Treating Unstable Distal Radius Fractures With a Nonspanning External Fixation Device: Comparison With Volar Locking Plates in Historical Control Group

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Abstract

We conducted a study to compare functional and radiographic outcomes of unstable comminuted intra-articular distal radius fractures (DRFs) treated with a nonspanning external fixation device and outcomes achieved with volar locking plates in a historical control group. Clinical and radiographic data from 25 patients with these fractures, treated with the external fixation device, were compared with outcomes data from historical control matched patients with fracture patterns treated with volar locking plates.

There was no statistically significant difference in the measured outcomes for wrist flexion and extension, radial deviation, pronation and supination, volar tilt, radial height, radial inclination, and Disabilities of the Arm, Shoulder, and Hand (DASH) scores between the 2 groups. The external fixator group had significantly more postoperative ulnar deviation than the historical control group. Complications included pin-tract infection and fracture in 1 patient who fell 2 weeks after fixator removal.

Nonspanning external fixation is an alternative treatment option for unstable comminuted DRFs. It is minimally invasive and has functional and radiographic results similar to those achieved with volar locking plates in matched patients in historical control studies.

In the United States, distal radius fractures (DRFs) are among the most common fractures, comprising about 15% of all extremity fractures.[1] With a DRF, the primary treatment goal is anatomical reduction with restoration of radiographic parameters and stable fixation of the fracture to restore wrist function.

Take-Home Points

- Clinical and radiographic outcomes of patients treated with non-spanning external fixation are comparable to those treated with open reduction and internal volar locked plate fixation.
- Non-spanning external fixation can lead to satisfactory outcomes based on the following features: fragment specific fixation, subchondral support, fixed angle strength, limited dissection, distraction/length adjustment, joint distraction avoidance, and ability to perform early rehabilitation.
- Non-spanning external fixation should be considered as a treatment option for complicated unstable comminuted intra-articular distal radius fractures, specifically in the elderly.

This fracture type has a variety of treatment alternatives, including nonoperative closed reduction and casting of stable fractures, open reduction and internal fixation (ORIF) with dorsal or volar locking plates, and external fixation. Optimal surgical management of unstable DRFs remains controversial.[2] Closed reduction with percutaneous pinning or external fixation has become less common with a trend toward using volar locking plates for internal fixation.[3]

External fixation of DRFs traditionally has involved either spanning or simple nonspanning devices. Spanning fixation is particularly useful in open or highly comminuted fractures with an unstable soft-tissue envelope. In the past, non-

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spanning external fixation typically was reserved for fractures with a noncomminuted extra-articular distal fragment to which several large pins or Kirschner wires (K-wires) could be secured. The Non-Bridging External Fixator (NBX; Nutek Orthopaedics) may be used in cases that traditionally might be treated with locked plating or fragment-specific fixation. Specifically, this device is indicated for comminuted intra-articular DRFs in which bone quality may be less than ideal. The NBX, also suitable in open fractures with a stable soft-tissue envelope, can restore and maintain articular alignment by providing subchondral support and stability with fragment-specific fixation. A key advantage of this type of external fixation is that it involves percutaneous fixation and allows for early postoperative range of motion (ROM).

Numerous studies have found excellent outcomes of treating unstable DRFs with ORIF with volar locking plates.[4-6] However, few studies have compared the clinical and radiographic outcomes of ORIF with those of nonspanning external fixation in the treatment of unstable comminuted intra-articular DRFs. Windolf and colleagues[7] found that, in cadaveric unstable intra-articular DRFs, nonspanning external fixation with multiplanar K-wires had biomechanical characteristics comparable to those of volar locking plates. Other suitable DRF treatment options have been found: an alternative nonbridging external fixator with multiplanar K-wires (Gradl and colleagues[8]) and the Cross-Pin Fixation system (A.M. Surgical) (Mirza and colleagues[9]).

We conducted a study to compare functional and radiographic outcomes of unstable comminuted intra-articular DRFs treated with a nonspanning external fixation device (NBX) with outcomes achieved with volar locking plates in a historical control group.

