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Morphological Study on the Acetabular Labrum

Ye-Yeon Won[1], In-Hyuk Chung[2], Nam-Su Chung[1], and Kyung-Hun Song[1]

[1]*Department of Orthopedic Surgery, Ajou University College of Medicine, Suwon, Korea;*
[2]*Department of Anatomy, Yonsei University College of Medicine, Seoul, Korea.*

For the diagnosis and treatment of the labral pathology, the cross sectional morphology of the labrum is needed. Fifty-four labra (male:female=44:10) from 32 adult Korean cadavers were cut in radial and perpendicular fashions to their longitudinal axis. Each labrum was divided into 8 segments, resulting 8 equally distanced points. To analyze the 432 cut surfaces, which consisted of 378 labra and 54 transverse acetabular ligaments cut surfaces, all dimensions of the cut surfaces were measured, and the attachment patterns, including the sublabral slit, observed. The shapes of the cut surfaces were classified into four types (3 subtypes of triangle and 1 quadrangle) and the attachment patterns into five types. At the anterior portion of the labrum, which other studies reported as the predilection area for labral tears, there were several common findings: 1) Tall triangular shapes were dominant (61.1%) or relatively common type (25.9%). 2) The average heights of the labrum were longer (7.4 and 7.0 mm) than at the other sites (4.0 - 6.8 mm). 3) The attachment types with no extra-extended portion (68.5%) and sublabral slits (39.0%) were most commonly observed. It was concluded that there were different types of cut surface and attachment patterns of the acetabular labrum, and these findings had a tendency to be distributed with some labral tears. These anatomical data are believed could be useful in the management of an acetabular labral pathology.

Key Words: Acetabular labrum, morphology of cut surface, labral tear

INTRODUCTION

The acetabular labrum is a fibrocartilaginous rim attached to the margin of the acetabulum, thereby deepening its cavity.[1] The cut surface of the labrum is described as triangular in anatomy textbook.[1] Tears and detachments of the labrum have been recognized as a causes of hip pain and clicking. Much has been written about the shoulder labrum and its variations, but studies describing the morphology of the acetabular labrum in asymptomatic or symptomatic subjects are scarce.[2-7] Several studies have focused on correlating the MR appearance with age, sex and the labral pathology.[2,8-11] In those MR studies,[2,3,5,8,10,12] matched with or without cadaveric dissection or operative findings, the appearance of the labrum was described in a manner used in conventional MR imaging protocols. The acetabular labra have, therefore, been imaged with a constant direction, resulting in serial coronal and axial MR images. However, when performing a labrum related diagnosis or operation, the acetabular pathology can be recognized more easily if the surgeon's concept of the labral morphology is standardized in a radial fashion, rather than in coronal or axial fashions. The purposes of the present study were to describe the variability in the shape, size and attachment patterns of the acetabular labrum, and to find any morphological characteristics in terms of labral tears.

MATERIALS AND METHODS

Fifty four acetabula (male : female=44:10), from 32 Korean adult cadavers, without having had any hip joint related disorders, were studied. The mean age of the subjects was 53 years old, ranging from 18 to 83 years. The acetabula, which were denuded of all soft tissue attachment, except the labrum, were isolated using a surgical saw (3M Maxi-Driver Electric™, 3M Health Care, Irvine,

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Reprint address: requests to Dr. Ye-Yeon Won, Department of Orthopaedic Surgery, Ajou University School of Medicine, San 5, Wonchon-dong, Paldal-gu, Suwon 442-721, Korea. Tel: 82-31-219-5223, 5220, Fax: 82-31-219-5229, E-mail: thrtkr@ajou.ac.kr

CA, USA). The acetabula were sectioned into 8 segments, resulting in 8 corresponding evenly distanced points (Fig. 1a-1c), using the following steps.

(1) A line from the anterior superior iliac spine, to the center of the acetabulum, and another perpendicular to the first, were drawn at the center of the acetabulum. With these 2 lines the acetabulum was divided into 4 quadrants.

