# Histological Observation of the Retinacula of Weitbrecht and Its Clinical Significance

## A cadaveric study

**Abstract**

**Background:** The retinacular arteries provide major supply to the femoral head, their injuries may lead to the femoral head necrosis (FHN) in femoral neck fractures. Although the femoral neck fracture was seriously displaced in some patients, FHN did not occur, which suggests that the blood supply is not fully blocked. This study was aimed to find the association between the structure of the retinacula of Weitbrecht and the mechanism of protecting retinacular arteries from being injured. **Materials and Methods:** Fourteen formalin-fixed cadaveric specimens (in 28 hips) with no significant vascular disease were observed. The retinacula were cut longitudinally and then cut into three parts: medial, middle, and lateral. These specimens were stained using hematoxylin and eosin and improved Masson Trichrome stain. The microstructure and tightness of the retinacula fixed to the bone and the distribution of vessels were examined under a stereoscope, an optical microscope, and a scanning electron microscope. **Results:** The microstructure and compactness in each part of retinacula were different, and the tightness of the fibers of the retinacula fixed to the bone in each part were different. A particular structure which resembled a Sandwich panels was observed, and it may be an effective mechanism of protecting retinacular arteries. **Conclusion:** The Sandwich panels structure existed generally in the retinacula of Weitbrecht, and this sandwich panelture may play very important role in protecting the retinaculum artery from being injured, which show the importance of protecting the retinacular artery in the treatment of femoral neck fractures.

**Keywords:** *Femoral head necrosis, femoral neck fracture, histology, retinacula of Weitbrecht, retinacular artery*

**MeSH terms:** *Femoral neck fractures, histology, femur head, synovium, avascular necrosis of bone*

**Bang Dou[1,2], Jiong Mei[3], Zhiyuan Wang[1], Ming Ni[1], Guangyao Jia[1], Shiwei Liu[1]**

*[1]Department of Orthopaedics, Tongji Hospital, Tongji University School of Medicine, [2]Department of Orthopaedics, Songjiang District Central Hospital, [3]Department of Orthopedic Surgery, Shanghai Jiao Tong University Affiliated Sixth People's Hospital, Shanghai, China*

## Introduction

The intraarticular synovial plicae of the hip passing along the femoral neck was first described by Weitbrecht in 1742[1] and named retinacula by Henle in 1856.[2] The retinacula have been called the retinacula of Weitbrecht since the turn of the twentieth century in anatomical papers.[3,4]

The retinacula of Weitbrecht are located superior (lateral), inferior (medial), and anterior to the femoral neck. The superior part is connected to the hip joint capsule, and the inferior part ends at the edge of the articular cartilage of the femoral head, which signifies the merging of the femoral head and neck. The subordinate arteries of the lateral and medial femoral arteries branch out as they run through the inside of the capsule at the base of the femoral neck.[5,6] These new arteries divide into more branches in the femoral neck and head, along with the spread of the retinacula of Weitbrecht, and are known as retinacular arteries.[7-10] Retinacular arteries are the main blood source to the femoral head.[9,11,12] The retinacula of Weitbrecht are so close to the femoral neck that they might be hurt once the femoral neck fractures, thus, the retinacular arteries would be affected.[12,13] Maruenda *et al*. concluded that the femoral head necrosis (FHN) only depends on the vascular damage at the time of fracture.[14]

However, FHN did not occur although the femoral neck fracture was seriously displaced in some patients,[15,16] which suggests that the blood supply was not fully blocked. To find out whether there are special structures of the retinacula of Weitbrecht to protect the retinacular arteries when the femoral neck is seriously displaced, which may be the cause of these clinical observations, we observed and analyzed the micro-structure of the retinacula of Weitbrecht.



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***Address for correspondence:***
*Dr. Jiong Mei, Department of Orthopedic Surgery, Shanghai Jiao Tong University Affiliated Sixth People's Hospital, Shanghai, 200233, China.*
*E-mail: meijiong@sjtu.edu.cn*

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## Materials and Methods

### Specimens

This study of cadaveric specimens was approved by the Ethics Committee of our institute, which is affiliated with University. Fourteen formalin-fixed specimens (28 hips) with no significant vascular disease were observed. The retinacula of Weitbrecht were entirely anatomized, and the retinacula of Weitbrecht with some bone cortex around it were cut off entirely. After that, these harvested ligaments were cut longitudinally from the mid-line, and every part was cut into three parts, which were named the medial part (including the retinacula of Weitbrecht and the edge of the migration of the femoral head cartilage), the middle part, and the lateral part (including the capsule and the folded part of the retinacula of Weitbrecht) [Figure 1].

