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# Posterior calcaneal spur length and angle are predictors of pain and functional limitation in insertional Achilles tendinopathy

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## ABSTRACT

**Objectives:** This study aimed to quantitatively evaluate the clinical impact of posterior calcaneal spur (PoCS) morphology, specifically spur length and inclination angle, in patients with insertional Achilles tendinopathy (IAT).

**Methods:** This retrospective study analyzed 200 patients with symptomatic IAT who underwent standardized weight-bearing lateral ankle radiographs. Spur length and inclination angle were measured, and patients were stratified into nine subgroups based on three length categories (<5 mm, 5-10 mm, >10 mm) and three angle categories (<10°, 10-20°, >20°). Clinical outcomes were assessed using the Visual Analog Scale (VAS), American Orthopaedic Foot and Ankle Society (AOFAS) score, and Victorian Institute of Sport Assessment-Achilles (VISA-A) score. Kruskal-Wallis tests and multivariate linear regression analyses were used to evaluate associations between spur morphology and outcomes.

**Results:** Both longer spurs (>10 mm) and steeper inclination angles (>20°) were significantly associated with worse clinical scores including higher VAS scores and lower AOFAS and VISA-A scores (P<0.001). Patients with spur lengths >10 mm and angles >20° had a mean VAS score of 7.22±0.65, VISA-A score of 49.72±2.54, and AOFAS score of 60.00±4.24, indicating greater pain and functional limitation. In contrast, patients with spur lengths <5 mm and angles <10° had lower VAS scores (5.18±0.82) and higher VISA-A (63.43±3.92) and AOFAS (72.57±4.33) scores, reflecting lower pain intensity and higher functional capacity (P < 0.001 for all). Regression analysis confirmed that spur length and angle were independent predictors of clinical outcome (P<0.001), while age, sex, and BMI were not statistically significant contributors (P>0.05).

**Conclusions:** Spur morphology - specifically length and angle - has a measurable impact on symptom severity in IAT. Radiographic evaluation of PoCS morphology should be integrated into clinical decision-making for more tailored management.

**Keywords:** Posterior calcaneal spur, insertional Achilles tendinopathy, spur angle, spur length

Posterior heel pain is a common musculoskeletal complaint, affecting a significant portion of the population, particularly middle-aged and older adults [1]. It accounts for up to 15% of all foot and ankle complaints in clinical practice [2, 3]. Among the various etiologies, insertional Achilles tendinopathy

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(IAT) and posterior calcaneal spur (PoCS) formation are frequently implicated [3]. Studies estimate that PoCS is present in 65%-80% of patients with IAT but also occurs in 25%-35% of asymptomatic individuals [3-5]. This raises the critical question of whether spur morphology influences clinical symptoms or if these bony outgrowths are simply incidental findings.

PoCS forms at the Achilles tendon insertion, often due to chronic traction, calcification, and degenerative changes within the tendon [5, 6]. In contrast, Haglund's deformity is a bony prominence at the posterosuperior calcaneus that leads to impingement of the Achilles tendon and retrocalcaneal bursitis [7, 8]. While Haglund's deformity is primarily a mechanical compression issue, PoCS is more closely associated with insertional Achilles tendinopathy and enthesopathy [7, 8]. These differences necessitate distinct treatment approaches, yet both conditions may coexist and contribute to posterior heel pain.

Despite the high prevalence of PoCS in IAT, there is a lack of studies examining how the size and orientation of the spur affect clinical outcomes. Previous research on plantar calcaneal spurs (PCS) has demonstrated that spur length and slope correlate with pain severity and functional impairment, yet no study has systematically evaluated these factors for posterior calcaneal spurs [9-11].

This study aims to investigate the relationship between posterior calcaneal spur morphology (length and slope) and clinical outcomes in patients with insertional Achilles tendinopathy. To our knowledge, this is the first study to classify PoCS based on its morphological characteristics and assess its impact on pain, function, and Achilles tendon pathology. By establishing objective measurement criteria for PoCS, we aim to improve diagnostic accuracy, treatment decision-making, and patient outcomes in posterior heel pain syndromes.

## METHODS

### Study Design

The study was designed as a retrospective cohort investigation and performed at Bursa City Hospital, Department of Orthopedics and Traumatology. It adhered to the ethical principles outlined in the Declaration of Helsinki and received approval from the institutional ethics committee (approval number: 2025-5/3; date: 05.03.2025).

### Patient Selection

This study included adult patients aged 18 years or older who presented to the Orthopedics and Traumatology outpatient clinic at Bursa City Hospital between January 2021 and December 2023 with posterior heel pain. Additional demographic and clinical variables - such as age, sex, body mass index (BMI), symptom duration, and physical activity level - were documented and included in the statistical models to control for potential confounding factors. All outcome measures were recorded during the same clinical visit as radiographic assessment to maintain temporal consistency.

