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CONE-BEAM COMPUTED TOMOGRAPHY COMPARED TO X-RAY IN DIAGNOSIS OF RADIAL FRACTURES

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ABSTRACT

Background: The purpose of this study was to determine whether radiological measurements of radial fracture position made in cone beam computed tomography (CBCT) projection images are comparable to those made on traditional radiographs and could potentially substitute them.
Methods: One hundred patients with fractures of the distal radius referred for radiographs were recruited for an additional CBCT scan which was performed immediately afterwards between January and December 2021 were analyzed retrospectively.
Results: Using plain radiographs compared to CBCT wrist fracture was confirmed in 98 cases and CBCT in 100 cases. Median effective dose of CBCT was as low as 1,41mSv comparated with 0,19mSv for standard radiography. According to fracture localization, conventional radiography diagnosed 54% intra-articular fractures, 5,9% extra-articular, 60% multi-fragmented, 13,9% dislocated, 74,3% distal and scaphoid fractures 6.9% and CBCT imaging method diagnosed 64,4% intraarticular fractures, 6,9% extraarticular, 68,3% multifragmented, 19,8% dislocated, 76,2% distal and scaphoid fractures 13,9%. The inter-rater correlation was higher in the CBCT compared to radiography (p=0,01; p=0,00; p=0,00; p=0,013;p=0,032; p=0,037).
Conclusion: The cone beam imaging method is of great importance as a supplementary method to conventional radiography, which still remains the primary method in diagnosing wrist fractures.
Keywords: Cone-beam computed tomography (CBCT), Radiography, Radius Fractures

INTRODUCTION

The human hand has 27 bones that are divided into three groups: the wrist (ossa carpi) or carpal bones, the wrist bones (ossa metacarpi) or metacarpal bones, and the finger joints or phalanges (phalanges digitorum manus). A distal radius fracture, commonly known as a wrist fracture, is defined by the involvement of the distal radius metaphysis. Distal radius fracture is the most common fracture of the upper extremity. These fractures occur in all patient populations and are the most common orthopedic injury. Criteria that must be included in the classification of fractures according to the International Federation of Societies of Hand Surgery (IFD). The International Federation of Societies for Surgery of the Hand (IFSSH) are: location, configuration, displacement, ulnar styloid integrity, distal radioulnar joint integrity, stability, and associated injuries. Scaphoid bone fractures are the most common carpal joint fractures in accounting for 60-70% of all carpal joint fractures [2]. The incidence of fracture of the scaphoid was 12.4 in 100 000 each year in the general population [3]. Early diagnosis of scaphoid bone fractures is crucial because scaphoid bone fractures have a high risk of long-term complications, such as non-healing, avascular necrosis, and carpal instability, without timely diagnosis and appropriate treatment [4]. Imaging techniques play an important role in assessing the complex anatomy of the bones and soft tissues of the wrist. Standard X-rays of the wrist represent a very important imaging modality for detecting the pathology of the wrist in its simplest forms [5]. The bones are imagined in two projections, which are at an angle of 90 degrees to each other. Typical images are often not enough to make a diagnosis, so supplementary, e.g. hair, axial and comparative images of paired bones, especially in children, are also made, and preferably on the same film to compare sick and healthy

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bone. Cone- Beam Computed Tomography (CBCT) was developed for dental imaging purposes in the 1990s. It is an imaging technique, also known as digital volumetric tomography that consists of X-ray computed tomography, which offers high-quality, fast and three-dimensional images of the body with a low dose of radiation. CBCT produces volumetric images during a single 360º rotation of the X-ray beam and detector around a stationary patient. CBCT is a promising imaging modality in the research and management of bone fractures and could gradually replace conventional X-rays thanks to the following reasons [6]. Superior and fine spatial resolution for diagnosing occult bone fractures, reduced radiation doses compared to X-rays that usually require more than two orthogonal radiographs, shorter scanning times than X-rays, easy access in current practice as the first tool in the emergency department for trauma in younger people, in the elderly with osteoporosis of the bone, in post-orthopedic surgery, and an optimized price-effectiveness ratio by limiting the number of unnecessary immobilization. The limitation of CBCT is that it does not show soft tissues as it has a limited nasal contrast resolution due to various physical and technical factors that bring limitations for soft tissues. CBCT is the latest technological achievement of modern digital radiology, and four technological factors are responsible for such an achievement: the development of special detectors, the development of cheap X-ray tubes, cheaper computers and the target site of application. Standard 2D radiography in combination with the Cone Beam method enabled the diagnosis and more detailed preparations for the surgical procedure in patients [7].