### Histochemistry

Two-thirds of these specimens were embedded in paraffin and sectioned. Half of these sections were stained with hematoxylin and eosin (H and E), and the rest were stained with the improved Masson Trichrome staining.

The rest of these specimens were decalcified and observed with an electroscope.

### Histological morphology observation

A stereoscope (Olympus, SZX10, Tokyo, Japan), an optical microscope, and a scanning electron microscope (SEM) (S-3400N, Hitachi, Tokyo, Japan) were used to observe the histological morphology of the stained tissue slides. The retinacula of Weitbrecht with bone cortex around it were observed under the stereoscope, and the compactness in different parts of the retinacula of Weitbrecht stained by H and E and Masson staining was measured.

The longitudinal section and cross section of the retinacula of Weitbrecht stained by H and E were observed under an optical microscope and a SEM. The characteristics of the fibrous structure, the characteristics of the retinaculum fixed to the bone, and the characteristics of vascular distribution were observed [Table 1].

## Results

### The fibrous structure of the retinacula of Weitbrecht

The retinacula of Weitbrecht were composed of fat, blood vessels, nerves, interweaving collagen fibers, and elastic fibers. The connection between layers of fiber in the superior retinaculum (SR) was relatively loose; much connective tissue filled the area between these layers, and many blood vessels and nerves ran through this loose connective tissue [Figure 2a]. There was no layering in the fiber bundles of the SR, and the direction was mixed, which could be observed clearly under SEM [Figure 2b and c]. The fibrous structure of the anterior retinaculum (AR) was compact and composed of 6–10 layers of fibers. These layers were clear to distinguish: the directions of fiber between adjacent layers were different, in a criss-cross pattern, and there were a few staggered fibers connecting adjacent layers [Figure 3]. The fibrous structure of the inferior retinaculum (IR) was more compact and composed of more layers of fibers.

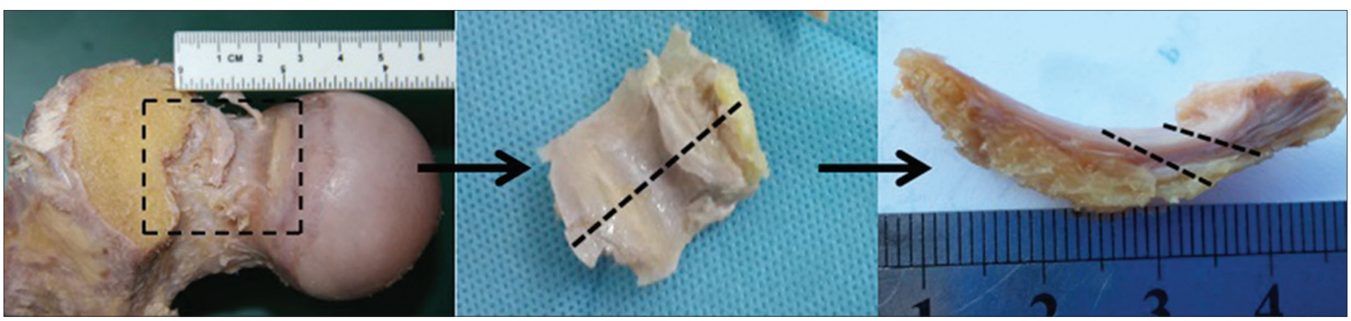

**Figure 1: The retinacula of Weitbrecht were cut longitudinally from the mid-line, and every part was cut into three parts: the medial part which including the retinacula of Weitbrecht and the edge of the migration of the femoral head cartilage, the middle part, and the lateral part which including the capsule and the folded part of the retinacula of Weitbrecht**

