HAND
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Computed tomography's influence on the classifications and treatment of the distal radius fractures

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Abstract
Introduction Distal radius fractures are common in emergency centers. The radiographic routine includes at least two radiographic projections used for diagnosing most of these fractures. Computed tomography (CT) is indicated for evaluating complex fractures that affect the articular surface, as well as the fragments' size and position. There are not enough comparative studies on choosing classification and treatment by means of the four radiographic projections and computed tomography (CT) and the association of these with the levels of expertise.
Methods We conducted a randomized cross-sectional study by observing images from 61 patients with distal radius fractures organized in two phases: the first phase comprising radiographic images alone and the second one with those same images associated with tomograms. Seventeen evaluators with different levels of training and expertise classified the fractures according to the AO and Universal classification systems and proposed treatment guidelines.
Results The agreement between the AO and Universal classification ratings was poor (worse for the former), with smaller Fleiss' kappa resulting from data obtained by orthopedics residents and non-specialist orthopedists. CT influenced the classification choice, with a higher change frequency for more complex patterns in the AO classification system and intra-articular and irreducible fractures in the Universal classification system, especially in the group comprised of orthopedic residents and orthopedic physicians. CT did not influence the treatment choice made by the group comprised of hand surgery residents and hand surgeons.
Conclusion The less experienced in hand surgery the observer was, the more important computed tomography was for determining the fracture pattern.

Evidence Level Level IV, case series

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Introduction

Distal radius fractures are common in emergency and urgent care centers, with an approximate incidence varying between 10 and 12 % of all fractures of the human skeleton, thus being the commonest fracture affecting the upper limb [1]. The characteristics of such lesions may vary from a cortical discontinuity without deviation, which results in no major deformities, to comminuted patterns and large deviations. Those involving articular dislocation and fragmentation constitute a complex challenge both for evaluation and treatment [18, 22]. For such cases, computed tomography (CT) stands out as a helpful tool for enhanced diagnostic elucidation, allowing for easier and reliable classification and thus leading to otherwise non-recommended treatments [21]. The importance of this diagnostic tool for evaluating distal radius fractures is under discussion in the literature [12, 14, 15]. There exist, however, few studies correlating CT usage with the institution where care is provided [4, 15]. There are only a few studies comparing residents, specialists in orthopedics, traumatology, and hand surgery in terms of classification of fractures and indications for treatment [3, 5, 7, 13]. Only one of them used CT scans.

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The authors aim to evaluate the intraobserver agreement in the AO and Universal ratings and in the treatment of distal radius fractures after the inclusion of CT. Furthermore, they also seek to establish the group of specialties that benefited the most from the inclusion of CT regarding the AO and Universal ratings and treatment of those fractures.

Methods

This is a cross-sectional study involving the analysis of images from patients with distal radius fractures hospitalized at the Orthopedic Service in the period between June and November 2012. Included were patients above 18 years of age with distal radius fractures, irrespective of gender, race, or laterality, and who, at the time of hospital admission, had their radiographic images taken in the four projections (posteroanterior—PA; profile—P; 45° semi-pronated oblique—PO; 45° semi-supinated oblique—SO) and their sagittal, axial, and coronal CT scans obtained. Patients who were skeletally immature or had inappropriate or insufficient images were excluded. Soft tissue injuries, associated fractures, and bone quality were not considered. Only images with ideal conditions and availability were used, regardless of their relevance to social, financial, or regional issues.

By applying the aforementioned criteria, 83 patients were admitted to hospital and 22 were excluded. Each patient was identified following the order they were admitted to hospital, from 1 to 61. Their radiographic images and tomograms were selected and arranged by the author with the aid of a slide show model (Microsoft Office Power Point 2007®).

Seventeen evaluators participated in the study: four hand surgery residents; four orthopedics and traumatology residents in their final year of residency; six medical specialists in hand surgery; and three orthopedists.

The study comprised of two phases: the first one involving only the four radiographic images (PA, P, PO, and SO), totaling 61 groups, arranged in a randomized sequence (obtained through the website www.randomizer.org). After four weeks and following another randomized sequence, the evaluators were given the very same radiographic images now accompanied by two selected tomograms corresponding to each cross-section (sagittal, coronal, and axial—two-millimeter cross-sections), considered by the author as being the most representative ones for the lesions involved.

