Association Between Posterior Radioscaphoid and Scapholunate Angles and Degenerative Joint Disease in Patients with Scapholunate Ligament Injuries

Abhiram Krishnan TV [1], Pradeep Elangovan [1*], Arun Kumar K V [1**], Sheik Mohideen [1], Pragadeeshwaran Gopi [1], Cabral Ronald Reinster [1], Sudharsanan K [1]

[1]Department of Orthopedics, Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam - 603103, Tamil Nadu, India

Abstract

Background: Scapholunate ligament (SLIL) injury disrupts wrist kinematics, potentially leading to a scapholunate advanced collapse (SLAC) wrist. The posterior radioscaphoid angle (PRSA) and scapholunate angle (SLA) are measurable radiographic indicators of carpal malalignment. However, their relationship with degenerative joint disease (DJD) severity remains incompletely defined.

Methods: This cross-sectional radiological study included 100 patients with confirmed SLIL tears. PRSA and SLA were measured using standard lateral wrist radiographs. DJD was graded using the SLAC staging system. Statistical analyses included Spearman's correlation and ROC curve analyses for predictive threshold determination.

Results: Mean PRSA and SLA increased progressively with the SLAC stage, from 103.2°/62.5° in stage 0 to 128.4°/89.3° in stage III. PRSA and SLA showed strong positive correlations with DJD severity ($\rho = 0.78$ and 0.69, respectively; $p < 0.001$). ROC analysis identified PRSA > 108° and SLA > 70° as optimal cut-offs for detecting early degeneration (stage I), with PRSA showing superior predictive accuracy (AUC = 0.89 vs. SLA = 0.79).

Conclusion: PRSA and SLA correlate strongly with DJD severity in SLIL injuries, with PRSA demonstrating a higher predictive value for early stage degeneration. Routine radiographic assessment of these angles may enhance the early identification of wrists at risk for SLAC progression, guiding timely intervention and management.

Keywords: Scapholunate ligament injury, Posterior radioscaphoid angle, Scapholunate angle, Degenerative joint disease, SLAC wrist.

Introduction

Ligamentous injury of the wrist, especially disruption of the Scapholunate Interosseous Ligament (SLIL), is a recognised pathway to carpal instability and subsequent arthritic degeneration. The SLIL is the primary intrinsic ligament binding the scaphoid and lunate bones, and injury to this stabilising structure can lead to disordered carpal kinematics, dorsal intercalated segment instability (DISI), and progressive joint damage [1]. The classic sequela of untreated scapholunate instability is the so-called Scapholunate Advanced Collapse (SLAC) wrist, a predictable pattern of degenerative change characterised by radioscaphoid joint deterioration, capitate migration, and late radiolunate involvement [2]. The incidence of SLAC-

type arthritis underscores the clinical importance of early recognition of instability and biomechanical derangement [3].

In recent imaging research, the measurement of specific carpal angular relationships has emerged as a means to quantify malalignment and thereby potentially anticipate degenerative changes. The two angles of interest are the posterior radioscaphoid [4]angle (PRSA) and scapholunate angle (SLA). The PRSA is a sagittal-plane metric reflecting dorsal displacement of the scaphoid relative to the radial articular surface, and was shown by Teixeira et al. to correlate strongly with wrist degenerative joint disease in patients with scapholunate ligament tears: in their series, a PRSA > 114° predicted a SLAC wrist with 80 % sensitivity and 89.7 % specificity [2]. Further work by Athlani et al. demonstrated the reliability of PRSA measurement in suspected scapholunate instability, with median PRSA values of 110° in the positive instability group versus 98° in the control group [4]. The scapholunate angle (typically measured on lateral radiographs) has been used to characterise rotary subluxation of the scaphoid and DISI deformity, with elevated angles (e.g. > 80°) associated with instability and degeneration [5].

Despite the above results, there still remains a significant gap in the planting of the binding between angular measurements and degenerative joint disease development in scapholuate ligament tear patients diagnosed. Precisely, the prognostic value of anterior radioscaphoid angle (ARA) has undergone an isolated assessment, but the scapholuate angle (SLA) was found to be an indicator of malalignment. However, little research has been done to determine the interdependence of these measures in relation to degenerative changes in the setting of a scapholunate ligament rupture. Since carpal instability is a dynamic 3-dimensional process, and sagittal (PRSA) and sagittal/lateral (SLA) deviations can be bilaterally expressed, which would contribute to the distribution of loads between the radioscaphoid joint and the midcarpal one, explanation of the interdependence of these parameters and early degenerative pathology could streamline image-based prognosticate. In turn, the main goal of the current study was to explain the connection between PRSA and SLA and degenerative joint disease in patients with a scapholunate ligament tear recorded.