**Table 1: Histological findings of the micro-structure of the retinacula of Weitbrecht**

| Contents | Results | | |
|---|---|---|---|
| | **SR** | **AR** | **IR** |
| Characteristics of the fibrous structure | Loose fatty tissue in the middle layer, compact fibrous layers on both sides | Compact fibrous layers | Compact fibrous layers, strongest |
| Characteristics of the retinaculum fixed to the bone | Tight on both ends, loose in the middle | Tight on both ends, loose in the middle | Tight on both ends, separated in the middle |
| Characteristics of the vascular distribution | Surrounded by loose fatty tissue, pierce the compact tissue to the nutrient foramen | The same with SR | The same with SR |

SR=Superior retinaculum, AR=Anterior retinaculum, IR=Inferior retinaculum

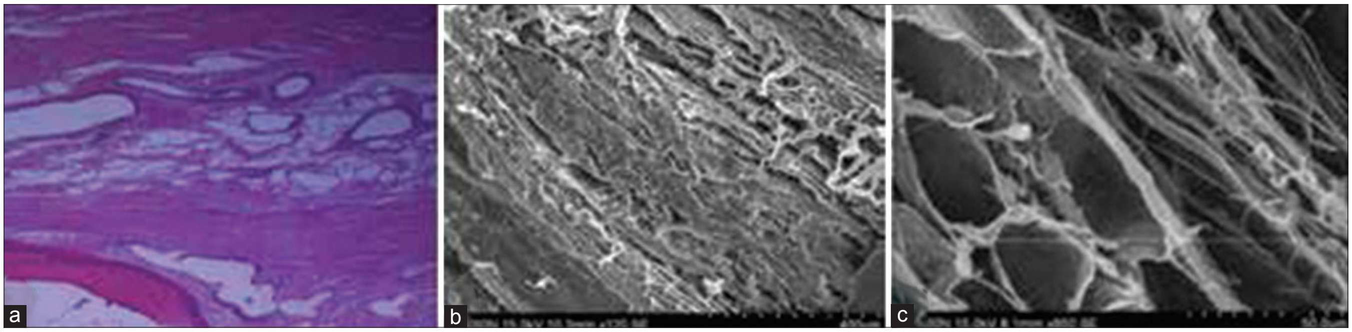


**Figure 2: (a) H and E stained histological transection of the superior retinaculum, showed it was relatively loose, and many blood vessels ran through it. (b and c) There was no layering in the fiber bundles, and the direction was mixed, with no clear separation between adjacent layers**

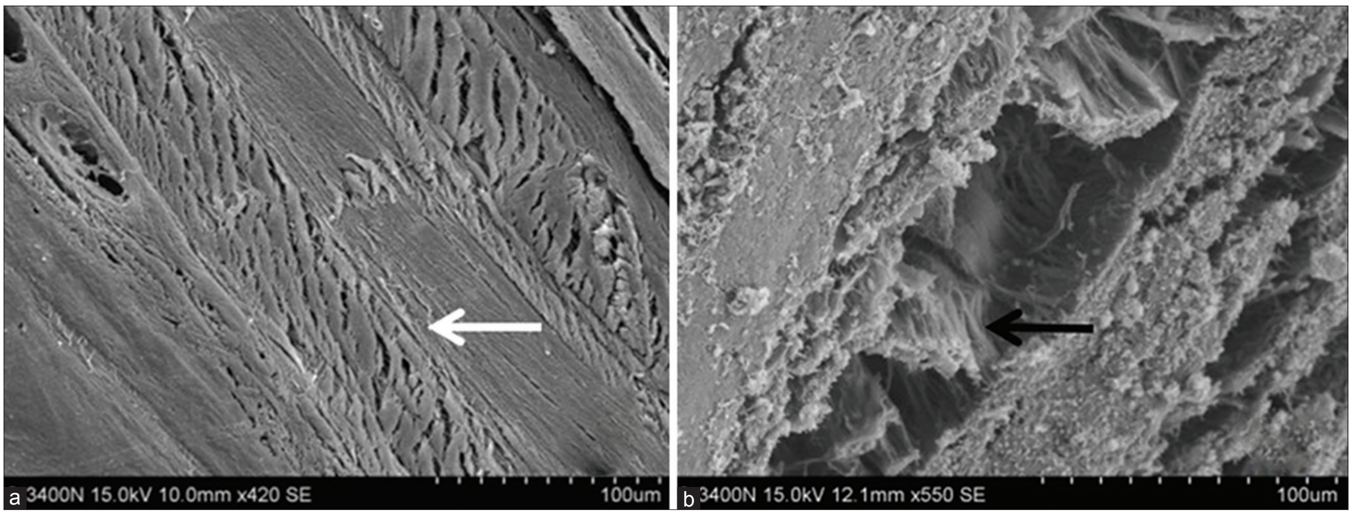


**Figure 3: (a) Scanning electron microscopy: The anterior retinaculum was compact, and these layers were clear to distinguish: the directions of fibers between adjacent layers were different, in a criss-cross pattern (white arrow). (b) Scanning electron microscopy: There were a few staggered fibers connecting adjacent layers in the anterior retinaculum (black arrow)**

