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Analyses of imaging presentations, full endoscopic and pathological features of a novel interlaminar ligament

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Abstract

Background To analyze the characteristics of an unnamed interlaminar ligaments(ILL) through magnetic resonance image (MRI), endoscopy and pathological examination.

Method A retrospective study was conducted to analyze the clinical data of patients who underwent posterior endoscopic surgery for lumbar disc herniation or lumbar spinal stenosis from January 2021 to February 2022 at our medical center. The height, width and cross-sectional thickness of the ligament was analyzed using T2 weighted MRI. Meanwhile, the morphological and pathological characteristics were also compared with those of the ligamentum flavum to highlight the differences between above mentioned ligaments.

Result Forty-three patients were included in this study, including 27 males and 16 females, with an average age of 46.6 ± 12.1y. There were 20 cases of lumbar disc herniation and 23 cases of lumbar spinal stenosis. The width, length, thickness of the ILL, the thickness of LF and surgical time in the lumbar disc group were 17.7 ± 3.5 mm, 4.3 ± 1.3 mm, 18.3 ± 3.5 mm, 5.3 ± 1.9 mm, 53.2 ± 14.5 min, respectively. In the lumbar spinal stenosis group, the corresponding parameters were 16.0 ± 3.1 mm, 4.1 ± 1.6 mm, 17.6 ± 4.8 mm, 6.3 ± 0.8 mm, 61.8 ± 12.4 min, respectively. The intergroup difference in thickness of the ligamentum flavum was statistically significant ($P=0.02$). The difference in surgical time was also established($P=0.04$). Endoscopic differences were identified as to the location of the anchor points and appearances among the two ligaments. Significant differences in the density and direction of fibrous structures were also observed under biopsy. Under endoscopy, significant difference as to the grade of ILL thickness was established when compared regarding disease spectrum ($P=0.09$.)

Conclusion The interlaminar ligament is a structure that has not yet been officially named, which has significant structural differences from those of the ligamentum flavum. For posterior endoscopic procedure, its clinical significance lies in its ability to serve as the endpoint of soft tissue channel establishment. The thickness of the ligamentum flavum in MRI and the thickness of ILL under endoscopy vary according to the disease spectrum.

Keywords Interlaminar ligament, Endoscopy, Pathology, Image

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Introduction

In recent years, with the deepening of minimally invasive concepts and the development of the technologies, the proportion of minimally invasive spinal surgeries is increasing yearly [1–3]. Minimally invasive spinal surgeries, represented by techniques such as transforaminal endoscopy, percutaneous interlaminar endoscopy, and unilateral biportal endoscopy(UBE), greatly improves the surgical safety due to utilizing of liquid media, real-time observation characteristics, and excellent image quality [2, 4]. At the same time, it can analyze subtle structures that cannot be observed during open surgeries.

In daily practice, the author identified one ligamental structure covering ligamental flava (LF) superficially, which was not reported previously and might be misidentified as the superficial layer of LF. It could serve as the start point of exposing of the LF to enhance the ability of intraoperative structural identification and improve the safety in LF piercing. The aim of this study is to analyze the ligament of its magnetic resonance imaging presentations, endoscopic features, and its pathological features compared to those of LF. Through literature search, our study is the first systematic clinical study on this ligament. Based on its location, this ligament was referred to as the interlaminar ligament (ILL) in the research.

Research objects

The information of patients with lumbar disc herniation or lumbar spinal stenosis who underwent posterior endoscopic treatment at Xi'an Honghui Hospital from January 2020 to February 2022 was collected retrospectively. Exclusion criteria include as follow: previous surgeries at the operational sites, incomplete image data tampering the accuracy of measurement, significant bone hyperplasia or skeletal deformities, history of previous connective tissue diseases, rheumatic or rheumatoid diseases.