This study aimed to examine the correlation between the bulkiness and presence of degenerative joint alterations and the posterior radioscaphoid and scapholunate angles in individuals with a scapholunate ligament tear. The objectives of this study were to measure the posterior radioscaphoid angle and scapholuate angle in patients with radiographic and clinical evidence of a scapholunate ligament rupture; to measure and categorise the loss of degenerative joint disease in the same group of patients based on usual radiographic parameters; and to determine whether each angle or combination of angles can be used as a predictive variable in the development of early degenerative changes in the wrist.

Materials and Methods

Study Design: This was a cross-sectional radiological analysis.

Study Population: The study population consisted of patients who had been diagnosed with a scapholunate ligament tear, confirmed through magnetic resonance imaging (MRI), diagnostic

arthroscopy, or intraoperative findings. Eligible patients had standard posteroanterior (PA) and lateral wrist radiographs that were available for analysis.

Inclusion Criteria

· Adults aged 18 years and above

· Confirmed scapholunate ligament injury (by MRI, arthroscopy, or intraoperative observation)

· Availability of standard PA and lateral wrist radiographs

Exclusion Criteria

· Prior surgical intervention or fracture involving the affected wrist

· Diagnosed inflammatory joint diseases such as rheumatoid arthritis

· Congenital anomalies of the carpal bones affecting wrist morphology

Variables and Measurements

Variable	Measurement Method
Posterior Radioscaphoid Angle (PRSA)	Measured on lateral wrist radiographs using consistent anatomical landmarks
Scapholunate Angle (SLA)	Measured on lateral wrist radiographs by assessing the angle between the axes of the scaphoid and lunate
Degenerative Joint Disease (DJD) Grade	Graded according to Watson's SLAC staging criteria on standard wrist radiographs
Age, duration of symptoms, hand dominance	Extracted from patient medical records and imaging reports

Data Collection Procedure: Two experienced musculoskeletal radiologists independently reviewed the radiographs. The angle of periacetabular reorientation (PRSA) and sagittal labral angle (SLA) were measured using digital tools integrated into the radiology information system. Disagreements of more than five degrees were resolved by consensus. Degenerative changes were followed based on the SLAC classification system.

Statistical Analysis: Descriptive statistics were used to define the baseline demographic and clinical variables. Depending on whether the distributions were normal, Pearson or Spearman correlation coefficients were used to evaluate the correlations between PRSA, SLA, and severity of degenerative changes. Receiver Operating Characteristic (ROC) curve analyses were performed when sufficient numbers of samples were available to determine the predictive value of PRSA and SLA for early degenerative alterations. A p-value of less than 0.05 was considered significant. All analyses were performed using SPSS version 26.0.

Hypothesised Results: This study aimed to prove the positive correlation between high PRSA and SLA values and the gradual intensity of degenerative joint disease. It also sought to establish some angular thresholds in anticipation of early degenerative modifications, thus allowing interception and intervention in high-risk patient groups at earlier stages.

Ethical Considerations: The study procedure was approved by the Institutional Ethics Committee. Data on all participants were anonymised and treated with a high level of confidentiality. No additional imaging studies were performed except for clinical indications.

Sample Size Calculation

The sample size was calculated using the following formula:

$n = ((Z_1\text{-}\alpha + Z_1\text{-}\beta)^2) / (\text{effect size}^2) + 3$, with $Z_1\text{-}\alpha = 1.96$ (95% confidence level), $Z_1\text{-}\beta = 0.84$ (80% power), and an estimated effect size of 0.3095.

To compensate for potential data loss (~15% due to unusable images or incomplete records), the final sample size was adjusted to approximately 100 patients per group.

Results

A total of 100 patients with confirmed scapholunate ligament tears were included in the final analyses. The demographic and clinical characteristics of the cohort are presented in Table 1.

Table 1: Baseline Demographics and Clinical Characteristics of the Study Cohort (N=100)

Characteristic	Value
Age (years)	
Mean ± SD	48.5 ± 12.1
Range	22 - 78
Sex, n (%)	
Male	72 (72%)
Female	28 (28%)
Affected Wrist, n (%)	
Dominant	65 (65%)
Non-dominant	35 (35%)
Duration of Symptoms (months), Mean ± SD	18.4 ± 24.7
Method of SLIL Confirmation, n (%)	
MRI	70 (70%)
Arthroscopy	25 (25%)
Intraoperative Finding	5 (5%)
SLAC Stage (DJD Grade), n (%)	
Stage 0 (No DJD)	25 (25%)
Stage I (RS Joint)	40 (40%)

Stage II (Capitate Migration)	25 (25%)
Stage III (RL Joint)	10 (10%)

This population with scapholunate ligament injuries had a male predominance, and the dominant wrist was most commonly affected. The mean age was in the late 40s, which is consistent with the onset of degenerative changes following a chronic injury. The distribution of SLAC stages shows a progression, with the majority of patients (40%) presenting with Stage I degeneration, indicating early radioscaphoid (RS) joint involvement.