Materials and Methods

This retrospective case-control study was approved by our Institutional Review Board and conducted at 2 institutions. Included in the study were 25 consecutive patients (2 institutions) who underwent closed reduction and external fixation (CREF) with NBX as treatment for unstable DRFs (diagnosis based on radiographic parameters or inability to maintain acceptable alignment after closed reduction and casting). Of these 25 patients, 11 were available for clinical follow-up and medical records review; the other 14 were not available for follow-up but had their charts reviewed for radiographic data and treatment details. Six of the 14 patients declined to participate in the study, and the other 8 were lost to follow-up because of nonstandardized follow-up protocols. Patients were excluded from the study if their final follow-up had not occurred, or if it occurred before 6 months. For their participation in clinical follow-up, patients received nominal time compensation and mileage reimbursement through a grant from the NBX manufacturer.

The 25 patients underwent CREF with NBX between November 2008 and March 2013. Indications for external fixation consideration were intra-articular extension or significant comminution in patients with poor soft tissue or in patients who wanted to avoid invasive surgery or a permanent implant. Of the 11 patients who agreed to participate in the study, 7 were women and 4 were men; mean age was 64 years (range, 15-81 years). Of the 14 patients unable to follow up, 11 were women and 3 were men; mean age was 63 years (range, 26-89 years). At the last available follow-up, each of the 25 patients was doing well, was satisfied with treatment received and function regained, and had a healed DRF. In almost every case, the mechanism of injury was a fall onto an outstretched hand; most fractures were type C per AO (Arbeitsgemeinschaft für Osteosynthesefragen) classification (**Table 1**).

The surgical technique for this nonspanning external fixator involves closed reduction with longitudinal traction using ligamentotaxis to grossly align the fracture fragments, with small adjustments made throughout the procedure. A dorsally placed radiolucent fixator is used with fluoroscopic guidance to percutaneously affix a subchondral raft of smooth bicortical .062-inch K-wires. The fixator's abundant pin holes allow for each specific distal fragment to be captured by pins that are a part of the external fixation construct. Furthermore, radially based pins that use a side bar allow for a "weave" of fixation. Radial length is then obtained and maintained by attaching the distal complex to proximal pins in the radial diaphysis. After pins are cut and wrist and digits are taken through full ROM to ensure smooth tracking, fluoroscopy is used to confirm final fracture fixation and alignment (**Figure 1**).

In ideal scenarios with good fixation, patients can begin gentle ROM exercises within 1 week after surgery. This regimen can progress to more aggressive motion exercises and even light strengthening (**Figure 2**). Given the comminution, the treating surgeons immobilized all patients in a removable short-arm volar wrist splint for 4 to 6 weeks after surgery; patients could temporarily re-

Table 1. **Demographics and Outcomes Data of Study Patients Treated With Nonspanning External Fixation**

