Surgery Article

HAND
1–7

DOI: 10.1177/1558944720975135
journals.sagepub.com/home/HAN

Percutaneous Threaded Pin Fixation of Distal Radius Fracture in the Athlete

Patrick M. Luchini[1], Julie E. Glener[1], Justin Vaida[1], Lucy A. McCabe[2], Andrea B. Lese[1], and John S. Taras[1]

Abstract

Background: The purpose of this study was to examine the outcomes and return to play with early rehabilitation in athletes who sustained unstable extra-articular distal radius fractures treated with a purpose-designed threaded pin technique. **Methods:** This prospective study examined athletes with displaced and unstable distal radius fractures treated surgically with purpose-designed threaded pins. Patients were enrolled in an early rehabilitation protocol, with formal therapy initiated on postoperative days 1 to 3. Range of motion and strength measurements were documented throughout the postoperative period, noting the time until return to athletic competition. These results were compared with historical values using other forms of fixation. **Results:** Nineteen athletes, average age of 35 years, were treated with threaded pin technique with early rehabilitation; all had complete healing and maintained alignment based on radiographic evaluation. The average time span between surgery and release to competition was 8 weeks, with all but 1 patient returning to sport within 12 weeks of injury. Average postoperative flexion measured 58°, extension was 57°, pronation was 81°, and supination was 74°. JAMAR grip strength in position 3 measured 25.22 kg, which equated to 73% of the uninjured side's grip strength at the time of release to play. **Conclusions:** Surgical fixation using a purpose-designed threaded pin is a useful alternative to volar plating for isolated radial styloid and extra-articular distal radius fractures in athletes. The purpose-designed threaded pin may afford athletes rapid recovery during the early postoperative period, preserving strength and dexterity and minimizing time lost before return to play.

Keywords: distal radius fracture, threaded pin, athlete, fixation, early mobilization, return to competition

Introduction

Distal radius fracture is the most frequent bony injury in the upper extremity, accounting for 8% to 15% of all skeletal injuries (Figures 1a and 1b).[1-4] The rates of distal radius fractures have continued to increase in the adolescent and young adult population over the past several decades.[5] This upward trend has been attributed to a substantial increase in sport-related distal radius fractures, particularly in soccer, gymnastics, rugby, and snowboarding.[3,6] Up to 23% of all sport fractures occurred in the distal radius.[5] Successful management of these fractures in the athlete requires balancing the short-term goal of allowing safe return to play with the long-term goal of minimizing deformity, traumatic arthritis, and ulnar impaction.

Distal radius fractures in the athlete require careful consideration of preinjury function and sport-specific treatment goals. Kinematic studies have demonstrated that these fractures can severely impair an athlete's ability to throw, catch, grasp, shoot, strike, or push off.[7] Deformity after an articular fracture can result in degenerative changes at the radiocarpal joint; thus, maintenance of anatomical reduction of the articular surface should be the treating surgeon's foremost concern. Studies identified a greater than 60% incidence of fracture redisplacement after reduction and casting or splinting.[8] In an attempt to prevent redisplacement, surgical techniques such as closed reduction and percutaneous pinning, pins and plaster, and external fixation were developed. These methods were shown to lessen the occurrence of displacement but required prolonged wrist immobilization.[9,10] Development of more robust internal fixation devices such as volar plates and the purpose-designed threaded pin (T-Pin, Union Surgical, LLC, Philadelphia, Pennsylvania)

[1]West Virginia University, Morgantown, USA
[2]Union Surgical LLC, Doylestown, PA, USA

Corresponding Author:
John S. Taras, Department of Orthopaedics, West Virginia University, P.O. Box 9196, Morgantown, WV 26506-9196, USA.
Email: john.taras@hsc.wvu.edu