Materials and methods

The demographic data were collected including the age, gender, diagnosis, operational time and segments. This retrospective imaging study was approved by the Ethics Committee of Xi'an Red Cross Hospital affiliated to Xi'an Jiaotong University (Ethics number: 202403048). Informed consents were also obtained from patients before the research.

Methods of analysis of the image data

The X-ray films were used to ensure the operational sites, analyze the stability of the target segment. Three-dimensional computer tomography was applied to measure the interlaminar width preoperatively. The thickness, length and width of ILL were measured in MRI. The scanning line was set at the medial edge of the articular process for the length measurement and midpoint of the interlaminar space for the width and thickness measurement. The thickness of the LF was measured at the same location. The equipment involved in the study were list as follow: GE Brivo XR575 in X-ray examinations, SIEMENS SOMATOM Definition CT with scanning thickness 2 mm and spacing 2 mm, 1.5 Tesla MRI (UNITED IMAGING uMR570) with a scanning thickness 2 mm and spacing 2 mm.

The exposure of ligaments and the comparison of ligamental features

Joimax ILESSYS Delta system (Munich, Germany) was used in all operations which were performed under general anesthesia without neurophysiologic mm mm.

monitoring. Patients was settled in prone position. An incision about 7 mm was made with a distance from the spinal process ranging from 10 mm to 15 mm basing on the location of the lesion and the size of the patient. Soft tissue dilators were used to create operational space. Intraoperation fluoroscopy was applied to confirm the operational segment. Radio frequency and nucleus pulposus forceps were used to remove the soft tissue to expose the ILL. The edge, thickness and appearance of the ILL were depicted endoscopically. Partial edge of upper and lower lamina was removed secondary to the removal of ILL in order to expose the LF. The texture, anchor points, thickness and appearance of LF was also recorded. The thickness of ILL was scaled endoscopically as referred to the width of front opening of Kerrison punch. Biopsies were conducted for both ligaments respectively to distinguish the structural differences.

The histological analysis of ligaments

Hematoxylin eosin staining was conducted to highlight the characteristics of both ligaments under microscope with a section thickness of 1.5 mm.

Data measurement and analysis

All data measurements were completed independently by two senior surgeons who had practiced in spinal surgery over 15 years. Cohen's Kappa coefficient was used to evaluate consistency. The indication of Kappa values is assigned as follow: $0 \sim 0.20$ for poor consistency, $0.21 \sim 0.40$ for small consistency, $0.41 \sim 0.60$ for moderate consistency, $0.61 \sim 0.80$ for good consistency, and $0.81 \sim 1.00$ for excellent consistency.

All statistical analyses were performed using statistical software for Windows (version 26.0; SPSS Inc, Chicago, IL). Quantitative data were listed as $X \pm S$ such as age, surgical time, thickness, length of ILL and LF both under endoscopy and MRI. Paired t-tests were used for comparison of ILL and LF for its endoscopic and imaging parameters. Independent sample t-tests were used for the comparison of surgical parameters. The χ^2 test was used to analyze frequency data. Two-sided *P*-values were reported for all clinical outcomes. A *P*-value of 0.05 was customarily considered as significant.

Result

Demographic data

Among the 43 patients, there were 26 cases with surgical segments located at L4/5, 17 cases at L5/S1. Twenty patients were grouped as lumbar disc herniation group, the rest 23 patients were belonged to lumbar spinal stenosis group. The surgical time for the lumbar disc group was 53.2±14.5 min. For the lumbar spinal stenosis group, it was 61.8±12.4 min. The statistical difference was established with a *P* value of 0.04.