Eligible patients were required to have a clinical diagnosis of IAT, supported by symptoms of chronic pain localized to the Achilles tendon insertion, tenderness upon palpation, and functional limitation during dorsiflexion or tiptoe walking [4, 5]. Radiographic confirmation of PoCS was mandatory, based on lateral weight-bearing ankle radiographs. Patients were included only if both clinical and radiographic criteria were met, and high-quality imaging was available for morphological analysis.

Patients were excluded if they exhibited radiographic signs of Haglund's deformity, defined as a prominent posterosuperior calcaneal exostosis, in order to isolate the effect of PoCS on IAT. Additional exclusion criteria included the presence of pre-insertional or non-insertional Achilles tendinopathy, a history of Achilles tendon rupture or previous surgery in the region, retrocalcaneal bursitis, or systemic inflammatory disorders such as rheumatoid arthritis or ankylosing spondylitis. Patients with diabetes mellitus, gout, neurological disorders, or peripheral neuropathies were also excluded due to their potential impact on tendon pathology. Furthermore, individuals with a history of corticosteroid injections or other invasive interventions targeting the Achilles tendon within the preceding six months were not included. After applying these criteria, a total of 200 patients were selected for the final cohort, ensuring that the study population represented isolated cases of insertional Achilles tendinopathy associated with posterior calcaneal spur formation, free from confounding mechanical or systemic influences.

## Radiographic Evaluation and Spur Morphology Classification

All patients underwent standard lateral weight-bearing ankle radiographs to assess bony morphology at the Achilles tendon insertion. The radiographs were independently reviewed by two orthopedic surgeons who were blinded to clinical data and had at least five years of experience in musculoskeletal imaging interpretation.

PoCS were defined as osseous protrusions emanating from the posterior aspect of the calcaneus at the insertion site of the Achilles tendon. Special attention was given to distinguish PoCS from Haglund's deformity, which is characterized by a posterosuperior calcaneal prominence located superior and lateral to the Achilles insertion [6-8, 12].

Two morphological features of PoCS were evaluated: spur length and spur angle. Spur length was measured as the linear distance from the posterior cortical base of the calcaneus to the distal tip of the posterior calcaneal spur. For subgroup analysis, spur length was stratified into three categories: short (<5 mm), intermediate (5-10 mm), and long (>10 mm) (Fig. 1).

PoCS angle was defined as the angle formed between a line drawn from the tip of the spur to its base at the posterior calcaneal cortex and a second line tangent to the posterior surface of the calcaneus, representing the longitudinal axis of the calcaneal body. This angle was further classified into three groups based on inclination severity: mild (<20°), moderate (20°-30°), and severe (>30°) (Fig. 2). These thresholds were adapted from previous studies on PCS morphology, which used similar groupings to evaluate spur-related mechanical effects [9, 11]. All radiographic measurements were performed using calibrated digital software (Fonet DICOM Viewer, Version 4.1; Fonet Information Technologies, Ankara, Turkey), and interobserver reliability was assessed to ensure consistency, with high agreement achieved through consensus in cases of discrepancy.

## Outcome Measures

Clinical evaluation focused on both pain severity and functional impairment associated with insertional Achilles tendinopathy. To ensure a comprehensive assessment, three validated instruments were employed: the Visual Analog Scale (VAS) for pain intensity [13], the American Orthopaedic Foot and Ankle Society (AOFAS) Hindfoot Score for functional performance [14], and the Victorian Institute of Sport Assessment-Achilles (VISA-A) Questionnaire, which is specific to Achilles tendon-related disorders [15].

Pain intensity was measured using the VAS, a 10-cm horizontal line where patients marked their average pain experienced over the previous week. The score ranged from 0 (no pain) to 10 (worst imaginable pain), allowing for a simple yet reliable quantification of symptom severity.

