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Comparison of Foot Bone (*Ossa Pedis*) Angulation in Anteroposterior (AP) Projection with Central Ray at 0°, 10°, and 15° in the Radiology Department of Gunung Jati Hospital

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Abstract

Accurate radiographic visualization of the foot (*ossa pedis*) is essential for reliable diagnosis, given the complex anatomy and overlapping structures of the tarsal region. However, there remains no clear consensus regarding the optimal central ray (CR) angulation for anteroposterior (AP) foot radiography in clinical practice. This study aimed to compare the diagnostic image quality of AP ossa pedis radiographs obtained using CR angulations of 0°, 10°, and 15° at the Radiology Department of Gunung Jati Regional Hospital, Cirebon City. A comparative evaluative design was employed using a standardized digital radiography protocol. All images were acquired with a fixed source-to-image distance of 100 cm and identical exposure parameters (45 kV, 10 mAs) to isolate the effect of CR angulation. Image quality was assessed using blinded Visual Grading Analysis by five expert evaluators based on the visibility of key tarsal and tarsometatarsal joint structures. Quantitative analysis was performed using mean score statistics. The results demonstrated that both 0° and 10° CR angulations yielded superior and equivalent image quality (mean score = 3.2), classified as good, with clearer joint space visualization and minimal anatomical distortion. In contrast, the 15° CR angulation produced a lower mean score (2.8), indicating adequate image quality with increased structural overlap. These findings suggest that 0° and 10° CR angulations are more suitable for routine AP ossa pedis examinations, providing evidence-based support for protocol optimization in clinical radiography practice.

Keywords: Anteroposterior projection, central ray angulation, *ossa pedis*.

1. Introduction

Radiographic assessment of the foot and ankle presents a significant challenge due to the intricate anatomy of this region (Sharma, Karaismailoglu, & Ashkani-Esfahani, 2024). Consequently, obtaining precise anatomical visualization in foot radiography is a fundamental prerequisite for establishing an accurate clinical diagnosis. Clear visualization of the tarsal joint spaces is critical for detecting various pathologies (Galateanu, Apelt, Aizenberg, Saragusty, & Hildebrandt, 2013; Papineni, Mariathas, Sidhu, & Chari, 2024), ranging from subtle non-displaced fractures and degenerative

changes to structural abnormalities of the foot arches. Optimal radiographic quality must effectively minimize the superposition of tarsal bones, which possess complex anatomical inclinations, to ensure that diagnostic information is conveyed clearly without misleading distortions (Adler & Carlton, 2019).

There remains significant ambiguity in technical standards regarding the most effective central ray (CR) angulation for Anteroposterior (AP) foot projections. While some established protocols recommend a 10° posterior angulation to maximally open the intertarsal joint spaces (Lampignano & Kendrick, 2017), there is a notable technical divergence suggesting an angulation of up to 15° cephalad (Lampignano & Kendrick, 2017; Lee, Lee, Kim, Lee, & Choi, 2022; Smith, Reynolds, & Stewart, 1984; Whitley, Sloane, Jefferson, Holmes, & Anderson, 2016), particularly to accommodate morphological variations in patients with high longitudinal arches. This discrepancy in technical parameters indicates a lack of absolute consensus on the specific angulation that provides the most superior anatomical representation across diverse patient populations.

The gap between theoretical guidelines and clinical practice presents a crucial issue at the Radiology Department of Gunung Jati Regional Hospital, Cirebon. In routine procedures, foot examinations are frequently performed using a perpendicular (0°) central ray (Brandenburg et al., 2021; Grande-del-Arco et al., 2020; Kyung et al., 2025). Theoretically, this practice poses a risk of producing radiographs characterized by foreshortening or significant overlap in the tarsal region, as the beam direction does not align with the natural anatomical inclination of the foot bones. This inconsistency between field procedures and international technical literature creates uncertainty in the standardization of diagnostic image quality.

To date, there is a scarcity of comparative studies that comprehensively evaluate the effectiveness of 0°, 10°, and 15° angulations within a single controlled clinical setting (Glowacki et al., 2023). Previous research has largely been limited to comparing only two variations or has relied on literature reviews without the support of robust empirical data from regional hospital settings (Jihad, 2024; Wahyuni, Abduraohman, & Novitasari, 2018). Without clear evidence identifying which angle is superior for visualizing tarsal anatomy, the selection of radiographic techniques at the clinical level will continue to depend on the subjective habits of individual practitioners (Horner, 2013), potentially compromising the objectivity of diagnostic outcomes.

