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Original Research

## Intraoperative Fluoroscopy Versus Postoperative Radiographs in Assessing Distal Radius Volar Plate Position: Reliability of the Soong Classification



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**Purpose:** Fluoroscopic imaging remains the standard intraoperative imaging modality for volar locking plate fixation of distal radius fractures, and correlation with postoperative radiographs remains unclear. The purpose of this study was to assess the reliability of the Soong classification system between intraoperative fluoroscopy and postoperative radiographs for distal radius volar plate position.

**Methods:** Eleven hand surgery resident physicians (3 in postgraduate year 2, 2 in postgraduate year 3, 3 in postgraduate year 4, and 3 in postgraduate year 5) and 4 attending physicians classified images using the Soong classification system. Fluoroscopic and radiographic lateral images from 30 patients were randomized and deidentified. Thirty percent of the images were duplicated for intraobserver reliability. Seventy-eight images were randomized and presented to each observer in 1 consecutive session. Cohen kappa values were calculated for intraobserver reliability, and Fleiss kappa values were calculated for interobserver reliability.

**Results:** Intraobserver reliability demonstrated moderate reliability overall. The intraobserver reliability was highest among postgraduate year 4 residents and attending physicians demonstrating substantial reliability. Lateral intraoperative fluoroscopic and postoperative radiographic imaging demonstrated no difference in intraobserver reliability overall. Interobserver reliability was highest among postgraduate year 5 residents demonstrating moderate reliability and attending physicians demonstrating substantial reliability.

**Conclusions:** There was no difference in the intraobserver reliability of the Soong classification system between the lateral images of intraoperative fluoroscopy and postoperative radiographs. Fluoroscopic analysis using the Soong classification system is a reliable method to determine plate prominence and has demonstrated increasing reliability based on year of training. Fluoroscopic analysis using the Soong classification system and direct visualization during surgery for the assessment of plate prominence is recommended, with the understanding that higher Soong grades are associated with increased rates of complications.

**Type of study/level of evidence:** Diagnostic III.

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Volar locking plate fixation has revolutionized the treatment of distal radius fractures. Despite its many advantages, there exist unique complications associated with volar plate

prominence and positioning, including flexor tendon ruptures and implant irritation.<sup>1–3</sup> Soong et al<sup>4</sup> developed a classification system for volar plate positioning in relation to the watershed line of the distal radius, as viewed on lateral radiographs. The concept of the watershed line was originally described as an anatomic area on the volar distal radius where the capsule inserts.<sup>5,6</sup> There is controversy as to the definition of the watershed line, as studies have shown wide variability in the volar distal radius anatomy in relation to plate positioning and flexor tendon irritation.<sup>7–11</sup>

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Fluoroscopic imaging remains the standard intraoperative imaging modality for distal radius fracture fixation, but no studies have examined its use in the assessment of plate prominence. Studies have shown significant differences between fluoroscopic imaging compared with radiographic imaging and have suggested that fluoroscopy alone may be insufficient.<sup>12–14</sup> Although these studies did not focus on distal radius fracture fixation, plate positioning, or plate prominence, their findings were notable in the context of comparing the differences between imaging modalities. The differences attributed to the imaging modalities may arise from inherent differences in technology and the technical skill of the operator. Although research has shown that the Soong classification system demonstrated good reliability in assessing the degree of plate prominence on plain radiographs, there are no studies to date examining the reliability of the Soong classification system when comparing intraoperative fluoroscopy with postoperative plain radiographs.<sup>15,16</sup>

The purpose of this study was to assess the reliability of the Soong classification system for intraoperative fluoroscopy and postoperative radiographs for distal radius volar locking plate position. We hypothesized that using the Soong classification system for intraoperative fluoroscopy was as reliable as plain radiographs for the volar plate. Additionally, we assessed the reliability of the Soong classification system among different levels of training.

