Is the Distal Tibial Slope Associated With Medial Osteochondral Lesions of the Talus? A Radiographic Case-Control Study

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Research Article

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Abstract

Background: Medial osteochondral lesions of the talus (OLT) are a recognized cause of chronic ankle pain, yet the morphologic factors associated with them remain incompletely understood. This study evaluated whether the distal tibial slope measured on weight-bearing lateral ankle radiographs is associated with medial OLT.

Methods: In this retrospective case-control study, 76 patients with medial OLT confirmed on magnetic resonance imaging and 170 control subjects without OLT were included. Distal tibial slope was calculated from the anatomic anterior distal tibial angle on weight-bearing lateral radiographs. Logistic regression and receiver operating characteristic (ROC) analyses were performed.

Results: Distal tibial slope was significantly lower in the medial OLT group than in controls (5.10 vs 6.60, $P < .001$). Each 1° decrease in distal tibial slope was associated with increased odds of medial OLT (OR 1.26; 95% CI 1.12–1.42). ROC analysis yielded an area under the curve of 0.66. A threshold value of ≤4.6° was associated with a threefold increased likelihood of medial OLT (OR 3.02; 95% CI 1.71–5.33), with 44.9% sensitivity and 77.6% specificity.

Conclusion: A decreased distal tibial slope on weight-bearing lateral radiographs was associated with medial osteochondral lesions of the talus. Although its discriminatory performance was modest, distal tibial slope may represent a subtle radiographic morphologic parameter associated with medial OLT rather than a diagnostic criterion. Further prospective and biomechanical studies are needed to clarify its clinical relevance.

Background

Osteochondral lesions of the talus (OLT) are focal abnormalities of the articular cartilage and subchondral bone and are a recognized cause of chronic ankle pain [1]. These lesions most commonly involve the medial or lateral talar dome, with medial lesions occurring more frequently and often without a clearly defined traumatic mechanism [2–4]. Although trauma and repetitive microstress are established contributors, the role of underlying morphologic factors remains incompletely understood [5].

Previous studies have explored associations between foot and ankle morphology and the occurrence of OLT. Radiographic parameters such as the calcaneal inclination angle, lateral talocalcaneal angle, and Meary angle have been investigated, and some reports have suggested associations between these measurements and medial OLT [6–9]. However, these parameters primarily reflect hindfoot or midfoot alignment and may not directly characterize the sagittal orientation of the distal tibial articular surface.

Furthermore, some studies have examined sagittal-plane morphology to better clarify the etiology of OLT, mainly by focusing on talar shape and position, such as the TAS/TAL ratio [10]. However, sagittal-plane investigations have largely remained limited to the talus or more distal foot structures, whereas the sagittal orientation of the distal tibial articular surface has received little attention. Because sagittal joint orientation may influence ankle kinematics, contact area, and load distribution, evaluating distal tibial morphology may provide additional insight into the development of medial OLT.

The anatomic anterior distal tibial angle (aADTA) is an important parameter for assessing sagittal alignment of the distal tibial articular surface [11]. Because sagittal distal tibial orientation may influence ankle kinematics, joint contact area, and load distribution, distal tibial slope (DTS), calculated as 90° minus aADTA, was used in the present study to evaluate its association with medial OLT. We hypothesized that a lower DTS may be associated with altered load transfer across the medial talar dome. Therefore, the aim of this study was to investigate the association between aADTA-derived DTS and medial OLT and to compare this parameter with other radiographic foot morphology measurements.

Methods

This single-center, observational study retrospectively evaluated patients who presented to the orthopedic outpatient clinic with ankle pain between 2013 and 2023 and were diagnosed with medial osteochondral lesions of the talus (OLT) on magnetic resonance (MR) imaging. Eligible patients were identified retrospectively from the institutional MRI database, and the study cohort represented a consecutive series.

All ankle MRI examinations were evaluated using T1- and T2-weighted sequences acquired in the sagittal, coronal, and axial planes. Imaging was performed on 1.5-T Siemens Symphony and Aera (Erlangen, Germany) MRI systems with dedicated ankle coils. A medial OLT was defined as a cartilage surface irregularity or defect accompanied by subchondral bone edema (Fig. 1). Lesion localization was classified according to Raikin’s nine-zone anatomical grid system, and lesions located in the medial column (zones 1, 4, and 7) were included [12]. Lesions were staged using Anderson’s MRI classification, and only Grade II–IV lesions were included [13].

