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Anatomic relationships in distal radius bridge plating: a cadaveric study

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Abstract

Background Two separate approaches have been described for radiocarpal spanning internal fixation for high-energy distal radius fractures with metaphyseal extension. To our knowledge, relevant anatomic relationships and structures at risk for iatrogenic injury have not been identified in the literature.

Methods Twelve fresh frozen cadaver arms were randomized to fixation with a dorsal radiocarpal spanning plate using one of two techniques: (1) index finger metacarpal fixation (index group) or (2) middle finger metacarpal fixation (middle group). Cadaveric dissection and relevant anatomic relationships were assessed in relation to the plate.

Results Superficial branches of the radial sensory nerve were in contact with the index group plate in all specimens, while no contact occurred in the middle group specimens. No extensor digitorum comminus (EDC) middle extensor tendons contacted the plate in the index group; an average of 10 cm of plate contact was seen in the middle group. The extensor pollicis longus (EPL) tendon contacted the plate in both the index and middle groups for an average distance of 12.4 and 25.5 mm, respectively. One complication [EPL and extensor indicis proprius (EIP) entrapment] was observed in the middle finger metacarpal group.

Conclusion Mounting the dorsal bridge plate to the index finger metacarpal places the superficial branches of the radial sensory nerve at risk during dissection, while mounting the plate to the middle finger metacarpal leads to a greater degree of tendon-plate contact.

Keywords Distal radius fracture · Distraction plate · Bridge plate · Cadaver

Introduction

Fractures of the distal radius are common injuries and account for roughly one sixth of all fractures [9]. Prior to the mid-1900s, most distal radius fractures, independent of fracture type, were treated without surgery [36]. Since that time, there has been considerable progress in the treatment of these injuries.

Today, a wide variety of surgical options are available for treatment of distal radius fractures including percutaneous pinning, external fixation, volar or dorsal plating, and spanning internal fixation [2, 5, 10, 25]. High-energy distal radius fractures with articular surface comminution and extension into the radial diaphysis remain a challenge for the treating surgeon. The treatment goals are to restore and maintain the length and alignment of the radius and to re-establish congruity of the radiocarpal and distal radioulnar joints [36]. These are goals that are not always easily achieved.

External fixation has been shown to be an effective treatment modality for high-energy distal radius fractures, relying on the principles of ligamentotaxis to obtain an indirect reduction of the fracture [33]. Despite multiple studies showing high (78–92 %) healing rates with the use of external fixation, several problems may still be encountered during the course of treatment [4, 8, 14, 16, 22, 31, 32]. Complication rates may be

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substantial with some studies reporting rates as high as 63 % [1, 7, 13, 19, 20, 30, 34]. These include pin-tract infections, loosening, breakage, osteomyelitis, iatrogenic injury to the superficial radial nerve, and pin-tract skin compromise. Most pin-related complications are correlated with the amount of time that the external fixator remains in place. In some cases, this effectively limits the duration that an external fixator can be used. This presents a problem, as high-energy distal radius fractures often require prolonged immobilization for healing [28].

Burke and Singer and Becton et al. introduced radiocarpal-spanning internal fixation of distal radius fractures in 1998 in two separate papers [3, 5]. Advantages of this technique over external fixation include elimination of pin-related complications, dorsal buttressing of the fracture, and increased construct stability, which may allow greater patient participation in transfers and other activities in the early recovery period [6, 28, 35]. In addition, the elimination of a bulky, unsightly, metal frame attached to the patient's wrist may significantly improve quality of life during the treatment period [15, 26].

Ruch et al. and Hanel et al. have further refined radiocarpal-spanning internal fixation with two separate techniques [11, 28]. Each method uses a different extensor compartment (the second or fourth dorsal compartments) for guiding the plate across the dorsal wrist and a different point of distal fixation (the index finger or middle finger metacarpals). However, relevant anatomic relationships and structures at risk for iatrogenic injury with either technique have not been fully described in the literature. Hanel et al. described 62 highly comminuted metadiaphyseal distal radius fractures treated with bridge plating fixed to the index finger metacarpal and reported one complication in a patient who had a broken plate and extensor tendon rupture when he did not return for planned plate removal [11]. In a follow-up study, Hanel et al. studied 140 patients treated with bridge plating affixed to either the index or middle finger metacarpal and found minor and major complication rates of 4.6 and 8.5 %, respectively [12]. Ruch et al. reviewed 22 high-energy distal radius fractures treated with bridge plating with fixation to the middle finger metacarpal and reported complications in three patients who experienced middle finger extensor lag but no extensor tendon ruptures [28].