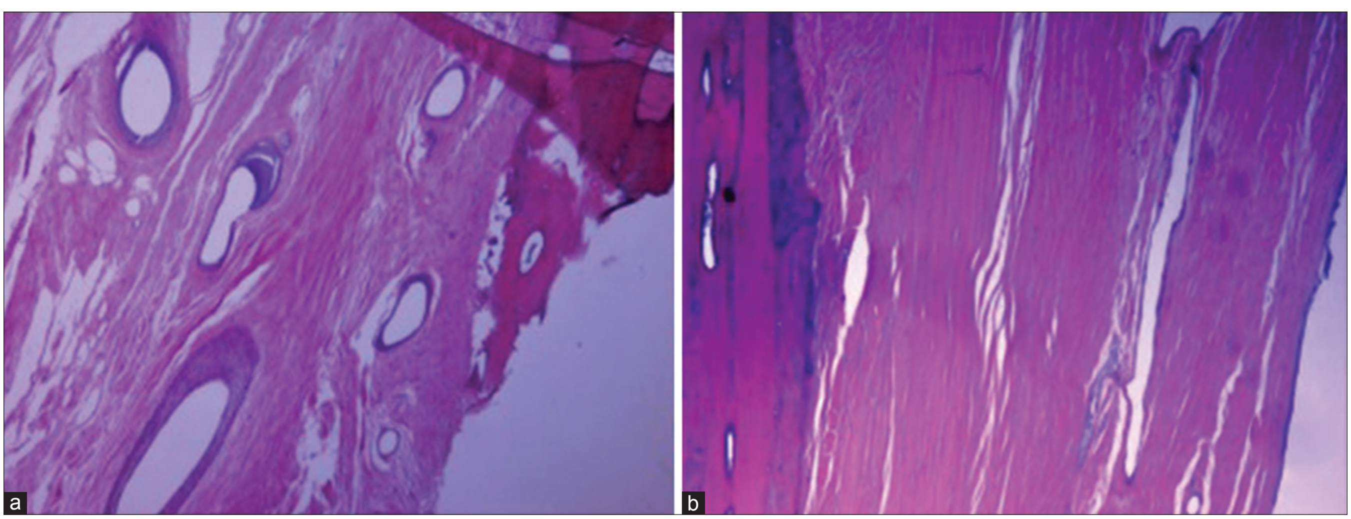


**Figure 4: (a) H and E staining: The overall structure of superior retinaculum was loose, especially between adjacent layers of fibers, with much loose connective tissue, and rich in blood vessels. (b) H and E staining: Both the structure and fibers in the anterior retinaculum were compact, with less loose connective tissue and blood vessels**

### Observation of the retinacular artery

The longitudinal and cross sections of the retinacula of Weitbrecht were observed under an optical microscope, showing that the overall structure of the SR was loose, especially between adjacent layers of fiber, which allowed many vessels to go through and distribute easily [Figure 4a]. The number of vessels in the anterior retinaculum was less than that in the SR, which may be related to the overall tight structure of the anterior retinaculum, especially between adjacent layers of fiber [Figure 4b]. In this lamellar structure, the directions of fiber between adjacent layers were different, criss-cross, and not so much loose tissue existed. It was, therefore, difficult for the arteriole and veinlet to go through.

### The tightness between fibers of the retinacula of Weitbrecht and the bone

Although the separation between the retinacula of Weitbrecht and the bone was not clear under the stereoscope, the microscope and SEM showed us the details of the separation and the tightness between fibers of the retinacula of Weitbrecht and the bone.

