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# What Is the Influence of Femoral Version on Size, Tear Location, and Tear Pattern of the Acetabular Labrum in Patients With FAI?

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## Abstract

*Background* Femoral version deformities have recently been identified as a major contributor to femoroacetabular impingement (FAI). An in-depth understanding of the specific labral damage patterns caused by femoral version deformities may help to understand the underlying pathomorphologies in symptomatic patients and select the appropriate surgical treatment.

*Questions/purposes* We asked: (1) Is there a correlation between femoral version and the mean cross-sectional area of the acetabular labrum? (2) Is there a difference in the location of lesions of the acetabular labrum between hips with increased femoral version and hips with decreased femoral version? (3) Is there a difference in the pattern of lesions of the acetabular labrum between hips with increased femoral version and hips with decreased femoral version?

*Methods* This was a retrospective, comparative study. Between November 2009 and September 2016, we evaluated 640 hips with FAI. We considered patients with complete diagnostic imaging including magnetic resonance arthrography (MRA) of the affected hip with radial slices of the proximal femur and axial imaging of the distal femoral condyles (allowing for calculation of femoral version) as eligible. Based on that, 97% (620 of 640 hips) were eligible; a further 77% (491 of 640 hips) were excluded because they had either normal femoral version (384 hips), incomplete imaging (20 hips), a lateral center-edge angle < 22° (43 hips) or > 39° (16 hips), age > 50 years (8 hips), or a history of pediatric hip disease (20 hips), leaving 20% (129 of 640 hips) of patients with a mean age of 27 ± 9 years for analysis, and 61% (79 of 129 hips) were female. Patients were assigned to either the increased (> 30°) or decreased (< 5°) femoral version group. The labral cross-sectional area was measured on radial MR images in all patients. The location-dependent labral cross-sectional area, presence of labral tears, and labral tear patterns were assessed using the acetabular clockface system and compared among groups.

*Results* In hips with increased femoral version, the labrum was normal in size (21 ± 6 mm$^2$ [95% confidence interval 20

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to 23 mm$^2$]), whereas hips with decreased femoral version showed labral hypotrophy (14 ± 4 mm$^2$ [95% CI 13 to 15 mm$^2$]; p < 0.01). In hips with increased femoral version, labral tears were located more anteriorly (median 1:30 versus 12:00; p < 0.01). Hips with increased femoral version exhibited damage of the anterior labrum with more intrasubstance tears anterosuperiorly (17% [222 of 1322] versus 9% [93 of 1084]; p < 0.01) and partial tears anteroinferiorly (22% [36 of 165] versus 6% [8 of 126]; p < 0.01). Hips with decreased femoral version showed superior labral damage consisting primarily of partial labral tears.

*Conclusion* In the evaluation of patients with FAI, the term "labral tear" is not accurate enough to describe labral pathology. Based on high-quality radial MR images, surgeons should always evaluate the combination of labral tear location and labral tear pattern, because these may provide insight into associated femoral version abnormalities, which can inform appropriate surgical treatment. Future studies should examine symptomatic patients with normal femoral version, as well as an asymptomatic control group, to describe the effect of femoral version on labral morphology across the entire spectrum of pathomorphologies.

*Level of Evidence* Level III, prognostic study.

## Introduction

Abnormal femoral version is a known cause of hip pain and has been proposed as a contributing factor to the development of hip osteoarthritis [15, 36, 37]. Until recently, investigations of femoroacetabular impingement (FAI) have tended to focus on the morphology of the acetabulum and proximal femur, with classically described cam and pincer deformities. More recently, femoral version has been introduced as an additional factor in FAI [5, 39]. Published reference values for normal femoral version vary widely depending on the measurement method used. However, abnormal femoral version is present in half of symptomatic patients with FAI, as well as in three of four patients with radiographically "unremarkable" hip pain [21]. Decreased femoral version, or relative femoral retroversion, can aggravate a concomitant cam-type morphology, leading to an intra-articular mechanical conflict [15]. Increased femoral version presents with increased internal and reduced external rotation and is a reported cause of posterior intra-articular or extra-articular FAI [2, 22, 32]. It is also associated with hip instability via anterior levering out of the femoral head [39].

Specific hip pathomorphologies can be associated with typical intra-articular damage patterns. Although cam-type FAI leads to chondrolabral separation and the so-called outside-in lesion [1, 17], pincer impingement can result in labral hypotrophy and ossification [25, 35]. Mucoid degeneration, labral hypertrophy, and the inside-out lesion have been reported in hip dysplasia [14, 16, 23, 27, 35]. However, there are few data on the association between abnormal femoral version and potential lesions of the acetabular labrum in symptomatic individuals.

We therefore asked the following: In a selected group of patients with hip pain presenting to our outpatient clinic, (1) is there a correlation between femoral version and the mean cross-sectional area of the acetabular labrum? (2) Is there a difference in the location of lesions of the acetabular labrum between hips with increased femoral version and hips with decreased femoral version? (3) Is there a difference in the pattern of lesions of the acetabular labrum between hips with increased femoral version and hips with decreased femoral version?

## Patients and Methods

### *Study Design and Settings*

This was a single-center, retrospective, comparative study at the Department of Orthopaedic Surgery, Inselspital Bern, University of Bern, Bern, Switzerland. We performed a retrospective radiographic review of all patients who presented to our outpatient clinic with hip pain between November 2009 and September 2016.