Preoperative imaging parameters

Key imaging parameters were measured on MRI. The consistency test showed a Kappa value of 0.76, indicating a good consistency between two inspectors. The typical MRI images of both ligaments are shown in Figs. 1 and 2. According to the diagnosis and surgical segment respectively, patients were divided into two groups, for which the results of imaging parameters are shown in Tables 1 and 2. Grouped on the categories of diagnosis, significant deference was established regarding to the thickness of

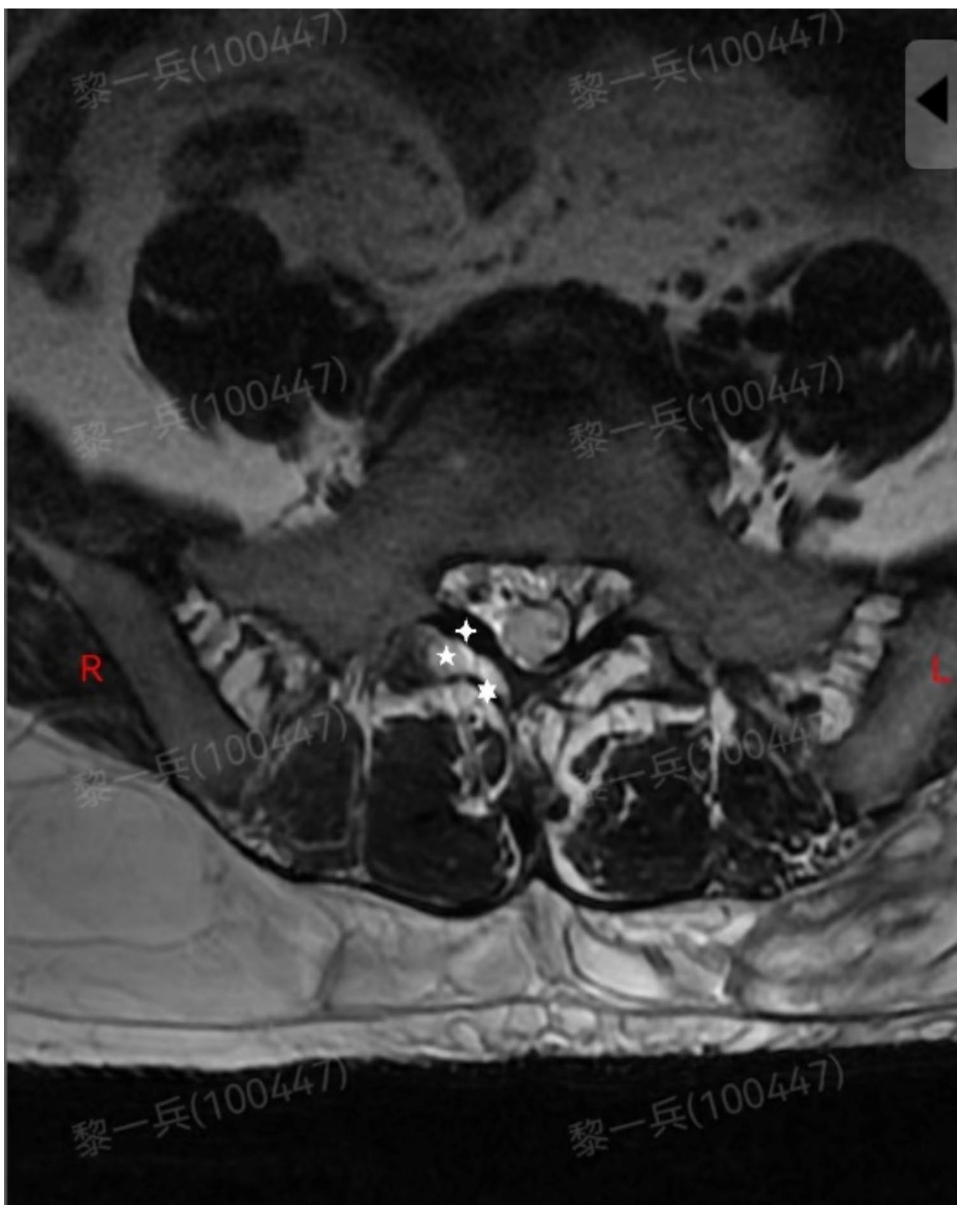

Fig. 1 Demonstration of ligaments on transverse T2 weighted image: four pointed star indicates LF, six pointed star indicates ILL, five pointed star indicates adipose tissue between two layers of ligaments

