Validity and Reliability of Image Intensifier Articular Step-off and Gap Measurements for Distal Radius Fractures Using a Cadaveric Model

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ABSTRACT

Objectives. The purpose of this study was to determine the accuracy and reproducibility of image intensifier (fluoroscopic) measurements of gap and step-off displacements on the articular surface of the distal radius using a standard cadaver osteotomy fracture model.

Methods. Fourteen orthopedic residents were randomly assigned using the fish bowl method to measure the gap and step-off displacements in cadaveric fluoroscopic images using a digital caliper. Each physician was randomly assigned the images where they examined the images twice and the average taken using a standard technique. The interobserver and intra-observer reliability were calculated using the intraclass correlation coefficient (ICC). Rank Sum test was used to evaluate the validity of measurements.

Results. The results of the study showed that there was no significant difference between the cadaveric and measured step-off and gap displacements. Intraclass correlation coefficient scores showed moderate (0.41) to perfect (1.0) agreement.

Conclusion. The study showed that fluoroscopy can aid in the interpretation of gap and step-off displacements in acute distal radius fractures.

Keywords: distal radius fracture, displacement, image intensifier, cadaveric model

INTRODUCTION

Distal radius fractures are the most common fractures of the upper extremity. Unlike extraarticular fractures, intraarticular distal radius fractures can result in post-traumatic arthritis, deformity, and decreased function.[1-3] Several studies have emphasized the relevance of anatomic reduction in intra-articular fracture treatment.[1-3] Displaced intra-articular fractures of the distal radius are often treated surgically in order to reduce the articular congruity and prevent complications. In the intra-operative setting, the decision on whether anatomic reduction of the intra-articular fracture was achieved was dependent on either intraoperative x-rays, fluoroscopy, or arthroscopy. The measurement of the step-off and gap of the articular surface of less than 2 mm were reported to have a more satisfactory outcome.[4] The use of fluoroscopy often aids the surgeon in restoring articular congruity without opening the wrist joint.

Few studies in the hand have reported the accuracy of using fluoroscopy in the assessment of reduction of intra-articular fractures. In 2009, Capo et al.[5] investigated the

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use of fluoroscopy, radiographs and direct visualization in a cadaveric study that assessed the articular gap, step-off and displacement after percutaneous fixation of simulated Bennett's fracture. They noted significant differences in the three measurements. This is in contrast to a similar cadaveric study by Greeven et al.[6] in 2012 in which their results showed that fluoroscopic evaluation of simulated Bennett's fracture provided an accurate measurement of intra-articular displacement and step-off. In one study,[7] fluoroscopy was used to assess the step-off and gap distances in the treatment of distal radius fractures using fragment specific fixation. The authors used arthroscopy to confirm the reduction of the articular fragments and concluded that fluoroscopy can provide accurate assessment of gap and step-off displacements in the management of intra-articular fractures of the distal radius using fragment specific fixation. In the management of articular distal radius fractures, less favorable outcomes were due to problems restoring and maintaining an anatomic reduction of the articular surface.[8] It is important that during reduction and fixation of intra-articular distal radius fractures that displacement and step-off are addressed to optimize outcomes.

The purpose of this study was to determine the validity and reliability of image intensifier measurements of step-off and gap displacement on the articular surface of the distal radius fracture using a standard cadaver osteotomy model.

MATERIALS AND METHODS

The model for distal radius fractures were six cadaveric distal radii from the Department of Anatomy of the University of the Philippines Manila for this study. For each distal radius, a Melone 3-part intra-articular osteotomy was created using an oscillating saw. The osteotomy cut proceeded 2 to 4 cm proximally to create a radial styloid and volar Barton fragments. Intra-articular step-off and gap displacements were established by manipulating the fragments and fixing it using 0.062-inch Kirschner wires, as seen in Figure 1. Careful measurements to the nearest 0.1 mm were made using a digital caliper (Tactix digital caliper). The cadaveric models were labelled using English alphabet and data were input in an Excel spreadsheet. For each cadaveric distal radius osteotomy, the gap and step-off displacements were measured.

Fourteen orthopedic residents of the Department of Orthopedics were selected to review the images through convenience sampling. They included 5 first-, 2 second-, 2 third- and 5 fourth-year residents. The participants were grouped as either Junior or Senior residents, based on their year level of training. First year and second year residents were grouped as Junior residents, and third year and fourth year residents were assigned as Senior residents. Informed consent was obtained by the principal investigator prior to the procedure from the participants.