In each phase, the examiners filled in a table numbered from 1 to 61 with the AO and Universal classification ratings, as well as with information regarding treatment and access route for each case individually. Regarding therapy choices, nine options were suggested: conservative treatment, not involving surgery or plastering; closed reduction and internal fixation with Kirschner's wires; open reduction and internal fixation with locking volar plate; closed reduction and external fixation with dynamic external fixator; closed reduction and external fixation with static external fixator; open reduction and internal fixation with supporting volar plate; closed reduction and percutaneous fixation with screws; open reduction and internal fixation with orthogonal dorsal plates; and other and/or combined methods. The suggested access routes, whose details were filled in the form only in case of surgical treatment, were the following ones: volar, double, dorsal, percutaneous, or others.

Prior to each phase, examiners were instructed about the guidelines of the AO and Universal classification systems, with an emphasis on their highlights, as well as about how to complete the form.

Each participant was given a schematic drawing containing the guidelines of both classification systems for reference. No minimum or maximum amount of time was stipulated for applying the method. In order to avoid any misunderstanding- and gauging-related bias stemming from the weariness caused by the elevated number of cases, it was suggested that each examiner would finish the evaluations in 2 days (30 cases on the first day and the remainder of them the next day).

The data obtained were arranged in graphics, tables, and slides and then underwent analytical statistical analysis. Initially, complexity degrees were attributed to the classification, treatment, and access route options in order to assess whether or not CT usage promoted an increase or decrease in the severity of the lesions as compared to the initial choice—or whether it remained unchanged. Both classification and treatment were considered while describing the results obtained with the aid of radiographs alone or in association with tomograms and provided by each evaluator. In order to compare each evaluator's performance and assess whether there existed significant differences in the results obtained in both situations, the paired Wilcoxon test was employed.

Fleiss' kappa agreement coefficients were calculated for assessing the level of intraobserver agreement between the first and second evaluations—the latter relying also on the added tomograms.

The changes observed for each phase were described according to the evaluators' specialty and training level; the chi-square test was used to verify their association. We adopted a 5 % significance level (p=0.05).

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 [5]. Informed consent was obtained from all patients for being included in the study. The authors declare that they have no conflict of interest.

Results

Table 1 summarizes Fleiss' kappa coefficient results for each evaluator across specialty groups. Evaluators 1–4 are orthopedic residents; 5–8, hand surgery residents; 9–14, hand surgeons; and 15–17, orthopedists.

We observed a statistically significant difference ($p<0.05$) in the AO classifications for all orthopedic residents after the tomograms were included, as denoted by the low Fleiss' kappa coefficient values, and agreement varying from poor to unsatisfactory, and for 75 % of them regarding the Universal classifications, with results varying from discordant to unsatisfactory. There was no statistical difference ($p>0.05$) in the treatment recommended by most evaluators after the tomographic assessment.

When evaluating hand surgery residents, their results were similar to the previous ones in relation to the AO classification, varying from unsatisfactory to moderate in 75 % of the evaluators. These showed no statistically significant difference ($p>0.05$) with regard to the Universal classification or treatment recommended after the inclusion of tomograms.

In the second phase, two-thirds of the hand surgeons changed their AO classification, with a statistically significant difference ($p<0.05$) and agreement varying from unsatisfactory to moderate. The same number of evaluators changed their Universal classification, with agreement. The majority of these specialists did not change the treatment with statistical significance ($p<0.05$).

Lastly, among orthopedic physicians, only one did not change his Universal classification. After checking the tomograms, all the others obtained significant ($p<0.05$) changes in their AO and Universal classification ratings, as well as in the recommended treatment, with agreement varying from poor to moderate.

The rate of increase in the complexity of classifications, procedures, and access routes was greater than that of reduction when tomograms were included in the assessments (Table 2). There was a statistically significant association between specialty levels and changes in all of the evaluated parameters ($p<0.05$). We also observed that orthopedic residents showed a greater rate of increase in the complexity of classifications, predominantly those in the AO system.

