Skeletal Radiol (2011) 40:897–904
DOI 10.1007/s00256-010-1068-0

SCIENTIFIC ARTICLE

High-resolution ultrasound evaluation of the trapeziometacarpal joint with emphasis on the anterior oblique ligament (beak ligament)

Pedro A. Gondim Teixeira · Patrick Omoumi · Debra J. Trudell · Samuel R. Ward · Alain Blum · Donald L. Resnick

Received: 4 January 2010 / Revised: 17 March 2010 / Accepted: 23 March 2010 / Published online: 1 December 2010
© ISS 2010

Abstract
Introduction The anterior oblique ligament is one of the main stabilizers of the trapeziometacarpal joint. Insufficiency of this ligament is closely linked to degenerative joint disease. High-resolution musculoskeletal ultrasound has advantages over magnetic resonance imaging (availability, dynamic nature, cost, patient comfort). This study evaluates the feasibility of ultrasound of the anterior oblique ligament.
Material and methods Ten cadaveric thumb specimens and 10 volunteers with normal trapeziometacarpal joints underwent imaging with high-frequency ultrasound. An ultrasound-guided, progressive dissection technique was used to confirm the ultrasound findings. Two radiologists reviewed the images in consensus. The detectability of the ligament was rated.
Results The anterior oblique ligament was identified and measured in 90% of the specimens and 100% of the volunteers. The ultrasound findings correlated well with the dissections. This ligament appeared as a thin hypoechogenic structure in the ulnar-most part of the trapeziometacarpal joint, with a thickness that varied from 1.0 to 2.0 mm. Detectability of this ligament was good in 66% of the specimens and 100% of the volunteers.
Conclusion Ultrasound evaluation of the anterior oblique ligament of the trapeziometacarpal joint is feasible with state of the art equipment.

Keywords Ultrasound · High resolution · Trapeziometacarpal joint · Anterior oblique ligament · Beak ligament

D. J. Trudell · S. R. Ward · D. L. Resnick
Department of Radiology,
Veterans Administration Medical Center,
3350 La Jolla Village Drive,
San Diego, CA 92161, USA

P. Omoumi
Department of Radiology,
Cliniques Universitaires St Luc - UC Louvain,
Avenue Hippocrate 10,
Brussels 1200, Belgium

A. Blum
Service d'imagerie Guilloz, CHU Hôpital Central,
29, avenue du Maréchal De Lattre De Tassigny,
54035 Nancy, France

P. A. Gondim Teixeira (✉)
Service d'imagerie Guilloz, CHU Hôpital Central,
10 boulevard du Recteur Senn, appt. 220, 3eme étage,
54000 Nancy, France
e-mail: ped_gt@hotmail.com

Introduction

The anterior oblique ligament, also known as the beak ligament, along with the dorsoradial ligament, is one of the main stabilizers of the first carpometacarpal, or trapeziometacarpal, joint [1–5]. It can be divided into deep and superficial portions. Although some authors use the term beak ligament specifically to describe the deep portion of the anterior oblique ligament, we will use this denomination to designate both of its components [6]. The beak ligament corresponds to a thickening of the articular capsule located at the volar aspect of the trapeziometacarpal joint, thus preventing dorsal translocation (Fig. 1) [1, 2]. Insufficiency of this ligament is closely linked to degenerative trapeziometacarpal joint disease, a condition that can lead to great compromise in hand function. This condition, often designated basal joint arthropathy, usually affects middle-

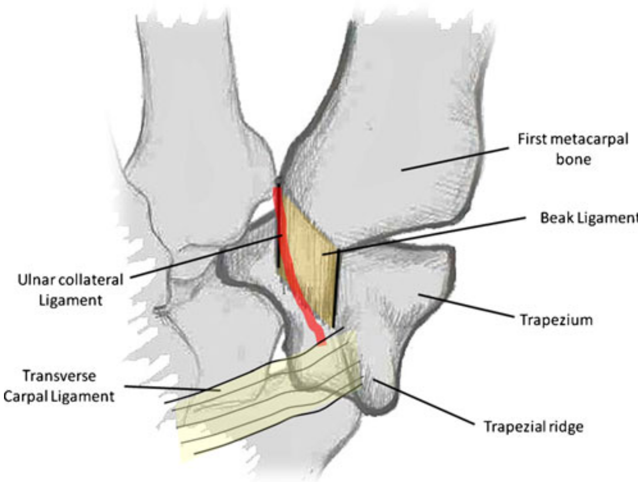

Fig. 1 Schematic representation of the volar trapeziometacarpal joint showing the anterior oblique ligament (beak ligament), ulnar collateral ligament, and the transverse carpal ligament. Note the proximity of these structures at their trapezial insertions

aged women, but can also affect men and women of any age when related to injury or joint hyperlaxity [1, 3, 7–9].

