Radiostereometric analysis of distal radial fracture displacement during treatment

A randomized study comparing Norian SRS and external fixation in 23 patients

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ABSTRACT – In a randomized study, we included 23 osteoporotic patients with a distal radial fracture and loss of reduction after 1 week. The fracture was re-reduced. In one group, a self-setting hydroxyapatite, Norian SRS, was injected into the fracture and the wrist was immobilized for 2 weeks with a dorsal splint (n 12). In the other group, the fracture was immobilized for 5 weeks with an external fixator (n 11). During the operation, the fracture fragments were marked with tantalum markers, so that loss of reduction during the immobilization and after mobilization could be studied with radiostereometric analysis (RSA). We found some recurrence of compression in the fracture in both groups during immobilization. After mobilization, the motion of the fracture, measured by displacement of the fragments along the longitudinal axis, was less than 2 mm, except in 3 cases treated with Norian SRS. A compression along the longitudinal axis of less than 2 mm is not likely to cause any problem in the long term. From the first to the last investigation, 7/12 patients with Norian SRS and 4/11 with external fixation lost more than 2 mm of the reduction along the longitudinal axis. We conclude that 5 weeks of immobilization is sufficient for healing with external fixation in this age group. This immobilization time might be reduced to 2 weeks for fractures treated with Norian SRS, but additional hardware should be used to ensure stability of the fracture system.

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The treatment of the distal radial fracture can be improved by reducting the immobilization time. Early mobilization leads to rapid recovery of joint mobility and grip strength (de Bruijn 1987, Mac Auliffe et al. 1987). However, there is a conflict between early mobilization and sufficient immobilization time to allow healing without deformity. Norian SRS, an injectable hydroxyapatite, provides mechanical strength for stabilization by filling the cancellous defect so that the immobilization time can be reduced (Constantz et al. 1995, Kopylov et al. 1996, Jupiter et al. 1997). We compared this treatment to the commonly accepted treatment by external fixation, in a randomized study on osteoporotic patients with redislocated distal radial fractures. The clinical and radiological results of the study have been reported earlier (Kopylov et al. 1999). In a subgroup of the 40 patients in the above randomized study, fracture fragments were marked with tantalum markers so that possible loss of reduction could be studied by radiostereometric analysis (RSA) during the immobilization period and after mobilization. We now report the RSA findings.

Patients

All distal radial fractures primarily treated by closed reduction in the Department of Orthopedics in Lund between 1995 and 1997 were seen 7 and 10 days after the injury. Patients were invited to participate in the clinical study, if radiographs showed loss of reduction according to one or more of the following criteria: ≥ 20 degrees dorsal compression, ≥ 2 mm axial compression, ≥ 2 mm incongruity in the radio-carpal or distal radio-ulnar

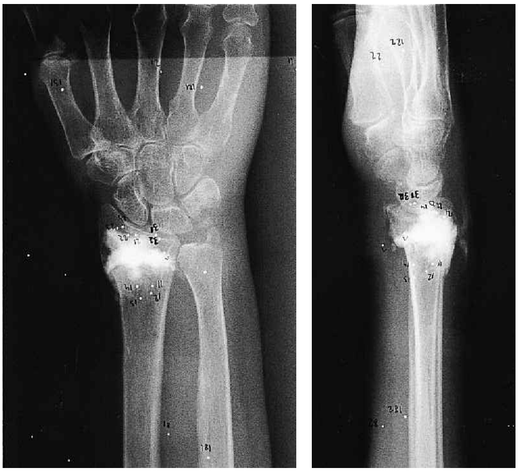

Figure 1. The position of the tantalum markers in the distal radius and in the calibration cage of a case treated with Norian SRS.