However, there are not enough studies to truly define the risks posed by either insertion technique. As a first step toward identifying the complications presented by each approach, we reasoned that identification of the relevant anatomic structures at risk in a cadaveric model would be appropriate. This would allow surgeons to know how these plates might best be inserted so as to reduce the associated complications with each placement technique.

Thus, this cadaveric investigation aims to identify relevant anatomic relationships and structures at risk for iatrogenic injury when using a percutaneously placed dorsal bridge plate using two differently described techniques.

Materials and Methods

Twelve fresh frozen cadaver upper extremities were used in this investigation. There were seven male and five female arms used, with an average age of 81.17 years (range 71–90). All cadavers underwent baseline radiographic examination using fluoroscopic imaging to identify and eliminate specimens with prior fracture, deformity, or presence of hardware. All specimens were found to be acceptable, without apparent injury or deformity, and were included in the study.

The operative technique was based on the previously published reports of Ruch et al. and Hanel et al. [11, 28]. A 2.4-mm straight wrist locking compression plate (LCP) 170-mm in length (Synthes, Paoli, PA) was used for internal fixation throughout all experiments.

To minimize potential bias, computer randomization was used to assign each specimen into either the index metacarpal (index group) or middle metacarpal groups (middle group) [21]. Each plate was then mounted according to the standard described technique using fluoroscopic imaging for guidance.

Operative Technique

Middle Group

For all specimens in the middle group, a 2.4-mm straight wrist LCP, 170-mm in length, was placed over the dorsal middle finger metacarpal. Fluoroscopy was used to scrutinize plate placement, and skin incisions were marked over the dorsal middle finger metacarpal and proximally over the dorsal radial shaft. The approach was made as described by Ruch et al. [28]. A dorsal incision was made, centered over the middle finger metacarpal shaft, and the extensor tendons retracted to allow visualization of the dorsal metacarpal surface. A second incision was made at the dorsoradial aspect of the radius. Dissection was carried down to the dorsal shaft of the radius, ulnar to the brachioradialis muscle. To assist with smooth passage of the plate through the fourth dorsal compartment, a third incision was made at Lister's tubercle, and the extensor pollicis longus tendon was released and transposed radially to avoid tendon impingement between the plate and the tubercle. A tissue elevator was then passed to develop a plane between the extensor tendons and the dorsal periosteum. The plate was then introduced in a retrograde manner through the metacarpal incision, beneath the long finger extensor tendon, and along the floor of the fourth dorsal compartment in a distal to proximal direction.

The plate was then provisionally fixed to the middle finger metacarpal shaft under fluoroscopic guidance. Gentle manual traction was applied, and the plate was fixed proximally onto the radial shaft with fluoroscopic guidance. The remaining screw holes in both ends of the plate were then drilled, measured, and filled with the appropriate screws.

Index Group

For all specimens in the index group, a bridge plate was again superimposed onto the skin, and placement was verified with fluoroscopy. Skin incisions were marked distally over the index metacarpal and proximally over the dorsal distal radius shaft. The approach was made as described by Hanel et al. [11]. An incision was made over the index finger metacarpal shaft and carried down until the dorsal metacarpal shaft was exposed. Proximally, a second incision was made, and dissection was carried down in the interval between the extensor carpi radialis brevis (ECRB) and longus (ECRL) muscles until the radial diaphysis was clearly visualized. A tissue elevator was passed in an antegrade fashion along the dorsal distal radius and through the second dorsal compartment to develop a plane between the second compartment tendons and dorsal radial periosteum. The bridge plate was then introduced through the proximal incision and a proximal-to-distal direction, beneath the ECRB and ECRL tendons, through the second dorsal compartment and onto the index metacarpal. Fixation proceeded as described above.