Trapeziometacarpal joint instability is difficult to assess clinically due to the complex anatomy and biomechanics of this region and the fact that this joint is deep to the thenar muscles [3, 10]. Furthermore, its symptoms and signs are similar to those of other wrist conditions, including De Quervain’s tenosynovitis and tendinosis of the flexor tendons (particularly the flexor carpi radialis tendon, which is intimate with this joint [3, 7]. Multiple surgical and arthroscopic procedures are used to treat basal joint arthritis, and the precise identification of pathological features in this region is crucial to patient management [11, 12].

Trapeziometacarpal joint degeneration was classified using conventional radiography by Eaton and Littler (stage I: widening of the joint space; stage II: at least one third subluxation of the joint; stage III: more than one third subluxation; stage IV: advanced degenerative changes). Eaton and Littler’s classification scheme correlates well with histological alterations of the beak ligament and with joint instability [3, 8]. This ligament can be evaluated with MR imaging [7]. However, to the best of our knowledge there are no reports concerning the ultrasound evaluation of the anterior oblique ligament. Modern high-frequency ultrasound has successfully been used in the analysis of the hand and wrist and can depict fine anatomical details owing to its high resolution [13]. Because ultrasound has well-known advantages, such as its widespread availability and low cost, as well as no patient exposure to ionizing radiation, we sought to evaluate this method’s capability to assess the beak ligament.

Materials and methods

Ten human hands (6 right hands and 4 left hands) were obtained from 7 fresh frozen cadavers (6 male and 1 female, age at death: 58–92 years old). The specimens consisted of the whole hand, wrist, forearm, elbow joint, and proximal half of the arm. The specimens were deep-frozen at −40°C for at least 30 days (Forma Bio-Freezer; Forma Scientific, Marietta, OH, USA). All specimens were thawed for 24 h at room temperature before ultrasound imaging. Additionally, 10 elbows from 5 healthy volunteers (4 female and 1 male, age: 24–29 years old) with no history of previous hand trauma and normal physical examination were evaluated. Physical examination included the grind test proposed by Eaton and Littler and thumb retropulsion test proposed by Takwale et al. [3, 14].

Ultrasound was performed in the cadaveric specimen using an IU22 system (Philips, Best, Netherlands) and a high frequency transducer (15–17 MHz) and in volunteers using an Aplio XG, SSA-790A Toshiba (Zilverstraat 1. 2718 RP, Zootermeer, Netherlands) with both an 8- to 15-Mhz frequency linear transducer and a 12-MHz golf club transducer. The thumb was positioned in extension, abduction, and supination (external rotation) using a volar approach (the wrist in supination) (Fig. 2). In two specimens the injection of saline solution in the trapeziometacarpal joint was performed under ultrasound guidance with a dorsal approach, using a 22-gauge needle to evaluate the ultrasound assessment of this ligament in the setting of joint effusion. Two milliliters of saline were injected. Two fellowship-trained musculoskeletal radiologists, performed all the examinations and evaluated the images together in consensus. The thickness of the ligament was also measured with ultrasound. The detectability (i.e., ease of detection) of the ligament was evaluated. The ultrasound detection of the ligament was considered to be good when it could be seen in its entirety and separated from the periarticular tissue, intra-articular fluid, and underlying bone/cartilage (Fig. 3). The detectability was

Fig. 2 Photograph shows the position of the probe position for the visualization of the beak ligament. Note the ulnar position and inclination of the probe. The examiner maintains the thumb positioned in forced extension, abduction and supination (external rotation)

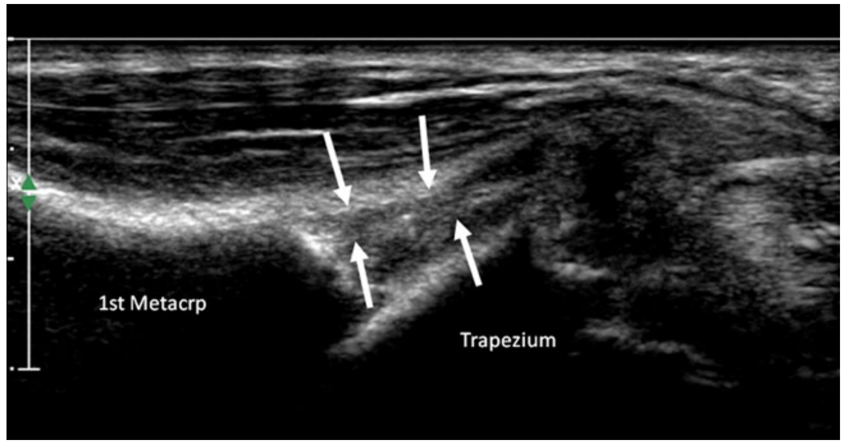

Fig. 3 Good detectability of the beak ligament. Longitudinal ultrasound image in a 77-year-old left hand specimen shows a hypoechogenic structure (*arrows*), with no fibrillary pattern, clearly separated from the overlying muscles