In this study, magnetic resonance imaging was used to confirm the presence, localization, and grade of osteochondral lesions. Because the primary focus of the study was the evaluation of sagittal radiographic morphology, detailed MRI-based quantitative parameters such as lesion size, depth, associated soft-tissue abnormalities, and the relationship between DTS and lesion severity were not included in the analysis.

Exclusion criteria included prior foot or ankle fracture or surgery, congenital foot deformity (pes planus/cavus, tarsal coalition), documented chronic ankle instability based on clinical records, Charcot arthropathy, infection, and tumor. Additionally, patients with advanced osteoarthritis—defined as Kellgren–Lawrence grade 3–4 with marked degeneration and osteophyte formation—were excluded from the study [14].

Approximately 600 ankle MRI scans were reviewed. After applying the exclusion criteria, 76 patients diagnosed with medial OLT on MRI (23 males, 53 females; mean age: 45.20 ± 10.30 years) constituted the study group. The control group consisted of 170 patients (61 males, 109 females; mean age: 42.4 ± 11.65 years) who underwent ankle magnetic resonance imaging due to ankle pain or discomfort, in whom no medial or lateral OLT was detected, and who had similar age and sex distributions to the study group after applying the exclusion criteria. Only one ankle per patient was included in the analysis.

Weight-bearing lateral ankle radiographs retrieved from the PACS (Picture Archiving and Communication System) were used for radiological assessment. For inclusion, each radiograph was required to demonstrate a clearly visualized tibiotalar joint line and an acceptable lateral projection with minimal rotational malpositioning. Because aADTA and the derived DTS may be influenced by foot rotation and beam angle, only radiographs considered appropriate for measurement quality were included. The following parameters were measured (Figs. 2 and 3):

- Anatomic anterior distal tibial angle (aADTA)
- Distal tibial slope (DTS)
- Calcaneal inclination angle (CIA)
- Lateral talocalcaneal angle (LTCA)
- Böhler angle (BA)
- Gissane angle (GA)
- Meary angle (MA)

To evaluate distal tibial joint orientation, the anatomic anterior distal tibial angle (aADTA) was measured according to the method described by Magerkurth et al [11]. Two cortical circles were placed 5 cm and 10 cm proximal to the joint line on the tibial diaphysis, and the centers of these circles were connected to establish the tibial longitudinal axis. The angle between this axis and the distal tibial articular surface was recorded as the aADTA. The distal tibial slope (DTS), as defined in this study based on the proximal tibial slope, was calculated using the 90° – aADTA formula (normal value: 83° ± 3.6°).

The calcaneal inclination angle (CIA) was measured as the angle between a line drawn from the plantar aspect of the calcaneus to the plantar surface of the first metatarsal head and a line connecting the most plantar aspects of the calcaneal tuberosity and the anterior calcaneus (normal value: 20°–30°) [15].

The lateral talocalcaneal angle (LTCA) was defined as the angle between the mid-talar axis and the calcaneal inclination axis on weight-bearing lateral ankle radiograph (normal value: 35°–50°) [16,17].

The Böhler angle (BA) was measured as the angle between a line from the posterior superior aspect of the calcaneus to the highest point of the posterior subtalar joint surface and a line from the highest point of the anterior calcaneal process to the posterior margin of the subtalar surface (normal value: 20°–40°) [18].

The Gissane angle (GA) was measured as the angle formed between the posterior joint facet and the anterior process of the calcaneus (normal value: 120°–145°) [19].

The Meary angle (MA) (talus–first metatarsal angle) was defined as the angle between a line bisecting the talar body, neck, and head and the longitudinal axis of the first metatarsal (normal value: 0° ± 4°) [20].

Two orthopedic surgeons independently and blindly performed all radiological measurements on two separate occasions to assess intraobserver reliability. Patients diagnosed with medial OLT and individuals in the control group were compared in terms of radiological morphological parameters, including DTS, CIA, LTCA, BA, GA, and MA.

Ethical approval was obtained for this study (approval no: 2025/6087). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA). Because of the retrospective design of the study, an a priori sample size estimation was performed assuming equal group sizes. Using G*Power software (version 3.1.9.4; Heinrich-Heine University, Düsseldorf, Germany), a medium effect size (Cohen's d = 0.5), a two-sided alpha level of 0.05, and a minimum statistical power of 80% were assumed, indicating that at least 64 patients per group were required. In addition, after completion of the statistical analyses, a post hoc power analysis was performed for the primary outcome variable, distal tibial slope (DTS), and the achieved statistical power with the available sample size was calculated to be 98.9%.

