Occult Fractures: The Contribution of Cone Beam Computed Tomography in Detecting Carpal Injuries Missed on X-ray

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ABSTRACT

Physiotherapists are frequently the first point of contact for patients with acute wrist injuries. Initial clinical impressions rely on radiographic (X-ray) imaging to rule out fracture, yet standard radiography has limited sensitivity for detecting carpal injuries. This study quantified the number of acute radiocarpal fractures missed on initial X-rays but later identified using cone beam computed tomography (CBCT). It also examined whether fracture location differed between X-ray and CBCT findings. A retrospective review was undertaken for patients presenting with acute wrist trauma to a specialist fracture clinic between 1 December 2023 and 30 May 2024 (n = 333). Data were extracted from electronic health and imaging records. Descriptive statistics and bivariate analyses assessed fracture location, detection rates, imaging modality, and demographic characteristics. Of the 325 wrist injuries analysed, 186 fractures were identified. X-rays detected approximately 75% of these, leaving one in four occult. CBCT identified 41 fractures in cases where X-rays appeared normal, highlighting the limitations of standard radiography. While X-rays predominantly identified distal radius and scaphoid fractures, CBCT detected a broader spectrum of carpal injuries. Physiotherapists should recognise the limitations of X-ray imaging in diagnosing radiocarpal fractures, as findings suggest carpal fractures are more common than previously understood and have been historically underdiagnosed. If a wrist injury presents clinically as a fracture despite normal X-rays, therapists should remain aware of the possibility of an occult fracture.

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Key Words: Carpal, Cone Beam Computed Tomography (CBCT), Fracture, Occult, Wrist

INTRODUCTION

Physiotherapists are frequently the first point of contact for patients presenting with acute wrist injuries, as the Accident Compensation Corporation's (ACC's) direct-access model allows patients to attend physiotherapy without a GP referral (Accident Compensation Corporation, 2026). In this context, early and accurate identification of potential fractures is a critical component of safe physiotherapy practice. Although radiography (X-ray) remains the first-line imaging modality due to its affordability and accessibility, its diagnostic accuracy is limited, with reported sensitivities of 39% for carpal fractures (excluding scaphoid fractures), 58% for distal radius fractures, and 66–81% for scaphoid fractures (Balci et al., 2015; Welling et al., 2012). These figures highlight a substantial clinical risk: a normal X-ray does not reliably exclude fracture, and carpal injuries may be missed despite clear clinical symptoms.

Advances in high-resolution imaging, particularly cone beam computed tomography (CBCT) and magnetic resonance imaging (MRI) have improved detection of previously occult fractures. Originally developed for dental use, CBCT now supports orthopaedic applications with high spatial resolution (slice thickness down to 0.2 mm), low radiation exposure, and protection of radiosensitive organs (Neubauer et al., 2018; Vitéz et al., 2021). Recent systematic reviews report that CBCT demonstrates 88% sensitivity and 99% specificity for scaphoid fractures (Fitzpatrick et al., 2022; Yang et al., 2021), and European studies consistently demonstrate its superior diagnostic detail compared with X-ray (Colville et al., 2022; Edlund et al., 2016; Krayem et al., 2021; Neubauer et al., 2018). While MRI remains the gold standard, its cost limits routine use in acute settings, making CBCT a more practical option for timely diagnosis.

Because of the diagnostic limitations of X-ray, timely access to advanced imaging becomes important. In New Zealand however, physiotherapists are unable to directly refer for CBCT or MRI, meaning specialist input is required and may not be immediately accessible. Delays in diagnosis can contribute to prolonged pain, functional limitations, slower recovery, and increased healthcare utilisation. Early identification is crucial for managing scaphoid waist and proximal pole fractures, as these have a higher risk of non-union (Clementson et al., 2020; Colville et al., 2022; Peterson et al., 2020) and may progress to scaphoid non-union advanced collapse if not managed appropriately (Alanen et al., 2025; Maris et al., 2024). Accurate diagnosis also supports clearer recovery planning, helping patients, therapists, and employers set realistic expectations for healing and return-to-work timeframes.

Despite growing international evidence supporting the use of CBCT, data from Australasia remains limited, particularly regarding its use in the acute care setting and the current detection rate of occult radiocarpal fractures. This New Zealand-based research was undertaken to determine if European findings are transferable to local practice. The aims of this study were 1. to quantify the number of acute radiocarpal fractures missed on initial X-rays but subsequently identified using CBCT imaging, and 2. to determine whether the anatomical location of radiocarpal fractures identified differs significantly between X-ray and CBCT imaging.

