Soft Tissue Complications of Distal Radius Fractures

Damien I. Davis, MD[a], Mark Baratz, MD[a,b,c,d,e,*]

KEYWORDS

• Distal radius fracture • Soft tissue • Complications • Wrist

Distal radius fractures account for approximately 15% of all fractures in adults. Care of these fractures is associated with a myriad of complications.[1] Complication rates associated with Colles fractures have been reported as high as 31%.[2] There are numerous ways to treat fractures of the distal radius, which include closed reduction and casting, closed reduction and percutaneous pinning, external fixation, and open reduction with internal fixation. Complications associated with each treatment method are unique and being cognizant of them can minimize their eventual occurrence. Complications associated with the soft tissues may be more problematic than the bone injury itself. This review focuses on the soft tissue complications encountered during the management of distal radius fractures, including tendon injury, nerve dysfunction, vascular compromise, skin problems, compartment syndrome, and complex regional pain syndrome.

NEUROVASCULAR DYSFUNCTION

Fractures of the distal radius can affect the median, ulnar, or radial nerves as they cross the wrist, although the median nerve is most frequently affected. Cadaver dissections performed by Vance and Gelberman[3] showed that the distance between the radius and the median nerve decreased as one travels distally down the forearm, from at least 1 cm at the middle of the forearm, to 5 mm at the proximal aspect of the pronator quadratus, to only 3 mm at the level of the wrist. Median nerve injury can occur at the time of injury or during reduction or fixation. Direct injury, such as transection or entrapment of the nerve, is less common than secondary median neuropathy caused by increased carpal tunnel pressure. It is important to differentiate between nerve contusion and compartment syndrome. Compartment syndrome tends to develop slowly with progressively increasing symptoms. Symptoms associated with a median nerve contusion will be present at the time of injury and improve with fracture reduction. Carpal tunnel syndrome can occur acutely, subacutely, or late after distal radius fractures. The incidence of acute transient median nerve compression syndrome sustained after distal radius fracture is estimated to be 4%.[4] The incidence of acute posttraumatic carpal tunnel syndrome requiring urgent decompression is estimated to be between 5.5% and 9% of all distal

[a] Division of Hand & Upper Extremity Surgery, Allegheny General Hospital, Federal North Building, 1307 Federal Street, Second Floor, Pittsburgh, PA 15212, USA
[b] Department of Orthopaedic Surgery, Allegheny General Hospital, 1307 Federal Street, Pittsburgh, PA 15212, USA
[c] Department of Orthopaedic Surgery, Drexel University College of Medicine, 1307 Federal Street, Pittsburgh, PA 19129, USA
[d] Allegheny General Hospital of Upper Extremity Surgery, 1307 Federal Street, Pittsburgh, PA 15212, USA
[e] Allegheny General Hospital Orthopedic Residency & Fellowship Programs, 1307 Federal Street, Pittsburgh, PA 15212, USA
* Corresponding author. Division of Hand & Upper Extremity Surgery, Allegheny General Hospital, Federal North Building, 1307 Federal Street, Second Floor, Pittsburgh, PA 15212.
E-mail address: mbaratz@wpahs.org

Hand Clin 26 (2010) 229–235
doi:10.1016/j.hcl.2009.11.002

hand.theclinics.com

radius fractures treated operatively. Dyer and colleagues[5] noted a prevalence of acute carpal tunnel syndrome among patients with a surgically treated fracture of the distal radius of 5.4%. In their analysis, the only significant predictor of acute carpal tunnel syndrome was the amount of fracture translation, specifically in females younger than 48 years.

Acute carpal tunnel syndrome can occur in fractures treated nonoperatively secondary to positioning. The Cotton-Loder position, which entails excessive wrist flexion and ulnar deviation, should be avoided, as a hyperflexed wrist increases the pressure in the carpal tunnel. Gelberman and colleagues[6] showed an average carpal tunnel pressure of 47 mm Hg at 40° flexion compared with 18 mm Hg at neutral flexion. The first step in the initial management of acute carpal tunnel syndrome is placing the wrist in a neutral position with a nonconstrictive dressing. If the median nerve function does not improve, the nerve should be decompressed. Delayed treatment of acute carpal tunnel syndrome can result in permanent median nerve dysfunction. Bauman and colleagues[7] reported complete return of median function in only 1 of 4 operatively treated patients, despite operative intervention within 36 to 96 hours.