Interobserver agreement was assessed using a two-way random-effects intraclass correlation coefficient with absolute agreement (ICC[2,1]), and intraobserver reliability was assessed using a two-way mixed-effects model (ICC[3,1]). All ICC values were reported with 95% confidence intervals.

The distribution of continuous variables was evaluated using the Shapiro–Wilk test. Parameters with a normal distribution were expressed as mean ± standard deviation (SD), whereas non-normally distributed parameters were presented as median (minimum–maximum) values. Categorical variables were reported as numbers and percentages (%).

For comparisons between groups, the independent samples t-test was used for normally distributed variables, whereas the Mann–Whitney U test was applied for non-normally distributed variables. The chi-square test was used for the comparison of categorical variables such as sex.

The relationship between the presence of medial OLT and distal tibial slope or other radiological parameters was evaluated using univariate logistic regression analysis, and the resulting odds ratios (OR) were reported with 95% confidence intervals (CI).

$P < .05$ was considered statistically significant for all analyses.

Results

The intraobserver and interobserver reliability of the radiological measurements ranged from moderate to excellent, with ICC values ranging from 0.64 to 0.95 (Table 1).

Table 1. Intraclass correlation coefficients (ICC) and 95% confidence intervals for radiological measurements by two observers.

Parameters	Intra-rater observer-1/ Intra-rater observer-2 / Interrater	
	Medial OLT	**Control**
DTS (°) (90° − aADTA)	0.93 (0.88–0.95) / 0.82 (0.71–0.88) / 0.89 (0.84–0.93)	0.95 (0.94–0.96) / 0.83 (0.78–0.87) / 0.90 (0.87–0.93)
CIA (°)	0.83 (0.73–0.89) / 0.77 (0.67–0.85) / 0.76 (0.64–0.83)	0.86 (0.81–0.89) / 0.84 (0.79–0.88) / 0.84 (0.78–0.88)
LTCA (°)	0.76 (0.40–0.89) / 0.77 (0.43–0.91) / 0.64 (0.20–0.83)	0.77 (0.51–0.90) / 0.76 (0.49–0.89) / 0.72 (0.44–0.86)
BA (°)	0.93 (0.90–0.95) / 0.77 (0.69–0.84) / 0.86 (0.80–0.90)	0.95 (0.94–0.97) / 0.79 (0.72–0.85) / 0.90 (0.86–0.92)
GA (°)	0.74 (0.52–0.87) / 0.75 (0.54–0.86) / 0.72 (0.49–0.85)	0.81 (0.76–0.86) / 0.75 (0.68–0.81) / 0.76 (0.67–0.82)
MA (°)	0.91 (0.85–0.94) / 0.85 (0.78–0.89) / 0.86 (0.79–0.90)	0.89 (0.85–0.92) / 0.87 (0.81–0.91) / 0.86 (0.81–0.89)

Abbreviations: DTS, distal tibial slope; aADTA, anatomic anterior distal tibial angle; CIA, calcaneal inclination angle; LTCA, lateral talocalcaneal angle; BA, Böhler angle; GA, Gissane angle; MA, Meary angle; OLT, osteochondral lesion of the talus.

The mean age was 45.20 ± 10.30 years in the medial OLT group and 42.40 ± 11.65 years in the control group, with no statistically significant difference between the groups (P = .08). There was also no significant difference between the groups in terms of sex distribution (P = .476) (Table 2).

Table 2. Comparison of age and sex distribution between patients with medial OLT and the control group.

	Medial OLT (n=76)			Control group (n=170)			
	n	Mean±SD	Min-Max	n	Mean±SD	Min-Max	P
Age (year)	76	45.20±10.30	19-60	170	42.40±11.65	18-60	.08
Sex/		-	-		-	-	.476
Male	23			61			
Female	53			109			

Abbreviations: OLT, osteochondral lesion of the talus; n, number; SD, standard deviation.

Radiological parameters that did not demonstrate a normal distribution were summarized as median (minimum–maximum) values. Among the measured parameters, only DTS showed a statistically significant between-group difference (*P* < .001). In the logistic regression analysis, each 1° decrease in DTS was associated with an odds ratio of 1.26 (95% CI: 1.12–1.42) (Table 3).