METHODS

Ethical approval for this study was obtained from the Auckland University of Technology Ethics Committee (reference 24/344). A retrospective audit was conducted of patient records for all individuals presenting with acute wrist injuries to a specialist fracture clinic operating within a 24-hour medical care facility in Christchurch. This multidisciplinary clinic runs five days per fortnight and is staffed by emergency medicine specialists, radiographers, nurses, and New Zealand registered hand therapists. The audit spanned a six-month period from 1 December 2023 to 30 May 2024. Records of all patients who presented to the specialist fracture clinic with a suspected radiocarpal fracture were included in the review. Radiocarpal fractures were defined as involving the distal radius and/or carpal bones. No exclusion criteria were applied.

Each patient received an initial X-ray as part of standard protocol. Decisions regarding subsequent imaging were made by the attending emergency specialist, following established clinical guidelines that considered the mechanism of injury, clinical assessment, and relevant risk factors. All X-ray and CBCT imaging were performed on-site at the 24-hour clinic. MRI was not available on-site and was outsourced to an alternative provider. Specifics regarding the imaging techniques utilised are provided in Appendix A. All imaging was interpreted by consultant musculoskeletal radiologists. Reports for X-ray and CBCT were typically available on the same day as acquisition, most often within an hour of image download. Magnetic resonance imaging reports were provided within 24 hours, in accordance with standard local practice.

Prior to study initiation, a codebook was created to guide data collection. The codebook defined how each variable was structured, labelled, and coded, ensuring consistent and reproducible data collection and reducing ambiguity in how imaging modality, fracture status, and diagnostic outcomes were interpreted and recorded. Patient data were sourced from electronic health records and imaging archives. During the six-month inclusion period, 1,011 patients attended the specialist fracture clinic, with 325 wrist injuries identified across 316 individuals. Demographic variables, including sex, ethnicity, and age at initial X-ray were extracted from health records (by JB). Imaging data included the modality (X-ray, CBCT, MRI), fracture presence (none, fracture, occult fracture), and anatomical location. Occult fractures were defined as those not visible on X-ray but detected on CBCT or MRI. Multiple fractures per patient were recorded individually.

Data were entered into an Excel spreadsheet, after which National Health Index numbers were removed to generate a de-identified dataset. Data were subsequently filtered by variable to identify and correct errors. Thirteen coding discrepancies were resolved through file review, and one duplicate entry was removed. A data quality check was conducted to assess the accuracy, consistency, and reliability of the collected dataset (JB). A 10% sample ($n = 32$ of 317 patients) was systematically reviewed by a research assistant (AB), a New Zealand-registered physiotherapist and hand therapist with relevant postgraduate qualifications. The research assistant signed a confidentiality agreement and received training in data extraction and coding procedures (from JB), guided by the codebook.

For the quality check, there was a 96% agreement rate, with 14 discrepancies identified (4% error rate). Of these, 10 coding errors were attributed to the research assistant and three to the researcher and first author (JB); all were corrected in both raw and clean datasets. One discrepancy involved a diagnostic disagreement regarding an ulnar styloid fracture. Following consultation with the reporting radiologist, the fracture was deemed historical, and the patient data were retained in the study.

Statistical analysis

Descriptive statistics (frequencies, percentages, median, range, and ratios) were used to summarise the key characteristics of the cohort. Age, originally collected as a continuous variable, was categorised into 10-year age groups for subsequent analysis; categorical variables such as sex, ethnicity, and imaging received were summarised using frequencies and percentages. Continuous variables that remained in their original form were described using measures of central tendency (median) and variability (range).

Categorical data (age, sex, imaging modality, location of fracture, age group) were analysed using Pearson's chi-square test. Fisher's exact test was applied when expected cell counts were small, and comparisons were conducted using the Mann–Whitney U test where there was a skewed distribution. Statistical significance was defined as a p value < 0.05. Statistical procedures were selected and reviewed in consultation with a university biostatistician (IZ).

RESULTS

In this study, 325 injuries were identified in 316 patients. At the time of injury, eight patients had either sustained fractures to two separate bones within the same wrist or presented with bilateral wrist injuries, and one patient was treated for two separate injuries.

