

## Treatment of highly comminuted distal radius fractures with temporary distraction plate

Cindy Bouvet, Christina Steiger, Alexander De Smet, Marie Loret, Philippe Vostrel, Jean-Yves Beaulieu

### ABSTRACT

Surgical treatment of highly comminuted distal radius fractures in elderly patients with poor bone quality or in polytrauma patients is a technical challenge.

**Aim:** The aim of this study was to evaluate the results of temporary bridge plating in these patients.

**Method:** A retrospective review using data from 21 patients undergoing temporary bridge plating in our department was performed. All patients had fractures classified as type C3 by AO classification. To achieve optimal joint surface reduction, supplementary fixation was necessary in all cases. Data was evaluated for clinical and radiological parameters.

**Results:** Radiological results showed a mean post-operative positive ulnar variance of 1.2 mm, mean radial inclination of 18° and a mean radial length of 10 mm. Furthermore, correlations between fracture patterns and ligament injuries were analyzed.

**Conclusion:** Temporary bridge plating is indicated in the treatment of highly comminuted distal radius fractures in elderly patients with poor bone quality and young polytrauma patients. (Level of evidence: Level 4)

**Key words:** *Highly comminuted radius fracture, bridging plate, anatomic congruency*

### Introduction

The AO C3-type radius fracture is predominantly found in young polytrauma or elderly patients with osteoporotic bones. In addition to the high comminution of the articular surface and metaphysis these fractures are often associated with ligament injuries [1-3]. It is generally accepted that anatomic restoration of the articular surface, radial height and inclination are the most important factors influencing the long-term

outcomes in these cases [4]. However, elderly and polytraumatized patients often do not tolerate long surgeries and thus surgeons prefer techniques that are simple but at the same time allow addressing articular reconstruction.

The method of joint distraction for treating comminuted intra-articular fractures dates back to Böhler in 1929 [5,6]. A decade later, Anderson and O'Neil propagated the use of the external fixator [7,8], which

**Author affiliations** : Department of Orthopedics and Trauma Surgery, Hand Surgery and Peripheral Nerves Unit, Geneva University Hospital, Geneva, Switzerland

**Correspondence** : Cindy Bouvet, MD, Department of Orthopedics and Trauma Surgery, Hand Surgery and Peripheral Nerves Unit, Geneva University Hospital, Geneva, Switzerland. e-mail: cindy.bouvet@hcuge.ch

**Received / Accepted** : August 03, 2016 / October 17, 2016

is also a currently frequently used treatment tool [9]. It is appreciated for its easy application but has the disadvantage of a non-neglectable complication rates [10-15]. Pin-tract infections occur in up to 23% of the patients, and fractures at the pin-entry site have been reported along with aesthetic issues and inconvenience to dress [6,16]. A further problem is the reduction of small fracture fragments without ligament attachments. As the reduction effect of the external fixator [17] is based on ligamentotaxis [18], these detached fragments have to be reduced by external maneuvers and, as a result, often lack stability leading to secondary displacement after a few days [11,19].

With the development of volar- and dorsal-locking plates, internal osteosynthesis of many multifragmentary fractures [13] became possible [20]. However, high comminution of the articular surface, small fracture fragments and severe osteoporotic bones are still a limiting factor of their application.

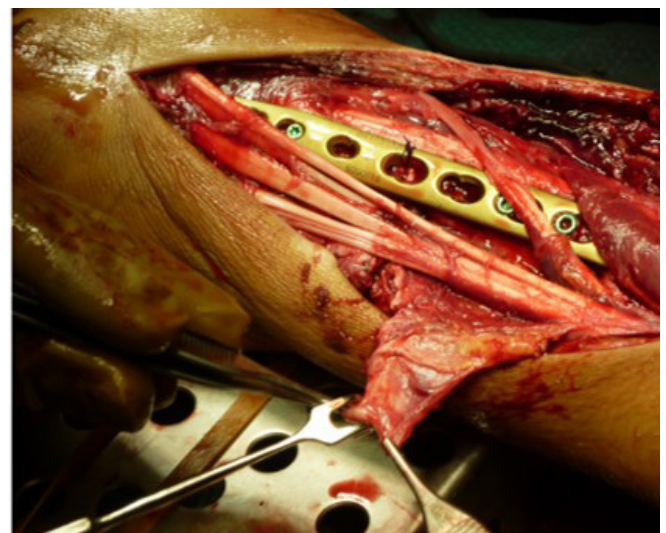
The bridging plate technique we describe in this paper is based on the old principle of joint distraction. The plate acts as an internal fixator distracting and stabilizing the fracture. The technique is relatively simple, cost-effective and permits reduction and stabilization of the joint facet using additional plates or Kirschner (k-) wires. As it is an all-internal technique, complications related to external devices are avoided. Up to now, very little has been published concerning this method of temporary arthrodesis.