(2) An additional 2 lines, bisecting the aforementioned quadrants, were drawn through the center of the acetabulum, dividing the acetabulum into 8 segments (Fig. 1c).

(3) Following these 4 lines, the acetabulum was cut into 8 evenly distanced segments using a high speed dental cutter attached with a disc tip. At the peripheral margin of these 8 segments, 8 evenly distanced points were obtained on the labrum.

(4) To localize and describe a labral morphology, the numbers 1 to 8 were given to the above 8 points, starting from the anterior horn of the lunate surface, in a counter-clock wise direction.

On each cut, the labrum was cut exactly perpendicular to its longitudinal axis. After washing with pressurized tap water, the cut labrum surfaces were observed under a surgical microscope (Zeiss®, Oberkochen, Germany), and all dimensions of the cut surfaces measured with Digital Calipers (Mitutoyo®, Tokyo, Japan).

From these data, the shape of the cut surface and patterns of the labral attachments to the articular cartilage and bone were classified. When classifying the shape of the cut surfaces, only the portion of the labrum above the acetabular bony rim was taken into consideration. The extended attachment of a labral tissue beyond the apex of the bony rim only was considered in classifying the patterns of the labral attachment. Four cutting surface shapes, types A, B, C and D, were found, as shown in Fig. 2. Types A, B and C were triangular, but types B and C were taller than type A, with the tips leaning toward the center of the acetabulum. The attachment patterns of the acetabular labra were classified into 5 types, depending on the characteristics of their attachment to the articular cartilage and bony rim (Fig. 7). Types I, II and III were triangular in shape, but type I had no extended portion beyond the bony rim, whereas types II and III did. Type IV was quadrangular in shape and attached inside of the bony rim. Type V labra were actually belonged to the transverse acetabular ligament, so there was no attachment to bone or articular cartilage.

In addition, the sublabral slits, which were observed between the articular cartilage and acetabular labrum, were measured and analyzed. To describe the location of these slits, the 8 segments corresponding to the numbers of 8 points were numbered counter-clockwise, starting from the point closest to the anterior horn of the lunate surface.

RESULTS

(1) The shapes of the cut surfaces (Fig. 2, 3 and 4, and Table 1)

The most frequent type over the whole labrum area was A (68.8%), with types B, C and D occupying 17.7, 6.6 and 6.9%, respectively. Type B was the most dominant (61.1%) at point 1, closest to the anterior horn of lunate surface, and second most dominant (25.9%) at point 2. However, at the other points (points 3 - 7), type A was observed more frequently (64.8 - 83.3%), and type B the least (1.9 - 14.8%). At point 7, closest to the posterior horn of the lunate surface, type D occupied 27.8%, although type A was still most dominant

Table 1. Table Showing the Occupied Ratio (%) of the Labral Shape Distributed Along the Eight Points

Type \ Point	1	2	3	4	5	6	7	8
A	35.2	59.3	75.9	83.3	79.6	83.3	64.8	24.1
B	61.1	25.9	14.8	3.7	13	3.7	1.9	68.5
C	1.9	11.1	3.7	11.1	5.6	7.4	5.6	0
D	1.9	3.7	5.6	1.9	1.9	5.6	27.8	7.4

Table 2. Table Showing the Occupied Ratio (%) of the Labral Attachment Patterns Distributed Along the Eight Points

Type \ Point	1	2	3	4	5	6	7	8
I	24.1	68.5	55.6	64.8	42.6	38.9	46.3	16.7
II	13	13	18.5	29.6	48.1	42.6	16.7	3.7
III	1.9	14.8	20.4	3.7	5.6	11.1	3.7	1.9
IV	1.9	3.7	5.6	1.9	3.7	7.4	31.5	7.4
V	59.3	0	0	0	0	0	1.9	70.4

(64.8%) at this point. At the other points, type D occupied 1.9 - 7.4%.

(2) The height of the labrum (Fig. 5 and 6)

The averages of inner heights at points 1 and 2, 7.4 and 7.0 mm, respectively, were relatively longer than those at the other points (4.0-6.8 mm), which was statistically significant, especially at the posteroinferior portions (independent samples t-test, $p < 0.05$).