considered to be poor when the ligament was identified, but it was indistinct and difficult to differentiate from peri-ligamentous structures and/or when the ligament was not entirely visualized (Fig. 4). If no ligamentous tissue was found at the expected location of the beak ligament, it was classified as non-identifiable (Fig. 5). The observers also evaluated the degree of degeneration of the trapeziometacarpal joint. Degenerative joint disease was subjectively classified into absent, moderate or advanced, based on the presence of osteophytes and the evaluation of the joint space.

Two specimens were later dissected by an anatomist and photographs were taken of all the steps of the procedure. The progressive dissection technique described by De Maeseneer et al. was used in one specimen [15]. In this procedure, ultrasound imaging of the specimen is performed before and after each layer of tissue is removed with dissection. First, the anterior oblique ligament was identified with ultrasound in the whole specimen. Then, after each layer of tissue was removed, the ligament was re-evaluated. In the first stage, the skin and subcutaneous tissue were removed. The muscle bellies of the thenar eminence were then removed (abductor pollicis brevis, flexor pollicis brevis, and opponens pollicis), allowing direct visualization of the capsular ligaments of the trapeziometacarpal joint. The target ligament was then identified by the anatomist and ultrasound imaging was performed directly over the ligament. The images were correlated with the pre-dissection images. Finally, the ligament itself was removed and ultrasound attested the absence of the ligament. A thick layer of ultrasound gel was used to separate the probe from the imaged area. The same ultrasound device and probe that were used in the imaging of the whole specimens were used for the staged dissection. The ultrasound machine was transported to our institution's dissection laboratory for this procedure. The ultrasound probe was wrapped with a latex glove to avoid contamination and all measures to prevent skin contact with the specimens were taken. The authors felt no need to perform an anatomical correlation in all the specimens because the anatomy of the region has already been fully described and the ultrasound findings were repeatedly confirmed in the specimens we did dissect and section [1, 6, 7, 13, 16].

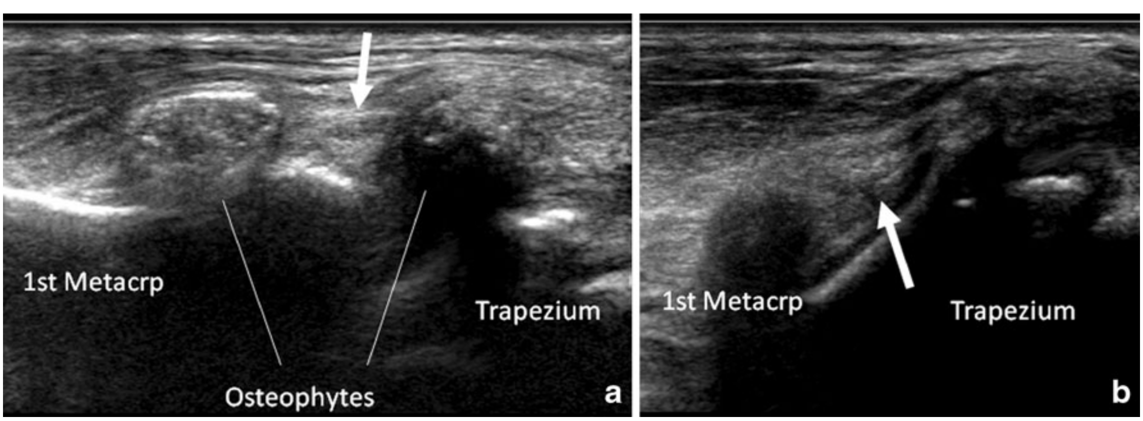

Fig. 4 Poor detectability of the beak ligament. Longitudinal ultrasound images of two different specimens. **a** Large osteophytes preclude the visualization of the proximal and distal attachments, the body of the ligament is identified (*arrow*) and it is not clearly separated from the overlying muscles. **b** Hypoechogenic tissue is seen in the expected location of the beak ligament (*arrow*); however, the boundaries of the ligament are not well defined

