An Anatomical Study of the Anterosuperior Capsular Attachment Site on the Acetabulum

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Background: Despite the fact that many surgeons perform partial capsular detachment from the anterosuperior aspect of the acetabulum to correct acetabular deformities during hip arthroscopy, few studies have focused on whether these detachments influence hip joint stability. The aim of this study was to investigate the capsular attachment on the anterosuperior aspect of the acetabulum. We hypothesized that the attachment on the inferior aspect of the anterior inferior iliac spine (AIIS) is wide and fibrocartilaginous and might have a substantial role in hip joint stability.

Methods: Fifteen hips from 9 cadavers of Japanese donors were analyzed. Eleven hips were analyzed macroscopically, and the other 4 were analyzed histologically. In all specimens, the 3-dimensional morphology of the acetabulum and AIIS was examined using micro-computed tomography (micro-CT).

Results: Macroscopic analysis showed that the widths of the capsular attachments varied according to the location, and the attachment width on the inferior edge of the AIIS was significantly larger than that on the anterosuperior aspect of the acetabulum. Moreover, the capsular attachment on the inferior edge of the AIIS corresponded with the impression, which was identified by micro-CT. Histological analysis revealed that the hip joint capsule on the inferior edge of the AIIS attached to the acetabulum adjacent to the proximal margin of the labrum. In addition, the hip joint capsule attached to the inferior edge of the AIIS via the fibrocartilage.

Conclusions: The capsular attachment on the inferior edge of the AIIS was characterized by an osseous impression, large attachment width, and distributed fibrocartilage.

Clinical Relevance: It appeared that the capsular attachment on the inferior edge of the AIIS was highly adaptive to mechanical stress, on the basis of its osseous impression, attachment width, and histological features. Anatomical knowledge of the capsular attachment on the inferior edge of the AIIS provides a better understanding of the pathological condition of hip joint instability.

Femoroacetabular impingement is a condition that results when extra bone grows along the bones that form the hip joint, leading to abnormal contact between the femur and acetabulum during hip movement[1-4]. Femoroacetabular impingement is one of the most common indications for hip arthroscopy and may lead to the development of hip osteoarthritis[1-4]. The aim of hip arthroscopy is to correct osseous abnormalities and repair any associated soft-tissue damage[3-5].

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Although hip instability after hip arthroscopy is generally considered a rare complication[6,7], its prevalence has increased in recent years[8-16]. In clinical cases and biomechanical studies, management of the hip joint capsule has been regarded as critical and has garnered more attention in recent years[2,17-19]. During some surgical procedures for femoroacetabular impingement, the hip joint capsule is partially detached from the anterosuperior aspect of the acetabulum for the purpose of labral repair[20,21] and decompression of the anterior inferior iliac spine (AIIS)[22,23]. Although these partial detachments of the anterosuperior part of the joint capsule have been usually left without repair, few studies have focused on how these detachments potentially influence hip instability[24].

The part originating from the inferior edge of the AIIS of the anterosuperior part of the capsule is known as the iliofemoral ligament and has an important role in hip joint stability[25,26]. However, few studies have investigated the capsular attachment of the anterosuperior aspect of the acetabulum. According to Wolff's law, the osseous structure is sensitive to the mechanical stresses loaded on it[27]. In addition, the presence of fibrocartilage at the entheses, which are the connective tissues where tendons, ligaments, and joint capsules attach to bone, has been shown to be a response to the mechanical stresses[28,29]. Therefore, knowing the anatomy of the capsular attachment on the anterosuperior aspect of the acetabulum on the basis of its osseous structure and histological features may be important to understanding the key elements of hip joint stability.

This aim of this study was to investigate the capsular attachment of the anterosuperior aspect of the acetabulum on the basis of the osseous morphology, macroscopic findings, and histological anatomy. We hypothesized that the attachment of the hip joint capsule on the inferior edge of the AIIS is wide and fibrocartilaginous and is thus important for hip joint stability.

Materials and Methods

Cadaveric Specimen Preparations

Seventeen hips from 9 cadavers (5 Japanese men and 4 Japanese women; mean age at the time of death, 80.8 years), which were donated to the Department of Anatomy, were used in this study. All cadaver specimens were fixed in 8% formalin and preserved in 30% ethanol. The skin and subcutaneous tissues were removed for dissection of the proximal side of the hip joint capsule. After removal of the gluteus maximus and hip adductor muscles, the proximal osseous shape of the femur was identified and all specimens were cut at the level of the femoral neck using a diamond saw. One specimen was excluded because of previous hip joint surgery.

In the remaining specimens, the osseous configuration of the acetabulum and AIIS was examined using micro-computed tomography (micro-CT) (inspeXio SMX-100CT; Shimazdu) with a 200-μm resolution, and the 3-dimensional (3-D) images were reconstructed using application software (VGStudio Max 2.0; Volume Graphics). One hip with severe calcification seen on the 3-D image was excluded. Then, 11 and 4 hips were randomly assigned to macroscopic and histological analyses, respectively.