Research goals

- Determine the variation in the anatomical distribution of fractures after the CBCT method and standard X-ray in two planes.
- To determine the difference in radiation dose (DAP) in a patient undergoing the standard X-ray method and the CBCT method.

Determine the level of correspondence between the setting of the CBCT method and X-ray imaging with the diagnosis after surgery.

PATIENTS AND METHODS

A retrospective study was conducted between January and December 2021. The study included cases of wrist fractures that were assessed by conventional radiography and additionally by CBCT method. The study involved 100 patients who were examined at the Department of Radiology at the University Clinic of Würzburg.

All subjects are first given conventional radiography, including a posteroanterior (PA) and lateral scan. First, a posteroanterior image of the wrist is done on the detector, so that the subject's arm is bent at the elbow at an angle of 90º, the wrist is stretched forward. The distance of the scanned object from the X-ray tube is 100 cm, and the central beam falls on the bones of the root of the hand. After that, a lateral image is made with the same imaging parameters, but the wrist is rotated to a lateral position so that the radius is facing upwards. The effective radiation dose of a standard radiograph in two projections is 0.16μSv [8]. After conventional radiography, CBCT imaging is performed on all subjects. CBCT images were obtained using the Siemens Multitiom CBCT 3D device. The imaging is performed in a supine position by placing the subject's wrist between the X-ray tube and the detector for the 2D image. The total time to collect the footage is about 14 seconds. The mean effective radiation dose is 3.65μSv [8].

Statistical data processing included descriptive methods (absolute and percentage frequencies, arithmetic means, standard deviations, mode and meridian) and inferential statistical methods the Chi-square test and the comparative t-test. All statistical hypotheses were tested at a 95% confidence level. 5% risk ($p<0.05$).

RESULTS

Of the total number of examinees, 44 respondents are male, and 56 of the respondents are female. The minimum age of subjects with wrist fractures was 16 years, and the maximum age was 93 years. The mean age of the subjects was 53.46 years with a standard deviation (SD) ±19.1 years.

The median is 57 years and the mod is 68 years. The average age of male subjects with wrist fracture is 41.64 with SD ±18.7 years, the minimum age is 16 years, and the maximum is 84 years, while the average age of female subjects with wrist fracture is 62.95 with SD ±13.3 years, the minimum is 21 years and the maximum is 93 years. The arithmetic mean of the effective radiation doses obtained after X-ray imaging is 0.22 mSv with SD±0.14 mSv. The minimum effective dose for X-ray imaging was 0.07 mSv and the maximum dose was 0.92 mSv, while the median dose was 0.19 mSv. In CBCT imaging, the arithmetic mean of effective radiation doses was 1.6 mSv with SD ±1.02 mSv. The minimum effective dose for CBCT imaging was 1.31 mSv, amaxillary 6.51 mSv, while the median was 1.41 mSv as shown in Table 1.

Table 1. Distribution of effective doses in X-ray and CBCT imaging

	ED(mSv)-X-ray (AP+LAT)	ED (mSv)-CBCT
N (total number of valid cases)	101	101
Arithmetic mean	0.22	1.60
Median	0.19	1.41
Standard deviation	0.14	1.05
Minimum	0.07	1.32
Maximum	0.92	6.51

There is a statistically significant difference of p<0.002 between the effective radiation doses obtained by X-ray imaging and the effective doses obtained by CBCT imaging.