Different retinaculum had a different tightness to the bone. As the fibrous tissue in the SR was loose, the outer fiber layers were easy to tear, but some fibrous bundles in the innermost fiber layer were still riveted to the bone. The fibrous structure of the AR was compact, and the connection between the fibrous layer and the bone were tight, just like a rivet to the bone, it was difficult to tear and difficult to separate it from the bone compared to the SR [Figure 5]. While the IR connected to the femur on both ends with no connection to the bone in the middle.

Different part of the retinaculum had a different tightness to the bone too. In the lateral part of the superior and anterior retinaculum, the fibers arose from the trochanter or intertrochanteric ridge perpendicularly, and all fiber bundles were firmly riveted to the bone [Figure 6a and b]. In the middle part, most of the fibers were parallel to the bone surface; a small number of the fibers pierced the bone perpendicularly, to fix the retinacula of Weitbrecht to the femoral neck bone, like feet of Boston ivy fixed to the wall [Figure 6c and d]. In the medial part, at the edge of the articular cartilage of the femoral head, the fiber bundle riveted obliquely to the bone layer-by-layer along the curvature of the femoral head, step-by-step, similar to a hook or a slot mating structure [Figure 6e and f]. This style of connecting to the bone was different from the middle part of the retinacula of Weitbrecht, where only a few fibers were riveted to the bone, not fiber bundles. This difference that fibers assembled as bundles to rivet to

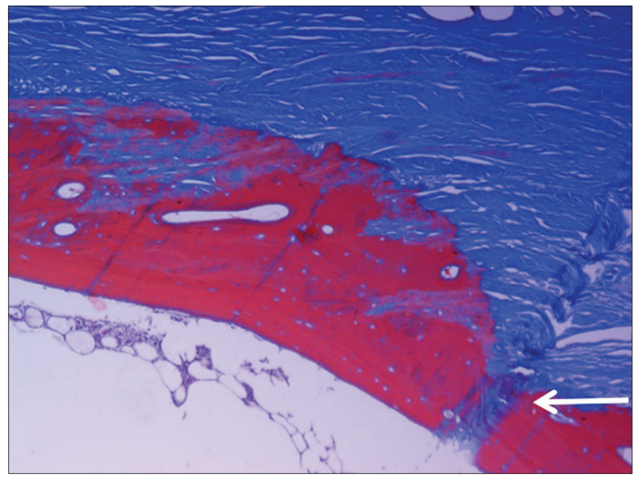

**Figure 5: Masson stained histological transection of the anterior retinaculum showing that fibers assembled as bundles to fixed to the bone tightly, just like a rivet be fixed to the bone (white arrow)**