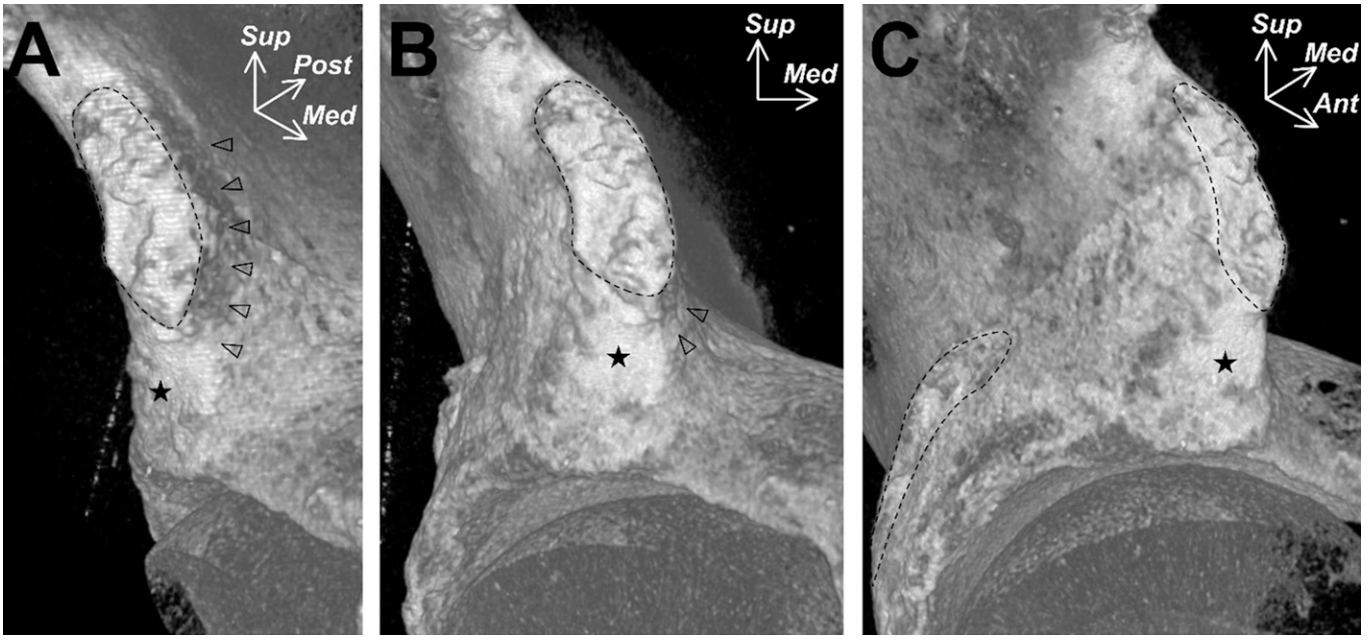

Fig. 1

Osseous configuration of the AIIS and acetabulum shown by micro-CT. The dashed lines indicate the rough impression at the superior portion of the AIIS and anterolateral wall of the ilium. The arrowheads indicate the shallow groove at the anteromedial surface of the AIIS. The star indicates the smooth impression at the inferior portion of the AIIS. Ant = anterior, Med = medial, Post = posterior, and Sup = superior. The anteromedial (**Fig. 1-A**), anterior (**Fig. 1-B**), and anterolateral (**Fig. 1-C**) aspects of the right hip are shown.

Macroscopic Analysis: Attachment of the Hip Joint Capsule and Its Superficial Muscles

For macroscopic analysis of 11 hips, the hip joint capsule and its superficial muscles were carefully removed and their attachment was observed. Initially, the iliopsoas, sartorius, tensor fasciae latae, and gluteus medius and minimus were removed to expose the rectus femoris. During removal of each muscle, the deep fascia was also observed. Second, the direct and reflected heads of the rectus femoris were removed to expose the hip joint capsule. Finally, the hip capsular attachment on the acetabulum was detached and the attachment width of the articular capsule was measured. Measurements were conducted by 2 independent observers. Interclass correlation coefficients (ICCs) for each value were calculated to evaluate measurement validity between the 2 observers for each group of measurements.

Histological Analysis of the Attachment of the Hip Joint Capsule

We performed histological examinations of the attachment of the hip joint capsule in the 4 randomly selected hips. The AIIS and acetabulum with the hip joint capsule and its superficial muscles were harvested as en bloc specimens using a diamond saw, perpendicular to the acetabular margin in 3 small regions: the middle position between the iliopubic ramus and the anteroinferior edge of the AIIS, the center of the AIIS, and the anterior edge of the

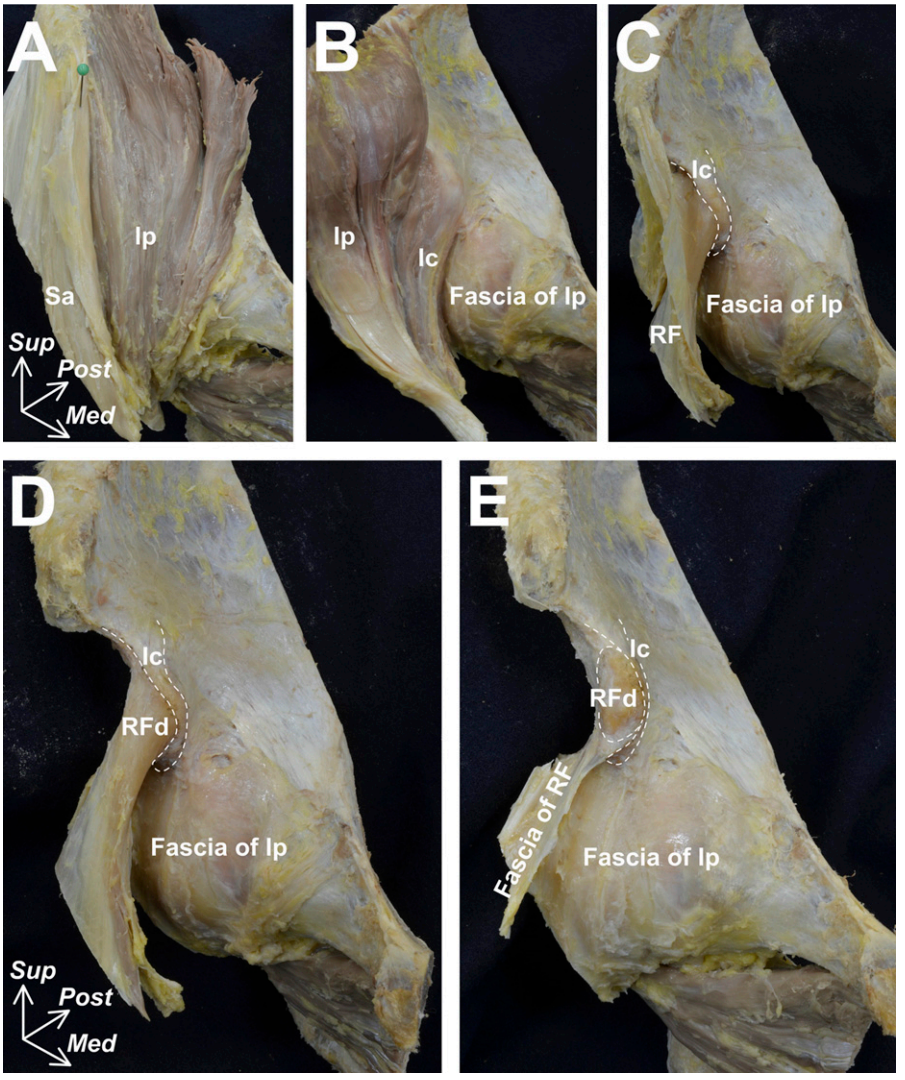

Fig. 2

Spatial geometry of the rectus femoris and its superficial structures on the anteromedial aspect of the AIIS. Ip = iliopsoas, Sa = sartorius, Ic = iliocapsularis, RF = rectus femoris, RFd = direct head of the rectus femoris, Med = medial, Post = posterior, and Sup = superior. **Fig. 2-A** Anteromedial aspect of the right Ip. **Fig. 2-B** The Ip was partly detached from the iliac fossa and reflected to the lateral side. **Fig. 2-C** The origin site of the Ic is indicated by the white dashed line. **Fig. 2-D** The RFd after removal of the fasciae of the Ip on the surface of the RFd. **Fig. 2-E** Positional relationship between the origin site of the RFd and that of the Ic (indicated by the white dashed line).