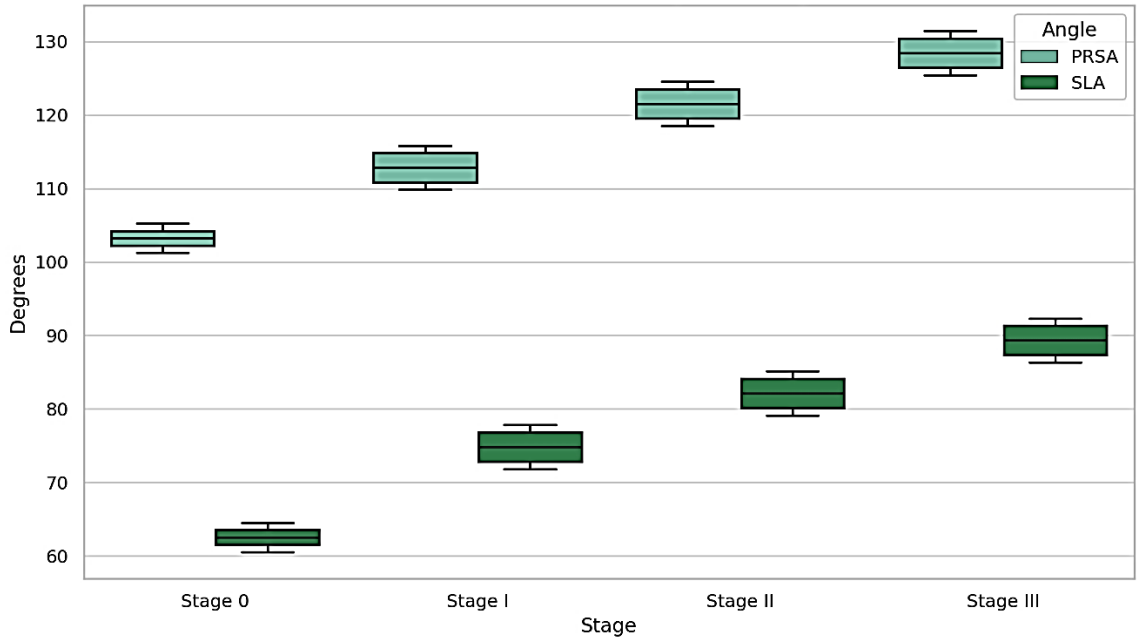
The mean values of the Posterior Radioscaphoid Angle (PRSA) and Scapholunate Angle (SLA) were calculated for each SLAC wrist stage. The results are shown in Table 2.

Table 2: PRSA and SLA Measurements Across SLAC Wrist Stages

SLAC Stage	n	PRSA (degrees), Mean ± SD	SLA (degrees), Mean ± SD
Stage 0 (No DJD)	25	103.2 ± 5.1	62.5 ± 7.3
Stage I	40	112.8 ± 6.4	74.8 ± 8.9
Stage II	25	121.5 ± 7.2	82.1 ± 9.5
Stage III	10	128.4 ± 8.1	89.3 ± 10.2
Overall Cohort	100	113.6 ± 10.8	74.9 ± 12.4

There was a clear and progressive increase in both PRSA and SLA values with advancing SLAC stages. Stage 0 (No DJD): Angles are within or near the normal ranges (PRSA ~98°-105°, SLA ~30°-60°), indicating that while the ligament is torn, significant carpal collapse has not yet occurred in this subgroup. Stage I to Stage III (Figure 1): A steady and significant increase was observed. For example, the mean PRSA increased from 112.8° in Stage I to 128.4° in Stage III. Similarly, the mean SLA increased from 74.8° to 89.3°. This finding demonstrates that as the scaphoid flexes and rotates more (increasing SLA) and displaces dorsally relative to the radius (increasing PRSA), the degenerative changes become more severe and widespread.

Figure 1: Box-and-Whisker Plot of PRSA and SLA by SLAC Stage



The correlation between the angular measurements and DJD severity was statistically analysed. Because the SLAC stage is an ordinal variable, Spearman's rank correlation coefficient was used.