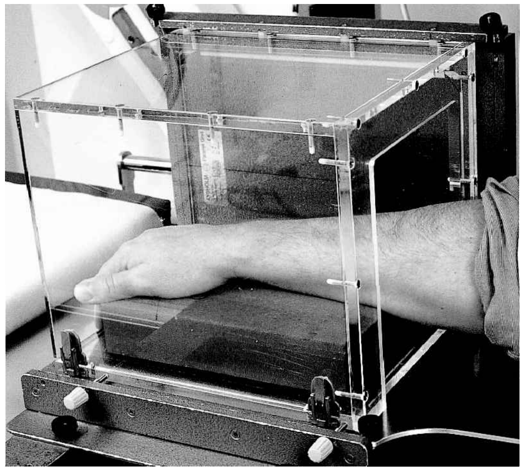

Figure 2. Position of the wrist in the calibration cage.

joints. Men between 60 and 80 years old and women between 50 and 80 years were included. The study was approved by the Ethics Committee of Lund University. Randomization between the 2 treatments was performed in the operating room after re-reposition and the groups were stratified according to sex and fracture type (extra- or intraarticular) (Kopylov et al. 1999). Of the 40 patients in the clinical study, the last 23 were recruited for the present RSA study, 12 in the Norian SRS group with a mean age of 68 years (5 extra- and 7 intra-articular fractures) and 11 in the external fixation group with a mean age of 65 years (5 extra- and 6 intra-articular fractures).

Methods

The fractures were re-reduced by traction with fingertraps and the arm in 60 degrees of abduction, using an extension table. This position ensured stability during the Norian SRS setting-time. The entire procedure was controlled with image intensification. In the Norian SRS group after closed re-reduction, the fractures were partly exposed through a dorsal incision less than 5 cm long, and if necessary, further reduced through the wound. Hematoma, callus and debris were scraped out of the defect, which was flushed with saline. Norian SRS was then injected, filling the defect from palmar to dorsal. A short-arm dorsal splint was applied and kept in place for 2 weeks. Thereafter the wrist was mobilized. In the external fixation group, after closed re-reduction, 2 pins were drilled into the second metacarpal and 2 pins into the radius, and the fracture was immobilized with an external fixator (Hoffmann, Howmedica, Malmö, Sweden). After 5 weeks, the pins were removed and the wrist was mobilized.

In all cases, tantalum bone markers were inserted on both sides of the fracture at the time of re-reduction, using a canula penetrating the bone in the fracture site dorsally. We tried to place the markers in the radial styloid, at the distal ulnar border of the metaphysis and in the radial diaphysis proximal to the fracture (Figure 1). Stereo-radiographs were obtained after the operation, before mobilization and at 3 months, with the wrist in a calibration cage (Figure 2). At the same time, conventional radiographs were taken and axial, dorsal and radial compression were measured. The stereo-radiographs were digitized using a high-precision tablet and the x and y coordinates fed into IBM AT clone micro-computer. Using the RSA software package, the 3-D coordinates of the patient markers were obtained. Then the migration of the fracture fragments relative to the radius diaphysis was obtained by Euler rigid-body kinematics (Selvik 1974). Motion of the center of gravity of the rigid body representing the distal fragment was expressed as a rotation and translation along the three cardinal axes, coinciding with the main

Results of the RSA study: fragment displacement along the x, y and z axes and MTPM during the immobilization period (A) and the mobilization period (B) are shown in each patient