origin site of the reflected head of the rectus femoris. These regions were identified by 3-D conformations of the micro-CT images. The en bloc specimens were decalcified for 1 week with Plank-Rychlo solution ($AlCl_3$:$6H_2O$ [126.7 g/L], HCl [85.0 mL/L], and HCOOH [50.0 mL/L]) and were dehydrated[30]. After fixation, the specimens were embedded in paraffin solution. Subsequently, the blocks were serially sectioned (5-μm thickness) and were stained using the Masson trichrome staining protocol.

Statistical Analyses

Statistical tests were performed using JMP 14.0 software (SAS Institute). Statistical comparisons of the attachment widths of the hip joint capsule were performed using a 1-way analysis of variance (ANOVA) with the Bonferroni correction for multiple comparisons, and the significance level was set at $p < 0.00017$. ICCs were determined using a measurement process analysis. A score above 0.75 was considered to indicate excellent agreement. All ICCs were ≥0.86 (range, 0.86 to 0.97). Data were given as the mean and standard deviation.

Results

Osseous Configuration of the Acetabulum and AIIS

Facets of the AIIS were separated into 2 (superior and inferior) regions (Figs. 1-A, 1-B, and 1-C). The superior

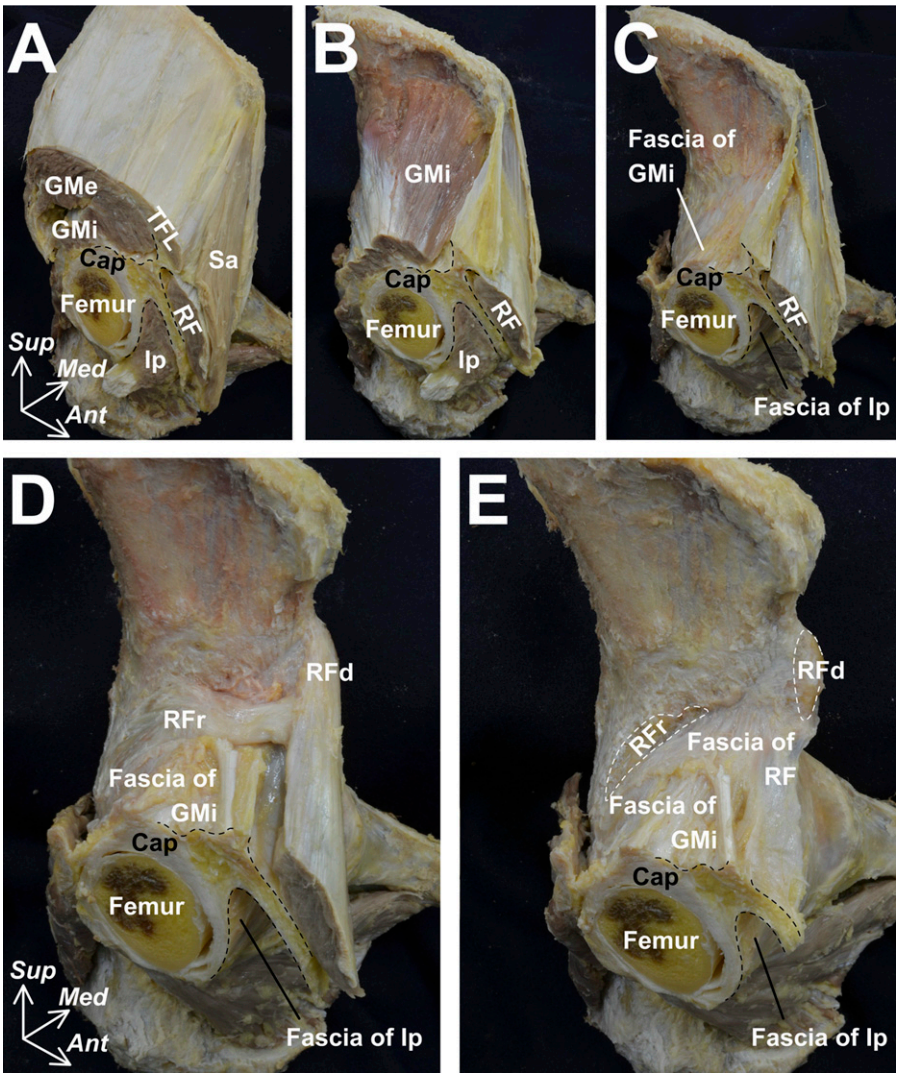

Fig. 3

Spatial geometry of the rectus femoris and its superficial structures on the anterolateral aspect of the AIIS. GMe = gluteus medius, GMi = gluteus minimus, TFL = tensor fasciae latae, Sa = sartorius, Cap = hip joint capsule, RF = rectus femoris, Ip = iliopsoas, RFd = direct head of the rectus femoris, RFr = reflected head of the rectus femoris, Ant = anterior, Med = medial, and Sup = superior. **Fig. 3-A** Anterolateral aspect of the right hip cross-section at the level of the femoral neck. **Fig. 3-B** Superficial muscles including the GMe, the TFL, and Sa were removed. **Fig. 3-C** The GMi and Ip were removed. The black dashed lines indicate deep fasciae of the GMi, Ip, and RF. **Fig. 3-D** The RFd and RFr after removal of the fascia of the GMi on the surface of the RFr. **Fig. 3-E** The origin sites of the RFd and RFr are indicated by the white dashed lines.