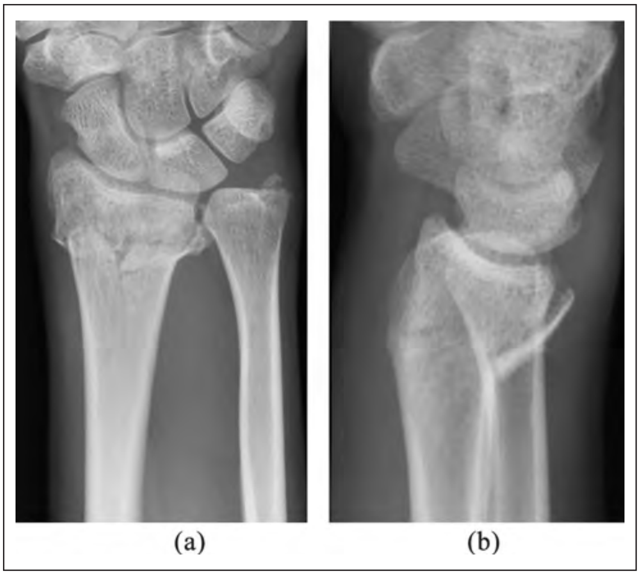

Figure 1. Preoperative radiographs of a typical extra-articular distal radius fracture amenable to fixation with purpose-designed threaded pins: (a) posteroanterior view and (b) lateral view.

Figure 2. Postoperative radiographs of the fracture shown in Figures 1a and 1b: (a) posteroanterior view and (b) lateral view.

has allowed for earlier rehabilitation, which may significantly benefit the athlete (Figure 2).[11]

Successful rehabilitation after a distal radius fracture is critical before an athlete is allowed to resume play without the protection of a cast or splint. The primary goals of rehabilitation are to restore range of motion, strength, and dexterity while preventing reinjury. Several studies have shown that hand therapy can significantly influence short-term outcome after distal radius fracture.[2,12-16] Early initiation of therapy has been shown to improve grip strength and range of motion in the early postoperative period and reduce the duration of time and number of therapy sessions required to regain functional wrist and forearm range of motion.[2,15] Rozental et al[14] reported that distal radius fractures treated with volar plating and early range of motion showed better functional results in the early postoperative period when compared with fractures treated with percutaneous pinning and cast immobilization. In the current series of athletes treated with the purpose-designed threaded pin and early rehabilitation, similar outcome measures were evaluated.

Materials and Methods

Data Collection

Institutional review board approval was obtained before beginning this study. A consecutive series of athletes with distal radius fractures treated with the purpose-designed threaded pin was identified. Athletes were defined as patients who identified themselves as having a primary goal of returning to their athletic activity as soon as possible without undue risk of compromising their recovery or long-term function. Inclusion criteria were isolated fracture of the distal radius treated with purpose-designed threaded pin fixation; initiation of an early rehabilitation protocol; and dedicated participation in an athletic sport at the time of injury (Table 1). Fracture displacement requiring fixation was defined by dorsal angulation of 10°, volar tilt of 20° perpendicular to the long axis of the radius, or ulnar variance greater than 2 mm compared with the contralateral side. Patients who were unable or unwilling to comply with the postoperative protocol were ineligible for inclusion. In addition, severely comminuted intra-articular fractures (AO type C2 and C3) or injury patterns that were beyond the isolated distal radius fracture (ie, radial styloid fractures with perilunate instability or scaphoid fractures) were excluded from this study.

Demographic information included sex, age, hand dominance, sport played, and profession. Treatment-specific parameters included mechanism of injury; AO fracture pattern; operative indications; purpose-designed threaded pin configuration; postoperative flexion; extension, pronation, and supination; postoperative complications; and the number of weeks before return to sport. Grip strength was recorded for both the injured and contralateral wrists.

The mechanism of injury was noted to be a fall from standing height in 12 cases, a fall from a bicycle in 3 cases, and a direct blow in 5 cases. The fractures were classified according to the AO classification system. There were nine A2 fractures and four A3 fractures, 4 type B1 fractures, and 2 type C1 fractures. The operative criteria comprised dorsal

Table 1. Demographic Data and Results of All Participants.