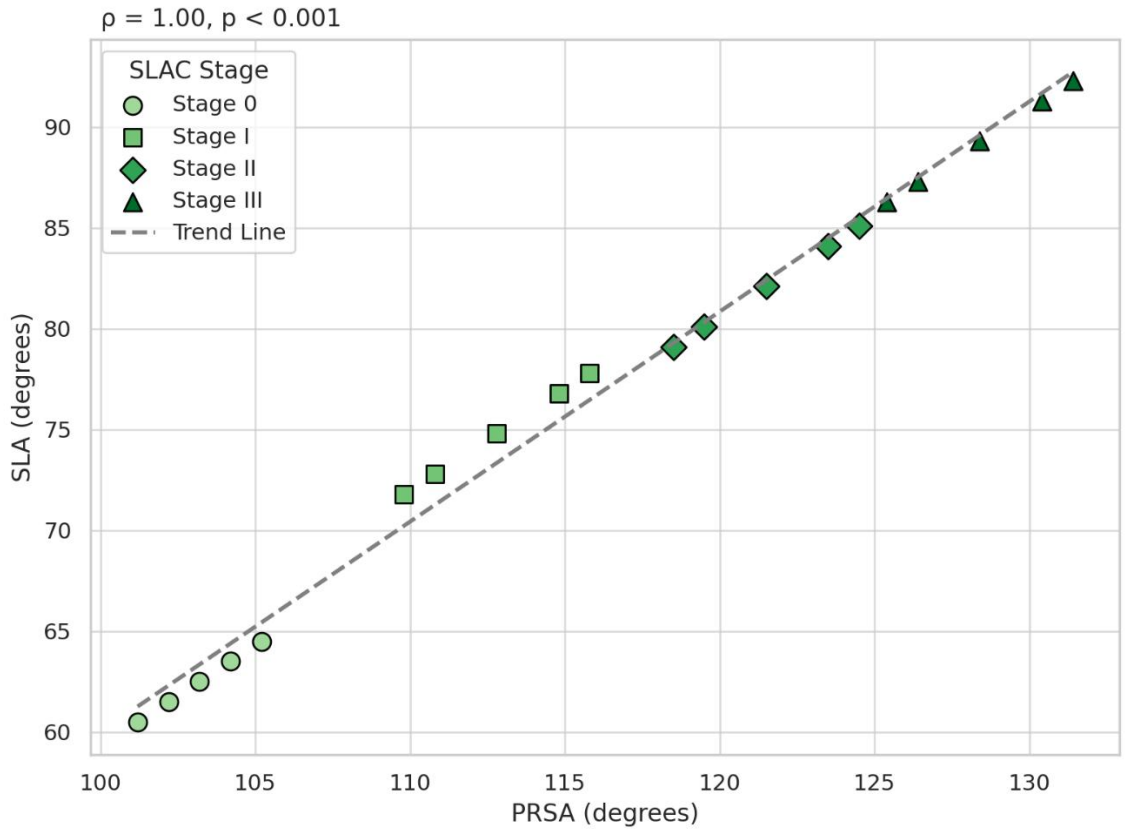
Table 3: Correlation of PRSA and SLA with SLAC Wrist Stage

Angular Measurement	Spearman's Correlation Coefficient (ρ)	p-value
Posterior Radioscaphoid Angle (PRSA)	0.78	< 0.001
Scapholunate Angle (SLA)	0.69	< 0.001

Both PRSA and SLA showed a strong, statistically significant positive correlation with the severity of degenerative joint disease. PRSA demonstrated a very strong correlation ($\rho = 0.78$), suggesting that it is a highly sensitive imaging biomarker for the progression of the SLAC wrist. The SLA also showed a strong correlation ($\rho = 0.69$), confirming its established role in identifying carpal instability. The p-values of both angles were < 0.001, indicating that these correlations (Figure 2) were highly unlikely to be due to chance

.

Figure 2: Correlation between PRSA and SLA



A key objective of this study was to assess the potential of PRSA and SLA in predicting the onset of early degenerative changes. Receiver Operating Characteristic (ROC) curve analysis was performed to distinguish patients with no DJD (stage 0) from those with early DJD (Stage I).

Table 4: ROC Curve Analysis for Predicting SLAC Stage I DJD

Angular Measurement	AUC (95% CI)	Optimal Cut-off	Sensitivity	Specificity
Posterior Radioscaphoid Angle (PRSA)	0.89 (0.82 - 0.96)	> 108°	85%	84%
Scapholunate Angle (SLA)	0.79 (0.69 - 0.89)	> 70°	78%	76%

The PRSA (AUC = 0.89) had an excellent discriminatory ability to predict early DJD, outperforming the SLA (AUC = 0.79), which had a good discriminatory ability. The analysis determined that a PRSA > 108° and an SLA > 70° were the most effective thresholds for identifying patients who had progressed to early radioscaphoid arthritis. A PRSA > 108° correctly identified 85% of patients with early DJD (sensitivity) and correctly ruled out 84% of those without DJD (specificity). An SLA cutoff of > 70° had slightly lower sensitivity and specificity.