Fig. 2 Demonstration of ligaments on T2-weighted sagittal image on para-zygapophysial joint level : four pointed star indicates LF, six pointed star indicates ILL, five pointed star indicates adipose tissue between two layers of ligaments

Table 1 Comparison of parameters between groups according to diagnosis($\bar{x}\pm s$)

Variables	Disc herniation group (20 cases)	Lumbar stenosis group(23 cases)	
ILL width(mm)	17.7 ± 3.5	16.0 ± 3.1	t = 1.71 *P* = 0.09
ILL thickness(mm)	4.3 ± 1.3	4.1 ± 1.6	t = 0.34 *P* = 0.74
ILL length(mm)	18.3 ± 3.5	17.6 ± 4.8	t = 0.52 *P* = 0.61
LF thickness(mm)	5.3 ± 1.9	6.3 ± 0.8	t = 2.42 *P* = 0.02

Notes: ILL means interlaminar ligament, LF means ligamentum flavum

Table 2 Comparison of parameters between groups according to operational segments($\bar{x}\pm s$)

Variables	L4/5(26 cases)	L5/S1(17 cases)	
ILL width(mm)	16.3 ± 3.3	17.6 ± 3.4	t = 1.28 *P* = 0.21
ILL thickness(mm)	4.0 ± 1.5	4.5 ± 1.3	t = 1.22 *P* = 0.23
ILL length(mm)	17.5 ± 4.5	18.6 ± 3.7	t = 0.78 *P* = 0.44
LF thickness(mm)	5.8 ± 1.3	5.8 ± 1.8	t=-0.09 *P* = 0.93

Notes: ILL means interlaminar ligament, LF means ligamentum flavum

the ligamentum flavum with a *P* value of 0.02. Statistical difference was not found when the rest parameters were compared.

Comparison of distinctive interlaminar structures under endoscopy

The cranial anchor points of ILL were on the lower edge of upper lamina. The medial loose edge of ILL was attached to the base of spinal process. The lateral edge emerged with the capsule of zygapophysial joint. The caudal anchor points on the lower lamina varied morphologically. In some cases, the ILLs sticked to the edge of the lower lamina in a full range with contrast to discontinuous anchor points in other cases. The diagram of ILL is displayed in Fig. 3. Compared to the yellowish appearance of LF, ILL was silvery under endoscopy. The texture of ligamental stump was distinguishable, which resembled cotton for ILL compared to that fibrous appearance of LF. Adipose tissue was identified between the two layers. The typical structures of ILL and LF under endoscopy are exhibited in Figs. 4 and 5.

Measured by the width of the front opening of Kerrison punch (Ø300 X 3.5 mm X 135° with an opening of 8.5 mm), the thickness of ILL under endoscopy was defined as follow: grade 1 indicates a thin ILL, grade 2 refers to a ligamental thickness thinner than 50% of the width of the punch opening, grade 3 means the ligamental thickness exceeds 50% of the width of the punch opening. Likelihood ratio χ^2 test was used to analyze the ILL thickness under endoscopy grouped both on the diagnosis and operational segments respectively. No significant difference was established ($P=0.09$ and 0.67 respectively).

