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Original article

Comparison of intraoperative flat panel imaging and postoperative plain radiography for the detection of intraarticular screw displacement in volar distal radius plate ostheosynthesis

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ABSTRACT

Objectives: To investigate if intraoperative 3D flat panel imaging improves the detection of radiocarpal intraarticular screw misplacement (RCSM) in comparison to standard postoperative x-ray.
Methods: In a study on cadaver specimens, we evaluated the sensitivity and specificity to detect RCSM using X-ray, intraoperative 3D-fluoroscopy as well as the digital volume tomography. The gold standard reference was computed tomography.
Results: Sensitivity for the detection of RCSM for X-ray was 58% and specificity 88%. For DVT, the sensitivity to detect RCSM was 88% and the specificity 53%. For 3D-fluoroscopy, the sensitivity for RCSM was 68% and specificity 95%. When combining the methods, the best performance was found, when combining the two intraoperative imaging methods, with a resulting sensitivity of 88% and a specificity of 73%.
Conclusions: Intraoperative 3D fluoroscopy and digital volume tomography appear to be at least as sensitive and specific to detect RCSM than the regular postoperative radiography in two planes. However, especially discrete screw misplacements can be missed with either method.
Level of evidence: Level IV. Diagnostic device study.

1. Introduction

Fractures of the distal radius account for more than 15% of fractures seen in the emergency room. The prevalence of intraarticular distal radius fractures accounts to approximately 60% of all radius fractures [1,2]. For good clinical outcome of distal radius fractures (DRF), the correct anatomic reduction of the joint surface is crucial [3–5]. In order to obtain good results in periarticular implantation of plate osteosynthesis at the distal radius, the screw placement close to the subperiosteal lamella is recommended in order to provide optimal stability of the cortical joint surface [6,7]. However, the correct extraarticular screw placement is difficult to assess with projectional radiography due to the three-dimensional concave articular surface of the distal radius in the radiocarpal joint with the overlying projection of the ulnar and radial styloid processus and possible metal artefacts [8–10]. For the fractured radius, marginal irregularities of the joint surface, as well as intraarticular screw placements are associated with severe chondromalacia [4,11]. Although the complication is severe and likely to occur, the reported prevalence of radiocarpal screw misplacement (RCSM) is very low, compared to the prevalence of postoperative pain syndroms [12–14]. The complication of x-ray detected RCSM is being associated to < 1% of cases and approximately 5% of cases in which implants need to be removed [12,15]. It remains unclear whether the existing study data reflects the true rate of RCSM.

In order to improve the detection of RCSM as well as possible failure in reconstruction of the joint surface, the early detection of intraarticular screw misplacement and periarticular cortical screw penetration during the surgical procedure appears to be a promising strategy. New technologies have been developed that aim to solve this problem in the surgery room, allowing

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intraoperative 3D-fluoroscopy (e.g. CineView®) and 3D C-arm digital volume tomography (DVT) to be performed. These methods offer additional qualities to the conventionally and widely used intraoperative fluoroscopy, the plain radiography as well as the option of a post-procedural computed tomography (CT) [15]. However, the opportunity to achieve an improvement in patient care with additional imaging modalities must be counterbalanced with the risk of repeated and imprudent exposure to methods using radiation, as well as additional false positive or false negative findings. With the hypothesis that state of the art intraoperative flat panel imaging is as good as the postoperative computed tomography (CT) for depicting intraarticular screw placement, we compared conventional postoperative two plain radiography with intraoperative 3-D fluoroscopy and DVT for the detection of RCSM. For this purpose, we chose an ex vivo approach to compare the sensitivity and specificity of the indicated imaging modalities, with computed tomography serving as the reference standard.

2. Materials and methods

2.1. Specimens and surgical procedures

Twelve human cadaver specimens of the forearm were used for this study. Approval was obtained from the local ethic commission. An oscillating saw was used to create a coronal and a sagittal osteotomy in order to imitate a complete intraarticular distal radius fracture (AO 23-C.1). Following osteotomy, a standard distal radius T-plate (2.4 distal radius locking compression plate [LCP], Synthes, Umkirch, Germany) was used to stabilize the fracture in a surgical procedure. Three or four screws were placed into the distal fragment and two screws were placed into the shaft. During reduction and placement of the implant, standard fluoroscopy (Ziehm, Expo 8000, Erlangen, Germany) was used to determine correct positioning in anteroposterior and lateral position, as frequently performed. After reaching sufficient reduction and plate positioning, the screws were inserted according to the standard method using a length gauge.

