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Graft-supplemented, Augmented External Fixation in the Treatment of Intra-articular Distal Radial Fractures

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Abstract

This article compares the functional and radiographic outcomes of intra-articular distal radial fractures treated with augmented external fixation in which autologous cancellous bone grafting or Norian SRS (Norian Corp, Cupertino, Calif) was used for filling the metaphyseal void. Thirty non-randomized patients, 15 in each group, with AO type C distal radius fractures (20 men and 10 women; average age: 48 years) were operatively treated between 1998-2000 and retrospectively evaluated. Radial inclination, radial length, volar tilt, and Modified Mayo Wrist Score were assessed at the most recent follow-up evaluation (average: 33.3 months). Overall, 12 (80%) patients in the Norian group had an excellent or good result, 2 had fair, and 1 had poor. In the autologous iliac bone graft group, the results were excellent or good in 11 (73.3%) patients, fair in 1, and poor in 2. No statistical difference between the two types of grafting was noted. Norian SRS is equally effective to cancellous bone as supplementary graft in comminuted distal radial fractures treated by external and Kirschner-wire fixation.

Distortion of the articular surface and concomitant collapse of the metaphyseal cancellous bone complicate intra-articular distal radial fractures. Surgical intervention is often mandatory to restore and stabilize the fragments and to offer structural support. That includes various means of stabilization of which external fixation and Kirschner-wires are the most popular.[1] The remaining metaphyseal defect after reduction can lead to malunion[2-4] and decreased function.[5-7] An alternative approach is the primary use of a material that can provide structural support.

Both bone graft and polymethylmethacrylate have been used for primary stabilization of distal radial fractures with good results,[8-11] but morbidity at the donor site (pain, infection, hematoma, nerve injury, and pathologic fracture)[12,13] and the lack of osseointegration of polymethylmethacrylate[14] have reduced interest in these methods of treatment. Norian SRS (Norian Corp, Cupertino, Calif) is an osteoconductive synthetic material that transforms under physiological conditions into a carbonated apatite similar to the mineral phase of bone, providing some of the mechanical properties of natural bone.[15]

Norian SRS is biocompatible, does not interfere with fracture healing, and is remodeled by the same osteoclastic-osteoblastic process as living bone.[16] In a cadaver study,[17] Norian SRS provided more stability than K-wires for intra-articular distal radial fractures, whereas several clinical series[18-20] have shown that this product can be safely used for these fractures with acceptable final results. Three studies have compared Norian SRS with external fixation,[21] cast immobilization,[22] and functional treatment[23] in correspondence. A recent study compared the supplementary use of Norian SRS in pin and screw fixation of intra-articular distal radial fractures in osteoporotic women with that of pin and screw fixation alone.[24] A comparison of SRS with autologous bone graft in K-wire–augmented external fixation has not been previously reported. This study retrospectively evaluated the supplementary use of autologous cancellous bone graft and Norian SRS in the treatment of comminuted distal radius fractures treated with K-wire–augmented external fixation.

Materials and Methods

Between January 1998 and September 2000, 30 non-randomized patients with comminuted intra-articular distal radial fractures were surgically treated in our department by two of the authors (T.M. and G.D.) with external fixation, open K-wire stabilization of the fragments, and supplementary grafting of the metaphyseal defect with either autologous bone graft (15 patients) or Norian SRS (15 patients). There were 20 men and 10 women. Average patient age was 46 years (range: 21-83 years) and mean follow-up was 33.3 months (range: 26-44 months). The right side was involved in 13 patients and the dominant hand in 17. The mechanism of injury was fall on the outstretched hand in 18 patients and traffic accident in 12.

Inclusion criteria

All patients had type C fractures according to AO classification (9 C1, 11 C2, 10 C3) and underwent surgery within 3 days of their admission. The inclusion criteria in the study were:

- Unstable intra-articular fracture with either methaphyseal compression void of at least 5 mm or step-off or gap in the articular surface >2 mm (Figures 1 and 2).
- Absence of previous fractures in both wrists.
- Absence of associated injuries in the upper limbs.
- No preoperative effort for reduction of the fracture.