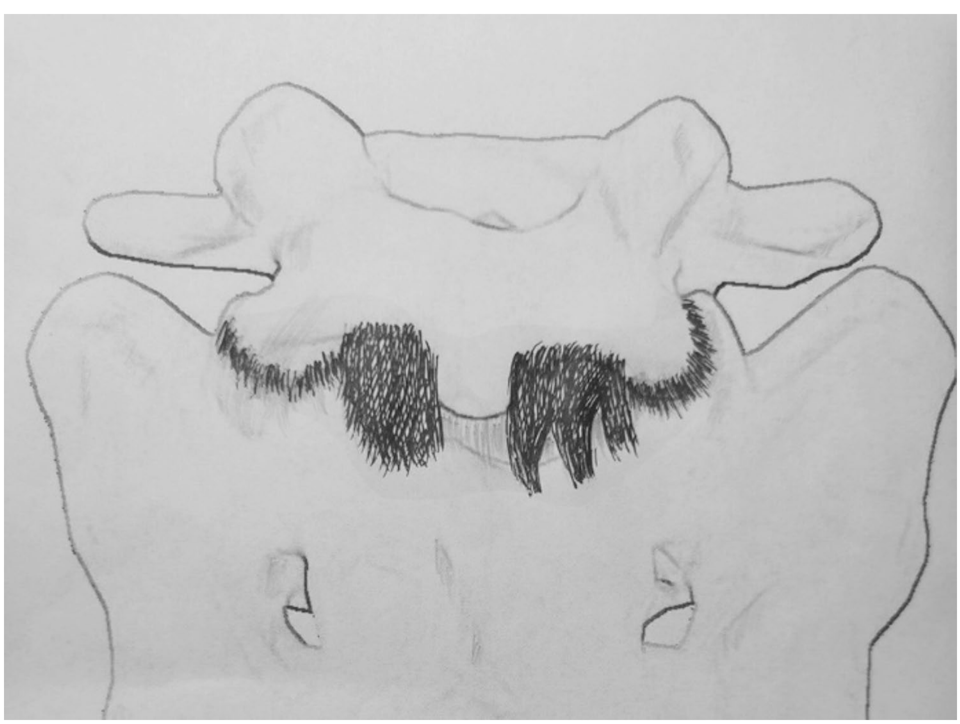

Fig. 3 Diagram of ILL at L5S1 shows similar anchor points at cranial, lateral, and medial side bilaterally, but continuous caudal anchor points on the left side compared to three separated anchor points on the right side

