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The Quantitative Anatomy of the Dorsal Scapholunate Interosseous Ligament

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Abstract

Background: The anatomy of the scapholunate interosseous ligament (SLIL) has been described qualitatively in great detail, with recognition of the dorsal component's importance for carpal stability. The purpose of this study was to define the quantitative anatomy of the dorsal SLIL and to assess the use of high-frequency ultrasound to image the dorsal SLIL. **Methods:** We used high-frequency ultrasound imaging to evaluate 40 wrists in 20 volunteers and recorded the radial-ulnar (length) and dorsal-volar (thickness) dimensions of the dorsal SLIL and the dimensions of the scapholunate interval. We assessed the use of high-frequency ultrasound by comparing the length and thickness of the dorsal SLIL on ultrasound evaluation and open dissection of 12 cadaveric wrists. Student's *t* test was used to assess the relationship between measurements obtained on cadaver ultrasound and open dissection. **Results:** In the volunteer wrists, the mean dorsal SLIL length was 7.5 ± 1.4 mm and thickness was 1.8 ± 0.4 mm; the mean scapholunate interval was 5.0 mm dorsally and 2.5 mm centrally. In the cadaver wrists, there was no difference in dorsal SLIL length or thickness between ultrasound and open dissection. **Conclusions:** The dorsal SLIL is approximately 7.5 mm long and 1.8 mm thick. These parameters may be useful in treatment of SLIL injuries to restore the native anatomy. High-frequency ultrasound is a useful imaging technique to assess the dorsal SLIL, although further study is needed to assess the use of high-frequency ultrasound in detection of SLIL pathology.

Keywords: scapholunate ligament, carpal instability, wrist ultrasound, interosseous ligament, carpal ligament anatomy

Introduction

The scapholunate interosseous ligament (SLIL) plays a critical role in carpal stability, functioning as the primary stabilizer of the scapholunate articulation.[1-3] Disruption of this ligament results in altered carpal alignment and biomechanics, and surgical treatment is often recommended to restore the integrity of the scapholunate articulation and carpal kinematics, and prevent development of posttraumatic arthritis and carpal collapse (scapholunate advanced collapse [SLAC] wrist).[4-6] When identified acutely, SLIL injuries are often repaired primarily. When primary repair is not possible, the optimal treatment method remains controversial, but many techniques to reconstruct the scapholunate ligament have been described.[7-15] Detailed knowledge of the scapholunate ligament anatomy may be beneficial to optimize surgical outcomes.

In a landmark cadaveric study, Berger described the scapholunate ligament as a U-shaped structure with 3 anatomically and histologically distinct components: dorsal, proximal, and volar.[16] His histological analysis and subsequent biomechanics studies have demonstrated the importance of the dorsal component of the scapholunate ligament in carpal stability, and it is restoration of this dorsal component that is the focus of scapholunate ligament repair and many reconstructive techniques.[1-3,8,9,16-18] Although Berger's study provides a qualitative description of the scapholunate ligament, the quantitative anatomy of this ligament, in particular the dorsal component, is not well detailed.

The purpose of this study is to present the quantitative anatomy of the dorsal component of the SLIL, including its length and thickness, and the dimensions of scapholunate interval, using high-frequency ultrasound. In addition, we assess the use of high-frequency ultrasound imaging in assessing the dorsal scapholunate ligament.

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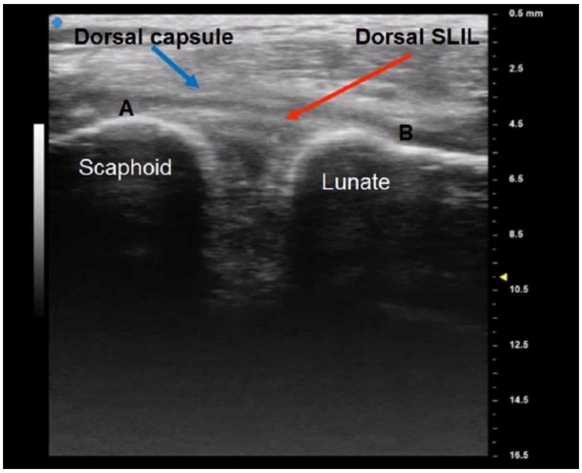

Figure 1. A representative ultrasound in vivo evaluation demonstrating visualization of the scaphoid, lunate, dorsal scapholunate ligament, and dorsal capsule using a 22 MHz ultrasound transducer.
Note. The scaphoid and lunate are the dark (hypoechoic) structures at the bottom of the figure. The dorsal scapholunate ligament is the white (hyperechoic) band between A (scaphoid insertion) and B (lunate insertion). The dorsal capsule is the white band superficial to the scapholunate ligament.