The radial nerve can be injured with both nonoperative and operative treatment. A poorly molded splint or cast can result in a radial sensory neuritis secondary to compression at the level of the radial styloid or dorsum of the thumb. The dorsal sensory branch of the radial nerve exits beneath the deep fascia between the brachioradialis and extensor carpi radialis longus, and is prone to injury during percutaneous pining or placement of external fixation pins. Injury to the radial sensory nerve can be avoided by using an open technique, making a small incision, spreading down to bone and using a drill guide or oscillating drill during pin insertion (Figs. 1 and 2).

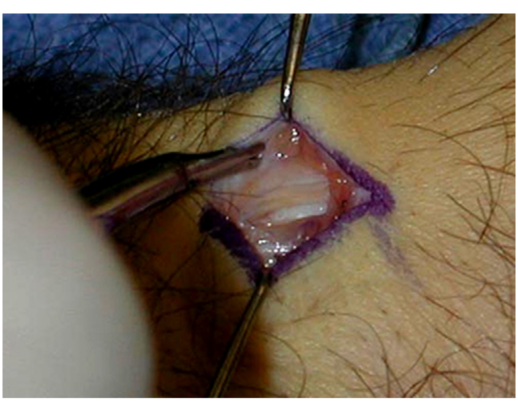

Fig. 1. A small incision over the radial styloid identifies and protects the superficial branch of radial nerve.

Fig. 2. A drill guide fashioned from a syringe is placed in the small incision over the radial styloid to facilitate K-wire insertion and protect the superficial radial nerve.

Injury to the ulnar nerve following a distal radius fracture is rare. The ulnar nerve travels down the forearm under the flexor carpi ulnaris (FCU) and becomes superficial at the level of the FCU tendon; it passes superficial to the transverse carpal ligament, lateral to the pisiform, and then enters the Guyon canal. This anatomic path explains why ulnar nerve dysfunction is less common than that of the median nerve with fractures of the distal radius. At the level of the wrist both the median and ulnar nerves are 3 mm from the radius.[3] However, the median nerve is contained within the carpal tunnel while the ulnar nerve has more available space within the Guyon canal, making it less susceptible to compression. Traumatic ulnar neuropathy tends to be associated with higher energy trauma and more dorsal displacement of the distal radius fragment. Ulnar nerve injuries reported in the literature include severing of the nerve over the sharp edge of the fractured radius, entrapment in the distal radioulnar joint, encasement of the nerve in scar tissue, and displacement of the nerve dorsal to the ulnar styloid.[8–11] Initial treatment of an ulnar nerve palsy following a distal radius fracture is closed reduction of the fracture fragments. If the ulnar nerve function does not improve within 24 to 36 hours, the nerve should be explored with a release of the Guyon canal to minimize the chance of permanent nerve dysfunction.[3]

Complex regional pain syndrome (CRPS) has been associated with distal radius fractures treated both operatively and nonoperatively. CRPS has been associated with overdistraction of the carpus in fractures treated with external fixation. This syndrome is an abnormally intense, prolonged pain response that is disproportionate to the actual tissue damage. The incidence of CRPS after plate fixation of distal radius fractures ranges from 3% to 6%.[12,13] Early intervention should be the focus of treatment. Management includes pain medication, therapy, and sympathetic blocks. The authors' treatment algorithm includes prescribing a Medrol dose pack and a mild analagesic at the first visit. Elavil is added if the patient is experiencing difficulty sleeping. Patients are referred for daily therapy, and instructed to carry something and not isolate the affected hand. Then they are rechecked in 48 hours if they are not sleeping or in 1 week if their sleep is not disturbed. If the pain is improved and the patient feels as if he or she is getting better, therapy is continued. If the pain is refractory, the patient is referred for a sympathetic stellate ganglion block. A recent study by Zollinger and colleagues[14] showed a decreased rate of CRPS in wrist fracture patients treated with vitamin C for 50 days after injury.

