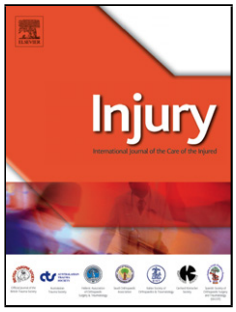

Title: Volar Plating in Distal Radius Fractures: A Prospective Clinical Study on Efficacy of Dorsal Tangential Views to Avoid Screw Penetration

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Title: Volar Plating in Distal Radius Fractures: A Prospective Clinical Study on Efficacy of Dorsal Tangential Views to Avoid Screw Penetration

Running Short Title: Efficacy of the Dorsal Tangential View

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Abstract

Purpose: The purpose of this prospective cohort study of patients treated with volar plating for distal radius fractures is to evaluate the efficacy (defined as detection rate, or the ability to detect dorsally protruding screws) of additional dorsal tangential views (DTV) after obtaining standard anteroposterior (AP) and elevated lateral views by evaluating the change in intraoperative strategy in 100 patients.

Materials and Methods: 100 patients aged 18 years and older undergoing volar plating for acute extra- or intra- articular distal radius fractures were prospectively enrolled. Intraoperative fluoroscopy views, including AP, elevated lateral and DTV were obtained. Intraoperative –screw– revision frequency for dorsal screw protrusion, screw position relative to volar plate and to dorsal compartment, and screw lengths were evaluated.

Results: **Additional DTV led to a change of intraoperative management in 31 of 100 (31%) of patients. A total of 35 out of 504 screws (6.9%) were changed. Screws in the two most radial screws in the plate were at the highest risk of being revised; 16 (46%) screws in most radial position and nine (26%) screws in the 2nd from radial position were revised. Furthermore, five (14%) screws in both the 2nd from ulnar and most ulnar screw holes were revised after DTV. No screws were revised in the central hole. The average length of revised screws was 21 mm (range, 12 to 26 mm), and these were changed to an average length of 18 mm (range, 10 to 22 mm).**

Conclusion: In this prospective series of 100 patients, obtaining additional DTV is found to be efficient as it led to change in intraoperative strategy in one-third of patients. We concur with previous pilot studies that DTV, after obtaining conventional AP and elevated lateral views, is advised to avoid dorsally protruding screws, which could minimize the potential for iatrogenic extensor tendon rupture after volar plating for distal radius fractures. Diagnostic accuracy of DTV is subject of a subsequent prospective cohort study with post-operative CT to serve as the reference standard.

Level of Evidence: Diagnostic II

Key Words: Distal Radius Fracture, Dorsal Tangential View, Open Reduction and Internal Fixation, Protruding Screws, Volar Locking Plate

Introduction

Volar plates for distal radius fractures are increasingly popular[1-5] and have demonstrated to reduce the incidence of post-operative iatrogenic –extensor– tendon injuries as compared to tendon ruptures in the extensor compartments that were traditionally seen with dorsal plating[6,7]. However, some tendon related complications remain. **The -in our hospital standardly used- 20-degree elevated lateral view (a view equivalent to the radial inclination to optimally visualize the radio-carpal joint) is often used as a final check in volar plating for distal radius fractures.** The potential complication of a dorsally protruding screw that is obscured by Lister's tubercle on these elevated lateral radiographs is a preventable iatrogenic pitfall[8-10].

In 2015, Hill and colleagues recommended the intraoperative use of dorsal tangential view (DTV) to best detect dorsal screw penetration after volar plating based on a cadaveric study[11]. In prior work, Ozer and colleagues also compared lateral-, supination-, pronation-,

and DTV fluoroscopy views in cadavers to avoid protruding screws in extensor compartments, and subsequent possible extensor tendon rupture, as standard lateral views failed to detect all screw penetrations[12]. All these pre-clinical studies agree that the use of DTV increases accuracy in detecting dorsal screw penetration in cadavers after volar plating of the radius[11-15]. Oblique views do show increased accuracy as well. However, they are only sensitive for isolated screw positions, do not image the third extensor compartment[16] and have a low overall sensitivity[12]. Therefore, they are not standardly used in our hospital. Interestingly, the accuracy of DTV in clinical practice has been recently debated in a retrospective review of 26 non-consecutive patients with both DTV and post-operative computed tomography (CT) available as the reference standard[17].