Age, y	Sex	Sport	Fracture pattern	Postoperative day	Postoperative flexion/extension	Postoperative pronation/supination	Grip (lb)	Return to sport (wk)
53	Female	Rollerblading	A2	98	45°/40°	90°/45°	34	4
44	Male	Cycling	B1	68	65°/55°	90°/90°	65	8
52	Female	Ice skating	A3	72	55°/60°	80°/85°	25	8
28	Male	Softball	B1	51	75°/55°	80°/80°	71	6
37	Male	Ice hockey	A2	101	50°/40°	80°/80°	75	12
27	Female	Tennis	A3	118	60°/70°	80°/80°	56	8
32	Female	Cycling	A3	83	60°/42°	60°/70°	30	10
29	Female	Mountaineering	A3	70	62°/65°	70°/75°	50	10
50	Female	Ice skating	C1	103	80°/60°	90°/70°	31	2
32	Male	Cycling	A2	37	50°/60°	80°/80°	70	4
18	Female	Softball	B1	61	65°/70°	90°/90°	38	8
19	Male	Street hockey	A2	116	90°/75°	90°/90°	66	10
46	Male	Skiing	B1	69	40°/60°	90°/90°	95	10
27	Male	Football	C1	71	70°/75°	85°/88°	100	8
22	Female	Lacrosse	A2	18	25°/40°	90°/75°	50	6
17	Male	Soccer	A2	57	70°/80°	60°/45°	60	4
54	Male	Baseball	A2	99	60°/60°	90°/80°	75	12
48	Male	Cycling	A2	47	55°/50°	85°/68°	65	4
26	Female	Snowboarding	A2	17	20°/35°	60°/30°	0	20

angulation in 5 patients, dorsal angulation and radial shortening in 8 patients, and unstable fracture pattern in 6 cases. Fractures were assessed with standard radiographs.

Surgical Technique

All surgeries were performed under the supervision of 1 fellowship-trained orthopedic hand surgeon at academic tertiary care medical centers. All procedures were performed under conscious sedation with a local field block using bupivacaine 0.5% without epinephrine. Fluoroscopy was used to confirm the injury pattern and inclusion criteria. There were no cases where intraoperative fluoroscopy revealed a fracture pattern that precluded use of the purpose-designed threaded pin. Reduction was performed under fluoroscopic guidance to achieve anatomical restoration of radial height and volar angulation. For cases in which attempted reduction failed to recreate anatomical alignment, a 0.062-inch Kirschner wire (K-wire) was used as a joystick to manipulate the distal fragment. In some radial styloid cases, open reduction with direct visualization of the fracture site was required. After anatomical reduction, a 1- to 2-cm longitudinal incision was made over the radial styloid. Care was taken to protect the dorsal sensory branches of the radial nerve, and the dissection was carried down to bone between the first and second dorsal compartments. For radial styloid fractures, the first dorsal extensor compartment was released, which facilitated visualizing the fracture's reduction. Next, a 1-mm guide wire was advanced across the fracture site from the starting point at the radial styloid. The guide wire was positioned at a 20° to 45° oblique angle relative to the longitudinal axis of the radial shaft and advanced to the proximal ulnar cortex of the radius. The guide wire was measured, and the appropriate length purpose-designed threaded pin was inserted. The guidewire was removed, and the smooth driver portion of the threaded pin was manually broken off. A single pin was implanted for radial styloid fractures. For extra-articular fractures, a second purpose-designed threaded pin was inserted either adjacent to the first radial styloid pin in a divergent fashion or between the fourth and fifth extensor compartments in a crossed-pin configuration. The fracture pattern and availability of distal bone stock determined which pin configuration was chosen. In fractures with minimal dorsal comminution, the technique of placing 2 purpose-designed threaded pins from the radial styloid was used. In cases where there was notable dorsal comminution, the cross-pin configuration was used to better stabilize the ulnar column of the radius and prevent settling which would lead to ulnar impaction. After fixation, fracture stability was assessed by performing wrist range of motion under fluoroscopy. Care was taken to ensure that all purpose-designed threaded pins were flush with bone to prevent soft tissue irritation. Incisions were then closed with nylon suture. Postoperative dressings consisted of sterile gauze and a volar plaster splint. Typical tourniquet time ranged from 15 to 20 minutes.