Table 3. Comparison of radiological parameters between medial OLT and control groups and univariate logistic regression analysis

Parameter	Medial OLT (n=76) Median (min–max)	Control (n=170) Median (min–max)	P	OR (95% CI)
DTS (°) (90° – aADTA)	5.10 (1.00–14.00)	6.60 (0.70–14.50)	**< .001**	**1.26 (1.12–1.42)**
CIA (°)	23.85 (9.30–44.80)	24.20 (4.00–46.50)	.112	1.06 (0.98–1.15)
LTCA (°)	43.35 (31.30–112.10)	44.60 (31.80–126.80)	.382	0.98 (0.92–1.04)
BA (°)	33.80 (19.20–42.50)	31.05 (10.60–55.00)	.116	0.96 (0.90–1.02)
GA (°)	111.50 (97.50–156.00)	113.25 (83.40–136.10)	.064	1.03 (1.00–1.06)
MA (°)	9.80 (-19.10–31.10)	6.70 (-32.40–32.80)	.061	0.95 (0.90–1.00)

Abbreviations: DTS, Distal tibial slope; Aadta, Anterior distal tibial angle; CIA, Calcaneal inclination angle; LTCA, Lateral talocalcaneal angle; BA, Böhler angle; GA, Gissane angle; MA, Meary angle; OLT, Osteochondral lesion of the talus; OR, Odds ratio; CI, Confidence interval.

Footnote: Odds ratios (ORs) represent the change in odds of medial OLT per 1° decrease in DTS and per 1° increase in the remaining radiological angular parameters.

No significant differences were observed between groups for the remaining radiological parameters (CIA, LTCA, BA, GA, and MA; all P > .05) (Table 3).

ROC curve analysis performed for distal tibial slope revealed an area under the curve (AUC) of 0.66 (Fig. 4).

The optimal cut-off value determined using the Youden index was ≤ 4.6°. In patients with a distal tibial slope below this threshold, the prevalence of medial OLT was 47.4%, whereas this rate was 22.9% in the control group. Individuals with a DTS ≤ 4.6° had an approximately threefold increased risk of developing medial OLT (OR = 3.02, 95% CI: 1.71–5.33, *P* < .01). For the DTS ≤ 4.6° cut-off value, the sensitivity was 44.9% and the specificity was 77.6% (Table 4).

Table 4. Association of medial OLT with distal tibial slope (DTS) cut-off (≤ 4.6°).

DTS (°) (90° – aADTA)	Medial OLT (n=76)	Control (n=170)	P	OR (95% CI)
≤ 4.6° Sensitivity: 44.9% Specificity: 77.6%	36 (47.4%)	39 (22.9%)	< .001	3.02 (1.71 – 5.33)
> 4.6°	40 (52.6%)	131 (77.1%)		

Abbreviations: DTS, distal tibial slope; OLT, osteochondral lesion of the talus; OR, odds ratio; CI, confidence interval.

Discussion

In this study, the relationship between medial talar osteochondral lesions (OLT) and the distal tibial slope (DTS), as defined in this study based on the proximal tibial slope, was investigated. Distal tibial slope values were found to be significantly lower in patients with medial OLT. Logistic regression analysis demonstrated that each 1° decrease in DTS was associated with a 1.26-fold increase in the odds of developing OLT (OR = 1.26). Individuals with DTS values ≤ 4.6° had approximately threefold higher odds of medial OLT (OR = 3.02, 95% CI: 1.71-5.33, $P < .01$). However, the sensitivity of 44.9% and specificity of 77.6% for this cut-off indicate that DTS is not suitable for use as a diagnostic criterion. Based on these findings, DTS should be interpreted not as a threshold applicable for the diagnosis of medial OLT, but rather as a risk-associated morphological parameter reflecting increased susceptibility to medial OLT development.

The decrease in DTS may be associated with a reduction in the effective sagittal tibial curvature and a consequent decrease in the tibiotalar contact area. Athanasiou et al. previously reported that tibial cartilage is stiffer than talar cartilage and that the mechanical resistance of talar cartilage is lower in the equatorial regions [21]. As a result of these biomechanical characteristics, increased contact stress within the talus may contribute to cartilage fatigue and subchondral bone marrow edema. In this context, it may be suggested that, particularly in individuals with DTS ≤ 4.6°, a more horizontal distal tibial articular orientation may be associated with altered load distribution across the medial talar dome, which could contribute to medial OLT formation.