Materials and Methods

Approval for this investigation was obtained from our university's institutional review board.

Evaluation of Volunteer Wrists

We recruited 20 volunteers (9 male, 11 female; 18 right-hand dominant, 2 left-hand dominant; mean age: 44.2 years, range: 20-69 years) without hand or wrist complaints to participate in the study. A commercially available high-frequency clinical ultrasound (VevoMD, Visualsonics, Toronto, Ontario, Canada) with 22 MHz and 48 MHz transducers (resolution to 100 μm and 50 μm, respectively) was used to evaluate the bilateral wrists of each volunteer with the wrist and forearm positioned in neutral. A musculoskeletal-trained sonographer performed the ultrasound examinations.[19,20] In each wrist, the dorsal SLIL was identified as the most distal transversely oriented fibers coursing between the radial margin of the dorsal horn of the lunate and the ulnar-dorsal margin of the scaphoid, as described by Berger.[16] All measurements were obtained in the distal 5 mm of the scapholunate joint to ensure we measured the dorsal, not the proximal, component of the ligament, according to Berger (Figure 1). We recorded the radial to ulnar ("length") and dorsal to volar ("thickness") dimensions of the dorsal scapholunate ligament in each wrist, as well as the width of the scapholunate joint at both the dorsal margin ("dorsal interval") and central portion ("central interval") (Figure 2).

Assessment of High-Frequency Ultrasound

Twelve cadaveric upper extremities (10 male, 2 female; 6 right, 6 left; mean age: 84.5 years, range: 63-102 years) were obtained from our university's body donation program. All cadaveric upper limbs were previously frozen and thawed to room temperature immediately prior to the investigation. Limbs with evidence of trauma, prior surgery, or deformity were excluded. In an identical manner as the evaluation of the volunteer wrists, all cadaveric wrists were examined with the high-frequency clinical ultrasound. The dorsal SLIL length and thickness were measured as described above. We also identified and recorded the location of the scapholunate ligament insertions on the scaphoid and lunate, relative to the articular margin of the scapholunate joint (Figure 3).

Following the ultrasound evaluation, an open dissection of each cadaveric wrist was performed. A ligament-sparing dorsal approach to the wrist was performed as described by Berger.[21] The dorsal component of the SLIL was then identified, and a handheld digital caliper (High-Accuracy Digimatic Digital Micrometer, Mitutoyo, Aurora, Illinois) with 0.1 μm resolution and 0.5 μm margin of error was used to manually measure the scapholunate ligament length and insertion points on the scaphoid and lunate relative to the articular margin of the scapholunate joint. The ligament was then transected at the scaphoid insertion and the thickness of the dorsal SLIL was measured with the calipers (Figure 4).

Student's *t* test was used to compare the dorsal SLIL dimensions obtained with ultrasound and open dissection.

Results

Evaluation of Volunteer Wrists

The dorsal SLIL was visualized in all 40 volunteer wrists. Both the 22 MHz and 48 MHz transducers, which have focal depths of 18 mm and 9 mm, respectively, provided clear visualization of the ligament. We measured a mean scapholunate ligament length of 7.5 ± 1.4 mm and thickness of 1.8 ± 0.4 mm. The mean dorsal scapholunate interval was 5.0 ± 1.0 mm, and the mean central interval was 2.5 ± 0.9 mm (Table 1). We incidentally identified an occult dorsal scapholunate ganglion cyst in 3 wrists, all in female volunteers who denied wrist pain or other symptoms localized to the wrist.

Assessment of High-Frequency Ultrasound Imaging

Using ultrasound imaging, the dorsal scapholunate ligament was clearly identified in 11 of the 12 cadaver wrists (92%).