The AOFAS Hindfoot Score was used to assess foot and ankle function, incorporating components of pain (40 points), function (50 points), and alignment (10 points) for a maximum of 100 points. This composite score captures both subjective patient feedback

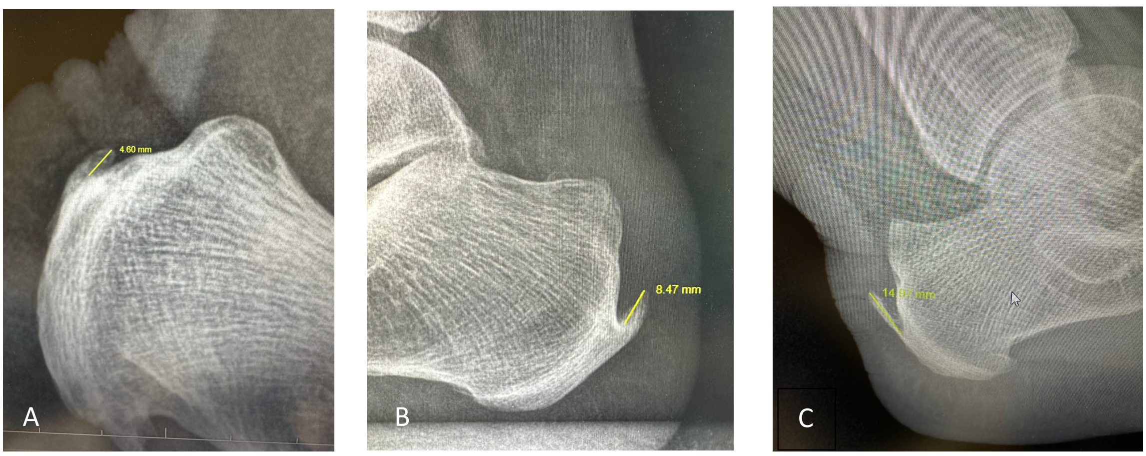


**Fig. 1. Representative lateral radiographs illustrating posterior calcaneal spurs of varying lengths. A) Short spur (<5 mm), B) Intermediate spur (5-10 mm), C) Long spur (>10 mm). Spur length was measured from the calcaneal cortex to the tip of the bony outgrowth using standardized radiographic tools under weight-bearing conditions.**


**Fig. 2.** **Representative lateral radiographs demonstrating posterior calcaneal spur angles categorized by severity. A) Mild angle (<10°), B) Moderate angle (10-20°), C) Steep angle (>20°). Spur angle was measured as the angle between a line drawn from the spur tip to its base and a line tangent to the posterior surface of the calcaneus. All measurements were performed under standardized weight-bearing radiographic conditions.**

and objective clinical findings. All clinical examinations contributing to the AOFAS were performed by two independent orthopedic specialists blinded to the radiographic spur morphology.

The VISA-A questionnaire was utilized to specifically evaluate symptoms and functional limitations due to Achilles tendinopathy. This validated tool consists of eight items assessing domains such as pain, function during daily living, and physical activity. The total VISA-A score ranges from 0 to 100, with higher scores indicating better Achilles tendon function and lower symptom burden. The VISA-A is especially sensitive in detecting clinical changes in both athletic and non-athletic populations suffering from insertional or midportion Achilles tendinopathy.

## Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA), with the level of statistical significance set at P<0.05. Descriptive statistics were expressed as means and standard deviations (SD) for continuous variables and as frequencies and percentages for categorical variables. The normality of continuous variables, including VAS, AOFAS, and VISA-A scores, was evaluated using the Shapiro–Wilk test and Q–Q plots. Since the normality assumption was not fully satisfied for several outcome variables, non-parametric tests were employed for group comparisons where appropriate. To determine independent predictors of pain intensity and functional limitation, multiple linear regression analyses were performed using VAS and AOFAS scores as dependent variables. Independent variables entered into the model included age, sex, BMI, symptom duration, spur length, spur angle. Multicollinearity was checked using the variance inflation factor (VIF), with all values remaining below 2.0, indicating acceptable levels. Additionally, to evaluate the interaction between spur size and angle, patients were stratified into nine morphological subgroups based on combinations of spur length (<5 mm, 5-10 mm, >10 mm) and spur angle (<20°, 20°-30°, >30°). The Kruskal–Wallis test was used to compare VAS, AOFAS, and VISA-A scores across these subgroups due to the non-parametric nature of the data. Post hoc pairwise comparisons were adjusted using Bonferroni correction to control for Type I error. All subgroup results were graphically displayed as boxplots for visual inspection of score distributions and potential outliers.