### *Participants*

We included all patients who underwent complete diagnostic imaging of the symptomatic hip including magnetic resonance arthrography (MRA) with acquisition of radial slices and axial imaging of the distal femoral condyles, allowing us to calculate femoral version according to the method of Murphy et al. [24]. Other causes of hip pain that were not associated with FAI were excluded during diagnostic imaging in all patients. A total of 620 hips were available for further analysis based on these inclusion criteria. We subsequently excluded all hips with femoral version between 5° and 30° (384 hips), patients with a history of pediatric hip disease (20 hips), and all hips with incomplete imaging (20 hips). In addition, 59 hips with radiographic evidence of acetabular undercoverage (defined as a lateral center-edge angle < 22°) or overcoverage (defined as a lateral center-edge angle > 39°) were also excluded. To minimize the influence of degenerative hip disease, all patients 50 years or older (8 hips) were also excluded. The remaining 129 hips (117 patients) were then assigned to either the decreased femoral version group (< 5°, 58 hips) or increased femoral version group (> 30°, 71 hips) (Fig. 1).

### *Demographics*

The study groups showed no age differences, but there were more female patients in the increased femoral version group.

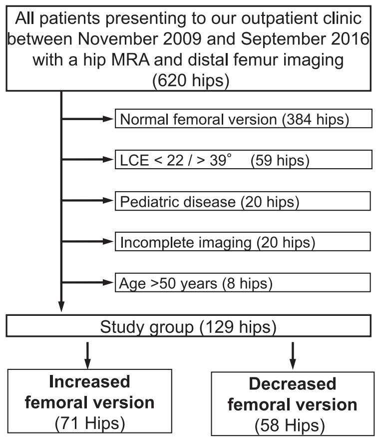


**Fig. 1** This study flowchart shows the inclusion and exclusion criteria for this study.

Consequently, we observed that patients in this study group had lower mean weight, height, and BMI than patients in the decreased version group (Table 1). However, there was no effect of sex on the mean labral cross-sectional area in a univariate regression analysis, and there was no correlation between height or weight and labral cross-sectional area. There were more hips who underwent subsequent surgery in the increased version group than in the decreased version group (56% [40 of 71] versus 33% [19 of 58]; p = 0.01). Surgical hip dislocation was the most common procedure in the increased femoral version group (73% [29 of 40] of operated-on hips), and hip arthroscopy was the most common procedure in the decreased femoral version group (53% [10 of 19] of operated-on hips). More than half (55% [16 of 29]) of the hips undergoing surgical hip dislocation for increased femoral version underwent a concomitant subtrochanteric derotation osteotomy.

*Radiographic Evaluation*

All patients underwent standardized AP pelvis and axial cross-table radiographs of the symptomatic hip according to a described acquisition technique [34]. Acetabular and femoral morphology was assessed using Hip2Norm [33, 38]. In addition to slightly higher mean central acetabular version in the increased femoral version group, no differences in acetabular morphology were observed between study groups (Table 2). The increased femoral version group had higher femoral version (p < 0.01) and a higher caput-collum-diaphyseal angle (p < 0.01) than the decreased femoral version group. There were no differences in the mean alpha angle between the study groups. We performed additional stratification for cam morphology in both subgroups and for all hips and found no differences in the total cross-sectional area of the labrum depending on the presence or absence of concomitant cam morphology. In addition, a univariate analysis showed no correlation between central acetabular version and the mean labral cross-sectional area (p = 0.40).

*MRA*

All included hips underwent direct MRA with a small field of view of the affected hip. MRAs were performed on a 3T-scanner (Siemens) using a six-channel flexible body matrix phased-array coil according to a published protocol [29]. According to our institutional protocol, the following sequences were routinely acquired: axial, coronal, sagittal, and radial sequences along the femoral neck axis, as well as axial T1 images of the hip and fast morphologic T2-w turbo-spin echo sequences of the femoral condyles. Typically, 12 radial slices parallel to the femoral head-neck axis were obtained in a 2D proton density-weighted turbo-spin echo sequence without fat saturation.

*Measurement of Femoral Version*

Femoral version was measured according to Murphy et al. [24]. Decreased femoral version was defined as femoral version < 5°, and increased femoral version was defined as femoral version > 30°. Our institution uses 10º to 25º according to Murphy et al.'s method [24], as published by Lerch et al. [20], for the normal range of femoral version in our daily clinical practice, although reported normal values for femoral version vary [6, 8, 9, 37]. For this study, we added 5° to this range to account for potential intraobserver

**Table 1.** Demographics

| Parameter | Increased femoral version (n = 71) | Decreased femoral version (n = 58) | p value |
|---|---|---|---|
| Age in years | 25 ± 8 | 29 ± 10 | 0.08 |
| Sex, female | 83 (59) | 34 (20) | < 0.01 |
| Weight in kg | 64 ± 12 | 77 ± 12 | < 0.01 |
| Height in m | 1.70 ± 0.08 | 1.74 ± 0.07 | < 0.01 |
| BMI in kg/$m^2$ | 22 ± 3 | 26 ± 3 | < 0.01 |

Data presented as mean ± SD or % (n).

**Table 2.** Radiographic morphology

| Parameter | Increased femoral version (n = 71) | Decreased femoral version (n = 58) | p value |
|---|---|---|---|
| Acetabular morphology | | | |
| LCE angle in ° | 29 ± 5 | 31 ± 4 | 0.95 |
| Acetabular index in ° | 3 ± 5 | 4 ± 5 | 0.21 |
| Extrusion index, % | 21 ± 5 | 20 ± 5 | 0.12 |
| Crossover sign, positive | 65 (46) | 78 (45) | 0.07 |
| Retroversion index, % | 13 ± 15 | 13 ± 12 | 0.61 |
| Central acetabular version in ° | 20 ± 5 | 17 ± 7 | < 0.01 |
| Femoral morphology | | | |
| Alpha angle in ° | 50 ± 10 | 56 ± 11 | 0.09 |
| CCD angle in ° | 136 ± 8 | 130 ± 6 | < 0.01 |
| Femoral torsion in ° | 40 ± 8 | 0 ± 4 | < 0.01 |

Data presented as mean ± SD or % (n); CCD = caput-collum-diaphyseal.

and interobserver variability and to ensure that our cohort fell reasonably outside of published normal values for this measurement method. Fifty-five percent (71 of 129 hips) had increased femoral version and 45% (58 of 129 hips) had decreased femoral version.