Therefore, the goal of this study was to determine the outcome of bridge plating in combination with joint surface reconstruction by plate or k-wire osteosynthesis in highly comminuted radius fractures. Data was analysed with regard to clinical function, pain, strength and radiological parameters to evaluate whether this technique should be considered as a therapeutic option.

### Materials and Methods

Between January 2011 and March 2014, 21 patients presenting with a distal radius fracture were treated in our hand surgery unit using the bridge-plat-

ing technique. Our study cohort comprised 12 female and 9 male patients with an average age of 52 years (range: 17- to 92-years-old). The patients' profession was documented as following: two students, two manual workers, one banker, one nurse, one engineer, three unemployed and 11 retired. Patient demographics, additional injuries and comorbidities are listed in Table 1. Fracture stabilization by palmar- and/or dorsal-plate osteosynthesis was deemed impossible because of comminution, bone quality or severity of other injuries leaving bridge plating as the method of choice. An identical surgical technique (four different surgeons) was applied across all cases. A standard dorsal approach to the wrist extending to the third metacarpal provided excellent access to the fracture. The extensor retinaculum was incised between the third and the fourth compartment enabling us to thermocoagulate the posterior interosseous nerve. The fracture was then reduced under direct vision and in five cases, a bone graft (Tutoplast, Zimmer, Switzerland) was employed to fill structural defects. The bridge plate (Standard LCP 3.5 plate Synthes, Zuchwill, Switzerland, 10° angulation LCP 3.5 plate Synthes, Zuchwill, Switzerland, Buchler plate 3.5 Synthes, Zuchwill, Switzerland) was applied under fluoroscopy guidance and secured with



**Figure 1.** Intra-operative image displaying how the extensor retinaculum can be used to cover the plate.

**Table 1.** Description of our cohort.

Patient number	Age	Sex	Comorbidities	Radius fracture site	Zone of comminution	Ulnar styloid fracture	Additional injuries	Specific problem
1	75	F	Colorectal cancer	Metaphyso epiphyseal	Scaphoid	Yes	-	Osteoporotic bone
2	55	F	Depression	Posterior	Lunate	Yes	CTS	-
3	29	F	-	Anterior	Scapho-lunate	Yes	DRUJ ins.	Polytrauma
4	80	F	Hypertension	Metaphyso epiphyseal	Scaphoid	No	-	Osteoporotic bone
5	25	M	-	Posterior	Lunate	Yes	CTS	Polytrauma
6	84	F	Ischemic cardiopathy	Posterior	Lunate	Yes	-	Osteoporotic bone
7	17	M	-	Anterior carpal dislocation	Slight depression	Yes	TFCC lesion	Polytrauma
8	92	F	Hypertension	Metaphyso epiphyseal	Comminuted	Yes	-	Osteoporotic bone
9	70	F	Hypertension	Posterior	Lunate	No	RT lesion	Osteoporotic bone
10	52	M	Diabetes	Posterior	Slight depression	Yes	RT lesion	-
11	80	F	Hypertension	Posterior	Lunate	Yes	-	Osteoporotic bone
12	29	F	-	Radial styloid	-	No	RT lesion	Polytrauma
13	83	F	Depression	Metaphyso Epiphyseal	Scapho-lunate	Yes	-	Osteoporotic bone
14	53	M	Diabetes	Metaphyso Epiphyseal	Comminuted	Yes	SL lesion	-
15	17	M	-	Posterior	Lunate	Yes	CTS	Polytrauma
16	57	M	Hypertension	Posterior	Scapho-Lunate	No	DRUJ ins.	-
17	75	F	Hypertension	Posterior carpal dislocation	Scapho-Lunate	No	CTS + DRUJ ins.	Osteoporotic bone
18	68	F	-	Antero posterior	Comminuted	Yes	CTS	Osteoporotic bone
19	25	M	-	Metaphyso Epiphyseal	Slight depression	Yes	CTS	Polytrauma
20	45	M	Depression	Metaphyso Epiphyseal	Comminuted	Yes	-	-
21	39	M	-	Posterior carpal dislocation	Comminuted	Luxation	CTS + complete avulsion ulno carpal lig.	Polytrauma

