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CASE REPORTS

A Novel Trigonometry Equation; Precisely Restoring Distal Radius Volar Tilt

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ABSTRACT

Introduction: Displaced distal radius fractures are often associated with loss of normal volar tilt. Restoration of volar tilt is critical for preservation of normal wrist biomechanics. There is no standardized way to reliably and predictably restore the volar tilt. We introduce a technique of using a locking screw in the most proximal hole of a locking plate to provide a predictable restoration of volar tilt in dorsally displaced distal radius fractures. The desired correction is dictated by the locking screw length to be used which can be calculated by the following equation: $\tan(\theta) \times d=b$. In this equation, θ is the desired correction angle to restore the volar tilt, d is the distance from the locking screw to the volar bend of the plate, and b is the length of the locking screw.

Methods: We performed a retrospective review of 20 patients who sustained distal radius fractures. The volar tilt status post closed reduction of the distal radius fracture was recorded for each patient. Additionally, the volar tilt status post open reduction internal fixation with our novel technique using a synthes 2.4mm volar plate was recorded for each patient. The length of the locking screw was documented and correction angle was calculated for each case.

Results: The average volar tilt status post closed reduction of the distal radius fracture was -3.3 degrees. The average volar tilt status post open reduction internal fixation with our novel technique was 6.55 degrees. The resultant correction angle post-operatively was 10.75 degrees. The average length of the locking screw was 6.7 mm and the distance from the locking screw to the volar bend of the plate was 25 mm in all cases.

Conclusion: Restoration of volar tilt is one of the most critical steps in the treatment of distal radius fractures. An accurate and highly reproducible technique is required to consistently achieve this goal. A simple technique using a locking screw in the most proximal hole of a locking plate can be utilized to restore the volar tilt accurately and reliably in dorsally displaced distal radius fractures.

INTRODUCTION:

Fracture of the distal radius is one of the most common upper extremity orthopaedic injuries with a bimodal peak incidence in the young and elderly populations1. The most common mechanism of injury is fall onto an outstretched upper extremity with dorsiflexion of the wrist between 40 and 90 degrees2. On average, 80% of axial load at the wrist is supported by the distal radius and the remaining 20% is supported by the triangular fibrocartilage complex (TFCC) and ulna2. The distal radius has a volar tilt of 10-12 degrees on average. Loss of normal volar tilt disrupts the joint mechanics and can result in increased load transfer onto the ulna and TFCC2. A cadaveric study done by Short and colleagues demonstrated an increase in the axial load supported by the distal ulna from 21% at 10 degrees of distal radius volar tilt to 67% at 45 degrees of distal radius dorsal tilt3. Moreover, the pressures at the radioscaphoid and ulnocarpal joints are transferred more dorsally as the normal distal radius volar tilt is lost; this increased load will ultimately result in pain and degenerative joint disease3. Additionally, failure to adequately restore the volar tilt in surgically treated distal radius fractures may cause increased pressure on the FPL tendon which may ultimately result in either tendonitis or even tendon rupture4. We aim to describe a simple technique that allows for accurate and reliable restoration of volar tilt in surgical treatment of dorsally displaced distal radius fractures. The "distal-first" technique consists of obtaining a preliminary open reduction of the distal radius fracture. This crude reduction is then usually held in place using percutaneously placed k-wires. The volar plate is then applied with the distal screws placed first in a subchondral position. Once the distal hardware is correctly placed, the plate is pushed down against the radial shaft further reducing the fracture and correcting volar tilt. While this technique can be used to increase volar tilt, it can be difficult to accurately judge if the plate is too far or too close to the shaft to reproduce volar tilt.

A "distal-first" technique using a specific length "kick-stand" locking screw in plate shaft provides a predictable restoration of volar tilt. The correct length of the locking, "kick-stand", screw can be calculated using fluoroscopy and "high school" trigonometry. This is accomplished by superimposing triangles onto a lateral fluoroscopy view of the distal radius and using a few known variables (figure 1). The trigonometric equation is the following:

$\tan(\theta)=\text{opposite}/\text{adjacent}$.

