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DIAGNOSTIC ACCURACY OF X-RAY COMPARED WITH COMPUTED TOMOGRAPHY FOR DETECTION OF NON-DISPLACED FRACTURES IN PAKISTAN

Amna Akbar[1], Areeba Aslam[2], Muanam Ali Butt[3], Sharka Saddique[4], Alisha Munawar[5], Muhammad Talha Gillani[6], Wajiha Zafar[*7]

[1,2,3,4,5,6]BS in Medical Imaging and Ultrasonography, University of Management and Technology, Lahore, Pakistan
*[*7]Master of Science in Diagnostic Ultrasound, University of Management and Technology, Lahore, Pakistan*

[*7]wajihazafar707@gmail.com

[*7]https://orcid.org/0009-0004-7148-0758

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Corresponding Author: *
Wajiha Zafar

Abstract

Non-displaced fractures may be difficult to identify on conventional radiographs because the fracture fragments remain anatomically aligned and the fracture line can be subtle or occult. This study evaluated the diagnostic accuracy of plain X-ray for detection of non-displaced fractures using computed tomography (CT) as the reference standard. A cross-sectional observational study was conducted over three months in the Radiology Department of Ghurki Trust Teaching Hospital, Lahore, Pakistan. Sixty-two symptomatic patients aged 1–70 years with localized pain, swelling, tenderness, or restricted movement following trauma were included using convenient sampling. Each participant underwent X-ray followed by CT, and findings were compared using a 2×2 diagnostic classification. CT

identified positive findings in 47/62 participants (75.81%), whereas X-ray was positive in 24/62 (38.71%). Against CT, X-ray yielded 20 true positives, 11 true negatives, 4 false positives, and 27 false negatives. The resulting sensitivity was 42.55% and specificity was 73.33%; the derived positive predictive value was 83.33%, negative predictive value 28.95%, and overall accuracy 50.00%. The large number of false-negative radiographs demonstrates the limitation of plain radiography for subtle, non-displaced fractures. X-ray remains useful because it is rapid, inexpensive, widely available, and involves less radiation than CT; however, CT should be considered when clinical suspicion remains high despite a negative or equivocal radiograph. Imaging decisions should balance diagnostic benefit with radiation exposure according to the ALARA principle. Larger multicenter studies using standardized anatomical subgroups and low-dose CT protocols are warranted.

INTRODUCTION

Fractures represent a major cause of morbidity, disability, and healthcare utilization worldwide. A fracture is a disruption of the structural continuity of bone that may range from a small cortical crack to a complete break. The burden is substantial across age groups, with particularly important consequences among older adults with fragility fractures. Global estimates have shown a continuing increase in the absolute number of fracture cases, reinforcing the importance of timely diagnosis and appropriate management (Wu et al., 2021).

A non-displaced fracture is a fracture in which the bone fragments remain in their normal anatomical alignment without significant displacement. These injuries may follow acute trauma, repetitive stress, or underlying weakening of bone. Patients commonly present with localized pain, tenderness, swelling, bruising, restricted movement, or difficulty bearing weight. Because gross deformity may be absent, clinical examination alone cannot reliably exclude a fracture. The diagnostic problem is particularly important when symptoms persist despite an apparently normal initial radiograph.

Plain radiography is commonly used as the first-line imaging examination because it is rapid, inexpensive, widely available, and associated with relatively low radiation exposure (Asim et al., 2026). However, its two-dimensional nature creates superimposition of anatomical structures, and subtle cortical disruptions may be obscured. Non-displaced or occult fractures can therefore be radiographically inconspicuous, particularly in anatomically complex regions. Repeat radiographs after an interval or cross-sectional imaging may be required when clinical suspicion remains high (Miao & Miao, 2023; Smith et al., 2020).

Computed tomography provides cross-sectional imaging with high spatial resolution and multiplanar reconstruction, allowing cortical fracture lines and complex fracture patterns to be assessed from multiple orientations (Mobeen et al., 2026). It is therefore useful when radiographic findings are negative or equivocal and clinical suspicion remains significant. Evidence summarized in the thesis indicates that CT improves detection of complex skeletal injuries and can provide information relevant to treatment planning (Bouche et al., 2022; Szymański & Zdanowicz, 2022; You et al., 2007). Nevertheless, CT exposes patients to more ionizing radiation than conventional radiography and may be less sensitive than MRI for some occult marrow injuries.

The rationale for the present study was the difficulty of detecting subtle non-displaced fractures on X-ray and the need for evidence to guide decisions regarding additional CT imaging. The objective was to evaluate the diagnostic accuracy of X-ray in detecting non-displaced fractures using CT as the reference standard in a Pakistani hospital population.