# RESULTS

Table 1 displays the demographic and clinical characteristics of patients stratified into nine subgroups based on PoCS length (<5 mm, 5-10 mm, >10 mm) and spur angle (<10°, 10°-20°, >20°). For each subgroup, av-

**Table 1.** **Combined distribution of posterior calcaneal spur (PoCS) length and angle categories with clinical and demographic parameters**

| Groups | Variables | <10° | 10-20° | >20° |
|---|---|---|---|---|
| <5 mm | Age | 43.93±9.02 | 45.58±9.83 | 42.33±3.66 |
| | BMI | 26.15±2.74 | 24.80±2.72 | 27.20±2.78 |
| | Duration | 13.89±1.93 | 13.50±1.41 | 13.89±1.64 |
| | Spur length | 3.96±0.47 | 4.36±0.31 | 3.88±0.68 |
| | Spur angle | 8.26±1.24 | 17.34±1.47 | 30.12±1.46 |
| | VISA-A | 63.43±3.92 | 61.00±3.68 | 62.11±3.34 |
| | AOFAS | 72.57±4.33 | 73.42±3.11 | 72.44±3.60 |
| | VAS | 5.18±0.82 | 5.58±0.50 | 5.89±0.32 |
| 5-10 mm | Age | 43.08±8.65 | 42.67±6.81 | 44.80±9.95 |
| | BMI | 25.31±2.90 | 25.90±2.54 | 26.09±1.98 |
| | Duration | 14.15±1.43 | 14.67±1.27 | 14.30±1.53 |
| | Spur length | 8.80±0.71 | 8.88±0.73 | 8.78±0.85 |
| | Spur angle | 7.80±1.17 | 16.58±1.18 | 30.63±1.57 |
| | VISA-A | 63.23±2.27 | 60.67±1.83 | 60.70±2.98 |
| | AOFAS | 71.85±3.32 | 73.13±3.97 | 70.35±3.50 |
| | VAS | 5.54±0.51 | 5.67±0.56 | 5.75±0.55 |
| >10 mm | Age | 46.77±5.24 | 44.45±11.25 | 47.00±10.85 |
| | BMI | 25.25±2.27 | 26.54±2.65 | 24.95±2.32 |
| | Duration | 14.00±1.63 | 14.70±1.89 | 17.33±1.61 |
| | Spur length | 13.69±0.74 | 13.74±0.72 | 13.80±0.70 |
| | Spur angle | 8.09±1.34 | 17.46±1.40 | 31.13±1.83 |
| | VISA-A | 62.14±3.03 | 60.20±4.53 | 49.72±2.54 |
| | AOFAS | 69.86±5.48 | 66.90±7.06 | 60.00±4.24 |
| | VAS | 6.14±0.64 | 6.35±0.67 | 7.22±0.65 |

Data are shown as mean±standard deviation. Spur length was stratified into three categories: short (<5 mm), intermediate (5-10 mm), and long (>10 mm). Spur angle was classified into mild (<10°), moderate (10-20°), and severe (>20°) inclination. Clinical outcomes assessed include the Visual Analog Scale (VAS), Victorian Institute of Sports Assessment-Achilles questionnaire (VISA-A), and American Orthopaedic Foot & Ankle Society (AOFAS) hindfoot scores, BMI=Body Mass Index.

erage values are provided for age, BMI, symptom duration, spur length, and spur angle. Additionally, clinical outcome scores including VISA-A, AOFAS, and VAS are reported.

Multiple linear regression analyses were conducted to evaluate the relationship between PoCS morphology and clinical outcomes, including VAS, VISA-A, and AOFAS scores. For the VAS score, spur length ($P<0.001$) and spur angle ($P<0.001$) were found to be statistically significant positive predictors of pain severity. In contrast, patient age ($P=0.112$), BMI ($P=0.525$), and sex ($P=0.963$) had no significant influence (Table 2).

In the VISA-A score regression, spur length ($P<0.001$) and spur angle ($P<0.001$) were again significant, demonstrating a negative correlation with functional status. Neither age ($P=0.560$), BMI ($P=0.453$), nor sex ($P=0.114$) had a statistically significant effect (Table 3).

Similarly, for AOFAS scores, longer spur length ($P<0.001$) and larger spur angles ($P=0.001$) were associated with significantly lower functional outcomes.

**Table 2.** Multivariate linear regression analysis identifying predictors of VAS score

| Variables | t value | P value | 95% Confidence Interval |
|---|---|---|---|
| **Age** | -1.596 | 0.112 | -0.018-0.002 |
| **BMI** | -0.636 | 0.525 | -0.045-0.023 |
| **Spur angle** | 5.846 | 0.0 | 0.046-0.092 |
| **Spur angle** | 5.746 | 0.0 | 0.019-0.038 |
| **Sex** | -0.046 | 0.963 | -0.183-0.175 |

Values are based on multivariate linear regression analysis. VAS=Visual Analog Scale, BMI=Body Mass Index. Significant predictors of pain severity include spur length and spur angle (P<0.001), while age, BMI, and sex were not statistically significant.

Age (P=0.503), BMI (P=0.133), and sex (P=0.917) did not exhibit a meaningful relationship with AOFAS scores (Table 4).