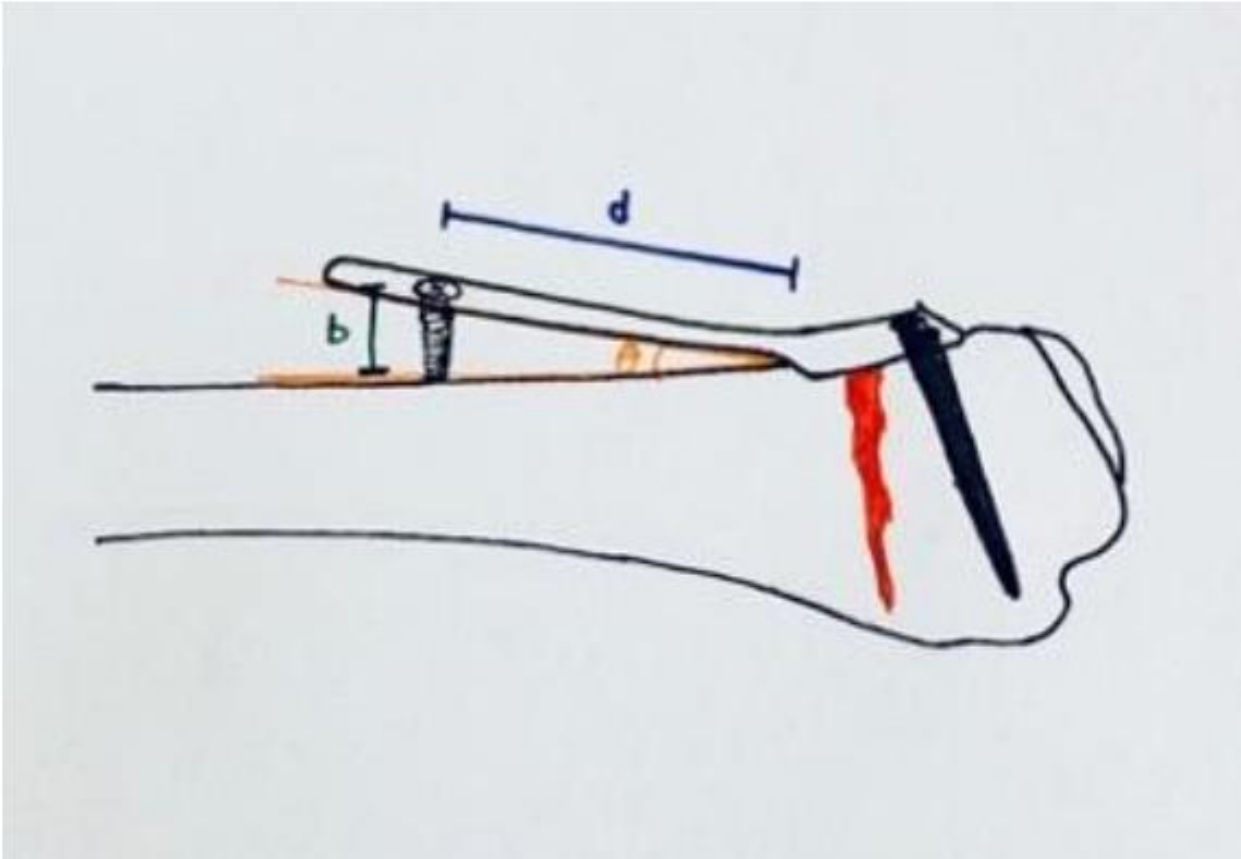

Figure 1: Volar tilt (θ) restoration based on the equation tan (θ) x d=b, where b is the length (mm) of the locking screw and d is the distance (mm) from the locking screw to the volar bend of the plate.

In this situation, θ = the amount of the desired correction in degrees, opposite = the "kick-stand" screw length in mm, and adjacent = the length between the volar bend of the plate and the center of the hole for the "kick-stand" locking screw. One can isolate the locking screw length on one side of the equation by rewriting it as the following: tan(θ) x length on plate = length of screw.