Figure 1. Cadaveric model of distal radius with intra-articular fracture fixed with K-wires.

Figure 2. Image intensifier (fluoroscopic) picture of the distal radius cadaveric model with an object of known dimension for reference.

Table 1. Gap and Step-off Displacement (mm) in Cadaver Distal Radii

Cadaver Number	Gap	Step-off
1	3	3
2	2.5	2.3
3	2.2	1.6
4	1.1	1.5
5	3.2	3.2
6	1.2	1.6

Table 2. The Validity of the Measured Gap and Step-off Displacement

Group	Step-off		P-value#	Gap		P-value#
	Measured (Median, IQR*)	Cadaveric (Median, IQR)		Measured (Median, IQR)	Cadaveric (Median, IQR)	
Juniors	1.6, 2.7	1.6, 1.4	0.6	3.0, 2.0	2.2, 1.8	0.8
Seniors	1.95, 0.69	1.6, 0.10	0.8	2.3, 0.47	2.2, 1.1	0.9

*#Wilcoxon Signed-Ranked Test, significant at p < 0.05; *IQR-Interquartile Range*

Each resident was randomly assigned using fish bowl technique to measure the cadaveric fluoroscopic images using the same digital caliper used in the cadaveric models. Each resident measured the cadaveric gap and step-off twice and the average taken. The residents were not aware of the actual measurements for the gap and step-offs. Measurements to the nearest hundredth of a millimeter were recorded. Standard magnification was achieved by placing the image intensifier 40 centimeters from the specimen and confirmed using an object with a known dimension, as seen in Figure 2.

Data Collection and Statistical Analysis

Data were imported from MS Excel into STATA 14.1 SE (Statacorp, College Station, Texas, USA) and were thoroughly checked for completeness, accuracy, and consistency prior to analysis. Continuous variables were summarized using medians and interquartile range, and were compared using Wilcoxon signed-rank test. The agreement between resident measurement of gap and step-off with that of the actual cadaveric gap and step-off were assessed using Cohen's Kappa Statistic. A p-value of less than 0.05 was considered statistically significant for all tests. The statistical values were interpreted using the criteria for the interpretation of κ and ICC agreement statistic scores published by Landis and Koch.[9] According to their article, statistic values of .00 to .20 represent slight agreement, .21 to .40 represent fair agreement, .41 to .60 represent moderate agreement, .61 to .80 represent substantial agreement, and greater than .81 represent almost perfect agreement.

The accuracy of observers in recognizing the step-off and gap displacements were described by recognizing a step-off or gap displacement of less than or equal to 2 mm versus greater than 2 mm.

Ethical Consideration

This study utilized cadaveric models of distal radius. The cadaveric models were coded using English alphabet to ensure anonymity of the specimen, in accordance to the Data Privacy Act. After conducting the study, the cadaveric models were disposed by the staff of the Department of Anatomy, in accordance to proper and safe disposal of cadavers.

This study was approved by the Institutional Research Ethics Board. Participant information were kept anonymous and confidential, in accordance to the National Ethical Guidelines for Health and Health-Related Research of 2017. Data were recorded in an Excel spreadsheet, that was password protected and only accessible to the principal and supervising investigators.

The goal of this study was to determine the accuracy of the measurements of gap and step-off displacements from a distal radius fracture osteotomy model obtained from the image intensifier compared to actual measurements using a precision caliper. No foreseeable risk was involved and there was no conflict of interest in any form.

RESULTS

Table 1 presented the amount of gap and step-off created and measured on the cadaveric models. To ensure that no further displacements had occurred during the handling process, the gap and step-off were remeasured.

Table 2 compared and analyzed the measurements obtained by the participants under fluoroscopy with direct measurements from the cadavers. Wilcoxon signed-rank test showed that there was no statistical difference between the measured gap and step-off in cadaveric models as compared to the measurements obtained by the participants (P>0.05).