According to the location of the fracture, 60 (54%) intra-articular fractures were diagnosed by X-ray imaging, 64 (64.4%) by CBCT method, while after surgery in 66 (65%) cases, the diagnosis of intra-articular fractures was made, which is shown in Figure 1.

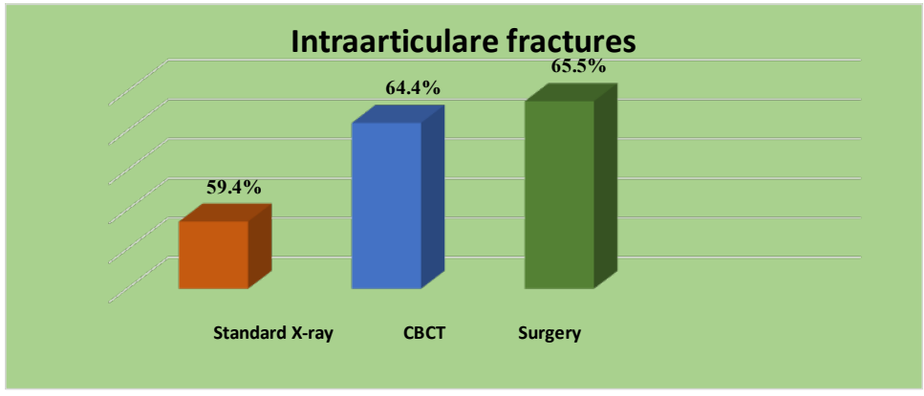

Figure 1. Distribution of intra-articular fractures of the wrist after standard X-ray, CBCT imaging and after surgery

With the CBCT imaging method, significantly more wrist fractures are diagnosed as intra-articular than X-rays. There is a statistically significant difference (p=0.01) between the percentage of diagnosed intraarticular fractures obtained by CBCT method compared to standard X-rays, which was confirmed after the surgery.

Extraarticular fractures were diagnosed after X-ray imaging in 6 (5.9%) cases, and after CBCT imaging in 7 (6.9%) cases. After the surgery, extra-articular fracture was diagnosed in 8 (7.9%) cases, which is shown in Figure 2.

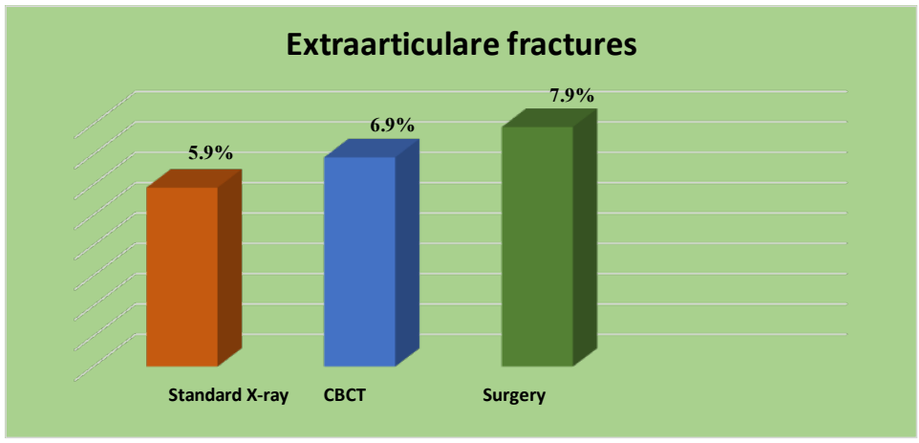

Figure 2. Distribution of extraarticular fractures of the wrist after standard X-ray, CBCT imaging and after surgery

CBCT imaging was used to diagnose more extraarticular fractures compared to X-ray imaging, which means that there is a statistically significant difference (p=0.00) in the percentage of diagnosed extraarticular fractures obtained by CBCT imaging compared to standard X-ray, which was confirmed after surgery.

X-ray imaging diagnosed 60 (60%) multifragmented fractures, and after CBCT imaging 69 (68.3%), until after surgery, the diagnosis of multifragmented fractures was made in 71 (70.3%) cases, which is shown in Figure 3.