Treatment protocol

The operation took place under general or regional anesthesia. A mini AO external fixator (AO/ASIF; Synthes, Betlach, Switzerland) or a Distal Radius System (Richards, Memphis, Tenn) was applied according to the standard technique. The choice of hardware depended on the availability of the equipment. Open reduction was achieved through a dorsal longitudinal incision 6-7 cm proximal to the radiocarpal joint. The retinaculum was opened at the third dorsal compartment and the extensor pollicis longus

displaced radially. The second and fourth compartments and their tendons were subperiostally elevated, the fracture site was identified, and the joint was vertically incised. Under direct vision and traction, any articular step-off was restored. The fragments were stabilized with two to three K-wires. To maintain reduction of the radiocarpal joint, a 1.2- or 2-mm K-wire was inserted at the radial styloid and placed subchondrally, parallel to the radiocarpal joint. One or two 2-mm K-wires were inserted afterwards from the radial styloid to the radial shaft to maintain radial joint angles and radial length. The frame was then applied with moderate traction of the wrist (ie, enough to keep the articular surface of the radius, scaphoid, and lunate apart).

If there were any indication, in the preoperative radiographs of additional ligamentous rupture, the wrist would be checked under an image intensifier and any ruptures would be repaired accordingly. This was necessary in one patient in each group. The remnants of the ligaments were sutured and additional Mitek bone anchors (Mitek, Norwood, Mass) used as necessary.

In all cases, the cavity created after elevation of the fragments was packed either with cancellous bone graft (Figure 3) taken from the iliac crest or with an injection of 5 cm^3 appropriately prepared Norian (Figure 4). The time of injection was <2 minutes. The limb was then kept immobile for 10 minutes to avoid disruption of the product. Extravasation of Norian into the wrist was avoided by unforced insertion of the product into the cavity, provided that an excellent reduction of the articular surface had been achieved. In cases of articular gap, a small elevator was kept against it at the time of product insertion. The choice of graft type depended on the preference of the surgeon.

The patient was advised to move the hand, elbow, and shoulder as soon as tolerated. Serial radiographs were obtained 2, 4, 6, and 12 weeks postoperatively and at final follow-up. The external fixator was removed when palpation on fracture site elicited no pain (between the sixth and seventh postoperative week). Active range of motion (ROM) was initiated after external fixation removal and lasted 2-4 weeks by passive ROM, if necessary.

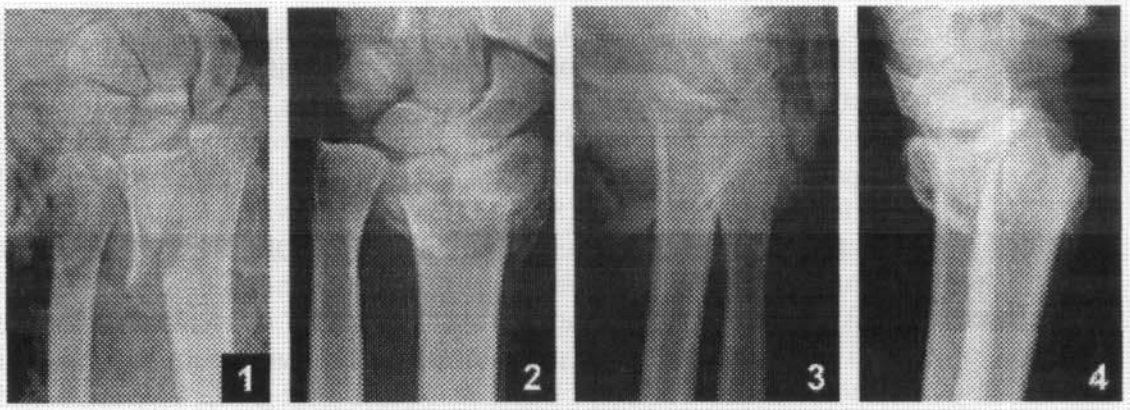

Figure 1: *Patient 11, cancellous group.* Preoperative radiograph of an AO type C2 distal radial fracture. **Figure 2:** *Patient 12, Norian group.*

