ORIGINAL ARTICLE

Computed Tomography vs Standard Radiograph in Preoperative Planning of Distal Radius Fractures with Articular Involvement

Matheus L Azi[1], Marcelo B Teixeira[2], Suedson F de Carvalho[3], Armando A de Almeida Teixeira[4], Ricardo B Cotias[5]

Abstract

Introduction: Distal radius fractures with articular involvement are more likely to require surgical management. Treatment decisions are based on parameters which are obtained from plain radiographs. This study aims to determine the differences between computed tomography and standard radiographs in the preoperative planning of distal radius fractures with articular involvement. This was performed by measuring the intraobserver and interobserver reliability between three systems used to interpret the main fracture characteristics and two treatment decisions.

Materials and methods: Forty-three cases of distal radius fractures with articular involvement were included. Fracture displacement was measured using plain radiographic and computed tomography. Five orthopedic surgeons evaluate the images to determine the AO/OTA classification, the articular fragments, the biomechanical columns involved, and recommend a surgical approach and implant for fracture fixation.

Results: An articular step-off was identified in 13 cases (30%) with the standard radiographs and in 22 (51%) cases with the computed tomography ($p = 0.00$). Interobserver variation for preoperative planning was slight when evaluated using the standard radiographs. Computed tomography improves reliability for AO/OTA classification and articular fragments but not for the biomechanical columns. Intraobserver variation for preoperative planning was slight to moderate for AO/OTA classification and slight to fair for identification of articular fragments and biomechanical columns. With regard to selection of the surgical approach, there was slight to moderate variation and, finally, for fracture fixation it was slight to fair.

Conclusion: Information provided by conventional radiography and computed tomography are sufficiently different as to induce the surgeon to select different treatments for the same fracture.

Keywords: Distal radius fracture, Fracture fixation, Intra-articular fractures, Radiography, Tomography, X-ray computed.

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Introduction

Distal radius fractures are frequent in adults, especially in the elderly.[1–3] Although less common, distal radius fractures with articular involvement are more likely to require surgical treatment.[3–5]

Treatment decisions have been based on well-established parameters which are from plain radiographs.[6,7] Computed tomography permits reconstruction of images in two or three planes allowing better visualization of the fracture characteristics. Thus, several authors have questioned whether computed tomography could contribute in treatment selection.[8–11]

The objective of this study was to determine the differences between bi-dimensional computed tomography and standard radiographs in the preoperative planning of surgical treatment of distal radius fractures with articular involvement. This was performed by measuring the intraobserver and interobserver reliability between three systems that were used to determine the main fracture characteristics (AO/OTA fracture and dislocation classification system, key articular fragments and biomechanical columns) and two treatment decisions (surgical approach and implant selection).

Materials and Methods

With the approval of the Research Ethics Committee, the medical records of the patients with fractures of the distal radius admitted between June 2011 and August 2012 were reviewed retrospectively.

[1]Department of Orthopaedic Trauma, Manoel Victorino Hospital, Salvador, Bahia, Brazil

[2–5]Department of Orthopaedic Trauma, Suburbio Hospital, Secretary of Health for the State of Bahia, Salvador, Bahia, Brazil

Corresponding Author: Matheus L Azi, Department of Orthopaedic Trauma, Manoel Victorino Hospital, Salvador, Bahia, Brazil, Phone: +55 71 988701708, e-mail: mlazi@hotmail.com

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Inclusion criteria were: adult patients (closed distal radius growth plate) sustaining a distal radius fracture with articular involvement who had plain radiographs on admission in the posteroanterior and lateral projections, followed by computed tomography. Cases were excluded when manipulation combined with the application of a cast was done before computed tomography or when images were taken with the wrist improperly positioned or had not been performed.