## Materials and Methods

After obtaining an institutional review board approval, images were gathered from an electronic medical record search of distal radius fracture surgery from January 2016 to September 2019. We identified 179 patients over the age of 18 using Current Procedural Terminology codes 25607, 25608, and 25609. Exclusion criteria included insufficient lateral imaging or additional fixation beyond volar plate fixation; eg, percutaneous pinning, dorsal plates, radial styloid plates, and fixation of the ulna or distal radioulnar joint. A total of 117 patients met the inclusion criteria, 30 of whom were then chosen at random to be included in the study. This was obtained as a sample of convenience, and no a priori power analysis was performed at the time of patient selection.

The Soong classification system uses lateral imaging to assess plate positioning; therefore, lateral views of both intraoperative fluoroscopic and early postoperative radiographic imaging for these patients were deidentified and randomized. Thirty patients yielded 30 lateral postoperative radiographs and 30 lateral intraoperative fluoroscopic images, totaling 60 images. Intraoperative fluoroscopic imaging was performed by radiology technicians with direction from the operative surgeon. The best available fluoroscopic and radiographic lateral images was selected, confirmed to be appropriate by projection of the palmar margin of the pisiform between the palmar margins of the distal scaphoid and the capitate.<sup>17</sup> Early postoperative radiographic imaging was defined as having been completed within 2 weeks from the index surgery. Of the 30 patients, 9 (30%) patients were chosen at random to be duplicated in pairs (lateral intraoperative fluoroscopic and postoperative radiographic images) and included for intraobserver reliability for an additional 18 images. A total of 78 images were randomized and presented to each observer in 1 consecutive session. Chart review was performed, and all implants (Synthes 2.4 mm variable angle LCP, DePuy Synthes) were noted to be 2-column volar distal radius plates and volar rim distal radius plates. The distribution of Soong grades was determined after the selection of patients, with 12 images in grade 0, 15 images in grade 1, and 3 images in grade 2.

Eleven hand surgery resident physicians in postgraduate years 2 through 5 (3 in postgraduate year (PGY)2, 2 in PGY3, 3 in PGY4, and

3 in PGY5) and 4 attending physicians were asked to classify the fluoroscopic and radiographic images using the Soong classification system. All the images was presented without editing the quality of the original image, except for deidentification. Fluoroscopic images was presented in the same format as the original imaging modality, without inversion of contrast, to better approximate how fluoroscopic imaging would be visualized in the operating room. The observers were allowed to manipulate the images and draw lines as they saw fit. Any manipulation of the images was not recorded or included in the final analysis. The attending physicians included a hand fellowship-trained hand surgeon, a sports fellowship-trained hand surgeon, a trauma fellowship-trained hand surgeon, and a musculoskeletal fellowship-trained radiologist. Observers were blinded to the previously assigned classification and to clinical information regarding the patient. Each observer was shown the images in [Figure 1](#) before grading any images.

Data analysis was performed by an independent statistician. Cohen kappa values were calculated for intraobserver reliability, and Fleiss kappa values were calculated for interobserver reliability. The reliability of using the Soong classification system to compare intraoperative fluoroscopy and postoperative radiographs was calculated as intraobserver reliability. Kappa value ( $\kappa$ ) interpretation was based on Landis and Koch ([Fig. 2](#)).<sup>18</sup>

Post hoc power analysis was performed to detect a difference of  $\kappa$  in the range of 0.40 to 0.50 from 0.<sup>19</sup>

## Results

The intraobserver reliability of lateral imaging showed moderate reliability for all observers for each imaging group: fluoroscopic images ( $\kappa = 0.55$ ), radiographic images ( $\kappa = 0.55$ ), and fluoroscopic and radiographic images combined ( $\kappa = 0.56$ ). For all images, substantial intraobserver reliability was found among PGY4 ( $\kappa = 0.66$ ) residents and attending physicians ( $\kappa = 0.68$ ). There was no statistically significant difference between fluoroscopic versus radiographic intraobserver reliability overall ( $P = .99$ ) ([Table 1](#)).