CTS = Carpal Tunnel Syndrome, RT = Radio Triquetral, DRUJ ins. = Distal radio ulnar joint instability, SL = Scapho-lunate

three angular stable screws in the third metacarpal and three angular stable screws in the distal radius. During closure, the extensor retinaculum was utilized to cover the plate (Figure 1). To maintain reduction of the articular surface of the radius, additional osteosynthesis was required in all cases as described in Table 2. Postoperative treatment consisted of a long-arm cast for two days followed by a short-arm cast for two weeks. Afterwards,

a removable splint was carried until the end of the sixth postoperative week. During this time, patients were allowed to remove the splint during rest.

All patients had preoperative anterior-posterior and lateral radiographs and CT scans of the wrist. Radiographic and CT imaging was repeated several days postoperatively to assess the articular reduction and thereafter in three-month intervals to verify consolida-

**Table 2.** Description of additional surgical treatment and material used in each case.

Patient number	Plate used	Additive treatment on the RADIUS	Additive treatment on the ULNA	Other	Time to plate removal (in months)	Follow-up in months	Complications
1	LCP 3.5	2 screws	-	Bone graft	2	11	-
2	LCP 3.5 10° angulation	Palmar plate	Darrach	Bone graft + median nerve decompression	3	15	-
3	Buchler 3.5	1 screw + 2 k-wires	Tension band wiring	-	3	20	-
4	LCP 3.5	2 screws + 1 k-wire	-	Bone graft	3	4	-
5	LCP 3.5	1 k-wire	-	Median nerve decompression	3	9	-
6	LCP 10° angulation	1 k-wire	-	-	3	6	-
7	Buchler 3.5 10° angulation	Palmar plate + 1 k-wire	-	Median nerve decompression + TFCC reconstruction	5	7	-
8	LCP 3.5	1 k-wire	-	Bone graft	3	12	-
9	LCP 3.5	1 screw + 2 k-wires	-	-	6	12	-
10	LCP 3.5	Palmar plate + 1 k-wire	-	-	3	6	Poor wound healing
11	LCP 3.5	2 k-wires + 1 screw k-wires	LCP distal plate	-	3	11	Metaphyseal pseudarthrosis
12	LCP 3.5	3 k-wires	-	Radiotriquetral reinsertion	4	7	-
13	LCP 3.5	2 k-wires	-	-	4	4	-
14	LCP 3.5	2 k-wires + dorsal plate	-	Scapholunate reinsertion	3	8	Pseudarthrosis
15	LCP 3.5	2 k-wires	-	Median nerve decompression	3	8	-
16	LCP 3.5	Dorsal plate	-	TFCC reinsertion	4	7	-
17	LCP 3.5	Palmar plate	Tension band wiring	Median nerve decompression	4	5	-
18	LCP 3.5	Palmar plate	LCP distal plate	Median nerve decompression + bone graft	4	3	-
19	LCP 3.5	2 k-wires	1 k-wire	Median nerve decompression + TFCC reinsertion	4	2	-
20	LCP 3.5	2 k-wires	-	-	2	2	-
21	LCP 3.5	1 k-wire	-	Median nerve decompression + TFCC and ulnocarpal lig. repair	2	2	Metaphyseal pseudarthrosis

tion. All bridging plates were successfully removed after a mean of 3.5 months. Regular clinical and radiological controls were undertaken during the first postoperative year. During clinical examination range of motion in flexion-extension and grip strength (jamar dynamometer) were assessed. Furthermore, pain score (visual analogue scale (VAS)) and score of Disabilities of the Arm, Shoulder and Hand (DASH) were recorded. Radiologic assessment concerned ulnar variance, radius length,

radial inclination and time of radiologic fracture consolidation. Data was obtained from medical records and archived radiographs that were reviewed retrospectively.