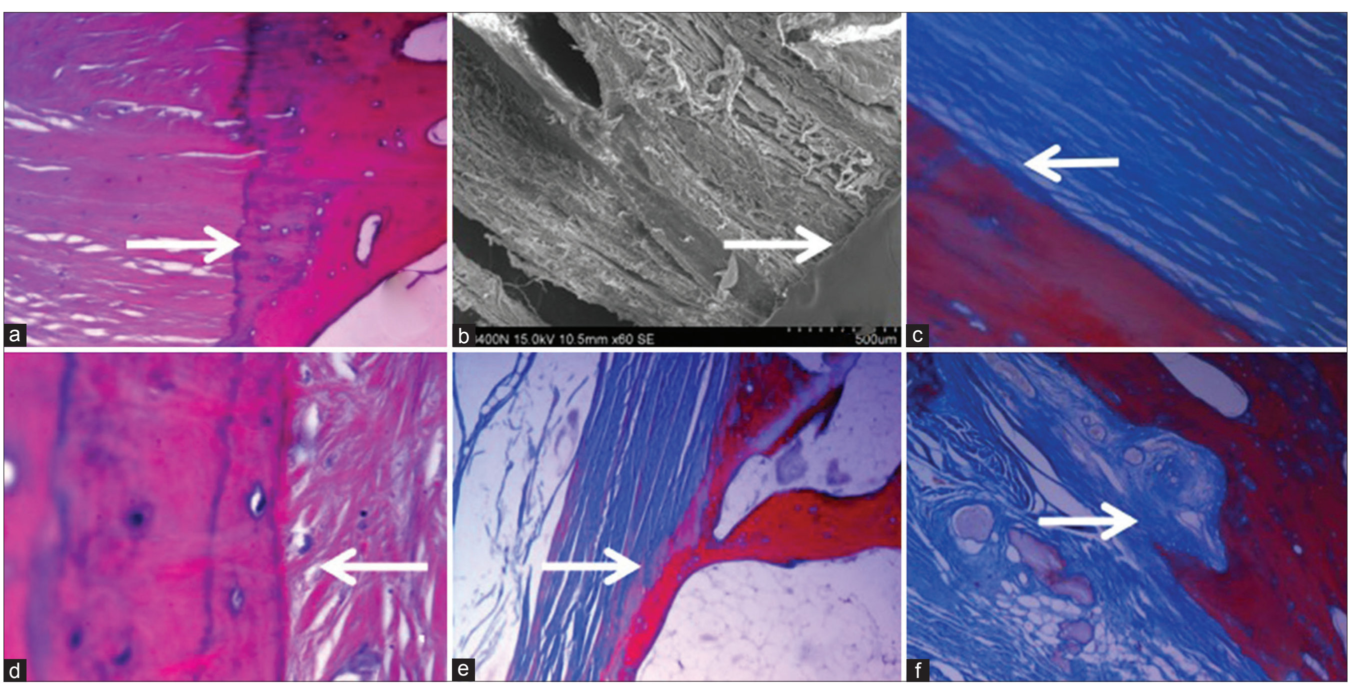


**Figure 6: (a and b) H and E staining and scanning electron microscopy: In the lateral part, fibers arose from the trochanter or intertrochanteric ridge perpendicularly, assembled as bundles to rivet to the bone firmly (white arrow). (c and d) In the middle part, most of the fibers were parallel to the bone surface, a small number of the fibers pierced the bone perpendicularly, to fix the retinaculum to the bone, like feet of Boston ivy fixed to the wall (white arrow). (e and f) In the medial part, fibers riveted obliquely to the bone layer-by-layer (white arrow), similar to a hook or a slot mating structure (white arrow)]**

the bone at both ends while only a few vertical fibers riveted to the bone in the middle part could be observed more clearly under SEM [Figure 7].

### A special sandwich panels structure

When we observed the retinacular vessels under high-power SEM, we found that most of them went through loose connective tissue, the two sides of which contained tighter fibrous layers. The whole structure was similar to that of a sandwich panels structure [Figure 8a and b].

Then, we used the low-power optical microscope to observe the overall structure of the SR, and once again, we found that the overall structure of the SR was similar to the Sandwich panels structure, with the bone and the dense connective fibers as the outside hard panels and the loose connective tissue with blood vessels as the middle soft panel [Figure 8c]. We observed that the vascular wall in the middle layer of the loose connective tissue remained intact, even though the outside of the sandwich (the bone) was broken and displaced [Figure 8d].