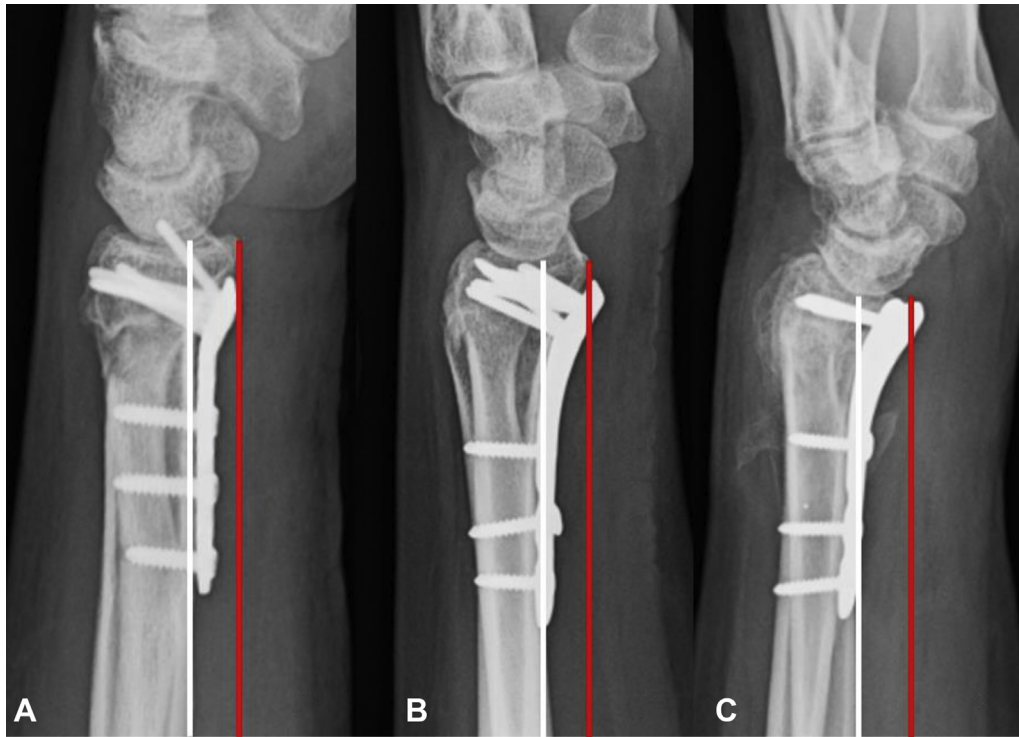
Additionally, each individual observer kappa for intraobserver reliability was documented. Among the 4 attending physicians, only 2 demonstrated substantial reliability ( $\kappa > 0.61$ ), and among those 2, only 1 demonstrated perfect reliability ( $\kappa = 0.89$ ) overall ([Table 2](#)).

Comparatively, interobserver reliability of lateral imaging for fluoroscopy showed moderate reliability ( $\kappa = 0.51$ ), radiographs showed fair reliability ( $\kappa = 0.40$ ), and overall demonstrated moderate reliability ( $\kappa = 0.45$ ). There was a statistically significant difference found between fluoroscopy and radiographs for the PGY4 group ( $P < .001$ ) and overall ( $P < .001$ ) ([Table 3](#)). Interobserver reliability was highest among PGY5 residents ( $\kappa = 0.49$ ) and attending physicians ( $\kappa = 0.63$ ).

Subgroup analysis of agreement for each Soong grade was performed for all observers. Kappa was 0.53 for grade 0, 0.41 for grade 1, 0.41 for grade 2, and 0.45 overall; each grade demonstrating moderate reliability ([Table 4](#)).

## Discussion

The Soong classification system demonstrated moderate intraobserver reliability overall for both intraoperative fluoroscopy ( $\kappa = 0.55$ ) and postoperative radiographs ( $\kappa = 0.55$ ) without a statistically significant difference ( $P = .99$ ). Substantial intraobserver reliability was found among PGY4 ( $\kappa = 0.66$ ) residents and attending physicians ( $\kappa = 0.68$ ), with 1 attending physician who demonstrated perfect intraobserver reliability overall ( $\kappa = 0.89$ ). For each observer group, no statistically significant difference was found in the intraobserver reliability between fluoroscopic images



**Figure 1.** **A** Grade 0: Plate is dorsal to critical line (red). **B** Grade 1: Plate is volar to critical line (red) but proximal to the volar rim. **C** Grade 2: Plate is volar to critical line (red) and on or distal to the volar rim.