Preoperative radiograph of an AO type C3 distal radial fracture. **Figure 3:** *Patient 11, cancellous group*. Preoperative radiograph of an AO type C2 distal radial fracture. **Figure 4:** *Patient 12, Norian group*. Preoperative radiograph of an AO type C3 distal radial fracture.

Radiographic Parameters

Standard posteroanterior and lateral radiographs of the most recent follow-up visit were compared with the preoperative ones. Radial inclination, volar tilt, and radial length were measured in the radiographs by two of the authors who were not related to the original treatment (M.P. and P.A.).

Clinical Outcome

At final follow-up, all patients were reassessed clinically. At the most recent follow-up, grip strength was obtained using a Jamar dynamometer (Asimow Engineering, Los Angeles, Calif), ROM was measured, and the Modified Mayo Wrist Score questionnaire was answered by the patients. Clinical outcome was graded accordingly.

Statistical Analysis

Clinical and radiological statistical analysis and graphs were performed using the GraphPad Prism 2.01 package (GraphPad Software Inc, San Diego, Calif). The Mann-Whitney test or the Wilcoxon matched pairs test was used for testing relationships between non-continuous categorical variables as appropriate. A P value $<.05$ was considered significant.

Results

Clinical

The Modified Mayo Wrist Score System was used for clinical assessment. Eleven patients in the Norian group and 9 in the cancellous graft group stated they had no pain, 3 and 5 patients respectively had mild pain with vigorous activities, and 1 patient in each group had mild pain with activities of daily living. Range of motion and grip strength were evaluated as a percentage of the normal wrist. Two patients in the cancellous graft group had moderate restriction of motion (55% of normal). Four patients in the Norian group and 2 in the cancellous graft group had regained full ROM. The remaining 11 patients in each group had 75%-99% of normal. Eight patients in the Norian group and 10 in the cancellous graft group regained normal grip strength while 7 and 5 respectively had 75%-99% of normal ROM. Overall, 12 patients in the Norian group had good or excellent results, 2 had fair, and 1 had poor. In the cancellous graft group, 11 patients had good or excellent results, 1 had fair, and 2 had poor (Tables 1 and 2). The Mann-Whitney test for the parameters of the Mayo Score was not statistically significant ($P>.05$) between the Norian and cancellous groups.

Table 2

Patient Data: Cancellous Group

Patient	Follow-up (mo)	Preoperative/Postoperative/Follow-up Radial Length	Radial Inclination	Volar Tilt	Mayo Score
1	28	9/12/11	13/24/28	−40/17/16	90
2	32	1/9/11	7/25/20	−40/16/17	75
3	33	2/9/10	18/24/28	−30/14/12	90
4	38	4/10/8	11/22/23	−25/8/6	85
5	27	14/14/14	13/21/21	7/11/10	95
6	32	3/9/-2	14/22/45	3/6/10	60
7	30	15/10/10	10/10/10	−20/22/22	100
8	28	1/11/15	14/22/22	−30/8/9	85
9	38	7/13/20	11/24/25	4/8/10	65
10	40	8/12/12	16/24/26	−32/11/12	85
11	42	11/12/12	12/19/20	4/9/11	80
12	29	7/9/10	12/17/17	3/10/10	90
13	35	7/11/12	12/19/20	−20/17/17	90
14	44	3/6/6	3/7/8	11/18/18	60
15	42	8/10/10	8/18/20	−30/21/21	85