Acute vascular injuries associated with fractures of the distal radius are exceedingly rare. Case reports have described entrapment of the ulnar artery preventing fracture reduction, dorsal displacement of the ulnar artery around the ulnar styloid, and radial artery pseudoaneurysm with subsequent microembolism to the thumb.[11,15,16]

SKIN

A large percentage of fractures of the distal radius are fragility fractures, occurring in an older patient population. This population, along with patients with inflammatory arthropathy or taking systemic corticosteroids, possess fragile skin and are more vulnerable to complications stemming from the fracture itself or the subsequent treatment. Tearing of the skin may occur during manual reduction of the fracture. Performing the closed reduction under regional or general anesthesia improves muscle relaxation and enables a gentler reduction maneuver, decreasing the potential for skin tearing. The majority of skin complications associated with distal radius fractures arises from problems secondary to splint or cast application. Complications due to casting include stiffness, pressure sores, and compartment syndrome. As a general rule, sugar tong splints should be applied in the acute setting of a distal radius fracture, followed by delayed casting once the potential for further swelling is minimal.

Infection is a known complication of any surgical procedure. Whereas it is rarely reported with plate fixation, it is more prevalent with percutaneous pinning and external fixation. Hargreaves and colleagues[17] reported superficial pin site infection rates of 34% when the Kirschner wires were left out of the skin, and 7% when the wires were buried. Pin site infections ranging from 21% to 37% have been reported with external fixators.[18,19] Ahlborg and colleagues[19] recommend removing percutaneous Kirschner wires by 8 weeks.

COMPARTMENT SYNDROME

Compartment syndrome is a rare complication following fracture of the distal end of the radius, with a prevalence of less than 1%.[2] Potential sites of compartment syndrome include the hand and forearm. There are ten separate osteofascial compartments of the hand: 4 dorsal interossei, 3 volar interossei, the adductor pollicus, and the thenar and hypothenar muscle groups. Traditional anatomic texts describe the forearm as containing 3 distinct compartments: volar, dorsal, and mobile wad. The volar compartment has been further subdivided into superficial and deep compartments. More recently, a third anatomically distinct volar compartment has been described, the pronator quadratus compartment.[20] Compartment syndrome can theoretically occur in any of the aforementioned compartments, but it is seen most frequently in the volar compartment of the forearm. Compartment syndrome has been reported following closed reduction and immobilization, open reduction and internal fixation, and external fixation. Compartment syndrome is most commonly seen, prior to treatment, as a result of high energy trauma. Acute compartment of dorsal and volar compartments has been reported following a low energy fall.[21]

Diagnosis of compartment syndrome is primarily based on clinical findings. Intracompartmental pressure measurements are a useful confirmatory test, but should not substitute for a thorough physical examination. Physical examination findings include tense compartments, pain out of proportion to the injury, and pain with passive stretch of the involved compartment. In cases of suspected compartment syndrome, patients should be monitored closely with attention to the neurovascular examination and pain medication requirements. Compartment syndrome associated with a distal radius fracture has been reported to occur from 12 to 54 hours after the initial injury.[22,23] Regional anesthesia may mask the symptoms of compartment syndrome and this must be considered when monitoring patients postoperatively.

Initial treatment of compartment syndrome should be to relieve circumferential pressure by splitting the cast or loosening the splint. Plaster cast cutting and spreading can reduce pressures by 40% to 60%. Release of the padding underneath may reduce the pressure an additional 10% to 20%.[24,25] Operative fasciotomy is required if symptomatic improvement after the release of casts and constrictive bandages does not occur. The incision for the volar compartment fasciotomy begins proximally at the antecubital fossa to release the lacertus fibrosus, and extends distally down the forearm in a curvilinear manner to terminate in the palm to facilitate the release of the carpal tunnel. A volar forearm fasciotomy will often reduce pressures in the dorsal compartments. However, if dorsal compartment pressures remain elevated, a dorsal, linear, longitudinal forearm incision is made between the mobile extensor wad and the extensor digitorum communis muscle bellies to release both compartments. Delayed diagnosis or treatment of forearm compartment syndrome can have catastrophic consequences, resulting in Volkmann ischemic contracture and muscle loss with significant functional compromise.