Kappa value ( $\kappa$ )	Degree of agreement
<0.00	No agreement
0.00-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Perfect

**Figure 2.** Kappa value reliability interpretation.<sup>18</sup>

and radiographic images (Table 1). Post hoc power analysis revealed that the study was adequately powered to detect a difference of kappa values in the range of 0.40 to 0.50 from 0.<sup>19</sup> This suggested our study was adequately powered for the overall average intraobserver and interobserver findings. However, there is a possibility that the study is underpowered for the subanalysis reported. This supports that there is no statistically significant difference between fluoroscopy and radiographs in the analysis of plate positioning. Essentially, in the setting of an individual hand surgeon analyzing distal radius volar plate position, fluoroscopic imaging is as reliable as postoperative radiographs.

Comparatively, interobserver reliability for fluoroscopy showed moderate reliability ( $\kappa = 0.51$ ) and radiographs showed fair reliability ( $\kappa = 0.40$ ). There was a statistically significant difference between fluoroscopy and radiographs for the PGY4 group ( $P < .001$ )

and overall ( $P < .001$ ), with almost no interobserver agreement ( $\kappa = 0.05$ ) (Table 3). Although there was more disagreement in the interobserver reliability between fluoroscopy and radiographs for the PGY4 group, all other experience levels showed similar interobserver reliability between the 2 modalities. The overall difference in the interobserver reliability between fluoroscopy and radiographs may be explained by the PGY4 group.

Previous studies showed good reliability of the Soong classification system for distal radius volar locking plate fixation in radiographic imaging without examining fluoroscopic imaging.<sup>15,16</sup> Plate positioning and plate prominence are more often assessed during surgery with fluoroscopy as the standard intraoperative imaging modality. By demonstrating moderate intraobserver reliability of fluoroscopy for the Soong classification system and agreement with postoperative radiographs, this study demonstrates that fluoroscopy is a reliable imaging modality for the assessment of plate prominence. Despite the difference demonstrated in interobserver reliability, there was no difference in the intraobserver reliability of the Soong classification system between the lateral images of intraoperative fluoroscopy and postoperative radiographs.

The use of postoperative radiographs to assess plate prominence, although demonstrated to be reliable, may not be as beneficial as intraoperative fluoroscopy because of the time at which the images are obtained.<sup>15,16</sup> Our study suggests that early postoperative radiographs contribute no significant information with respect to plate prominence in comparison to intraoperative fluoroscopy but may be beneficial when examining the loss of fixation. For fracture reduction and fixation, the value of early postoperative radiographs in the treatment of distal radius fracture fixation has been questioned, and some studies have demonstrated that these images do not change postoperative management.<sup>20–22</sup> Sharma et al<sup>21</sup> found that among 172 patients with early postoperative radiographs following distal radius fracture fixation, only 7 patients

**Table 1**  
Intraobserver Reliability for Each Observer Group

Observer Group	Fluoroscopy		X-ray		Overall <sup>‡</sup>		Fluoroscopy Versus X-ray
	Kappa <sup>*</sup>	95% CI <sup>†</sup>	Kappa <sup>*</sup>	95% CI <sup>†</sup>	Kappa <sup>*</sup>	95% CI <sup>†</sup>	P Value
PGY2	0.349 (0.180)	-0.004–0.701	0.468 (0.167)	0.141–0.795	0.409 (0.122)	0.170–0.648	.63
PGY3	0.488 (0.170)	0.154–0.821	0.254 (0.195)	-0.129–0.636	0.360 (0.134)	0.098–0.621	.37
PGY4	0.777 (0.100)	0.581–0.973	0.560 (0.168)	0.230–0.890	0.662 (0.112)	0.443–0.881	.27
PGY5	0.579 (0.177)	0.233–0.926	0.611 (0.160)	0.298–0.925	0.602 (0.118)	0.371–0.833	.89
Attending	0.552 (0.240)	0.081–1.022	0.708 (0.133)	0.448–0.968	0.679 (0.142)	0.401–0.957	.57
Overall <sup>§</sup>	0.553 (0.178)	0.204–0.902	0.550 (0.160)	0.236–0.865	0.564 (0.126)	0.317–0.810	.99

\* Reported as kappa (standard error).

