

PRELIMINARY RADIOGRAPHIC CLASSIFICATION OF FIRST METATARSAL OSTEOTOMY HEALING FOLLOWING MINIMALLY INVASIVE HALLUX VALGUS SURGERY

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Background:

- Minimally invasive or percutaneous surgery (MIS) for hallux valgus correction has seen increased adoption because of a growing evidence base of positive clinical and radiographic outcomes following surgery.
- However, no standardized or validated radiographic classification exists to evaluate the first metatarsal osteotomy healing following MIS hallux valgus surgery.
- The aim was to develop a new radiographic classification system for assessing bone healing following MIS distal transverse osteotomy for hallux valgus.

Methods:

- A 4-domain radiographic classification system based on callus formation, anteroposterior (AP) osteotomy line, lateral osteotomy line, and remodeling for MIS osteotomy healing was developed and tested on a cohort of 27 feet that underwent percutaneous transverse osteotomy for hallux valgus correction.
- Patients had simultaneous postoperative weightbearing computed tomography (WBCT) and standard radiographs following surgery.
- Five surgeons reviewed anonymized radiographs to evaluate interobserver reliability. WBCT was used to confirm union status and classification interpretation.

Results:

- The classification system demonstrated substantial interobserver reliability for lateral osteotomy line (Fleiss kappa = 0.671, 95% CI 0.505-0.814) and AP osteotomy line assessment (Fleiss kappa = 0.664, 95% CI 0.459-0.811), with moderate agreement for callus formation (κ = 0.465) and remodeling (κ = 0.439).
- The classification showed strong correlation with WBCT findings, with an optimal threshold of 8 points identified to differentiate union from nonunion, achieving an overall classification accuracy of 85.2%.
- This finding was supported by the area under the receiver operating characteristic (ROC) curve of 0.832. At the optimal threshold, the classification demonstrated 90.0% sensitivity and 71.4% specificity for detecting union.

Conclusion:

- This preliminary classification provides a reliable tool for assessing first metatarsal bone healing following MIS hallux valgus osteotomies, with substantial interobserver reliability.
- It offers a standardized approach for radiographic evaluation, which may enhance comparability across studies and serve as a radiographic research tool pending further validation. Its clinical applicability remains to be determined.

Figure 1. Stages of healing and pattern of remodeling following percutaneous hallux valgus surgery using a distal extra-articular transverse osteotomy.



Figure 3. Flowchart demonstrating the methodology of the study.

