

Original Research Article

Incidence and predictors of syndesmotic injuries in ankle fractures: a cross-sectional study correlating radiographic assessment with intraoperative findings

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Received: 27 March 2025

Revised: 07 May 2025

Accepted: 29 May 2025

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ABSTRACT

Background: Syndesmotic injuries are clinically significant ankle injuries that may lead to chronic instability and functional impairment when inadequately managed. While literature suggests these injuries occur in 10-20% of ankle fractures, their true incidence remains poorly characterized. This study aimed to determine the incidence of syndesmotic injuries in ankle fractures and evaluate the diagnostic accuracy of radiographic assessment compared to intraoperative findings.

Methods: This 18-month cross-sectional study conducted at a tertiary care center in Pune, India included 49 patients with ankle fractures requiring surgical intervention. Standardized radiographic evaluation was performed to assess syndesmotic parameters (tibiofibular clear space, tibiofibular overlap, and medial clear space). Fractures were classified using the Lauge-Hansen system, and intraoperative assessment was conducted using the Hook test as the reference standard. Statistical analysis included calculation of diagnostic accuracy metrics and multivariate logistic regression to identify independent predictors of syndesmotic injuries.

Results: Syndesmotic injuries were identified in 16 patients (32.7%, 95% CI: 19.9%-47.0%), with highest prevalence in Pronation-External Rotation fractures (46.7%) and those resulting from road traffic accidents (44.4%). Radiographic assessment demonstrated good diagnostic performance (sensitivity 87.5%, specificity 81.8%) compared to intraoperative findings. Multivariate analysis identified three independent predictors of syndesmotic injury: Pronation-External Rotation fracture pattern (OR 3.82, $p=0.006$), road traffic accident mechanism (OR 2.96, $p=0.026$), and tibiofibular clear space >6 mm (OR 8.35, $p<0.001$). Patients with syndesmotic injuries demonstrated significantly worse immediate post-operative pain scores ($p<0.001$) and functional outcomes ($p<0.001$).

Conclusions: Syndesmotic injuries are more common in ankle fractures than previously reported, particularly in high-energy trauma and specific fracture patterns. While systematic radiographic evaluation provides valuable diagnostic information, intraoperative assessment remains essential for definitive diagnosis. These findings emphasize the importance of maintaining a high index of suspicion for syndesmotic injuries in high-risk scenarios to optimize patient outcomes.

Keywords: Ankle fractures, Syndesmotic injuries, Tibiofibular syndesmosis, Radiographic assessment, Intraoperative diagnosis, Hook test, Lauge-Hansen classification

INTRODUCTION

Ankle fractures are among the most common musculoskeletal injuries worldwide, affecting diverse age

groups and presenting a significant healthcare burden with an incidence of approximately 187 cases per 100,000 person-years in developed nations.^{1,2} Within this spectrum, syndesmotic injuries—disruptions of the distal tibiofibular

syndesmosis—have emerged as clinically significant due to their potential for causing long-term functional impairment when inadequately managed.^{3,4}

The syndesmotic complex consists of four primary ligaments: the anterior inferior tibiofibular ligament (AITFL), posterior inferior tibiofibular ligament (PITFL), interosseous ligament (IOL), and transverse tibiofibular ligament. These structures collectively maintain ankle joint stability during weight-bearing activities.⁵ Disruption of these ligaments can occur in isolation or, more commonly, in association with malleolar fractures, resulting in a spectrum of injury patterns from partial tears to complete ruptures with mortise widening.⁶

Despite growing recognition in orthopedic literature, the true incidence of syndesmotic injuries in ankle fractures remains incompletely characterized, with current estimates suggesting occurrence in 10-20% of all ankle fractures.⁷ These figures may underestimate the actual incidence due to limitations in conventional diagnostic methods.

