 2% of our patients. In 7 patients (7%) a new reduction for a secondary displacement had to be performed. Three patients (3%) demonstrated some osteolysis around the pins without needing pin removal. Fracture of the second metacarpal occurred in one patient (1%) in the fourth week, owing to osteolysis around the pins. This was treated with an additional plaster cast for 3 weeks, while the external fixator was left in place for 7 weeks. A subluxation of the ulna was found in 2 patients (2%) after external fixation, but had no influence on the clinical outcome. A successful dorsal arthrolysis was performed in one patient (1%), whose dorsal flexion was limited by the presence of a large spur on the dorsal side of the radiocarpal joint. One patient (1%) developed a nonunion of the fracture, which required osteosynthesis and bone grafting after 3 months.

Algodystrophy was confirmed in 2 patients (2%) by clinical, radiological and scintigraphic findings. These 2 patients experienced persistent finger stiffness and loss of wrist motion at follow-up. In 2 patients (2%) algodystrophy was documented by clinical and radiological findings. Radiological features of algodystrophy were present in another 15 patients (15%) without influence on the final clinical result.

DISCUSSION

Comminuted intra-articular fractures of the distal radius are commonly observed in orthopedic practice (16). The goal of management of these fractures is to achieve anatomic reduction and to maintain it by firm fixation until fracture healing (3, 5, 6, 7, 9, 10, 11, 12, 18, 19, 20, 21, 22). Comminution of the dorsal cortex of the radius and intra-articular involvement render these fractures inherently unstable (3, 4, 5, 6, 9, 10, 11, 12, 18, 19, 21, 22). Even if a proper reduction can be achieved, loss of reduction and shortening of the radius after a few days or weeks is almost inevitable with conventional cast immobilization (3, 4, 5, 6, 7, 9, 10, 11, 12, 19, 21, 22).

A wide variety of orthopedic and surgical treatment methods has been proposed to prevent the loss of reduction and the shortening of the radius : supination casts, above-elbow casts in various degrees of rotation, percutaneous pinning of the distal fragment, percutaneous pinning according to Kapandji, longitudinal pins and even early Darrach resection have ben described (12, 19, 21, 22). Bohler introduced a method with pins incorporated in a plaster cast, in order to provide a fixed traction device to maintain length (5, 7, 19, 21, 22). The main disadvantages of this technique were its inability to restore normal palmar tilt of the distal radial articulation and a high complication rate, sometimes as high as 50% (5, 7, 13, 19, 22). Internal fixation has also been advocated as the method of choice, but it can be very hazardous owing to the quality of bone and the grade of comminution, and it is therefore not always attainable (2).

After Anderson's original description of the external fixator, improved anatomical and functional

results were reported (3, 4, 5, 6, 7, 9, 10, 11, 12, 16, 17, 18, 19, 20, 21, 22). We are aware of only two prospective randomized studies comparing the external fixator with a plaster cast. Uniformly excellent results were obtained with the external fixator (96% and 93%) as compared to the plaster cast (72% and 50%) (11, 12).

The external fixator was shown to be particularly effective in reducing and maintaining intra-articular comminution (3, 4, 5, 6, 7, 9, 10, 11, 12, 16, 17, 18, 19, 20, 21, 22). Reduction of intra-articular comminution is based on the principles of ligamentotaxis (7, 11, 18, 19, 22).

Our study, which showed 87% satisfactory and 13% unsatisfactory results, confirms other series with similar types of fractures and with satisfactory clinical results in 87 to 96% (3, 4, 7, 11, 12, 13, 14, 18, 21). However, Knirk and Jupiter reported only 61% satisfactory results in young adults. They observed that high energy impact may result in articular comminution and a dorsomedial fragment, the so-called "die-punch fragment" (fig. 4 a-b, 5 a-b). This fragment can not usually be reduced by ligamentotaxis alone (13). Several authors advise treating these high-velocity fractures by open reduction with internal fixation or by an external fixator in combination with limited internal fixation for a better reduction of this incongruity (2, 13, 19, 22).