Study No.	Treatment	x A	x B	y A	y B	z A	z B	MTPM A	MTPM B
20	SRS	0.41	0.03	–0.15	–0.42	–1.69	1.10	0.9	2.4
22	SRS	0.59	0.12	–1.07	–0.29	–0.39	0.11	1.9	0.6
24	SRS	6.66	–5.31	–7.83	–8.15	–2.35	11.08	11.2	16.4
26	SRS	–0.20	0.13	–0.76	–0.58	–0.89	–1.02	1.5	1.9
28	SRS	–0.57	0.04	–2.42	–0.14	1.38	–0.03	4.0	1.5
36	SRS	0.26	0.29	–0.20	–0.04	0.24	0.50	1.1	0.7
37	SRS	–0.05	0.35	–0.69	–0.28	1.26	–0.25	2.1	0.8
39	SRS	2.38	–0.19	–2.85	–1.02	1.05	–1.28	4.6	2.31
41	SRS	2.42	1.21	–5.50	–0.79	–8.63	–0.29	12.9	1.5
42	SRS	–4.15	0.19	–4.12	–3.60	2.54	3.58	7.0	6.1
43	SRS	2.18	–1.29	–3.68	–2.35	–2.00	–1.29	5.1	2.7
45	SRS	0.02	–0.15	–1.72	–0.60	2.91	–0.40	4.8	1.2
19	Xfix	–0.52	0.11	–1.39	–0.27	–1.57	–0.06	2.9	0.5
21	Xfix	–0.91	0.35	–0.81	–0.41	0.85	–0.45	2.4	2.5
23	Xfix		–0.12		–0.68		–0.45		1.6
25	Xfix	–0.22	–0.16	–1.09	–0.21	–0.03	0.13	1.3	0.4
27	Xfix	–0.30	0.24	–2.15	–0.25	–1.17	–0.60	2.8	1.0
32	Xfix	–0.32	–0.07	–1.37	–0.41	0.47	–0.08	1.6	2.5
33	Xfix	0.22	1.13	–1.83	–1.63	0.59	–1.35	2.9	3.0
34	Xfix	–1.13	–0.39	–1.83	–0.29	–0.87	0.08	2.7	1.2
35	Xfix	0.52	0.77	–1.22	–1.20	1.04	–0.07	2.6	2.0
40	Xfix	–0.10	–1.23	–0.74	–0.08	0.20	–0.67	1.0	3.0
46	Xfix	–0.61	–0.77	–2.48	–0.14	2.84	–1.21	4.3	2.3

planes of the body. If there were more than one rigid body, i.e., at least three markers in two distal fragments, the one with greatest migration was chosen for analysis. Further, the 3 dimensional vector, maximum total point motion (MTPM), of the fracture segment marker which moved the most, was given as a simple way to report the magnitude of the motion in all directions (Ryd 1992). Displacements in the fracture system measured with these methods were compared in the 2 treatment groups using t-statistics and with the conventional radiographic findings, using regression analysis.

Results

The clinical results have been reported previously (Kopylov et al. 1999). Here we report the stereometric findings (Table) and their relations to the conventional radiographic findings. The marker configuration in each rigid body was stable, indicating that the motion we found was not due to migration of individual markers within the bone. There was one major failure in the Norian SRS group with a redislocation of the fracture noted clinically and radiographically in both planes. Measured with stereophotogrammetry, the displacement between the fragments along the longitudinal axis was 16 mm from the first to the last investigation and 7.8 mm during the immobilization period, with a MTPM of 16.4 mm and 11.2 mm, respectively.

Some recurrence of the compression occurred in all patients in both groups during the immobilization time with a displacement along the longitudinal axis exceeding 2 mm in 6 Norian cases and 2 external fixation cases. After mobilization, the displacement measured along the longitudinal axis was less than 2 mm except in 3 Norian SRS cases. From the first to the last investigation, 7 fractures treated with Norian SRS and 4 treated with external fixation showed a longitudinal displacement exceeding 2 mm. The MTPM was larger in the Norian SRS group than in the external fixation group both during the immobilization time and after mobilization. However, the difference between the two groups was not statistically

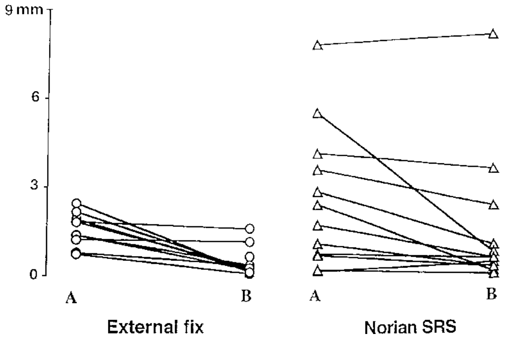

Figure 3. The marks above A give the value for migration along the y-axis during the immobilization period and the marks over B illustrate the migration from the time when mobilization started until 3 months after the fracture. In each individual, the two points are connected by a line.