TENDON INJURY

Tendon injury following a distal radius fracture is a rare complication. However, recently the frequency of tendon injury has increased as volar locking plates have become more popular. Injuries to flexor and extensor tendons can range from adhesion formation to simple irritation to frank rupture. Tendon complications have been reported in both conservatively treated and operatively treated fractures. Rupture of the extensor pollicus longus (EPL) during closed treatment of a nondisplaced distal radius fracture was first described by Duplay in 1876. The reported incidence of this complication is 0.07% to 0.88%.[26,27] The interval between fracture and tendon rupture ranges from days to years, but usually occurs within 8 weeks from the initial injury. The 2 proposed etiologies of this rupture are a mechanical theory and a vascular theory. Pundits of the mechanical theory have suggested that rupture results from a prominent edge of the dorsal cortex protruding into the third extensor compartment. Tendon injury according to the vascular theory is thought to occur in a vascular watershed area of the EPL tendon subjected to high-stress decreased third extensor compartment perfusion secondary to increased pressure from fracture callus and hematoma, or systemic factors such as systemic corticosteroid use that may alter blood flow to the tendon.[28]

Engkvist and Lundborg[28] described the vascularity of the EPL tendon as almost entirely intrinsic, with 2 longitudinal vessels running within the tendon from both its proximal and distal aspects. As these 2 systems converge near the Lister tubercle, there is an area of the tendon approximately 0.5 cm length without any vessels. Engkvist and Lundborg determined that this relatively avascular segment corresponds to the level of the rupture of the tendon, and also postulated that the anatomic course of the EPL tendon could be partially responsible for the susceptibility to injury. As the EPL tendon passes dorsally in the third extensor compartment, it takes a sharp turn around the ulnar aspect of the Lister tubercle. This angular course is subject to bending and torsional forces which could, in a tendon with compromised vascularity, contribute to its rupture.

Rupture of extensor tendons is also possible during or after treating a distal radius fracture with a volar plate. Sources of injury include drill-bit penetration and prominent dorsal screw tips (**Fig. 3**). The problem with prominent dorsal screw tips stems from 2 characteristics of distal radius fractures. First, it is difficult to determine screw length with a depth gauge when the dorsal cortex is comminuted. Second, screws penetrating the dorsal cortex that are at the same level as the Lister tubercle can appear contained within the bone on a lateral projection. Benson and colleagues[29] performed a retrospective review to evaluate techniques to minimize damage to the EPL tendon during volar plating of the distal radius. These investigators determined that screws 2 mm longer than the measured depth did not appear prominent on lateral images. The screw lengths needed to be at least 4 mm longer than the measured depth to observe penetration of the dorsal cortex. Benson and colleagues[29] suggested using shorter screws in the holes directed

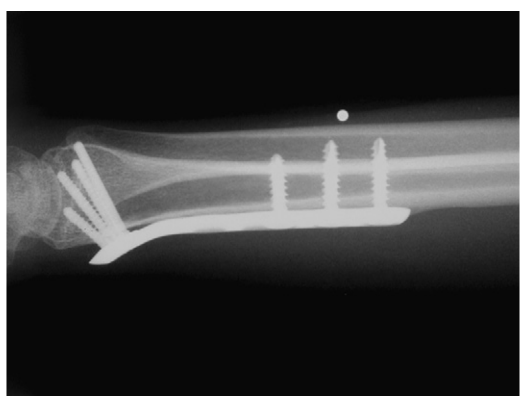

Fig. 3. Prominent dorsal screw tips of the proximal 2 shaft screws. These screws caused a tendonitis of the second extensor compartment, mimicking an overuse-type intersection syndrome.

toward the third extensor compartment, and proposed making a small incision just ulnar to the Lister tubercle to visually inspect the third compartment for prominent hardware after plate application in patients with dorsal comminution (**Fig. 4**). Complete rupture of any tendon may be preceded by tenderness or swelling over the tendon. If EPL tendonitis is suspected, exploration and decompression, or hardware removal if prominent, may prevent rupture. If rupture does occur, primary repair is not possible given the frayed tendon ends. Thumb extension can be restored by transferring the extensor indicis proprius tendon to the EPL tendon or reconstructing the tendon with an intercalary tendon graft.