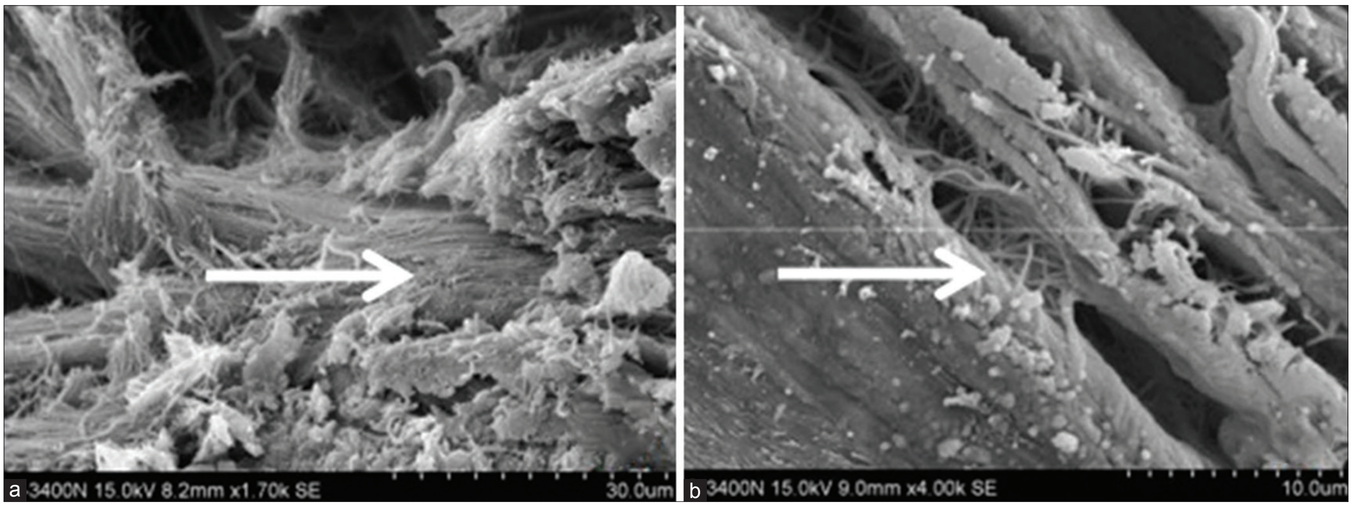


**Figure 7: (a) Fibers assembled as bundles to rivet to the bone at both ends of the retinaculum (white arrow). (b) Only a few vertical fibers riveted to the bone in the middle part (white arrow)**

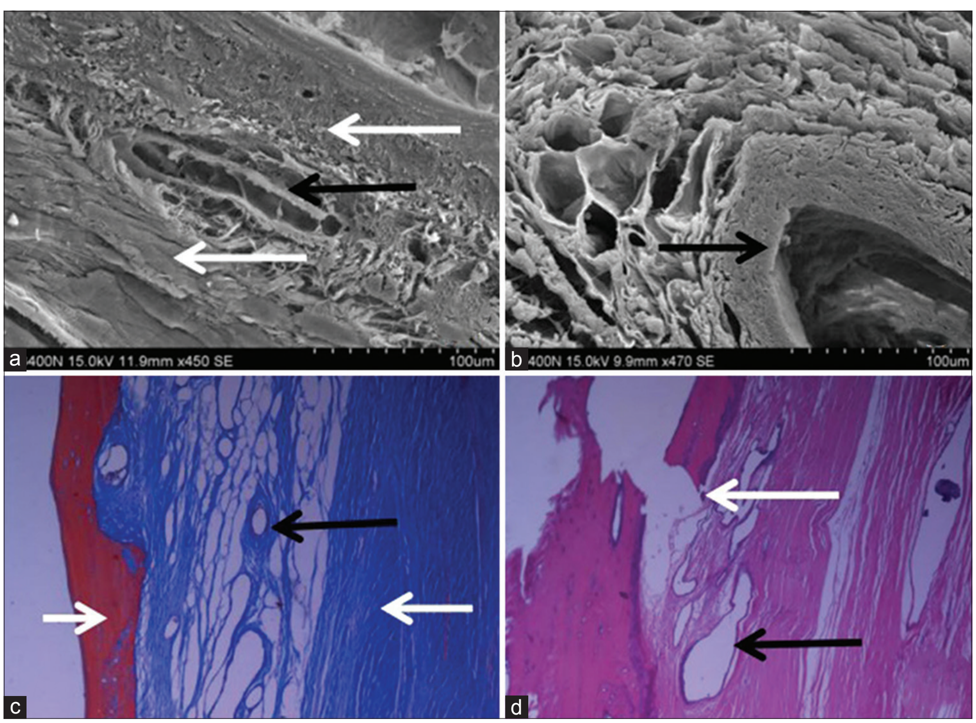


**Figure 8: (a and b) Scanning electron microscopy: Most of vessels run through loose tissue (black arrow), two sides were compact fibrous layers (white arrow), the whole structure was similar to a sandwich. (c) Low-power optical microscope: The overall structure of the SR was similar to the sandwich panels, with loose tissue existed among the dense fibrous layer and the bone (white arrow), and vessels distributed in the loose tissue (black arrow). (d) H and E staining: The vascular wall in the middle layer remained intact (black arrow), even though the outside of the sandwich (the bone) was broken and displaced (white arrow)**

## Discussion

The anatomy of the retinacula of Weitbreicht have been described in many papers; a few papers have definitely described their function.[7-9,17] Fawcett E thought that the main objective of the retinacula of Weitbrecht was to form buttresses which may, prevent femoral neck fracture happening, instead of affecting as a natural splint after the fracture.[3] Different from Fawcett E's research focused on the anatomy and the strain to explain the function of the retinacula of Weitbreicht, our research was focused on the relationship between the structural characteristics of the retinacula of Weitbrecht and the mechanism of protecting the retinacular arteries from being injured.