Cohort characteristics

The patient cohort ranged in age from five to 95 years, with a median age of 37. Of the 325 wrist injuries, 41% ($n = 133$) occurred in males and 59% ($n = 192$) in females, indicating a higher representation of female patients overall. The paediatric group (age ≤ 16 years, $n = 88$, 27% of cohort) showed a near-even gender split (male: $n = 45$; female: $n = 43$), while the adult group (age > 16 years, $n = 237$, 73% of cohort) reflected the broader trend, with 37% male ($n = 88$) and 63% female ($n = 149$), suggesting a greater proportion of female patients in older age groups. Ethnically, the cohort was predominantly European (86%, $n = 280$). Māori (5%, $n = 15$) and Asian patients (5%, $n = 16$) were the next most represented groups. A further 3% ($n = 10$) were categorised as undefined, while patients from the Pacific Islands accounted for 0.9% ($n = 3$) and those classified as other ethnicities comprised 0.1% ($n = 1$).

How many radiographically occult fractures were subsequently identified using CBCT imaging?

Figure 1 outlines the patient flow through the fracture clinic. Of the 181 confirmed radiocarpal fractures, 74% ($n = 134$) were detected on initial X-ray, while 22% ($n = 41$) were identified exclusively through CBCT. The remaining 4% ($n = 6$) were diagnosed via MRI or repeat X-ray.

Among the 130 patients who underwent additional imaging following a normal initial X-ray, 26% ($n = 47$) were subsequently diagnosed with a fracture. CBCT identified 41 fractures, while MRI and repeat X-rays each revealed three additional fractures. Median time to diagnosis for CBCT was 10 days (range 3 to 42). The patient who had a fracture diagnosed at 42 days also had a scaphoid fracture, which was visible on initial X-ray. On removal of plaster at six weeks post-fracture, this patient underwent CBCT to assess bone healing. Cone beam computed tomography imaging revealed a previously undetected fracture of the hook of hamate.

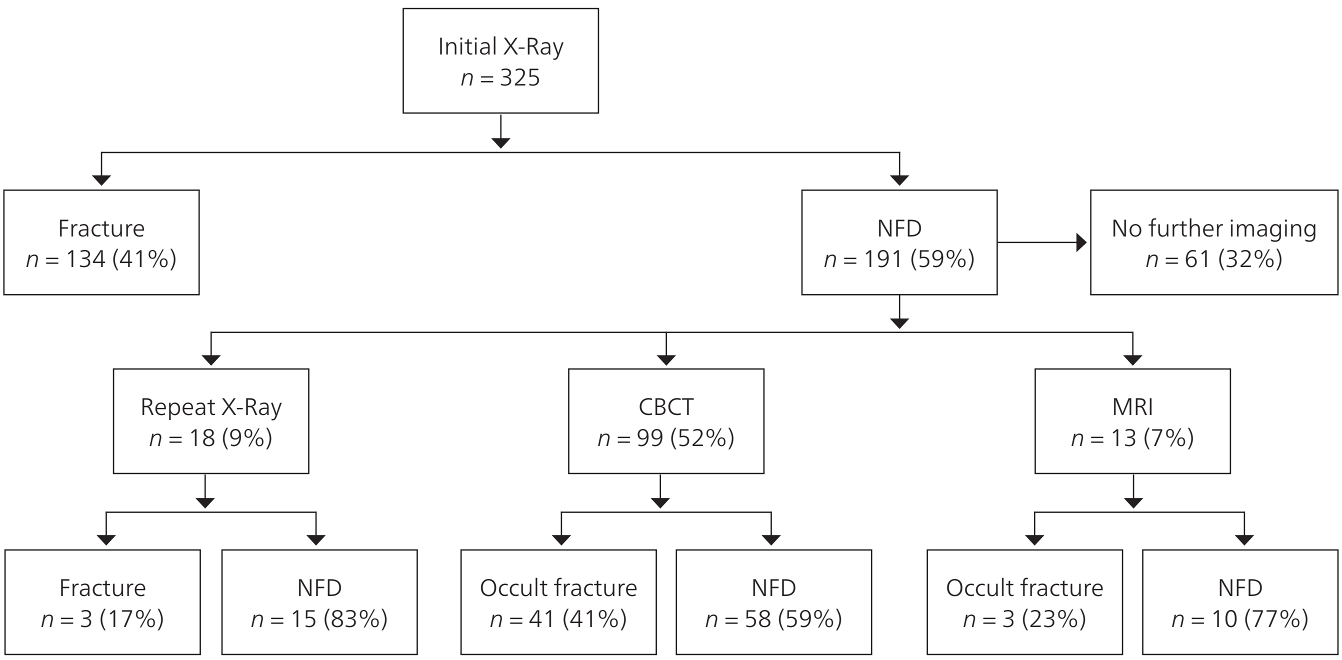
Do X-ray and CBCT identify fractures in significantly different anatomical locations?