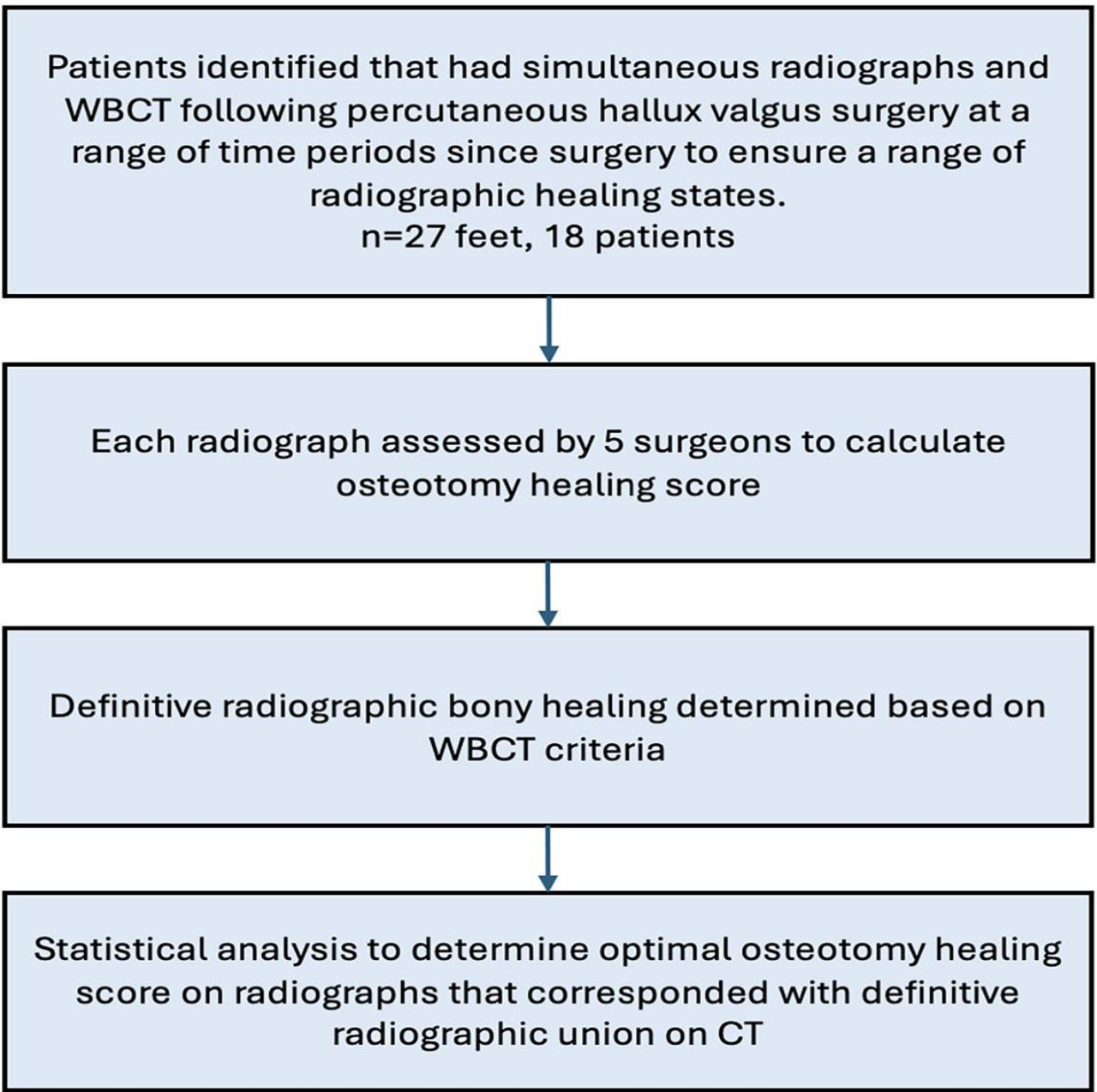


Table 1. Classification and Scoring Guide for Percutaneous Osteotomy Healing on Radiographs: The Percutaneous Osteotomy Healing Score.

Score	Callus Formation	Osteotomy Line (AP XR)	Osteotomy Line (Lateral XR)	Remodeling ^a	Total Score	Stage of Union
3	Homogenous	Not visible	Not visible	Lateral, medial, and central	Calculate total score by adding up the score for each column	≥8 Achieved
2	Massive- bone trabeculae-crossing osteotomy	Faintly visible—indistinct	Faintly visible—indistinct	Medial and central		
1	Apparent: Bridging of osteotomy site	Discernible	Dorsal osteotomy line visible	Central only		6-8 Uncertain
0	No callus seen Extensive hypertrophic	Clearly visible	Clearly visible	None		<6 Nonunion

Abbreviations: AP, anteroposterior; XR, radiograph.
^aRemodeling based relative to the medial and lateral cortex of the proximal first metatarsal fragment. Lateral: bone formation and remodeling lateral to the proximal screw; central: bone formation and remodeling between the proximal and distal screw; medial: bone formation and remodeling medial to the distal screw.