In our study, no statistically significant correlation could be found between age and the demerit score. We were also not able to demonstrate a statistical influence of the different intra-articular fracture types on the overall results. Therefore, the presence of a Frykman type VIII fracture does not systematically imply a bad result.

When we compared the grade of postoperative articular incongruity with the overall results, we were able to show a highly significant statistical difference ($p < 0.01$). Patients with a satisfactory overall score had a significantly lesser grade of postoperative articular incongruity. The better the articular congruity after reduction and fixation, the better the overall score.

The length of follow-up did not significantly influence the overall score. A highly statistical correlation was demonstrated between the grip strength and the overall results ($p < 0.01$). All the patients with an unsatisfactory overall score experienced a persistent loss of grip strength at follow-up.

Our overall results were highly influenced by the grade of osteoarthritis ($p < 0.01$). Patients with a satisfactory overall score had a significantly lesser grade of OA at follow-up than those with an unsatisfactory score.

We were not able to reveal a statistical link between the grade of osteoarthritis of the radiocarpal joint at follow-up and age, nor between the grade of OA and the different intra-articular fracture types.

When we compared the grade of OA at follow-up with the grade of postoperative articular incongruity, we noticed that wrists with a step-off less than 2 mm in the distal radial articular surface showed a significantly lesser amount of posttraumatic osteoarthritis than those with a 2 mm or greater step-off ($p < 0.01$).

Other authors also state that for intra-articular fractures, restoration of the articular congruity is more critical than the restoration of radial length and the reduction of the dorsal tilt of the distal radial articular surface (2, 13). Joint incongruity seems to lead to the rapid development of posttraumatic radiocarpal degenerative changes (2, 11, 13).

The length of follow-up did not influence the demerit score directly, but when we compared the grade of OA and the length of follow-up, we were able to show a significantly higher grade of OA when follow-up continued more than 24 months ($p < 0.05$). Further analysis of these results revealed that this more advanced OA was only a reflection of a greater postoperative articular incongruity for these wrists, and if therefore the length of follow-up were still to increase, more advanced OA would probably be observed. This would confirm the results of other authors, who claim that all non-anatomical restorations of the articular surface will lead to posttraumatic arthritis provided the length of follow-up is long enough (2, 11, 13).

No statistical correlation was noted between the grade of OA and the grip strength at follow-up.

Evaluation of the relation between the grade of postoperative articular incongruty and the Fryk-

Fig. 4 a

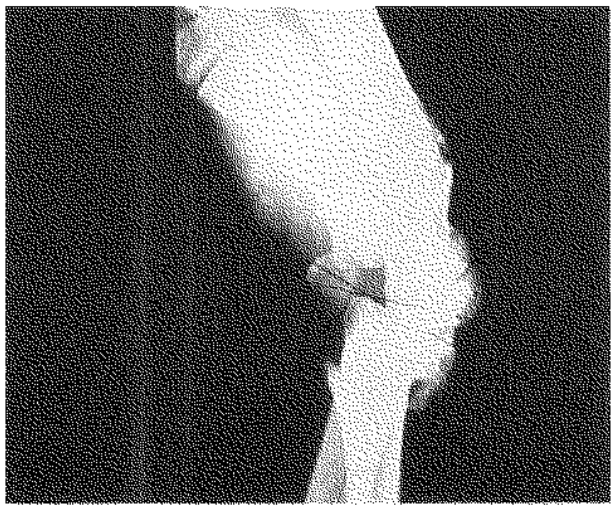


Fig. 4 b

Fig. 4 a-b. AP and lateral radiographs showing a "die-punch" fragment or impaction of the lunate fossa with a dorsomedial fragment.