Cadaver Dissection

Once final plate fixation was verified using fluoroscopy, careful anatomic dissection began. Skin flaps were elevated over the dorsal hand, wrist, and forearm to expose the underlying anatomy. All measurements were taken using a digital caliper (Mitutoyo ABSOLUTE 500-197-20, Kawasaki, Japan) and entered into a data collection table for later analysis. Further dissection continued with dorsal compartment release to fully expose the plate as it traversed the appropriate compartment. Photographic documentation and caliper measurements were again taken. Plate contact lengths were defined as the greatest diagonal measurement of plate-tendon contact. Each relationship was measured three times, with the average distance of the three measurements recorded. Following complete dissection and measurements, all plates were removed. Prior to removal of the middle metacarpal mounted plates, the footprint of the plate in the fourth compartment was outlined with a purple marker. The plates were then removed, and the relationship between the terminal portion of the posterior interosseous nerve (PIN) and the middle metacarpal/fourth dorsal compartment plate's footprint was examined and recorded.

Results

Radial Sensory Nerve in Relation to Plate

In all index group specimens, a branch of the radial sensory nerve crossed directly over the distal aspect of the plate (Fig. 1). The average plate contact distance was 13.5 mm (range 11.1 to 15.1 mm). No observable contact occurred between branches of the radial sensory nerve and the plate in middle group specimens. The average distance from the plate to the nerve in the middle group specimens was 8.1 mm (range 5.6 to 9.3 mm).

Posterior Interosseous Nerve in Relation to Plate

The terminal portion of the posterior interosseous nerve was dissected in the fourth extensor compartment and noted to be below the footprint of the plate in all middle group specimens. Since the index group plate traverses through the second extensor compartment, the terminal PIN-index metacarpal (MC) plate relationship was not assessed.

Extensor Carpi Radialis Brevis and Extensor Carpi Radialis Longus in Relation to Plate

The ECRB tendon contacted the plate in the index group specimens for an average distance of 61.2 mm (range 42.0 to 103.5). The ECRB insertion was directly contacted by the plate in one index group specimen but was bypassed in all others. The average distance from the ECRB insertion to the plate in middle group specimens was 4.1 mm (range 2.9 to 6.4 mm) with no explicit contact with the tendon or its insertion.

The ECRL tendon remained in direct contact with the plate in the index group specimens for an average of 64.5 mm (range 32.5 to 101.3 mm). The ECRL insertion was directly compressed by the plate in a single index group specimen. The average plate to ECRL insertion distance in the middle group was 15.8 mm (range 11.0 to 19.1 mm).

Extensor Digitorum Comminus Index and Extensor Indicis Proprius to Plate

The EDC index and EIP tendons were found to be in direct contact with the plate in all index group specimens. Contact ranged from small adjacent contact (three cases) to full overlay at the distal aspect of the plate (three cases). The average contact length was 7.5 mm (range 2.3 to 14.3 mm). The same tendons were found to be in direct overlaying contact with the plates in the middle group for an average distance of 51 mm (range 36.8 to 75.2 mm) with most contact occurring at the level of the wrist and extensor compartment.

Extensor Digitorum Comminus Middle to Plate

The EDC middle tendon was in direct overlying plate contact with the plate in all middle group specimens for an average distance of 103.8 mm (range 89.7 to 122.2 mm). As expected, there was no contact observed with the plate in the index group specimens (Fig. 2).

Fig. 1 Superficial sensory branches of the radial nerve crossing the plate in an index group specimen

Fig. 2 Finger extensor tendon plate contact in a middle group specimen

Extensor Pollicis Longus to Plate

All specimens in both index and middle groups had plate contact with the extensor pollicis longus tendon, though the location of plate contact was different between the two techniques. EPL traversed the plate in all index group specimens but was in full, direct plate contact in only two cases. In four cases, EPL was partially or fully protected from contact with the plate by the underlying ECRB/ECRL tendons. The average plate overlay distance was 12.4 mm (range 10.0 to 15.6 mm).

EPL was found to be in direct plate contact with all middle group specimens at a level proximal to the extensor compartments in the distal portion of the radius as the tendon proceeds to its origin on the posterior surface of the ulna and interosseous membrane. The average contact length was 25.5 mm (range 19.1 to 28.9 mm).

Additional Findings

In one middle group specimen, complete dissection revealed that the EIP and EPL tendons were entrapped beneath the plate. The location of tendon entrapment was proximal to the extensor compartments for both tendons. No entrapment or other complications were encountered in the index MC mounted plates.

Discussion

Two separate techniques utilizing different metacarpal fixations and compartment placements have been described in the literature [11, 28]. The relative merits of one insertion approach over the other are not yet fully understood, and there is a paucity of data relating to complications that is available to gauge the relative risks presented by each technique. The present study was undertaken to highlight the anatomical structures susceptible to iatrogenic injury with each approach so that these complications may be avoided when bridge plating is used in patients.

