EPiC Series in Health Sciences
Volume 5, 2022, Pages 166–169
Proceedings of The 20th Annual Meeting of the International Society for Computer Assisted Orthopaedic Surgery

Automatic method for computing radiographic parameters of radial metaphyseal fractures in radiographs for surgical decision support

Avigail Suna MSc[1], Amit Davidson[2] MD, Prof. Leo Joskowicz[1], Prof. Yoram Weil[2] MD.
[1] School of Computer Science and Engineering, The Hebrew University of Jerusalem, Israel.
2 Dept of Orthopedics, Hadassah University Medical Center, Jerusalem, Israel.

1 Purpose

Distal radius fractures (DRF) are common types of fractures with a high incident rate. Depending on fracture severity, DRF can be treated either by cast or surgery. To determine the clinical procedure and the operative management, standardized guidelines have become increasingly common [1]. As operative indications are controversial, radiographic parameters (RPs), e.g., radial inclination, dorsal tilt, and articular step-off, can provide objective support for effective decision making. Calculating the RPs manually from radiographs is time consuming and subject to observer variability and clinician experience.

Our aim was to develop an automatic method for accurately and reliably computing 10 RPs associated with DRF in anteroposterior (AP) and lateral radiographs with and without cast.

2 Methods

The inputs are the AP and lateral radiographs of the fractured hand with or without cast. The outputs are ten RPs values and composite images showing the landmark points and axes used in the RPs computation on the radiographs. Six RPs are computed in the AP radiographs: 1) Radial Angle (degrees); 2) Radial Length (mm); 3) Radial Shift (mm); 4) Ulnar Variance (mm); 5) Intra-Articular Gap (mm), and; 6) Intra-Articular Step (mm). Four RPs are computed in the lateral radiographs: 1) Palmar Tilt (degrees); 2) Dorsal Shift (mm), 3) Intra-Articular Gap (mm), and; 4) Intra-Articular Step (mm).

Our method comprises three main steps: 1) segmentation of the radius and the ulna with a deep learning radiograph pixel classifier model; 2) landmark points and axis extraction from the segmentations using geometric model-based methods; 3) RPs computation from the landmarks and generation of composite images. Fig. 1 illustrates the pipeline and its output.

F. Rodriguez Y Baena, J.W. Giles and E. Stindel (eds.), CAOS 2022 (EPiC Series in Health Sciences, vol. 5), pp. 166–169

The main challenge of the automatic RPs computation is the great variability of the radiographic images, which are acquired with different equipment and in various conditions. This affects the first step, bone contour segmentations, from which the landmark and axis are computed. To address this issue, we developed a pipeline consisting of five steps: a) hand bounding box detection in each radiograph; b) hand segmentation to establish an initial region of interest (ROI); c) image cropping and normalization in the ROI; d) ROI refinement from coarse radius segmentation; e) radius and ulna joint line segmentation. The hand bounding is computed with a deep Dynamic U-Net whose encoder is pretrained on ImageNet [2] and further trained on a dataset of 1,840 AP and lateral images -- 610 retrospectively obtained from the Hadassah University Medical Center, Jerusalem, Israel and 1,230 from the MURA dataset [3].

The landmarks for the RPs computation in step 2 of the main pipeline are extracted from the radius and ulna contours segmentation with geometric and model-based methods. The centroid shaft is computed from the radius using the PCA and a variation on the Hough transform. RPs are then automatically computed following the guidelines in [4].

Our study tested the accuracy of step 2: the computation of landmarks from the ulna and radius segmentations. The third step is the direct computation of the RPs values from the landmarks according to their definition in the guidelines in [1]. All RPs were computed for each radiograph from the ground truth segmentations of the ulna and the radius. The ground truth RP values were computed from the manually annotated landmarks. The computed RP values were computed from the landmarks computed in step 2.

The dataset consists of 95 pairs of AP and lateral radiographs of patients retrospectively obtained from the Hadassah University Medical Center, Jerusalem, Israel following IRB approval from the local ethical committee. Ground truth radius and ulna segmentations were manually performed by an expert clinician co-author. The first 20 annotated pairs were used as for the proof of concept. Ground truth landmarks were manually located and annotated by the expert clinician co-author; the process was repeated on a subset of 8 pairs 3-5 weeks later. In addition, the second expert clinician co-author manually annotated 5 pairs of AP and lateral radiographs. Four of the cases included a gap and step in both AP and lateral radiographs.

The computed RP was considered accurate (in range) when its value was inside the inter and intra observer variability range of the manual annotation. The overall accuracy of the AP and lateral measurements was obtained by averaging the accuracy of each RP.

3 Results

Fig. 2 summarizes the results. The accuracy of the computed AP RPs is 92.7%. The Radial Length and Radial Shift are within the observer variability range; for the Radial Angle, Ulnar Variance and Step all cases are within range except for one outlier; the Gap has two outlier cases. The accuracy of the computed lateral RPs is 100%: all four Palmar Tilt, Dorsal Shift, Gap, and Step are within the clinician observer variability.

4 Conclusion

Automatic computation of distal radius fractures RPs from AP and lateral radiographs of hands with and without cast can be performed within the manual inter and intra observer variability. Precise and consistent measurement of RPs may improve the clinical decision making process.