SURGICAL TECHNIQUE:

Patient is positioned supine with the operative extremity supported on an arm board. A nonsterile tourniquet is applied to the upper arm and the upper extremity is prepped and draped in the usual sterile fashion. The arm is elevated, exsanguinated with an Esmarch Bandage, and the tourniquet is inflated to 250 mmHg. Standard FCR approach is performed. The subcutaneous tissue is sharply divided down to the level of the fascia and opened in line with the incision. The flexor carpi radialis tendon is retracted ulnarly and the floor of the sheath is opened and incised longitudinally. The flexor pollicis longus is retracted ulnarly. The pronator quadratus is identified and elevated from the radius using an inverted L-shaped incision, being careful not to release the volar carpal ligaments. The fracture ends are identified and cleared of interposed clot and periosteum. The radial height is restored by applying axial traction and elevating the displaced fracture fragments over the volar cortex. The reduction is held provisionally via Kirschner wires from the radial styloid into the intact portion of the radial shaft. Volar tilt is calculated at that point. For demonstration purposes, in our case presentation, the volar tilt was 0 degrees, and the desired angle of correction was 12 degrees. Applying this to the equation, tan(12) x 25 mm = ~ 5.4mm; therefore, a size 6mm locking screw was utilized (figure 2). Note that a 6mm locking "kick-stand" screw was chosen due to size availability and to accommodate for plate thickness. A Synthes 2.4 mm volar plate with a 6mm locking screw in the most proximal locking hole are placed and provisionally held with Kirschner wires. AP and lateral images are taken to ensure proper positioning of the plate and to ensure the screws would be extra-articular. A cortical screw is placed in the distal segment to appose the plate to the bone. Locking screws are then placed in the distal segment. The "kick-stand" locking screw in the proximal end of the plate is removed prior to apposing the plate to the radial shaft. Two cortical screws are then placed in the shaft portion of the plate to restore the tilt. Final intraoperative fluoroscopy will confirm a predicted and calculated restoration of 12 degrees of volar tilt (figure 3). Closure proceeds in the usual fashion.