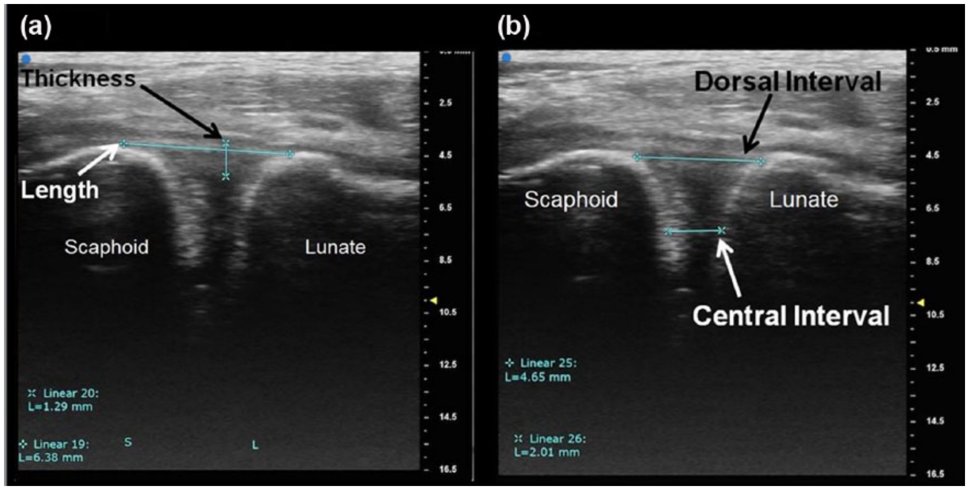

Figure 2. In vivo ultrasound images.
Note. In Figure 2a, the white arrow points to line measuring the radial-to-ulnar length, and the black arrow points to the line measuring the dorsal-to-volar thickness of the dorsal scapholunate ligament. In Figure 2b, the black arrow points to the line measuring the width of the dorsal aspect of the scapholunate joint interval, and the white arrow points to the line measuring the central scapholunate interval.

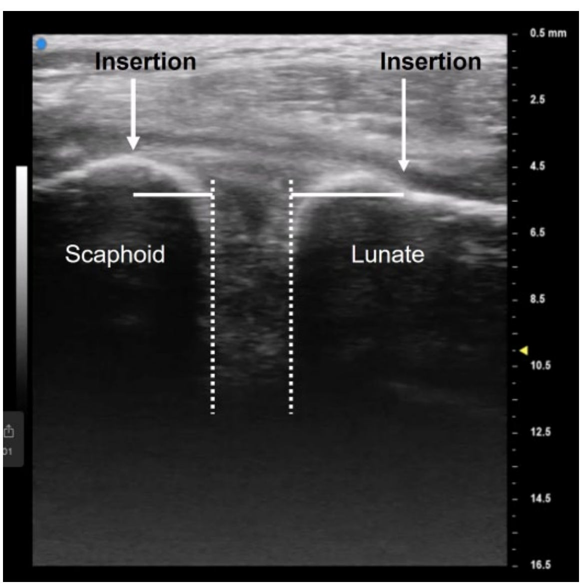

Figure 3. The method of measuring the location of the dorsal scapholunate ligament insertion on the scaphoid and lunate relative to the articular margin of the scapholunate joint.
Note. Plumb lines were drawn at the articular surface of the scaphoid and lunate (dotted white lines), and the distance from that plumb line to the insertion of the ligament on the scaphoid and lunate (white arrows) was measured. Solid white lines represent the distance of the dorsal SLIL insertion from the articular margin. SLIL = scapholunate interosseous ligament.

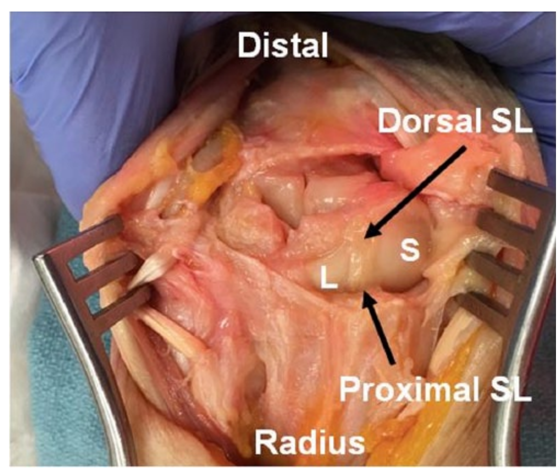

Figure 4. Cadaveric demonstration of the dorsal SL ligament.
Note. L = lunate; S = scaphoid; SL = scapholunate.

Table 1. SLIL Dimensions in Volunteer Wrists.

SLIL dimension	Millimeters
SLIL length	7.5 ± 1.4
SLIL thickness	1.8 ± 0.4
Dorsal SL interval	5.0 ± 1.0
Central SL interval	2.5 ± 0.9

Note. SLIL = scapholunate interosseous ligament; SL = scapholunate.

Table 2. SLIL Dimensions in Cadaver Wrists.