2.2. Imaging techniques

After reduction and screw placement, plain radiographs were taken as postoperative control study in standard sagittal and anteroposterior planes (50 kV, 10 mA, digital image acquisition with shutter priority, dose of approximately 50–100 μSv). Next, a three-dimensional fluoroscopy was performed with the digital flat panel detector (Ziehm Vision FD Vario 3D, Nuremberg, Germany). For this purpose, the specimen was positioned as in the clinical routine, palmar side up, on an acrylic glass table according to the manufacturer instruction (110 images, 50 kV, 10 mA, 90° rotation, dose of approximately 30–50 μSv) (Fig. 1). The data acquisition was completed within approximately three minutes and images were reconstructed in axial, coronal, and sagittal planes for evaluation. While the post-processing took around 1 minute of time, the software calculated a so-called cine mode of approximately 110 images. The images that constitute the 3D-fluoroscopy (Cine-view) were separately stored. The DVT reconstruction was performed based on the 3D-fluoroscopy data, providing a stack of 500 images with slice thickness of 0.25 mm (Fig. 2).

After the procedure, a high resolution CT scan was performed on a 64-row CT scanner (Somatom Sensation 64, Siemens, Erlangen, Germany) (Fig. 3). The scan was performed according to the protocol for the distal forearm that is used in our department in clinical routine. The high resolution protocol with 1-mm slice thickness, 120 mAs, 120 kV, a rotation-time of 0,5 sec, Kernel B70s and an effective dose of 1–1.5 mSv allowed 3D multiplanar reconstructions that were used for the determination of the gold-standard reference. Standard clinical procedures of image post-processing were applied.

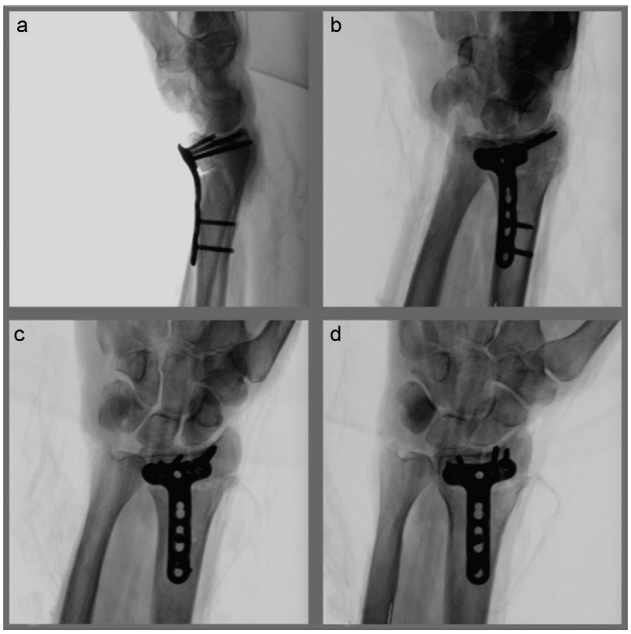

Fig. 1. a–d: four 3D-fluoroscopy images of a series of 110 images, showing distal radius LCP osteosynthesis. The image quality was rated to be very good. In this case, intraarticular screw cutting out of the medial radial screw (arrow) was suspected in X-ray. The oblique projections helped to identify the extraarticular screw position that was confirmed with computed tomography.

Fig. 2. a and b: two reconstructed image examples of a 3D DVT dataset, showing LCP osteosynthesis at the distal radius. In opposite to 3D-fluoroscopy and X-ray, the image quality of the DVT datasets, that was acquired with 50–100 μSv, was rated "low" due to the beam hardening artefacts as well as low contrast of the joint surface in the reconstructed images (Fig. 3a). However, the 3D DVT showed a higher sensitivity for the detection of intraarticular screw cutting out than X-ray and 3D fluoroscopy.

2.3. Image and data evaluation

The image evaluation of all studies was performed in consensus by a specialist orthopaedic surgeon (8 years of professional experience) and a specialist radiologist (10 years of professional