Subgroup analyses by Spur Morphology, patients were stratified into nine subgroups based on spur length (<5 mm, 5-10 mm, >10 mm) and spur angle (<10°, 10°–20°, >20°) to further explore morphological effects on outcomes. Group-wise comparisons using the Kruskal-Wallis test revealed significant differences in VAS, VISA-A, and AOFAS scores across the subgroups. Patients with spur lengths >10 mm and angles >20 exhibited the most severe symptoms, with VAS scores reaching a median of 7.5-8.0, VISA-A scores decreasing to around 50, and AOFAS scores falling to approximately 60. In contrast, those with spurs <5 mm and angles <10 showed milder symptoms, with VAS scores near 5.0, VISA-A scores of 65-70, and AOFAS scores of 75-80 (Fig. 3).

**Table 3.** Multivariate linear regression analysis for predictors of VISA-A score

| Variables | t value | P value | 95% Confidence Interval |
|---|---|---|---|
| **Age** | -0.584 | 0.56 | -0.079-0.043 |
| **BMI** | -0.752 | 0.453 | -0.282-0.127 |
| **Spur angle** | -4.499 | 0.0 | -0.463-0.181 |
| **Spur angle** | -6.295 | 0.0 | -0.249-0.130 |
| **Sex** | 1.587 | 0.114 | -0.212-1.956 |

VISA-A=Victorian Institute of Sports Assessment-Achilles questionnaire, BMI=Body Mass Index. Increased spur length and angle were independently associated with lower VISA-A scores (P<0.001), indicating worse symptom severity and reduced tendon function. Age, BMI, and sex were not statistically significant predictors

**Table 4.** Multivariate linear regression analysis for predictors of AOFAS score

| Variables | t value | P value | 95% Confidence Interval |
|---|---|---|---|
| **Age** | 0.67 | 0.503 | -0.051-0.103 |
| **BMI** | -1.509 | 0.133 | -0.457-0.061 |
| **Spur length** | -6.717 | 0.0 | -0.787-0.429 |
| **Spur angle** | -3.322 | **0.001** | -0.202-0.051 |
| **Sex** | 0.104 | 0.917 | -1.299-1.444 |

AOFAS=American Orthopaedic Foot & Ankle Society Hindfoot Score, BMI=Body Mass Index. Both increased spur length and angle were independently associated with significantly lower AOFAS scores (P<0.01), reflecting reduced ankle-hindfoot function. Age, BMI, and sex were not significant predictors.