Accurate diagnosis presents a significant clinical challenge due to the complex three-dimensional anatomy of the ankle joint and subtle radiographic signs associated with ligamentous disruption.⁸ Conventional radiography remains the initial imaging modality in most clinical settings, utilizing parameters such as tibiofibular clear space, tibiofibular overlap, and medial clear space measurements. However, standard radiographs demonstrate limited sensitivity, particularly in the absence of frank diastasis.⁹

The clinical significance of accurately diagnosing syndesmotic injuries lies in their potential for adverse outcomes when overlooked. Untreated syndesmotic instability has been associated with persistent pain, functional limitation, and poor long-term outcomes. Conversely, unnecessary fixation may lead to complications including malreduction and hardware failure.¹⁰

This study aims to determine the incidence of syndesmotic injuries in a cohort of patients with ankle fractures and assess the sensitivity and specificity of standard radiographic evaluation compared to intraoperative assessment using the Hook test as the reference standard. Furthermore, we seek to identify potential correlations between specific fracture patterns, injury mechanisms, and the likelihood of syndesmotic involvement to enhance clinical decision-making and improve patient outcomes.

METHODS

Study design and setting

This cross-sectional observational study was conducted Department of Orthopaedics, Bharati Hospital, Pune, Maharashtra, India, between August 2022 and February 2024 (18 months). The study protocol was approved by the

Institutional Ethics Committee (approval number: IEC/2022/157), and all participants provided written informed consent prior to enrollment. The investigation was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki for research involving human subjects.¹¹

Study population

We prospectively enrolled consecutive adult patients presenting with acute ankle fractures requiring surgical intervention. Sample size calculation was performed based on previously reported incidence rates of syndesmotic injuries (10-20%), with an expected precision of $\pm 5\%$ and confidence interval of 95%, yielding a minimum required sample size of 45 patients.⁷ To account for potential dropouts or incomplete data, we enrolled 49 patients.

Inclusion criteria

Adult patients (≥ 18 years) with acute ankle fractures confirmed on radiographic evaluation, fractures requiring surgical fixation as determined by standard clinical guidelines, and patients able to provide informed consent were included.¹²

Exclusion criteria

Patients with previous history of ankle fracture or syndesmotic injury on the affected side, pilon fractures involving the tibial plafond, pathological fractures secondary to tumor or metabolic bone disease, patients unable to undergo surgical intervention due to medical comorbidities, and patients with inadequate radiographic documentation were excluded.

Data collection

Standardized data collection forms were utilized to record demographic information, injury characteristics, clinical findings, and radiographic parameters. Basic demographic data included age, sex, body mass index (BMI), occupation, and comorbidities. Injury-specific information encompassed the mechanism of injury (categorized as road traffic accident, slip and fall, fall from height, or sports-related), time from injury to presentation, and pre-existing functional status.

Clinical assessment

All patients underwent comprehensive clinical examination by senior orthopedic surgeons with experience in trauma management. Pain assessment was performed using the visual analogue scale (VAS), with scores ranging from 0 (no pain) to 10 (worst imaginable pain).¹³ Functional status was evaluated using the validated foot and ankle outcome score (FAOS), which assesses five domains: pain, symptoms, activities of daily living, sport and recreational activities, and quality of life.¹⁴ Clinical indicators of syndesmotic injury, including

tenderness over the anterior inferior tibiofibular ligament, external rotation pain, and positive squeeze test, were systematically documented.¹⁵

Radiographic evaluation

Standardized radiographic series consisting of anteroposterior, lateral, and mortise views of the affected ankle were obtained for all patients using a consistent imaging protocol. All radiographs were independently assessed by two senior orthopedic surgeons (with more than 10 years of experience) who were blinded to clinical findings. In cases of disagreement, consensus was reached through discussion with a third reviewer.

Ankle fractures were classified according to the Lauge-Hansen system, which categorizes injuries based on the position of the foot at the time of injury and the direction of the deforming force.¹⁶ This classification system identifies four primary fracture patterns: supination-external rotation (SER), pronation-external rotation (PER), supination-adduction (SAD), and pronation-abduction (PAB).

Radiographic parameters suggestive of syndesmotom injury were systematically evaluated, including: tibiofibular clear space (TFCS) - measured at 1 cm above the tibial plafond, with values >6 mm considered abnormal, tibiofibular overlap (TFO) - measured at 1 cm above the tibial plafond, with values <6 mm considered abnormal, and medial clear space (MCS) - measured between the medial malleolus and the talus, with values >4 mm suggesting instability.¹⁷⁻¹⁹

Based on these radiographic criteria, cases were categorized as "likely" or "not likely" to have syndesmotom injury. The assessment was performed independently from the intraoperative evaluation to minimize bias.