Data on all fractures identified on initial X-ray or subsequent CBCT were extracted from the dataset and analysed separately. X-rays detected 90% of distal radius fractures, 80% of scaphoid, 60% of triquetral, 50% of pisiform, and 20% of hamate fractures. No trapezium, capitate, or lunate fractures were visible on X-ray. CBCT subsequently identified nine trapezial, three capitate, and one lunate fracture. No trapezoid fractures were recorded during the study period.

Figure 2 compares fracture detection rates between X-ray and CBCT. While X-rays predominantly identified distal radius and scaphoid fractures, CBCT uncovered a broader range of carpal bone injuries. Fractures of the other carpal bones accounted for 56% of all fractures detected by CBCT, compared to 7% on X-ray. These proportions reflect the distribution of fractures detected by each modality rather than a direct comparison of identical data sets. Statistical analysis revealed a significant difference in fracture detection between X-ray and CBCT ($p < 0.001$), with CBCT demonstrating a markedly higher sensitivity for occult, non-scaphoid carpal fractures.

Figure 1

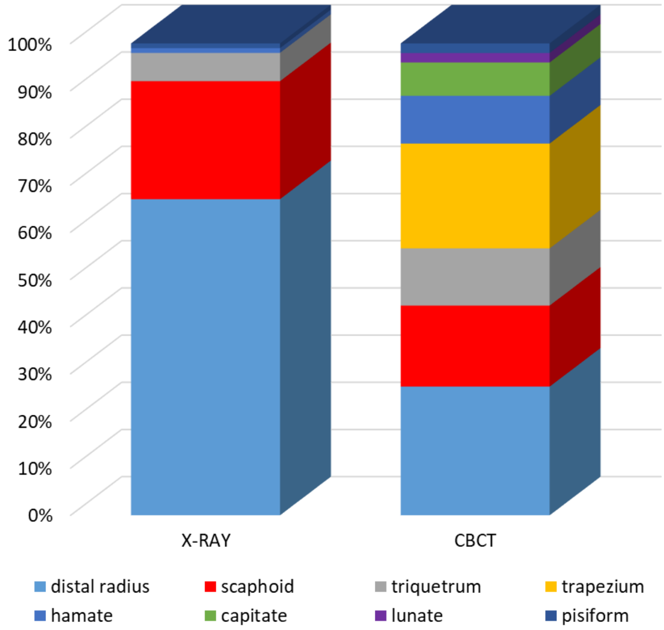
Suspected Radiocarpal Fracture – The Patient Pathway (N = *325*)



Note. CBCT = cone bone computed tomography; MRI = magnetic resonance imaging; NFD = no fracture detected.

Figure 2

Distribution of Fracture Types Identified on Initial X-ray (N = *134) Compared With Occult Fractures Identified on CBCT* (N = *41)*



Note. CBCT = cone beam computed tomography. The CBCT cohort represents a small subset of the total group who underwent initial X-ray, with CBCT performed only when clinically indicated. Percentages shown reflect proportions within each respective cohort rather than equivalent sample sizes.

DISCUSSION

This study aimed to evaluate the diagnostic performance of cone beam computed tomography (CBCT) in detecting radiocarpal fractures, particularly those missed on initial X-ray imaging, in a New Zealand acute care context. The study addressed two key questions: (1) To what extent did CBCT imaging identify radiocarpal fractures that were missed on initial X-ray evaluation? (2) Do X-ray and CBCT identify fractures in significantly different anatomical locations?

X-ray is the preferred initial imaging modality due to its affordability, accessibility, and diagnostic efficiency. International guidelines (American College of Radiology, 2018; Ministry of Health, 2015; NICE National Institute for Health and Care Excellence, 2016), consistently recommend X-ray as the first-line investigation for suspected wrist fractures. While advanced imaging such as MRI or CT may be warranted when X-ray results are inconclusive, X-ray remains the most practical and widely supported initial tool. In this study, three quarters of patients had fractures diagnosed via X-ray imaging, and 97% of all X-ray-detected fractures were identified at first presentation.