Fracture Characteristics

To confirm the articular involvement of the distal radius and measure fracture displacement, two of the authors (MB and SF) performed an unblinded assessment of the images using the software Carestream® (Carestream Health, Rochester, EUA). In the posteroanterior radiographic projection and the coronal slice of the computed tomography the radial inclination, radial height, ulnar variance and the articular step-off were measured.[12] In the lateral radiographic projection and the sagittal slice of the computed tomography, the palmar inclination of the radius and the articular step-off were measured.[12] Articular step-off was measured using the longitudinal axis technique.[13] From the 53 original cases, ten were excluded due to inadequate images or to a lack of articular involvement resulting in a total of 43 cases included in the study.

Preoperative Planning

To determine the differences between bi-dimensional computed tomography and standard radiographs in the preoperative planning the images were submitted to a blind assessment by five orthopedic trauma surgeons (2 with less than 5 years of practice and 3 with more than 10 years of practice) who had not been involved in the previous steps of the study.

The radiographic images were presented using Microsoft PowerPoint® (Microsoft, Redmond, EUA) software in a random sequence and without case identification. 1 month later computed tomography sections in coronal, sagittal and axial views were presented dynamically through the Carestream® software. Once again, a random sequence was used and without case identification. Evaluators were not allowed to manipulate images on their own nor have the ability to generate three-dimensional reconstructions.

At the beginning of each evaluation, the assessors were informed that the cases were to be treated surgically. For each set of images, a paper proforma with the following parameters needed completing: AO/OTA fracture and dislocation classification system,[14] key articular fragments,[15] biomechanical columns involved,[16] surgical approach and implant of choice for fracture stabilization (Table 1). A brochure with images and a description of the parameters under analysis was provided to each evaluator during the review. The fracture fixation methods referred to were either dorsal, radial or palmar positions of the plate in the distal radius. The assessors were not required to describe the technique used (buttress plate, double buttress technique or internal fixator principle) or the implant characteristics (conventional or locking plate). For fracture fixation with external fixators and Kirschner wires, the assessors described their preferred techniques with those devices.

Data Analysis

Data were analyzed using the statistical software Stata® version 13 (Stata Corporation, College Station, USA). Normal distribution of data were tested with the Shapiro–Wilk test. Continuous variables were then compared using the *t* test or the Wilcoxon–Mann–Whitney test. Categorical variables were compared using the Chi-square test. The level of significance was set at $\alpha = 0.05$. Interobserver reliability and intraobserver reliability were assessed with the kappa test with a 95% confidence interval. The kappa test measure agreement is a scale of 0 (agreement expected by chance) to 1 (perfect agreement). Intermediate values represent the range between random and perfect agreement. These were interpreted as suggested by Landis and Koch (values between 0.0 and 0.2 represent slight agreement, 0.21 and 0.40 fair, 0.41 and 0.60 moderate, 0.61 and 0.80 substantial and from 0.81 to 1 an almost perfect agreement).[17]

Results

Fracture Characteristics

The measures diverged significantly between the methods for the radial height, ulnar variance and articular step-off (Table 2). An articular step-off was identified in 13 cases (30%) with the standard radiographs and in 22 (51%) cases with the computed tomography ($p = 0.00$, Chi-square test). Average step-off in those cases was of −2.5 mm (range: −4 to −1) for plain radiograph and −3.6 mm (range: −11 to −1) for computed tomography ($p = 0.05$, Wilcoxon–Mann–Whitney test).

Interobserver Reliability

Interobserver reliability was slight when using the AO/OTA classification ($\kappa = 0.11$), key articular fragments ($\kappa = 0.00$), and biomechanical columns involved ($\kappa = 0.13$) were evaluated in the standard radiographs. Computed tomography improves this reliability to fair: in the AO/OTA classification ($\kappa = 0.28$) and articular fragments identification ($\kappa = 0.28$); but reliability remains slight for biomechanical columns involved ($\kappa = 0.17$).