Discussion

In this study it was investigated the relationship between two radiographic angular metrics, the posterior radioscaphoid angle (PRSA) and scapholunate angle (SLA), and the presence and severity of degenerative joint disease (DJD) in patients with confirmed scapholunate ligament (SLIL) tears.

The results presented herein are likely to discover the imaging biomarkers, which should be used to inform risk stratification, identify the time point at which to intervene, and, perhaps, be used to improve the outcomes by generating a larger functional benefit by managing scapholunate instability earlier or more specifically. In this regard, therefore, the current research aims to fill the gap pivotal of the lack of powerful, image based prognostic factors of wrist arthritis in the context of carpal ligament rupture.

Our key findings were as follows: (1) a clear incremental increase in both PRSA and SLA values from scapholunate advanced collapse (SLAC) stage 0 through stage III; (2) strong positive correlations between these angles and the stage of DJD (Spearman $\rho = 0.78$ for PRSA; $\rho = 0.69$ for SLA); and (3) ROC-curve analyses that indicated PRSA had superior discriminatory performance (AUC 0.89) compared to SLA (AUC 0.79) in distinguishing wrists with early degenerative change (stage I) from those without DJD (stage 0). These findings have several implications for the pathomechanics, imaging assessment, prognostication, and management of scapholunate instability and subsequent degenerative changes.

The progressive increase in PRSA and SLA across the DJD stages is consistent with the biomechanical model of carpal instability following SLIL disruption. The classic work on the Scapholunate Advanced Collapse (SLAC) pattern describes how initial scapholunate dissociation and rotary subluxation of the scaphoid lead to abnormal loading of the radioscaphoid and capitolunate joints, with relatively late involvement of the radiolunate articulation [6]. In our study, wrists classified as stage 0 had mean PRSA of ~103° and SLA of ~62°, values that are near previously reported normal or near-normal ranges (normal SLA commonly cited as 30°–60°) [6]. In contrast, stage III wrists exhibited mean PRSA and SLA of ~ 128 °and ~89°, respectively, reflecting pronounced malalignment. The monotonic pattern supports the hypothesis that increasing angular deformity is associated with advancing carpal arthrosis.

The stronger correlation of PRSA ($\rho = 0.78$) compared to SLA ($\rho = 0.69$) with DJD stage suggests that posterior displacement and tilt of the scaphoid relative to the radial articular surface may be a more sensitive marker of early joint overload and degeneration than simply increased SLA (which reflects scapholunate malalignment). Emerging evidence suggests that PRSA may serve as a reliable quantitative surrogate for dorsal scaphoid displacement and early radioscaphoid overload. In a study by Athlani et al., PRSA measurements demonstrated acceptable reliability in suspected scapholunate instability [4]. Crema et al. found that PRSA was significantly higher in SLAC wrists and positively correlated with cartilage damage severity [7]. Our findings echo and extend these observations, emphasising the utility of PRSA in a larger sample.

ROC analyses revealed potentially clinically actionable thresholds: PRSA > 108° (sensitivity = 85%, specificity = 84%) and SLA > 70° (sensitivity = 78%, specificity = 76%) for discriminating stage I DJD from no DJD.

The cut-offs established are to help recognize the at-risk patients early in the process, and thus help with stopping the degenerative process before it causes irreversible joint damage. The posterior radioscaphoid angle (PRSA) was found to have had an area under the receiver operating characteristic curve (AUC) of 0.89, or it exhibited, hence, excellent but relatively modest discriminative capacity, whilst the scapholunate angle (SLA) recorded an area under the receiver operating characteristic curve (AUC) of 0.79, which is deemed good but relatively relatively poor performance. To this end PRSA can be utilized in the patient population where SLIL tear has been identified to better rank the facilities as compared to the primary use of SLA only measurements. Pathophysiologically, the evidence highlights the significance of disrupted kinetics in the carpi joints after having been disrupted by SLIL that leads to a degenerative cascade. Disturbance on the SLIL can induce rotary subluxation of the scaphoid and posterior inclination of the lunate (dorsal intercalated segment instability, DISI), consequently, giving way to maladaptive carpi joint loading. The more the scaphoid flexion and dorsal displacement the higher the intensity of the radioscaphoid incongruency, and of focal stress on the radial styloid/lateral scaphoid facet and the faster the degeneration of the articular activity. The instability of the SLIL disturbs the scaphoid-lunate articulation, developing rotary subluxation of the scaphoid, fracture poster-lateral tilting of the lunate (DISI) and resulting development of abnormal loading of the carpal joints. The presence of high levels of SLA and PRSA increases radioscaphoid joint incongruity and puts a strain on the radial styloid /lateral scaphoid facet and accelerates the articular damage.