### *Measurement of the Circumferential Labral Cross-sectional Area*

To assess labral size, we measured the circumferential cross-sectional area of the labrum in $mm^2$ in all hips on all radial MR images according to a method described by Toft et al. [35]. Acetabular morphology is described on radial MRA slices using the acetabular clockface system, where the 12:00 position is superior, 3:00 anterior, 6:00 inferior, and 9:00 posterior (Fig. 2). Because each radial slice images the entire acetabulum, two directly opposite clock positions can be assessed per image. With 12 radial slices routinely acquired, 24 different clockface positions per hip were available for assessment. The acetabular notch, which is located inferiorly between 5:00 and 6:30 (Fig. 2), does not contain the labrum. Therefore, 20 possible clock positions per hip are usually available to measure labral size. We furthermore subdivided the labrum into four quadrants: anterosuperior (12:30 to 3:00), anteroinferior (3:30 to 6:00), posteroinferior (6:30 to 9:00), and posterosuperior (9:30 to 12:00).

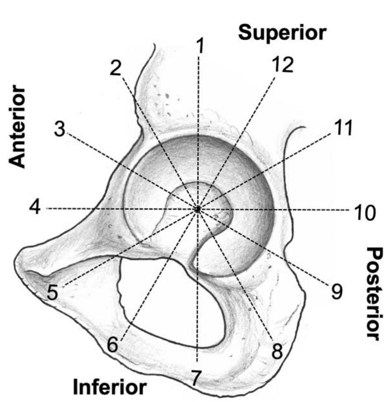


**Fig. 2** This is a depiction of the acetabular clock system for the spatial description of acetabular lesions on radial MRA slices.

Using our institutional picture archiving and communication system (GE Healthcare), we measured the circumferential labral cross-sectional area in $mm^2$ for all hips in all 20 positions on radial MR images using the software's area measurement tool (Fig. 3). Two observers (IAST and MV) independently measured the mean labral cross-sectional area in 30 randomly chosen hips covering the full spectrum of labral sizes for intraobserver and interobserver variability and reproducibility. Using the intraclass correlation coefficient (ICC), we found an interrater ICC of 0.90 (95% confidence interval 0.79 to 0.95) and an intrarater ICC of 0.87 (95% CI 0.80 to 0.95).

To address the first study question, we compared the mean labral cross-sectional area between the two study groups overall and for each acetabular clockface position and quadrant independently.

### *Assessment of Labral Tear Location*

The presence of labral damage was assessed on each radial MRI slice where the labrum was visible with respect to the acetabular clockface system and labral sections mentioned above. For this evaluation, a distinction was made only between an intact (normal) labrum and any labral lesion (such as a labral tear). Ninety-seven percent [69 of 71] of the hips in the increased femoral version group and 93% [54 of 58] of the hips in the decreased femoral version group (p = 0.28) had labral tears. To answer the second study question, we compared the location-dependent frequency of labral tears between the

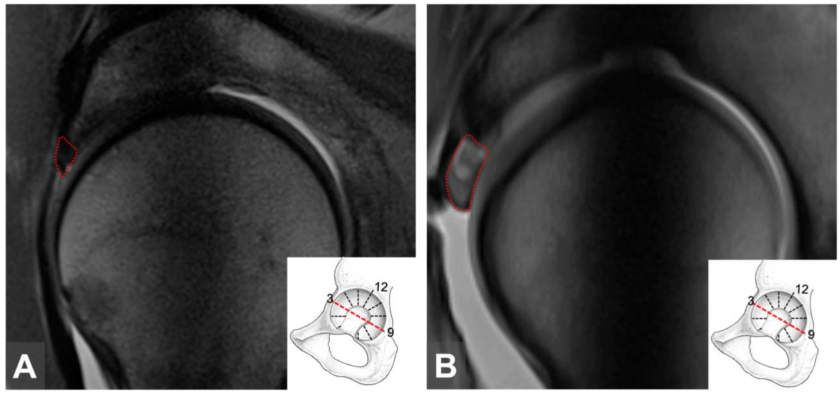


**Fig. 3** These images show measurement of the circumferential labral cross-sectional area in $mm^2$ (red dotted line) on radial MR images. (**A**) This image shows a 21-year-old female patient with femoral version of -2° and a circumferential labral cross-sectional area of 4 $mm^2$ in the 3:00 position. (**B**) This 18-year-old female patient has femoral version of 54° and a circumferential labral cross-sectional area of 38 $mm^2$ in the 3:00 position.

study groups overall and by frequency per acetabular clockface position.

### *Assessment of Labral Tear Pattern*

After identifying all radial MR images with labral pathology as described above, we subdivided all labral lesions according to their specific tear pattern using the MRA-based definition described by Schmaranzer et al. [29]. A partial tear is defined as a hyperintense signal extending between the labral base and acetabular rim. A full tear is complete interposition of a hyperintense signal between the labral base and acetabular rim. An intrasubstance tear is a focal, hyperintense signal extending into the labral surface [29]. In addition, labral hypotrophy was used to describe a nearly absent labrum [35] (Fig. 4). We calculated the overall frequency of the different labral lesions and the location-dependent frequency of lesions with respect to the acetabular clockface. To further characterize labral tear patterns, we compared the frequency between each of the four quadrants described above.