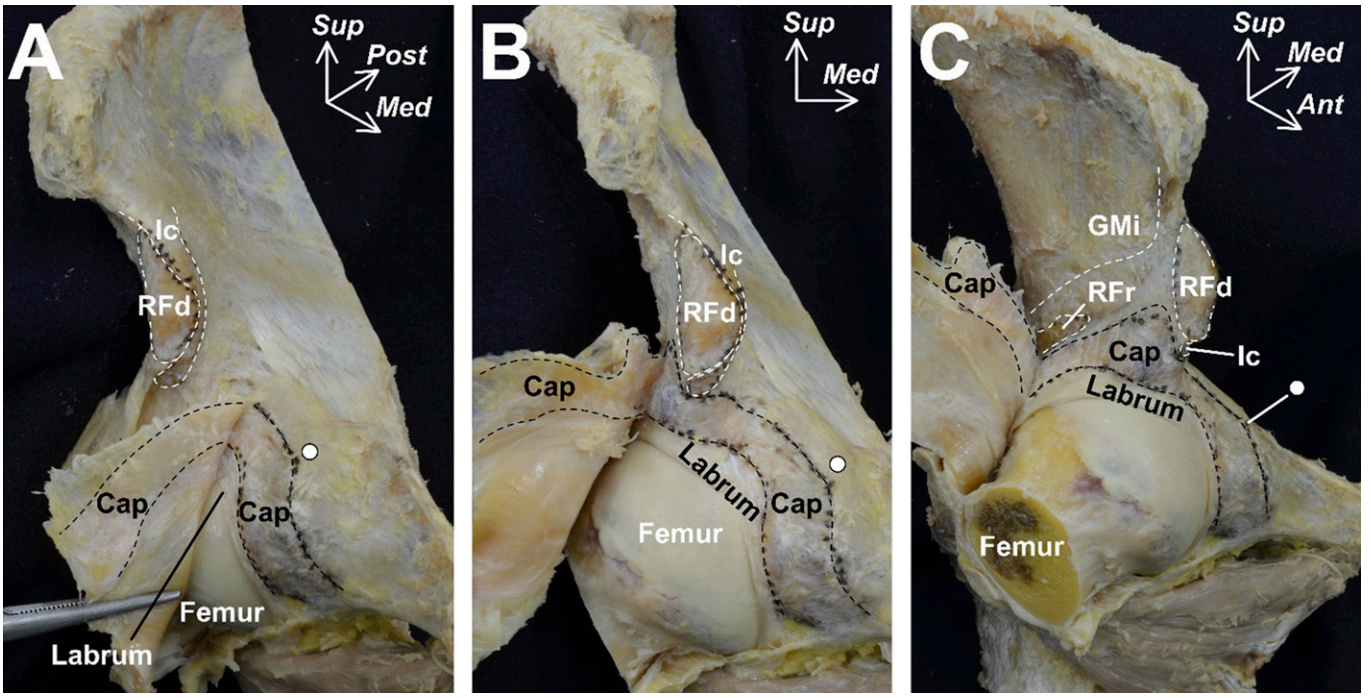

Fig. 4

Attachment of hip joint capsule on the anterosuperior aspect of the acetabulum. Ic = iliocapsularis, RFd = direct head of the rectus femoris, Cap = hip joint capsule, RFr = reflected head of the rectus femoris, GMi = gluteus minimus, Ant = anterior, Med = medial, Post = posterior, and Sup = superior. The black dashed lines indicate the osseous attachment of the hip joint capsule. The white dashed lines indicate the origin sites of the Ic, RFd, and RFr. The white circles indicate the iliopubic ramus. The right hip joint capsule was detached from the acetabulum in the following order: anteromedial (**Fig. 4-A**), anterior (**Fig. 4-B**), and anterolateral (**Fig. 4-C**) aspects of the hip joint.

AIIS region had a teardrop-shaped impression, and its anteromedial aspect was surrounded by a shallow groove. This groove extended to the inferior AIIS region. The inferior region of the AIIS had a distinct impression and extended anteromedially and anterolaterally to the acetabular margin.

Muscular Attachment Around the Hip Joint Capsule

The iliopsoas was observed from the anteromedial aspect of the hip (Fig. 2-A). After detachment of the iliopsoas from the iliac fossa, the surface of the iliocapsularis was revealed (Fig. 2-B). The iliocapsularis occupied the deepest portion of the iliopsoas and originated from the anteromedial surface of the AIIS. Removal of the muscular portion of the iliopsoas, including the iliocapsularis, allowed the deep fascia of the iliopsoas to be observed because it connected to the anteromedial surface of the hip joint capsule (Fig. 2-C). The deep fascia of the iliopsoas widely covered the anteromedial surface of the hip joint capsule and the deep and medial surfaces of the rectus femoris. In addition, the origin of the iliocapsularis corresponded with the shallow groove at the anteromedial surface of the AIIS, which was identified by micro-CT. Removal of the deep fascia of the iliopsoas on the medial surface of the rectus femoris allowed the origin of the direct head of the rectus femoris to be observed on the AIIS (Figs. 2-D and 2-E). Its origin corresponded with the teardrop-shaped impression at the superior aspect of the AIIS, which was also identified by micro-CT.

After removal of the gluteus medius, the gluteus minimus was observed on the anterolateral surface of the hip joint capsule (Figs. 3-A and 3-B). Removal of the muscular portion of the gluteus minimus revealed the surface of the deep fascia of the gluteus minimus because it covered and was connected to the distal part of the anterolateral surface of the hip joint capsule (Fig. 3-C). After removal of the proximal part of the deep fascia of the gluteus minimus, the origin of the reflected head of the rectus femoris was observed (Figs. 3-D and 3-E). The deep fascia of the proximal part of the rectus femoris covered and was connected to the proximal part of the anterolateral surface of the hip joint capsule.