(3) The pattern of the acetabular attachment (Fig. 7, 8 and 9, and Table 2)

Type I was most dominant (48.4%) over the whole labrum area, excluding the area of the transverse acetabular ligament. Types II, III and IV occupied 25.9, 8.7 and 7.9%, respectively. At point 2 (the anterior portion of the labrum), type I was most dominant (68.5%). The rate of this type decreased passing from points 2 to 7 (Fig. 8 and 9). At point 5, type II was most dominant (48.1%), although type I still occupied a significant area (42.6%). At point 7, type IV occupied 31.5%, although type I was still the most common (46.3%). There was a tendency for the distribution of the attachment patterns associated with a labral tear, which was statistically significant (chi-squared test, $p < 0.05$) (Fig. 9).

(4) The sublabral slit (Fig. 10 and 11)

The depth of the sublabral slits were found to vary. Of the 54 cadavers, 33 (61.1%) revealed sublabral slits in at least one segment, with mostly two or three slit segments observed per labrum. From the anterior to posterior segments, the numbers of observed slit were 14, 16, 8, 11, 10, 17 and 1, with the anterior portion of labrum (segments 1 and 2) occupying 39% (30/77) of the total slits observed. Because of the transverse acetabular ligament on the inferior portion of the acetabulum, the slits were observed only in 7 segments.

DISCUSSION

There have been many recent reports of acetabular capsular-labral lesions based on the operative and arthroscopic findings, cadaveric studies and MR images.[2,3,5,8,10,12] Leunig, et al.[7] assessed the value of MR arthrography of the hip, and reported 3 false negative findings, including two patients with erroneous MR arthrographies that suggested an intact labrum. Keene, et al.,[5] in their *in vivo* study with hip arthroscopy, reported that the arthroscopic anatomy was considerably enlarged and more extensive than described in the classical anatomy texts. Many authors have reported the usefulness of MR images, with or

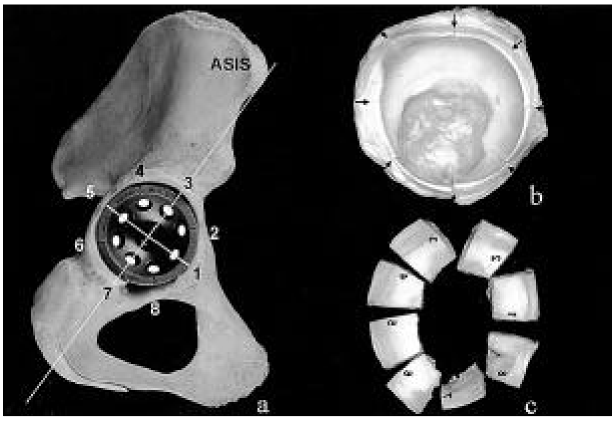

Fig. 1. Figures showing the method used to section the acetabulum into 8 segments to obtain 8 corresponding evenly distanced points.

without contrast media, but all these reports were made using conventional imaging techniques. However, the acetabular labrum has not been imaged using a technique where the labrum was sectioned perpendicularly to its longitudinal axis. Petersilege[13] and Petersilege, et al.[14] pointed out potential pitfalls in the interpretation of MR