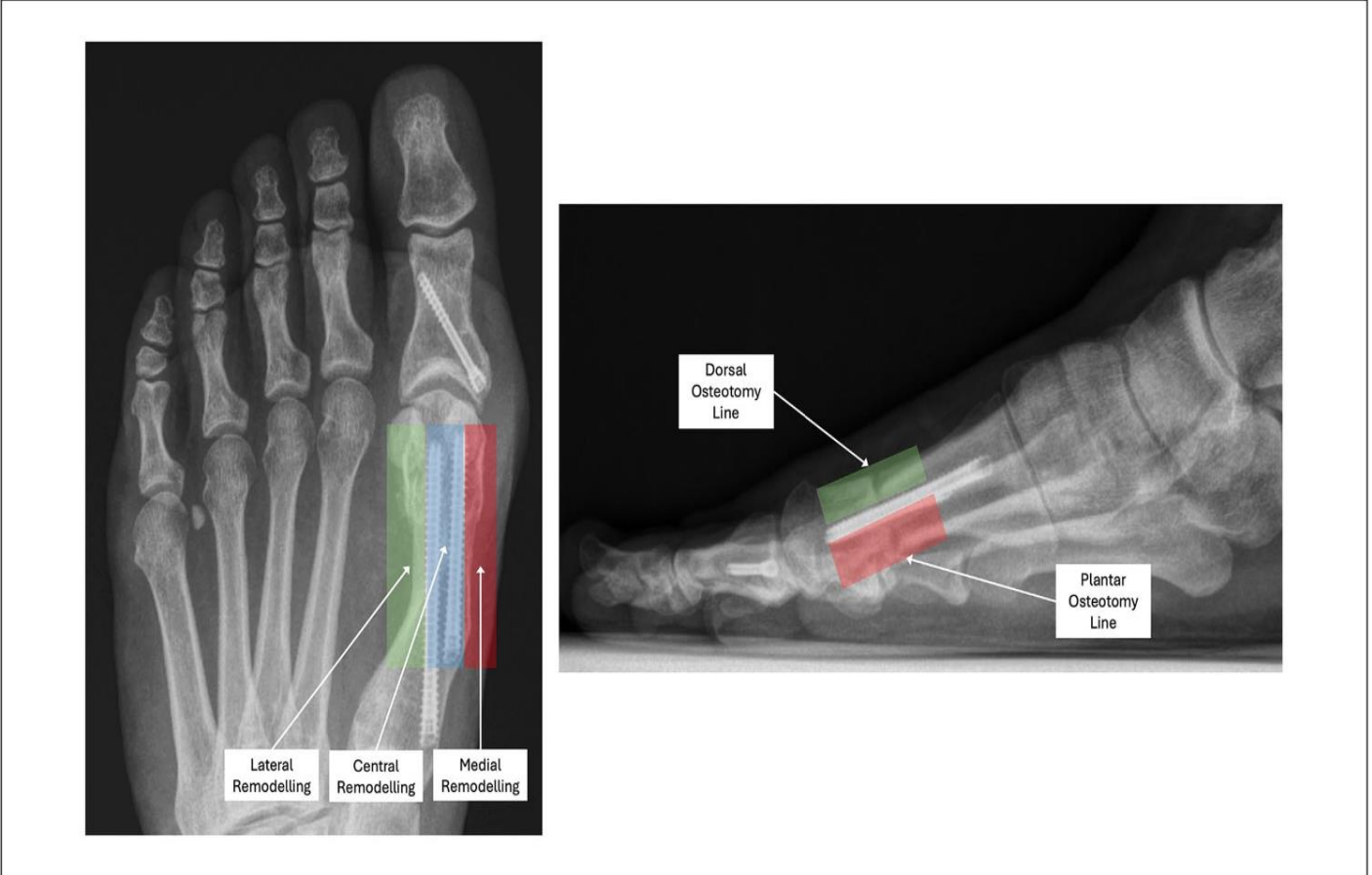


Figure 2. Illustrated anteroposterior and lateral radiographs highlighting key radiographic features of the percutaneous osteotomy healing classification including medial, central, and lateral remodeling zones and the presence of visible osteotomy lines.

Table 4. Contingency Table Based on Classification Threshold of 8 to Identify Bony Union.

Classification Outcome (Score >8)	Union Confirmed on WBCT	Nonunion Confirmed on WBCT
Union achieved	18	2
Union not achieved	2	5

Abbreviation: WBCT, weightbearing computed tomography.

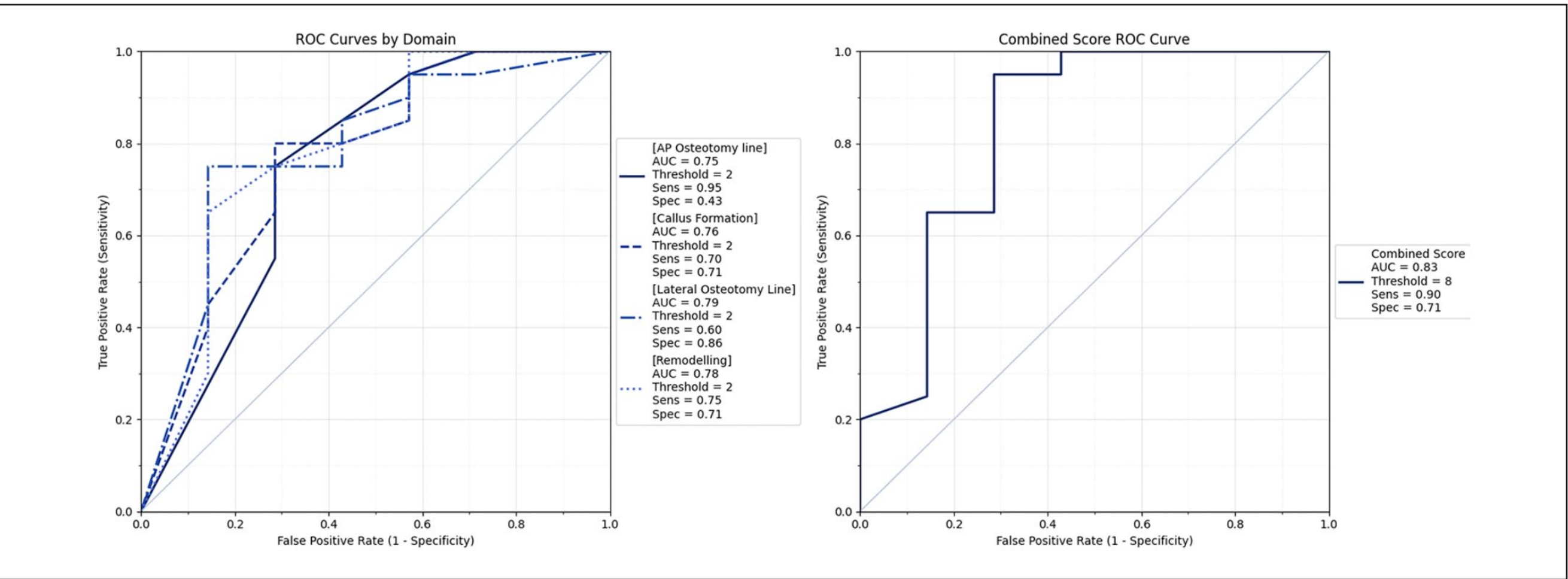


Figure 4. Receiver operating characteristic (ROC) analysis of osteotomy healing classification system. (Left) Individual domain ROC curves demonstrating varying diagnostic performance. (Right) Combined score ROC curve showing improved diagnostic performance with an optimal score threshold of 8.00. Diagonal reference lines represent random chance (area under the curve = 0.5).