Although the etiology of OLT is generally explained in the literature by trauma or repetitive stress mechanisms, the role of anatomical factors has been evaluated only to a limited extent [11]. Raikin et al. divided the talus into nine zones and reported that OLTs were most frequently localized in the medial and lateral equatorial regions (79%), yet they did not discuss the biomechanical rationale behind this distribution [12]. Sonnow et al. (2022) evaluated morphological parameters based on talar shape and position. By measuring the anterior–posterior width of the distal tibia (TAS) and the trochlea tali (TAL) in the sagittal plane, they examined the TAS/TAL ratio and found that this ratio was significantly lower in patients with OLT. They suggested that as the tibial surface area decreases, increased joint contact pressures may contribute to OLT formation [10]. In our study, the significant decrease in distal tibial slope supports the hypothesis that changes in tibial coverage may contribute to OLT formation. Flattening of the distal tibial articular surface may reduce the contact area and increase load concentration particularly in the equatorial region, leading to stress accumulation that could predispose to OLT. This result aligns with the observations of Sonnow et al. and may help explain the mechanical basis of the lesion concentration described by Raikin in the equatorial region.

The mechanism by which a lower DTS might be associated specifically with medial rather than lateral OLT remains uncertain. One possible explanation is that a more horizontal distal tibial articular orientation may subtly alter sagittal load transfer across the tibiotalar joint; however, this interpretation remains speculative. It is also possible that the observed association reflects, at least in part, a more global alignment pattern that was not captured in the present study, such as hindfoot alignment.

Özal et al. (2016), in a study with a limited number of patients, measured LTCA, BA, and CIA and reported that LTCA was significantly higher in the OLT group [6]. Similarly, Boz et al. (2022) investigated the effects of MA, LTCA, and CIA in the etiology of medial OLT and found that LTCA and CIA values were significantly higher in OLT patients compared with controls [7]. Yaka et al. (2024) examined the relationship between OLT and LTCA, CIA, BA, and GA measurements and reported results consistent with those of Boz et al. showing an association of CIA and LTCA with OLT [8]. These studies highlight the importance of ankle morphology in the etiology of OLT. Although these findings suggest that morphological parameters contribute to OLT formation, distal tibial slope has not been evaluated previously. Considering that tibial slope plays a decisive role in the distribution of load transmitted to the talus, our findings fill an important gap in the literature.

Sayer et al. (2024), in their comprehensive evaluation of morphological parameters, reported that MA values were lower in the OLT group, while aADTA showed nominal differences that did not reach statistical significance [9]. In our study, while sagittal talar tilt did not differ significantly, the distinct reduction in tibial slope suggests that alterations in sagittal-plane tibial orientation, rather than talar inclination, may be more relevant to changes in load distribution. These findings suggest that distal tibial slope may represent a morphologic parameter associated with medial OLT.

Differences between our findings regarding LTCA, CIA, and MA and those of previous studies may be explained by differences in patient selection and methodology. While earlier studies included heterogeneous populations or evaluated medial and lateral OLT together, the present study focused exclusively on medial OLT. In addition, the exclusion of conditions such as chronic ankle instability and congenital foot deformities may have limited the influence of global foot alignment parameters. However, the absence of statistically significant differences does not necessarily indicate a lack of association, as the sample size may have provided limited power for secondary outcomes. Distal tibial slope represents a relatively novel and exploratory morphometric parameter in the context of medial OLT.

The concept of distal tibial slope was adapted from the posterior tibial slope framework used in knee biomechanics. This analogy may offer a useful morphologic perspective for evaluating sagittal distal tibial alignment in the ankle. From a clinical perspective, distal tibial slope may represent an additional morphologic parameter worth considering in non-traumatic medial OLT cases, particularly when the etiology is not clearly explained. However, given the retrospective design, the relatively small absolute between-group difference, and the susceptibility of aADTA and the derived DTS to radiographic rotation and beam angle on lateral views, this observation should be interpreted cautiously. Although interobserver and intraobserver agreement were high, the finding is better regarded as a subtle morphologic association rather than a stand-alone clinically decisive measurement. Further prospective studies with standardized imaging protocols and biomechanical investigations are needed to clarify the robustness and clinical applicability of this observation.