The index and middle group techniques may offer unique advantages. Certain fracture patterns, such as lunate facet depression fractures or volar lip fractures, may require manipulation and separate fixation. Burke and Singer suggest that the fourth dorsal compartment approach provides an advantage in these injury patterns [5]. The second dorsal compartment technique as suggested by Hanel et al. uses one less incision and theoretically does not require an EPL transposition prior to plate placement [11].

In addition, the results of our study show several notable differences between these two techniques. During our anatomic dissection, no major branches of the radial sensory nerve were observed to be crossing over the bridge plates mounted on the middle finger metacarpal. However, when placing the plate on the index finger metacarpal, it should be noted that that several branches of the radial sensory nerve were encountered. Incisions made over the index finger metacarpal should be carried out with care to guard against the possibility of injury to these nerves.

Distal radius fractures treated with dorsal plates have been associated with an increased risk of extensor tendon irritation [17, 18, 24, 27, 29]. Placing the plate on the middle metacarpal exposes the middle finger extensor tendon to approximately 10 cm of plate contact, which may increase the risk of tendon irritation or possibly tendon rupture. While the index metacarpal plates had approximately 6 cm of tendon contact with the ECRB and ECRL, it is important to remember that these tendons remain static while the plate is mounted, thereby allowing only

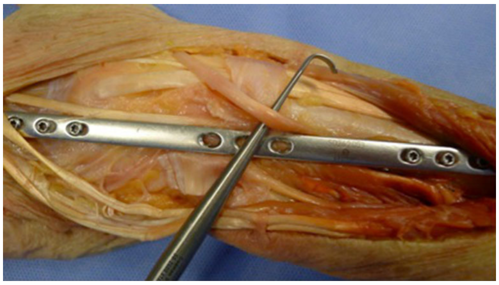

Fig. 3 EPL (beneath retractor) and EIP entrapment in a middle group specimen

minimal friction between the plate and tendons. In the middle group, the finger extensor tendons remain dynamic and may incur significant friction when gliding over the plate.

We did encounter an unexpected finding in one specimen from the middle group that would result in a significant complication if it occurred in a patient. Full dissection of that specimen revealed that the EIP and EPL tendons were trapped beneath the plate in a middle group specimen. The location of tendon entrapment was proximal to the extensor compartments for both tendons (Fig. 3). Entrapment of the EPL tendon was also observed in a cadaveric study by Lewis et al. when a bridge plate was affixed to the third metacarpal, although in their study, no measurements of proximity to nerves or tendons was performed [23]. Thorough testing of the construct during surgery can prevent this complication if encountered in the operating room. No entrapment or other unexpected findings were encountered in the index MC mounted plates.

We observed, as has been previously noted by Hanel et al. and earlier by Becton et al., that the surfaces of the second metacarpal, the second dorsal compartment, and the dorsal distal radius were collinear and made for easy placement of the plate [3, 11]. When placing the plates through the fourth dorsal compartment in middle group specimens, a degree of radially directed force was needed on the proximal end of the plate to bring the plate in line with the radial diaphysis. Impingement on Lister's tubercle was seen in each specimen. While this difficulty would likely be absent in a fracture situation, it does raise questions as to whether the middle metacarpal plate may, at times, contribute to difficulty in achieving an anatomic reduction.

This study does have limitations. There were no in vivo tests performed, and only fresh frozen cadaveric specimens were used. We did not create a fracture model in our cadaver specimens as we were seeking to identify plate placement and various relationships based on anatomic alignment. It is possible, though unlikely, that these relationships could change in the wrist in a post-traumatic state. Advanced imaging was not obtained; therefore, we are unable to comment on variations in pronation and supination alignment between the two plating techniques, nor were we able to assess potential differences in bone-plate contact area. In addition, though efforts were taken to assure accurate measurements to define all anatomic relationships, measurement errors could still occur.

As the use of dorsal spanning plates is becoming more common, we feel that the surgeon should be aware of the anatomical differences in the two previously described locations for plate placement, allowing him/her to choose the most appropriate placement for a given patient.

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Conflict of Interest The authors declare that they have no conflict of interest.

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 2000 and 2008.

Statement of Informed Consent The study is cadaveric in nature, and the cadaver tissue was donated from the Anatomic Gifts Program. Consent for anatomical specimens is kept on file in the Anatomic Gifts Program but is not shared with individual researchers due to confidentiality.

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