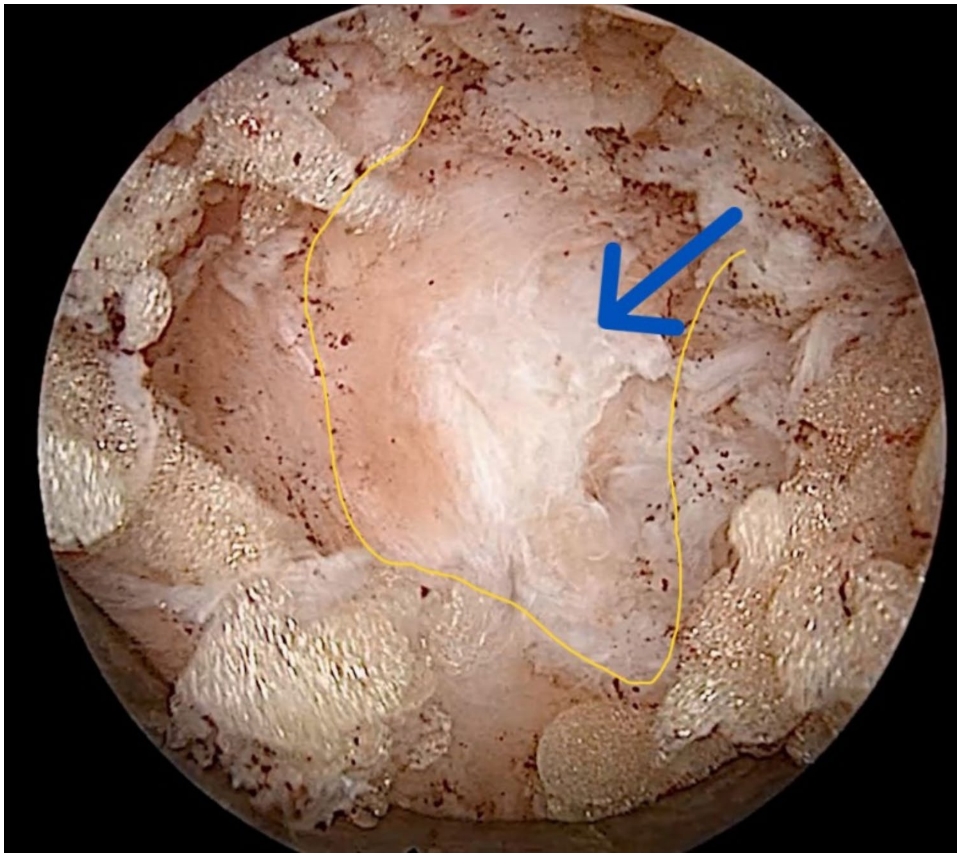

Fig. 4 The line indicates the edge of ILL, the arrow indicates its silvery appearance and fibrous texture under endoscopy

Result of histological exanimations

The biopsy results of both ligaments are exhibited in Figs. 6 and 7. Distinguishable characteristics of texture were identified between two ligaments.

Discussion

The development of spinal imaging technology enables surgeons to observe and measure structures of the spine in details [5, 6]. The utility of endoscopy can reveal subtle structures which are not clearly displayed in open surgeries. ILL is inclined to be misidentified as the superficial layer of LF or fascia attached to LF in open surgeries. Endoscopy amplifies the operational field which raises the possibility of identification of elaborate structures such as the ILL [7, 8]. This research, which focusing on both ligaments of its MRI characteristics, endoscopic appearances and pathological details, is conducted to differentiate ILL from LF.

LF is composed of two layers. The superficial layer of LF is bridged between the upper and lower edge of adjacent lamina with a gap between the articular joint and the lateral ligamental edge [9]. The deep layer varies in its upper and lower anchor points. The majority of anchor points are at lower edge of cranial lamina and the middle part of caudal limina with various degree of merging to the adjacent articular joint capsule [9, 10]. The anchor points of ILL are extremely loose to the edge of lamina. The slivery appearance of ILL and the distinguishable adipose tissue between ILL and LF make it reasonable to regard ILL as an independent structure. Through literature review, no systematic research has been conducted on this specific ligament which was temporarily named as the ILL in the article. ILL is a reliable mark before perforating the LF. A thoroughly exposure of ILL could be regarded as the endpoint of construction of soft tissue tunnel, which is of clinical importance to reduce the chance of straying during operations.

Based on the disease spectrum and the operational segments, patients were grouped to compare intergroup parameters. The thickness of LF was found significantly different between patients with lumbar stenosis and patients with disc herniation, which is reasonable because of the different etiology of each disease. This result is consistent with a report by Li et al. [11]. Statistical difference was not established when the rest of parameters were analyzed, which was presumably originated from the limited sample size and the difficult measurement via endoscopy.