Intraobserver Reliability

This was slight to moderate using the AO/OTA classification. It was slight to fair for identification of key fracture fragments and biomechanical columns. When deciding on the approach selection, intraobserver reliability was slight to moderate and, finally, for fracture fixation it was slight to fair (Table 3). Figure 1 depicts results of the AO/OTA classification and the implant selection. Figure 2 shows a case where the use of the computed tomography changed the fracture evaluation completely.

Discussion

Most of the criteria used to support decisions in the treatment of distal radius fractures were developed from studies using

Table 1: Parameters used in preoperative planning evaluation

AO class	*Articular fragments*	*Columns*	*Surgical approach*	*Implants*
23A1	Radial styloid (R)	Radial column (R)	Dorsal	Dorsal plate (D)
23A2	Palmarulnar (PU)	Intermediate column (I)	Palmar	Palmar plate (P)
23A3	Dorsoulnar (DU)	Ulnar column (U)	Dorsal + palmar	Radial plate (R)
23B1	Combined (R) + (PU)	Combined: (R) + (I)	Percutaneous	External fixator (EF)
23B2	Combined (R) + (DU)	Combined: (R) + (U)	Other	Kirschner wires (K)
23B3	Combined (PU) + (DU)	Combined: (I) + (U)		Combined (D) + (P)
23C1	Combined (R) + (PU) + (DU)	Combined: (R) + (I) + (U)		Combined (D) + (R)
23C2	Unable to define	Unable to define		Combined (EF) + (K)
23C3				Other

AO class, AO\OTA classification

Table 2: Measures of fracture displacement

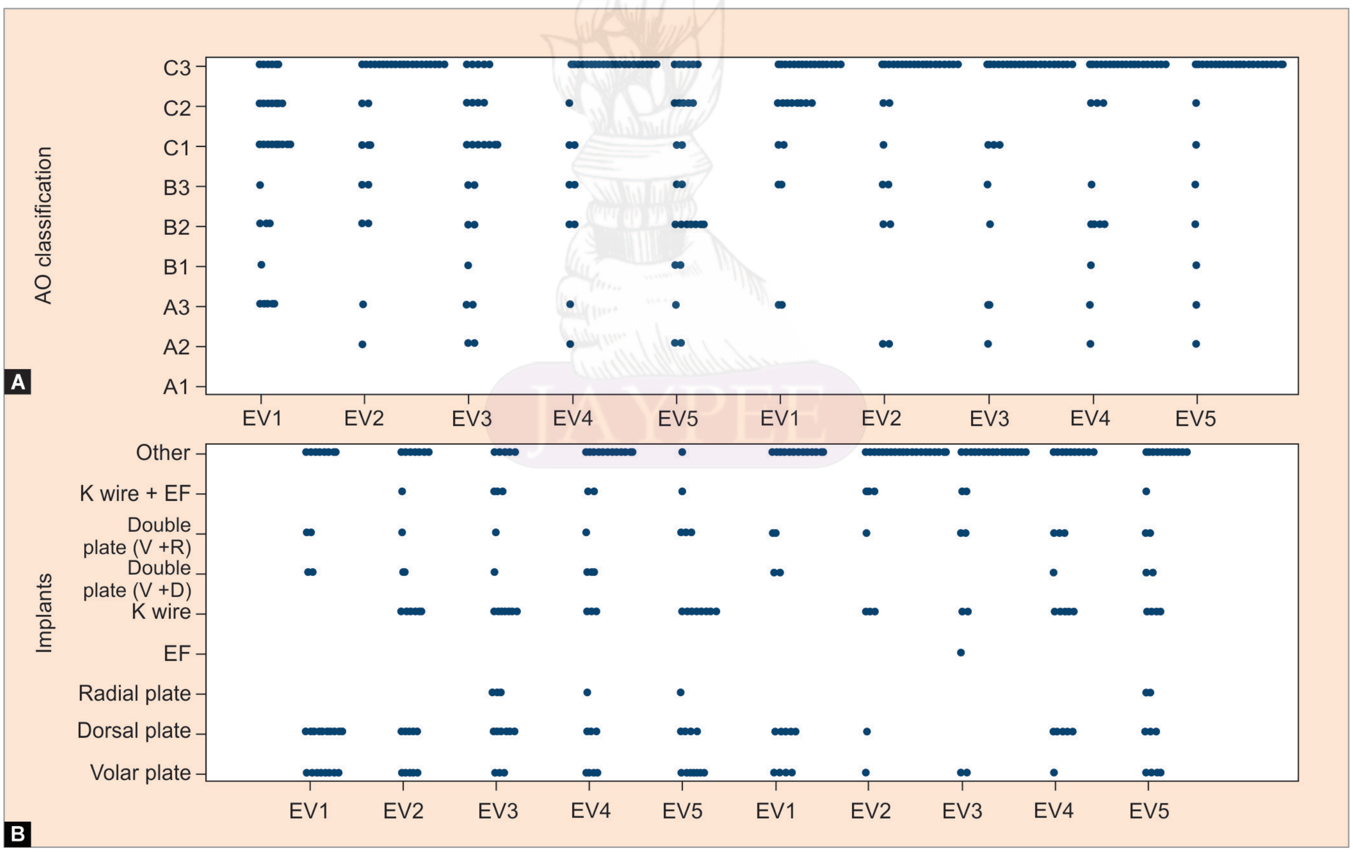
		Radiograph		*Computed tomography*		
	Projection	*Mean*	*SD (range)*	*Mean*	*SD (range)*	*p*$^{+}$
Radial inclination (°)	PA/coronal	14.9	9.1 (−20 to 33)	11.7	10.5 (−16 to 25)	0.14
Radial height (mm)	PA/coronal	7.6	4.2 (−7 to 18)	5.8	4.4 (−6 to 12)	0.03
Ulnar variance (mm)	PA/coronal	1.8	4.7 (−11 to 16)	−0.3	5.0 (−22 to 9)	0.05
Step-off* (mm)	PA/coronal	−0.3	1.0 (−4 to 0)	−1.4	2.1 (−11 to 0)	0.00
Palmar inclination (°)	Lateral/sagittal	−12.1	16.4 (−39 to 31)	−11.9	15.0 (−44 to 45)	0.71
Step-off* (mm)	Lateral/sagittal	−0.5	1.0 (−3 to 0)	−1.8	2.3 (−8 to 0)	0.00