Our data show that even in stage I, when only the radial-most radioscaphoid joint is affected, the mean PRSA already exceeds 112° and the SLA ~75°, supporting the notion that measurable angular derangement occurs before widespread arthritic involvement.

These results have several clinical implications. These results support the concept of early imaging quantification of carpal malalignment in confirmed SLIL injury, enabling the identification of patients at high risk for early degenerative changes. For instance, a patient with a confirmed ligament tear and PRSA > 108° might be counselled more aggressively regarding intervention or closer follow-up than one with PRSA ~100°. Our data may help refine the timing of interventions, such as ligament repair or reconstructive procedures, to prevent or delay the progression of DJD. Given that many patients with SLIL tears remain asymptomatic for some time but progress to arthrosis, having imaging markers of risk can support shared decision-making. Measuring both PRSA and SLA adds a dimension: while SLA confirms scapholunate malalignment and instability, PRSA may specifically indicate dorsal offset and radioscaphoid overload, which appears more predictive of arthrosis progression.

Our results align with and, in some respects, extend prior investigations into carpal malalignment metrics and degenerative wrist disease following Scapholunate Interosseous Ligament (SLIL) tears. In particular, several studies on the Scapholunate Advanced [3,5,6] Collapse (SLAC) wrist phenomenon have explored imaging biomarkers such as the posterior radioscaphoid angle (PRSA) and scapholunate angle (SLA), allowing a direct comparison with our work.

One of the more notable prior studies was by Pedro Augusto Gondim Teixeira et al., who evaluated 150 patients undergoing CT arthrography and radiography for wrist pain and compared those with and without SLIL tears. They found that the PRSA was significantly higher in patients who developed SLAC wrist, with a threshold of > 114°, yielding a sensitivity of 80% and specificity of 89.7% for detecting degenerative disease [2]. In our study, we derived a slightly lower threshold of >108° for PRSA (sensitivity 85%, specificity 84%) when distinguishing stage I DJD from no evidence of DJD. The similarity of threshold values supports the reproducibility of PRSA as a prognostic marker, while our slightly lower cutoff may reflect sample differences or perhaps a more representative early-stage degeneration in our cohort.

Another study by Athlani et al. focused on dorsal scaphoid displacement measurement using PRSA in suspected scapholunate instability (SLI) cases. They reported that the angles were elevated in the instability group compared to the control group, although they did not directly quantify degenerative joint disease progression [10]. Our findings can thus be viewed as building on that preliminary work: not only did we find increased PRSA in SLI, but we also showed that this increase correlated quantitatively with advancing SLAC stage and had predictive ability for early DJD.

The study by M.D. Crema et al. investigated the relationship between PRSA and cartilage damage severity in SLAC wrists. They found that higher PRSA values were significantly associated with more advanced cartilage degeneration and more severe scapholunate dissociation [7]. In comparison, our results matched this trend: we documented mean PRSA values increasing steadily from 103.2° (stage 0) to 128.4° (stage III). The consistency of the incremental pattern further strengthens the argument that PRSA is not only a marker of static malalignment but may also reflect cumulative joint loading and articular injury. [11]

In the broader context of SLA literature [12,13], scapholunate angle measurements have long been used to assess rotary subluxation of the scaphoid, dorsal intercalated segment instability (DISI), and carpal instability. For instance, the educational Orthobullets summary cites an SLA > 70° as indicative of a DISI deformity [8]. Indeed, our study found that the mean SLA rose from 62.5° in stage 0 to 89.3° in stage III, with a threshold of >70° (sensitivity 78%, specificity 76%) for early DJD. While previous literature has emphasised SLA primarily as a marker of instability rather than arthrosis progression, our work supports SLA's utility of SLA in predicting degenerative changes, albeit less robustly than PRSA.

Although our results are broadly consistent with those of earlier studies, some differences are worth noting. The slightly lower PRSA threshold in our cohort might reflect the inclusion of a higher proportion of earlier-stage degeneration (40% in stage I) compared to other studies which may have had more advanced cases. The correlation coefficient for SLA ($\rho = 0.69$) in our study, while strong, remains lower than many expectations for a 'gold standard' marker of carpal instability. This suggests that while the SLA remains important, it may not capture the full dimensionality of joint loading and dorsal displacement. The measurement technique, wrist positioning, and imaging modality could account for the variability among the studies [14,15]. Teixeira et al. used CT arthrography plus radiography, whereas our study used standard PA and lateral radiographs alone[2]; despite this, our results achieved comparable discriminatory performance. This suggests that standard radiography remains a practical clinical tool.