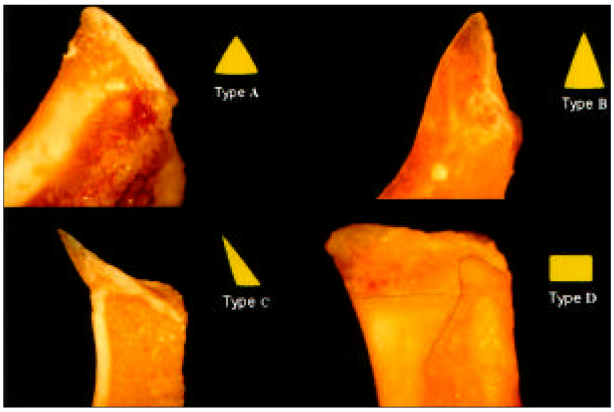

Fig. 2. Schematic drawings, and the corresponding photographs, showing the four shapes of the cut surfaces of the acetabular labrum. Type A: Grossly compatible to a regular triangle, but the height of the triangle is shorter than twice the base of the triangle. Type B: Grossly compatible to an isosceles triangle, but the height of the triangle is longer than twice the base of the triangle. Type C: Grossly compatible to a scalene triangle, with different border lengths. The extension line from the articular surface passes the labrum because of the leaning appearance toward the center of the acetabulum. Type D: Grossly compatible to a quadrangle, with the major portion located beneath and inside of the bony rim. In addition, this type is smaller than other types.

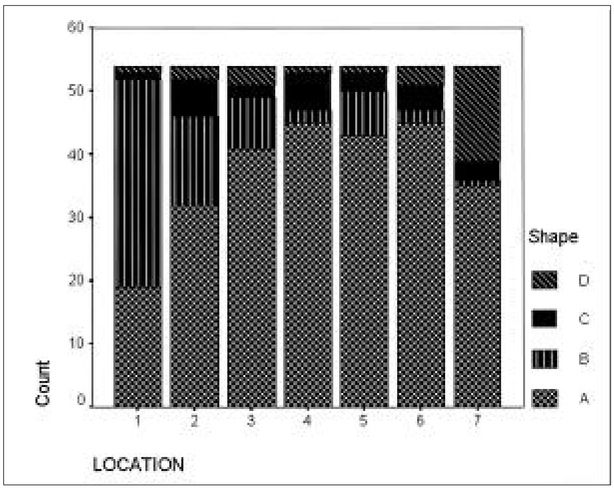

Fig. 3. Graph showing stacked ratio of the four shapes.

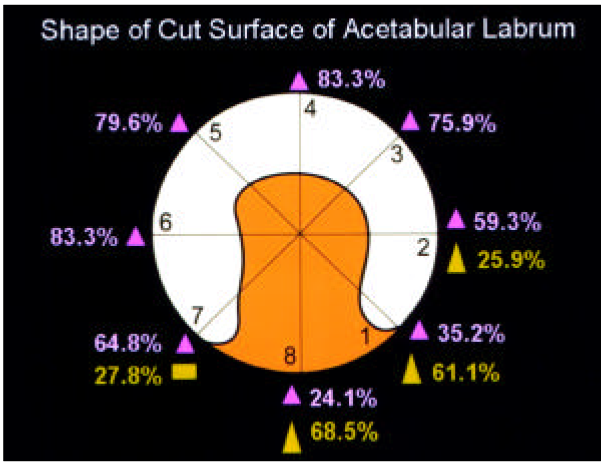

Fig. 4. Drawing showing the changes in the distributions of the four labral shapes.

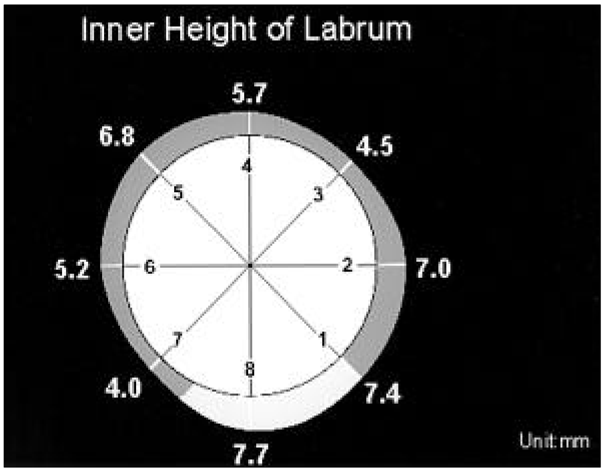

Fig. 5. Drawing showing the distribution of the average labra inner height.