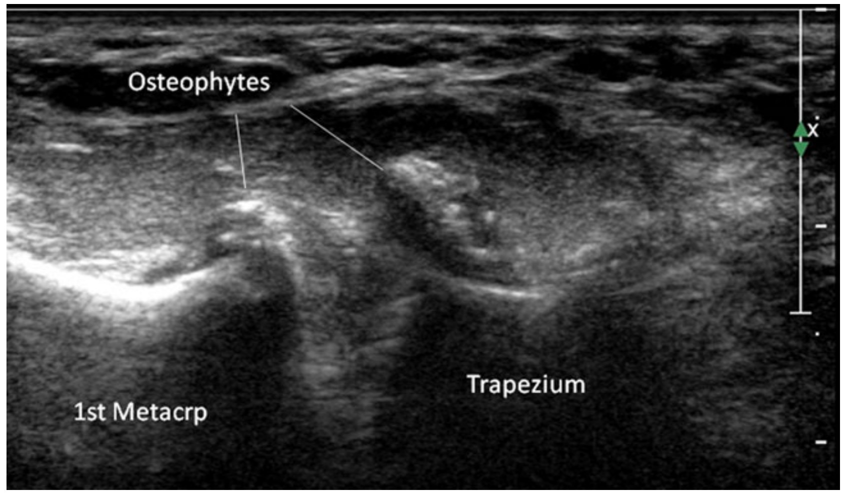

Fig. 5 Beak ligament not identifiable. Longitudinal ultrasound image of the trapeziometacarpal joint in a 91-year-old male specimen. The ligament fibers are not identified in this joint with advanced osteoarthritic changes. Note the prominent osteophytes in both the trapezium and the first metacarpal bone

Results

The anterior oblique ligament was visualized with ultrasound in 19 of the 20 thumbs evaluated (9 out of the 10 cadaveric specimens and all of the volunteers). In all volunteers the detectability of the beak ligament was considered good with both the linear and golf club transducers. In the cadaveric evaluation the detectability was good in 6 specimens and poor in 3 specimens. The anterior oblique ligament was seen as a band of tissue in the ulnar-most part of the trapeziometacarpal joint, medial to the trapezial ridge. It was hypoechoic to fat and isoechoic to muscular tissue (Fig. 3). No fibrillary pattern was identified in the whole specimens and in the volunteers. The superficial and deep portions of the anterior oblique ligament could not be distinguished nor could the anterior oblique ligament be differentiated from the ulnar collateral ligament. Its thickness varied from 0.9 to 2.0 mm, with a mean thickness of 1.28 mm (cadaveric specimens: 1.38 mm and normal volunteers 1.2 mm). The mean thickness of this ligament in thumb osteoarthritis was 1.5 mm and in those without it was 1.1 mm. The distal attachment of this ligament to the first metacarpal was clearly seen; the proximal attachment, however, was not identified.

Ultrasound findings of osteoarthritis were found in 7 specimens and in none of the volunteers. Osteoarthritis was considered advanced in 3 cases, in which the beak ligament was not identified, or was only poorly seen. When