Despite the apparent efficacy of radiographic imaging, CBCT identified a substantial number of occult fractures. Nearly a quarter of all radiocarpal fractures were not visible on X-ray imaging. These results are consistent with prior studies highlighting CBCT's superior spatial resolution and ability to detect subtle bony injuries (Krayem et al., 2021; Vitéz et al., 2021). While some researchers advocate CBCT as a new standard for evaluating wrist trauma (Edlund et al., 2016; Gibney, Smith, et al., 2019), others recommend its use as a complementary tool (Borel et al., 2017; Fitzpatrick et al., 2022). The detection rate of occult fractures in this study closely mirrors those previously reported (Borel et al., 2017; Gibney, Murphy, et al., 2019), reinforcing CBCT's diagnostic value in identifying radiographically occult fractures.

A significant difference in fracture detection was observed between X-ray and CBCT. While X-ray primarily identified fractures in the distal radius and scaphoid, CBCT revealed a broader distribution across eight of the nine wrist bones. Notably, X-ray failed to detect any fractures of the trapezium, capitate, or lunate, whereas CBCT identified 13 fractures (trapezium $n = 9$, capitate $n = 3$, lunate $n = 1$) in these bones. These findings suggest that carpal fractures are more prevalent than previously recognised, with historical underdiagnoses likely due to the limitations of standard radiography. This is supported by findings from Krayem et al. (2021), who reported a threefold increase in carpal fracture detection during the CBCT imaging period compared with the X-ray-only period.

Our findings underscore the diagnostic limitations of conventional radiography and highlight the value of CBCT in uncovering a wider array of carpal injuries. This broader detection capability is particularly relevant in the context of scaphoid fractures, which present a well-recognised diagnostic challenge due to the bone's retrograde blood supply (Yang et al., 2021). Timely and accurate diagnosis is essential to prevent non-union, persistent pain, and instability (Berber et al., 2020). In this study, 20% of scaphoid fractures were radiographically occult, consistent with previously reported MRI-based detection rates of 15–22% (Bäcker et al., 2020; Burton et al., 2025; Karl et al., 2015).

The trapezium emerged as a frequently fractured carpal bone, detected on CBCT but not visible on X-ray. Affected patients were predominantly female and had a median age of 56 years. This is clinically important, as tenderness at the first carpometacarpal joint following trauma has historically been attributed to age-related degenerative changes, potentially leading to missed diagnoses of true fractures. Although traumatic thumb pain is generally eligible for ACC cover (Accident Compensation Corporation, 2026), misattribution of post-traumatic symptoms to pre-existing degenerative change can delay recognition of an acute fracture and may complicate the establishment of a clear trauma-related diagnosis (Smithuis et al., 2025). In the New Zealand context, this distinction is important because ACC funding pathways depend on confirming that the presenting condition is attributable to injury rather than degeneration (Accident Compensation Corporation, 2026). Advanced imaging such as CBCT therefore contributes not only to clinical detection but also to ensuring patients access the appropriate funded care pathway. Internationally, Gibney, Murphy, et al. (2019) report that only one in 19 trapezial fractures identified on CBCT were retrospectively detectable on X-ray. Taken together, these results underscore the important role of advanced imaging in uncovering clinically relevant injuries that would otherwise remain undetected, especially in populations where symptoms may be misattributed to other causes.

This study is limited by its retrospective design and single-centre data collection. CBCT was performed only in patients with persistent clinical suspicion of radiocarpal fracture despite negative X-rays, introducing selection bias and potentially affecting the generalisability of findings. A prospective study evaluating all patients with both X-ray and CBCT would yield more accurate incidence rates. Ideally, MRI would be employed as the definitive reference standard for fracture detection (Fitzpatrick et al., 2022). However, implementing a prospective study of comparable scale would require substantial resources and was not deemed feasible by our institution.

The cohort included 88 patients aged ≤ 16 years, and incomplete carpal ossification in this age group may influence fracture visibility and distribution. As the study was designed to reflect real-world presentations to the acute care service, the dataset was analysed as a whole rather than stratified by age. This may limit generalisability to settings with different age distributions, and the findings should be interpreted with this context in mind.

The inclusion of all wrist trauma presentations, rather than restricting the cohort to radiographically occult fractures, improves both the generalisability and clinical applicability of the results. A 10% data quality check revealed a 96% agreement rate between reviewers, indicating a high level of consistency in data extraction and enhancing confidence in the validity of the reported outcomes.