					Injury/Final Radiograph[b]			Range of Motion, degrees: Wrist				Range of Motion, degrees: Forearm		Strength, lb	
Pt	Sex	Age, y	Injury Side	AO Class	Volar Tilt, degrees	Radial Inclination, degrees	Radial Height, mm	Flexion	Extension	Radial Deviation	Ulnar Deviation	Pronation	Supination	Corrected Grip	Key Pinch
1[a]	M	66	R	C3	–16/NA	13/NA	5/NA	77	51	24	44	80	85	76.5	22.3
2[a]	F	60	L	C3	–30/9	16/27	7/8	96	61	44	48	90	90	26	10.7
3[a]	F	74	L	C2	–35/NA	14/NA	6/NA	53	63	21	37	90	80	38	6.7
4[a]	M	15	L	B2	14/21	22/24	8/8	83	96	46	46	90	90	109	18.7
5[a]	M	61	L	C2	–10/–8	12/15	5/5	47	59	43	34	85	80	89	19.0
6[a]	F	71	L	B2	–8/NA	8/NA	3/NA	64	62	9	62	80	90	45	9.0
7	F	60	L	B1	–29/6	44/29	11/11	—	—	—	—	—	—	—	—
8	M	81	L	C3	–5/NA	10/16	5.8/8	—	—	—	—	—	—	—	—
9	F	60	L	C2	NA/4	NA	NA/5	—	—	—	—	—	—	—	—
10	F	61	L	C1	–14/–5	19/20	7/8	—	—	—	—	—	—	—	—
11	M	53	R	C2	NA/–16	NA/19	NA/7	—	—	—	—	—	—	—	—
12	M	39	L	C1	NA	NA	NA	—	—	—	—	—	—	—	—
13	F	85	R	C2	NA/–9	NA/28	NA/8	—	—	—	—	—	—	—	—
14	F	55	R	C1	–4/0	31/31	10.7/7	—	—	—	—	—	—	—	—
15[a]	M	80	L	C3	–19/11	16/27	8.5/13	70	50	23	47	80	80	43.3	15.0
16[a]	F	81	L	C2	2/13	10/18	4/7	68	72	7	44	85	85	53.3	14.0
17[a]	F	56	R	C1	–43/8	10/22	3/7	66	62	46	65	90	85	76.5	12.7
18	F	55	R	C3	NA/0	NA/20	NA/7	—	—	—	—	—	—	—	—
19	F	84	L	C2	–12/3	15/26	3/12	—	—	—	—	—	—	—	—
20	F	89	R	C1	–14/16	20/25	8/9	—	—	—	—	—	—	—	—
21	F	83	R	—	NA/13	NA/20	NA/9	—	—	—	—	—	—	—	—
22	F	26	R	C2	–3/NA	15/NA	9/NA	—	—	—	—	—	—	—	—
23	F	49	L	A3	–42/NA	–1/NA	0/NA	—	—	—	—	—	—	—	—
24	F	76	R	C2	–20/–8	–5/0	–2/0	50	60	40	40	80	80	5	7
25	F	69	L	C1	–30/2	0/6	0/4	60	50	30	40	80	60	5	8
Mean	—	**63.6**	—	—	**–16.7/3.3**	**14.2/20.7**	**5.4/7.5**	**66.7**	**62.4**	**30.3**	46.1	84.5	82.3	51.5	13.0
SD	—	18.4	—	—	15.1/9.9	11.0/8.0	3.6/2.9	14.6	13.0	14.5	9.6	4.7	8.5	33.5	5.3

[a]Clinical evaluation.
Abbreviation: AO, Arbeitsgemeinschaft für Osteosynthesefragen; NA, not available; pt, patient.

move this splint during physical therapy, starting at week 1. The splint was used after fixator removal as well. All patients began their supervised, nonimmobilized ROM and strength therapy between 1 and 4 weeks after surgery. This therapy initially focused on digit motion and gentle wrist motion. After fracture union was confirmed radiographically, 6 to 10 weeks after surgery, the external fixator was removed.

The 11 clinical follow-up patients underwent directed clinical examination, including ROM and strength evaluation, by Dr. Dwyer and Dr. Crosby. Follow-up also included completion of questionnaires and review of radiographs.

During the clinical follow-up, a standard goniometer was used to evaluate active ROM (wrist flexion and extension and wrist radial and ulnar deviation, measured down the long axis of the forearm and the index ray), and forearm pronation and supination were measured from the 90° elbow flexion position using the humerus as the reference point with the shoulders in 0° of flexion, abduction, and external rotation. In addition, a calibrated dynamometer (Sammons Preston) was used to measure grip strength (position 3) and key pinch strength, and the average of 3 trials of each strength test was calculated. ROM and strength values were calculated as percentages of the contralateral (uninjured) side, as these ratios are more sensitive in detecting clinical changes.[10] A 10% adjustment for dominant hand grip strength in right-handed patients was used for this comparison.[11]

Union (osseous bridging across fracture site on 2 of 3 views), radial height, radial inclination, and volar tilt were measured on standard posteroanterior and lateral radiographs taken at several points: time of injury, postreduction and/or preoperative, initial postoperative, and final follow-up. All radiographic measurements were independently taken by Dr. Dwyer and Dr. Crosby, who used a digital goniometer and ruler (Siemens Medical Solutions) or, when necessary, manual instruments. Means of the original and independent measurements were used for calculations.

The Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire, the Mayo wrist score, and the patient-rated wrist evaluation were used to assess activities of daily living, pain, and quality of life after surgery. Mayo wrist scores were adjusted for unemployed patients; work status was replaced with return to normal activities.