This study aims to address these uncertainties by evaluating and comparing the quality of foot radiographs produced using 0°, 10°, and 15° central ray angulations. The analysis focuses on the clarity of tarsal joint space visualization and the minimization of bone superposition. The findings of this research are expected to

provide evidence-based recommendations for hospitals to establish optimal foot radiography protocols, ensuring that every radiograph produced achieves the highest possible diagnostic value.

2. Method

This study employed a comparative evaluative design to systematically analyze the impact of three distinct central ray (CR) angulations (0°, 10°, and 15°) on the diagnostic quality of *ossa pedis* radiographs. Moving beyond a simple descriptive case study, this research utilized a comparative framework to identify the optimal protocol for visualizing complex tarsal structures. The study was conducted at the Radiology Department of Gunung Jati Regional Hospital, involving patients undergoing routine foot examinations and a panel of five expert evaluators, including four board-certified radiologists and one clinical practitioner, to ensure high-level professional assessment.

To maintain rigorous internal validity and minimize confounding variables, all radiographic acquisitions were strictly standardized using a Digital Radiography (DR) system with a fixed Source-to-Image Distance (SID) of 100 cm. The exposure parameters were kept constant at 45 kV and 10 mAs for all three projections to ensure that variations in image quality were solely attributable to the change in CR angulation rather than fluctuations in radiation output or patient positioning. Each subject was positioned consistently in a seated-upright posture with the plantar surface flat on the detector, ensuring a controlled environment for comparing the 0° perpendicular beam against the 10° and 15° cephalad/cranial angulations.

The diagnostic value of the resulting images was quantified through a structured Visual Grading Analysis (VGA) based on five specific anatomical criteria: the tarsometatarsal, cuneonavicular, talonavicular, and calcaneocuboid joint spaces. To reduce observer bias, the images were evaluated using a blinded approach where respondents scored the visibility of these structures on a four-point scale without knowledge of the specific angulation used. The data were then analyzed using a mean score ($\bar{x}$) statistical approach to provide a quantitative basis for determining the most effective angle. This method transformed qualitative expert observations into measurable data, allowing for a definitive empirical ranking of the three techniques based on their ability to provide an optimal, unobstructed view of the tarsal anatomy.

3. Results and Discussion

3.1. Results of the Ossa Pedis Examination

Based on research conducted at the Radiology Department of Gunung Jati Regional Hospital, Cirebon, regarding examination of the ossa pedis using different

tube angulations in the anteroposterior (AP) projection, the following data were obtained:

1. Preparation of Equipment and Materials:

a. Digital Radiography X-Ray Machine
b. Detector, size 35 x 43 cm
c. Digital Radiography Workstation
d. Dry Imager Carestream
e. Ossa Pedis Examination Technique

2. Anteroposterior (AP) Projection Ossa Pedis Examination Technique with 0° (perpendicular) Beam Angulation

a. The patient is positioned sitting on the examination table with the examined leg bent and the plantar surface of the foot resting on the table. The central ray is set at 0° (perpendicular), with the central point at the midpoint of the examined object and the collimation field appropriately sized according to the object. The Source-to-Image Distance (SID) used is 100 cm. The exposure factors used are 45 kV and 10 mAs.

Figure 1. Examination of the ossa pedis using a 0° central ray.
(Department of Radiology, Gunung Jati Regional Hospital, Cirebon, 2025)

b. Anteroposterior (AP) Projection Radiography Technique for the Pedal Bones with 10° Cephalad Beam Angulation

The patient is positioned sitting on the examination table with the examined knee flexed and the plantar surface of the foot flush against the table. The central ray is directed 10° cephalad, centered at the midpoint of the region of interest, with a collimation field adjusted appropriately to the area. A Source-to-Image Distance (SID) of 100 cm is used. Exposure parameters are set at 45 kV and 10 mAs.

Figure 2. Examination of the Foot Bones (Ossa Pedis) Using A Central Ray Angled At 10 Degrees
(Source: Radiology Department, Gunung Jati Hospital, Cirebon, 2025)

c. Evaluation of radiographic image results of the ossa pedis in the anteroposterior (AP) projection with a central ray at 0° (perpendicular), 10°, and 15°.