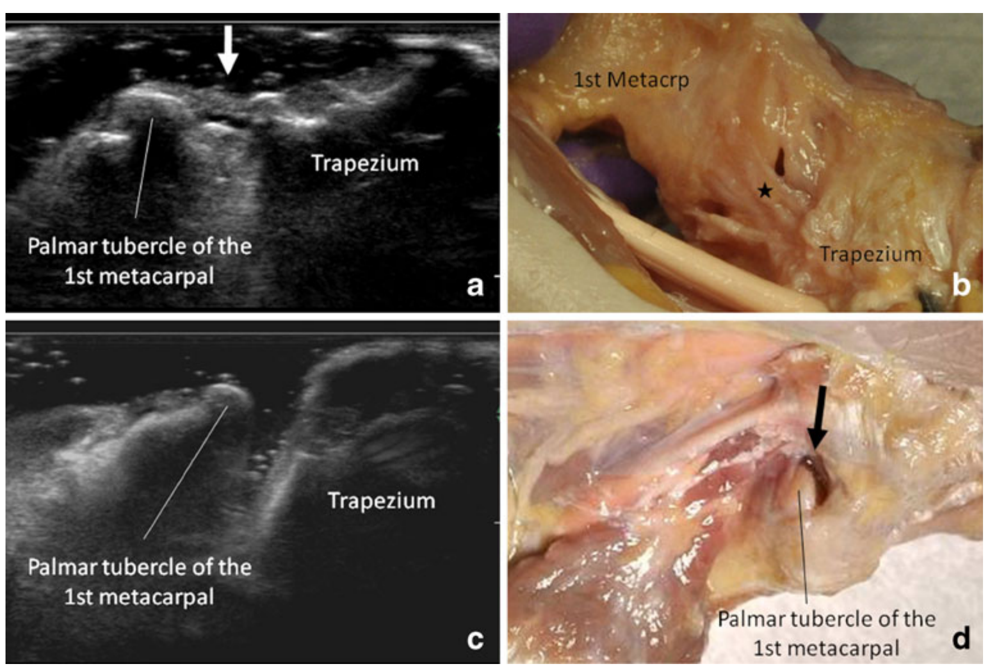

Fig. 6 **a** Longitudinal ultrasound image shows the beak ligament after removal of the overlying soft tissues (*white arrow*). Note the hyperechogenic aspect of the ligament. **b** Corresponding dissection photograph shows the beak ligament (*black star*). **c** Longitudinal ultrasound image shows the appearance of the trapeziometacarpal joint after the removal of the beak ligament. A thick layer of gel was applied to allow imaging of the denuded joint. **d** Corresponding dissection photograph shows the open joint space (*black arrow*)

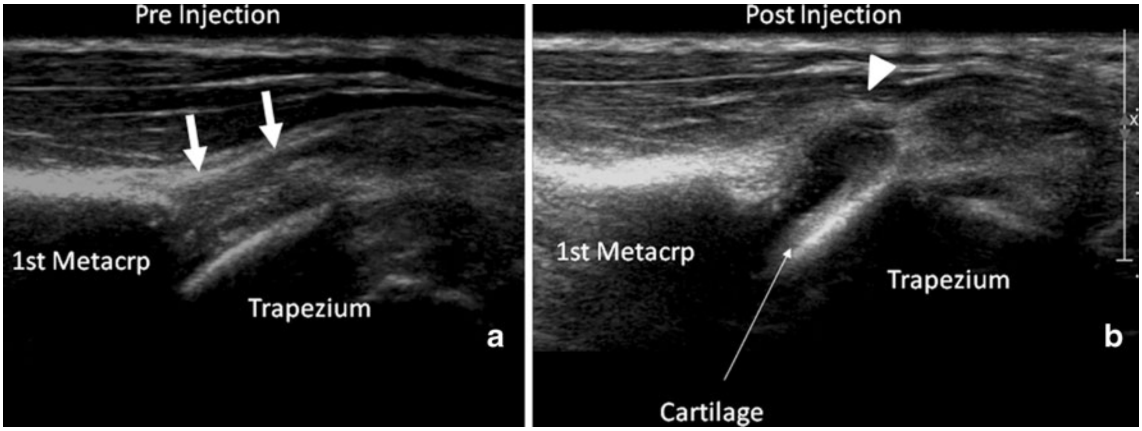

Fig. 7 Longitudinal ultrasound images of the trapeziometacarpal joint show the appearance of the beak ligament before and after intra-articular saline injection. **a** The ligament is seen as a hypoechogenic straight line (*arrows*), difficult to separate from the underlying cartilage. **b** After the intra-articular injection of about 2 ml of saline solution, the beak ligament is bowed and hyperechogenic (*arrow-head),* its inner margin is clearly identified and separated from the underlying cartilage (*arrow*)

osteophytes were present the ligament seemed to drape over them and to insert more distally into the adjacent bone, presenting as a curved structure. In one specimen, the ligament was poorly identified, while there were no signs of osteoarthritis.

The anterior oblique ligament proved to be precisely identified with ultrasound by the progressive dissection technique. The ligament was identified after each step of the dissection. It appeared hyperechogenic after removal of the more superficial layers. In the last step, when the ligament was removed, it could no longer be identified with ultrasound at its expected location and only the denuded bone and the trapeziometacarpal joint space were visible proving that the structure we analyzed was the beak ligament (Fig. 6).

For the two specimens in which saline solution was injected into the trapeziometacarpal joint under ultrasound guidance, detectability of the deep surface of the ligament was improved (Fig. 7). Intra-articular fluid allowed separation of the beak ligament form the underlying trapezial cartilage. This differentiation was difficult without intra-articular fluid because both of these structures are hypoechogenic.

Although it was not the main objective of this study the dorsoradial ligament was identified repeatedly in both specimens and live volunteers with good correlation with the dissections (Fig. 8)

The summary of our findings for cadaveric specimens and volunteers is presented in Tables 1 and 2.