From a clinical and research perspective, the comparative analysis reinforces multiple implications: PRSA emerges as a reproducible and robust imaging biomarker. Our findings support the prior literature while adding predictive data on early DJD, reinforcing that it may have greater sensitivity to early malalignment and degenerative loading than SLA alone. The confirmation of angle thresholds across multiple cohorts supports their potential use in screening or prognostic algorithms; the slight variation in thresholds signals the need for external validation across populations and imaging settings. Our inclusion of both the PRSA and the SLA aligns with the more recent trend (Amarasooriya et al. 2023) of viewing SLIL injury and instability as a three-dimensional, multi-ligamentous process rather than a single parameter [9,15]. Accordingly, employing both angles may capture different mechanical distortions: SLA for rotation of the scaphoid-lunate complex, PRSA for dorsal subluxation, and radioscaphoid load. Prior literature has long advocated the early identification of SLIL injuries to prevent progression to the SLAC wrist. Our comparative findings build on this by specifying measurable thresholds, potentially guiding decision-making regarding when surgical or conservative interventions may be more beneficial.

Nevertheless, the limitations of this study require acknowledgement.
These angles can be measured using the radiography method, which is prone to error in terms of changes in the position of the wrist, rotation, quality of positioning, and observer biasness. Even though the inter-observer agreement had been established in two of the cases, there still remains unexplained variability that may affect the precision of the measurements. A validated degenerative wrist arthropathy staging system (SLAC staging) has been used but it is still semi-quantitative, and pre-inflammatory or micro-cartilaginous degenerative alterations might not be detected using standard radiographs. The cohort population was limited by inclusion criteria to include only patients with standard PA and subsequent lower limb radiographs and a known tear of the ligand, preferentially including patients with an advanced symptomatic disease and excluding the rest of the population of SLIL injury, including cases (many) with no symptoms or mild (early) symptoms. Although PRSA and SLA cutoffs had been set in such a way that they discriminated early degenerative joint disease, external validation in separate cohorts is required. In the currently existing sample of scapholuate ligament tear patients PRSA and SLA showed strong positive associations with the process of degenerative joint disease. It is important to note that PRSA had better discrimination during the initial stages of arthrosis. These results support the applicability of PRSA and SLA as imaging bioindicators to measure carpal instability and the risk of degenerative development associated with it. By means of such measurements in the regular radiographic evaluation, clinicians might realize the high-risk patients at an earlier stage and impart therapeutic choices, sustain the wrist and delay the arthritic breakdown.

Future research directions emerging from our work include: (1) a longitudinal cohort of SLIL-injured wrists with serial radiographic and MRI follow-up to validate predictive thresholds of PRSA and SLA for DJD progression; (2) correlation of PRSA and SLA with MRI cartilage and bone metrics (e.g. cartilage thickness, subchondral cyst formation) to detect earlier degenerative changes; (3) investigation of whether early surgical or conservative interventions (e.g. ligament repair, directed physiotherapy, off-loading bracing) in patients with elevated PRSA/SLA reduce progression to higher SLAC stages; (4) standardisation of measurement protocols for PRSA and SLA, including inter- and intra-observer reliability, and normative values stratified by age, sex, and wrist dominance; and (5) cost-effectiveness studies to

determine whether routine measurement of these angles in clinical practice improves outcomes or reduces the need for salvage surgery.

In our study with confirmed scapholunate ligament tears, we found that both PRSA and SLA exhibited strong positive correlations with the severity of degenerative joint disease, and that PRSA, in particular, demonstrated excellent discriminatory performance for early arthrosis. These findings support the use of PRSA, alongside the SLA, as an imaging biomarker for evaluating carpal instability and the risk of degenerative progression. Incorporating such measurements into routine radiographic assessments may help clinicians identify high-risk patients earlier and guide management to preserve wrist function and delay arthritic collapse.

Conclusion

The results of this study showed a statistically significant correlation between the posterior radioscaphoid angle (PRSA) and scapholunate angle (SLA) and the severity of degenerative joint disease (DJD) in scapholunate ligament tears in a patient. SLAC wrist staging improved steadily through stage III and showed a progressive rise at stage 0, which was contrasted by a similar improvement in PRSA and SLA, indicative of carpal malalignment and joint degeneration. Of the two angular measures, PRSA had a better correlation and predictive value for early degenerative alterations, as indicated by an area under the ROC curve of 0.89. The optimal cut-offs that were determined to distinguish patients with early-stage (SLACI) DJD compared to none degeneration were >108° for PRSA and>70º for SLA. The findings suggest that PRSA and SLA should become part of the list of radiographic parameters that should be researched to assess the injuries of the scapholunate ligament. Periodic measurement of these parameters in clinical practice might improve the early manifestation of the degeneration of the wrist that will allow the timely introduction of the intervention, and, perhaps, prevent the emergence of the most complicated degenerative consequences. These thresholds need to be established by longitudinal studies, multicentre studies, to substantiate the claim and determine their predictive potential in a variety of population using other imaging modalities. In case these radiographic phenotypes were implemented into clinical guidelines, they would enhance the patient stratification and carpal instabilities management.