Capsular Attachment on the Acetabulum and AIIS

The widths of the capsular attachments to the acetabulum varied according to their location. The hip joint capsule attached with a relatively narrow width between the iliopubic ramus and the anterior edge of the AIIS (Fig. 4-A). The width of the capsular attachments inferior to the AIIS gradually increased from anterior to posterior (Fig. 4-B). The footprint of the hip joint capsule inferior to the AIIS corresponded with the impression at the inferior part of the AIIS, as identified by micro-CT. Additionally, the width of the capsular attachments posterior to the AIIS gradually decreased toward the region

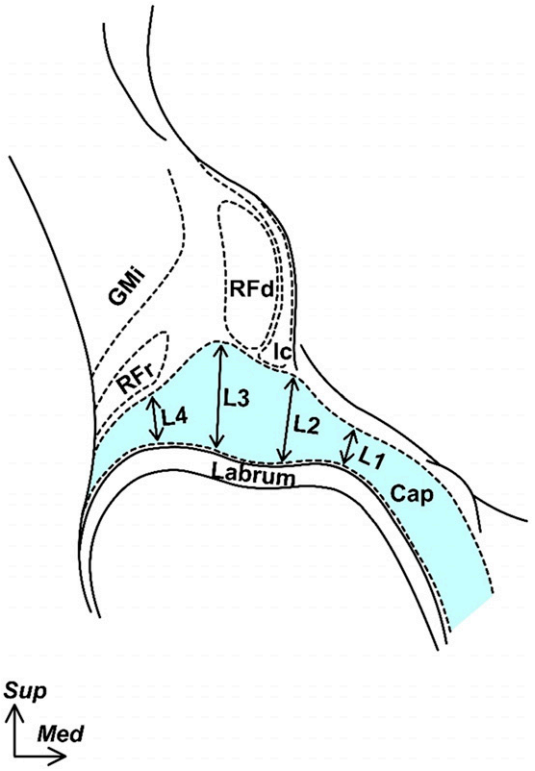

Fig. 5

Schematic diagram indicating the measurement of the attachment of the hip joint capsule on the anterior aspect of the hip. GMi = gluteus minimus, RFd = direct head of the rectus femoris, RFr = reflected head of the rectus femoris, Ic = iliocapsularis, Med = medial, and Sup = superior. The blue region indicates the osseous attachment of the right hip joint capsule (Cap). Attachment widths were measured at the middle position between the iliopubic ramus and the anteroinferior edge of the AIIS (L1), at the anteroinferior edge of the AIIS (L2), at the posteroinferior edge of the AIIS (L3), and at the anterior edge of the origin site of the RFr (L4).

inferior to the origin of the reflected head of the rectus femoris (Fig. 4-C).

The measurements of the widths of the capsular attachments are shown in Figure 5 and Table I. The widths of the capsular attachments at the anteroinferior and posteroinferior edges of the AIIS (L2 and L3, respectively, in Fig. 5 and Table I) were 12.9 ± 1.9 and 14.4 ± 1.8 mm, respectively. The attachment widths at the inferior edge of the AIIS were significantly larger than those at the middle position between the iliopubic ramus and the anteroinferior edge of the AIIS (L1 in Fig. 5) and the anterior edge of the origin of the reflected head of the rectus femoris (L4 in Fig. 5) ($p < 0.00017$ for L2 versus L1 and L4 and for L3 versus L1 and L4).

Histological Features of the Attachment of the Hip Joint Capsule

The hip joint capsule between the iliopubic ramus and the anterior edge of the AIIS was in close contact with the outer surface of the labrum and directly continued to the periosteum of the acetabulum (Figs. 6-A and 6-B). The hip joint capsule inferior to the AIIS was attached to the acetabulum through fibrocartilage (Figs. 6-A, 6-C, and 6-D). The hip joint capsule at the anterior edge of the origin site of the reflected head of the rectus femoris was also attached to the acetabulum through fibrocartilage (Figs. 6-A and 6-E). However, its synovial layer, which was composed of loose connective tissue, was attached to the distal part of the acetabulum proximal to the labrum and distal to the attachment of its fibrous layer. These histological features (Figs. 6-B through 6-E) were consistent among all 4 specimens.

Discussion

The present study revealed that a distinct impression inferior to the AIIS provided an attachment site for the hip joint capsule. The width of the attachment was significantly larger than that on the anterosuperior aspect of the acetabulum. In addition, histological analysis revealed that the hip joint capsule on the inferior edge of the AIIS attached to the acetabulum adjacent to the proximal margin of the labrum, and its capsular attachment was fibrocartilaginous. Therefore, these findings—i.e., that the inferior capsular attachment corresponded to the osseous impression and fibrocartilage—supported our hypothesis that the inferior attachment was important for hip joint stability.

Previous studies have focused on the osseous morphology of the inferior edge of the AIIS. Hetsroni et al. reported that the morphology of the AIIS in patients with hip impingement can be classified into 3 types based on the relationship between the distal extension of the AIIS and the acetabulum[31]. On the basis of this classification, Balazs et al. reported that osseous prominences on the inferior region of the AIIS or the extension of the inferior region of the AIIS to the acetabular margin were observed in the majority of cases without a history of hip pain or hip impingement[32]. In the present study, a distinct impression was identified at the inferior edge of the AIIS. According to Wolff's law, which indicates that mechanical stresses determine bone architecture[27], we postulate that the osseous morphology inferior to the AIIS might result from high mechanical stresses transmitted by the hip joint capsule attached to it.

TABLE I Widths of the Capsular Attachments

Location of the Measurements*	Width† *(mm)*
Middle position between iliopubic ramus and anteroinferior edge of AIIS (L1)	7.0 ± 1.6
Anteroinferior edge of AIIS (L2)	12.9 ± 1.9†
Posteroinferior edge of AIIS (L3)	14.4 ± 1.8†
Anterior edge of origin of reflected head of rectus femoris (L4)	8.8 ± 1.3

*The locations of the measurements are demonstrated in Figure 5. †The width is given as the mean and standard deviation. ‡P < 0.00017 as compared with L1 and L4.