### Results

Fracture healing was achieved in 18 cases with a mean time of 3.5 months. In the remaining three cases, formation of a pseudarthrosis was observed requiring a second surgical intervention. In one case, we opted for a radioscapulohumeral arthrodesis (patient number 14 in

**Table 3.** Clinical and radiological outcomes.

CLINICAL OUTCOMES	Mean flexion	37°
	Mean extension	50°
	Mean pronation	65°
	Mean supination	70°
	Grip strength	62% of controlateral side
	VAS at rest	0
	Quick DASH	23
RADIOLOGICAL OUTCOMES	Preoperative ulnar variance	+ 1.4mm
	Postoperative ulnar variance	+ 1.2 mm
	Radial inclination	18°
	Radial length	10 mm

**Figure 2.** Young polytrauma patient victim of motorcycle accident. (A,B) Pre-operative antero-posterior and lateral x-rays.

the Tables), in the second case, a metaphyseal graft with a phosphocalcique spacer was chosen (patient number 11 in the Tables), and in the third case, we opted for an iliac bone graft (patient number 21 in the Tables). At the time of the study, the bridge plates had already been removed in all cases. The mean time to plate removal was 3.5 months (range: two months to six months). Ligament reconstruction, carpal tunnel release and ulnar stabilization were carried out during the initial surgery. With the exception of one poor wound healing after plate removal, we did not observe any postoperative

**Table 4.** Relationship between fracture location, the articular surface comminution and the ligamentous injuries.

FRACTURE SITE	ARTICULAR SURFACE ON X-RAY			
	Highly comminuted fracture n=10	Die punch: lunate surface n=6	Scapho-lunate depression n=4	Scaphoid surface depression n=2
Metaphyso-epiphyseal n=10	2 Median nerve compression 2 Radiotriquetral lig disruption + TFCC disruption 1 Scapholunate lig. disruption 2 No lesions		1 No lesion	2 No lesion
Posterior n=8	1 Radiotriquetral lig disruption	3 Median nerve compression 1 Radiotriquetral lig. disruption 2 No lesion	1 DRUJ instability	
Anterior n=1			1 DRUJ instability	
Carpal anterior dislocation n=1	1 TFCC disruption			
Carpal posterior dislocation n=2		1 Median nerve compression + complete avulsion of the ulnocarpal lig.	1 DRUJ instability + Median nerve compression	





**Figure 3.** (A,B) Postoperative antero-posterior and lateral x-rays. To reconstruct the articular surface, k-wire osteosynthesis in addition to bridge plating was applied. (C,D,E) CT scan showing articular congruency.



**Figure 4.** (A,B) Antero-posterior and lateral x-rays after metal removal.

complications. All patients receiving decompression of the carpal tunnel showed full neurological recovery. Patients that benefited from ligamentous reconstruction did not complain about pain or mobility restriction. Clinical results at eight months follow-up were available in 20 of 21 patients (no clinical results of the patient undergoing arthrodesis). The range of motion of the wrist in flexion/extension was on average 37° and 50°, respectively, and pro- and supination were 65° and 70°, respectively. The mean grip strength was 19 kgs, 63% of the strength found in the contralateral hand (Table

3). CT evaluation confirmed a robust joint surface reconstruction with minimal articular steps (less than 1 mm). Radiographic results are list in Table 3. The mean quick DASH score was 22 (range: 19 to 34). During data analysis, fracture patterns and their concomitant ligament injuries were evaluated (Table 4). Bone grafting was predominantly required in elderly patients suffering with osteoporotic bone where substantial bone substance loss was encountered in the metaphyseal comminution zone. Young and polytrauma patients often had fractures associated ligament injuries, the most frequent being triangular fibrocartilage complex (TFCC), luno-triquetral (LT) and scapho-lunate (SL) lesions. With respect to fracture location and ligament injury, we observed an association between scapholunate impression fractures and distal radio-ulnar joint (DRUJ) instability, posterior wall comminution and radio-triquetral (RT) lesions and comminuted metaphyseal-epiphyseal fractures with a global surface impression and all different types of lesions. Scaphoid fossa impression fractures had no associated ligament injuries

### Discussion

Anatomic restoration of the articular surface, radial height and inclination are regarded as the most im-

portant factors influencing the long-term outcome of highly comminuted radius fractures [4,14]. To date, treatment of these fractures remains controversial [21]. Although volar- and dorsal-locking plates have greatly advanced treatment, they are often unsuitable for stabilizing complex fractures and the external fixator is associated with a relatively high complication rate. In the literature, the most common complications are pin infection with material removal needed, loose pins, loss of reduction and iatrogenic nerve palsy. Following the loss of reduction, residual deformities lead to poor functional outcome [6,10-13]. K-wire pinning of individual fragments is simple [22] but lacks stability, especially in osteoporotic bones [23,24]. Arthroscopic-assisted osteosynthesis has been promoted in severely comminuted articular fractures as it fosters perfect reduction of the joint surface under direct visualization. However this technique requires highly trained surgeons and special equipment and is not applicable in cases with additional injury to the wrist or forearm [25-28].