References

1. Management of Distal Radius Fractures Evidence-Based Clinical Practice Guideline. American Academy of Orthopedic Surgeons, 5 December 2020.
2. Jeremy H, Sylvain, G. Fastai: A Layered API for Deep Learning. Information 11(2) 2020.
3. Rajpurkar R, Irvin J, Bagul A, Ding D, Duan T, Mehta H, Yang B, Zhu K, Laird D, Ball RL, Langlotz C, Shpanskaya K, Lungren MP, Ng AY. MURA: Large Dataset for Abnormality Detection in Musculoskeletal Radiographs, 2018.
4. Kreder H, Hanel D, McKee M, Jupiter J, McGillivary G, Swiontkowski M. X-ray film measurements for healed distal radius fractures. J. of Hand Surgery 21 (1):31-39, 1996.

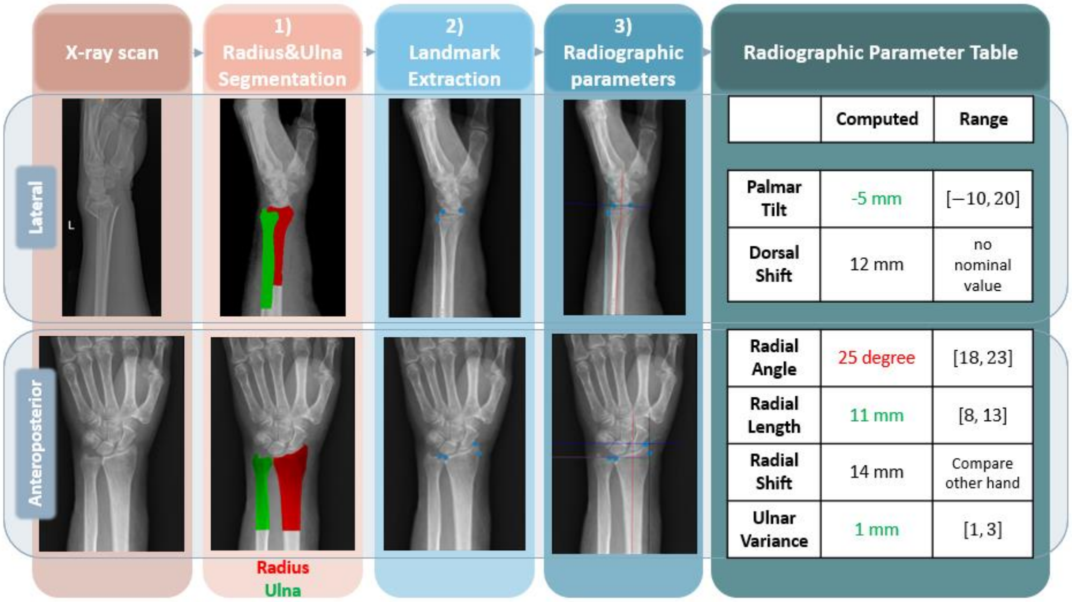
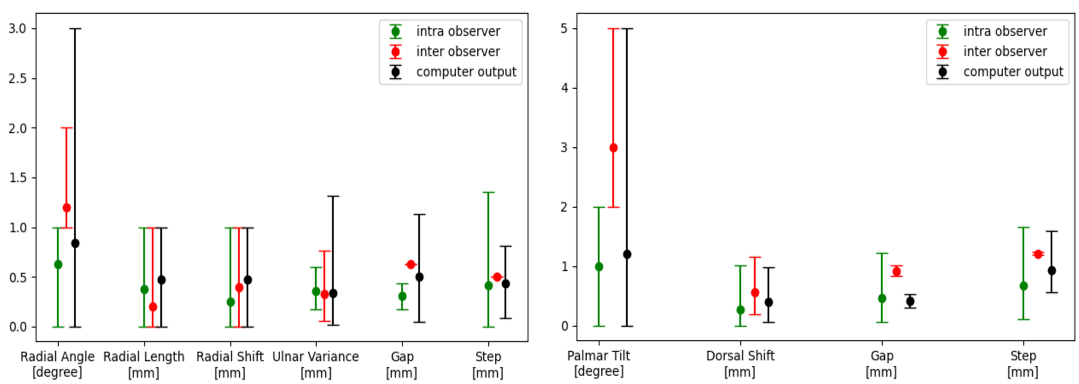


Fig. 1: Illustration of the method pipeline (from left to right). Input: AP and lateral radiographs; 1) Radius (red) and ulna (green) segmentations; 2) RPs landmark extraction (blue dots); 3) RPS computation: supporting lines (blue, purple) and axes (red). Output: RPS table: six main RPs and their computed values, and their ranges according to the guidelines in [1] (green numbers indicates inside the range, red outside the range).



(a) **(b)**

Fig. 2: Mean values (points) and ranges (variance, intervals) for RPs of the AP and lateral radiographs: computed (black) and ground truth clinician inter (red) and intra (green) observer variability. The horizontal axis shows the RP and its units; the vertical axis is the RP value: (a) AP RPs: Radial Angle, Radial Length, Radial Shift, Ulnar Variance, Gap and Step; (b) Lateral RPs: Palmar Tilt, Dorsal Shift, Gap and Step.