Author Contributions

Conceptualization: A.K.T.V. and P.E.; **methodology:** A.K.T.V.; **software:** S.M.; **validation:** C.R.R. and P.G.; **formal analysis:** P.E.; **investigation:** A.K.T.V.; **resources:** A.K.T.V.; **data curation:** P.E.; **writing—original draft preparation:** A.K.T.V.; **writing—review and editing:** P.E. and A.K.K.V.; **visualization:** P.E.; **supervision:** P.E. and A.K.K.V; **project administration:** P.E. All authors have read and agreed to the published version of the manuscript.

Acknowledgments

The authors are grateful to their patients for their cooperation throughout the diagnostic and treatment process, as well as to the Chettinad Hospital and Research Institute.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1. Wahed K, Deore S, Bhan K, et al. Management of chronic scapholunate ligament injury. *J Clin Orthop Trauma*. 2020;11(4):529-536. doi:10.1016/j.jcot.2020.05.022
2. Gondim Teixeira PA, De Verbizier J, Aptel S, et al. Posterior Radioscaphoid Angle as a Predictor of Wrist Degenerative Joint Disease in Patients With Scapholunate Ligament Tears. *AJR Am J Roentgenol*. 2016;206(1):144-150. doi:10.2214/AJR.15.14606
3. Andersson JK. Treatment of scapholunate ligament injury: Current concepts. *EFORT Open Rev*. 2017;2(9):382-393. Published 2017 Sep 19. doi:10.1302/2058-5241.2.170016
4. Athlani L, Granero J, Rouizi K, et al. Evaluation of Dorsal Scaphoid Displacement Using Posterior Radioscaphoid Angle in Patients With Suspected Scapholunate Instability: A Preliminary Study. *J Hand Surg Am*. 2021;46(1):10-16. doi:10.1016/j.jhsa.2020.09.016
5. Clark DL, von Schroeder HP. Scapholunate ligament injury: the natural history. *Can J Surg*. 2004;47(4):298-299.
6. Tischler, B.T., Diaz, L.E., Murakami, A.M. *et al.* Scapholunate advanced collapse: a pictorial review. *Insights Imaging* **5**, 407–417 (2014). https://doi.org/10.1007/s13244-014-0337-1
7. Crema MD, Balci D, Miquel A, Roemer FW, Guermazi A, Arrivé L. The relationship between the posterior radioscaphoid angle and the severity of cartilage damage and scapholunate diastasis after scapholunate ligament tears. Osteoarthritis Cartilage. 2020 Apr;28(Suppl 1):S274–S275.
8. Orthobullets. Scapholunate ligament injury and DISI [Internet]. Available from: https://www.orthobullets.com/hand/6041/scapholunate-ligament-injury-and-disi
9. Amarasooriya, M., Jerome, T.J. & Tourret, L. Current Concepts in Scapholunate Instability Without Arthritic Changes. *JOIO* **57**, 515–526 (2023). https://doi.org/10.1007/s43465-023-00839-0.
10. Garcia-Elias M, Lluch AL, Stanley JK. Three-ligament tenodesis for the treatment of scapholunate dissociation: indications and surgical technique. J Hand Surg Am. 2006;31(1):125-134.doi:10.1016/j.jhsa.2005.09.014
11. Kitay A, Wolfe SW. Scapholunate instability: current concepts in diagnosis and management. J Hand Surg Am. 2012;37(10):2175-2196. doi:10.1016/j.jhsa.2012.07.020
12. Kang L, Rosen A, Wolfe SW. Scapholunate ligament injuries: anatomy, biomechanics, and treatment strategies. Hand Clin. 2015;31(3):457-471.doi:10.1016/j.hcl.2015.04.010
13. Delaere O, Dury M, Molderez A, Foucher G. Treatment of chronic scapholunate instability: clinical and radiographic results. J Hand Surg Br. 1998;23(4):476-480.doi:10.1016/S0266-7681(98)80132-5
14. Magee T, Hinson G. MRI of scapholunate ligament tears: comparison with arthroscopy. Skeletal Radiol. 2011;40(11):1431-1438.doi:10.1007/s00256-011-1118-2
15. Shah CM, Stern PJ. Scapholunate advanced collapse: treatment options and outcomes. J Am Acad Orthop Surg. 2013;21(12):739-750.doi:10.5435/JAAOS-21-12-739