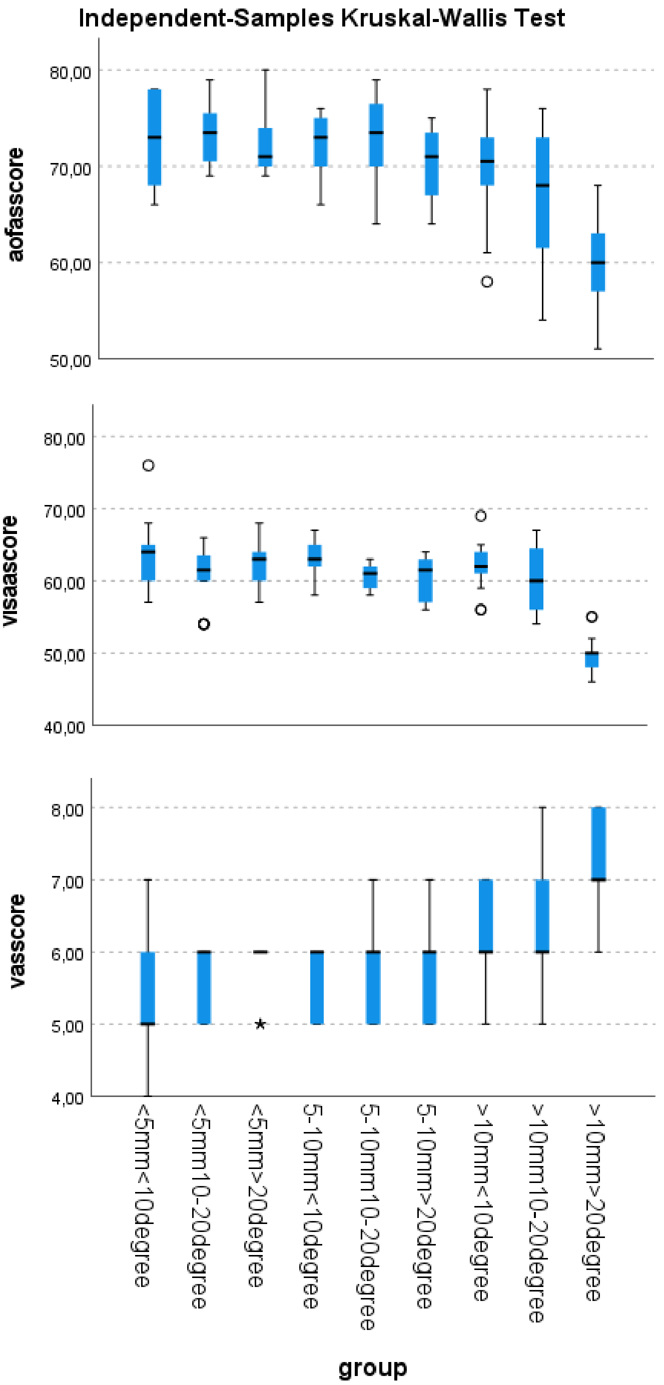


**Fig. 3.** **Comparison of clinical outcome scores across posterior calcaneal spur morphology subgroups. Box plots depicting AOFAS, VISA-A, and VAS scores stratified by posterior calcaneal spur length (<5 mm, 5-10 mm, >10 mm) and angle (<10°, 10-20°, >20°). The Kruskal-Wallis test indicated statistically significant differences among groups for all three clinical outcomes. Patients with spur lengths >10 mm and angles >20° had the lowest AOFAS and VISA-A scores and the highest VAS scores, reflecting worse function and greater pain severity. Medians are shown by horizontal lines, boxes represent interquartile ranges, whiskers indicate full ranges, and circles/asterisks denote outliers.**

## DISCUSSION

Our analysis revealed that both spur length and spur angle were significant independent predictors of pain and function. Specifically, multiple linear regression results demonstrated a positive correlation between VAS scores and both spur length and angle, indicating that patients with longer and more vertically inclined spurs experience greater pain severity. In contrast, demographic factors such as age, BMI, or sex did not show a significant association with pain levels.

Similarly, the VISA-A and AOFAS functional scores exhibited a significant inverse relationship with spur length and angle. As the size and inclination of the PoCS increased, functional scores decreased, suggesting that more prominent spurs compromise tendon insertion mechanics and contribute to functional limitations. These trends remained consistent across both scoring systems. Again, demographic parameters had no statistically significant influence on outcomes.

The subgroup analysis, stratifying patients into nine morphological categories based on combined spur length and angle, further confirmed these associations. Patients with extreme morphology (>10 mm length and >20° angle) consistently showed the highest VAS scores and the lowest VISA-A and AOFAS scores, highlighting the additive impact of both variables. Conversely, those with small (<5 mm) and shallow (<10°) spurs had better clinical outcomes.

These findings are reinforced by existing biomechanical insights. These relationships can be explained through established biomechanical mechanisms. Chimenti *et al*. [5, 16] emphasized the complex loading patterns at the Achilles enthesis, where the superficial fibers are subjected to tensile stress while the deep fibers experience compressive forces from the calcaneus. A steeply inclined PoCS (>30°) may amplify these compressive forces, creating a sharper mechanical interface at the deep tendon insertion. This intensified contact area can promote localized stress accumulation, microtears, inflammation, and collagen disorganization. In contrast, milder angles may permit more uniform load transmission, potentially reducing focal mechanical irritation. Thus, our observation that steeper angles are linked to more severe symptoms supports the hypothesis that specific angular morphologies critically disrupt enthesis mechanics and exacerbate degenerative changes.

Although not directly focused on posterior calcaneal spurs or insertional Achilles tendinopathy, two recent studies have evaluated plantar calcaneal spur morphology and its clinical relevance. Kaya *et al*. [17] demonstrated that the mere presence of a calcaneal spur is not necessarily a primary determinant of heel pain, implying that spur morphology - such as length and angle -may be more clinically meaningful. Similarly, Tuncer *et al*. [18] found that larger plantar calcaneal spurs and greater spur–calcaneus angles were significantly correlated with higher pain levels and worse functional scores in patients with plantar heel pain treated with ESWT. Although these studies primarily addressed plantar spurs and plantar fasciitis, the mechanistic insights they provide regarding the role of spur morphology in symptom severity are consistent with and indirectly support our findings in posterior calcaneal spurs.

In addition to angular effects, spur size appears to play a mechanical role. Larger PoCS (>10 mm) may project deeper into the tendon's insertional zone, increasing mechanical impingement and friction during ankle dorsiflexion - especially under load-bearing conditions. Chimenti *et al*. [5, 16] reported that symptomatic heels exhibit significantly longer spurs compared to asymptomatic ones, reinforcing the link between increased spur length and pathological mechanical interactions. This chronic mechanical interference likely contributes to enthesis overload and a failed healing response, leading to degenerative features such as neovascularization, fatty infiltration, and tendon thickening - hallmarks of chronic tendinopathy. As noted by Krishna Sayana and Maffulli [6] and Boberg and Anania [12], such enthesophytes may initially arise as adaptive responses to repetitive tensile stress but may evolve into pathological bony projections when combined with altered joint mechanics.