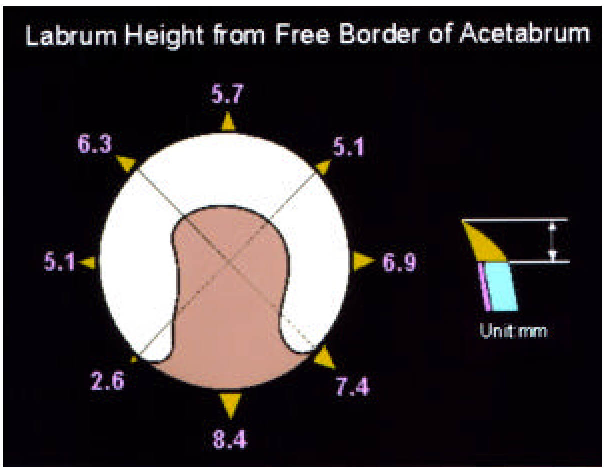

Fig. 6. Drawing showing the distribution of the average outer labra height.

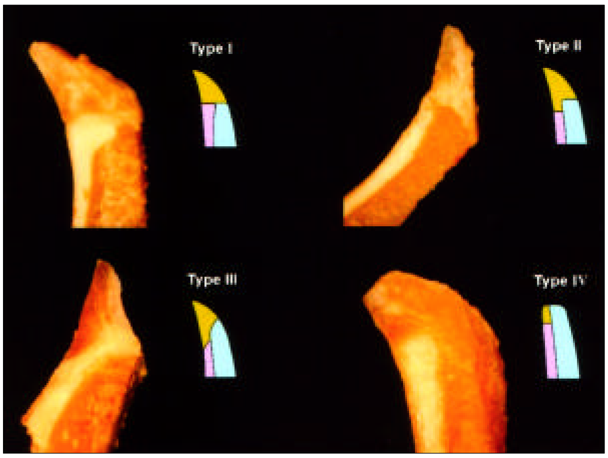

Fig. 7. Schematic drawings, and their corresponding photographs, showing the four patterns of a labral attachment. Type I: The entire portion of the labrum is triangular in shape and located above the bony rim. There is no extended portion beyond the bony rim. Type II: The main portion of the labrum is triangular in shape and located above the bony rim. A small portion of the labrum extended into the inner side only of the bony rim. Type III: The main portion of the labrum is triangular in shape and located above the bone. A small portion of the labrum extended, not only into the inner side, but also into the outer side of the bony rim. Type IV: The entire labrum, which was grossly quadrangular in shape, is located inside of the acetabular bony rim. This type of attachment belongs to the type D shape in the cut surface classification. Type V: The triangular portions actually belong to the transverse acetabular ligament, so there was no attachment to bone or articular cartilage.

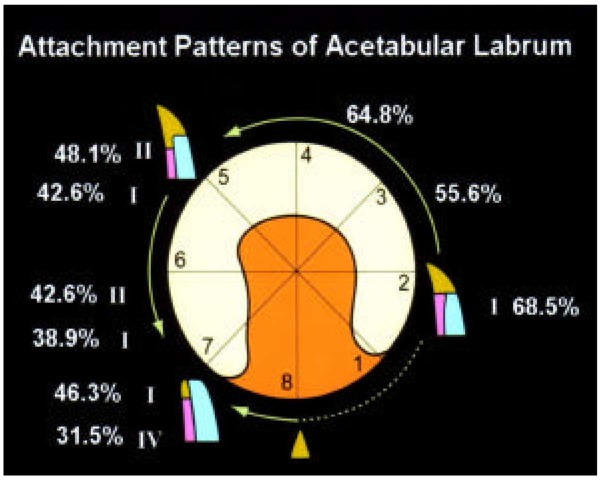

Fig. 9. Drawings showing the changes in the distribution of the labral attachment patterns. Type I, which had no extended portion for the attachment, was observed more commonly in the anterior areas of the labrum. However, as it passes by to the posterior areas of the labrum, the relative occupied rate decreased, with the other types, which have more extended portion of the attachment, observed more frequently.