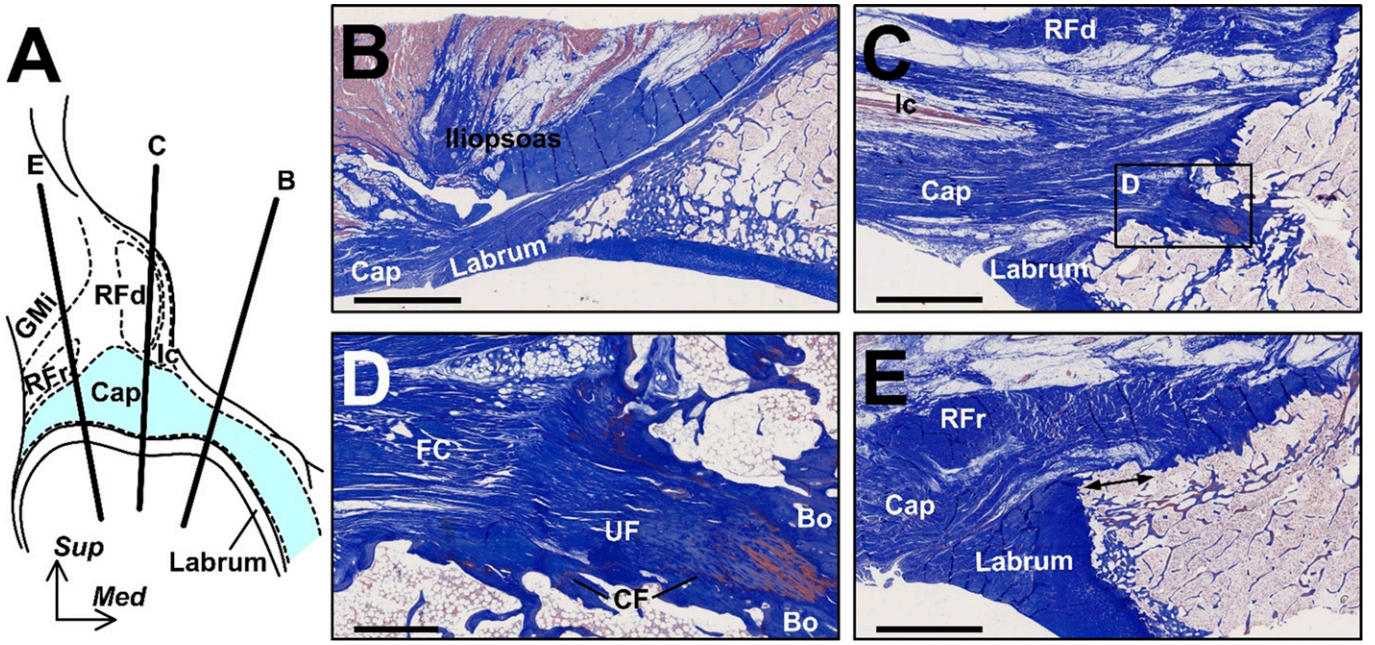

Fig. 6

Histological analysis of the hip capsular attachment (Masson trichrome stain). GMi = gluteus minimus, RFd = direct head of the rectus femoris, RFr = reflected head of the rectus femoris, Ic = iliocapsularis, Med = medial, and Sup = superior. **Fig. 6-A** Schematic diagram of the attachment site of the hip joint capsule (Cap) on the anterior aspect of the right hip. The blue region indicates the osseous attachment of the hip joint capsule. **Fig. 6-B** Cross-section along line B in Fig. 6-A. **Fig. 6-C** Cross-section along line C in Fig. 6-A. **Fig. 6-D** Magnified image of the boxed region in Fig. 6-C. Four zones of tissue are clearly distinguished: fibrous connective tissue (FC), uncalcified fibrocartilage (UF), calcified fibrocartilage (CF), and bone (Bo). **Fig. 6-E** Cross-section along line E in Fig. 6-A. Loose connective tissue attached to the distal part of the acetabulum is indicated by the double-headed arrow. Scale: Figs. 6-B, 6-C, and Fig. 6-E = 5 mm, and Fig. 6-D = 1 mm.

The inferior edge of the AIIS provides the attachment site of the anterosuperior aspect of the capsule. Cooper et al. measured the capsular attachment width at 8 locations on the acetabulum using the hemiquadrant system and reported the greatest width (8.8 mm) in the region posterior to the inferior edge of the AIIS[33]. Philippon et al. also reported that the capsular attachment was widest (10.9 mm) at the posteroinferior region of the AIIS, which corresponded with the arthroscopic anatomy at the 2 o'clock position[34]. In the present study, the widths of the capsular attachments on the posteroinferior and anteroinferior aspects of the AIIS were significantly wider than the attachment on the anterosuperior aspect of the acetabulum. The anterosuperior aspect of the hip joint capsule was covered with the deep fascia of the iliopsoas, rectus femoris, and gluteus minimus. These deep fasciae could be considered a reinforcing part of the hip joint capsule. Since we included the reinforcing part of the hip joint capsule in the analysis, we could precisely show the wide attachment of the hip joint capsule, which extended inferior to the AIIS. We recognize that some confusion may remain regarding terminology; that is, some authors have used "subspine" or "subspinal decompression" for the anatomical area. We propose that the distinct impression at the inferior region, where the anterosuperior aspect of the capsule attaches, be identified as the "subspine."

Some previous reports on the proximity between the attachment of the hip joint capsule and labrum indicated that the anterosuperior aspect of the hip joint capsule distantly attached proximal to the labrum[35,36]. The present study revealed that the proximity between the attachment of the hip joint capsule and labrum varied according to location, even on the anterosuperior aspect of the acetabulum. Furthermore, it was found that the hip joint capsule inferior to the AIIS was attached to the acetabulum without any distance from the proximal margin of the labrum.

Regarding the histological features of the capsular attachment, Wagner et al. previously described a fibrocartilaginous capsular attachment at the superior region of the acetabular margin[37]. According to Benjamin and Ralphs, there is a high correlation between the distribution of fibrocartilage within an enthesis and the levels of mechanical stress on it[28]. Some anatomical studies showed that, in other joints, histological features of the capsular attachment varied according to location and suggested that the fibrocartilage distributed in the region was highly subject to mechanical stress[38-40]. In the current study, the histological features of the capsular attachment inferior to the AIIS showed a fibrocartilaginous structure, in contrast to the hip joint capsule between the iliopubic ramus and the anteroinferior edge of the AIIS, which directly continued to the periosteum of the acetabulum. Therefore, we concluded that the fibrocartilaginous nature of the capsular attachment inferior to the AIIS should be correlated with the mechanical stresses loaded there.