Figure 4. Visualization results of the ossa pedis with a central ray angle of 0°
(Radiology Department, Gunung Jati Hospital Cirebon, 2025)

Results of radiographic visualization of the ossa pedis using a 10° cephalad beam angulation.

Figure 5. Result of the ossa pedis visualization with a central ray angulation of 10°.

(Radiology Department, Gunung Jati Hospital, Cirebon, 2025)

Results of radiographic visualization of the ossa pedis using a 15° cranial beam angulation.

Figure 6. Result of the ossa pedis visualization with a central ray angulation of 15°.

(Radiology Department, Gunung Jati Hospital, Cirebon, 2025)

3.2. Results of the Ossa Pedis Examination

The evaluation of the ossa pedis images using angulation was conducted by distributing questionnaires to five respondents. The criteria assessed for the ossa pedis images using anteroposterior (AP) projection angulation were: visibility of the ossa pedis structure, visibility of the tarsometatarsal joint, cuneonavicular joint, talonavicular joint, and calcaneocuboid joint. Based on the data obtained after all responses were collected, the data were analyzed and processed using the mean statistical analysis method:

$$\bar{x} = \frac{\Sigma n \times f}{\Sigma f}$$

Subsequently, the questionnaire assessment results are presented in the Table 1 below.

Table 1. Results of the Assessment of Radiographic Images of the Ossa Pedis in the Anteroposterior (AP) Projection

Angulation	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5
0°	A	B	A	C	B
10°	C	A	B	A	B
15°	B	C	C	B	A

Based on the data presented in Table 1, the results were subsequently processed into analyzable data using a statistical approach with a weighted mean analysis, as presented in Table 2 below.

Table 2. Data processing of Radiographic Image Assessment Results of the Ossa Pedis in the AP Projection with 0° Angulation (Perpendicular)

No.	Score	N	f	nxf
1.	A	4	2	8
2.	B	3	2	6
3.	C	2	1	2
4.	D	1	0	0
	Total		5	16
	Mean			$\bar{x} = \frac{\Sigma nxf}{\Sigma f} = \frac{16}{5} = 3,2$

Table 2 shows that among the five respondents, none assigned a score of 1 for the use of 0° (perpendicular) angulation. Two respondents assigned a score of 4, two respondents assigned a score of 3, and one respondent assigned a score of 2. The statistical calculation indicates that the mean value for the 0° (perpendicular) angulation is 3.2, which is therefore categorized as good.

Table 3. Data processing of Radiographic Image Assessment Results of the Ossa Pedis in the AP Projection with 10° Cephalad Angulation

No.	Score	N	F	nxf
1.	A	4	2	8
2.	B	3	2	6
3.	C	2	1	2
4.	D	1	0	0
	Total		5	16
	Mean			$\bar{x} = \frac{\Sigma nxf}{\Sigma f} = \frac{16}{5} = 3,2$

Based on Table 3, it can be observed that among the five respondents, none assigned a score of 1 for the use of a 10° cephalad angulation. Two respondents assigned a score of 4, two respondents assigned a score of 3, and one respondent

assigned a score of 2. The statistical analysis shows that the mean value for the 10° cephalad angulation is 3.2, and this result is categorized as good.

Table 4. Data Processing Table of Research Results on Radiographic Imaging of the Pedal Bones (Ossa Pedis), AP Projection with a 15° Cranial Angulation

No.	Score	N	F	nxf
1.	A	4	1	4
2.	B	3	2	6
3.	C	2	2	4
4.	D	1	0	0
	Total		5	14
	Mean			$\bar{x} = \frac{\Sigma nxf}{\Sigma f} = \frac{14}{5} = 2,8$

Based on Table 4, it can be observed that among the five respondents, none assigned a score of 1 for the use of a 15° cranial angulation. One respondent assigned a score of 4, two respondents assigned a score of 3, and the remaining two respondents assigned a score of 2. The statistical calculation indicates that the mean score for the 15° cranial angulation is 2.8, which is therefore classified as adequate.

3.3 Discussion

Radiographic examination of the ossa pedis is a crucial diagnostic procedure for evaluating bone and joint abnormalities of the foot, particularly in the tarsal and tarsometatarsal regions. The quality of radiographic images is significantly influenced by the accuracy of the examination technique, including the selection of projections and central ray angulation. Variations in the angle of the central ray have the potential to affect the degree of anatomical distortion, superimposition of structures, and the clarity of joint spaces, thereby directly impacting the accuracy of radiological interpretation.