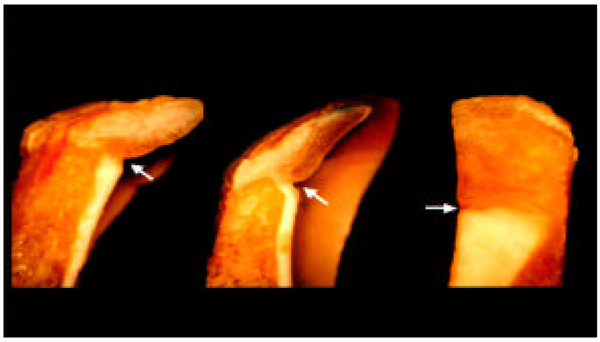

Fig. 10. Photographs showing the sublabral slits.

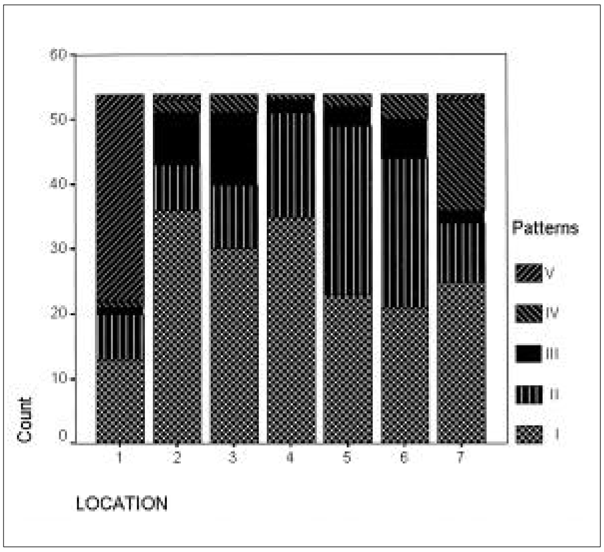

Fig. 8. Graph showing the stacked pattern ratios of the labral attachment.

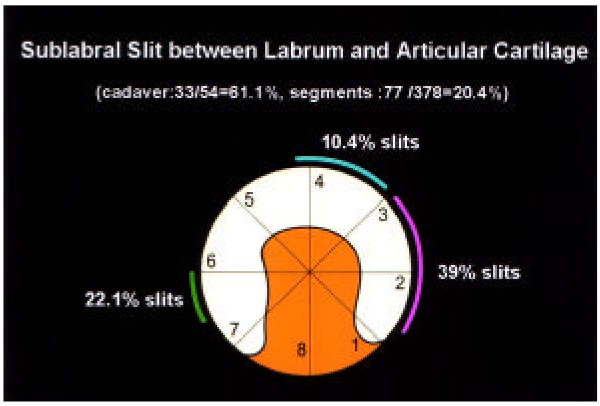

Fig. 11. Drawing showing the distribution of the sublabral slits.

arthrograms of the hip were likely to result from the limited experience of both the radiologists and orthopaedic surgeons evaluating the intraarticular structures of the hip. Recently, a new imaging technique, specifically developed to see the perpendicular sectional images of the labrum, has been developed, but to our knowledge there have been no anatomical studies using similar sectioning to this new imaging technique. The labrum was cut in a radial fashion, perpendicular to its longitudinal axis, so our data will be referenced to understand the labral pathology as a standardized 3-dimensional concept.