† Reported as lower and upper bounds of 95% CI.

‡ Fluoroscopy and x-ray imaging combined.

§ All observers.

**Table 2**  
Intraobserver Reliability for Individuals

Observer	Fluoroscopy		X-ray		Overall <sup>‡</sup>	
	Kappa	Standard Error <sup>*</sup>	Kappa	Standard Error <sup>*</sup>	Kappa	Standard Error <sup>*</sup>
DU_PGY2	0.633	0.19	0.791	0.14	0.719	0.116
KB_PGY2	0.133	0.18	0.195	0.17	0.159	0.125
ML_PGY2	0.28	0.17	0.418	0.19	0.349	0.125
MW_PGY3	0.695	0.15	0.23	0.2	0.446	0.131
HT_PGY3	0.28	0.19	0.277	0.19	0.273	0.136
LT_PGY4	0.787	0.14	0.448	0.19	0.626	0.123
TP_PGY4	1	0	0.635	0.16	0.788	0.1
RM_PGY4	0.545	0.16	0.597	0.155	0.573	0.112
JR_PGY5	0.378	0.19	0.572	0.15	0.488	0.122
TH_PGY5	0.575	0.19	0.556	0.17	0.57	0.125
TB_PGY5	0.785	0.15	0.706	0.16	0.748	0.107
BT_Att	1	0	0.843	0.15	0.886	0.11
RC_Att	0.286	0.33	1	0	0.805	0.127
WF_Att	0.545	0.36	0.614	0.19	0.607	0.168
MR_Att	0.375	0.27	0.375	0.19	0.417	0.162

Att, attending physician.

\* Standard error.

‡ Fluoroscopy and x-ray imaging combined.

**Table 3**  
Interobserver Reliability for Each Observer Group

	Fluoroscopy		X-ray		Overall <sup>‡</sup>		Fluoroscopy Versus X-ray
	Kappa <sup>*</sup>	95% CI <sup>†</sup>	Kappa <sup>*</sup>	95% CI <sup>†</sup>	Kappa <sup>*</sup>	95% CI <sup>†</sup>	P Value
PGY2	0.113 (0.054)	0.007–0.219	0.105 (0.054)	-0.001–0.211	0.113 (0.038)	0.039–0.187	.91
PGY3	0.155 (0.095)	-0.031–0.341	0.167 (0.093)	-0.015–0.349	0.168 (0.066)	0.039–0.297	.93
PGY4	0.425 (0.059)	0.309–0.541	0.048 (0.055)	0.040–0.256	0.287 (0.040)	0.208–0.365	<.001
PGY5	0.529 (0.060)	0.411–0.647	0.434 (0.056)	0.324–0.544	0.492 (0.040)	0.414–0.570	.25
Attending	0.619 (0.060)	0.501–0.737	0.636 (0.056)	0.526–0.746	0.629 (0.041)	0.549–0.709	.84
Overall <sup>§</sup>	0.508 (0.014)	0.481–0.535	0.396 (0.013)	0.371–0.421	0.453 (0.009)	0.435–0.471	<.001

\* Reported as kappa (standard error).

† Reported as lower and upper bounds of 95% CI.

‡ Fluoroscopy and x-ray imaging combined.

§ All observers.

had alterations in their postoperative management with only 1 patient requiring immediate surgical revision as indicated by imaging.