Table 1 Fleiss' kappa results after the inclusion of tomograms describing the agreement between individual assessments across specialties

Specialty	Evaluator	AO classification	Universal classification	Treatment	Route of access
Orthopedic residents	1	Unsatisfactory	Unsatisfactory	No statistically significant difference	No statistically significant difference
	2	Unsatisfactory	Unsatisfactory	Unsatisfactory	Discordant
	3	Poor	No statistically significant difference	Unsatisfactory	No statistically significant difference
	4	Unsatisfactory	Discordant	No statistically significant difference	No statistically significant difference
Hand surgery residents	5	Moderate	No statistically significant difference	No statistically significant difference	No statistically significant difference
	6	Unsatisfactory	No statistically significant difference	No statistically significant difference	No statistically significant difference
	7	No statistically significant difference	No statistically significant difference	No statistically significant difference	No statistically significant difference
	8	Unsatisfactory	Poor	Unsatisfactory	Unsatisfactory
Hand surgeons	9	No statistically significant difference	No statistically significant difference	No statistically significant difference	No statistically significant difference
	10	No statistically significant difference	Poor	No statistically significant difference	No statistically significant difference
	11	Moderate	Moderate	No statistically significant difference	No statistically significant difference
	12	Poor	Moderate	Poor	Unsatisfactory
	13	Unsatisfactory	Moderate	No statistically significant difference	No statistically significant difference
	14	Moderate	No statistically significant difference	Poor	Poor
Orthopedists	15	Poor	Poor	Moderate	Poor
	16	Poor	Poor	Poor	Poor
	17	Moderate	No statistically significant difference	Poor	Moderate

Table 2 Description of the changes in classification, procedure, and route of access according to the specialty level after the inclusion of tomograms and association of test results

Variable	Group								Total		*p*
	Resident				Hand surgery		General orthopedics				
	General orthopedics		Hand surgery								
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Universal											0.001
Decrease	42	17.2	36	14.8	55	15.0	18	9.8	151	14.6	
Unchanged	127	52.0	153	62.7	245	66.9	127	69.4	652	62.9	
Increase	75	30.7	55	22.5	86	18.0	38	20.8	234	22.6	
AO											<0.001
Decrease	28	11.5	40	16.4	48	13.1	21	11.5	137	13.2	
Unchanged	92	37.7	109	44.7	212	57.9	89	48.6	502	48.4	
Increase	124	50.8	95	38.9	106	29.0	73	39.9	398	38.4	
Surgical											0.020
Decrease	13	5.3	16	6.6	22	6.0	2	1.1	53	5.1	
Unchanged	191	78.3	200	82.0	305	83.3	148	80.9	844	81.4	
Increase	40	16.4	28	11.5	39	10.7	33	18.0	140	13.5	
Route of access											0.005
Decrease	16	6.6	17	7.0	22	6.0	3	1.6	58	5.8	
Unchanged	185	75.8	199	81.6	306	83.6	144	78.7	834	80.4	
Increase	43	17.6	28	11.5	38	10.4	36	19.7	145	14.0	
Total	244	100	244	100	366	100	183	100	1037	100	

Chi-square test results

Conversely, both hand surgery residents and hand surgeons showed lower frequencies of increase in the complexity of procedures.

Orthopedic residents changed their Universal and AO classifications (Table 1) in 30.7 and 50.8 % of the cases, respectively, to levels considered to be of greater severity after checking the tomograms associated with the radiographic images, whereas hand surgery residents changed their Universal and AO classifications to more complex fracture patterns in 22.5 and 38.9 % of the cases, respectively. Hand surgeons changed their Universal and AO classifications to more severe patterns in 18 and 29 % of the cases, respectively, whereas orthopedic physicians respectively changed their Universal and AO classifications in 20.8 and 39.9 % of the cases. With regard to therapeutic procedures, they were changed to more invasive ones in rates that varied between 10.7 and 18 % of the cases, with the highest ones observed in the group comprised of orthopedic residents and orthopedic physicians. Most of the surgeons changed from closed reduction and internal fixation with Kirschner's wires to open reduction and internal fixation with locking volar plate.

Discussion

The skillfulness in recognizing fracture traces in radiographs requires continuing education and training. The knowledge of some fracture patterns and negative socio-economic implications brought by procedures decided upon suboptimal images is of the utmost importance to orthopedists, as well as to the teaching and training of resident physicians. This is corroborated by the innumerable workers in labor dispute and even by the need for new corrective surgical procedures. Knowing how to classify and establish an appropriate therapeutic procedure requires continuing training and learning curve.