In our Level-I Trauma Centre DTV fluoroscopy is routinely obtained as per hospital protocol (Figure 1). In our hospital, this method is affectionately known as the Lleyton Hewitt view, after the "Come On" cry of the former number 1 tennis player from Adelaide (Figure 2). Due to his well-known pose, this radiological position has been commonly used in our hospital for many years. Clinical pilot studies found DTV to be clinically efficient for detection of dorsal screw protrusion in a small series of patients[17-22]. To the best of our knowledge, the clinical efficacy of DTV has not been evaluated to date in a large prospective cohort study[2,3]. Therefore, the purpose of this prospective cohort study is to evaluate the efficacy, measured as changes in intraoperative strategy (cases in which one or more screws were changed) based on the additional DTVs that are part of daily practice in our institution.

Based on our clinical experience and previous literature[17,18,20], we hypothesize that in one-third of patients undergoing volar plating for distal radius fractures dorsally protruding screws are identified and changed intraoperatively based on additional DTV after standardized AP and elevated lateral views did not identify incorrect screw lengths.

Materials and Methods

This project was approved by the local Human Research Ethics Committee, in accordance to the Declaration of Helsinki.

At our Level-I Trauma Centre, we prospectively included 100 patients undergoing volar plating for extra- or intra-articular distal radius fractures, between September 2016 and May 2017.

Inclusion Criteria

Patients were included in the study if they were aged 18 years or older, sustained an acute displaced fracture of the distal radius and had a complete radiographic assessment, including anteroposterior and lateral radiographs and/or CT scan displaying the complete fracture, and where open reduction and internal fixation (ORIF) with a volar approach and volar locking plate (VA-LCP, Synthes, North Ryde, NSW, Australia) was indicated. The indication for surgery was radiological evidence of distal radius fracture instability[23]; such as dorsal comminution, palmar metaphyseal comminution, dorsal tilt >20 degrees, fragment translation >1cm, radial shortening >5 mm, intra-articular disruption, associated ulna fracture or severe osteoporosis. Additionally, inclusion criteria included radiocarpal subluxation or dislocation, displaced fracture of the radial styloid, rotated fracture of the volar lunate faced, and displaced intra-articular fractures.

Exclusion Criteria

Exclusion criteria were in accordance with the recent study by Brunner and colleagues[18]: prior injuries or surgeries that could have affected the anatomy of the distal radius, and fractures that needed intraoperative augmentation. Patients who had a dorsal

approach or additional dorsal fixation were excluded. In our study period, two patients were excluded because no DTV were recorded on the Picture Archiving and Communication System (PACS).

Patients

A total of 100 patients with 100 distal radius fractures underwent surgery and met these inclusion criteria. Of these patients, the mean age was 57 years (range, 18-89). There were 30 (30%) men and 70 (70%) women. Distal radius fracture occurred in 50 right (50%) and 50 left (50%) wrists. According to the AO/Orthopaedic Trauma Association classification[24] 39 fractures were type A (A1:0, A2:17, A3:22), 39 were type B (B1:6, B2:14, B3: 19) and 22 were type C (C1: 9, C2:7, C3:6).

Surgical Treatment

All fractures were surgically treated by or under the supervision of an attending trauma consultant at the Department of Orthopaedic Surgery. A volar approach **through** the FCR-bed was used to expose the volar radius. Variable locking compression plates (VA-LCP, Synthes, North Ryde, NSW, Australia) were used. The plate was used according to the recommendations of the manufacturer. **Even though smooth pegs -that might reduce the risk on tendon pathology- are available for this design, the smooth peg configuration in this plate design potentially compromises the stability[25]. Therefore, our department has elected not to use smooth pegs with this plate design.** In 68 cases 4 distal holes were used and in 32 cases 5 distal holes were used. Depth gauge was used to determine the screw length. It is common practice in our hospital to subtract 2 mm from the measured gauge length to define the screw length. Screw lengths of initial and revised screws were recorded by direct observations of the researchers or based on surgeons' report.

Imaging Technique – Dorsal Tangential View

Prior to the index procedure, surgeons were instructed to save all their DTV views– including fluoroscopy views that revealed protruding screws– to our Digital Archiving System. Pre-operatively, surgeons did not receive additional specified instructions on performance or standardization of DTV fluoroscopy (Siemens, OEC 9900 Elite) as it has been common practice in our Level I Trauma Centre.