EPL ruptures are the most frequently reported extensor tendon complications, but extensor digitorum communis tendon ruptures, intersection syndrome, and extensor tenosynovitis associated with fractures of the distal radius have all been described. In addition, extensor tendon entrapment (**Fig. 5**) can also occur, specifically with injury to the distal radioulnar joint (DRUJ). The extensor carpi ulnaris and extensor digiti minimi have both been described as becoming interposed in the DRUJ. Entrapment of an extensor tendon in the DRUJ may be radiographically apparent as a widened DRUJ or clinically as a vacant extensor carpi ulnaris (ECU) sulcus over the distal ulna. This vacant ECU sulcus is referred to as the "empty sulcus sign."[30] The DRUJ remains irreducible, despite reduction and fixation of the radius fracture. Definitive fixation requires reduction of the DRUJ and repair of the extensor carpi ulnaris tendon sheath to optimize stability.

Flexor tendon injury following distal radius fracture is less common than extensor tendon injury. Nonetheless, flexor carpi radialis, flexor pollicus longus, flexor digitorum superficialis, and flexor digitorum profundus tendon ruptures have been

Fig. 4. The dorsal incision shows the prominent screw tip within the third extensor compartment.

Fig. 5. The arrow indicates the extensor tendon entrapped within the fracture site. (*Courtesy of* Terry Light, MD, Maywood, IL.)

reported as both acute and delayed complications of distal radius fractures.[31] The anatomy is thought to be partly responsible for the relative paucity of flexor tendon injuries compared with those of the extensor tendons. Flexor tendons are not as tightly enclosed over the distal aspect of the radius, and the pronator quadratus may serve to protect the flexor tendons from injury secondary to sharp bone edges. Distal to the edge of the pronator quadratus and proximal to the volar radiocarpal ligaments lies a transverse ridge known as the watershed line. The watershed line is within 2 mm from the articular surface on the ulnar aspect of the radius and 10 to 15 mm from the radial articular surface. The clinical significance of this area is that hardware placed distal to the watershed line can abut the flexor tendons and can increase the risk of tendonitis or rupture. In a study by Arora and colleagues[4] implants were placed over or distal to the watershed line in 11 patients and all developed tendon problems, either synovitis or rupture. These investigators recommended early removal of the hardware if the distal aspect of the plate is prominent or becomes prominent due to collapse of the fracture. Arora and colleagues also suggested early plate removal in patients who were on a long-standing regimen of steroids.[32–35]

LIGAMENT DYSFUNCTION

Chronic DRUJ instability is a known complication after distal radius fractures, particularly in those cases where the radius has malunited. There is little inherent bony stability to the DRUJ. Hence, soft tissues such as the pronator quadratus, extensor carpi ulnaris, interosseous membrane, DRUJ capsule, and triangular fibrocartilage comprise the majority of support for the DRUJ. Inadequate healing of the soft tissue structures after a distal radius fracture may result in chronic DRUJ instability. Patients may present with ulnar-sided wrist pain, loss of forearm rotation, and decreased grip strength. Nonsurgical treatment of chronic DRUJ instability is usually futile. A trial of immobilization in a sugar tong splint or long arm cast can be attempted for milder cases of instability, especially in lower demand patients. If nonoperative treatment is unsuccessful, it is useful to determine whether there is an associated malunion of the distal radius which can contribute to DRUJ incongruity and instability. In recent injuries, mild instability may be correctable with triangular fibrocartilage complex (TFCC) repair alone. Gross instability suggests a more extensive injury to the capsule surrounding the DRUJ and the interosseous membrane. In this scenario, TFCC repair may need to be augmented with repair of the capsule and, if necessary, pinning the radius to the ulna proximal to the DRUJ for 4 weeks. Chronic cases of mild instability can be managed with TFCC repair. Mild chronic instability with no TFCC tear can be managed with an ulnar shortening osteotomy. In chronic injuries with gross instability, it has been the authors' experience that either TFCC repair or ulnar shortening osteotomy alone is ineffective. The authors manage gross, chronic DRUJ instability with ligament reconstruction combined with a sigmoid notchplasty if the notch appears hypoplastic on computed tomography.