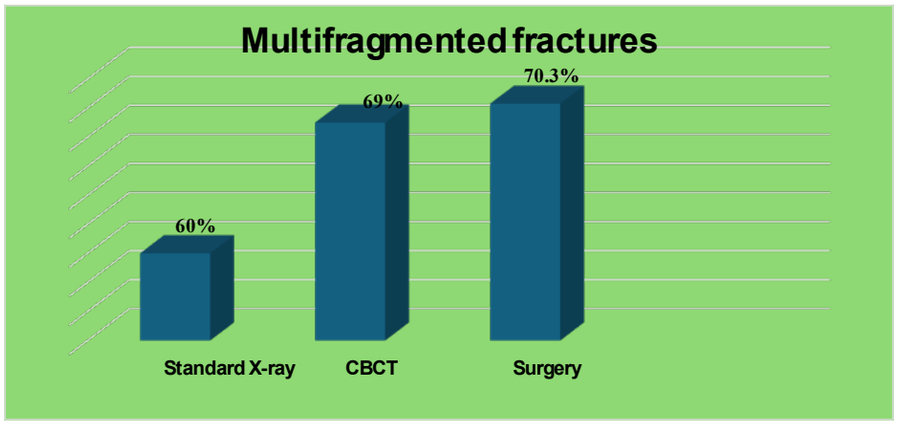

Figure 3. Distribution of multi-multifragmented wrist fractures after standard X-ray, CBCT imaging and after surgery

CBCT imaging was used to diagnose more multifragmented fractures compared to X-ray imaging, which means that there is a statistically significant difference (p = 0.00) in the percentage of diagnosed multifragmented fractures obtained by CBCT imaging compared to X-ray imaging, which was confirmed after the surgery.

According to the dislocation (dislocation) of the wrist fracture, 14 (13.9%) cases were diagnosed after X-ray, and 20 (19.8%) after CBCT, while the diagnosis of dislocated fractures of the wrist was made in 22 (22.2%) cases after the surgery, which is shown in Figure 4.

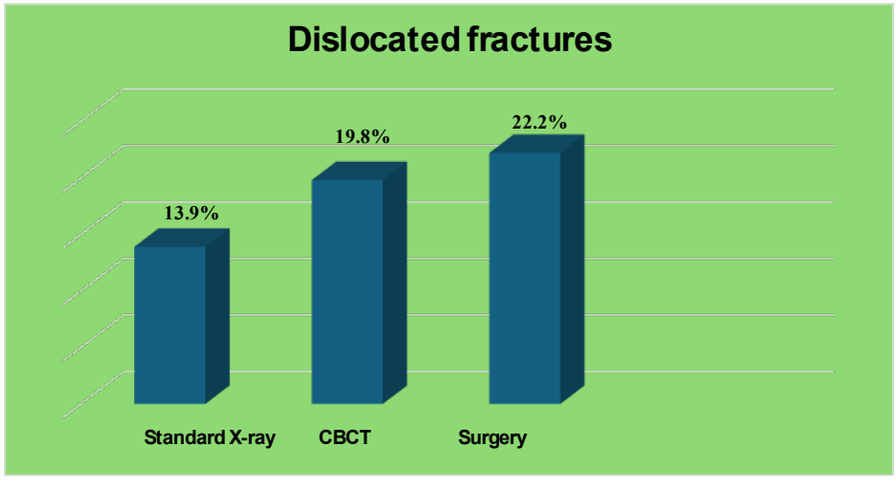

Figure 4. Distribution of dislocated wrist fractures after standard X-ray, CBCT imaging and after surgery

Compared to X-ray, more dislocated fractures were diagnosed with CBCT imaging, which means that there is a statistically significant difference (p=0.013) in the percentage of diagnosed dislocated fractures after CBCT imaging compared to X-ray, which was confirmed after the surgery.

According to the distal fracture of the wrist after X-ray imaging, it was diagnosed in 75 (74%) cases, while after CBCT imaging it was diagnosed in 77 (76.2%) cases, while after surgery, the distal fracture of the wrist was diagnosed in 78 (77.2%) cases, which is shown in Figure 5.