*Step-off values consider all cases included even the ones without articular depression; PA, posteroanterior; SD, standard deviation;
$^{+}$Wilcoxon–Mann–Whitney test

Table 3: Intraobserver reliability (plain radiography vs computed tomography) for fracture characteristics and surgical plan

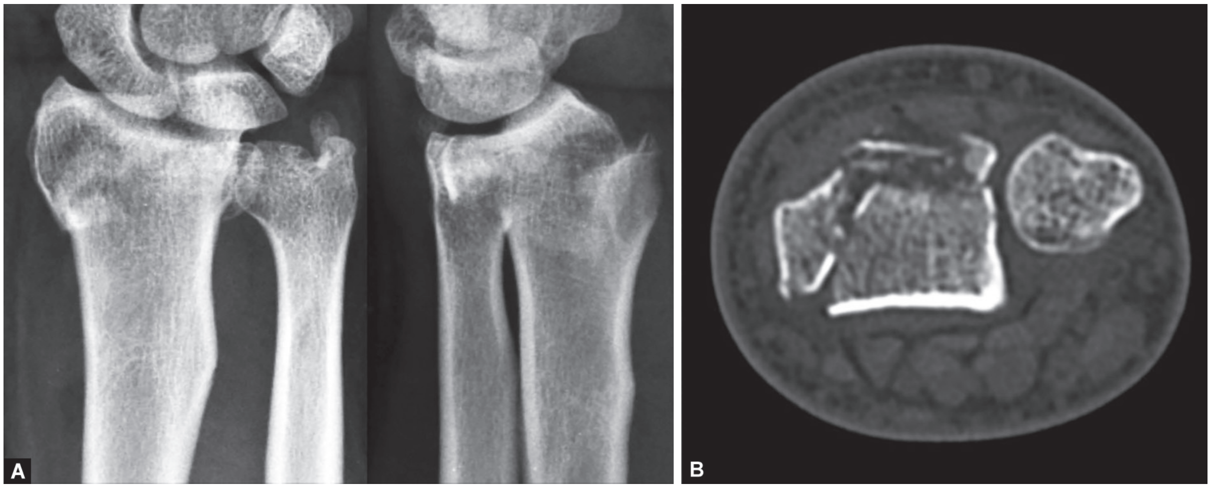
	AO/OTA class		*Fragments*		*Columns*		*Approach*		*Implants*	
	κ	*(95% CI)*	κ	*(95% CI)*	κ	*(95% CI)*	κ	*(95% CI)*	κ	*(95% CI)*
Ev1	0.11	(0.05–0.18)	0.35	(0.25–0.47)	0.23	(0.14–0.27)	0.45	(0.17–0.55)	0.37	(0.27–0.46)
Ev2	0.42	(0.27–0.57)	0.28	(0.07–0.39)	0.14	(−0.01 to 0.30)	0.08	(0.00–0.18)	0.08	(−0.06 to 0.18)
Ev3	0.18	(0.00–0.31)	0.11	(−0.05 to 0.14)	0.09	(−0.16 to 0.21)	0.38	(0.28–0.49)	0.21	(0.03–0.25)
Ev4	0.23	(0.05–0.37)	0.18	(0.08–0.26)	0.27	(0.20–0.31)	0.22	(0.17–0.25)	0.16	(0.11–0.26)
Ev5	0.14	(0.02–0.31)	0.15	(0.07–0.28)	0.14	(0.03–0.26)	0.05	(−0.08 to 0.09)	0.01	(−0.02 to 0.03)

Ev, evaluator



Figs 1A and B: Graphic representation of the evaluation of: (A) AO classification; (B) implant selection.
Ev, evaluator; K wire, Kirschner wire; EF, external fixator; V, volar; R, radial; D, dorsal

conventional radiography. The same is true for classification systems.[6,13–15,18,19] Difficulties in the interpretation of radiographs are partly related to the evaluation of a three-dimensional structure through two-plane images.[20] Additionally, variations in the alignment of fracture plane and radiographic projection could produce distinctly different images.[20]



Figs 2A and B: Distal radius fracture with articular involvement; (A) Radiography, four of the evaluators rated the fracture as extra articular (AO type I); (B) Computed tomography (axial slice) shows the articular involvement and as a result all the evaluators rated the fracture as complete articular (AO type III)

An articular step-off greater than 2 mm is considered indicative of surgical treatment in distal radius fractures.[7] However, previous studies have contested the ability to determine such displacement using plain radiographs. Cole et al.[13] demonstrated that plain radiographs failed to detect displacements greater than 2 mm in 24% of the cases while overestimating this in 6%. Katz et al.[8] also reported that articular displacement measured on computed tomography was greater than on plain radiographs. In the present study, the fracture displacement was measured before the intraobserver and interobserver reliability evaluation. A measurable articular step-off was identified in only 30% of the cases with the standard radiographs but in 51% of the cases using computed tomography. Contrary to this, radial inclination, radial height, ulnar variance and the palmar inclination were greater when measured in the standard radiographs. Suojärvi et al.[21] described similar results with higher values in the measurement of anatomic parameters of the distal radius when performed by conventional radiography as compared to cone beam computed tomography.

Recommendations for surgical treatment for distal radius fractures have increased.[2,22] New concepts and implants are now available like the fragment-specific fixation techniques with the locking plate concept expanding surgical treatment options.[22,23] A proper understanding of the fracture and its displacement is essential in the surgical planning. Correct fragment identification is critical to guide the approach and implant selection for fracture fixation.[22–24] The AO/OTA classification, the key articular fragments concept or the biomechanical columns concept are systems currently in use to characterize the fracture and support treatment decisions.