Complications of surgical treatment were eval-

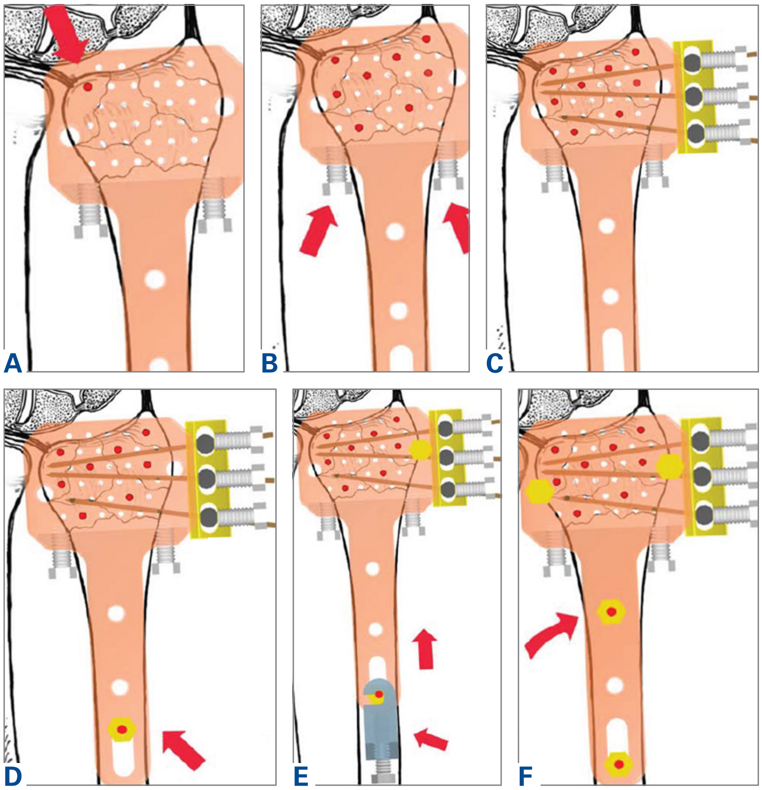

Figure 1. Surgical technique. (A) Alignment of fixator with the first pin placed in the distal ulnar corner (arrow) within the lunate facet fragment. (B) Remaining distal dorsal pins placed, including pin in the radial styloid fragment, followed by tightening of the slide plate bolts (arrows) with the plate 0.75 inch off skin. (C) Radial-to-ulnar pins placed in a weave pattern and locked into the side bar. (D) Pin placed proximally into the radial diaphysis through an oblong hole (arrow). (E) Radial length adjusted up to 1 cm using a distraction device (arrows). (F) Distraction maintained after placement of additional pin within diaphysis (arrow).

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Figure 2. Clinical photographs of 3 patients with fixator in place.

Table 2. **Descriptions and Data From Historical Control Studies**

Study	N	Mean Age, y	AO Class	Follow-Up, mo	Range of Motion, degrees: Flexion	Extension	Supination	Pronation	Ulnar Deviation	Radial Deviation	Strength, lb: Grip	Key Pinch	DASH	Radial Height, mm	Radial Inclination, degrees	Volar Tilt, degrees
Rozental et al[5] (2009)	23	52	A2 = 2 A3 = 8 C1 = 2 C2 = 11	12	68	64	88	88	40	28.00	40	44%	4	11	21	3
Wei et al[12] (2009)	12	61	A = 3 C = 9	12	53	63	81	89	28	13.00	16.9	4.7	4	9.5	17.6	4
Wright et al[6] (2005)	21	50	A3 = 2 C2 = 9 C3 = 10	17	64	63	80	78	36	23.00	75	—	16	—	22	10
Rozental & Blazar[13] (2006)	41	53	A2 = 3 A3 = 15 B2 = 4 C2 = 14 C3 = 5	17	52	53	71	73	—	—	94%	—	14	—	—	—
Osada et al[14] (2008)	49	60	A3 = 6 C1 = 1 C2 = 9 C3 = 33	12	66	75	88	78	37	23.00	92%	—	6	9	22	9
Orbay & Fernandez[15] (2004)	24	79	A2 = 3 A3 = 12 B3 = 1 C1 = 2 C2 = 5 C3 = 1	15	55	58	76	80	26	13.00	77%	—	8.28	0	20	5
Rein et al[16] (2007)	15	54	C3 = 15	22	45	50	76	79	21	18.00	18	—	14	14	22	3
Margaliot et al[17] (2005)	603	51	—	23	52.4	59.3	79.3	78.5	27	16.00	0.8	—	—	11.5	21.1	4.6

Abbreviations: AO, Arbeitsgemeinschaft für Osteosynthesefragen; DASH, Disabilities of the Arm, Shoulder, and Hand.

uated. Major complications evaluated were loss of reduction, malunion, nonunion, deep infection, neuropathy, and tendon rupture. Minor complication possibilities were transient extensor tendon irritation, superficial infection, and finger stiffness. Also noted were 1 patient who subsequently required another procedure and 7 patients who were immobilized after external fixation removal.