Discussion

The anterior oblique ligament of the trapeziometacarpal joint has two layers, a wide superficial layer and a narrower deep layer. However, the superficial and deep portions could not be distinguished with ultrasound. This ligament is reported to have a thickness of approximately 2 mm and a length of 10 mm, to originate at the ulnar to the trapezial ridge, and to attach in the palmar tubercle of the first

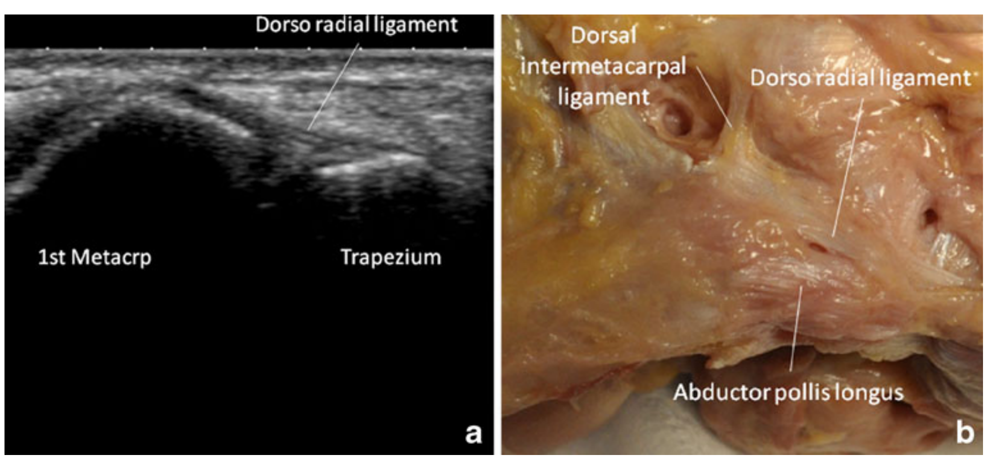

Fig. 8 **a** Ultrasound demonstration of the dorsoradial ligament in a healthy 29-year-old male volunteer. **b** Dissection image demonstrates the relation of this ligament with respect to adjacent structures (abductor pollicis longus tendon, dorsal intermetacarpal ligament)

Table 1 Cadaveric specimens

Sex, age	Side	Detectability	Osteoarthritis	Thickness (mm)
Male, 58 years	Left hand	Good	No	1.1
Male, 58 years	Right hand	Good	Moderate	1.8
Male, 92 years	Right hand	Good	No	1.0
Male, 77 years	Left hand	Good	Moderate	1.3
Male, 77 years	Right hand	Poor	Moderate	1.4
Male, 79 years	Left hand	Good	Moderate	2.0
Male, 91 years	Right hand	Not identified	Advanced	–
Male, 79 years	Right hand	Good	No	1.3
Male, 89 years	Left hand	Poor	Advanced	1.1
Female, 81 years	Right hand	Poor	Advanced	1.5

metacarpal bone in the ulnar most part of the trapeziometacarpal joint [6, 7]. Our findings were consistent with these previous anatomical descriptions of this ligament. This topography, however, made its ultrasound evaluation challenging. The probe had to be positioned at the ulnar side of this joint and angulated to be parallel to the ligament itself. However, because of the small space between the first and second metacarpal bones the ultrasound beam remained tangent to the beak ligament, precluding the visualization of the fibrillary structure, due to the anisotropy artifact. The use of the golf club probe in the volunteers allowed easier visualization of the ligament because of a smaller probe design. With this probe the beak ligament presented slightly hyperechoic, and was better distinguished from the underlying trapezial cartilage. When the overlying structures were removed at the time of the layered dissection, the beak ligament appeared hyperechoic. Dissection gave more leeway to position the probe parallel with the long axis of the ligament, reducing the anisotropy artifact. Additionally, artifactual echoic bands were sometimes present. Nevertheless, even with these difficulties, the beak ligament was identified in 90% of the specimens and 100% of the normal volunteers.

Classically, the anterior oblique ligament is reported to attach to the tip of the first metacarpal bone [1, 3, 7]. However, with degeneration, which occurs mainly at the metacarpal attachment, distal migration of this attachment is observed histologically [8]. This finding may explain why the anterior oblique ligament is seen to cover the osteophytes that are arising a few millimeters distal to the joint line in the specimens with osteoarthritis (Fig. 9).