Our findings highlight a few important clinical insights. It is generally accepted that the iliofemoral ligament has an important role in hip joint stability[25,26]. In this study, we determined that the capsular attachment inferior to the AIIS, which is the same as that of the origin of the iliofemoral ligament, was highly adaptive to mechanical stress. If hip surgeons place a suture anchor on the edge of the acetabulum, they have to partially detach the articular side of the hip capsule to expose the acetabular bone. At the inferior edge of the AIIS—namely, between the 1 and 2 o'clock positions, where labral tears are commonly seen in clinical situations—we observed no gap between the labrum and capsule. This anatomical finding might, to some extent, be related to an iliofemoral ligament injury during the exposure of the acetabulum rim. If surgeons extend the exposure of bone more proximally to perform AIIS decompression, the damage to the iliofemoral ligament can increase. Thus, when anticipating the outcomes of hip surgery such as labral repair or AIIS decompression, the surgeon must balance consideration of the results of the surgical procedures themselves with the possible loss of ligamentous stability caused by detachment of the proximal part of the capsule.

This study has some limitations. First, it was a purely anatomical investigation and was limited to uninjured specimens; therefore, we cannot prove the cause of hip instability after surgery and our explanations remain speculative. Second, our lack of radiographic evaluation meant that we could not exclude some osseous abnormalities, such as acetabular dysplasia. Third, the mean age of the study population was >80 years, which is considerably older than the general population of patients undergoing hip arthroscopy. Additionally, the anatomical measurements were not adjusted for the overall size of the donor or related anatomical structures. We also cannot exclude the possibility that the advanced age of the donors affected our findings, as previous reports suggested that the fibrocartilaginous composition changes with age[41,42]. Finally, we did not investigate the histological features of the capsular attachment on the whole acetabulum; thus, we could not conclude that the fibrocartilage was unique to the capsular attachment at the inferior edge of the AIIS. Additional biomechanical studies or studies with clinical case imaging are needed to validate our findings.

In conclusion, the capsular attachment on the inferior edge of the AIIS was characterized by an osseous impression, large attachment width, and distributed fibrocartilage. Anatomical knowledge of the capsular attachment on the inferior edge of the AIIS provides a better understanding of the pathological condition of hip joint instability. ■

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References

1. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. Clin Orthop Relat Res. 2003 Dec; 417:112-20.
2. Bedi A, Kelly BT. Femoroacetabular impingement. J Bone Joint Surg Am. 2013 Jan 2;95(1):82-92.
3. Griffin DR, Dickenson EJ, O'Donnell J, Agricola R, Awan T, Beck M, Clohisy JC, Dijkstra HP, Falvey E, Gimpel M, Hinman RS, Hölmich P, Kassarjian A, Martin HD, Martin R, Mather RC, Philippon MJ, Reiman MP, Takla A, Thorborg K, Walker S, Weir A, Bennell KL. The Warwick Agreement on femoroacetabular impingement syndrome (FAI syndrome): an international consensus statement. Br J Sports Med. 2016 Oct; 50(19):1169-76.
4. Griffin DR, Dickenson EJ, Wall PDH, Achana F, Donovan JL, Griffin J, Hobson R, Hutchinson CE, Jepson M, Parsons NR, Petrou S, Realpe A, Smith J, Foster NE; FASHIoN Study Group. Hip arthroscopy versus best conservative care for the treatment of femoroacetabular impingement syndrome (UK FASHIoN): a multicentre randomised controlled trial. Lancet. 2018 Jun 2;391(10136):2225-35. Epub 2018 Jun 1.
5. Pun S, Kumar D, Lane NE. Femoroacetabular impingement. Arthritis Rheumatol. 2015 Jan;67(1):17-27.
6. Harris JD, McCormick FM, Abrams GD, Gupta AK, Ellis TJ, Bach BR Jr, Bush-Joseph CA, Nho SJ. Complications and reoperations during and after hip arthroscopy: a systematic review of 92 studies and more than 6,000 patients. Arthroscopy. 2013 Mar;29(3):589-95.
7. Kowalczuk M, Bhandari M, Farrokhyar F, Wong I, Chahal M, Neely S, Gandhi R, Ayeni OR. Complications following hip arthroscopy: a systematic review and meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2013 Jul;21(7):1669-75. Epub 2012 Sep 2.
8. Benali Y, Katthagen BD. Hip subluxation as a complication of arthroscopic debridement. Arthroscopy. 2009 Apr;25(4):405-7.
9. Matsuda DK. Acute iatrogenic dislocation following hip impingement arthroscopic surgery. Arthroscopy. 2009 Apr;25(4):400-4. Epub 2009 Feb 1.
10. Ranawat AS, McClincy M, Sekiya JK. Anterior dislocation of the hip after arthroscopy in a patient with capsular laxity of the hip. A case report. J Bone Joint Surg Am. 2009 Jan;91(1):192-7.
11. Mei-Dan O, McConkey MO, Brick M. Catastrophic failure of hip arthroscopy due to iatrogenic instability: can partial division of the ligamentum teres and iliofemoral ligament cause subluxation? Arthroscopy. 2012 Mar;28(3):440-5. Epub 2012 Feb 1.
12. Sansone M, Ahldén M, Jónasson P, Swärd L, Eriksson T, Karlsson J. Total dislocation of the hip joint after arthroscopy and ileopsoas tenotomy. Knee Surg Sports Traumatol Arthrosc. 2013 Feb;21(2):420-3. Epub 2012 Nov 22.
13. Austin DC, Horneff JG 3rd, Kelly JD 4th. Anterior hip dislocation 5 months after hip arthroscopy. Arthroscopy. 2014 Oct;30(10):1380-2. Epub 2014 Jun 17.
14. Dierckman BD, Guanche CA. Anterior hip capsuloligamentous reconstruction for recurrent instability after hip arthroscopy. Am J Orthop (Belle Mead NJ). 2014 Dec; 43(12):E319-23.

15. Rosenbaum A, Roberts T, Flaherty M, Phillips N, Patel N, Das P. Posterior dislocation of the hip following arthroscopy - a case report and discussion. Bull Hosp Jt Dis (2013). 2014;72(2):181-4.

16. Wylie JD, Beckmann JT, Aoki SK. Dislocation after hip arthroscopy for cam-type femoroacetabular impingement leading to progressive arthritis: a case report. JBJS Case Connect. 2015 Sep 23;5(3):e80-7.

17. Yeung M, Memon M, Simunovic N, Belzile E, Philippon MJ, Ayeni OR. Gross instability after hip arthroscopy: an analysis of case reports evaluating surgical and patient factors. Arthroscopy. 2016 Jun;32(6):1196-1204.e1. Epub 2016 Mar 21.