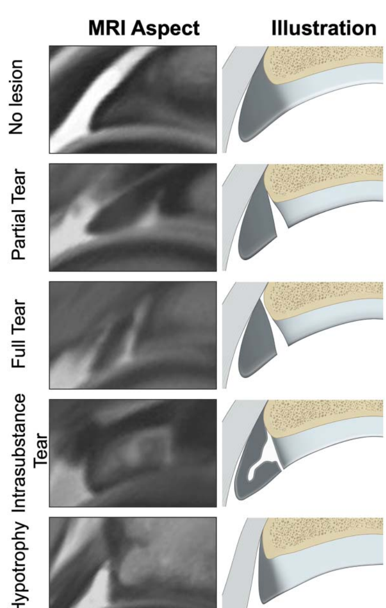


**Fig. 4** Labral tear patterns, corresponding MRI morphologic aspects, and associated illustrations are shown here.

### *Ethical Approval*

The local ethics committee approved the study protocol before initiation of the investigation (project ID 2018-00078).

### *Statistical Analysis*

Normal distribution testing was performed using a Kolmogorov-Smirnov test. For continuous, normally distributed data, an independent-samples t-test was used to compare the mean labral cross-sectional area between study groups at the different clock positions. For non-normally distributed data and categorical variables, a Mann-Whitney test was applied. We used the chi-square test to analyze differences in the distribution of tear patterns.

We performed an a priori power analysis using the two-tailed difference between two independent groups with a level of significance of 5% and a beta error of 5%, an assumed cross-sectional area of 19 $mm^2$ (15 $mm^2$) for the increased femoral version (decreased femoral version) group, and a reported standard deviation of 6 $mm^2$ [35]. This revealed a total of 120 hips (60 per group). The statistical analysis was performed with the statistical software add-in WinStat® for Microsoft Excel® (Version 2012.1.0.96, STATCON GmbH). Power analysis was performed using the open-source software G* power (Version 3.1.9.6, Heinrich Heine Universität).

## Results

### *Correlation Between Femoral Version and the Mean Labral Cross-sectional Area*

In hips with increased femoral version, the labrum was normal in size, whereas hips with decreased femoral version showed labral hypotrophy (Fig. 5).

The mean overall circumferential labral cross-sectional area was 21 ± 6 $mm^2$ (95% CI 20 to 23 $mm^2$) in hips with increased femoral version and 14 ± 4 $mm^2$ (95% CI 13 to 15 $mm^2$) in hips with decreased femoral version ($p < 0.01$) (Fig. 6). A normal labral cross-sectional area, according to Toft et al. [35], is 25.2 ± 6.2 $mm^2$. A smaller labral cross-sectional area in hips with decreased femoral version was found in all parts of the labrum, using the subgroup analysis (all $p < 0.01$) (Table 3).

### *Comparison of Labral Tear Location*

Overall, labral tears were located more anteriorly in hips with increased femoral version than in hips with decreased femoral version (median labral tear location at 1:30 versus 12:00; $p < 0.01$). In addition, we noted a higher incidence of labral tears in the anterior region in the increased femoral version group than in the decreased femoral version group (between 2:30 and 4:00; all $p < 0.05$) (Fig. 7). Otherwise, the frequency of labral tears was similar throughout the circumference of the acetabulum in both groups.

### *Comparison of Labral Tear Pattern*

Hips with increased femoral version showed an anterior labral damage pattern composed of intrasubstance tears anterosuperiorly and partial tears anteroinferiorly. Hips with decreased femoral version showed a superior labral damage pattern consisting primarily of partial labral tears (Fig. 8).

Hips with increased femoral version showed more intrasubstance tears, both overall (17% [222 of 1322] versus 9% [93 of 1084]; $p < 0.01$) and in the anterosuperior quadrant (31% [132 of 426] versus 13% [45 of 348]; $p < 0.01$) than hips with decreased femoral version. In addition, there was a higher frequency of partial tears in the

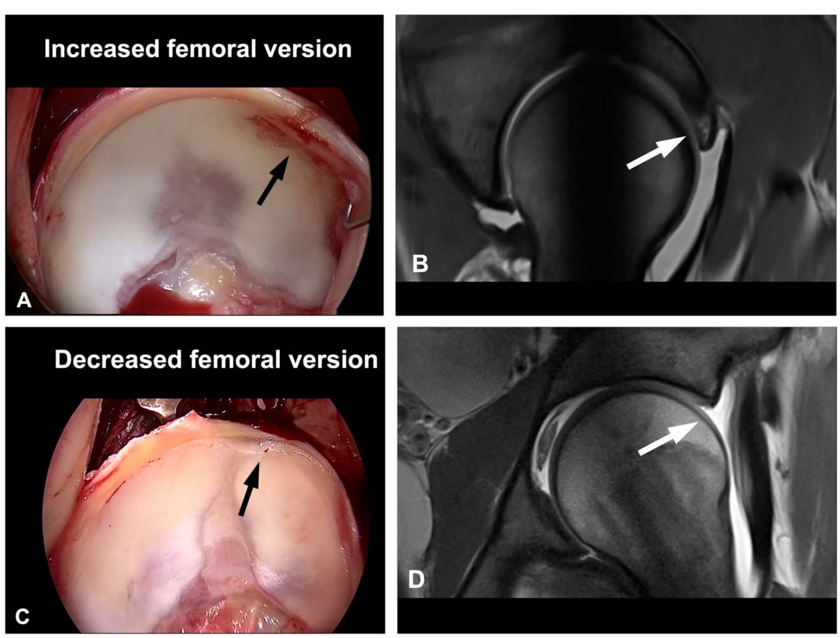


**Fig. 5** (**A**) This intraoperative en face view of the acetabulum and (**B**) corresponding radial MR image of a hip with increased femoral version show a hypertrophic labrum with an intrasubstance tear anteriorly (2:00 to 3:00). (**C**) A corresponding intraoperative and (**D**) radial MR image of a hip with decreased femoral version shows a hypotrophic, almost absent acetabular labrum anteriorly (black arrows).