SLIL dimensions	Ultrasound (mm)	Dissection (mm)	*P* value
SLIL length	6.2 ± 1.2	6.5 ± 1.3	.57
SLIL thickness	1.6 ± 0.5	1.6 ± 0.4	.62
Scaphoid insertion	1.0 ± 0.5	1.6 ± 0.3	<.05
Lunate insertion	2.2 ± 0.8	2.6 ± 0.5	.12

Note. SLIL = scapholunate interosseous ligament.

We found a mean scapholunate length of 6.2 ± 1.2 mm and thickness of 1.6 ± 0.5 mm. The insertion of the ligament on the scaphoid measured 1.0 ± 0.5 mm from the articular margin, while the insertion on the lunate measured 2.2 ± 0.8 mm from the articular surface of the joint (Table 2).

On open dissection of the cadaver wrists, we were able to identify the dorsal scapholunate ligament in all 12 specimens. Four of the 12 cadaver wrists (33%) had disruption of the proximal membranous portion of the scapholunate ligament, but none had disruption of the dorsal component of the ligament. Using the digital calipers, we measured a mean scapholunate length of 6.5 ± 1.3 mm and thickness of 1.6 ± 0.4 mm. The insertion points of the ligament on the scaphoid and lunate were 1.6 ± 0.3 mm and 2.6 ± 0.5 mm, respectively, from the articular margin. There were no statistically significant differences between the scapholunate ligament parameters obtained on ultrasound and those obtained on open dissection ($P > .05$), except for the location of the scaphoid insertion ($P < .05$) (Table 2).

Discussion

The purpose of this study is to provide a quantitative description of the anatomy of the dorsal component of the SLIL and scapholunate interval. We measured the length of the dorsal scapholunate ligament as 7.5 mm and the thickness as 1.8 mm. The scapholunate interval dorsally was 5.0 mm and centrally was 2.5 mm. These findings are consistent with Berger's cadaveric study, the only other study (to our knowledge) published in the English language with the purpose of describing the anatomy of the dorsal scapholunate ligament. In that study, Berger dissected 8 formalin-fixed and 20 fresh adult cadaveric wrists and reported an average dorsal scapholunate ligament thickness of 3 mm and proximal-to-distal length of 5 mm.[16] Although Berger's study provided a comprehensive description of the components of the SLIL, his article did not provide numerical data from the individual specimens or describe the technique of ligament measurement. The calculations (eg, mean, median, mode) used to arrive at a thickness and length of 3 mm and 5 mm, respectively, are not reported. In addition, it is possible that the SLIL in cadavers was distorted due to formalin-fixation or attenuated due to advanced age of the cadaver donor. For this reason, we elected to assess dorsal SLIL dimensions in healthy adult volunteers and use cadaver wrists only for ultrasound validation. Moreover, we chose to evaluate the radial-to-ulnar length of the ligament, rather than the proximal-to-distal length, as this is likely a more clinically relevant parameter for surgical repair or reconstruction of the dorsal scapholunate ligament. We also elected to measure the dimensions of the dorsal and central intervals of the scapholunate joint, as understanding these normal anatomic values may aid in scapholunate ligament repair and reconstruction, and accurate restoration of the scapholunate relationship.

The use of ultrasound for the evaluation of carpal anatomy is well described, with numerous reports demonstrating excellent visualization of the dorsal component of the SLIL and detection of pathology.[21-28] Further studies have compared the use of ultrasound with conventional arthrography,[29] magnetic resonance arthrography (MRA),[24] and arthroscopy[27] to assess the scapholunate ligament, and demonstrated excellent sensitivity, specificity, and accuracy of ultrasound. Our study is consistent with these reports, and we identified no significant difference between ultrasound and open dissection in scapholunate ligament dimensions, with the exception of the location of the ligament insertion on the scaphoid, which measured 1.0 mm on ultrasound and 1.6 mm on dissection. Although this difference met criteria for statistical significance, this discrepancy may not be clinically relevant. We believe this discrepancy is due to the fact that the values for ligament thickness and scaphoid insertion point are very small and more difficult to measure. Although our digital calipers have a precision to 0.0001 mm, small movements and changes in the pressure have large effects on such small measurements and lead to small errors on accuracy. Small differences such as a tenth or hundredth of a millimeter translate into large difference in correlation, and although are significant statistically, they may be less meaningful clinically.