Bridge plating of the radiocarpal joint has previously been described in the literature as an effective treatment method in patients with comminuted radius fractures. Based on joint distraction compression, forces are diverted away from the fracture facilitating its reduction. Direct plate application at the dorsal radial surface provides additional posterior support as has been shown in a biomechanical study [29]. Ginn et al. published results from a surgical technique in which the plate is applied in a minimally invasive fashion [30]. Using this technique, Hanel et al. [31] reported superior results in a study comprised of 62 patients with 41 of them returning to their pre-accident level of employment [31]. Richards et al. evaluated bridge plating in elderly patients and demonstrated equally promising results [32]. Although complications were encountered in both studies, their incidence was low. This finding is seen as one of the greatest advantages of bridge plating over the external fixator. Several authors have reported complication rates of the external fixator as high as 50%

whereas complications of internal fixation are below 15% [13,33,34]. Although both authors described the possibility of additional joint surface reconstruction, additional fracture stabilization was rarely applied in either of the two case series.

In our study, we evaluated the use of a bridging plate in highly comminutive radius fractures in combination with additional internal osteosynthesis for joint surface reconstruction. Bradway et al. [35] and also Jupiter [2] have shown that intra-articular incongruity of more than 2 mm is associated with poor functional outcomes and an increase in arthritis prevalence. Thus, we considered joint reduction an important element of the surgery and used an extensive approach which permitted placement of additional material using the same incision. In several cases, additional palmar approaches and volar plate osteosynthesis were necessary to achieve optimal fracture reduction. All patients in our study received CT scans that verified anatomic reconstruction and consolidation progress. In the bridge-plating case series by Hanel et al. [31], no cases with articular gaps or step-offs of more than 2mm among 62 patients were reported whereas Richard [32] found three of 33 cases with insufficient articular surface reduction. As Richard conducted the study in an elderly population, bone quality might have been an influencing factor for secondary displacement.

To date, less than 2 mm step-off at the articular surface is regarded as an acceptable result. However, in an articulation with high mobility under constant stress, 2mm might already lead to increased wear. Especially in elderly patients, where cartilage thickness is reduced, imprecise reduction can result in pain and diminished function. High activity levels in all age groups further affected outcomes if the articular surface was not congruent. In our patient cohort, we tried to achieve anatomic or near-anatomic reconstruction of the joint surface with less than 1 mm step-off with additional osteosynthesis in all patients. We considered the bridging plate an important tool to grossly stabilize the fracture

whereas reduction of smaller fragments without ligament attachments, where reduction by ligamentotaxis was impossible, were held in place by additional material. After plate removal, decreased force and range of motion values were observed in our patient cohort. These results are in concordance with previously published articles on the distraction method and which are also known for treatment with an external fixator or a simple cast. A very reliable parameter to evaluate functional outcome after an injury is the DASH score. In our study, we found significantly better values than previous reported by Richard [32], possibly a consequence of optimal joint surface reduction.

Geissler et al. [1] and Forward [3] reported a high incidence of ligamentous injuries with distal radius fractures in young patients seen during arthroscopy. Their results demonstrated a prevalence of TFCC lesions in 50% of all cases and up to 32% of scapho-lunate tears. In line with their data, we also found a large association of ligament injuries and distal radius fractures in the young. As such lesions can be the cause of prolonged pain or reduced wrist functioning, ligament reconstruction was performed during the initial procedure in our patient cohort.

Complications of the bridging plate are rare, the most frequent in our study being formation of a pseudarthrosis and a delayed wound healing. In the literature, the occurrence of complex regional pain syndrome (CRPS) and extensor tendon adhesions have also been reported [32,36]. One of the major benefits of this technique is the high level of stability that permits patients to use their arm for light daily activities. Elderly patients quickly regain autonomy and in polytrauma patients, it facilitates life during rehabilitation (Figures 2, 3 and 4). The downside of the technique is the necessity for plate removal. This second operation is well-tolerated in young and healthy patients but poses a risk to elderly patients with serious comorbidities.