The findings of this study have important implications for physiotherapists working in acute care. Findings support vigilant clinical decision-making when symptoms persist despite negative imaging and justify early referral for specialist assessment. Understanding which fracture locations are commonly overlooked on X-ray helps physiotherapists recognise high-risk injury patterns. Together, this evidence can strengthen patient care pathways, reduce diagnostic delays, and improve early detection of occult fractures in acute care settings. Access to advanced imaging, however, remains variable within New Zealand. At present, CBCT is routinely available only in Christchurch and Hamilton (Pacific Radiology Group, 2026; River Radiology, 2026), despite being widely utilised internationally for the assessment of wrist and carpal injuries (Colville et al., 2022; Krayem et al., 2021). Limited geographic availability may therefore constrain timely diagnosis for patients in regions without local CBCT access, particularly when initial X-ray findings are inconclusive. Although other centres offer MRI and conventional computed tomography, these modalities are less suited to rapid assessment in acute care due to higher cost, longer scan times, and greater radiation exposure for computed tomography. CBCT provides high-resolution imaging at lower radiation doses (Neubauer et al., 2018; Vitez et al., 2021) and lower cost (Health New Zealand – Te Whatu Ora, 2026), making it a practical option for early evaluation of suspected carpal fractures. As CBCT becomes more widely available in New Zealand, its integration into acute care pathways has the potential to support earlier identification of clinically relevant fractures and reduce the likelihood of missed injuries. This may also prompt review of existing referral pathways for advanced imaging, including whether clinicians such as hand therapists should be able to request CBCT when clinically indicated.

In conclusion, CBCT is emerging as a highly effective modality for identifying subtle or occult carpal fractures, providing diagnostic clarity that standard radiographs often fail to achieve. The findings of this Australasian study are consistent with growing European evidence, reinforcing that CBCT improves early fracture detection. For physiotherapists, these results emphasise the importance of recognising when advanced imaging may be appropriate, to avoid missed injuries and support safe, timely management. As more evidence becomes available, it is clear that fractures once hidden can now be identified with greater confidence.

KEY POINTS

1. Standard X-rays miss approximately one in four radiocarpal fractures in patients with acute wrist injuries.
2. Cone beam computed tomography (CBCT) provides high diagnostic accuracy and is a cost-effective option for timely fracture detection.
3. Carpal fractures are more common and more varied than previously recognised, indicating historical under-diagnosis.
4. Physiotherapists should consider the limitations of X-ray imaging and advocate for advanced imaging when clinical suspicion remains high.

DISCLOSURES

No financial support was obtained for this study. There are no conflicts of interest that may be perceived to interfere with or bias this study.

PERMISSIONS

Ethical approval was obtained from the Auckland University of Technology Ethics Committee (reference 24/344).

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CONTRIBUTIONS OF AUTHORS

Design conceptualisation and methodology, JB, NS, and JH; validation, JB, NS, and JH; formal analysis, JB, NS, and JH; data curation, JB, NS, and JH; writing – original draft preparation, JB, NS, and JH; writing – review and editing, JB, NS, and JH; supervision, NS, and JH.

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Appendix A

IMAGING TECHNIQUES

All X-ray and CBCT imaging were performed on-site at the 24-hour clinic. MRI was not available on-site and was outsourced to an alternative provider.

Radiography

Projections for all patients included posteroanterior (PA), oblique, and lateral views of the wrist in the neutral position with an additional scaphoid PA view with 20–30° tube angulation to the head in ulnar deviation. Digital images were obtained with a flat panel detector (Philips Diagnost 4) using voltage of 55 kV, tube current of 2 mAs, and a 110 cm film to focus distance.

CBCT

All CBCT images were obtained using a Planmed Verity extremity CBCT scanner (Planmed Oy). The examination was conducted using a voltage of 96 kV and tube current of 5 mA. Slice reconstruction thickness was 0.2 mm high definition. Field of view was 150 mm × 150 mm. Total scan acquisition time is approximately 25 s, with approximately 30 min of image processing time after the scan. Seven reconstructions (axial 0.6 mm, coronal 0.6 mm, sagittal 0.6 mm, coronal oblique 0.2 mm, sagittal oblique 0.2 mm, and 3D rotate and 3D roll) were sent to the picture archiving and communication system (PACS).

MRI

Images were obtained with a 3T unit (Magnetom Skyra, Siemens Healthcare) and a 16-channel wrist coil (hand/wrist 16, Siemens Healthcare). The protocol consisted of coronal and sagittal slices with two sequences: T1-weighted spin-echo (TR/TE, 553/12; slice thickness, 2 mm) and T2 with fat saturation (TR/TE, 3000/56; slice thickness, 2 mm). A 100-mm field of view with a 512 × 512 matrix was used for each sequence. No gadolinium was injected. Examinations were carried out in the "superman position" (prone with arm extended into the gantry).