Malunited fractures that include significant degrees of shortening or angulation are treated with corrective osteotomy. After the osteotomy is fixed with a plate, stability of the DRUJ is reassessed. The aforementioned algorithm applies to the corrected malunion with persistent instability of the DRUJ.

A contraindication to soft tissue reconstruction is an arthritic sigmoid notch. In these instances, salvage procedure including distal ulnar resection, the Sauve-Kapandji procedure or arthroplasty of the DRUJ, may be performed with great care to optimize soft tissue stability.[36]

SUMMARY

Although a fracture of the distal radius is primarily thought of as bone problem, it is important to be cognizant of the potential soft tissue complications that are associated with this injury to optimize outcomes. A thorough physical examination is necessary on initial evaluation and during follow-up to address any tendon injury, nerve dysfunction, vascular compromise, skin problem, compartment syndrome, CRPS, or ligament dysfunction that may arise.

ACKNOWLEDGMENTS

The authors would like to acknowledge Anne Morgan Selleck for her help and contributions in preparation of this article.

REFERENCES

1. Lofthus CM, Frihagen F, Meyer HE, et al. Epidemiology of distal forearm fractures in Oslo, Norway. Osteoporos Int 2008;19:781–6.
2. Cooney WP III, Dobyns JH, Linschied RL. Complications of Colles' fractures. J Bone Joint Surg Am 1980;62:613–9.
3. Vance RM, Gelberman RH. Acute ulnar neuropathy with fractures at the wrist. J Bone Joint Surg Am 1978;60:962–5.
4. 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):316–22.
5. Dyer G, Lozano-Calderon S, Gannon C, et al. Predictors of acute carpal tunnel syndrome associated with fractures of the distal radius. J Hand Surg 2008;33(8):1309–13.
6. Gelberman RH, Szabo RM, Mortensen WW. Carpal tunnel pressures and wrist position in patients with Colles' fractures. J Trauma 1984;24(8):747–9.
7. Bauman TD, Gelberman RH, Mubarak SJ, et al. The acute carpal tunnel syndrome. Clin Orthop Relat Res 1981;156:151–6.
8. Pazart F, Stindel E, Le Nen D. Fracture of the distal part of the radius associated with severed ulnar nerve. Chir Main 1999;18:197–201.
9. Clarke AC, Spencer RF. Ulnar nerve palsy following fractures of the distal radius: clinical and anatomical studies. J Hand Surg Br 1991;16:438–40.
10. Poppi M, Padovani R, Martinelli P, et al. Fracture of the distal radius with ulnar nerve palsy. J Trauma 1978;18:278–9.
11. Sohal JK, Chia B, Catalano LW. Dorsal displacement of the ulnar nerve after a displaced distal radius fracture: case report. J Hand Surg Am 2009;34:432–5.
12. Drobetz H, Kutscha-Lissberg E. Osteosynthesis of distal radius fractures with a volar locking screw plate system. Int Orthop 2003;27:1–6.