This study has several limitations. Its retrospective design and the fact that the control group consisted not of completely healthy individuals but of patients who underwent MRI because of ankle pain and were not diagnosed with OLT may have allowed subclinical or early-stage OLT to be overlooked. Additionally, parameters such as physical activity level, weight, sports participation, lower-extremity alignment, and global alignment parameters including hindfoot alignment were not evaluated in the control group. These variables may influence ankle joint biomechanics and load distribution and should be considered when interpreting the findings. In addition, magnetic resonance imaging was used for diagnostic confirmation in this study; however, detailed MRI-based characteristics such as lesion size, depth, and associated soft-tissue findings were not evaluated, which may have limited a more comprehensive analysis of the biomechanical relevance of these factors. Incorporating these variables in future prospective studies would provide further insight.

Conclusions

Distal tibial slope values were lower in patients with medial OLT compared with controls. These findings suggest that DTS may represent a subtle radiographic morphologic parameter associated with medial OLT. Given the modest discriminatory performance observed, DTS should not be considered a diagnostic criterion, and further prospective and biomechanical studies are warranted.

Abbreviations

OLT, osteochondral lesion of the talus; DTS, distal tibial slope; aADTA, anatomic anterior distal tibial angle; CIA, calcaneal inclination angle; LTCA, lateral talocalcaneal angle; BA, Böhler angle; GA, Gissane angle; MA, Meary angle; MRI, magnetic resonance imaging; ROC, receiver operating characteristic; AUC, area under the curve; OR, odds ratio; CI, confidence interval; ICC, intraclass correlation coefficient.

Declarations

Ethics approval and consent to participate: Ethics approval and consent to participate: This study was approved by the Necmettin Erbakan University Non-Drug and Non-Medical Device Research Ethics Committee (approval no: 2025/6087). The requirement for informed consent was waived by the ethics committee owing to the retrospective design of the study. All procedures were conducted in accordance with the principles of the Declaration of Helsinki.

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Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Figures

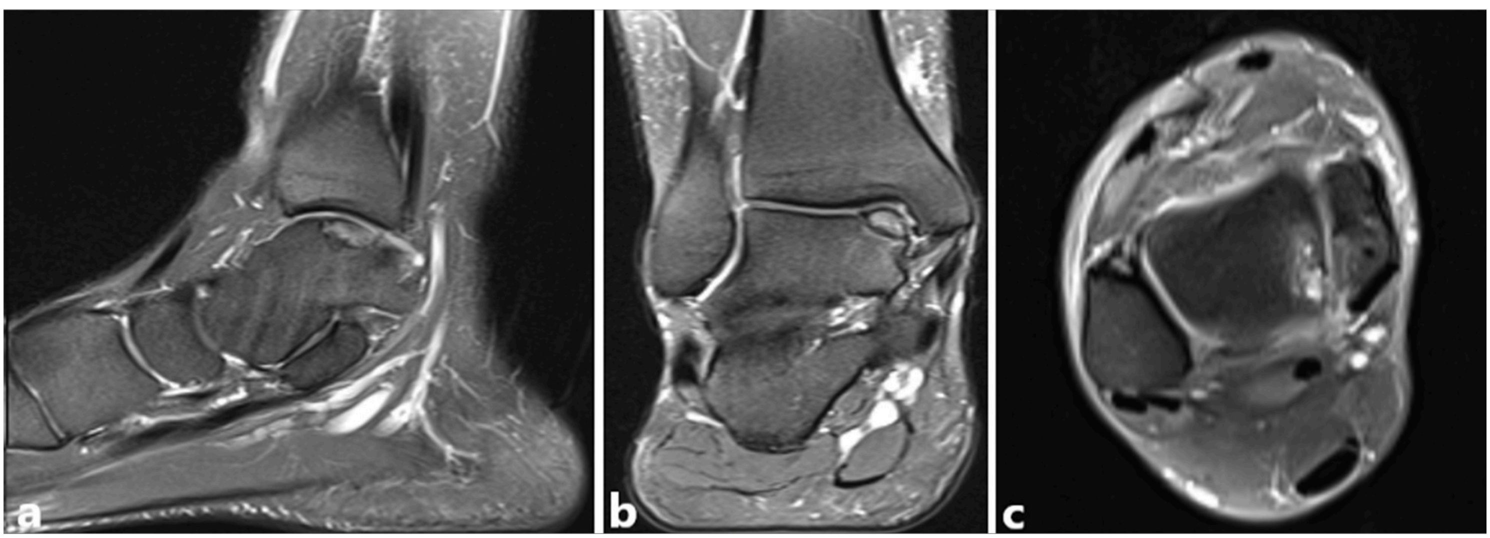

Figure 1

Magnetic resonance imaging of a medial talar osteochondral lesion.