Obtaining DTV as standardized in our trauma protocol is according to pre-clinical work by Haug[14] and Hill[11], as well the clinical recommendation by Brunner and colleagues[18] based on their pilot study: the forearm placed in 75° degrees inclination to the horizontal arm table, and the wrist held in maximum flexion. The dorsal cortex of the distal radius was thereby positioned with 15° of inclination to the vertical X-ray beam of the fluoroscope. As Brunner and colleagues concluded based on their pilot work, we also accounted for the variation in anatomy by performing a continuous view while changing angle between 5 and 20 degrees, rather than using a sterile goniometer for precise adjustment of forearm inclination[18]. During the defined study period, there was no protocolled post-operative CT assessment in place to evaluate the accuracy of DTV.

Statistical Analysis

Patient characteristics (age, gender, affected side and fracture type) were summarized with frequencies and percentages for categorical variables and with mean and standard deviation for continuous variables. SPSS 21.0 (IBM Corp, Armonk, New York) was used for statistical analyses.

Power analysis revealed that with an estimated 35% of patients[17,18,20] undergoing volar plating for distal radius fractures dorsally protruding screws are identified and changed intraoperatively based on additional DTV after standardized AP and elevated lateral views, 21

patients were needed in the AP & Lateral-group *versus* 21 patients in the additional DTV-group to detect this difference with 80 % power ($\alpha = 0.05$, $\beta = 0.2$).

Post-hoc power analysis reveals 99 % power ($\alpha = 0.05$) with a total of 100 patients.

Results

Efficacy of Dorsal Tangential Views (DTV)

A total of 35 out of 504 screws (6,9%) were changed after obtaining additional DTVs. This led to change of intraoperative strategy based on additional DTVs after standardized AP and elevated lateral views in 31 of 100 (31%) prospectively included patients.

DTVs revealed dorsal cortex protrusion in 26 of 100 included fractures (26%) –the remainder 5 cases (5%) had change to longer screws– with an average screw length of 21 mm (range, 12 to 26 mm) changed to 18 mm (range, 10 to 22 mm**). Only one screw of 26 mm was used and exchanged, which represents an outlier and is an uncommon screw length to use in volar plating for distal radius fractures.** Following changes to shorter screws, none continued to protrude on subsequent DTVs.

Treating surgeons decided to change to longer screws in 5 cases (5%) with lengths from 16 mm (range, 14 to 20 mm) to 20 mm (range 16 to 24 mm).

The exchange of screws was distributed equally among fracture types and was not found to be more prevalent in more complex cases: in Type A 13 cases out of 39 (33%), Type B 12 cases out of 39 (31%), Type C 6 cases out of 22 (27%) had one or more screws exchanged.

Screws in the radial styloid had highest risk of being too long; 16 (46%) were changed. No screws after DTV were changed in the central –Lister's Tubercle– hole in plates

with 5 holes. Nine (26%) in the 2nd from radial- and five (14%) in both 2nd from ulnar and ulnar positions were changed (Figure 3). There were no screws found to protrude the distal radio-ulnar joint (DRUJ).

During the study period, one patient had an extensor pollicis longus (EPL) rupture, which may have been caused by either the protruding screw that was not identified on DTV, or fracture fragment spica obscuring the obtained view as identified on computed tomography (Figure 4).

Discussion

The purpose of this prospective cohort study of patients treated with volar plating for distal radius fractures is to evaluate the efficacy (defined as detection rate, or the ability to detect dorsally protruding screws) of additional DTV after obtaining standard AP and elevated lateral views by evaluating the change in intraoperative strategy in 100 patients. To the best of our knowledge, to date there are no large prospective clinical trials to evaluate the efficacy of DTV in daily practice.

In our prospective cohort of 100 included distal radius fractures in 100 patients we found that DTV identified protruding screws in 26 cases (26%), and let to change of intraoperative management in 31 cases (31%) - after standardized AP and elevated lateral views were deemed satisfactorily.