There are several limitations to our retrospective cohort study. Firstly, patients were of different ages

and presented with low- and high-impact traumas, thus different associated injuries. Bridge plating was conducted in all patients but additional osteosynthesis was applied as needed for optimal fracture stabilization. Furthermore, ligament lesions were treated when present as was structural bone loss. Although follow-up data exists on almost all patients, the follow-up duration was sometimes relatively short (from two to 20 months). Therefore, in a number of cases, we could not be certain that our end results of wrist function will not further improve or deteriorate.

In our opinion, bridge plating is a reliable treatment option for severely comminuted radius fractures. While a nearly anatomic joint surface congruity is deemed important for the young, it is often questioned for the elderly population. However, as more and more elderly people have the desire to remain active and participate in sports activities, their expectations of postoperative hand and wrist functioning are high. Furthermore, the autonomy of elderly people and of polytrauma patients undergoing rehabilitation often depends on their ability to use both hands. Hence, we recommend the bridging plate technique of highly comminuted fractures in the both patient groups. We strongly believe that outcomes not only depend on restoration of adequate radial length but also on optimal joint surface reconstruction and ligament repair regardless of the patient's age or activity level.

#### **Conflict of interest statement**

The authors have no conflicts of interest to declare.

#### **References**

1. Geissler WB, Freeland AE, Savoie FH, McIntyre LW, Whipple TL. Intracarpal soft-tissue lesions associated with an intra-articular fracture of the distal end of the radius. *J Bone Joint Surg Am* 1996;78:357-65.
2. Jupiter JB, Lipton H. The operative treatment of intraarticular fractures of the distal radius. *Clin Orthop Relat Res* 1993;292:48-61.
3. Forward DP, Lindau TR, Melsom DS. Intercar-



- pal ligament injuries associated with fractures of the distal part of the radius. *J Bone Joint Surg Am* 2007;89:2334-40.
4. Bassett RL. Displaced intraarticular fractures of the distal radius. *Clin Orthop Relat Res* 1987;214:148-52.
  5. Green DP. Pins and plaster treatment of comminuted fractures of the distal end of the radius. *J Bone Joint Surg Am* 1975;57:304-10.
  6. Weber SC, Szabo RM. Severely comminuted distal radial fracture as an unsolved problem: complications associated with external fixation and pins and plaster techniques. *J Hand Surg Am* 1986;11:157-65.
  7. Anderson R, O'Neil G. Comminuted Fractures of the Distal End of the Radius. *Surg Gynec Obstet* 1944;78:434-40.
  8. Grana WA, Kopta JA. The Roger Anderson device in the treatment of fractures of the distal end of the radius. *J Bone Joint Surg Am* 1979;61:1234-8.
  9. Payandeh JB, McKee MD. External fixation of distal radius fractures. *Hand Clin* 2010;26:55-60.
  10. Clyburn TA. Dynamic external fixation for comminuted intra-articular fractures of the distal end of the radius. *J Bone Joint Surg Am* 1987;69:248-54.
  11. Farah N, Nassar L, Farah Z, Schuind F. Secondary displacement of distal radius fractures treated by bridging external fixation. *J Hand Surg Eur Vol* 2014;39:423-8.
  12. Gaston ABY, Rongi res M, Mansat P, Bonneville P, Mansat M. [Exp rience et place de la fixation externe dans les fractures comminutives du radius distal de l'adulte][Article in French]. In: *Fractures du radius distal de l'adulte*, Sauramps publishing, Paris; 2006:80-7.
  13. Leung F, Tu YK, Chew WY, Chow SP. Comparison of external and percutaneous pin fixation with plate fixation for intra-articular distal radial fractures. A randomized study. *J Bone Joint Surg Am* 2008;90:16-22.
  14. Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. *J Bone Joint Surg Am* 1986;68:647-59.
  15. Foster DE, Kopta JA. Update on external fixators in the treatment of wrist fractures. *Clin Orthop Relat Res* 1986;204:177-83.
  16. McKenna J, Harte M, Lunn J, O'Bierne J. External fixation of distal radial fractures. *Injury* 2000;31:613-6.
  17. Edwards GS, Jr. Intra-articular fractures of the distal part of the radius treated with the small AO external fixator. *J Bone Joint Surg Am* 1991;73:1241-50.
  18. Papadonikolakis A, Ruch DS. Internal distraction plating of distal radius fractures. *Tech Hand Up Extrem Surg* 2005;9:2-6.
  19. Estrella EP, Panti PL. Outcome of unstable distal radius fractures treated with open reduction and internal fixation versus external fixation. *Hand Surg* 2012;17:173-9.
  20. Mellstrand-Navarro C, Pettersson HJ, Tornqvist H, Ponzer S. The operative treatment of fractures of the distal radius is increasing: results from a nationwide Swedish study. *Bone Joint J* 2014;96-B:963-9.
  21. Obert L, Rey PB, Uhring J, Gasse N, Rochet S, Lepage D, et al. Fixation of distal radius fractures in adults: a review. *Orthop Traumatol Surg Res* 2013;99:216-34.
  22. Kapandji A. [Intra-focal pinning of fractures of the distal end of the radius 10 years later] [Article in French]. *Ann Chir Main* 1987;6:57-63.
  23. Huard S, Blanchet N, Leclerc G, Rochet S, Lepage D, Garbuio P, et al. [Fractures of the distal radius in patients over 70 years old: Volar plates or K-wires?] [Article in French]. *Chir Main* 2010;29:236-41.
  24. Board T, Kocalkowski A, Andrew G. Does Kapandji wiring help in older patients? A retrospective comparative review of displaced intra-articular distal radial fractures in patients over 55 years. *Injury* 1999;30:663-9.
  25. Del Pinal F, Klausmeyer M, Moraleta E, de Piero GH, Ruas JS. Arthroscopic reduction of commi-