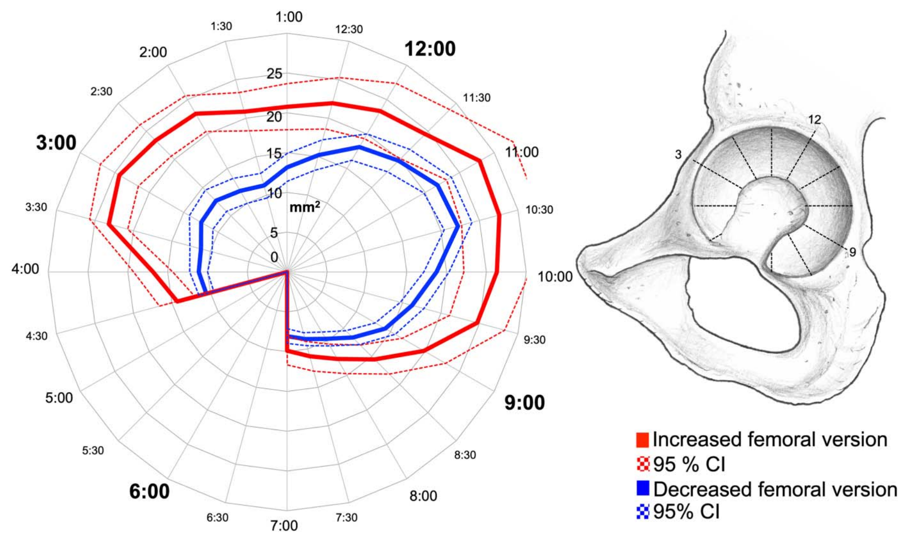


**Fig. 6** This spider diagram compares the labral size by the mean cross-sectional area (in mm$^2$) at each clock position between the increased femoral version group (red) and the decreased femoral version group (blue), including the respective 95% CIs (dotted lines). Differences (all p < 0.05) between groups were found in all clock positions except for the 7:00 position.



anteroinferior quadrant in these hips than in hips with decreased femoral version (22% [36 of 165] versus 6% [8 of 126]; p < 0.01) (Table 4).

In hips with decreased femoral version, the most frequent tear pattern was partial tears, which were more frequent in the anterosuperior and posterosuperior quadrants than in the anteroinferior and posteroinferior quadrants (25% [175 of 696] versus 9% [34 of 388]; p < 0.01).

## Discussion

Analysis of femoral version has become a diagnostic cornerstone in the treatment of patients with FAI [22, 39]. To date, the pathomechanic relationship between femoral version deformities and pathologic conditions of the acetabular labrum remains largely unexplored. To our knowledge, labral morphology has not been compared between patients with pathologically increased femoral version and those with decreased femoral version. Consequently, the impact of femoral version deformities on the labral size, tear location, and labral tear patterns is unclear. Hence, we performed a retrospective study assessing the labral cross-sectional area, tear location, and tear pattern on radial MRA images in symptomatic patients with abnormally increased or decreased femoral version. Increased femoral version was associated with

**Table 3.** Location-dependent labral size by mean cross-sectional area, divided by study group

| Acetabular clock-face position on radial MRI | Labral cross-sectional area in mm$^2$ | | |
|---|---|---|---|
| | Increased femoral version (n = 71) | Decreased femoral version (n = 58) | p value |
| Overall | 21 + 6 | 14 + 4 | < 0.01 |
| Anterior labrum (12:30 to 6:00) | 22 ± 8 | 12 ± 5 | < 0.01 |
| Posterior labrum (6:30 to 12:00) | 21 ± 6 | 16 ± 4 | < 0.01 |
| Anterosuperior quadrant (12:30 to 3:00) | 22 ± 8 | 13 ± 6 | < 0.01 |
| Anteroinferior quadrant (3:30 to 6:00) | 19 ± 8 | 11 ± 4 | < 0.01 |
| Posteroinferior quadrant (6:30 to 9:00) | 14 ± 4 | 11 ± 3 | < 0.01 |
| Posterosuperior quadrant (9:30 to 12:00) | 26 ± 8 | 19 ± 6 | < 0.01 |

Data presented as mean ± SD or % (n).