Radiographic

Preoperatively, the mean radial length in the Norian group was 7.6 mm, the average radial inclination was 14.1°, and the mean volar tilt was 17.4° dorsally. In the cancellous graft group, the mean radial length preoperatively was 6.6 mm, the average radial inclination was 11.6°, and the mean volar tilt was 19.9° dorsally. At the most recent follow-up, the mean radial length in the Norian group was 11.7 mm, the average radial inclination was 19.6°, and the mean volar tilt was 11.8° volarly. In the cancellous graft group, the mean radial length was 10.6 mm, the average radial inclination was 22.2°, and the mean volar tilt was 13.4° volarly. The Wilcoxon matched pairs test did not show any statistical difference regarding the radiological parameters (radial length, radial inclination, and volar tilt), especially when postoperative and follow-up radiographs were compared. Similarly, the statistical difference between the cancellous and Norian groups, according to the Mann-Whitney (unpaired) test, was not significant ($P>.05$).

There were no nonunions, infections, or sensory nerve irritation. The mean time of external fixation removal was 43.2 days in the Norian group and 47.8 days in the cancellous graft group. Between the sixth and seventh week postoperatively all fractures had united radiographically. Radiological fracture healing was defined as the presence of

Table 1

Patient Data: Norian Group

Patient	Follow-up (mo)	Preoperative/Postoperative/Follow-up			Mayo Score
		Radial Length	Radial Inclination	Volar Tilt	
1	26	10/13/13	16/27/24	−14/19/18	90
2	27	9/10/11	15/21/22	−18/10/12	80
3	28	10/11/11	26/20/22	−12/12/12	85
4	30	3/10/11	6/16/17	−19/19/17	90
5	28	0/8/10	10/18/19	−13/18/17	60
6	29	13/12/12	3/10/12	−30/6/8	90
7	31	9/12/11	13/14/15	4/12/12	90
8	36	8/12/13	22/20/22	−28/10/11	80
9	42	10/12/12	20/18/19	10/10/10	75
10	44	7/11/11	18/22/22	10/8/9	80
11	40	8/11/12	15/18/19	12/10/11	85
12	30	3/12/13	12/22/22	−33/8/9	100
13	28	5/10/11	2/22/24	−26/8/8	85
14	32	8/10/10	8/18/19	−30/6/6	85
15	40	11/16/15	26/19/17	3/18/17	70

bridging callus and indefiniteness of the fracture line on normal anteroposterior and lateral views.

In 2 patients in the Norian group, intra-articular extrusion of the product was detected on postoperative radiographs despite the measurements taken to avoid this complication. In another patient with severe radial metaphyseal collapse that had not been restored with surgery, ulna shortening was performed 6 months after the initial treatment.

One patient in the cancellous graft group was reoperated 2 days after the initial treatment because of inadequate reduction. Overall, 4 patients in this group had donor site complications: 1 underwent surgical drainage of an iliac crest hematoma, 1 had a superficial infection treated with intravenous antibiotic therapy, and 2 reported iliac crest pain several weeks postoperatively. Ulna plus was seen in 1 patient in this group, but he refused further treatment because he reported minor pain. Another patient with ulna minus refused further treatment for the same reason.

The average time of final rehabilitation was 74 days in the Norian group and 88 days in the cancellous graft group.

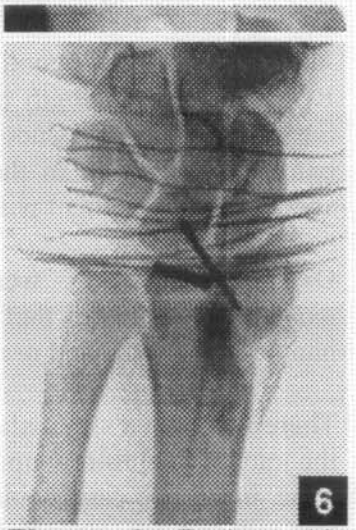

Figure 6: Patient 12, Norian group. The extended metaphyseal void was filled with Norian SRS and an external fixator and K-wires were used for reduction.

fixation, K-wires, and cancellous bone grafting.