The anatomical concept of a calcaneal "step," introduced by Fiamengo *et al* [19]., may offer further insight. This bony protrusion, situated at the tendon insertion, may function as a fulcrum that modifies the tendon's line of pull and increases mechanical tension during motion. Although its morphology was not specifically analyzed in terms of length or angle, its frequent appearance in symptomatic individuals highlights the clinical relevance of posterior calcaneal morphology. Additionally, Grambart *et al* [7]. and Caudell *et al* [8]. emphasized the importance of distinguishing PoCS from Haglund's deformity, noting that PoCS is more directly implicated in intratendinous degeneration and tendon entrapment, whereas Haglund's deformity primarily affects the retrocalcaneal bursa.

Although previous studies have examined the presence of posterior calcaneal spurs and their relationship with Achilles tendinopathy, no prior research has directly investigated the correlation between PoCS length and angle in relation to clinical outcomes. Kang *et al*. [4] reported that calcification width ranged from 1.0 to 10.4 mm and length from 3.5 to 16.2 mm in insertional Achilles tendinopathy, suggesting that a broader and longer calcific deposit may increase mechanical irritation. However, they did not directly analyze the correlation between width, length, and clinical symptoms, making it unclear whether larger calcifications necessarily lead to worse functional impairment. Furthermore, they found that Haglund's deformity was not indicative of insertional Achilles tendinopathy and was equally present in asymptomatic patients. Their study also confirmed that a majority of insertional Achilles tendinopathy patients had calcification at the tendon insertion, reinforcing the association between calcification and IAT but not providing a detailed assessment of how size impacts symptom severity. Lu *et al*. [20] analyzed posterior calcaneal step spurs and Achilles tendon calcifications in Haglund syndrome, showing that 56.8% of symptomatic patients had a posterior calcaneal step spur, compared to only 5% in the control group. Their study reinforces the importance of osseous variations in posterior heel pain, but it did not assess the impact of PoCS length or angle on clinical outcomes, which is the focus of our study. Fiamengo *et al*. [19] introduced the concept of the calcaneal step, an anatomical variation at the Achilles tendon insertion observed in symptomatic patients with posterior heel pain. Their findings indicated that a calcaneal step was present in 75% of symptomatic cases, suggesting that this anatomical feature may contribute to Achilles-related pathology. However, their study did not specifically assess the correlation between posterior calcaneal spur length, width, or angle and clinical outcomes, nor did it provide a biomechanical explanation for how the calcaneal step influences pain and function. Our study expands upon these findings by demonstrating the direct impact of PoCS on clinical outcomes, emphasizing the importance of spur morphology beyond simple anatomical variations. Nakajima [21] conducted a radiographic comparison of symptomatic and asymptomatic heels in patients with insertional Achilles tendinopathy and examined both calcification length and width. Their study primarily focused on differentiating calcifications seen in symptomatic patients from those in asymptomatic individuals, rather than directly correlating spur dimensions with pain and function. Notably, they did not find a clear association between PoCS width and Achilles tendinopathy severity, nor did they analyze spur angles. Their research was more focused on distinguishing Haglund's deformity measurements, rather than assessing the detailed impact of PoCS morphology on clinical outcomes. Johansson *et al*. [22] analyzed posterior calcaneal spur size and surgical outcomes, finding that while spur size was a key anatomical feature, it did not correlate with surgical success rates. However, their study did not examine the direct correlation between spur morphology and clinical symptoms, which our study addresses. Grambart *et al*. [7] distinguished Achilles insertional calcific tendinosis (AICT) from Haglund's deformity, emphasizing that AICT involves intratendinous calcifications at the Achilles insertion, whereas Haglund's deformity is a separate mechanical compression issue. However, they did not analyze PoCS morphology or its impact on clinical outcomes, a gap that our study fills. Caudell [8] highlighted the importance of radiographic imaging in distinguishing PoCS from Haglund's deformity, emphasizing that IAT is frequently misdiagnosed. Their study confirmed that PoCS often presents alongside Achilles tendon thickening and intratendinous calcifications, yet their analysis did not explore how PoCS morphology influences clinical symptoms. In contrast, our study provides a quantitative analysis of PoCS length and angle, directly correlating these parameters with patient-reported outcomes.