Surgical procedure and intraoperative assessment

All patients underwent surgical fixation under appropriate anesthesia (regional or general) as determined by the anesthesiology team. Standard surgical approaches were employed based on the fracture pattern and planned fixation strategy. After fracture reduction and provisional fixation of malleolar fragments, intraoperative assessment of syndesmotom stability was performed using the Hook test, which is considered the reference standard for diagnosing syndesmotom instability.^{20,21}

The Hook test was performed by applying lateral force to the fibula with a bone hook while visualizing the tibiofibular relationship through the surgical exposure or under fluoroscopic guidance. Excessive lateral displacement of the fibula relative to the tibia (>2 mm) was considered positive for syndesmotom instability.²² All Hook tests were performed by the senior operating surgeon to ensure consistency.

Patients with confirmed syndesmotom instability underwent syndesmotom fixation using either 3.5 mm cortical screws or suture-button devices according to the surgeon's preference and institutional protocol.²³ Post-operative management followed standardized rehabilitation protocols based on the type of fixation utilized.

Statistical analysis

Data were recorded in a standardized electronic database and analyzed using statistical package for the social sciences (SPSS) version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were employed to summarize demographic variables and clinical characteristics. Continuous variables were expressed as mean±standard deviation (SD) or median with interquartile range (IQR) based on data distribution. Categorical variables were presented as frequencies and percentages.

The primary outcome measure was the incidence of syndesmotom injuries as determined by intraoperative Hook test findings. Secondary outcomes included the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of radiographic assessment compared to intraoperative findings.

The association between fracture patterns (according to Lauge-Hansen classification) and the presence of syndesmotom injuries was analyzed using Chi-square or Fisher's exact test, as appropriate. Logistic regression analysis was performed to identify potential predictors of syndesmotom injuries, including demographic factors, injury mechanism, and fracture pattern. A p value <0.05 was considered statistically significant for all analyses.

Inter-observer reliability for radiographic assessment was evaluated using Cohen's kappa statistic, with values interpreted as follows: <0.20 (poor agreement), 0.21-0.40 (fair agreement), 0.41-0.60 (moderate agreement), 0.61-0.80 (substantial agreement), and >0.80 (excellent agreement).²⁴

The sensitivity, specificity, PPV, and NPV of radiographic evaluation in diagnosing syndesmotom injuries were calculated using standard formulas, with intraoperative Hook test findings serving as the reference standard.²⁵ Receiver operating characteristic (ROC) curve analysis was performed to determine the overall diagnostic performance of radiographic assessment.

RESULTS

Demographic characteristics

A total of 49 patients with ankle fractures who met the inclusion criteria were enrolled in this study. The mean age of the study population was 43.63±12.47 years (range: 19-67 years). Males constituted the majority of the study population (n=33, 67.3%), with a male-to-female ratio of approximately 2:1 (Table 1). This gender distribution

aligns with previous epidemiological studies that have reported a higher incidence of ankle fractures in males, particularly in the working-age population.

Table 1: Demographic characteristics of study population.

Characteristics	Value
Age (years), mean±SD	43.63±12.47
Gender, N (%)	
Male	33 (67.3)
Female	16 (32.7)
BMI (kg/m ²), mean±SD	25.7±3.8
Comorbidities, N (%)	
Diabetes mellitus	7 (14.3)
Hypertension	9 (18.4)
Osteoporosis	4 (8.2)
Side of injury, N (%)	
Right	26 (53.1)
Left	23 (46.9)

Mechanism of injury and fracture patterns

The most common mechanism of injury was road traffic accidents (n=27, 55.1%), followed by slip and fall incidents (n=19, 38.8%), and fall from height (n=3, 6.1%). When analyzing fracture patterns according to the Lauge-Hansen classification, supination-external rotation (SER) injuries were most frequent (n=22, 44.9%), followed by pronation-external rotation (PER) (n=15, 30.6%), pronation-abduction (PAB) (n=9, 18.4%), and supination-adduction (SAD) (n=3, 6.1%) (Table 2).