The original description of the Soong classification system and subsequent studies have only examined postoperative radiographs.<sup>2,4,16,23,24</sup> Determination of plate prominence may be best assessed during surgery with either direct visualization, intraoperative imaging, or a combination of both.<sup>10,11</sup> An anatomic study in 2012 by Imatani et al<sup>10</sup> suggested that the watershed line for volar plate positioning may not be a distinct line that is easily visualized because of anatomic variability. This suggests that direct visualization alone may be insufficient for the assessment of plate prominence and that the addition of intraoperative fluoroscopy or

postoperative radiographs may be beneficial. Our study supports the use of intraoperative fluoroscopy, as we have demonstrated no difference in intraobserver reliability between intraoperative fluoroscopy and postoperative radiographs. Intraoperative fluoroscopy allows the surgeon to control the imaging and change the implant position if it is a concern.

Other studies have examined the differences between various imaging modalities and during fracture fixation. Halvachizadeh et al<sup>14</sup> examined intraoperative computed tomography scans for the treatment of distal radius fractures and demonstrated an improvement in reduction and superior screw positioning after surgery with comparable durations of surgery with the use of intraoperative computed tomography compared with fluoroscopy



**Table 4**  
Kappa Values for Individual Soong Classification Categories

Grade	Conditional Probability	Kappa	Asymptotic Standard Error	Z	P value	Lower 95% Asymptotic CI Bound	Upper 95% Asymptotic CI Bound
0	0.681	0.527	0.012	42.139	.00	0.502	0.551
1	0.714	0.411	0.012	32.914	.00	0.387	0.436
2	0.506	0.412	0.012	32.959	.00	0.387	0.436
Overall		0.453	0.012	48.547	.00	0.435	0.472

and radiographs. Capo et al<sup>12</sup> demonstrated errors in fluoroscopy for the closed reduction and percutaneous pinning of Bennett's fractures in a cadaveric model compared with plain radiographs and direct examination. Various studies demonstrate differences between fluoroscopy, radiographs, and direct visualization, which may be reflected by the inherent differences in implants, anatomic location, and type of surgery.<sup>13,25–27</sup> Although these studies do not directly assess fluoroscopic imaging in distal radius fractures, there is a known and implied difference between fluoroscopy, radiographs, and direct visualization.

Plate prominence and higher Soong classification grades have been associated with increased rates of flexor tendinopathy and subsequent implant removal, although this is not universally accepted.<sup>2,23,24,28–30</sup> In response to Snoddy et al,<sup>30</sup> Soong et al<sup>31</sup> in 2015 reexamined the data comparing grade 2 with combined grade 0 and 1 and demonstrated a statistically significant difference in flexor tendon complications.

The relationship between physician experience and reliability of the Soong classification has been explored in prior research. Creighton et al<sup>15</sup> demonstrated that the intraobserver reliabilities of 6 physician observers of postoperative radiographs for distal radius volar plate prominence did not correlate with experience, as the lowest value was recorded by the most experienced surgeon. Lutsky et al<sup>16</sup> used fellowship-trained upper-extremity surgeons and found an interobserver intraclass correlation of 0.78. In contrast to the study by Creighton et al,<sup>15</sup> this study suggests that kappa values for interobserver reliability gradually increase for each year of training. The fluoroscopic interobserver reliability increased from 0.16 for PGY3 to 0.43 for PGY4, while the radiographic reliability did not demonstrate a significant increase until PGY4 ( $\kappa = 0.50$ ) (Table 3). Barring any instructional issues or data transposition issues, it seems that the learning process for assessment happens faster for fluoroscopy than it does for radiographs, by approximately 1 training year.