significant, neither for MTPM nor for longitudinal displacement (Figure 3). The mean loss of reduction measured on the conventional radiographs in the Norian SRS group was 4 degrees of the radial angle, 7 degrees of the dorsal angle and 2.8 mm of ulnar variance. The corresponding figures for external fixation were 4 degrees, 2 degrees and 1.1 mm respectively. In extraarticular fractures, there was a clear correlation ($r^2 = 0.5$, $p = 0.04$) between the longitudinal RSA displacement from the first to the last investigation and axial compression measured on the conventional radiographs (ulnar variance). The same correlation was found for radial compression ($r^2 = 0.5$, $p = 0.04$). No correlation was found for intraarticular fractures. In all fractures there was a good correlation ($r^2 = 0.93$, $p = 0.0001$) between the longitudinal RSA displacement from the first to the last investigation and MTPM.

Discussion

We have compared two methods of treatment, which differ by the time of immobilization. The immobilization time with external fixation has been disputed with recommendations ranging from 3 to 8 weeks (Cooney et al. 1979, Hutchinsson et al. 1995, MacQueen et al. 1996). Treatment with Norian SRS aims to stabilize the fracture at surgery. For these reasons, we arbitrarily set the consolidation time at 2 weeks in the SRS group and 5 weeks in the external fixation group. The RSA was used because of the precision of the information given by this technique in which the real migration of the fragments, defined by the rigid body, is measured. This was compared to the measurements done with a conventional radiographic technique, where the fracture displacement was estimated using articular surfaces as the reference. Although this technique is less precise, the measurements may be more clinically relevant. A longitudinal RSA displacement between the fragments of 2 mm or less can be regarded as irrelevant clinically and without consequence in the long term whereas a compression of more than 2 mm measured on plain radiographs means an increased risk of osteoarthritis and long-term disability (Kopylov et al. 1993, Villar et al. 1987, MacQueen et al. 1988). At the time of mobilization, the fractures were stable and no major migration of the fragments could be detected in the external fixation group between this moment and 3 months, showing that the immobilization time was adequate. In the Norian SRS group, 3/12 cases were still unstable showing that the fixation of the fracture can be further optimized. In neither group was the fracture system perfectly stabile during the immobilization. In the external fixator group, the compression between the fragments was minimal and without clinical relevance. The 2 patients who had a compression of more than 2 mm moved 2.2 mm and 2.5 mm, respectively. In the SRS group, 6 of 12 patients had a maximal migration of the fragments along the longitudinal axis which exceeded 2 mm, indicating that the fracture system was not rigid. This lack of rigidity can be explained by the osteoporotic bone being too weak, or by insufficient fixation by the Norian SRS. The stability of the fracture might be improved by the use of hardware. However, the migration never interfered with the recovery of the patients. MTPM reports the magnitude of the motion in all directions and not only the fracture migration in one plane that can be measured on conventional radiographs. For example, the rotation and dislocation of the radial styloid fragment, as in the gross failure case, had a MTPM of 16.4 mm during treatment, which corresponds to 26 degrees of radial compression, 13 degrees of dorsal compression and 5 mm of axial compression. Usually the marker that migrated the most, and thus provides the MTPM values, was situated near the tip of the radial styloid and a small rotation of the styloid fragment could correspond to a large MTPM value. In this study, the 2 methods for measuring fracture displacement correlated only for extra-articular fractures in which only 2 fragments must be defined. In intra-articular fractures with 3 or more fragments, the positioning of the tantalum markers is more difficult because they define the different fracture fragments with separate rigid bodies. In our study, the tantalum markers tended to be placed in the radial styloid more than on the ulnar border, and this may explain the poor correlation between RSA and conventional radiographs if the fracture was composed of more than one fragment. The positioning of the markers could be optimized by introduction through the dorsal cortex and located more precisely below the articular surface.

In conclusion, the stereometric analysis showed that 5 weeks of immobilization is sufficient for healing with external fixation in this age group. Treatment of the fracture with Norian SRS might reduce the immobilization time to 2 weeks but additional hardware may have to be used to ensure stability of the fracture system. The difficulty in positioning the markers and the small size of the rigid body within the radius limit the use of RSA for study of the distal radius fracture.

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