Taken together, these mechanistic insights align with our findings and support the notion that not only the presence but the detailed morphology of posterior calcaneal spurs plays a pivotal role in the pathophysiology and clinical severity of IAT. Recognizing the influence of both spur length and inclination angle may be essential in clinical evaluation, guiding prognosis, and informing surgical decision-making, particularly in patients who do not respond to conservative treatment.

## Strengths and Limitations

This study has several strengths that enhance the robustness and clinical relevance of its findings. First, to our knowledge, it is the first to quantitatively assess the impact of PoCS length and angle on clinical outcomes using validated patient-reported outcome measures (VAS, VISA-A, AOFAS). The incorporation of detailed radiographic measurements allows for objective stratification of spur morphology, moving beyond simple presence or absence toward a more nuanced understanding of structural contribution to symptoms. Second, the subgroup analysis offers granular insight by exploring the additive effects of combined spur length and angle variations on pain and function.

However, several limitations should be acknowledged. The retrospective design may introduce selection bias and limit causal inference. While radiographic measurements were standardized, interobserver variability in angle and length assessment is a potential source of measurement error. Furthermore, although patient-reported outcome measures provide valuable information, they are inherently subjective and may be influenced by external psychosocial factors. Advanced imaging modalities such as MRI or ultrasound were not routinely employed, which could have offered complementary insight into soft tissue pathology such as tendon degeneration, neovascularization, or bursal inflammation. Additionally, routine assessments of lower extremity alignment (genu varus/valgus) and additional foot deformities (e.g., pes planus, hallux valgus) were not investigated; thus, their potential role as confounding factors influencing clinical outcomes remains unknown and warrants investigation in future prospective studies. Lastly, the study population was drawn from a single tertiary center, which may limit generalizability to broader patient populations.

The present findings underscore the importance of incorporating detailed PoCS morphological assessment into the diagnostic and therapeutic algorithm for IAT. Clinicians often focus on tendon pathology or generalized bony abnormalities; however, this study shows that specific morphologic traits - particularly spur length >10 mm and angle >30° are significantly associated with greater symptom burden. Radiographic identification of such features may help in stratifying patients likely to respond poorly to conservative treatment and potentially benefit from early surgical intervention. Additionally, recognition of moderate-to-severe angular deformities could guide surgical planning, including decisions about whether to resect the spur or modify the tendon's insertion angle to restore favorable biomechanics.

Future prospective studies with larger, multicenter cohorts are needed to validate these findings and explore their prognostic utility. Incorporating advanced imaging techniques such as high-resolution ultrasound or MRI could help correlate PoCS morphology with tendon quality, neovascularization, or peritendinous inflammation. Additionally, biomechanical modeling or cadaveric studies may elucidate how different spur angles and sizes influence Achilles tendon loading, enthesis strain, and local tissue remodeling. Another avenue worth investigating is the impact of targeted surgical correction of spur morphology, particularly angle modification or step resection, on long-term pain relief and functional recovery. Such research would further clarify whether these radiographic parameters are merely markers of severity or modifiable contributors to disease progression.

## CONCLUSION

In conclusion, this study demonstrates that both the length and inclination angle of posterior calcaneal spurs are independent predictors of clinical severity in insertional Achilles tendinopathy. Patients with longer and steeper spurs experience higher pain levels and reduced function, likely due to increased mechanical stress and tendon impingement at the enthesis. These results suggest that detailed radiographic assessment of PoCS morphology should be an integral part of clinical evaluation and may help guide individualized treatment strategies. By shifting the focus from presence to morphologic characterization, clinicians can more accurately predict outcomes and tailor interventions for patients with IAT.

*Ethics Approval and Consent to Participate*

This study was approved by the Bursa City Hospital Scientific Research Ethics Committee (Decision No: 2025-5/3; date: 05.03.2025). All procedures were conducted in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments. Written informed consent was obtained from all individual participants included in the study.

*Data Availability*

All data generated or analyzed during this study are included in this published article. The data that support the findings of this study are available on request from the corresponding author, upon reasonable request.

*Authors' Contribution*

Study Conception: MD, ÖCS; Study Design: MD, RK; Supervision: MD, BA; Funding: MD, RK; Materials: MD, RK; Data Collection and/or Processing: MD, BA; Statistical Analysis and/or Data Interpretation: MD, HÇB; Literature Review: MD, BA; Manuscript Preparation: MD, BA and Critical Review: MD, RK.

*Conflict of Interest*

The author(s) disclosed no conflict of interest during the preparation or publication of this manuscript.

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*Generative Artificial Intelligence Statement*

The author(s) declare that no artificial intelligence-based tools or applications were used during the preparation process of this manuscript. The all content of the study was produced by the author(s) in accordance with scientific research methods and academic ethical principles.

*Editor's Note*

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