The ulnar collateral ligament shares an intimate relationship with the anterior oblique ligament. It is extracapsular, originating proximally in the flexor retinaculum and attaching more distally than the joint capsule in the first metacarpal bone close to the intermetacarpal ligament [6]. This ligament also plays a complementary role in joint instability [1]. Although the ulnar collateral ligament could be identified in the dissection, it was not visualized or distinguished from the beak ligament with ultrasound. This close relation between these two ligaments, and the fact that the ulnar collateral ligament blends with other ligamentous structures in its proximal portion probably contributes to the difficulty in identifying the proximal attachment of the beak ligament (Fig. 1).

The beak ligament is classically considered to be the main stabilizer of this joint [1–4]. Recent work, however, suggests that the dorsoradial ligament plays an important role and acts together with the beak ligament to promote joint stability [5, 17]. Due to the more superficial location

Table 2 Normal volunteers

Sex, age	Side	Detectability	OA	Thickness (mm)
Female, 29 years	Right hand	Good	No	1.1
Female, 29 years	Left hand	Good	No	1.3
Female, 24 years	Right hand	Good	No	1.4
Female, 24 years	Left hand	Good	No	1.2
Male, 29 years	Left hand	Good	No	1.2
Male, 29 years	Right hand	Good	No	1.3
Female, 25 years	Right hand	Good	No	1.0
Female, 25 years	Left hand	Good	No	1.2
Female, 24 years	Right hand	Good	No	1.2
Female, 24 years	Left hand	Good	No	1.1

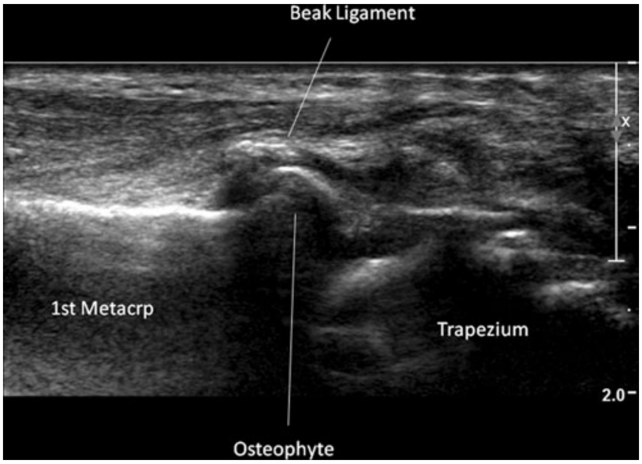

Fig. 9 Ultrasound image of the trapeziometacarpal joint in a specimen from an 81-year-old woman with moderate osteoarthritic changes shows the beak ligament draped over a metacarpal osteophyte, appearing to attach distally away from the joint line

(just radial to the insertion of the abductor pollis longus tendon) this ligament was more easily accessed by ultrasound and could be seen in both cadavers and normal specimens with good anatomical correlation (Fig. 8).

In the specimen in which the anterior oblique ligament could not be seen and in the two cases in which it was poorly identified, advanced degenerative changes were present. The large osteophytes distorted the capsular anatomy, and produced acoustic shadowing precluding the assessment of the beak ligament in these specimens (Fig. 5). The fact that the beak ligament was identified in all normal volunteers suggests that the poor or non-visualization of this ligament with ultrasound may be an indication of a pathological condition. With advanced arthropathy, this ligament is most likely pathological, which could explain the difference in thickness between patients with degenerative joint disease and those without [8]. Although conventional radiography is very accurate for osteoarthrosis, and is still the primary imaging tool used in this clinical situation early degenerative changes in the beak ligament cannot be assessed with conventional radiography [12]. These initial changes, however, are clinically important and influence the surgical prognosis [3]. This justifies further studies to evaluate the capability of ultrasound to assess the beak ligament in the early phases of the degenerative process.

In one of the specimens, the anterior oblique ligament was poorly identified, while there were only moderate osteoarthritic changes. Further studies are necessary to fully explain this finding. Previous traumatic injury and artifacts due to a tangential ultrasound beam are among the possible explanations for this finding.

In the setting of joint pathological conditions, intra-articular fluid can be present. As described for other ligaments, intra-articular fluid can be used as a negative contrast agent to better delineate the articular surface of the ligament, separate it from the underlying trapezial cartilage, and evaluate the continuity of the ligament [18]. These findings were confirmed in the specimens injected with intra-articular saline (Fig. 7).

Image deterioration in non-embalmed specimens has been described [15]. However, we encountered no significant artifacts, such as soft tissue gas and specimen stiffness, related to postmortem examinations in the anatomical regions studied.