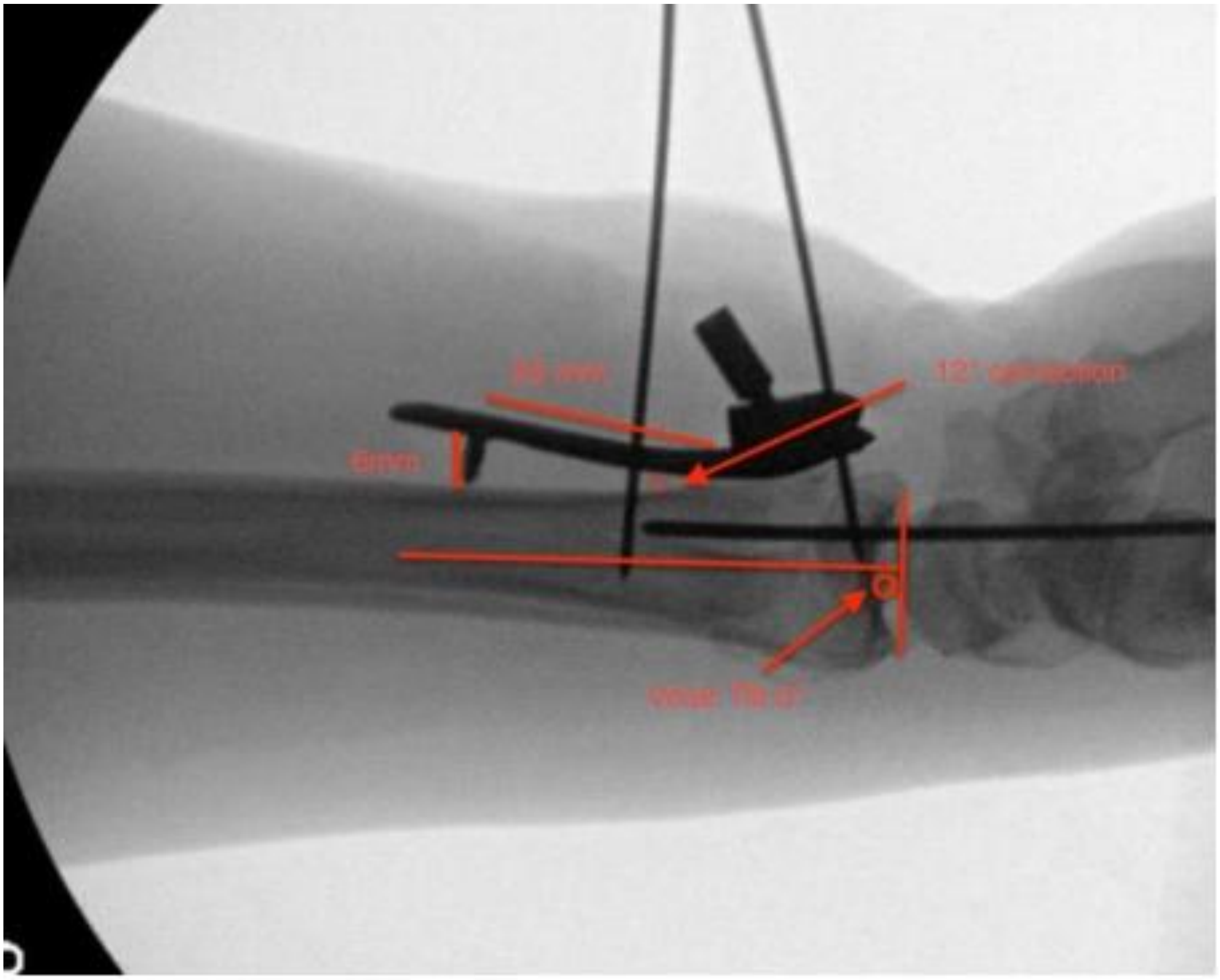

Figure 2: Volar tilt after traction and provisional fixation is 0 Degrees. Restoration of 12 degrees based on the equation: tan (θ) x d=b, where "b" is the length of the locking screw and "d" is the distance from the locking screw to the volar bend of the plate. Tan (12 degrees) x length 25 mm = an 5.3 mm "kick-stand" screw rounded up to 6mm to accommodate for plate thickness.

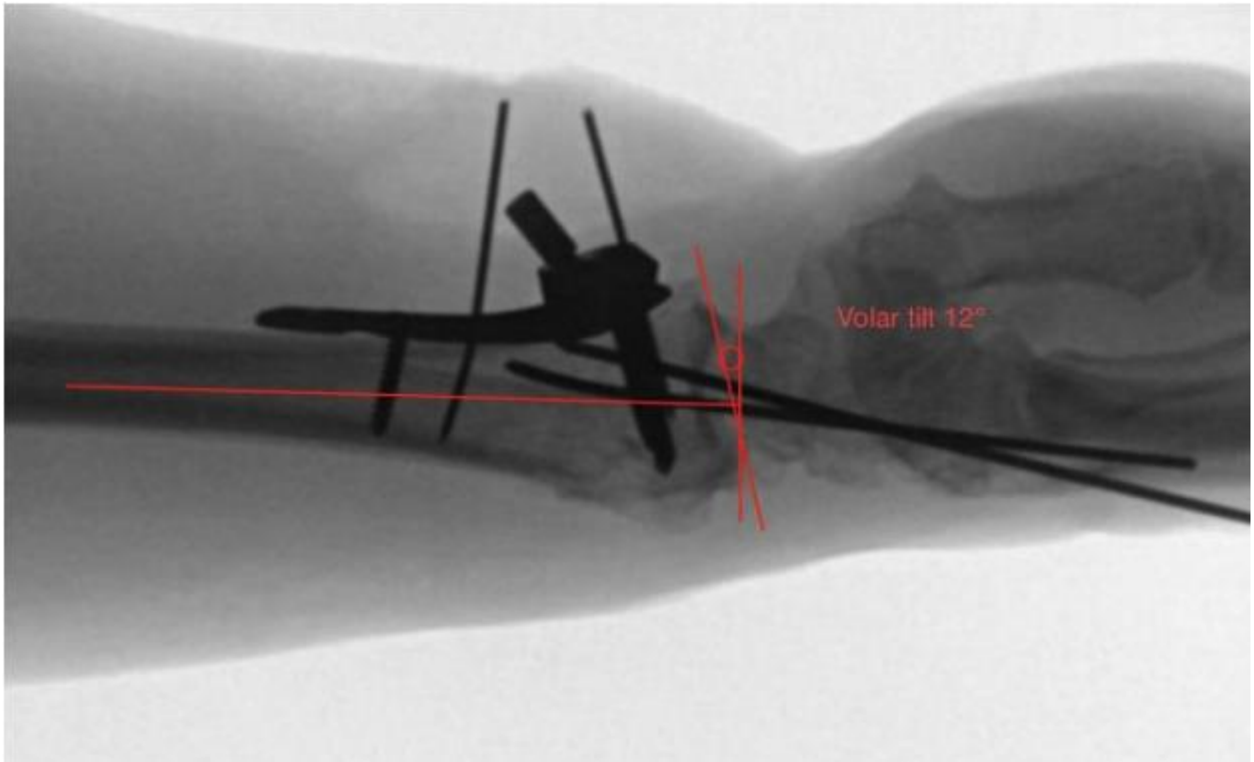

Figure 3: Lateral intraoperative fluoroscopic image showing the predicted restoration of 12 degrees of volar tilt after placement of cortical screw in the radial shaft and removal of "kick-stand" screw.