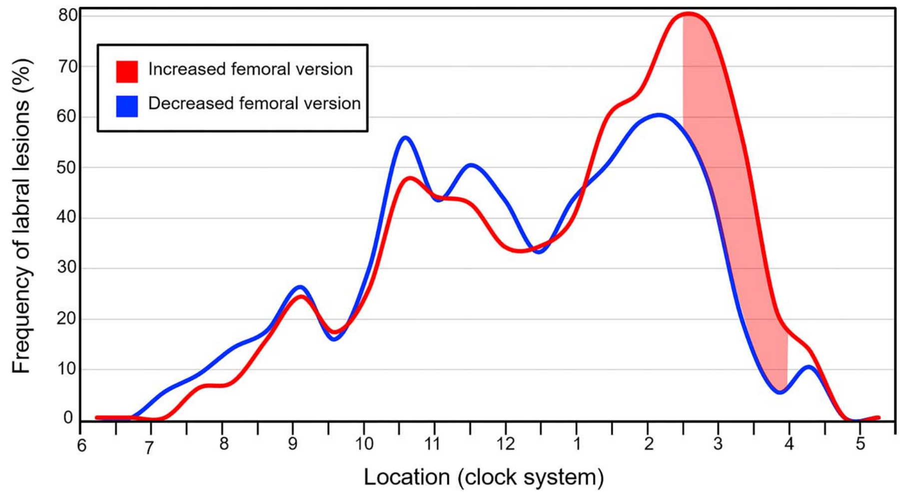


**Fig. 7** This figure shows the frequency of labral lesions (in %) broken down by location in the acetabular clockface system in hips with increased femoral version (red) and decreased femoral version (blue). Differences (red surface) between the study groups were found between 2:30 and 4:00 (all $p < 0.05$).

normal-sized labrums with anterior intrasubstance tears, while decreased femoral version was associated with labral hypotrophy and superior partial tears.

### *Limitations*

First, there was no asymptomatic control group and no group of symptomatic patients with normal femoral version. Without an asymptomatic control group, we do not know the actual prevalence of individuals with abnormal femoral version who have neither hip pain, nor limitation of motion, nor labral lesions. However, to minimize selection bias, we included all patients who fit our inclusion criteria and were not subject to our exclusion criteria. To ensure comparability and improve the generalizability of our findings, we used a described method to measure the mean labral cross-sectional area [35] and additionally performed an intrarater and interrater analysis of the measurements. For the labral tear pattern, previously validated, reliable and reproducible MRA-based definitions were applied [29]. We were interested in exploring pathomorphologic changes clearly related to femoral version deformities rather than characterizing the acetabular labrum in symptomatic patients with normal femoral version. Symptomatic patients with normal femoral version are very likely to suffer from other pathomorphologies of the acetabulum or proximal femur such as acetabular retroversion or pincer or cam morphology. Because these conditions are associated with known labral alterations [1, 17, 25], an analysis of labral morphology in this population would necessarily be biased. Obtaining hip MRAs from asymptomatic individuals was beyond the scope of this study. Second, when comparing our results with the existing research, it is important to view them in the context of the measurement methods used in our study versus those reported in other studies. For example, our definitions of increased and decreased femoral version differ from those of studies that use different measurement methods for femoral version. Because major differences in the reference values of femoral version exist between different measurement methods, a conversion formula was published by Schmaranzer et al. [30]. To highlight these differences, Dolan et al. [6] measured femoral version using the method described by Reikerås et al. [26] and defined a normal range as 5º to 25°. When using the Schmaranzer [30] conversion formula, 25° of femoral version measured by the Reikerås method is equivalent to 40º of femoral version as measured by the Murphy method (the method used in this study). In addition, depending on the measurement method, a certain degree of measurement variability was observed when the same measurement method for femoral version was used for different imaging modalities [4, 28]. Therefore, absolute values of femoral version should be interpreted in the context of the measurement method and imaging modality used. Third, although sex, height, and weight were not associated with the labral cross-sectional area, some influence of demographic differences (sex, height, and weight) between the study groups on the location of lesions cannot be excluded and thus represents a possible bias.

### *Discussion of Key Findings*

Hips with increased femoral version had a higher mean labral cross-sectional area than hips with decreased femoral