Previous studies use 5 to 12 MHz ultrasound for the evaluation of the hand and wrist anatomy,[30] whereas this study uses higher frequency ultrasound (22 MHz and 48 MHz). As the frequency (megahertz, MHz) of the ultrasound increases, there is a proportional increase in image resolution and decrease in the depth of penetration of the ultrasound waves.[31] Consequently, higher frequency ultrasound has the capacity to provide a much more detailed image and can distinguish between very small objects, as long as the structures of interest are superficial. The focal depth and resolution of the transducers used in this study are 18 mm and 100 to 200 µm for the 22 MHz transducer, and 9 mm and 50 to 110 µm for the 48 MHz transducer. In comparison, a 5 MHz transducer has substantially decreased resolution (500 µm) but a much greater penetration depth (70 mm). Because the dorsal SLIL is a relatively superficial structure, the greater depth of penetration provided by a lower

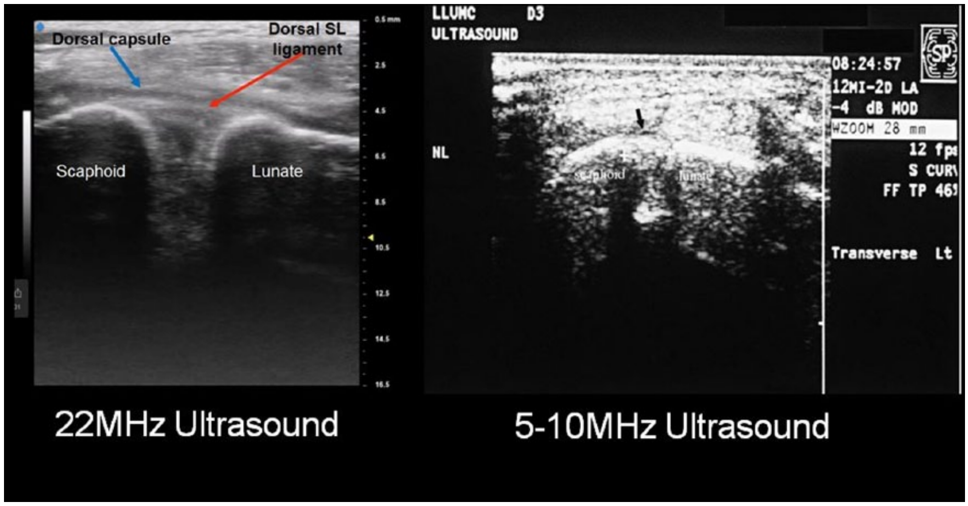

Figure 5. Comparison of 22 MHz with 5 to 10 MHz ultrasound, demonstrating improved resolution with the use of higher frequency ultrasound in the evaluation of the scapholunate ligament.
Note. SL = scapholunate.
Source. Used with the permission of Dao et al.[30]

frequency ultrasound is not needed, and a more detailed picture can be provided by a higher frequency ultrasound, resulting in enhanced image quality, improved visualization of the ligament, and potentially better detection of pathology (Figure 5).

There are limitations to this study. The number of volunteers and cadavers in our study is a sample size of convenience and is small. We did not perform an a priori sample size calculation to determine whether the number of cadavers included in the study is sufficient to detect a difference between ultrasound imaging and open dissection. Second, we present our use of high-frequency ultrasound to visualize the dorsal SLIL, but did not directly compare its use with conventional ultrasound or other imaging modalities, and therefore cannot determine the superiority of this imaging modality over the other imaging techniques. Moreover, we did not evaluate the effectiveness of high-frequency ultrasound in detecting pathology of the scapholunate ligament, only to define the anatomy in healthy volunteers. Last, although improved understanding of the native dorsal SLIL anatomy may improve surgical outcomes, this is an area that needs further investigation.

This study presents the quantitative anatomy of the dorsal SLIL and introduces the use of high-frequency ultrasound to evaluate this anatomic structure. Improved understanding of the dorsal scapholunate ligament anatomy may be helpful in surgical procedures aimed at anatomic repair and reconstruction of the ligament and restore carpal alignment and kinematics. In addition, we found high-frequency ultrasound easy and convenient to use and its high-resolution images easy to interpret. Future comparative studies, including comparison of the sensitivity and specificity of high-frequency ultrasound and magnetic resonance imaging, as well as cost analyses, are needed to determine the utility of potential benefits of high-frequency ultrasound imaging in the clinical setting and surgical decision-making.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised on 2008.

Statement of Informed Consent

Informed consent was obtained from all individual participants included in the study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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