Fig. 5 a

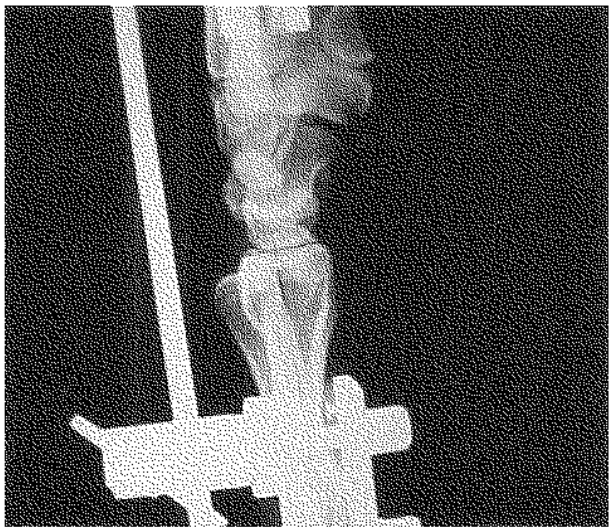


Fig. 5 b

Fig. 5 a-b. — In this case, a good reduction of the articular surface could be obtained without any supplementary fixation.

man score showed that the intra-articular fracture type did not have any statistical influence on the grade of postoperative articular incongruity. In our series, the presence of a Frykman type VIII fracture did not imply a worse postoperative AI than would be expected for a Frykman type IV fracture.

Despite the high overall complication rate (40%), most complications were minor and transient in character. Half of them were pin-related. In the literature, the complication rate varies between 14 (21) and 61 (22)%, most complications being pin-related (6, 7, 12, 17, 19, 22). In one patient, a nonunion of the fracture was observed, probably

Fig. 6 a

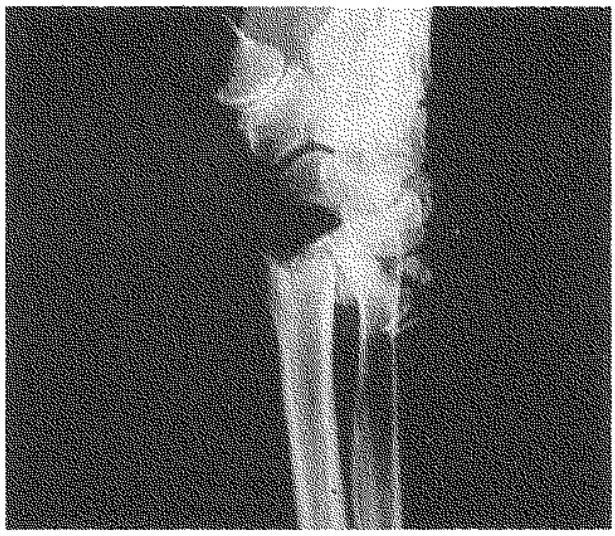


Fig. 6 b

Fig. 6 a-b. — Another Frykman type VIII fracture.

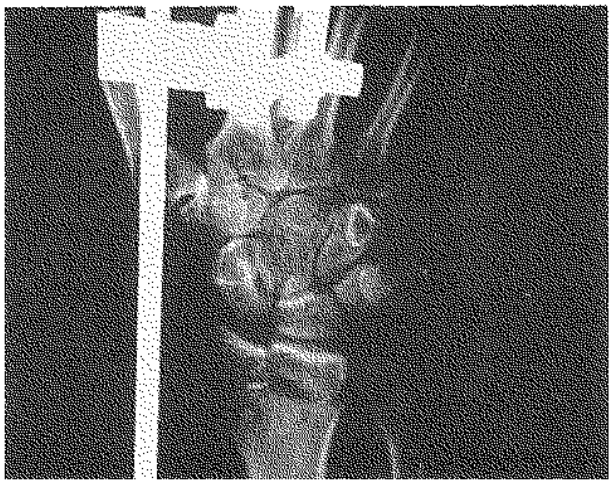


Fig. 7 a

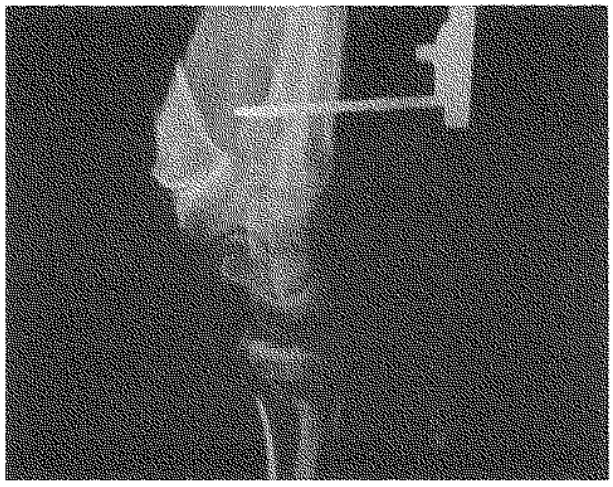


Fig. 7 b

Fig. 7 a-b. — After reduction and external fixation, an intra-articular 2-mm step-off was still visible.