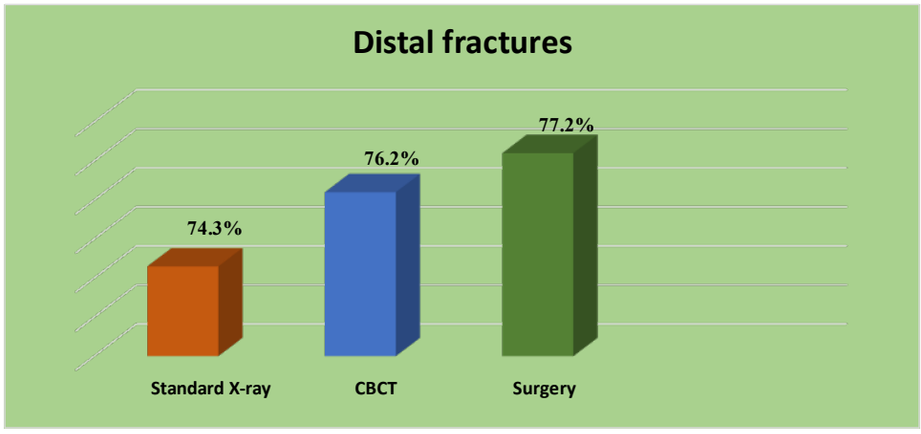

Figure 5. Distribution of distal wrist fractures after standard X-ray, CBCT imaging and after surgery

CBCT imaging has been used to diagnose more distal fractures of the wrist compared to X-ray. This means that there is a statistically significant difference (p=0.032) in the percentage of diagnosed distal fractures of the wrist after CBCT imaging compared to X-ray, which was confirmed after the surgery.

A fracture of the scaphoid bone was diagnosed in 7 (6.9%) cases, a suspected fracture of the scaphoid bone was diagnosed in 5 (5%) cases, and in the remaining 89 (88.1%) cases it was not diagnosed after X-ray. CBCT imaging diagnosed a fracture of the scaphoid bone in 13.9% of cases, while after the surgery, the diagnosis was made in 14.9% of cases, which is shown in Figure 6.

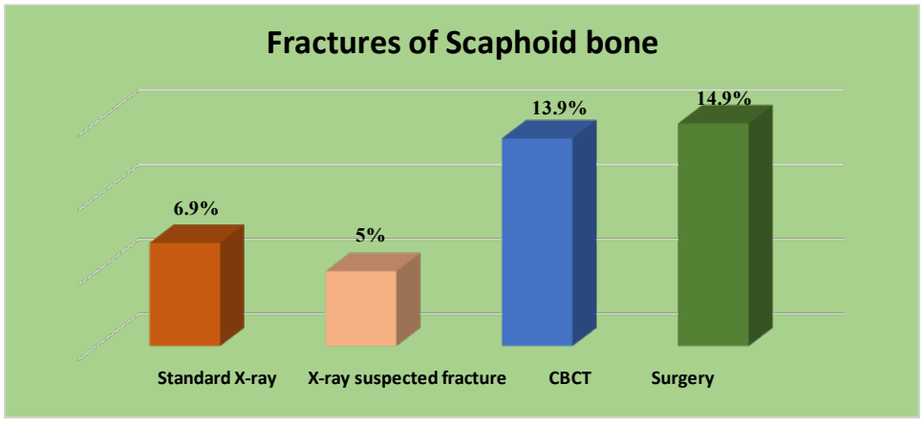

Figure 6. Fracture of the scaphoid bone after standard X-ray, CBCT imaging and after surgery

Compared to X-ray, more fractures of the scaphoid bone were diagnosed with CBCT imaging, which means that there is a statistically significant difference (p=0.037) in the percentage of diagnosed scaphoid bone fractures after CBCT imaging compared to X-ray, which was confirmed after the surgery.