METHODOLOGY

This study used a cross-sectional observational design. It was conducted over a three-month period in the Radiology Department of Ghurki Trust Teaching Hospital, Lahore, Pakistan. The study population consisted of 62 patients who presented with symptoms associated with suspected non-displaced fractures and underwent both X-ray and CT examinations. Patients were selected by convenient sampling based on availability and eligibility during the study period.

Patients aged 1–70 years of either sex were eligible when they had a history of fall, sports injury, or twisting injury and symptoms such as localized pain over a bone, swelling, tenderness, or restricted movement of the affected limb or joint. Pregnant females, patients who underwent surgical intervention, and patients who did not undergo X-ray were excluded. Data were collected using a structured proforma covering demographic information, mechanism of injury, symptom duration, X-ray views and findings, CT findings, and the comparison between the two modalities.

Plain radiography was performed as the initial examination, with AP, lateral, and/or oblique views selected according to the suspected anatomical region. CT was subsequently performed and its findings were treated as the reference standard for the study comparison. The study questionnaire recorded whether a fracture was visualized on X-ray, whether CT demonstrated an abnormality, and whether the X-ray result matched the CT result.

Diagnostic performance was summarized using a 2×2 contingency table. A true positive was defined as an X-ray positive result with a CT-positive reference result; a true negative as an X-ray-negative result with a CT-negative result; a false positive as an X-ray-positive/CT-negative result; and a false negative as an X-ray-negative/CT-positive result. Sensitivity was calculated as TP/(TP+FN) and specificity as TN/(TN+FP). Positive predictive value, negative predictive value, and overall accuracy were additionally derived from the reported contingency table.

RESULTS

The study included 62 participants. The largest age group was 31–40 years, comprising 16 participants (25.8%), followed by 21–30 years with 12 participants (19.4%). Participants aged 0–10 years represented the smallest group with 3 participants (4.8%). Overall, adults aged 21–40 years constituted the largest portion of the cohort.

Age group (years)	n	Percent
0–10	3	4.8%
11–20	7	11.3%
21–30	12	19.4%
31–40	16	25.8%
41–50	9	14.5%
51–60	9	14.5%
61–70	6	9.7%
Total	62	100.0%

The cohort contained 40 males (64.5%) and 22 females (35.5%). The distribution of examined anatomical regions was broad. Skull plain examinations were the most frequent (23/62; 37.1%), followed by femur joint examinations (7/62; 11.3%). Ankle, shoulder, and knee examinations each accounted for 8.1% of the sample.

Characteristic	n	Percent
Male	40	64.5%
Female	22	35.5%
Total	62	100.0%

Scan area	n	Percent
Lumbar spine	3	4.8%
Skull plain	23	37.1%
Lower limb scan	3	4.8%
Femur joint	7	11.3%
Ankle joint	5	8.1%
Shoulder joint	5	8.1%
Knee joint	5	8.1%
Wrist joint	3	4.8%
Pelvis joint	3	4.8%
Tibial joint	1	1.6%
Skull scan with bone window	1	1.6%
Elbow joint	2	3.2%
Talus joint	1	1.6%
Total	62	100.0%

CT demonstrated positive findings in 47 participants (75.81%) and negative findings in 15 (24.19%). In contrast, X-ray was positive in 24 participants (38.7%) and negative in 38 (61.3%). Thus, CT identified a substantially larger proportion of abnormal examinations than plain radiography.

Imaging result	Positive n (%)	Negative n (%)	Total
X-ray	24 (38.7%)	38 (61.3%)	62
CT	47 (75.81%)	15 (24.19%)	62

Diagnostic Accuracy of X-ray Against CT

	CT positive	CT negative	Total
X-ray positive	20 (32.2%)	4 (6.4%)	24

X-ray negative	27 (43.5%)	11 (17.7%)	38
Total	47 (75.8%)	15 (24.2%)	62

Performance measure	**Value**
True positives	20
True negatives	11
False positives	4
False negatives	27
Sensitivity	42.55%
Specificity	73.33%
Positive predictive value*	83.33%
Negative predictive value*	28.95%
Overall accuracy*	50.00%

The principal diagnostic finding was the high number of false-negative X-ray examinations. Of the 47 CT-positive cases, only 20 were also identified by X-ray, while 27 were missed on radiography. Consequently, the sensitivity of X-ray was 42.55%. Specificity was higher at 73.33%, indicating that a negative CT reference result was more often accompanied by a negative X-ray than a positive CT result was accompanied by a positive X-ray.

