Postoperative imaging of orthopaedic hardware in the hand and wrist: is there an added value for tomosynthesis?

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AIM: To prospectively investigate digital tomosynthesis (DTS) as an alternative to digital radiography (DR) for postoperative imaging of orthopaedic hardware after trauma or arthrodesis in the hand and wrist.

MATERIALS AND METHODS: Thirty-six consecutive patients (12 female, median age 36 years, range 19–86 years) were included in this institutional review board approved clinical trial. Imaging was performed with DTS in dorso-palmar projection and DR was performed in dorso-palmar, lateral, and oblique views. Images were evaluated by two independent radiologists for qualitative and diagnosis-related imaging parameters using a four-point Likert scale (1=excellent, 4=not diagnostic) and nominal scale. Interobserver agreement between the two readers was assessed with Cohen's kappa (k). Differences between DTS and CR were tested with Wilcoxon's signed-rank test. A p-value <0.05 was considered statistically significant.

RESULTS: Regarding image quality, interobserver agreement was higher for DTS compared to DR, especially for fracture-related parameters (delineation osteosynthesis material [OSM]: KDTS 0.96 versus KDR 0.45; delineation fracture margins: KDTS 0.78 versus KDR 0.35). Delineation of fracture margins and delineation of adjacent joint spaces scored significantly better for DTS compared to DR (delineation fracture margins: DTS 1.54, DR 2.28, p<0.001; delineation adjacent joint spaces: DTS 1.31, DR 2.24, p=0.001). Regarding diagnosis-related findings, interobserver agreement was almost equal. DTS showed a significantly higher sharpness of fracture margins (DTS 1.94, DR 2.33, p=0.04). Mean dose area product (DAP) for DTS was significantly higher compared to DR (mean DR 0.219 Gy·cm², mean DTS 0.903 Gy·cm², p<0.001).

CONCLUSION: Fracture healing is more visible and interobserver agreement is higher for DTS compared to DR in the postoperative assessment of orthopaedic hardware in the hand and wrist.

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Introduction

Wrist and hand fractures are very common1 and surgery is considered if the fracture is unstable, displaced, or open.2 Postoperative follow-up imaging is important to verify the
correct placement of components and to detect possible complications. The clinical standard for postoperative assessment after implantation of osteosynthesis material (OSM; typically Kirschner wires, plates, and/or screws in wrist and hand fractures) is digital radiography (DR) even though its limitations in fracture healing diagnostics are well-known. For example, the superposition of structures and the interobserver variability because of high subjectivity in DR indicate the need for a more objective alternative in order to improve the evaluation of fracture healing.

Current studies assess the potential utility of digital tomosynthesis (DTS) as a new imaging method for postoperative follow-up of fracture healing and control of OSM. This section-imaging method is a compromise between DR and computed tomography (CT), based on X-ray, with a variable tube rotation of between 30°–60° (compared to 360° in CT). The sections are focused into one single plane of the volume, blurring the anatomical structures above and below, but have a high in-plane resolution. DTS is already well-established in breast cancer detection and is an active field for thoracic and musculoskeletal research.

Several studies have proven the superiority of DTS compared to DR in the detection of fractures and bone erosions and specifically, for wrist and hand bones. The described advantages of DTS compared to DR are less tissue overlap, better anatomical visualisation, less dependence on the technical skills of the radiographers as well as better interobserver agreement. In comparison with CT, it is reported to have a reduced radiation dose, lower costs, and less metal artefacts.

In the evaluation of total hip joint arthroplasty with suspicion of loosening, Göthlin and Geijer showed better visualisation of demarcation and extent of demineralisation and osteolysis in DTS compared to DR. DTS added more detailed evaluation, but did not change the diagnosis from that provided by DR. It is stated that DTS may give a more detailed insight into fracture healing.

The purpose of this study was to prospectively investigate DTS as an alternative to DR for postoperative imaging of orthopaedic hardware after trauma or arthrodesis in the hand and wrist.

Materials and methods

Patients

Ethics committee approval was granted by the local ethical committee (PB_2016-00682) for this prospective study and written informed consent was obtained from all patients. Between February and August 2016 patients of Clinic of Hand Surgery, University Hospital Zurich undergoing follow-up radiography after wrist or hand hardware placement for fracture fixation or arthrodesis were consecutively recruited. DR and DTS were always performed at the same date. Exclusion criteria were failure to attend both examinations, inability to position the forearm and hand correctly for at least two DR projections, and clinically inappropriate imaging.

Imaging technique

DR was performed using a standard clinical radiography unit (FDR AcSelerate, Fujifilm Medical Systems, Düsseldorf, Germany). The patients underwent two or three projections, depending on the fracture site. Images were acquired with a tube current of 29 mA and a tube voltage of 55 kVp, according to the departmental clinical standard. The exposure time was 9 ms.

DTS series were performed using the same radiography unit (FDR AcSelerate). Special metal markers were placed left and right next to the hands or wrists in all images to computationally compensate for vibrations and subsequent motion artefacts caused by the engine. Imaging included projections at a tube current of 39 mA and a tube voltage of 49 kVp. The position of the detector was fixed, while the X-ray tube fulfilled a continuous movement from −20° to 20° (tubular angle 40°). The movement was elected to be in the longitudinal axis of OSM, lessening the amount of tissue overlap by the OSM. The tomographic image acquisition resulted in 30 coronal section images with a 1 mm increment. The scan duration was 6 seconds. The number of exposures was 20 and one exposure lasted 300 ms.

All images were transferred to the hospital picture archiving and communication system (IMPAX, AGFA Healthcare, Bonn, Germany).

Image evaluation

All analyses were performed for the entire study population as well as for the following two subgroups: fixation with screws or wires (n=25) or plates (n=11). For patients with screws/wires and plates, only the screws/wires were evaluated and the patients were assigned to the screw group.

Quantitative evaluation

Quantitative image data were measured by one author (A.D.). DAPs were obtained from the electronically logged protocol. Background noise was defined as the standard deviation of air density in a circular region of interest (ROI) of 88 mm² (adapted if needed; mean 82.3 mm², range 7–97 mm²) on the right top corner of the DR and DTS images. If this corner was covered with anatomical structures or markers, the measurement was made as closely as possible to this reference point.

Qualitative evaluation

Two blinded and independent radiologists (T.F. and A.S.B., 15 and 4 years of experience) performed the qualitative image evaluation. The images were presented in a random order and the assessment was made separately for both imaging methods. Both radiologists were allowed to use diagnostic PACS workstation software features, such as interactive window and level setting or magnification of images, for comprehensive image evaluation.

DR and DTS images were assessed with Likert scale for multiple parameters, split into two categories: image
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