Postoperative Protocol

All patients were seen for their initial postoperative therapy visit between postoperative days 1 and 3. At this visit, the splint and dressings were removed, and the patient was fitted with a custom thermoplastic volar wrist splint. The splint was molded to position the wrist in slight extension. Patients also received instruction on a home exercise program. This program comprised tendon gliding exercises, active wrist range of motion through an arc of motion of 30° flexion and 30° extension, gentle wrist radial and ulnar deviation, and gentle forearm range of motion. All exercises were performed in sets of 10 repetitions, 4 times per day. At the patients' 2-week postoperative visit, they were allowed to advance to active wrist flexion and extension as tolerated beyond the initial guidelines of 30° each of flexion and extension. Patients began to wean from their splint at 4 weeks and started strengthening. Resistance was increased according to the patient's tolerance. Athletes were permitted to return to play when they could perform painless range of motion and when grip strength of the injured side recovered to approximately 70% of the uninjured side. Patients were followed up for 4 to 6 weeks after full return to sport to evaluate function of the injured extremity.

Results

Nineteen patients (10 men and 9 women) met the criteria for inclusion in this study. The average patient age was 35 years (range, 17-54 years). All fractures healed without loss of alignment. The purpose-designed threaded pin configuration included a single radial styloid pin in 9 patients with radial styloid fractures, 2 divergent radial styloid purpose-designed threaded pins in 6 patients, and 2 crossed purpose-designed threaded pins in 4 patients for treatment of extra-articular distal radius fractures. Range of motion and strength evaluations performed at 7 weeks after surgery and return to competition are presented. Average postoperative flexion measured 58°, extension was 57°, pronation was 81°, and supination was 74°. JAMAR grip strength in position 3 measured 25.22 k, which equated to 73% of the uninjured side's grip strength at the time of release to play. The average time span between surgery and release to competition was 8 weeks. All but 1 patient (18 of 19) returned to sport within 12 weeks of injury, the other patient requiring 20 weeks before return to sport.

Four patients requested removal of hardware, indicating they no longer wanted to have pins in place despite not having symptomatic hardware. Hardware removal was offered after at least 3 months of healing at a time when interference to sporting activity was minimal. An implant-specific removal device was used to engage the head of the threaded pin and allow for removal without complication. Patients were instructed to perform no heavy lifting, pushing, or pulling for 1 month after hardware removal. One patient who presented with acute median neuropathy requiring a carpal tunnel release at the time of his primary procedure complained of postoperative wrist aching, which resolved by 6 months postoperative. One patient treated with a crossed purpose-designed threaded pin configuration complained of ulnar-sided wrist pain that resolved by 6 months postoperative. There were no cases of infection, delayed union, or nonunion. There were no patients who had subsidence of their fracture or loss of reduction compared with their immediate postoperative films. A change in volar tilt of 10° or a loss of radial height of more than 5 mm indicated a loss of reduction.

Discussion

This prospective study using a purpose-designed threaded pin demonstrated postoperative wrist range of motion comparable to published results of patients treated with volar plating and early rehabilitation at a similar time period. Moreover, grip strength at the 3-month follow-up was superior to published results for patients treated with volar plating and early range of motion.[17] Previously, this percutaneous treatment of extra-articular distal radius fractures was examined with 24 patients, and all showed range of motion, grip strength, and functional outcomes equivalent to those reported for volar or dorsal internal fixation.[18] The aim of this study was to prospectively use this technique in the athlete to allow for early return to play.