The use of computed tomography for evaluating wrist fractures is not recent. Studies demonstrate that coronal cross-section scans are superior to axial ones [9, 14], except for evaluating the distal radioulnar articulation and hamate hamulus [9].

In most studies reviewed, the authors use only two radiographic projections [16, 20] and, to a lesser extent, all four projections [2, 4, 15]. Few of them include CT in their methodology [4, 15]. Our study relied on the visualization of all four radiographic projections in the first phase already so as to contribute to a detailed assessment of the fractures by using low cost tests. In the second phase, the inclusion of tomograms allowed evaluators to compare the different tests, which is especially important when one considers that the degree of articular incongruity and comminution is frequently over- or underestimated during radiographic evaluation due to superimposition of multiple fragments [21]. The CT scans increase the distal radius fracture costs in 15 to 30 % in Brazil. Because of this, it should only be done when an experienced hand or orthopedic surgeon needs it to understand the articular comminution and the fragments' position.

The statistically significant changes occurred mainly in the classifications conducted by most evaluators: the use of CT contributed to higher severity classifications both when the AO and Universal classification systems were employed ($p<0.05$). Some evaluators presented statistically significant changes with regard to procedure and route of access after tomograms were included for assessment ($p<0.05$). The kappa coefficient varied between −1 and 1; the closer its value is to 1, the greater the agreement is in the range being evaluated. Values close to zero imply poor agreement, whereas negative values are related to greater discordance rather than agreement. Values may still be arbitrarily attributed to subdivisions: between 0.00 and 0.20, they indicate unsatisfactory agreement; between 0.21 and 0.40, poor agreement; between 0.41 and 0.60, moderate agreement; and between 0.61 and 0.80, satisfactory and adequate agreement. Values above 0.80 suggest perfect agreement (Fleiss, 1986). Almost all of the calculated agreements were inferior to 0.5 (kappa<0.5), sometimes approaching zero, thus corroborating the changes in classifications and treatment after tomograms were included.

In order for it to be considered useful, a classification system should be anatomically reproducible, easily understood and memorized, provides treatment guidelines, and predicts prognosis [17]. The AO classification system receives constant criticism due to the fact that it is highly complex, difficult to memorize, and associated with poor reproducibility and reliability. Altogether, 27 types are described, which lead orthopedists and specialists in the field to adopt but only nine—such procedure has also been followed by our group. The Universal classification system can be easily memorized, is deductive, and applicable to any fracture, yet there are few studies on its reproducibility. In our study, we observed poor to moderate agreement for the Universal classification system and poor agreement for the AO classification system after the inclusion of tomograms in the second phase, as shown by the low kappa coefficient values obtained—the same as described by several authors comparing the phases relying solely on radiographic images [2, 8, 11, 16, 20].

When we analyzed the change rate in the classifications, both suffered significant changes upon the inclusion of tomograms. However, the AO classification was the most affected across groups in the following descending order: orthopedic residents, orthopedic physicians, hand surgery residents, and hand surgeons. This fact led us to conclude that specialty and training level influenced the final results, enabling specialists and specialty residents to have greater confidence when evaluating fractures already in the first phase while relying on four radiographic images. Our study registered a statistically significant change in the AO classification conducted by all orthopedic residents and orthopedic physicians and by more than 50 % of hand surgeons and hand surgery residents (66.7 and 75 %, respectively), which corroborate aforementioned studies on the reproducibility of the AO classification system [8, 16, 20]. After tomograms were included, the classifications tended towards more complex fracture patterns, with a predominance of types AO 23-C2 and AO 23-C3, characterized by simple articular involvement in the former and multifragmented in the latter. With regard to the Universal classification, the results obtained were not uniform. Most of the orthopedic residents (75 %) changed their Universal classification as opposed to hand surgery residents, who practically did not change theirs (25 %). When considering orthopedic surgeons and hand surgeons, slightly more than half of them changed their Universal classification (66.7 % in both groups). The most commonly found modifications during the second phase were those concerning unstable intra-articular and irreducible intra-articular fractures.