This study has some limitations. Clinical information of the donors was not available, which made it difficult to determine the cause and clinical significance of our findings. Pathological subjects were not included, and further studies are necessary to evaluate the ultrasound aspects of the beak ligament in this patient population. Although the ultrasound devices utilized provided high-quality images, specimens and normal volunteers were not evaluated with the same equipment. The images were evaluated in consensus, which did not allow assessment of interobserver agreement and might have introduced some bias to the interpretation. However, this is an observational and feasibility study, which did not aim at assessing interobserver agreement.

In conclusion, the ultrasound evaluation of the anterior oblique ligament of the trapeziometacarpal joint is feasible with state of the art equipment. A thorough knowledge of the complex anatomy of this region is necessary to accurately evaluate this ligament. Ultrasound correctly identified the anterior oblique ligament of the trapeziometacarpal joint in both cadavers and normal volunteers. Although further studies are necessary to determine the clinical importance of this technique in the evaluation of basal thumb pain, we believe that ultrasound might potentially play a role in this setting.

References

1. Imaeda T, An KN, Cooney WP, Linscheid R. Anatomy of trapeziometacarpal ligaments. J Hand Surg Am. 1993;18(2):226–31.
2. Pellegrini VD, Olcott CW, Hollenberg G. Contact patterns in the trapeziometacarpal joint: the role of the palmar beak ligament. J Hand Surg Am. 1993;18(2):238–44.
3. Eaton RG, Littler JW. Ligament reconstruction for the painful thumb carpometacarpal joint. J Bone Joint Surg Am. 1973;55 (8):1655–66.
4. Day CS, Gelberman R, Patel AA, Vogt MT, Ditsios K, Boyer MI. Basal joint osteoarthritis of the thumb: a prospective trial of steroid injection and splinting. J Hand Surg Am. 2004;29(2):247–51.
5. Edmunds JO. Traumatic dislocations and instability of the trapeziometacarpal joint of the thumb. Hand Clin. 2006;22 (3):365–92.

6. Nanno M, Buford WL, Patterson RM, Andersen CR, Viegas SF. Three-dimensional analysis of the ligamentous attachments of the first carpometacarpal joint. J Hand Surg Am. 2006;31(7):1160–70.
7. Cardoso FN, Kim H, Albertotti F, Botte MJ, Resnick D, Chung CB. Imaging the ligaments of the trapeziometacarpal joint: MRI compared with MR arthrography in cadaveric specimens. AJR Am J Roentgenol. 2009;192(1):W13–9.
8. Doerschuk SH, Hicks DG, Chinchilli VM, Pellegrini VD. Histopathology of the palmar beak ligament in trapeziometacarpal osteoarthritis. J Hand Surg Am. 1999;24(3):496–504.
9. Cognet J, Oberlin C. Bilateral juvenile trapezometacarpal osteoarthritis in congenital hyperlaxity. Rev Chir Orthop Reparatrice Appar Mot. 2007;93(1):78–83.
10. Cooney WP, Chao EY. Biomechanical analysis of static forces in the thumb during hand function. J Bone Joint Surg Am. 1977;59 (1):27–36.
11. Badia A. Arthroscopy of the trapeziometacarpal and metacarpophalangeal joints. J Hand Surg Am. 2007;32(5):707–24.
12. Croog AS, Rettig ME. Newest advances in the operative treatment of basal joint arthritis. Bull NYU Hosp Jt Dis. 2007;65(1):78–86.
13. Lee JC, Healy JC. Normal sonographic anatomy of the wrist and hand. Radiographics. 2005;25(6):1577–90.
14. Takwale VJ, Stanley JK, Shahane SA. Post-traumatic instability of the trapeziometacarpal joint of the thumb. Diagnosis and the results of reconstruction of the beak ligament J Bone Joint Surg Br. 2004;86(4):541–5.
15. De Maeseneer M, Jager T, Vanderdood K, Van Roy P, Shahabpour M, Marcelis S. Ultrasound during dissection of cadaveric specimens: a new method for obtaining ultrasound–anatomic correlations in musculoskeletal radiology. Eur Radiol. 2004;14(5):870–4.
16. Bettinger PC, Linscheid RL, Berger RA, Cooney WP, An KN. An anatomic study of the stabilizing ligaments of the trapezium and trapeziometacarpal joint. J Hand Surg Am. 1999;24(4):786–98.
17. Colman M, Mass DP, Draganich LF. Effects of the deep anterior oblique and dorsoradial ligaments on trapeziometacarpal joint stability. J Hand Surg Am. 2007;32(3):310–7.
18. Bianchi S, Martinoli C, Derchi LE, Baert AL, Rizzatto G, Abdelwahad IF, et al. Ultrasound of the musculoskeletal system. Heidelberg: Springer; 2007.