The cut surface of the labrum is described as triangular in most anatomy textbooks. However, the study of Lecouvet, et al.[6] used the coronal MR images in 200 asymptomatic subjects, and the labral shapes were found to be triangular (66%), round (11%), flat (9%) or absent (14%), depending on the individuals and sites, but had previously reported a rate upto 28% for the absence of a normal labrum.[15] They concluded that the large variability of the MR appearance of the labrum in asymptomatic hips must be considered when interpreting the MR examinations of patients where labral lesions are suspected. Petersilege[13] and Petersilege, et al.[14] reported potential pitfalls in the interpretation of MR arthrograms of the hip that can derive from morphologic abnormalities. Recently, Czerny, et al.[3] reported no instances of absent labra, and explained why thickened labra often have a round appearance as they merge with the joint capsule, especially on conventional MR images, as used in Lecouvet's study. In our series, using cadaver labra, type A was most common (68.8%), and types B, C and D occupied 17.7, 6.6 and 6.9%, respectively. Theoretically, the triangular shape imaged were types A, B and C, and the sum of these triangular varieties was 93.1% in our series. The measured inner height of the labra ranged from 1.0 - 33.6 mm (mean 5.9 mm). Nineteen (5%) out of a total 378 cut surfaces measured less than 3 mm in their inner height in our series. Thin tissue could not be recognized on the MR image, with these thin portions of the labrum being imaged as round, flat and absent in shape, due to artifacts of MR imaging (partial volume artifact). Additionally, the type D labrum it is thought could be imaged as the absence of a labrum due to the MR artifacts derived from the signal changes of the labrum with the surrounding hyaline cartilage and bony rim. Therefore, the absence of a labrum in their series[6,15] would correspond to the type D, and other types with very thin heights, in ours. Lastly, the fact that the labra were not imaged in a perpendicular manner would be another cause for the differences in the labral shape in previous studies. Considering these possibility for imaging conversion, the portion of triangular shapes in Lecouvet's series would be increased up to 86%, as the round and flat shape would be included. In addition, the frequency of the triangular shapes decreased significantly, and absence of a labrum increased significantly with age in Lecouvet's report. Round and flat labra were found in 11 and 9% of subjects, respectively, with no significant age correlation in their series. Therefore, these changes in the frequency with age could be considered when comparing the frequency of the shapes with other reports.

With regard to the frequent labral tear sites, there have been some confusing reports. Ikeda, et al.[16] reported seven young athletes in whom tears were detected arthroscopically. Among these seven tears, six were located posterosuperiorly. Suzuki, et al.[17] also reported labral tears (all posterosuperior) in five of nine hips with hip pain. Ueo, et al.[18] reported two cases of posterior labral tears proved by arthroscopy. However, Fitzerald[4] recently reported his surgical experience in the diagnosis of 56 hips in 55 patients with acetabular labral tears. Among these hips, 49 (85%) did not respond to conservative treatment, so underwent surgery. Anterior labral tears were present in 92% of these 49 patients, with posterior labral tears in 8%. However, these authors did not comment on the possible causes for the predilection area of the tears in terms of the labral morphology. The type B shape is suggested to be taller than other shape types (A, C and D), so will be exposed more easily to tears, but the type D shape, which is located inside of the bony rim, will not. There was statistical significance (chi- squared test, $p < 0.001$) in the distribution of types A and type B between the anterior and posterior portions of the labrum, points 1 and 2 and points 5, 6 and 7, respectively. There was also statistical significance (chi-squared test, $p < 0.001$) in the distributions of types A, B, C and D between the anterior and posterior portions of the labrum. These distribution characteristics correlated with the tear sites reported by Fitzeralds.[4]

The type I attachment pattern was most common (48.4%) over the whole area of the labrum, excluding the area of the transverse acetabular ligament. Types II, III, IV and V occupied 25.9, 8.7, 7.9 and 9%, respectively. A tendency was found in the distribution of the attachment patterns in terms of labral tears, which was statistically significant (chi-squared test, $p < 0.05$). Type I, which had no extended portion of the attachment, occupied a relatively large portion in the anterior areas of labrum. However, passing to the posterior areas of the labrum, the relative occupied portion of type I decreased, with the other types, which have more extended portions of attachment, observed more frequently. A labral attachment pattern, which are structurally weak due to additional attachment extensions, such as type I, was observed more commonly at the anterior portion. Contrary to this, the labral attachment patterns, which are structurally strong due to additional attachment extensions, were observed more commonly at the posterior portion. For example, the portion of type II increased from 13.0 - 29.6% at the anterior portion to 48.1 - 42.6% at the posterior portion (points 5 and 6). At point 7, the portion of type IV, located inside of the bony rim, resulting in protection against tears, increased to 31.5%. These distribution characteristics also have some correlation with the tear sites reported by Fitzeralds.[4]