We believe that computed tomography was more helpful to physicians undergoing training and who were not hand surgery specialists, as evidenced by the changes in classification during the second phase, especially regarding the AO classification in the group comprised of orthopedic residents. Similar results were described by Flikkilä et al. [11], who did not find any improvement in the reproducibility of the AO classification system after including CT in the evaluations. On the other hand, the greatest changes in our study were observed in the Universal classification conducted by the group of hand surgeons, with poor to moderate agreement.

The findings in the current study meet our initial expectations: increased classification change rates, to a greater extent in the AO classifications conducted by the group of orthopedic residents after tomogram visualization, with classifications tending towards patterns of greater complexity. This confirms that CT allows for a better understanding of fracture traces, dislocations, and articular involvement, thus offering greater reliability for assigning a given fracture to its corresponding classification group. Furthermore, the smaller change rates observed for the Universal classification system reaffirm its effortless applicability to any type of fracture.

The treatment of fractures of the distal end of the radius ranges from conservative approaches to complex surgical procedures, with a combination of synthesis materials and/or bone grafting. Despite the fact that the number of surgeries has increased exponentially with the emergence of new stability concepts and synthesis materials [19], it is still not clear when surgery will yield better results than the non-surgical treatment, or which surgical or conservative methods are best indicated for certain types of fractures [6, 10].

In the current study, we observed a change in the choice for treatment in all of the orthopedic surgeons and in 50 % of the orthopedic residents. When expertise was considered, there was a tendency to keep the initial choice, as shown in a study by Katz et al. [15], who verified satisfactory agreements in a group comprised of hand surgeons. For most of hand surgery residents and hand surgeons, CT did not alter the therapeutic procedure, as opposed to orthopedists, whose agreement varied from poor to moderate in the second phase after tomograms had been included. Similar studies also indicate changes in therapeutic procedures after CT is used.

We believe that these results can be attributed to greater enlightenment and diffusion of the stability and reducibility concepts associated with a stable synthesis and precocious mobility, which are constantly discussed among specialists and thus lead them to keep the initial procedures already decided upon the visualization of the four radiographic images in the first phase. Conversely, the group of non-specialists showed a tendency to migrate towards more aggressive procedures probably because they could now better interpret the fragments not previously visualized in the radiographs.

Our study revealed that the final treatment was little changed in the group of specialists and hand surgery residents. Nevertheless, the procedure change rates in the other groups were not too high in terms of absolute numbers (inferior to 20 %); yet, they were statistically significant. This fact also leads us to believe that continuing training and expertise influenced the determination and maintenance of previous procedures. We, thus, affirm that the CT can be considered as an adjuvant method, rather than a substitute, for radiographs in their four projections (Table 2). CT scans should be reserved to understand the articular fragmentation.

The strengths of our study were: (a) evaluators holding different levels of training and expertise, which aimed to verify whether these influenced the choice for classification and treatment—in practical terms, this could determine whether or not more sophisticated complementary tests are needed for elucidating some types of fracture; (b) high number of cases comprehending, if not all, most of the fracture patterns described; (c) inclusion of semi-supinated and semi-pronated oblique images, in association with the posteroanterior and profile ones—we believe that such projections aid in establishing diagnosis and therapeutic procedures already in the first evaluation, which may then reserve requests for CT for those cases considered dubious; (d) evaluation of only nine AO classification types, since we consider that all 27 possibilities are difficult to understand, memorize, and of little practical usefulness; and (e) association of tomograms to the radiographic images in the second phase aimed to contribute to the training of those who are less experienced.

Conclusions

The AO and Universal classifications showed low agreement after tomograms were included in all specialty groups, which was worse in the AO classification and in the group comprised of non-specialists in hand surgery.

Tomograms brought little change to the final treatment as recommended by specialists and hand surgery residents.

The less experienced in hand surgery the observer was, the more important computed tomography was for determining the fracture pattern.

Conflict of Interest The authors declare that they have no competing interests.

Statement of Human and Animal Rights All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Informed Consent Informed consent was obtained from all individual participants included in the study.