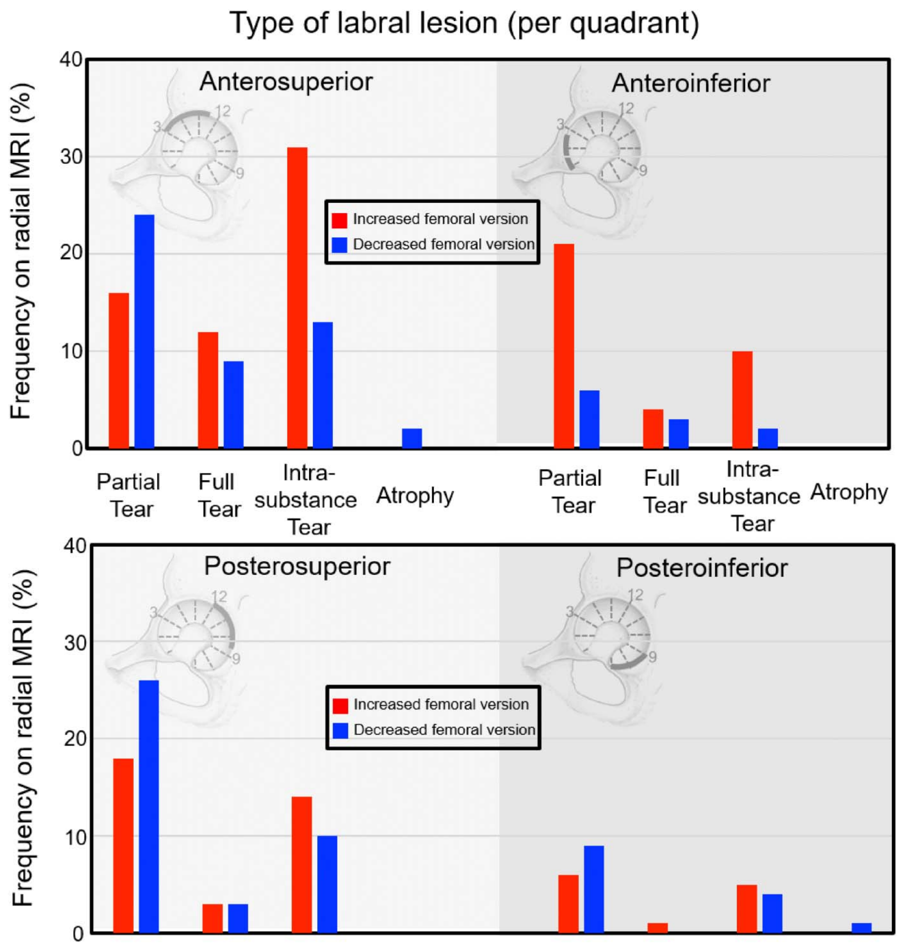


**Fig. 8** This figure shows the frequency of the different labral tear patterns of hips with increased femoral version (red) and decreased femoral version (blue) on radial MR images (in %) by quadrant in the acetabular clockface position. Differences were found for anterosuperior intrasubstance tears ($p < 0.001$) and anteroinferior partial tears ($p < 0.001$).

version. To our knowledge, this is the first study to investigate labral size in relation to femoral version on radial MRI. This imaging sequence is a useful technique for evaluating labral pathology [18] and has been used to study the relationship between acetabular coverage and labral cross-sectional area [35]. As repeatedly reported [10, 11, 16, 19, 31], hips with a hypertrophic labrum show decreased femoral head coverage. In a study by Toft et al. [35], hips with a normal-sized labrum had normal acetabular coverage. However, this trend did not continue when patients with hypotrophic labrums were analyzed. In fact, the group with hypotrophic labrums did not differ from the group with normal-sized labrums in any of the radiographic parameters used to quantify acetabular morphology or femoral head coverage. This suggests that the influence of acetabular coverage on labral size might decrease with increasing coverage, as described by Kraeutler et al. [16]. In our study, hips with decreased femoral version had labral hypotrophy, whereas hips with increased femoral version had normal-sized labrums. Strikingly, the distribution of labral size in hips with decreased femoral version (Fig. 6) was almost identical to the distribution of labral size of hips with labral hypotrophy in the study by Toft et al. [35]. Based on these findings, we conclude that there may be a relationship between femoral version and labral size that could be approximated logarithmically, with a decrease in femoral version being associated with a smaller labral size (Fig. 9).

Labral tears were located more anteriorly in hips with increased femoral version than in hips with decreased femoral version. There is limited evidence regarding the relationship between femoral version and labral tear location. Ejnisman et al. [7] investigated the relationship between femoral version and intraoperative findings during hip arthroscopy. Consistent with our results, hips with the highest femoral version had the largest mean labral tear size (38 mm

**Table 4.** Location-dependent frequency of labral intrasubstance tears, divided by study group

| Acetabular clockface position on radial MRI | Frequency of labral intrasubstance tear | | |
|---|---|---|---|
| | Increased femoral version (n = 71) | Decreased femoral version (n = 58) | p value |
| 12:00 | 14 (10) | 12 (7) | 0.74 |
| 12:30 | 17 (12) | 5 (3) | 0.04 |
| 1:00 | 17 (12) | 14 (8) | 0.04 |
| 1:30 | 32 (23) | 10 (6) | < 0.01 |
| 2:00 | 28 (20) | 10 (6) | 0.01 |
| 2:30 | 28 (20) | 5 (3) | < 0.01 |
| 3:00 | 23 (16) | 7 (4) | 0.02 |
| 3:30 | 7 (5) | 3 (2) | 0.37 |
| 4:00 | 4 (3) | 2 (1) | 0.42 |
| 4:30 | 0 (0) | 0 (0) | 0.25 |
| 7:00 | 0 (0) | 0 (0) | 0.25 |
| 7:30 | 1 (1) | 0 (0) | 0.37 |
| 8:00 | 1 (1) | 2 (1) | 0.89 |
| 8:30 | 0 (0) | 2 (1) | 0.27 |
| 9:00 | 3 (2) | 3 (2) | 0.84 |
| 9:30 | 3 (2) | 2 (1) | 0.68 |
| 10:00 | 4 (3) | 0 (0) | 0.12 |
| 10:30 | 6 (4) | 3 (2) | 0.56 |
| 11:00 | 10 (7) | 5 (3) | 0.32 |
| 11:30 | 11 (8) | 7 (4) | 0.40 |

Data presented as % (n) of radial MR images with intrasubstance tears per group.



versus 34 mm versus 30 mm; p = 0.01). Further, these hips were 2.2 (95% CI 1.1 to 4.2) times more likely to have labral tears extending beyond the 3:00 position. Another study similarly reported more labral tears beyond the 3:00 position in hips with high femoral version [9]. The reported mean labral tear size in this group, however, was only 27 mm and

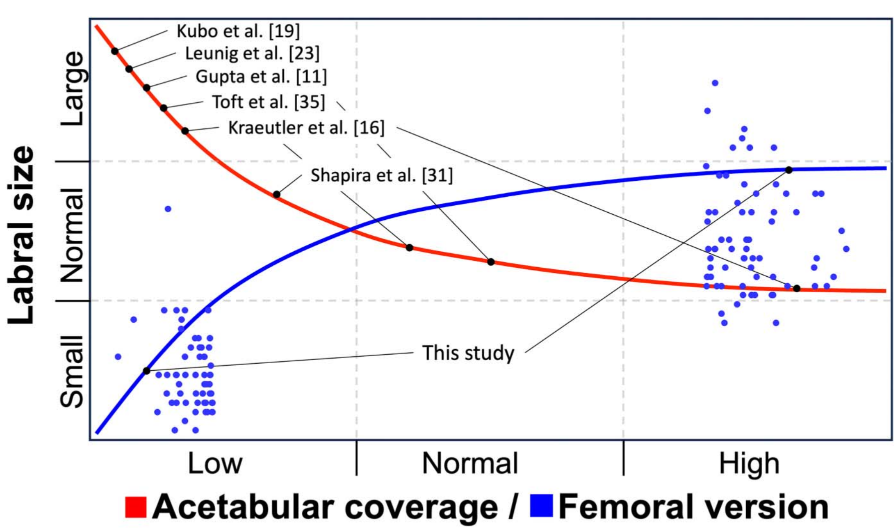


**Fig. 9** This is a presumed model of the relationship among labral size, acetabular coverage (red), and femoral version (blue). Although a lack of acetabular coverage appears to be the main factor in labral hypertrophy, decreased femoral version appears to be the main contributor to the development of labral hypotrophy.