There are several limitations to this study. All images were shown in 1 session, as compared to multiple sessions, which may result in considerable recall bias. Each observer was given the capability of using annotations on the images; however, the use of annotations was not evaluated in this study. All imaging were performed by various technicians and various surgeons, introducing additional variability and inconsistency, although this likely is more representative of clinical practice. Owing to the ability to manipulate the extremity by the operative surgeon, it is likely that intraoperative fluoroscopic imaging is more advantageous than postoperative radiographic imaging when evaluating plate positioning. The individual differences among the attending physician group compared to their years in practice were also not fully elucidated. The distribution of Soong grades may also be a limitation to this study, because of the small number of Soong grade 2 images. Another limitation is that only Synthes plates were used in this study. Sato et al<sup>32</sup> examined 6 different plate designs and found that plate prominence on lateral radiographs varied by which type of plate was used. This is a major limitation of the Soong classification system, and conclusions from this study can only be applied to Synthes plates. Despite these limitations, the Soong classification system not only demonstrated moderate intraobserver reliability

between fluoroscopy and radiographs, but also demonstrated increasing reliability based on years of training.

After preliminary fracture reduction and before definitive volar locking plate fracture fixation, plate prominence and positioning are best assessed by direct visualization and fluoroscopic imaging. Any adjustments can be made based on Soong classification. Fluoroscopic analysis of the Soong classification is a reliable method to determine plate prominence and position with the understanding that higher Soong grades are associated with increased rates of complications.

## References

- Sato K, Murakami K, Mimata Y, Doita M. Incidence of tendon rupture following volar plate fixation of distal radius fractures: A survey of 2787 cases. *J Orthop.* 2018;15(1):236–238.
- Kitay A, Swanstrom M, Schreiber JJ, et al. Volar plate position and flexor tendon rupture following distal radius fracture fixation. *J Hand Surg Am.* 2013;38(6):1091–1096.
- Asadollahi S, Keith PPA. Flexor tendon injuries following plate fixation of distal radius fractures: a systematic review of the literature. *J Orthop Traumatol.* 2013;14(4):227–234.
- Soong M, Earp BE, Bishop G, Leung A, Blazar P. Volar locking plate implant prominence and flexor tendon rupture. *J Bone Joint Surg Am.* 2011;93(4):328–335.
- Windisch G, Grechenig W, Peicha G, Tesch NP, Seibert FJ. Capsular attachment to the distal radius for extracapsular placement of pins. *Surg Radiol Anat.* 2001;23(5):313–316.
- Windisch G, Clement H, Tanzer K, et al. Promontory of radius: a new anatomical description on the distal radius. *Surg Radiol Anat.* 2007;29(8):629–633.
- Orbay JL, Touhami A. Current concepts in volar fixed-angle fixation of unstable distal radius fractures. *Clin Orthop Relat Res.* 2006;445:58–67.
- Gasse N, Lepage D, Pem R, et al. Anatomical and radiological study applied to distal radius surgery. *Surg Radiol Anat.* 2011;33(6):485–490.
- Pichler W, Clement H, Hausleitner L, Tanzer K, Tesch NP, Grechenig W. Various circular arc radii of the distal volar radius and the implications on volar plate osteosynthesis. *Orthopedics.* 2008;31(12).
- Imatani J, Akita K, Yamaguchi K, Shimizu H, Kondou H, Ozaki T. An anatomical study of the watershed line on the volar, distal aspect of the radius: implications for plate placement and avoidance of tendon ruptures. *J Hand Surg Am.* 2012;37(8):1550–1554.
- Imatani J, Akita K. Volar Distal radius anatomy applied to the treatment of distal radius fracture. *J Wrist Surg.* 2017;6(3):174–177.
- Capo JT, Kinchelov T, Orillaza NS, Rossy W. Accuracy of fluoroscopy in closed reduction and percutaneous fixation of simulated Bennett's fracture. *J Hand Surg Am.* 2009;34(4):637–641.
- Kenney S, Schlechter J. Do fluoroscopic and radiographic images underestimate pin protrusion in paediatric supracondylar humerus and distal radius fractures? A synthetic bone model analysis. *J Child Orthop.* 2019;13(1):57–61.
- Halvachizadeh S, Berk T, Pieringer A, et al. Is the additional effort for an intraoperative CT scan justified for distal radius fracture fixations? A comparative clinical feasibility study. *J Clin Med.* 2020;9(7).
- Creighton JJ, Jensen CD, Kaplan FT. Intraobserver and interrater reliability of the Soong classification for distal radius volar locking plate placement. *Hand (N Y).* 2020;15(3):414–417.
- Lutsky KF, Jimenez M, Rivlin M, Matzon JL, Maltenfort M, Beredjikian PK. Reliability of the Soong classification for volar plate position. *J Hand Surg Am.* 2016;41(7):e199–e202.
- Yang Z, Mann FA, Gilula LA, Haerr C, Larsen CF. Scaphoiscapitate alignment: criterion to establish a neutral lateral view of the wrist. *Radiology.* 1997;205(3):865–869.
- Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics.* 1977;33(1):159–174.
- Bujang MA, Baharum N. Guidelines of the minimum sample size requirements for Cohen's Kappa. *Epidemiol Biostat Public Health.* 2017;14:e12267–e12271.
- Bohl DD, Lese AB, Patterson JT, Grauer JN, Dodds SD. Predicting radiographic changes at the first visit following operative repair of distal radius fractures. *J Hand Surg.* 2015;40(1):49–56.