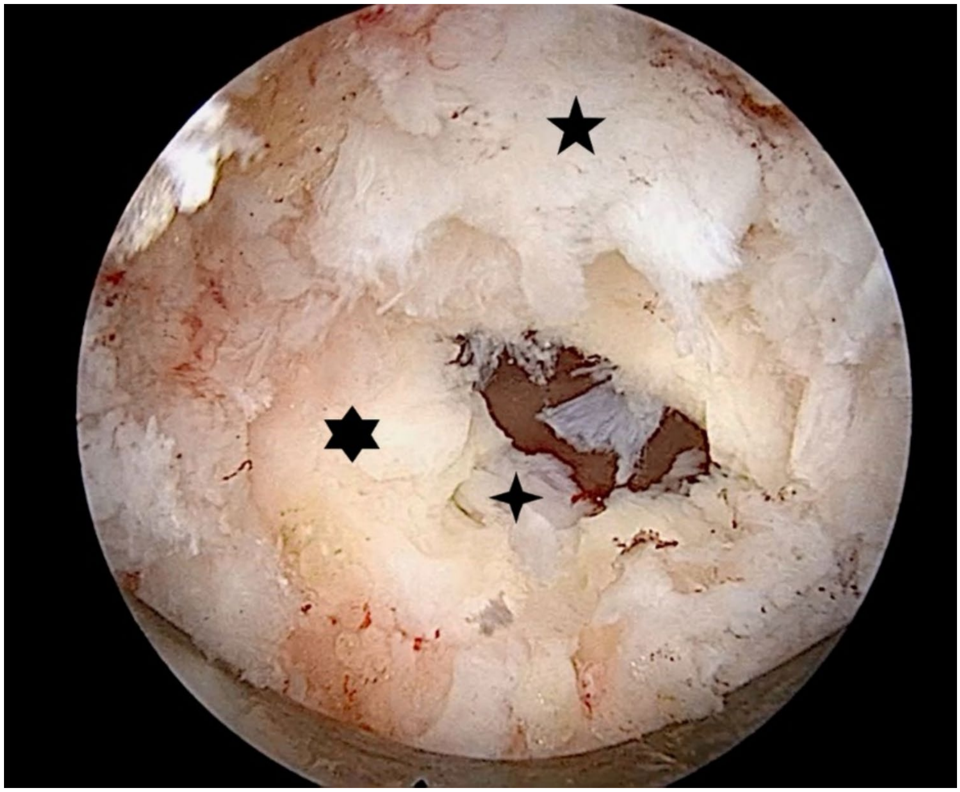

Fig. 5 The five pointed star indicates the stump of ILL, the six pointed star indicates the superficial layer of LF and four pointed star indicates the deep layer of LF. Residual adipose tissue between ILL and LF could be identified at six o`clock position