References

1. Alffram PA, Bauer GC. Epidemiology of fractures of the forearm. A biomechanical investigation of bone strength. J Bone Joint Surg. 1962;44A:105–14.
2. Andersen DJ, Blair WF, Stevers CM, Adams BD, El-Khouri GY, Brandser EA. Classification of distal radius fractures: an analysis of interobserver reliability and intraobserver reproducibility. J Hand Surg [Am]. 1996;21A:574–82.
3. Arealis G, Galanopoulos I, Nikolaou VS, Lacon A, Ashwood N, Kitsis C. Does the CT improve inter- and intra-observer agreement for the AO, Fernandez and Universal classification systems for distal radius fractures? Injury. 2014;45(10):1579–84.
4. Arora S, Grover SB, Batra S, Shama VK. Comparative evaluation of postreduction intra-articular distal radius fractures by radiographs and multidetector computed tomography. J Bone Joint Surg Am. 2010;92:2523–32.
5. Avery DM, Matullo KS. Distal radial traction radiographs: interobserver and intraobserver reliability compared with computed tomography. J Bone Joint Surg Am. 2014;96(7):582–8.
6. Bales JG, Stern PJ. Treatment strategies of distal radius fractures. Hand Clin. 2012;28(2):177–84.
7. Belloti JC, Santos JBG, Moraes VY, Wink FV, Tamaoki MJS, Faloppa F. The ideal classification system: a new method for classifying fractures of the distal extremity of the radius—description and reproducibility. Sao Paulo Med J. 2013;131(4):252–6.
8. Belloti JC, Tamaoki MJS, Franciozi CES, Dos Santos JBG, Balbachevsky D, Chap EC, et al. Are distal radius fracture classifications reproducible? Intra and interobserver agreement. Sao Paulo Med J. 2008;126(3):180–5.
9. Biondetti PR, Vannier MW, Gilula LA, et al. Wrist: coronal and transaxial CT scanning. Radiology. 1987;163:149–51.
10. Diaz-Garcia RJ, Chung KC. Common myths and evidence in the management of distal radius fractures. Hand Clin. 2012;28(2):127–33.

11. Flikkilä T, Nikkola-Sihto A, Kaarela O, Pääkkö E, Raatikaine T. Poor interobserver reliability of AO classification of fractures of the distal radius: additional computed tomography is of minor value. J Bone Joint Surg (Br). 1998;80B:670–2.
12. Harness NG, Ring D, Zurakowski D, Harris GJ, Jupiter JB. The influence of three-dimensional computed tomography reconstructions on the characterization and treatment of distal radial fractures. J Bone Joint Surg. 2006;88A:1315–23.
13. Jafari D, Taheri H, Shariatzadeh H, Mazhar FN, Nojomi M. The interobserver and intraobserver reliability of the Fernandez classification of distal radius fracture. Med J Islam Repub Iran. 2008;21(4):223–6.
14. Jonhston GHF, Freidman L, Kreigler JC. Computerized tomographic evaluation of acute distal radial fractures. J Hand Surg [Am]. 1992;17A:738–44.
15. Katz MA, Beredjiklian PK, Bozentka DJ, Steinberg DR. Computed tomography scanning of intra-articular distal radius fractures: does it influence treatment? J Hand Surg [Am]. 2001;26:415–21.
16. Küçuk L, Kumbaraci M, Günay H, Karapinar L, Özdemir O. Reliability and reproducibility of classifications for distal radius fractures. Acta Orthop Traumatol Turc. 2013;47(3):153–7.
17. Kural C, Sungur I, Kaya I, Ugras A, Ertürk A, Cetinus E. Evaluation of the reliability of classification systems used for distal radius fractures. Orthopedics. 2010;33:801.
18. Medoff RJ. Essential radiographic evaluation for distal radius fractures. Hand Clin. 2005;21:279–88.
19. Meier R, Krettek C, Probst C. Treatment of distal radius fractures. Percutaneous Kirschner-wires or palmar locking plates? Unfallchirurg. 2012;115(7):598–605.
20. Oliveira Filho OM, Belangero WD, Teles JBM. Distal radius fractures: consistency of the classifications. Rev Assoc Med Bras. 2004;50(1):55–61.
21. Pruitt DL, Gilula LA, Manske PR, Vannier MW. Computed tomography scanning with image reconstruction in evaluation of distal radius fractures. J Hand Surg [Am]. 1994;19(5):720–7.
22. Trumble TE, Culp RW, Hanel DP, Geissler WB, Berger RA. Intra-articular fractures of the distal aspect of the radius. Instr Course Lect. 1999;48:465–80.