21. Sharma V, Witney-Lagen C, Cullen S, et al. The role of early postoperative radiographs following distal radius fracture fixation with a volar locking plate: time for change? *J Hand Surg Asian Pac Vol*. 2019;24(4):435–439.
22. Weil NL, El Moumni M, Rubinstein SM, Krijnen P, Termaat MF, Schipper IB. Routine follow-up radiographs for distal radius fractures are seldom clinically substantiated. *Arch Orthop Trauma Surg*. 2017;137(9):1187–1191.
23. Selles CA, Reerds STH, Roukema G, van der Vlies KH, Cleffken BI, Schep NWL. Relationship between plate removal and Soong grading following surgery for fractured distal radius. *J Hand Surg Eur Vol*. 2018;43(2):137–141.
24. Gören Y, Sauerbier M, Arsalan-Werner A. Impact of Soong grading on flexor tendon ruptures following palmar plating for distal radial fractures. *J Hand Surg Eur Vol*. 2020;45(4):348–353.
25. Horst TA, Mooney JF, Hooker JA, Barfield WR, Glaser JA. Comparison of intraoperative c-arm fluoroscopy to postoperative radiographs in operative fracture fixation. *J Surg Orthop Adv*. 2015;24(3):180–183.
26. Lehmann CL, Nepple JJ, Baca G, Schoenecker PL, Clobis JC. Do Fluoroscopy and postoperative radiographs correlate for periacetabular osteotomy corrections? *Clin Orthop Relat Res*. 2012;470(12):3508–3514.
27. Holst DC, Levy DL, Angerame MR, Yang CC. Does the use of intraoperative fluoroscopy improve postoperative radiographic component positioning and implant size in total hip arthroplasty utilizing a direct anterior approach? *Arthroplast Today*. 2020;6(1):94–98.
28. Tanaka Y, Aoki M, Izumi T, Fujimiya M, Yamashita T, Imai T. Effect of distal radius volar plate position on contact pressure between the flexor pollicis longus tendon and the distal plate edge. *J Hand Surg Am*. 2011;36(11):1790–1797.
29. DeGeorge BRJ, Brogan DM, Shin AY. The relationship of volar plate position and flexor tendon rupture: should we question the validity of the Soong classification? *Plast Reconstr Surg*. 2020;146(3):581–588.
30. Snoddy MC, An TJ, Hooe BS, Kay HF, Lee DH, Pappas ND. Incidence and reasons for hardware removal following operative fixation of distal radius fractures. *J Hand Surg Am*. 2015;40(3):505–507.
31. Soong M, Blazar P, Earp B. Further analysis of Soong grade and flexor tendon complications. *J Hand Surg Am*. 2015;40(7):1505.
32. Sato K, Kikuchi Y, Mimata Y, Murakami K, Takahashi G, Doita M. Volar locking plates not touching the flexor pollicis longus tendon appear as prominences on radiographs: a cadaver study. *J Orthop Traumatol*. 2019;20(1):29.