18. Ramos N, Dold A, Youm T. Postoperative considerations following hip arthroscopy. JBJS Rev. 2017 Jul;5(7):e3.

19. Ortiz-Declet V, Mu B, Chen AW, Litrenta J, Perets I, Yuen LC, Domb BG. Should the capsule be repaired or plicated after hip arthroscopy for labral tears associated with femoroacetabular impingement or instability? A systematic review. Arthroscopy. 2018 Jan;34(1):303-18. Epub 2017 Aug 31.

20. Fry R, Domb B. Labral base refixation in the hip: rationale and technique for an anatomic approach to labral repair. Arthroscopy. 2010 Sep;26(9)(Suppl):S81-9. Epub 2010 Jul 7.

21. Krych AJ, Thompson M, Knutson Z, Scoon J, Coleman SH. Arthroscopic labral repair versus selective labral debridement in female patients with femoroacetabular impingement: a prospective randomized study. Arthroscopy. 2013 Jan;29(1):46-53.

22. Hapa O, Bedi A, Gursan O, Akar MS, Güvencer M, Havitçioğlu H, Larson CM. Anatomic footprint of the direct head of the rectus femoris origin: cadaveric study and clinical series of hips after arthroscopic anterior inferior iliac spine/subspine decompression. Arthroscopy. 2013 Dec;29(12):1932-40. Epub 2013 Oct 18.

23. Michal F, Amar E, Atzmon R, Sharfman Z, Haviv B, Eisenberg G, Rath E. Subspinal impingement: clinical outcomes of arthroscopic decompression with one year minimum follow up. Knee Surg Sports Traumatol Arthrosc. 2018 Apr 2. Epub 2018 Apr 2.

24. Slikker W 3rd, Van Thiel GS, Chahal J, Nho SJ. The use of double-loaded suture anchors for labral repair and capsular repair during hip arthroscopy. Arthrosc Tech. 2012 Nov 2;1(2):e213-7.

25. Phillips AM, Konchwalla A. The pathologic features and mechanism of traumatic dislocation of the hip. Clin Orthop Relat Res. 2000 Aug;377:7-10.

26. Myers CA, Register BC, Lertwanich P, Ejnisman L, Pennington WW, Giphart JE, LaPrade RF, Philippon MJ. Role of the acetabular labrum and the iliofemoral ligament in hip stability: an in vitro biplane fluoroscopy study. Am J Sports Med. 2011 Jul; 39(Suppl):85S-91S.

27. Wolff J. Das gesetz der transformation der knochen. Berlin: Hirschwald; 1892.

28. Benjamin M, Ralphs JR. Fibrocartilage in tendons and ligaments—an adaptation to compressive load. J Anat. 1998 Nov;193(Pt 4):481-94.

29. Benjamin M, McGonagle D. The anatomical basis for disease localisation in seronegative spondyloarthropathy at entheses and related sites. J Anat. 2001 Nov; 199(Pt 5):503-26.

30. Plank J, Rychlo A. [A method for quick decalcification]. Zentralbl Allg Pathol. 1952 Dec 10;89(8):252-4. German.

31. Hetsroni I, Poultsides L, Bedi A, Larson CM, Kelly BT. Anterior inferior iliac spine morphology correlates with hip range of motion: a classification system and dynamic model. Clin Orthop Relat Res. 2013 Aug;471(8):2497-503.

32. Balazs GC, Williams BC, Knaus CM, Brooks DI, Dickens JF, McCabe MP, Anderson TD. Morphological distribution of the anterior inferior iliac spine in patients with and without hip impingement: reliability, validity, and relationship to the intraoperative assessment. Am J Sports Med. 2017 Apr;45(5):1117-23. Epub 2017 Jan 6.

33. Cooper HJ, Walters BL, Rodriguez JA. Anatomy of the hip capsule and pericapsular structures: A cadaveric study. Clin Anat. 2015 Jul;28(5):665-71. Epub 2015 Apr 14.

34. Philippon MJ, Michalski MP, Campbell KJ, Goldsmith MT, Devitt BM, Wijdicks CA, LaPrade RF. An anatomical study of the acetabulum with clinical applications to hip arthroscopy. J Bone Joint Surg Am. 2014 Oct 15;96(20):1673-82.

35. Seldes RM, Tan V, Hunt J, Katz M, Winiarsky R, Fitzgerald RH Jr. Anatomy, histologic features, and vascularity of the adult acetabular labrum. Clin Orthop Relat Res. 2001 Jan;382:232-40.

36. Field RE, Rajakulendran K. The labro-acetabular complex. J Bone Joint Surg Am. 2011 May;93(Suppl 2):22-7.

37. Wagner FV, Negrão JR, Campos J, Ward SR, Haghighi P, Trudell DJ, Resnick D. Capsular ligaments of the hip: anatomic, histologic, and positional study in cadaveric specimens with MR arthrography. Radiology. 2012 Apr;263(1):189-98. Epub 2012 Feb 27.

38. Nimura A, Fujishiro H, Wakabayashi Y, Imatani J, Sugaya H, Akita K. Joint capsule attachment to the extensor carpi radialis brevis origin: an anatomical study with possible implications regarding the etiology of lateral epicondylitis. J Hand Surg Am. 2014 Feb;39(2):219-25.

39. Nasu H, Nimura A, Sugiura S, Fujishiro H, Koga H, Akita K. An anatomic study on the attachment of the joint capsule to the tibia in the lateral side of the knee. Surg Radiol Anat. 2018 May;40(5):499-506. Epub 2017 Nov 10.

40. Sato T, Nimura A, Yamaguchi R, Fujita K, Okawa A, Akita K. Intramuscular tendon of the adductor pollicis and underlying capsule of the metacarpophalangeal joint: an anatomical study with possible implications for the Stener lesion. J Hand Surg Am. 2018 Jul;43(7):682.e1-8. Epub 2018 Feb 1.

41. Ralphs JR, Benjamin M. The joint capsule: structure, composition, ageing and disease. J Anat. 1994 Jun;184(Pt 3):503-9.

42. Benjamin M, Ralphs JR. Biology of fibrocartilage cells. Int Rev Cytol. 2004;233:1-45.