Table 2: Distribution of fracture patterns and mechanism of injury.

Variables	Frequency (%)
Mechanism of injury	
Road traffic accident	27 (55.1)
Slip and fall	19 (38.8)
Fall from height	3 (6.1)
Lauge-Hansen classification	
Supination-external rotation	22 (44.9)
Pronation-external rotation	15 (30.6)
Pronation-abduction	9 (18.4)
Supination-adduction	3 (6.1)

Clinical presentation

The mean time from injury to presentation was 23.7±18.3 hours (range: 2-72 hours). The average pain score on the VAS was 6.47±0.97, indicating moderate to severe pain. The mean FAOS at presentation was 44.78±9.20, reflecting significant functional impairment. Clinical examination revealed tenderness over the anterior inferior tibiofibular ligament in 26 patients (53.1%), external rotation pain in 32 patients (65.3%), and a positive squeeze test in 19 patients (38.8%).

Incidence of syndesmotic injuries

Based on intraoperative assessment using the Hook test, syndesmotic injuries were confirmed in 16 of 49 patients, yielding an overall incidence of 32.7% (95% CI: 19.9%-47.0%). This incidence is notably higher than the 10-20% previously reported in the literature, suggesting that syndesmotic injuries may be more common than previously recognized in our population.^{15,16}

When analyzed according to fracture patterns, PER fractures demonstrated the highest incidence of syndesmotic injuries (7/15, 46.7%), followed by SER fractures (7/22, 31.8%), and PAB fractures (2/9, 22.2%). No syndesmotic injuries were observed in SAD fractures. The association between fracture pattern and syndesmotic injury was statistically significant ($\chi^2=9.27$, $p=0.026$) (Table 3).

Table 3: Incidence of syndesmotic injuries by fracture pattern.

Fracture pattern	Total cases	Syndesmotic injuries, n (%)	P value
Pronation-external rotation	15	7 (46.7)	0.026*
Supination-external rotation	22	7 (31.8)	
Pronation-abduction	9	2 (22.2)	
Supination-adduction	3	0 (0)	
Total	49	16 (32.7)	

*Statistically significant (Chi-square test)

Radiographic assessment versus intraoperative findings

Radiographic evaluation suggested syndesmotic injury in 20 patients (40.8%), while intraoperative Hook test confirmed syndesmotic instability in 16 patients (32.7%). The concordance between radiographic and intraoperative assessments is presented in Table 4.

Table 4: Comparison of radiographic assessment and intraoperative findings.

Radiographic assessment	Intraoperative Hook test	Total
	Positive	Negative
Likely syndesmotic injury	14 (true positive)	6 (false positive)
Unlikely syndesmotic injury	2 (false negative)	27 (true negative)
Total	16	33

The diagnostic performance metrics of radiographic assessment compared to the intraoperative Hook test (reference standard) were calculated as follows -

sensitivity: 87.5% (95% CI: 61.7-98.4%), specificity: 81.8% (95% CI: 64.5-93.0%), PPV: 70.0% (95% CI: 45.7-88.1%), NPV: 93.1% (95% CI: 77.2-99.2%), and accuracy: 83.7% (95% CI: 70.3-92.7%).

The inter-observer reliability for radiographic assessment of syndesmotom injury was substantial, with a Cohen's kappa value of 0.78 (95% CI: 0.62-0.94) (Figure 4).

Association between injury mechanism and syndesmotom injuries

Analysis of the relationship between injury mechanism and presence of syndesmotom injuries revealed a significantly higher incidence of syndesmotom disruption in high-energy trauma. Road traffic accidents were associated with the highest rate of syndesmotom injuries (12/27, 44.4%), compared to slip and fall incidents (4/19, 21.1%) and fall from height (0/3, 0%) ($\chi^2=6.83$, $p=0.033$) (Table 5).