First, we observed the microstructure characteristics of the retinacula of Weitbrecht because the compactness and the strength of the retinaculum were related to the distribution and protection of the retinacular vessels. We found that the internal structure and the degree of the compactness of the retinaculum were significantly different among the superior, the anterior and the IR.[9] The fibrous structure of the SR was loose, and no layering in the fiber bundles, which allowed blood vessels and nerves to run through easily, we inferred that this may be a buffer for absorbing energy when it is under attack. While the whole structure of the AR was compact, similar to the lamellar structure, and fiber directions were different between adjacent layers, appearing as a woven structure, on the one hand, the strength and resistance against compression improved greatly, it was useful for protecting the retinacular artery, on the other hand. The structure of the IR was more compact than the anterior retinaculum, and was the strongest among them.[9]

Then the characteristics of the retinacular arteries distribution were observed. Although there have been many anatomy studies on the blood supply of the femoral head and neck, none of these studies observed the micro-structure of characteristics of the retinacular arteries.[4,9,18,19] We found that vessels were rich in the loose connective tissue, and there were more blood vessels existed in the SR than the anterior retinaculum, because the whole structure of the anterior retinaculum was more tighter than the anterior retinaculum.

After that, we observed the degree of tightness between fibers of the retinacula of Weitbrecht and the bone, because the more tightness between them, the more likely that retinacula vessels be injured when the fracture is displaced. If the contact is loose, there will be a buffer if a fracture occurs, which is helpful to protect arteries. Our study found that different retinaculum had a different tightness to the bone, and different part of the retinaculum had a different tightness to the bone too. The anterior retinaculum connected to the bone much more tightly than the SR. The IR connected to the femur just on both ends with no connection to the bone in the middle, so the inferior retinacular artery was more mobile than the other retinacular vessels and might be more likely to escape injury after fractures, and this had been observed both in anatomy study and the clinic cases.[15,20] Although the superior and anterior retinaculum were found connecting to the bone all the path, the degree of tightness of each segment was different. The retinacula of Weitbrecht were fixed to the bone tightly at both ends but loose to the bone in the middle. When the middle part of femoral neck fractured, the middle part of the retinacula of Weitbrecht might detach from the bone easily, escaped from being torn after the fracture displaced, while both the ends of the retinacula of Weitbrecht were still tightly connected. As a result, the retinacular artery may be protected to some extent.

The most significant finding during our study is the Sandwich panels structure. When we observed the retinaculum under a high-power microscope, we found that most of these arterioles and veinlets in the retinacula of Weitbrecht went through loose connective tissue, the two sides of which were compact fibrous layers, the whole structure was similar to a Sandwich panels structure. When we observed the lateral retinaculum under a low-power optical microscope, we also found the sandwich panels structure, with the bone and the dense connective fibers as the outside hard panels and the loose connective tissue with blood vessels as the middle soft panel. This illustrated that the sandwich panels structure generally existed in the retinacula of Weitbrecht. Considering so many advantages of the Sandwich panels structure such as high strength and high resistance to wear, fracture, and shock,[21-23] we inferred that the Sandwich panels structure may help protect blood vessels, and this structure may be an effective mechanism of protecting the retinacular artery from being injured in femoral neck fractures.

The latest research found that the foraminal distribution parallels the retinacula of Weitbrech, the largest numbers of nutrient foramina were found on the superior surface, followed by the anterior and posterior surfaces, and then the inferior (medial) surface, this fully corresponds to our finding that vessels are rich in loose SR and poor in compact anterior and IR.[24] As the retinacular arteries provide dominate supply to the femoral neck, if the retinacula of Weitbrecht are injured in femoral neck fracture, will there be injuries to these retinacular arteries, which are protected by these special structures mentioned above, and to what degree? The severity of injury to retinacular arteries is more important for us to predict FHN than the degree of displacement of the femoral neck fracture. Therefore, it should be considered vital to plan an individual treatment of either internal fixation or arthroplasty.

## Conclusion

The Sandwich panels structure existed generally in the retinacula of Weitbrecht, and this particular structure may play a very important role in protecting the retinaculum artery from being injured. Knowledge of the anatomical and histological features of the retinacula of Weitbrecht is necessary for diagnostics and operations on the femoral neck fracture, especially for the individual treatment in elderly patients.

### Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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### Conflicts of interest

There are no conflicts of interest.

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