- nuted intra-articular distal radius fractures with diaphyseal-metaphyseal comminution. *J Hand Surg Am* 2014;39:835-43.
26. Ruch DS, Vallee J, Poehling GG, Smith BP, Kuzma GR. Arthroscopic reduction versus fluoroscopic reduction in the management of intra-articular distal radius fractures. *Arthroscopy* 2004;20:225-30.
27. Varitimidis SE, Basdekis GK, Dailiana ZH, Hantes ME, Bargiotas K, Malizos K. Treatment of intra-articular fractures of the distal radius: fluoroscopic or arthroscopic reduction? *J Bone Joint Surg Br* 2008;90:778-85.
28. Doi K, Hattori Y, Otsuka K, Abe Y, Yamamoto H. Intra-articular fractures of the distal aspect of the radius: arthroscopically assisted reduction compared with open reduction and internal fixation. *J Bone Joint Surg Am* 1999;81:1093-110.
29. Wolf JC, Weil WM, Hanel DP, Trumble TE. A biomechanic comparison of an internal radiocarpal-spanning 2.4-mm locking plate and external fixation in a model of distal radius fractures. *J Hand Surg Am* 2006;31:1578-86.
30. Ginn TA, Ruch DS, Yang CC, Hanel DP. Use of a distraction plate for distal radial fractures with metaphyseal and diaphyseal comminution. Surgical technique. *J Bone Joint Surg Am* 2006;88 (Suppl 1 Pt 1):29-36.
31. Hanel DP, Lu TS, Weil WM. Bridge plating of distal radius fractures: the Harborview method. *Clin Orthop Relat Res* 2006;445:91-9.
32. Richard MJ, Katolik LI, Hanel DP, Wartinbee DA, Ruch DS. Distraction plating for the treatment of highly comminuted distal radius fractures in elderly patients. *J Hand Surg Am* 2012;37:948-56.
33. Orbay J. Volar plate fixation of distal radius fractures. *Hand Clin* 2005;21:347-54.
34. Gutow AP. Avoidance and treatment of complications of distal radius fractures. *Hand Clin* 2005;21:295-305.
35. Bradway JK, Amadio PC, Cooney WP. Open reduction and internal fixation of displaced, comminuted intra-articular fractures of the distal end of the radius. *J Bone Joint Surg Am* 1989;71:839-47.
36. Hanel DP, Ruhlman SD, Katolik LI, Allan CH. Complications associated with distraction plate fixation of wrist fractures. *Hand Clin* 2010;26:237-43.