(a) Sagittal T1-weighted MR image. (b) Coronal T2-weighted MR image. (c) Axial T2-weighted MR image demonstrating subchondral bone edema and cartilage surface irregularity in the medial talar dome of a 45-year-old man.

Figure 2

Measurement of distal tibial slope on weight-bearing ankle radiographs.

Weight-bearing lateral ankle radiograph of a 38-year-old woman demonstrating measurement of the anatomic anterior distal tibial angle (aADTA) and distal tibial slope (DTS). The tibial longitudinal axis was defined using two reference circles placed along the tibial diaphysis.

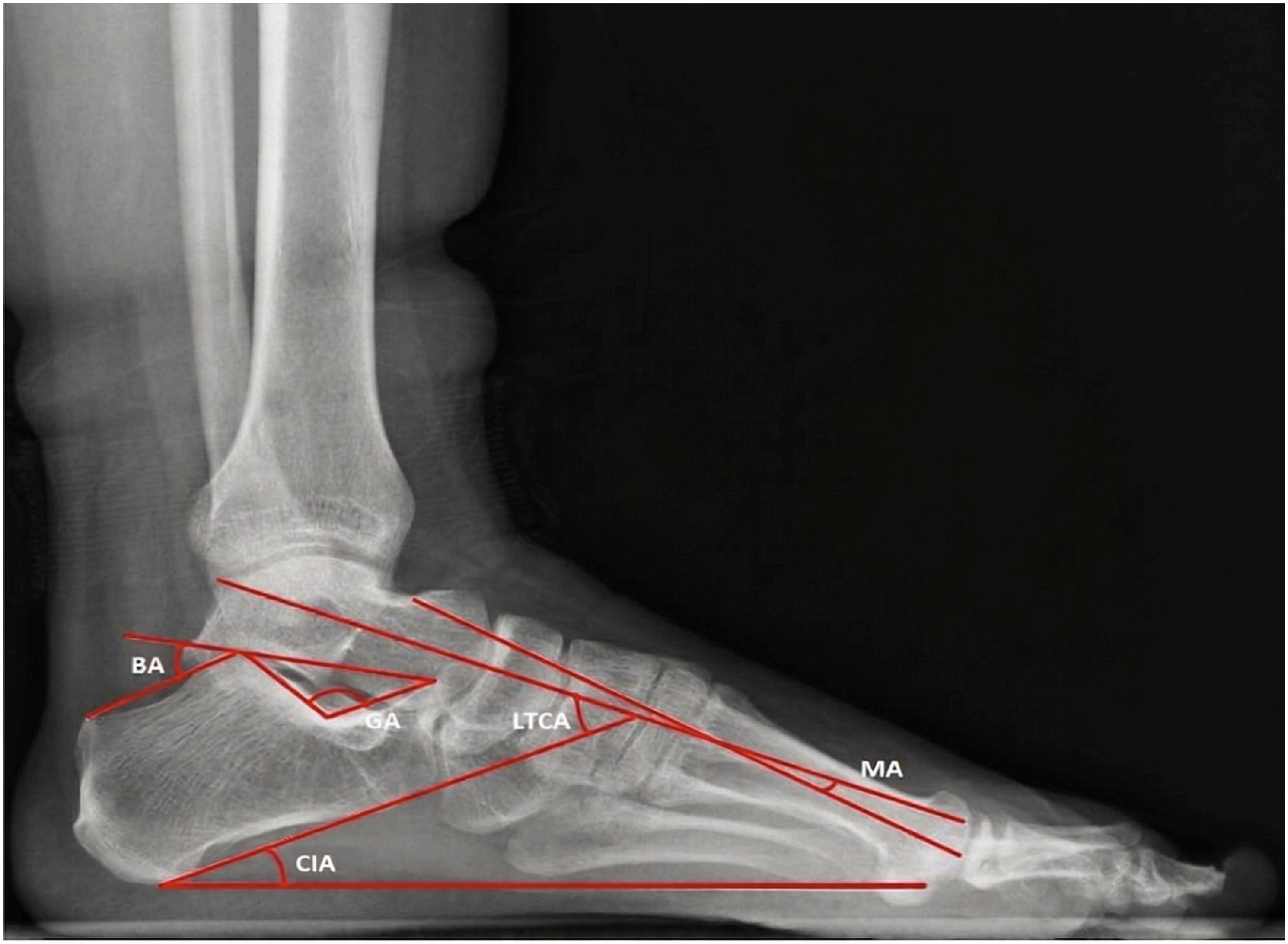

Figure 3

Measurement of radiographic hindfoot and sagittal alignment parameters.