did not differ from hips with low femoral version. In contrast, Jackson et al. [13] reported a lower incidence of labral tears at 3:00 in hips with elevated femoral version. However, their study involved an intraoperative arthroscopic assessment of labral tears in a smaller cohort of older patients with lower mean femoral version than in our study group of hips with increased femoral version. The greater anterior clearance in hips with increased femoral version could explain the lower incidence of anterior labral tears observed in their study. Posterior extra-articular impingement with subsequent anterior subluxation of the femoral head may occur with even more elevated femoral version [3, 12, 22, 32]. This phenomenon could contribute to the labral damage pattern we observed in the anterior labrum in patients with increased femoral version (Fig. 10A-C). An increased intra-articular superior impingement area has been reported in hips with decreased femoral version [2]. This might explain the superior labral damage pattern in hips with decreased femoral version, especially because the labrum did not show cam morphology typical inclusion-type lesions, but rather labral hypotrophy otherwise associated with impaction-type impingement in pincer FAI (Fig. 10D and 10E).

The pattern of labral tears in hips with increased femoral version was distinct from the pattern of labral tears in hips with decreased femoral version. The studies we have referenced [7, 9, 13] were similar in that they evaluated tear location but they did not provide any data about tear pattern. Although the linear size of tears was reported, a qualitative classification of labral tear patterns using a comprehensive classification system such as the system proposed by Schmaranzer et al. [29] used in this study may help provide additional information. Although our study was not designed to explore the pathomechanism of labral damage in patients with abnormal femoral version, the finding that labral tear patterns in high femoral version are distinct from those of low femoral version raises the question of what the contributing pathomechanisms to these patterns are.

*Conclusion*

We found differences in labral size, tear localization, and damage pattern when comparing hips with increased femoral version and those with decreased femoral version. Hips with increased femoral version show a normal-sized labrum and an anterior damage pattern with predominantly intrasubstance tears. By contrast, decreased femoral version was associated with labral hypotrophy. In evaluating patients with FAI, the term “labral tear” is not accurate

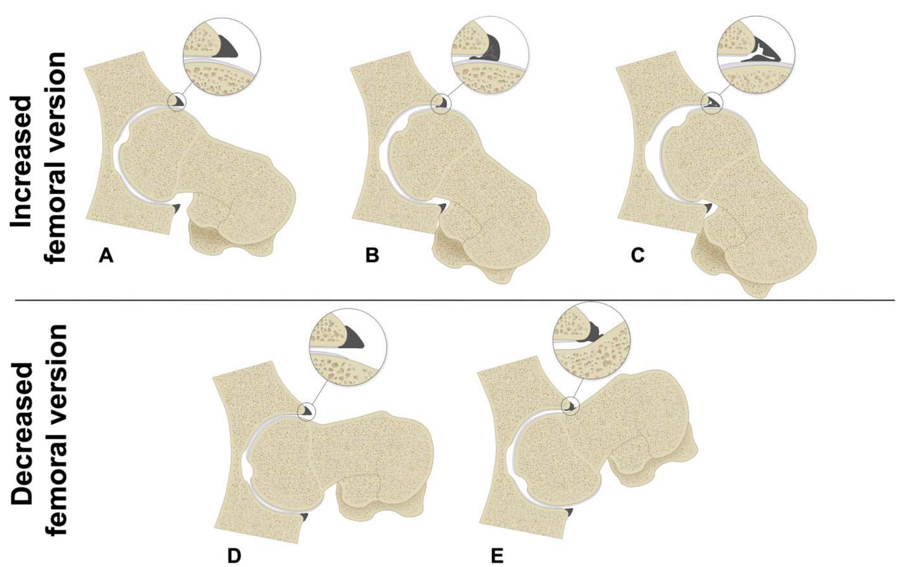


**Fig. 10** This illustration shows the possible pathomechanisms of labral damage in hips with increased and decreased femoral version. In (**A**) hips with excessively increased femoral version, external rotation leads to posterior extraarticular impingement with initially (**B**) moderate decentration of the femoral head and central suction of the anterior labrum. With continued external rotation, the suction seal is broken, leading to (**C**) anterior subluxation of the femoral head and, subsequently, damage to the anterior chondrolabral transition zone in the form of intrasubstance labral tears. In (**D**) hips with decreased femoral version, internal rotation results in (**E**) an impaction-type impingement with entrapment of the anterior labrum between the femur and acetabulum, leading to labral hypotrophy over time.

enough to describe labral pathology. Based on high-quality radial MR images, surgeons should always evaluate the combination of labral tear location and labral damage pattern, because these may provide insight into associated femoral version abnormalities, which can inform appropriate surgical treatment. Future studies should examine symptomatic patients with normal femoral version, as well as an asymptomatic control group, to delineate the effect of femoral version on labral morphology across the entire spectrum of pathomorphologies.



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