In Table 3, the interobserver reliability of gap and step-off measurements among the junior and senior residents were in agreement and the range of the Cohen Kappa statistic

Table 3. Agreement on Gap and Step-off Displacement

Group	Gap			Cohen's Kappa Statistic
	Cadaveric	Measured		
		<2 mm	>2 mm	
Juniors	<2 mm	2	1	0.70 Substantial Agreement
	>2 mm	0	4	
Seniors	<2 mm	2	0	1.00 Perfect Agreement
	>2 mm	0	5	
Group	**Step-off**			**Cohen's Kappa Statistic**
	Cadaveric	**Measured**		
		<2 mm	**>2 mm**	
Juniors	<2 mm	3	1	0.41 Moderate Agreement
	>2 mm	1	2	
Seniors	<2 mm	4	2	0.43 Moderate Agreement
	>2 mm	1	0	

ranged from 0.41 to 1.0. The results also showed that a measurement of error of >1mm was present in three cases each for the gap and step-off displacement measurement. In the gap displacement, two were in the junior group and only one in the senior group. For the step-off displacement, all three were in the junior group.

DISCUSSION

The results of the study showed that substantial agreement was achieved in the evaluation of a distal radius fracture osteotomy model between actual measurements and fluoroscopy in the assessment of gap and step-off displacements. This affirms the usefulness of fluoroscopy in the intra-operative evaluation of fracture reduction in distal radius fractures. In the clinical setting, attempts to improve articular reduction were done by comparing arthroscopic evaluation and reduction with fluoroscopy in distal radius fracture management. Arthroscopic reduction provided the advantage of minimally invasive assessment of reduction, as opposed to arthrotomy, and direct visualization of the intra-articular displacement. This served as the gold standard for direct visualization of the articular displacement of the fracture. However, not all centers have the equipment nor the expertise to perform such arthroscopic procedures. Studies comparing fluoroscopic evaluation of distal radius fractures to fluoroscopy and arthroscopic evaluation showed that the addition of arthroscopy showed better supination, and wrist flexion and extension, but the functional scores remained the same.[10,11]

In a recent systematic review by Aguirre et al.,[12] a total of 463 patients were evaluated. Comparing arthroscopic and fluoroscopic reduction of intra-articular distal radius fractures, they found that the literature provided no clear advantage of one over the other and that the results were inconclusive. Other authors attempted to investigate the accuracy of radiography and direct measurement in a cadaveric fracture model. Kreder et al.[13] in 1996 evaluated 16 raters who assessed six x-ray films of healed distal radius fractures. They noted that two randomly chosen clinicians measuring step and gap deformity on a random x-ray film will differ by more than 3 mm at least 10% of the time. Moreover, repeat step or gap measurements by the same observer were expected to differ by more than 2 mm at least 10% of the time. They stated that some parameters (such as step-off and gap) were more readily quantified in the acute situation, since fracture lines have not been obscured by the healing process. Furthermore, a reference measurement using a cadaveric model was not used in this study. In another study,[14] the reliability of plain radiography versus computed tomography (CT) for the measurement of small (<5 mm) intra-articular displacements of distal radius fracture fragments were evaluated and compared them with CT scan results. They found out that thirty percent of measurements from plain radiographs significantly underestimated or overestimated displacement compared to CT scan measurements. They concluded that CT scanning data were more reliable for quantifying articular surface incongruities of the distal radius than were plain radiography measurements. Unfortunately, a reference measurement using a cadaveric model was not used in this study as well.

McCallister et al.[15] performed a cadaveric evaluation of accuracy and reproducibility of plain radiograph step-off and gap measurement for distal radius fracture. They reported that observers, independent of skill level, may measure step-off and gap displacements accurately to within 0.62 ± 0.53 mm. They noted that the accuracy of measurement was influenced by the quality of the radiograph. Intraclass correlation coefficient scores showed "substantial" (0.78) to "almost perfect" (0.81) inter- and intra-observer agreement. However, an image intensifier was not used in this study.

Among the limitations of the study was the interpretation of the displacement by the evaluators. In the clinical setting, the use of a ruler will probably the most common method instead of using a caliper. Also, changes in the distance between the wrist and the beam source may vary, thus may result in not so accurate assessment of gap and step-off displacement.

CONCLUSION

The results of the study showed that measurements obtained from fluoroscopy were accurate when compared to cadaveric models simulated distal radius fracture osteotomy models. Furthermore, there were better results obtained in gap measurement, which showed substantial to perfect agreement among the participants.

Statement of Authorship

EPE contributed in the conceptualization of work, revising of manuscript, and final approval of the version to be published; EJBW contributed in the conceptualization of work, acquisition and analysis of data, drafting and revising of manuscript, and final approval of the version to be published.

Author Disclosure

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