We compared our study group's outcomes with those of historical control patients who underwent fixation with internal volar locking plates. The 2 groups had similar demographic characteristics. To obtain the historical controls, we used the key words *distal, radi**, *volar,* and *plat** in a PubMed search. From the 169 citations found, we removed biomechanical cadaver studies, studies that focused on patients with demographics and fracture types dissimilar from our patient population's, and studies that focused on special circumstances, such as complications or patient characteristics. Eight studies remained for historical comparison.

From these comparative studies, we extracted

Table 3. **Outcomes Data: Comparison of Nonspanning External Fixation and Pooled Historical Control Data**

	External Fixation		Pooled Data[b]	
Outcome Measure	**Mean**	**SD**	**Weighted Mean**	**SD**
Range of motion, degrees				
Flexion	66.7	14.6	59	9.9
Extension	62.4	13.0	62	12.9
Supination	82.3	8.5	80	10.7
Pronation	84.5	4.7	79	8.0
Radial deviation	30.3	14.5	34	7.2
Ulnar deviation[a]	46.1	9.6	21	8.3
DASH score	11.4	10.5	7	11.1
Volar tilt, degrees	3.3	9.9	6	3.3
Radial inclination, degrees	20.7	8.0	21	3.2
Radial height, mm	7.5	2.9	8	1.8

[a]$P = .01$ (statistically significant); all other outcome measures, $P > .1$.
[b]N = 173.
Abbreviation: DASH, Disabilities of the Arm, Shoulder, and Hand.

outcomes data and study characteristics (**Table 2**).[5,6,12-17] Not all applicable information was available in each study. For statistical analysis, we pooled the historical control data. In some cases, data ranges were used to calculate standard deviations.[18] Calculation of weighted means was based on number of participants in each study. These means were then compared with our study means, and an independent *t* test was used to evaluate the statistical significance of the results (**Table 3**).

Intraoperative radiographs were available for all patients, but they varied in image quality and measurement capability. Therefore, we used preoperative and final radiographs to obtain the most reliable results in our assessment of radiographic parameters. Of the 25 study participants, 16 had injury and final (post-external fixator removal) radiographs. The radiographic outcome parameters of these 16 patients were compared with historical control data.

Results

Radiographic Outcomes

On the injury radiographs, mean volar tilt was –16.7° (range, 2° to –42°), mean radial inclination was 14.1° (range, –1° to 44°), and mean radial height was 5.3 mm (range, –2 mm to 11 mm). Minor improvement after reduction was noted. All patients had intraoperative or postoperative radiographs with external fixation in place (**Figure 3**).

On the final (post-fixation removal) radiographs, mean volar tilt was 3.3° (range, –16° to 21°), mean radial inclination was 20.7° (range, 0° to 31°), and mean radial height was 7.5 mm (range, 0 mm to 13 mm). Comparison of the injury and final means revealed correction of ~20° for volar tilt, 6° for radial inclination, and 2 mm for radial height. All but 5 patients had type C fractures (AO classification).

Clinical Outcomes

Eleven patients underwent clinical evaluation (functional assessment, physical examination). Mean DASH score was 11.4 (SD, 10.5; range, 0-27.3), mean Mayo wrist score was 79.0 (SD, 12.2; range, 65-100), and mean patient-rated wrist evaluation was 12.2 (SD, 11.9; range, 0-25.5). There was no statistical difference in DASH scores between this group and the historical control group (Table 3). ROM was measured under active effort. In our group, mean wrist flexion was 69.3° (86% of contralateral side), and mean extension was 64.0° (94%). Mean radial deviation of the wrist was 47.4° (135% of relative normal for patient), and mean ulnar deviation was 29.2° (101%). Mean (SD) pronation was 84.6° (4.7°), and mean (SD) supination was 82.3° (8.5°), or about 100% of contralateral pronosupination.