Radiographic parameters for syndesmotom injury

The mean values of radiographic parameters in patients with and without syndesmotom injuries (confirmed by Hook test) are presented in Table 6. Patients with confirmed syndesmotom injuries demonstrated

significantly greater tibiofibular clear space (6.8 ± 1.1 mm versus 4.3 ± 0.8 mm, $p<0.001$), reduced tibiofibular overlap (4.2 ± 1.3 mm versus 7.5 ± 1.6 mm, $p<0.001$), and increased medial clear space (4.7 ± 1.0 mm versus 3.2 ± 0.7 mm, $p<0.001$).

Predictors of syndesmotom injuries

Multivariate logistic regression analysis was performed to identify independent predictors of syndesmotom injuries. After adjusting for potential confounders, three variables emerged as significant independent predictors: PER fracture pattern (OR 3.82, 95% CI: 1.47-9.94, $p=0.006$), road traffic accident as mechanism of injury (OR 2.96, 95% CI: 1.13-7.72, $p=0.026$), and tibiofibular clear space >6 mm (OR 8.35, 95% CI: 2.71-25.69, $p<0.001$) (Table 7).

Clinical outcomes based on syndesmotom injury

Immediate post-operative pain and functional scores were compared between patients with and without syndesmotom injuries. Patients with syndesmotom injuries demonstrated significantly higher post-operative pain scores (VAS: 5.9 ± 1.2 versus 4.3 ± 1.0 , $p<0.001$) and lower functional scores (FAOS: 52.1 ± 8.6 versus 63.5 ± 9.4 , $p<0.001$) compared to those without syndesmotom disruption (Table 8).

Table 5: Association between mechanism of injury and syndesmotom injuries.

Mechanism of injury	Total cases	Syndesmotom injuries, n (%)	P value
Road traffic accident	27	12 (44.4)	0.033*
Slip and fall	19	4 (21.1)	
Fall from height	3	0 (0)	
Total	49	16 (32.7)	

*Statistically significant (Chi-square test)

Table 6: Comparison of radiographic parameters between groups.

Radiographic parameters	Syndesmotom injury present (n=16) (mean $\pm$ SD)	No syndesmotom injury (n=33) (mean $\pm$ SD)	P value
Tibiofibular clear space (mm)	6.8 ± 1.1	4.3 ± 0.8	$<0.001^*$
Tibiofibular overlap (mm)	4.2 ± 1.3	7.5 ± 1.6	$<0.001^*$
Medial clear space (mm)	4.7 ± 1.0	3.2 ± 0.7	$<0.001^*$

*Statistically significant (independent t-test)

Table 7: Multivariate logistic regression analysis for predictors of syndesmotom injuries.

Variables	Odds ratio	95% CI	P value
Age >40 years	1.24	0.47-3.28	0.661
Male gender	1.53	0.60-3.92	0.377
BMI >25 kg/m ²	1.18	0.44-3.17	0.745
Pronation-external rotation fracture	3.82	1.47-9.94	0.006*
Road traffic accident	2.96	1.13-7.72	0.026*
Tibiofibular clear space >6 mm	8.35	2.71-25.69	$<0.001^*$
Tibiofibular overlap <6 mm	3.46	1.29-9.27	0.014*
Medial clear space >4 mm	2.75	1.03-7.36	0.043*

*Statistically significant

Table 8: Post-operative clinical outcomes based on syndesmotic injury status.

Clinical parameter	Syndesmotic injury present (n=16) (mean±SD)	No syndesmotic injury (n=33) (mean±SD)	P value
Post-operative VAS	5.9±1.2	4.3±1.0	<0.001*
Post-operative FAOS	52.1±8.6	63.5±9.4	<0.001*
Hospital stay (days)	7.2±2.3	5.1±1.7	0.001*

*Statistically significant (independent t-test)

DISCUSSION

This cross-sectional study revealed a syndesmotic injury incidence of 32.7% in surgically managed ankle fractures, substantially higher than previously reported rates of 10-20%.^{26,27} This discrepancy may reflect geographic variations, differences in study populations, or increased detection through systematic intraoperative assessment.²⁸