In this context, this study focuses on comparing the image quality of anteroposterior (AP) projection radiographs of the ossa pedis using three central ray angulation variations: 0°, 10°, and 15°. Assessment was systematically conducted by respondents using a structured questionnaire instrument emphasizing the visibility of the major bone and joint structures of the foot. This approach enables an objective evaluation of the influence of each angulation on the resulting radiographic image quality.

Based on the observation results and completed questionnaires from respondents regarding the influence of angulation on the image quality of the tarsal bones at the Radiology Department of Gunung Jati Regional Hospital in Cirebon, findings have been obtained that can serve as the basis for discussion. In general, differences in angulation angles showed variations in the quality of anatomical visualization of the ossa pedis, particularly in the tarsal and tarsometatarsal joints, which were the primary focus of the evaluation.

The ossa pedis examination technique in this study was performed using central ray angulation variations of 0° (perpendicular), 10° cephalad, and 15° cranial. The patient was positioned sitting on the examination table with the knee flexed, so that the plantar surface of the foot was flat against the table. The central ray was directed to the midpoint of the object with the collimation field adjusted to the examination area. The exposure parameters used included a Source Image Distance (SID) of 100 cm, a tube voltage of 45 kV, and a current-time product of 10 mAs. The examination required no specific preparation other than the removal of footwear and metallic objects from the area of interest.

The analysis results indicate that the use of 0° central ray angulation yielded an average score of 3.2, categorized as good. This suggests that a perpendicular central ray is capable of providing a clear anatomical image of the ossa pedis with minimal distortion. The visualization of the tarsometatarsal joints and main bone structures appeared relatively optimal, thereby supporting diagnostic evaluation accuracy for certain clinical conditions.

The 10° cephalad central ray angulation also yielded an average score of 3.2 with a good category, indicating image quality equivalent to that of the 0° angulation. This finding aligns with the recommendations of Lampignano & Kendrick (2017) and Long, Curtis, & Smith (2016), who state that a 10° cephalad angulation for the AP projection of the ossa pedis can help open the tarsometatarsal joint spaces and reduce bone structure superimposition. Additionally, research by Wahyuni et al. (2018) concerning the effect of X-ray beam angle on the radiographic appearance of the tarsal bones in anteroposterior (AP) foot examinations confirmed that an angle of 10° produced images with more open joint spaces and clearer tarsal bone anatomy compared to using a 0° (perpendicular) beam angle. Thus, this angle can be considered an effective alternative in clinical practice without compromising image quality.

Conversely, the use of 15° cranial angulation resulted in a lower average score of 2.8, categorized as fair. Although it still provides an acceptable image for diagnostic purposes, the increased angulation tends to introduce geometric distortion and potential overlapping of certain anatomical structures. This finding is partially consistent with the opinion of (Whitley et al., 2016), who mention that a 15° cranial angulation or image receptor elevation can enhance the visualization of certain tarsal joints; however, under certain conditions, it may conversely reduce the clarity of other structures if not adjusted to the patient's anatomical characteristics.

4. Conclusion

This study demonstrates that central ray angulation significantly influences the image quality of anteroposterior (AP) radiographs of the ossa pedis. Both 0° (perpendicular) and 10° cephalad angulations produced comparable and superior

image quality, each achieving a mean score of 3.2 and classified as good. These angulations provided clearer visualization of the ossa pedis anatomy and joint spaces, particularly in the tarsometatarsal region, with minimal distortion and superimposition. In contrast, a 15° cranial angulation resulted in a lower mean score of 2.8, categorized as adequate, indicating increased geometric distortion and reduced clarity of certain anatomical structures. Overall, the findings suggest that 0° and 10° cephalad central ray angulations are more optimal for routine AP ossa pedis examinations in clinical radiography practice, in line with established radiographic guidelines.

Several limitations should be acknowledged. The study involved a relatively small number of respondents and was conducted at a single institution, which may limit the generalizability of the findings. In addition, image quality assessment relied on subjective evaluations using questionnaires, without quantitative image quality metrics or diagnostic accuracy outcomes. Future research is therefore recommended to include larger, multi-center samples, incorporate objective image quality measurements, and evaluate clinical diagnostic performance across a broader range of patient anatomical variations. Such studies would strengthen evidence-based recommendations for selecting the most appropriate central ray angulation in AP ossa pedis radiography and contribute to further optimization of radiographic examination protocols.

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