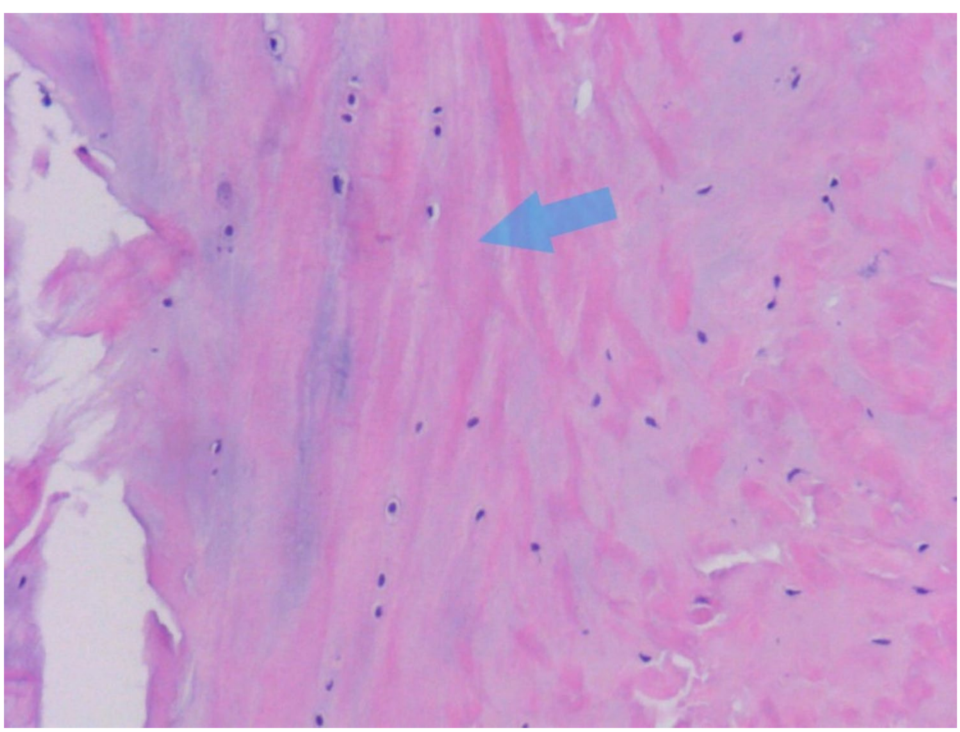

Fig. 6 The fiber of LF is highly intense and weaved in same direction

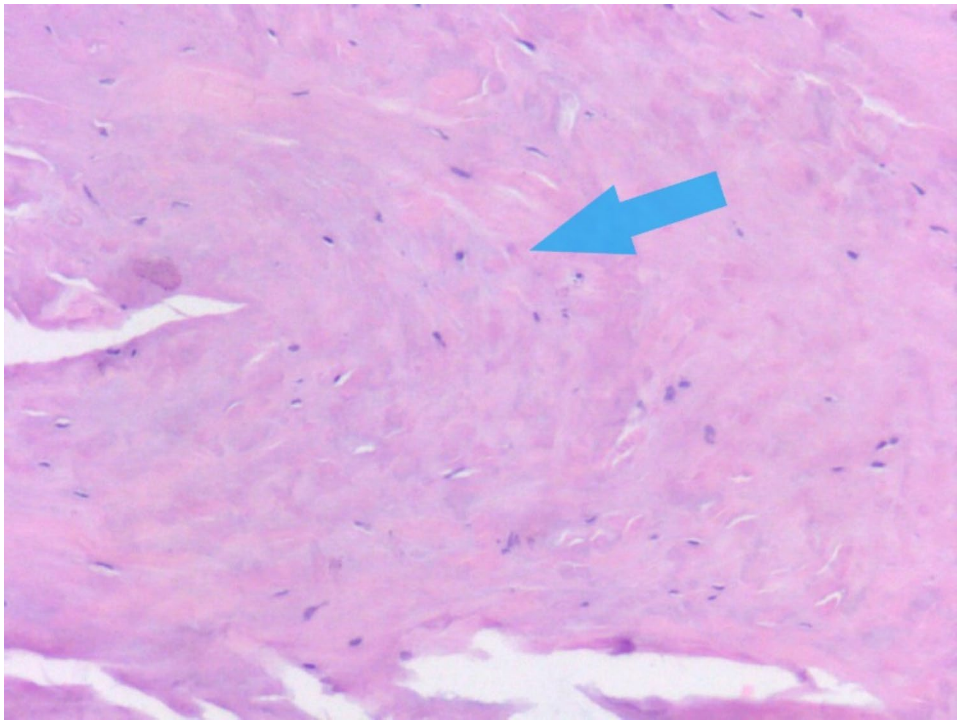

Fig. 7 The fiber of ILL is loose and diverse in orientation。

Study limitations

There are some limitations about this study. First, as this is not a prospective controlled randomized study, selection bias may potentially influence the result. Second, the sample size is relatively small because of its nature of one center research. Third, the measurement of ILL via endoscopy is quite rough. Last but not least, the anatomical role of ILL still remain unclear. We recommend that a multicenter, large sample, randomized study is needed to reveal the importance of ILL.

Conclusion

In summary, there are significant differences in anatomical structures and pathological features between ILL and LF. Based on our literature review, this study is the first systematic morphological analysis of this ligament. The complete exposure of this ligament can serve as an endpoint of complete preparation of soft tissue channels before perforating in the LF. Further research is recommended on the physiological function of this ligament in the future.

Author contributions

YBL contributed to the idea of this study. XFL searched literatures and screened them independently. Both authors contribute equally in writing the first draft and in polishing the the definitive version. All authors read and approved the final manuscript.

Funding

Not applicable.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

this study was approved by the Ethics Committee of Xi'an Jiaotong University (approval number: 202403048). All aspects of this study were conducted with adherence to the current version of the Declaration of Helsinki, the guidelines established by the International Conference on Harmonization of Good Clinical Practice, and the laws of China.

Consent for publication

All participants signed informed consent forms for publication.

Competing interests

The authors declare no competing interests.

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