METHODS:

We performed a retrospective chart review of 20 patients who sustained distal radius fractures that were treated with our novel "distal-first" technique. We measured the volar tilt status post closed reduction of distal radius fracture and the volar tilt status post open reduction internal fixation with our described technique. Correction angle was calculated and the length of the "kick-stand" locking screw was documented for each case. A Synthes 2.4 mm volar plate was utilized in all cases.

RESULTS:

Our retrospective study included 20 patients with an average age of 53.4 years (17-82 years). Our patient population included 15 females (75%) and 5 males (25%). The average volar tilt status post closed reduction of distal radius fracture was -3.3 degrees. The average volar tilt status post open reduction internal fixation with "distal-first" technique was 6.55 degrees. The average correction angle status post open reduction internal fixation with our novel technique was 10.75 degrees. The average length of the "kick-stand" locking screw was 6.7 mm (table 1). The distance from the "kick-stand" locking screw to the volar bend of the plate was 25 mm in all cases.

Patient #	Sex	Pre-ORIF Volar Tilt (degrees)	Post-ORIF Volar Tilt (degrees)	Correction Angle (degrees)	Screw Length used (mm)
1	F	1	3	4	6
2	F	0	12	12	5
3	F	-2	5	7	6
4	M	0	6	6	5
5	F	0	7	7	8
6	F	-6	14	20	8
7	F	-11	4	15	8
8	F	0	16	16	6
9	F	0	13	13	6
10	F	-13	7	20	8
11	M	-9	2	11	6
12	M	-7	1	8	6
13	F	-5	9	14	6
14	M	-6	4	10	6
15	F	0	8	8	6
16	F	-2	8	10	8
17	F	-2	5	7	6
18	F	8	3	11	6
19	F	-12	-5	7	8
20	M	0	9	9	6

Table 1: Patient demographic and volar tilt measurements in 20 patients with distal radius fracture pre- and post- open reduction internal fixation.

DISCUSSION:

Volar plating of distal radius fracture has become more popular over the last decade as it utilizes greater soft tissue coverage to reduce hardware prominence while minimizing tendon irritation or rupture as seen with dorsal plates1. Volar plates provide stable fixation by transferring forces from the distal fracture fragments to the volar cortex of the intact radial shaft5. One of the goals of reconstruction of distal radius fracture is restoration of volar tilt. Reduced volar tilt associated with distal radius fracture is a risk factor for subsequent pain and disability due to increased contact forces in the radiocarpal and radioulnar joints6. Mignemi and colleagues studied 185 patients who were surgically treated with volar plates for distal radius fractures and concluded that even with volar plating of distal radius fractures, only

50% of fractures had restored and maintained volar tilt post-operatively7. Given the clinical significance of restoring volar tilt in distal radius fractures, we aim to present a surgical technique that reliably and accurately restores volar tilt in distal radius fractures treated with volar plating. The surgical method described herein utilizes a “kick-stand” locking screw in the most proximal hole of the volar plate to lever the plate in a stable manner, allowing insertion of distal screws without loss of plate positioning as well as restoration of volar tilt in dorsally displaced distal radius fractures. To achieve optimal results with this technique, it is important to avoid over-correcting the volar tilt by ensuring that the tip of the locking screw is in contact with the volar cortex of the radial shaft. This technique can be especially helpful when performing an open treatment of sub-acute fractures and distal radius malunions. In the inveterate fracture, it is still mandatory to release the thickened dorsal periosteum and callous prior to attempting a distal first reduction as placing undo force on the plate and screw-bone interface can cause iatrogenic fractures or plate failure.

CONCLUSION:

Restoration of volar tilt is one of the most critical steps in the treatment of dorsally displaced distal radius fractures. We present a simple method for surgical restoration of volar tilt using a “distal first” volar plating technique combined with a reproducible equation and a proximal “kick-stand” locking screw.

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