The interobserver reliability of distal radius fracture classifications is questionable, but it is better when evaluated in conventional radiography than in the computed tomography alone.[25] The inclusion of the group and subgroup components of the AO/OTA classification reduces the interobserver and intraobserver reliability of the system.[26] Additionally, the use of the computed tomography does not increase the reliability of this classification.[27] Traction radiographs improved interobserver reliability regarding the number of fracture fragments[28] but no change was observed in the agreement about articular involvement.[28] Despite this, the interobserver reliability of traction radiographs and computed tomography images for specific fracture fragment identification can vary from fair to poor.[29] In our study, the intraobserver reliability for fracture characterization systems (AO/OTA classification, articular fragments, and biomechanical columns) was improved with computed tomography, but it remains poor to moderate.

The use of traction radiographs alters surgeons' decisions between nonoperative and surgical treatment[28,29] but no change was observed in the selection of surgical approach.[28] Avery et al.[29] compared combinations of incidences under traction with computed tomography in 17 cases of distal radius fractures with articular involvement. Operative treatment was recommended for 90.4% of the cases (open reduction and internal fixation for 75.4%) based on traction images and in 93.6% of the cases (open reduction and internal fixation for 72.2%) based on computed tomography. When both imaging modalities were used concomitantly, open reduction and internal fixation was recommended in only 61% of the cases.[29]

Katz et al.[8] assessed the impact of computed tomography images in 15 distal radius fractures with articular extension. The treatment plan was converted from closed surgical to open surgical procedures in 62% to 92% of the cases.[8] They concluded that additional information from the CT appeared to influence the management of distal radius fractures.[8] Harness et al.[10] assessed the influence of three-dimensional computed tomography in 30 cases of distal radius fractures with articular involvement. Computed tomography increased reproducibility and accuracy in the characterization of the fractures. As a result, the treatment plan was altered in 48% of the cases with an increase in recommendations for surgical treatment.[10] Kleinlugtenbelt et al.[11] found that experienced surgeons can predict the usefulness of the computed tomography for the treatment of the intra-articular distal radius fractures. However, for preoperative planning, the usefulness of the computed tomography is much harder to predict.[11] das GraçasNascimento et al.[30] also showed the relationship between surgeon experience and the need for a computed tomography. They found that computed tomography had minimal impact on the selection of treatment recommended by specialists and hand surgery residents but it was more useful for those less experienced in hand surgery.[30]

In the present study a considerable number of cases had a nondisplaced articular fracture. This is relevant to the treatment decision because a nondisplaced articular fracture may be suitable for nonoperative treatment or less invasive surgical techniques. However, other factors like metaphyseal comminution and ulnar variance should be considered as well.[6] Intraobserver reliability over surgical treatment planning (approach and implant selection) was very low. The large number of factors included in the analysis had probably decreased the interrater and intrarater reliability but this study tried to simulate the situation that surgeons have to face in clinical practice. Our findings suggest that the diagnostic methods evaluated in this study influenced the surgeons' interpretation of the fracture and their resulting treatment choice.

Limitations of this study include its retrospective design and a limited sample size. The evaluators had limited contact with the images and were unaware of the clinical conditions of the patients. Many treatments are in use for distal radius fractures with different implants. Additionally, the surgeon's preference plays an important role in treatment selection. The low reliability of the systems for fracture characterization remains a barrier to implementing surgical treatment algorithms. Future studies comparing preoperative planning with the intraoperative findings could assist in the definition of which image modality is more useful to assist surgical treatment.

In conclusion, the intraobserver reliability was low for preoperative planning performed with the standard radiograph when compared to computed tomography. Information provided by conventional radiography and computed tomography are so distinct that surgeons frequently select different treatments techniques for the same fracture.

Compliance with Ethical Standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or National Research Committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study formal consent is not required.

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