due to excessive distraction, which was not discontinued after 3 weeks, with subsequent failure of gap healing. Therefore, we propose applying just enough distraction at the time of reduction, that the safe limits of gap healing are not exceeded. After 3 weeks, distraction must be discontinued by unlocking and immediately relocking the external fixator. Excessive distraction is probably a causative factor for algodystrophy, although algodystrophy is encountered as a complication of wrist fractures even after plaster immobilization (1). A very recent study in which more sensitive techniques were employed showed an incidence of 37% 9 weeks after fracture (1). In our study, 2 patients (2%) demonstrated the clinical, radiological and scintigraphic features of algodystrophy. In 2 other patients (2%) clinical and radiological features were present. Radiological features of

algodystrophy were present in 15 patients (15%). Dolorimetry would be very accurate, not only in diagnosing the syndrome, but also in assessing the treatment (1). This technique includes the assessment of finger tenderness by the use of a dolorimeter (1).

CONCLUSION

The use of an external fixator in the treatment of comminuted intra-articular fractures of the distal radius gives good to excellent results if an anatomical reduction of the distal radial articular surface can be obtained by ligamentotaxis. In the presence of a "die-punch" fragment, an additional open or closed pinning of the fragment can be performed. In the presence of a step-off of more than 2 mm in the distal radial articular surface after ligamentotaxis, we propose to perform an open reduction with subsequent internal fixation, while the external fixator can be left in place as a neutralization device (figs. 6 a-b, 7 a-b, 8 a-b).

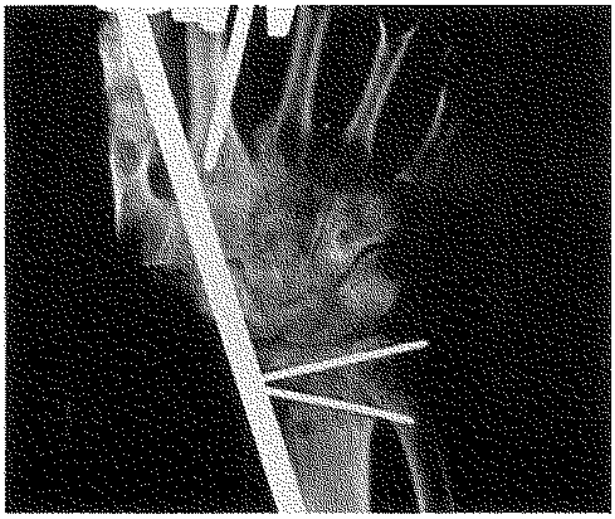


Fig. 8 a

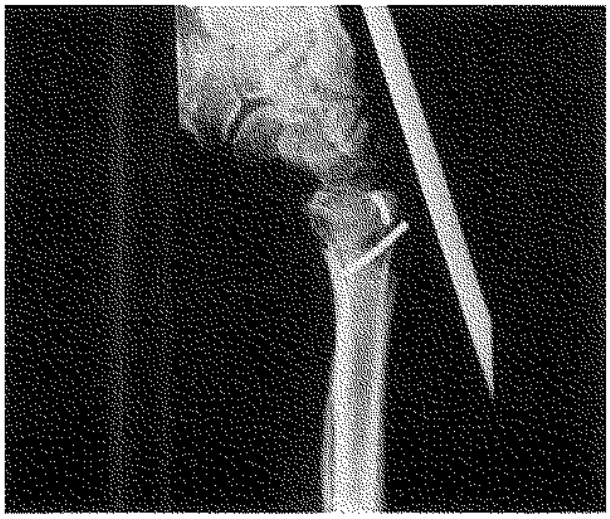


Fig. 8 b

Fig. 8 a-b. — Additional percutaneous pinning with two Kirschner wires was performed, which gave good restoration of the articular surface.