Distal radius fractures are common injuries in athletes. Given increased demands of sporting activities, emphasis should be placed on restoring anatomical alignment, achieving fracture union, and effectively rehabilitating the injured extremity before allowing return to play. Debate continues over the necessity of operative treatment, consequences of prolonged immobilization, and effectiveness of early rehabilitation. However, athletes are a unique patient population who may benefit from operative stabilization and early rehabilitation after distal radius fracture. Return to competition is a complex decision factoring in the sport, position, and the athlete's competitive desire.

Many sporting activities place considerable demand on the wrist and require precise regulation of the joint through its complete arc of motion. Biomechanical studies of the wrist have shown baseball pitching requires a 94° arc of motion, swinging a golf club a 103° arc in the dominant wrist, and a basketball free throw a 120° arc.[19,20] In contrast, most activities of daily living demand only 40° of extension, 40° of flexion, and 40° each of radial and ulnar deviation.[19] In addition, athletes tend to place higher loads across the radiocarpal joint during sporting activities; therefore, any instability or malalignment after distal radius fracture will be tolerated poorly in this group and predisposes them to accelerated degenerative change. These factors support a more assertive approach to managing the distal radius fracture in the athlete.

Rozental et al showed that distal radius fractures treated with open reduction and internal fixation in conjunction with early rehabilitation had superior short-term results when compared with fractures treated with percutaneous pinning and cast immobilization. They identified better Disabilities of the Arm, Shoulder, and Hand (DASH) scores, range of motion, strength, and patient satisfaction values at postoperative weeks 6 and 9 than in patients treated with volar plating and early rehabilitation. At week 9, the average range of motion in these patients measured 56° of flexion, 54° of extension, 81° of supination, and 86° of pronation.[14] The current series' range of motion values are very similar to those reported in the study by Rozental, but grip strength is greater after threaded pin fixation.

Average grip strength in this study measured 25.22 kg (73% of the uninjured side) at 7 weeks. In contrast, Rozental reported average grip strength of 29 lb (19% of the uninjured side) at a similar time period.[14] This study's findings are consistent with those of Kreder et al[21] who reported improved grip strength after indirect fixation of distal radius fractures (with K-wires, small fragment screws, or a small AO fixator) when compared with open reduction and internal fixation. The authors of this study hypothesize that indirect fixation results in enhanced grip strength by minimizing soft tissue trauma around the extrinsic flexor tendons of the wrist. Volar surgical approaches such as the trans-flexor carpi radialis approach used for volar plate fixation produce more soft tissue trauma, which may delay recovery of grip strength.

Previous studies have established that the advantages of surgical treatment and early rehabilitation decrease over time. Lozano-Calderón et al[22] reported no difference between distal radius fractures mobilized within 2 weeks or after 6 weeks of volar plating. In that study, all patients wore a removable thermoplastic splint during the first postoperative week. Follow-up was conducted at 3 and 6 months after surgery and included assessment of range of motion, grip strength, Gartland and Werley score, and Mayo wrist score.[22,23] It is important to note that patients in that study did not receive a directed therapy program, and the authors did not confirm patient adherence to splint wear. In the study by Rozental, differences in range of motion and strength were no longer significant after 12 weeks; yet, patients with internally fixed fractures maintained superior DASH scores, patient satisfaction, and patient-perceived wrist function until follow-up at 1 year. The authors concluded that, although the advantages of internal fixation and early rehabilitation diminish over time, this treatment should be considered for patients requiring faster return to function after injury.[14]