Weight-bearing lateral ankle radiograph of a 38-year-old woman demonstrating measurement of the calcaneal inclination angle (CIA), lateral talocalcaneal angle (LTCA), Böhler angle (BA), Gissane angle (GA), and Meary angle (MA).

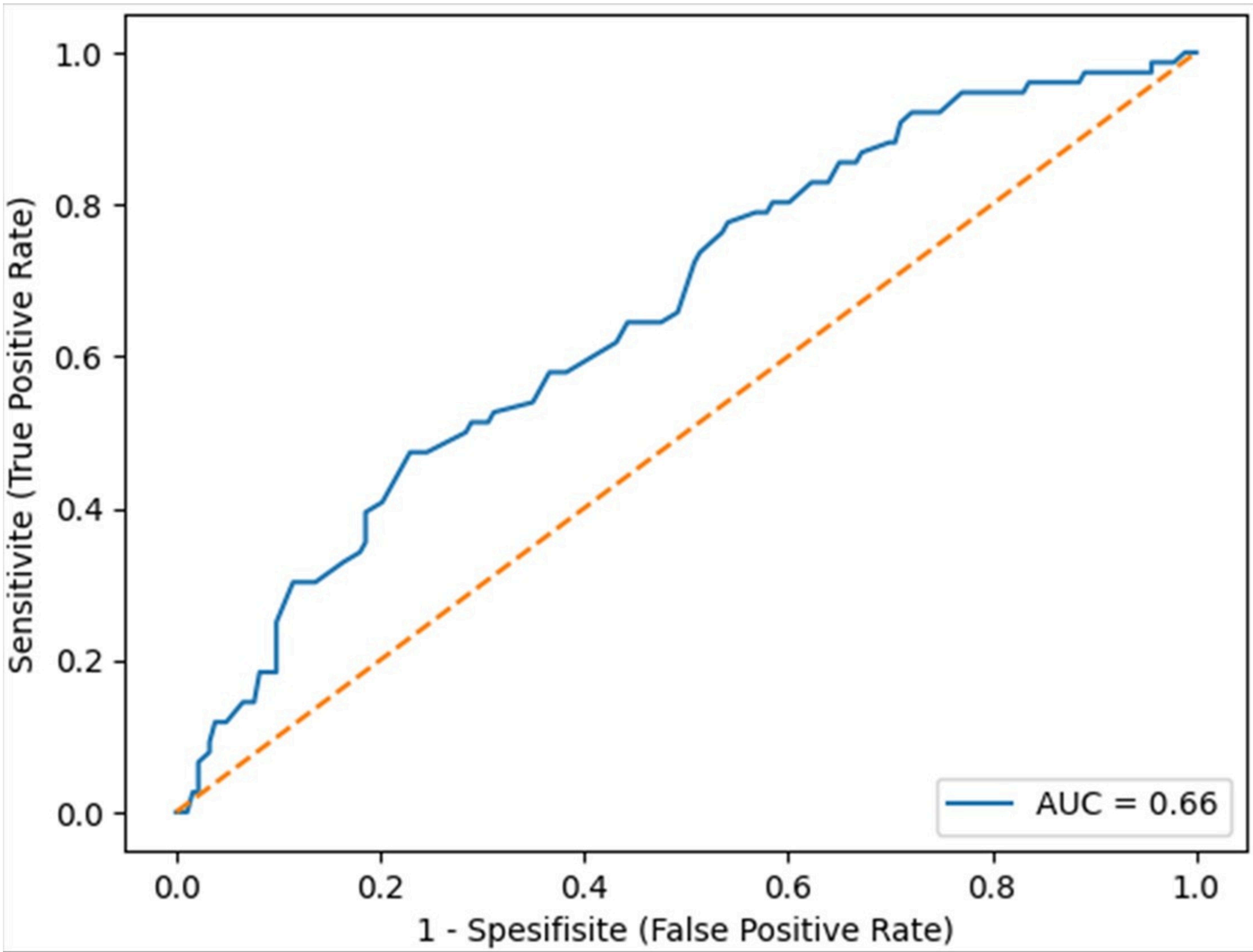

Figure 4

ROC curve analysis of distal tibial slope.

Receiver operating characteristic (ROC) curve analysis of distal tibial slope (DTS) for identification of medial osteochondral lesions of the talus. The area under the curve (AUC) was 0.66.