Delayed ruptures of extensor tendons secondary to the use of volar locking compression plates for distal radial fractures is in some cases an avoidable iatrogenic complication[26,27] of the increasingly popular open reduction and volar plating techniques for fractures of the distal radius[28]. Multiple pre-clinical studies evaluated specific fluoroscopy views in cadaveric specimens to identify the optimal per-operative view to identify dorsal screw penetration in the extensor compartments [11-14,29,30]. These studies highlighted that

standardized anteroposterior and lateral view are insufficient to appreciate screw penetration due to complex bony anatomy of the distal radius, especially with regards to Lister's tubercle and the EPL groove on the dorsal side. Subsequently, three clinical pilot studies found DTV to be clinically reliable for assessment of the distance between the screw tip and the dorsal cortex in a small series of patients[18-20]. The authors also stated that choosing locking screw length 2-4 mm shorter than measured, aids to prevent protruding screws[17]. **Furthermore, the availability of new generation low profile dorsal plates, which are associated with less tendon rupture[31] might proof to reduce tendon ruptures in the future.**

In 2015, Brunner and colleagues evaluated the reliability of DTV clinically in a preliminary study of 22 patients. The authors found DTV to be reliable in terms of in vivo visualisation of the –fractured– dorsal radial cortex and reliable assessment of the distance between the screw tip and the dorsal cortex. In line with pre-clinical studies[11,14,29,32,33], the authors also conclude that DTV may allow for detection of dorsal screw perforation during volar plating of distal radius fractures.

In contrast in 2016, the accuracy of DTV was debated in a review of 26 –non-consecutive– patients with both DTV and post-operative computed tomography (CT) available as the reference standard[17]. This is illustrated by one case in our series where the DVT was found to be negative for dorsal screw penetration, but this patient did have an EPL tendon rupture either caused by a protruding screw or a fracture fragment. To date, there has not been a larger subsequent prospective cohort study to evaluate efficacy, nor accuracy.

In a recent review article Balfour advocated the use of ultrasound (US) to identify excessively long screws or screw penetration into joints[34]. Similar to the above listed pre-clinical cadaveric and small clinical work using image intensifier (ii), various studies evaluated the reliability and accuracy of US for the detection of dorsal screw penetration, and

found US to be useful for accurate measurement of structures around the wrist in cases where intra-articular and/or comminuted fractures require engagement of screws in the dorsal cortex.[35,36]. A recent study compared ultrasound and the dorsal horizon view in a cadaveric setting, and found ultrasound to be a slightly more reliable and effective procedure for detection of dorsal screw penetrations[37]. Although promising, US may not be as readily available as fluoroscopy and, in addition, accuracy may be user dependent.

This study should be interpreted in the light of strengths and weakness. This study is limited by the purpose and design –a prospective cohort study– rather than a randomized controlled trial comparing traditional AP and elevated lateral views in group 1, and an additional DTV in group 2. We considered a RCT to be unethical as the latter has been common practice in our institution with a pre-study estimate of 35% of change in intraoperative practice (i.e. change of screws)[17,18,20] as a result of these protocolled additional fluoroscopy views. Another weakness by design is the lack of reference standard: screw penetration is not objectified by direct dorsal visualisation (as done in vitro studies) [11,14,29,32,33] nor by postoperative CT scanning[17,18], and therefore accuracy of DVT is beyond the scope of this study. The latter is subject of our subsequent future prospective accuracy study. **The quality of DTV is subject to the positioning of the patient[14]. Although in our hospital the full-sized C-arm is commonly used for distal radius fracture surgery, the available space in the mini C-arm could challenge good DTV positioning. Furthermore the quality of the obtained DTV images, might be influenced by the experience of the surgeon. We will therefore study the influence of training on the DTV in a future inter-observer reliability study.**

We conclude that obtaining additional DTV is found to be efficient as it led to change in per-operative strategy in one-third of patients. We concur with previous pilot studies that DTV –the Lleyton Hewitt view in South Australia– after obtaining conventional AP and

elevated lateral views is advised to avoid dorsally protruding screws, which could further minimise the potential for iatrogenic extensor tendon rupture caused by protruding screws after volar plating for distal radius fractures. Despite using this technique, the surgeon needs to be mindful that there is still a 1% chance of EPL tendon rupture[37]. Finally, we recommend further prospective studies to determine the accuracy of DTV using CT as the reference standard, and long-term follow-up studies to evaluate the clinical significance of this potential problem.

Conflict of Interest Statement

There are no conflicts of interest do declare.