Several studies support the use of directed therapy after distal radius fracture. Valdes investigated the effect of early rehabilitation after internal fixation in 23 patients. She reported that patients who began therapy during the first postoperative week required significantly fewer therapy visits (6.5 visits compared with 17 visits) and more quickly regained functional wrist range of motion (35 vs 72 days) than patients who began therapy after 6 weeks of immobilization.[15] Kay et al performed a randomized controlled trial to investigate the effect of therapy in 56 patients after cast immobilization. They reported an improved QuickDASH score at 3 weeks and improved Patient-Rated Wrist Evaluation pain score at 3 and 6 weeks in patients who received a directed program of advice and exercises.[12] Lyngcoln et al prospectively evaluated the effect of patient compliance on 15 patients receiving therapy after immobilization of distal radius fractures. He noted a positive relationship between compliance with hand therapy and short-term outcomes in rehabilitation after fracture of the distal radius and found that adherence to therapy predicted more than 50% variance in wrist extension change, Levine questionnaire score change, and change in the simulated feeding item of the Jebsen Test of Hand Function at 6 weeks.[13]

There are some limitations to this study; it was not randomized, and there was no direct control group. The study by Rozental provides a good model for comparison, although the patient populations lack standardization.[14] The patients in this study were significantly younger and may have been stronger given their participation in athletics. These variables should be considered when interpreting this study's range of motion and grip strength results. In addition, there were proportionally more AO type C fracture patterns in the study by Rozental. Despite these limitations, this study provides insight into the clinical outcomes after treatment of distal radius fractures with a new fixation device in the athlete. Prompt recovery of grip strength makes intuitive sense considering the percutaneous technique by which the purpose-designed threaded pin is implanted compared with the more invasive volar plating. Even when the fracture required limited open reduction, the threaded percutaneous pin avoids the known complications of volar plating such as tendon rupture, tenosynovitis, and secondary procedures for hardware removal.[24] The benefits of rehabilitation are well established in the early postoperative period after volar plating, and similar results would be expected following purpose-designed pinning, which also provides sufficiently rigid fracture fixation. Proper patient selection and recognition of the appropriate fracture classification are important factors for success with the threaded pin.

Surgical fixation with the purpose-designed threaded pin is an effective alternative to volar plating in isolated radial styloid and extra-articular distal radius fractures in the athlete. Both techniques maintain reduction and allow for early rehabilitation. By minimizing soft tissue dissection, the purpose-designed threaded pin may afford rapid recovery of grip strength during the early postoperative period. In addition, the use of purpose-designed threaded pins may reduce the risk of flexor tendon irritation and rupture that can occur after volar plating. In both techniques, early rehabilitation protocols likely benefit the athlete by reducing disuse atrophy, stiffness, and loss of dexterity after a distal radius fracture. These benefits promote a safer and earlier return to play.

Authors' Note

Study work was completed at The Philadelphia Hand Center and Thomas Jefferson University Hospital, Philadelphia, Pennsylvania 19107.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. This study was granted a waiver of authorization for protected health information use and was approved by the institutional review board.

Statement of Informed Consent

A waiver of informed consent was granted by the institutional review board.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: J.S.T. is the owner of Union Surgical, LLC, and a patent for the threaded pin device has been issued. He has no other disclosures. L.A.M. reports personal fees and other from Union Surgical, LLC. All other authors declare that they have no conflict of interest.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Patrick M. Luchini https://orcid.org/0000-0002-5420-4178
John S. Taras https://orcid.org/0000-0001-9130-7582