For each hand, 3 grip strength values and 3 key pinch strength values were obtained. These values were averaged, and the injury and contralateral sides were compared. Mean grip strength was

Figure 3. (A) Injury radiographs, anteroposterior and lateral. (B) Postoperative radiographs, posteroanterior and lateral. (C) Final radiographs, posteroanterior and lateral.

49.6 pounds (85% of contralateral), and mean key pinch strength was 14.0 pounds (97%).

Complications

Of the 25 patients, 6 (24%) had a pin-tract infection treated with oral antibiotics. One of these infections resulted in the removal of the entire fixator. One (4%) of the 25 patients reported transient hypoesthesia of the dorsal first webspace, and 3 (12%) reported pain at the pin sites.

Although all fractures achieved complete bony union, 1 patient (4%) had a refracture on the same fracture line after a fall within 6 weeks after fixator removal; this refracture was successfully treated with a cast worn for 6 weeks. Of the 3 patients with complete follow-up (27%) who lost reduction with external fixation in place, 2 had radiographic parameters maintained within acceptable limits, and 1 (9%) had a malunion with –16° volar tilt.

Our study patients had no tendon rupture, tendon irritation, or stiffness. By contrast, fixation with volar locking plates has been associated with extensor tendon and flexor tendon injury, flexor pollicis rupture, carpal tunnel syndrome, complex regional pain syndrome, loss of reduction, and hardware failure.[19] Flexor pollicis longus ruptures that occur after volar plate fixation of DRFs are often attributed to plate positioning.[20-22]

Discussion

With volar locking plate internal fixation on the rise, CREF has become less widely used.[3] This is especially true for comminuted and intra-articular fractures—most earlier external fixators required either spanning of the wrist or limited fixation in the distal articular fragment. Although many studies have found excellent outcomes of ORIF with volar locking plates in the treatment of unstable DRFs,[4,6] few studies have compared volar locking plate ORIF with nonspanning external fixation for unstable comminuted intra-articular DRFs. Both Gradl and colleagues,[8] using a nonbridging external fixator with multiplanar K-wires, and Mirza and colleagues,[9] using the Cross-Pin Fixation system, found wrist function, quality-of-life, and radiographic outcomes similar to those of volar plate fixation in the treatment of DRFs. A comparative meta-analysis by Margaliot and colleagues[17] revealed no superiority of internal fixation over external fixation for unstable DRFs, given the similarity in wrist function, radiographic, and subjective outcomes.

At a mean follow-up of 12.8 months (range, 6-23 months), our retrospective study found that the functional and radiographic outcomes of treating unstable comminuted DRFs with a nonspanning external fixator were similar to those reported in similarly matched control studies. Although follow-up of >2 years has been shown to be unnecessary,[23-25] small differences may have been detected with interval results over these 2 years. The effect of selection bias on our study results should be considered in light of patients' involvement in selecting fixation type. Our results parallel those of the temporal studies of Rozental and colleagues[5] and Wei and colleagues[12] (Table 2) while allowing for patients to return to function with limited morbidity and complications, similar to Orbay and Fernandez[15] though with a less invasive procedure.

Although we found patient-rated outcome measure values analogous to those of the volar plate fixation group and bridging external fixator group in the study by Wright and colleagues,[6] we did not measure intra-articular step-off. Another variable not addressed here was operative time. The nonspanning external fixator treatment that we investigated should undergo further study. A randomized prospective study that includes the additional outcome measures of intra-articular step-off and operative time is warranted.

We found that our study patients, who had their comminuted intra-articular DRFs treated with a nonspanning external fixator, and similar historical control patients, treated with volar locking plate internal fixation, had similar clinical and radiographic outcomes at final follow-up. There was no statistically significant difference in measured outcomes—wrist flexion and extension, radial deviation, pronation and supination, volar tilt, radial height, radial inclination, DASH scores—between the 2 groups. Compared with the historical control group, the external fixator group had significantly more postoperative ulnar deviation.

Given the functional and radiographic outcomes found at final follow-up in this study, we recommend considering a nonspanning external fixator in the treatment of unstable complex comminuted intra-articular DRFs, particularly those that occur in the elderly.

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This paper will be judged for the Resident Writer’s Award.