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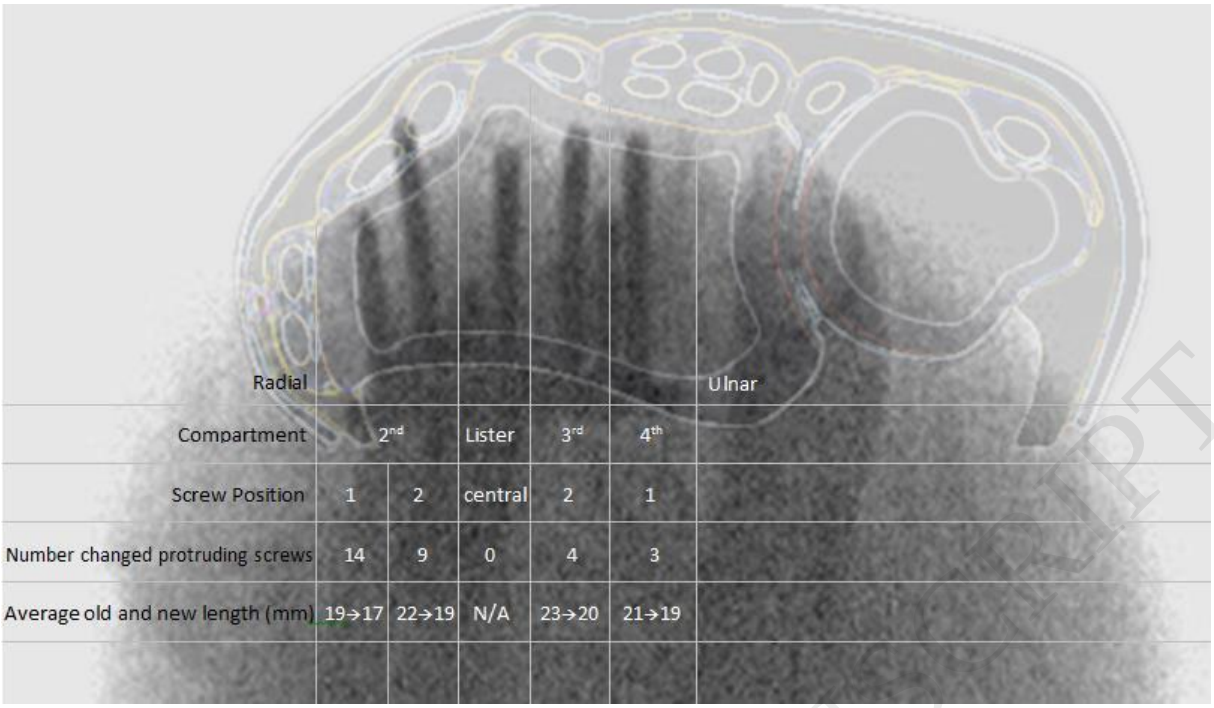
Figure Legends:

Figure 1: The purpose of this prospective cohort study is to evaluate the efficacy, measured as changes in intraoperative strategy after standardized anteroposterior (AP) and 20-degree elevated lateral view, **(a)** based on additional DTVs **(b)**.

Figure 2: Obtaining DTV as standardized in our trauma protocol is according to pre-clinical work by Haug[14] and Hill[11], as well the clinical recommendation by Brunner and colleagues[18] based on their pilot study: the forearm placed in 75 degrees inclination to the horizontal arm table, and the wrist held in maximum flexion. In our Level-I Trauma Centre DTV fluoroscopy is routinely obtained as per hospital protocol, perhaps because it is popularised throughout South Australia as the Lleyton Hewitt View (Doornberg JN. Volar Plating in Distal Radius Fractures: a Prospective Clinical Study on Efficacy of Dorsal Tangential Views (aka Lleyton Hewitt View) to Avoid Dorsal Screw Penetration. Podium Presentation presented at Annual

Meeting of the Australian Orthopaedic Association, South Australian Branch; 2017; Lyell McEwin Hospital, Adelaide). The use of the eponym Lleyton Hewitt View has been approved by Mr. Hewitt.

Figure 3: Screws in the radial styloid had highest risk of misplacement; 16 (46%) were changed. No screws after DTV were changed in the central –Lister's Tubercle– hole in plates with 5 holes. Nine (26%) in the 2nd from radial- and 5 (14%) in both 2nd from ulnar and ulnar positions were changed.



Radial						Ulnar
Compartment	2nd		Lister	3rd	4th	
Screw Position	1	2	central	2	1	
Number changed protruding screws	14	9	0	4	3	
Average old and new length (mm)	19→17	22→19	N/A	23→20	21→19	

Figure 4: During the study period, one patient had an extensor pollicis longus (EPL) rupture, which may have been caused by either a protruding screw that was not identified on DTV, or fracture fragment spice obscuring the obtained view as identified on computed tomography.