The sublabral slit in our study has been a confusing structure, due to the different description in many papers using MR images.[3,10,12-14] Our definition for a "sublabral slit" was 'a fissure or groove like structure located underneath the acetabular labrum between the fibrocartilage and hyaline cartilage'. When this structure was everted, it appeared more evident. In our opinion, a sublabral structure is a kind of normal structure instead of a pathological one. Marianacci, et al.[12] reported that a normal sublabral sulcus can be confused with a tear, although the criteria they used to differentiate the sulcus from a tear are unknown. Hodler, et al.,[10] in their study on MR arthrography for a acetabular labrum, with histological correlation in cadavers, reported the histological features of the labral base. According to their report, the MR signal alterations correlated with cartilage degeneration concentrated at the labral base, the partial detachment of the labrum from the underlying bone and the presence of small fissures at the transitional zone between the fibrocartilage of the labrum and subchondral bone. They also indicated that MR arthrography of the hip significantly improved the detection of surface abnormalities, particularly those near the base. Similar degenerative changes, and slits at the transitional zone from labrum to cartilage, were also observed in our series. It is thought that the sublabral slit in our study would be a normal structure, or degenerative fissure, compatible to the histological findings of the labral base mentioned in Hodler's study.[10] Petersilege, et al.[13,14] reported potential pitfalls in the interpretation of MR arthrograms of the hip are likely to result from the difficulty in differentiating a subchondral sulcus from the appearance of a tear at the labral base. Recently, Czerny, et al.[3] also reported that the presence of a sublabral sulcus as a potential pitfall in the diagnosis labral tears. However, they stressed that the presence of such a sulcus has not been documented in arthroscopic studies, and was not found in any of their patients or cadaveric hip joint specimens. Therefore, they believe that any intralabral collection of contrast material should not be mistaken for a normal sublabral sulcus, but should rather be suspected as a tear or detachment. Keene, et al.[6] reported another potential pitfall with MR arthrography in their arthroscopic study of 100 hips, which described a groove separating the acetabular labrum from acetabular articular cartilage in the region of the acetabular fossa, but Czern,y et al.[3] did not observe this groove in any of their patients, but suggested if one was seen it should not be confused with a labral tear, as its location is different from that of a labral tear. Keene, et al.,[5] in their in vivo study with hip arthroscopy, reported that the labrum was separated from the hyaline cartilage by a distinctive groove at the margins of the acetabular fossa. In our series, which was conducted on subjects with normal hips, slits were observed in 17.8% of the 378 labrum segments, distributed over the whole labrum area. Although there was no statistical significance, the slits were observed more commonly in the anterior portion of the labrum (Fig. 11). The depth of the slits was found to vary. It is thought that the slits in our series would be similar to the groove or a sublabral sulcus structures reported in other studies, but that they should be differentiated from the intralabral sulcus described in Czerny's report.[3] According to Leunig, et al,[7] the most common site for a tear was at the junction of the labrum and the articular cartilage, although most of their patients had associated hip dysplasia. It is suggest that the junction of the labrum and the articular cartilage could be a structurally weak, predilection area, for the initialization of a labral tear. Nishii, et al.[11] evaluated the effects of continuous leg traction on the contrast enhanced MR imaging of the hip joint in terms of detecting its usefulness in demonstrating acetabular labral tears. This technique can be helpful in differentiating the slits from tears, as the slits, which are a kind of normal structure, almost always have firm attachment to the bony rim.

It would be possible to inspect the gross findings suggestive of intralabral degeneration that would be compatible to the intralabral signal intensity changes reported in the studies using MR images. However, in this study, specimens older than 65 years rated as 20.4% (11/54) of total acetabula, were not analyzed it in detail. Therefore, our data do not cover the deformation or distortion of the acetabular labrum.

In conclusion, different types of cut surface and attachment patterns of the acetabular labrum were found distributed along the acetabular rim, showing some tendency for labral tears. These anatomical data are believed could be useful in the management of torn acetabular labra, acetabular fractures and in hip osteoarthritis.

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