13. Kamano M, Koshimune M, Toyama M, et al. Palmar plating system for Colles' fractures—a preliminary report. J Hand Surg 2005;30:750–5.
14. Zollinger PE, Tuinebreijer WE, Breederveld RS, et al. Can vitamin C prevent complex regional pain syndrome in patients with wrist fractures? A randomized, controlled multicenter dose-response study. J Bone Joint Surg 2007;89:1424–31.
15. Fernandez DL. Irreducible radiocarpal fracture-dislocation and radioulnar dissociation with entrapment of the ulnar nerve, artery, and flexor profundus II-V—a case report. J Hand Surg Am 1981;6:456–61.
16. Dao KD, Venn-Watson E, Shin AY. Radial artery pseudoaneurysm complication from use of AO/ASIF volar distal radius plate: a case report. J Hand Surg Am 2001;26:448–53.
17. Hargreaves DG, Drew SJ, Eckersley R. Kirschner wire pin tract infection rates: a randomized controlled trial between percutaneous and buried wires. J Hand Surg Br 2004;29(4):374–6.
18. Anderson JT, Lucas GL, Buhr BR. Complications of treating distal radius fractures with external fixation: a community experience. Iowa Orthop J 2004;24:53–9.
19. Ahlborg HG, Josefsson PO. Pin-tract complications in external fixation of fractures of the distal radius. Acta Orthop Scand 1999;70(2):116–8.
20. Sotereanos DG, McCarthy DM, Towers JD, et al. The pronator quadratus: a distinct forearm space? J Hand Surg Am 1995;20:496–9.
21. Kupersmith LM, Weinfeld SB. Acute volar and dorsal compartment syndrome after a distal radius fracture: a case report. J Orthop Trauma 2003;17:382–6.
22. Simpson NS, Jupiter JB. Delayed onset of forearm compartment syndrome: a complication of distal radius fracture in young adults. J Orthop Trauma 1995;9(5):411–8.
23. Stockley I, Harvey IA, Getty CJ. Acute volar compartment syndrome of the forearm secondary to fractures of the distal radius. Injury 1988;19(2):101–4.
24. Garfin SR, Mubarak SJ, Evans KL, et al. Quantification of intracompartmental pressure and volume under plaster casts. J Bone Joint Surg Am 1981;63:449–53.
25. Halanski M, Noonan KJ. Cast and splint immobilization: complications. J Am Acad Orthop Surg 2008;16:30–40.
26. Heidemann J, Gausepohl T, Pennig D. Narrowing of the third extensor tendon compartment in minimal displaced distal radius fractures with impending rupture of the EPL tendon. Handchir Mikrochir Plast Chir 2002;34:324–7 [in German].
27. Hove LM. Delayed rupture of the thumb extensor tendon: a 5 year study of 1 consecutive cases. Acta Orthop Scand 1994;65:199–203.
28. Engkvist O, Lundborg G. Rupture of the extensor pollicus longus tendon after fracture of the lower end of the radius: a clinical and microangiographic study. Hand 1979;11:76–86.
29. Benson EC, DeCarvalho A, Mikola EA, et al. Two potential causes of EPL rupture after distal radius volar plate fixation. Clin Orthop Relat Res 2006;451:218–22.
30. Paley D, McMurtry RY, Murray JF. Dorsal dislocation of the ulnar styloid and extensor carpi ulnaris tendon into the distal radioulnar joint: the empty sulcus sign. J Hand Surg Am 1987;12:1029–32.
31. DiMatteo L, wolf JM. Flexor carpi radialis tendon rupture as a complication of a closed distal radius fracture: a case report. J Hand Surg Am 2007;32(6):818–20.
32. Bell JS, Wollstein R, Cintron ND. Rupture of the flexor pollicis longus tendon: a complication of volar plating of the distal radius. J Bone Joint Surg Br 1998;80:225–6.
33. Koo SC, Ho ST. Delayed rupture of flexor pollicis longus tendon after volar plating of the distal radius. Hand Surg 2006;11:67–70.
34. Berglund LM, Messer TM. Complications of volar plate fixation for managing distal radius fractures. J Am Acad Orthop Surg 2009;17(6):369–77.
35. Kozin SH, Wood MB. Early soft tissue complications after fractures of the distal part of the radius. J Bone Joint Surg Am 1993;75:144–53.
36. Adams BD, Lawler E. Chronic instability of the distal radioulnar joint. J Am Acad Orthop Surg 2007;15:571–5.