References

1. Karl JW, Olson PR, Rosenwasser MP. The epidemiology of upper extremity fractures in the United States, 2009. *J Orthop Trauma*. 2015;29(8):e242-e244.
2. Quadlbauer S, Pezzei C, Jurkowitsch J, et al. Early complications and radiological outcome after distal radius fractures stabilized by volar angular stable locking plate. *Arch Orthop Trauma Surg*. 2018;138(12):1773-1782.
3. Beleckas C, Calfee R. Distal radius fractures in the athlete. *Curr Rev Musculoskelet Med*. 2017;10(1):62-71.
4. Fernandez D, Jupiter J. *Fractures of the Distal Radius: A Practical Approach to Management*. New York, NY: Springer; 1996.
5. Nellans KW, Kowalski E, Chung KC. The epidemiology of distal radius fractures. *Hand Clin*. 2012;28(2):113-125.
6. De Putter CE, van Beeck EF, Looman CW, et al. Trends in wrist fractures in children and adolescents, 1997-2009. *J Hand Surg Am*. 2011;36(11):1810-1815.
7. Pappas AM, Morgan WJ, Schulz LA, et al. Wrist kinematics during pitching. A preliminary report. *Am J Sports Med*. 1995;23(3):312-315.
8. Mackenney PJ, McQueen MM, Elton R. Prediction of instability in distal radial fractures. *J Bone Joint Surg Am*. 2006;88(9):1944-1951.
9. Gupta R, Raheja A, Modi U. Colles' fracture: management by percutaneous crossed-pin fixation versus plaster of Paris cast immobilization. *Orthopedics*. 1999;22(7):680-682.
10. Rodriguez-Merchan EC. Plaster cast versus percutaneous pin fixation for comminuted fractures of the distal radius in patients between 46 and 65 years of age. *J Orthop Trauma*. 1997;11(3):212-217.
11. Kessler M, Taras J, Bachoura A, et al. Threaded distal radius pin and volar plate fixation of distal radius fractures: early functional recovery. Paper presented at the Annual Meeting of the American Society for Surgery of the Hand; September 2012; Chicago, IL.
12. Kay S, McMahon M, Stiller K. An advice and exercise program has some benefits over natural recovery after distal radius fracture: a randomised trial. *Aust J Physiother*. 2008;54(4):253-259.
13. Lyngcoln A, Taylor N, Pizzari T, et al. The relationship between adherence to hand therapy and short-term outcome after distal radius fracture. *J Hand Ther*. 2005;18(1):2-8; quiz 9.
14. Rozental TD, Blazar PE, Franko OI, et al. Functional outcomes for unstable distal radial fractures treated with open reduction and internal fixation or closed reduction and percutaneous fixation. A prospective randomized trial. *J Bone Joint Surg Am*. 2009;91(8):1837-1846.
15. Valdes K. A retrospective pilot study comparing the number of therapy visits required to regain functional wrist and forearm range of motion following volar plating of a distal radius fracture. *J Hand Ther*. 2009;22(4):312-318; quiz 319.
16. Watson N, Haines T, Tran P, et al. A comparison of the effect of one, three, or six weeks of immobilization on function and pain after open reduction and internal fixation of distal radial fractures in adults: a randomized controlled trial. *J Bone Joint Surg Am*. 2018;100(13):1118-1125.
17. Taras JS, Ladd AL, Kalainov DM, et al. New concepts in the treatment of distal radius fractures. *Instr Course Lect*. 2010;59:313-332.
18. Taras JS, Saillant JC, Goljan P, et al. Distal radius fracture fixation with the specialized threaded pin device. *Orthopedics*. 2016;39(1):e98-e103.
19. Werner SL, Plancher KD. Biomechanics of wrist injuries in sports. *Clin Sports Med*. 1998;17(3):407-420.
20. Ohnishi N, Ryu J, Chung I, et al. Analysis of wrist motion during basketball shooting. In: Nakamura R, Linscheid RL, Miura T, eds. *Wrist Disorders*. New York, NY: Springer; 1992:49-55.
21. Kreder HJ, Hanel DP, Agel J, et al. Indirect reduction and percutaneous fixation versus open reduction and internal fixation for displaced intra-articular fractures of the distal

radius: a randomised, controlled trial. *J Bone Joint Surg Br*. 2005;87(6):829-836.

22. Lozano-Calderón SA, Souer S, Mudgal C, et al. Wrist mobilization following volar plate fixation of fractures of the distal part of the radius. *J Bone Joint Surg Am*. 2008;90(6): 1297-1304.
23. Gartland JJ Jr, Werley CW. Evaluation of healed Colles' fractures. *J Bone Joint Surg Am*. 1951;33-A(4):895-907.
24. Arora R, Lutz M, Hennerbichler A, et al. Complications following internal fixation of unstable distal radius fracture with a palmar locking-plate. *J Orthop Trauma*. 2007;21(5): 316-322.