Discussion

Distal radial fractures are complex injuries with a variable prognostic outcome depending on fracture type, metaphyseal defect, treatment modality, and the patient's demands.[25-27] Studies have shown that articular incongruity of the distal radius predisposes to aggregation of symptoms and decreased ROM and grip strength,[28] and even to post-traumatic osteoarthritis[29] if left untreated. There is a well-established correlation between the failure to maintain accurate fracture reduction and functional outcome.[30,31] Open reduction and stabilization with K-wires combined with external fixation has been proposed as an effective method of treatment of intra-articular distal radius fractures.[32] Grafting of the metaphyseal cavity with autogenous corticocancellous or bone replacement materials is necessary because clinical studies have shown improved outcome due to earlier removal of the external fixation and initiation of motion.[24,26,30,33] Bone autograft has osteoconductive and osteoinductive properties and offers structural support while promoting healing.[34] However, it is available in limited quantity and related to donor site morbidity.[12,13,35]

Norian compared with cancellous bone has higher compressive strength (55 MPa) and lower tensile and shear strength.[36] Since intra-articular fragments were very small, we

used Norian to fill the cavity and K-wires to stabilize the fragments, relying on the osteoconductive properties of the product rather than on the compressive ones. The cancellous graft group and Norian group yielded equally excellent and good results. In addition, no difference in fair and poor results was found between the two groups. We also found no relation between the fracture type and the pain score according to Mayo Wrist Score. The worst result, mild pain with daily activities, occurred in one patient in the Norian group with concomitant rupture of the scapholunate ligament and one patient in the cancellous graft group with significant ulna minus at most recent follow-up.

Patients had equally good results regarding ROM and grip strength. No one had <75% ROM and grip strength compared with the normal wrist, regardless of fracture type. Satisfaction score was not related to fracture type. Patients who reported pain, those with extrusion of Norian in the joint, and those who were reoperated had low satisfaction scores. Another patient with no pain was moderately satisfied.

Overall, our results were comparable with those of other series. Radiographic examination revealed that after surgery radial length, radial inclination, and palmar tilt had been corrected and remained so at most recent follow-up (Figures 5 and 6).

There was only a slight alteration in the radiographic image of Norian within the bone or the joint at final follow-up. This alteration is related to replacement of the product by host bone. In the two cases with Norian in the joint space, ROM was normal, but grip strength was reduced. It is doubtful that grip strength weakening is related to the presence of the product within the joint because in the first patient there was also articular step-off postoperatively and in the second, the flexor pollicis longus was ruptured. We believe that when extravasation occurs, thorough lavage of the joint is imperative. We removed the external fixation 4-6 days earlier on average in the Norian group because the product offers better support of the fragments in the postoperative period.

Donor site morbidity is described in the literature as one of the disadvantages of this method. This was apparent because donor site morbidity occurred in 4 patients.

Mid-term follow-up period is probably the main reason we did not see signs of severe osteoarthritis. It is most likely that in some patients with articular step-off, osteoarthritis will occur in the future.

Since harvesting of autologous cancellous bone graft is related to donor site morbidity and there are no differences in overall clinical and radiographic results between patients treated with cancellous graft and those treated with Norian SRS, the latter could be used in intra-articular distal radial fractures along with other means of stabilization. Extrusion of the product in the joint is of concern and should be carefully monitored.

What is already known on this topic

- Cancellous bone grafts have been the gold standard for filling the gap at the metaphyseal region in comminuted, unstable fractures of

the distal radius.

- Norian SRS, a relatively new product, has been effectively used in extra-articular fracures of the distal radius.
- There are reports for successful use in intra-articular distal radial fractures.

What this article adds

- Norian SRS yields equal results with cancellous bone grafts in the treatment of comminuted, unstable fractures of the distal radius.

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