REFERENCES

1. ATKINS R., DUCKWORTH T., KANIS J. Features of algodystrophy after Colles' fracture. *J. Bone Joint Surg.*, 1990, *72-B*, 105-110.
2. BRADWAY J., AMADIO P., COONEY W. Open reduction and internal fixation of displaced, comminuted intra-articular fractures of the distal end of the radius. *J. Bone Joint Surg.*, 1989, *71-A*, 839-847.
3. CLYBURN T. Dynamic external fixation for comminuted intra-articular fractures of the distal end of the radius. *J. Bone Joint Surg.*, 1987, *69-A*, 248-254.
4. COONEY W., LINSCHEID R., DOBIJNS J. External pin fixation for unstable Colles' fractures. *J. Bone Joint Surg.*, 1979, *61-A*, 840-845.
5. COONEY W., DOBIJNS J., LINSCHEID R. Complications of Colles' fractures. *J. Bone Joint Surg.*, 1980, *62-A*, 613-619.
6. COONEY W. External fixation of distal radial fractures. *Clin. Orthop.*, 1983, *180*, 44-49.
7. D'ANCA A., STEINLIB S., BYRON T. External fixator management of unstable Colles' fractures. *Orthopedics*, 1984, *7*, 853-885.
8. DE LEE J. External fixation of the forearm and wrist. *Orthop. Rev.*, 1981, *10*, 43-48.
9. FORGON M., MAMMEL E. The extrnal fixateur in the management of unstable Colles' fracture. *Int. Orthop.*, 1981, *5*, 9-13.
10. GRANA W., KOPTA J. The Roger Anderson device in the treatment of fractures of the distal end of the radius. *J. Bone Joint Surg.*, 1979, *61-A*, 1234-1238.

11. HOWARD P., STEWART H., HIND R., BURKE F. D. External fixation or plaster cast for severely displaced comminuted Colles' fractures ? *J. Bone Joint Surg.*, 1989, *71-B*, 68-73.
12. JENKINS N., JONES D., JOHNSON S., MINTOWTCZYZ W. J. External fixation of Colls' fractures. *J. Bone Joint Surg.*, 1987, *69-B*, 207-211.
13. KNIRK J., JUPITER J. Intra-articular fractures of the distal end of the radius in young adults. *J. Bone Joint Surg.*, 1988, *68-A*, 647-659.
14. KONGSHOLM J., OLERUD C. Plaster cast versus external fixation for unstable intra-articular Colles' fractures. *Clin. Orthop.*, 1989, *241*, 57-65.
15. MC QUEEN M., CASPERS J. Colles' fracture : does the anatomical result affect the final function ? *J. Bone Joint Surg.*, 1988, *70-B*, 649-651.
16. RICCIARDI L., DIQUIGUIVANNI The external fixation treatment of distal articular fractures of the radius. *Orthopedics*, 1984, *7*, 637-641.
17. RIGGS S., COONEY W. External fixation of complex hand and wrist fractures. *J. Trauma*, 1983, *23*, 332-336.
18. SCHUIND F., DONDERWOLCKE M., BURNY F. External fixation of wrist fractures. *Orthopedics*, 1984, *7*, 841-844.
19. SZABO R., WEBER S. Comminuted intra-articular fractures of the distal radius. *Clin. Orthop.*, 1988, *230*, 39-48.
20. THOMINNE J., DEMESY M. Le fixateur externe métacarporadial dans le traitement des fractures graves de l'extrémité inférieure du radius. *Ann. Chir.*, 1979, *33*, 731-734.
21. VAUGHAN P., LUI S., HARRINGTON I., MAISTRELLI G. L. Treatment of unstable fractures of the distal radius by external fixation. *J. Bone Joint Surg.*, 1985, *67-B*, 385-389.
22. WEBER S., SZABO R. Severely comminuted radial fracture as an unsolved problem : complications associated with external fixation and pins and plaster techniques. *J. Hand Surg.*, 1986, *11-A*, 157-165.

E. VERHAVEN
University Hospital
Vrije Universiteit Brussel
Laarbeeklaan 101
1090 Brussels (Belgium)