Of the total number of cases of Colles' fracture of the wrist after X-ray, CBCT and after surgery, it was diagnosed in 2 (2%) cases.

The diagnosis of Colles' wrist fracture was made in the same number of cases after X-ray and CBCT imaging, as well as after surgery, which means that there is no statistically significant difference (p=0.978) in the percentage of diagnosis of Colles' wrist fracture.

DISCUSSION

Fractures of the wrist are among the most common traumatic injuries of the locomotor system. Study by Omsland et al. [9] showed that there is a higher incidence of fractures in women living in urban areas, compared to those coming from rural areas. Of the total number of respondents, a higher number of women were diagnosed with a fracture of the wrist than men. As for the age of the respondents, most of them are in the age group of 50-69 years. The arithmetic mean of the effective dose achieved by conventional radiography in the study was 0.22μSv. In the CBCT method, the arithmetic mean of the effective dose was 1.6μSv, which is in line with other studies [10].

Studies have shown that the CBCT method outperforms conventional radiography in detecting occult fractures of small bones, but these conclusions are usually undermined by insufficient reference standards such as clinical monitoring and assisted magnetic resonance imaging [11].In our research, several fractures were diagnosed using the CBCT method according to the localization of fractures, which are dislocated whether they are intra-articular or extra-articular fractures, i.e. This method has proven to be more accurate compared to conventional radiography. This is supported by a higher incidence of matching the diagnoses obtained by the CBCT method with the diagnoses made after the surgery compared to conventional radiography, and with regard to the location of the fracture. According to the configuration, the CBCT method diagnosed more fractures that are classified in the category of multifracture than is the case with conventional radiography, which was confirmed after the surgery. Classical radiography does not sufficiently detect the dislocation of the scaphoid fracture [12], which is the case of the fractures covered by our study because conventional radiography diagnosed significantly less fracture displacement (20%) than is the case with the CBCT imaging method and which was confirmed after the surgery. Diagnosis of a scaphoid bone fracture is a challenge for clinicians. Anamnesis [13], physical examination [13], conventional radiography [14] do not have sufficient sensitivity and specificity for the diagnosis of scaphoid bone. Study by Neubauer et al.[15] showed that sensitivity, specificity, positive and negative predictive values are higher for the CBCT method than for conventional radiography ($p < 0.019$) where for the CBCT method the diagnostic sensitivity was 93%, the specificity was 96%, the positive predictive value was 96% and the negative predictive value was 92%, and for conventional radiography the sensitivity was 87%, the specificity was 77%, the positive predictive value was 80% and the negative predictive value was 84%. In our study, conventional radiography in 5% of cases was diagnosed as a fracture of the scaphoid bone, while in CBCT there was no doubt that it was a fracture of the scaphoid bone. CBCT imaging diagnosed a fracture of the scaphoid bone in 13.9% of cases, which was confirmed after the OP procedure in 14.9% of cases, i.e. that the CBCT method ($p<0.05$) is significantly more accurate in diagnosing scaphoid bone fractures than conventional radiography. Clinical evaluation of wrist fractures must be supported by radiographic examination. X-rays in the AP, lateral and oblique planes often cannot make an accurate diagnosis of wrist fractures, leading to inappropriate treatment. A study by Wouri et al.,[16] showed that in 39% of cases (59 patients) a diagnostic X-ray was not performed immediately after trauma. If the X-rays are negative and an injury is still suspected, the CBCT imaging method can detect occult fractures and may be useful in forming a surgical treatment plan [17].

CONCLUSION

The Cone Beam imaging method significantly contributes to the detailed diagnosis of wrist fractures compared to conventional radiography. The effective radiation dose of the Cone Beam imaging method is on average up to 7 times higher than the effective dose of conventional radiography, but it is often necessary to perform more conventional radiographic imaging, which increases the effective radiation dose. The CBCT imaging method can facilitate the diagnosis of wrist fractures and has higher diagnostic accuracy even without highly experienced personnel. The cone beam imaging method is of great importance as a complementary method to conventional radiography, which still remains the primary method in diagnosing wrist fractures.

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