The derived positive predictive value of 83.33% indicates that most X-ray-positive cases were also CT-positive, whereas the negative predictive value of 28.95% indicates that a negative X-ray result did not reliably exclude a fracture in this cohort. The overall proportion of correctly classified examinations was 50.00% based on the reported 62-patient contingency table.

DISCUSSION

The present study demonstrates a clear difference between conventional radiography and CT in the detection of non-displaced fractures. CT identified positive findings in 75.81% of the cohort, compared with 38.7% by X-ray. The most important feature of the comparison was not simply the difference in positive rates but the 27 false-negative radiographs among 47 CT-positive cases. This finding indicates that a negative X-ray cannot be considered sufficient evidence to exclude a subtle non-displaced fracture when clinical suspicion remains high.

The lower sensitivity of X-ray is consistent with the physical limitations of projectional imaging. Plain radiographs compress three-dimensional anatomy into two-dimensional projections, allowing overlapping structures to obscure small fracture lines. Patient positioning, fracture orientation, image quality, and the absence of displacement may further reduce conspicuity. CT overcomes much of this limitation by providing cross-sectional images and multiplanar reformations, improving visualization of cortical integrity and fracture orientation.

Previous studies cited in the thesis similarly support the greater diagnostic yield of CT for difficult fracture patterns. Research involving carpal fractures reported markedly improved detection with CT, while studies of ankle and posterior malleolar fractures found that routine radiography could miss clinically important findings that were demonstrated on CT (You et al., 2007; Bouche et al., 2022). A study of talus injuries also reported limited overall sensitivity for plain radiographs compared with CT-based assessment (Fereidooni et al., 2025). These observations support the current finding that cross-sectional imaging can be particularly valuable when the fracture is subtle or the anatomy is complex.

Despite its superior detection performance, CT should not automatically replace X-ray in every trauma patient. Radiography remains fast, inexpensive, widely available, and associated with lower radiation exposure. These advantages are important in settings where access to CT is limited. The more appropriate interpretation of the present results is that CT should be used strategically, particularly for patients with persistent focal symptoms and negative or equivocal radiographs. This approach can improve diagnostic certainty while avoiding unnecessary CT examinations.

Radiation protection is an important consideration. If patients undergo X-ray followed by CT solely because the initial radiograph was unable to demonstrate a subtle fracture, cumulative exposure increases. The thesis therefore emphasizes the ALARA principle—keeping radiation as low as reasonably achievable while maintaining adequate image quality. Where clinically appropriate and technically available, low-dose CT protocols may help reduce this burden.

The study has several limitations. First, the sample size was small at 62 patients, which limits generalizability. Second, convenient sampling was used, so the sample may not represent the broader Pakistani population. Third, the study included multiple anatomical regions rather than focusing on a single fracture site, making site-specific diagnostic performance difficult to establish. Finally, CT was used as the reference standard in the study protocol, whereas MRI can be more sensitive for certain occult injuries involving bone marrow or soft tissues. These limitations should be considered when interpreting the observed sensitivity and specificity.

CONCLUSION

In this hospital-based cohort, plain X-ray demonstrated limited sensitivity for detecting non-displaced fractures when CT was used as the reference standard. CT identified positive findings in 47 of 62 participants (75.81%), while X-ray identified 24 (38.7%). The reported contingency table produced a sensitivity of 42.55% and specificity of 73.33%, with 27 false-negative X-ray examinations. These findings indicate that a negative or equivocal radiograph does not reliably exclude a non-displaced fracture in a patient with persistent clinical suspicion. X-ray remains useful as a rapid and accessible initial test, but CT should be considered when the clinical picture and radiographic findings do not agree. Imaging pathways should balance diagnostic accuracy, timeliness, availability, and radiation exposure in accordance with ALARA principles.

RECOMMENDATIONS

• Use high-resolution X-ray and CT equipment and maintain appropriate image-quality standards.

• Consider CT when clinical suspicion for a non-displaced fracture remains high despite a negative or equivocal X-ray.

• Evaluate low-dose CT protocols where diagnostically appropriate to reduce radiation exposure.

• Conduct larger multicenter Pakistani studies to improve statistical power and external validity.

• Analyze diagnostic performance separately for major anatomical regions such as wrist, hip, ankle, pelvis, and spine.

• Future studies should consider MRI or clinical follow-up as an additional reference when evaluating truly occult fractures.

DECLARATIONS

Ethical considerations: The thesis documents participant consent procedures and states that participant identity would not be revealed in resulting publications. The present manuscript is based on the completed thesis dataset.

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