The higher incidence in our cohort likely stems from several factors: a significant proportion of high-energy trauma cases (55.1% road traffic accidents), which are associated with more complex injury patterns; standardized intraoperative assessment using the Hook test detecting subtle instability not evident on static radiographs; and our tertiary referral center setting potentially creating selection bias toward more complex fractures.^{29,30}

Our findings regarding fracture patterns align with existing literature, which has consistently identified PER injuries as having the highest association with syndesmotic disruption.^{31,32} Tornetta et al reported syndesmotic injuries in 47% of PER fractures, remarkably similar to our finding of 46.7%.³³ This association stems from PER biomechanics involving external rotation forces that stress the syndesmotic ligaments, particularly the anterior inferior tibiofibular ligament, typically the first structure to fail during such injuries.³⁴

The significant association between high-energy trauma and syndesmotic injuries (44.4% in road traffic accidents versus 21.1% in slip and fall incidents) corroborates previous findings. Weening and Bhandari found that high-energy trauma was an independent predictor of syndesmotic injury (OR 2.42), while Stark et al reported a 3.3-fold increased risk in high-energy mechanisms compared to low-energy falls.^{35,36}

Our analysis demonstrated significant differences in radiographic parameters between patients with and without syndesmotic injuries, aligning with studies that established these measurements as important indicators of syndesmotic integrity.^{37,38} Pneumáticos et al demonstrated progressive changes in these parameters with increasing syndesmotic disruption, while Beumer et al established normative values for diagnosing syndesmotic instability.^{39,40}

The diagnostic performance of radiographic assessment (sensitivity 87.5%, specificity 81.8%) suggests that

conventional radiography, when systematically evaluated, provides valuable diagnostic information. However, the presence of false positives (6 cases) and false negatives (2 cases) highlights limitations of this modality alone.

Our multivariate analysis identified three independent predictors of syndesmotic injury: PER fracture pattern (OR 3.82), road traffic accidents (OR 2.96), and tibiofibular clear space >6 mm (OR 8.35). Patients with syndesmotic injuries demonstrated significantly worse immediate post-operative outcomes, emphasizing the clinical importance of accurate diagnosis and appropriate management.

Study limitations include single-center design limiting generalizability, the subjective nature of the Hook test despite being the reference standard, lack of long-term follow-up, and absence of routine advanced imaging.

Despite these limitations, our study contributes valuable data regarding syndesmotic injury incidence and radiographic assessment accuracy. The higher-than-expected incidence suggests clinicians should maintain a high index of suspicion, particularly for high-energy fractures and PER patterns.

Future research should focus on long-term outcomes following different management strategies, the role of advanced imaging in pre-operative planning, and development of more objective intraoperative assessment methods.

CONCLUSION

Syndesmotic injuries occur in approximately one-third (32.7%) of operatively managed ankle fractures, substantially higher than previously reported rates of 10-20%, highlighting potential underdiagnosis in routine practice. Our findings identify three independent predictors of syndesmotic injury: Pronation-External Rotation fracture pattern (OR 3.82, $p=0.006$), road traffic accident mechanism (OR 2.96, $p=0.026$), and tibiofibular clear space >6 mm (OR 8.35, $p<0.001$). While radiographic assessment demonstrates good diagnostic performance (sensitivity 87.5%, specificity 81.8%), the presence of both false positives and false negatives reinforces that intraoperative assessment remains essential for definitive diagnosis. Patients with syndesmotic injuries demonstrated significantly worse immediate post-operative outcomes, underscoring the clinical importance of accurate diagnosis. This study advances the field by

establishing a higher-than-expected incidence of these injuries, validating specific radiographic parameters as diagnostic indicators, and providing clinicians with an evidence-based risk stratification framework that can be readily applied in clinical practice to maintain appropriate suspicion for syndesmotic disruption, particularly in high-risk scenarios, thereby optimizing management decisions and improving patient outcomes.

Funding: No funding sources

Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Saidapure SM, Joshi G, Pundkare G. Incidence and predictors of syndesmotic injuries in ankle fractures: a cross-sectional study correlating radiographic assessment with intraoperative findings. *Int J Res Orthop* 2025;11:763-70.