OXFORD

Is labral hypotrophy correlated with increased acetabular depth?

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ABSTRACT

Labral hypertrophy is a distinct feature in hip dysplasia. Occasionally, very small, hypotrophic labra are observed. However, there is no literature concerning this pathology. We investigated if the size of the labrum correlated with any radiologic parameters reflecting the amount of acetabular coverage. It was hypothezised that there is a negative correlation between labrum size and acetabular coverage. Labra were categorized into three groups depending on the relation between length of the articular sided surface and height of bony attachment. Labra with a height:length ratio of 2 were classified as hypotrophic, with a height:length ratio of 1 as normal and with a ratio of 0.5 as hypertrophic. Labral cross-sectional areas (CSA) were measured on radial magnetic resonance imaging-arthrography slices using the measuring tool of the PACS system of 20 hips with hypotrophic labra (group 1), 20 hips with normal labral appearance (group 2) and 10 hips with hypertrophic labra (group 3). These values were then analyzed against following parameters: neck-shaft-angle (NSA), lateral center-edge angle (LCE), acetabular index (AI), femoral extrusion index (FEI) and acetabular retroversion index (ARI). Analyses of variance were used to determine differences in mean values between the three groups. Mean labral CSA differed significantly between all groups (group 1: $12.1 \pm 2.9 \, \text{mm}^2$; group 2: $25.2 \pm 6.2 \, \text{mm}^2$; group 3: $41.1 \pm 12.3 \, \text{mm}^2$; $P < 0.001$). NSA, LCE, AI and FEI all showed a significant difference between group 3 and 1 or 2. The ARI showed no difference between groups. Stepwise linear regression analyses showed a significant correlation between LCE angle and labral CSA with a corrected R^2-value of 0.301. Labral CSA correlates with the LCE. No statistically significant difference between groups 1 and 2 concerning the LCE, AI or FEI could be identified. Nevertheless, group 1 had the highest mean coverage of all groups, hips with hypertrophic labra the lowest.

INTRODUCTION

The normal acetabular labrum acts as an extension of the articular surface of up to 27%, increasing acetabular volume by up to 30%, providing a seal-effect that resists distraction of the femoral head and enhances joint stability [1–4]. Furthermore, it inhibits the synovial fluid from extruding the central compartment under load, thus ensuring an equally distribution of forces across the joint cartilage and minimizing rotational friction forces [5–10]. The labral blood supply derives from radial branches of a periacetabular vascular ring, which is mainly fed by the superior and inferior gluteal arteries, with minor contributions from the medial and lateral circumflex femoral arteries and intrapelvic vessels [11]. This blood supply enables healing of the labrum after tearing or repair, as described by Audenaert *et al.* [12]. Nerve supply has also been reported with free nerve endings and receptors found in histological examinations, thus explaining labral pathology to cause painful symptoms [13, 14].

Several studies have shown that acetabular labra in dysplastic hips are larger than in normal control groups or in hips with femoro-acetabular impingement (FAI) [15–20]. Higher load- and shear forces at the labro-acetabular-interface due to an insufficient bony femoral coverage and thus transition of the femoral head center towards the acetabular rim are thought to lead to a compensatory labral hyperplasia as an attempt to stabilize the unstable hip joint [21].

Occasionally, very small, hypotrophic labra are observed in young patients, but there is a lack of information in the literature about this condition (Fig. 1).

Of interest may be, that hips with small labra do not have a suction seal during surgical dislocation of the femoral head, which is normally present in hips with a normal labrum [22, 23].

Up to date, there is no definition of labrum size being small, normal or hypertrophic. Several studies described the different magnetic resonance imaging (MRI) appearance of the acetabular labrum [24–28]. Most asymptomatic labra were found to have a triangular cross section (66–80%); apart from that, round (11–16%), flat (9–13%), or irregular contours were recorded. Some studies also described hypoplastic labra or even an absence (1–3% and up to 14%, respectively) [24–28]. Labral absence was only observed in patients over 50 years of age and is likely to be a result of natural degeneration during aging or progressive ossification of the labrum [27, 29]. Unfortunately, the true cross-sectional or volumetric size of the different labra have not been determined, and there

has not been any effort so far to correlate the different shapes or sizes to the bony anatomy of the patients.

Our goal was to determine (i) the labral cross-sectional area (CSA) circumferentially around the acetabulum on radial MR arthrography and (ii) find out if there is any anatomical difference between the groups with respect to acetabular coverage and shape of the femoral head neck junction. It was hypothesized that hips with hypotrophic labra have more bony acetabular coverage than hips with normal or hypertrophic labra.

MATERIALS AND METHODS

The MR-arthrographies of all patients attending our clinic between 2008 and 2013 were scrutinized for the size of the labrum and categorized into three groups. Categorization was based on the relation of height and length, height being the distance of the attachment measured from the joint surface to the perilabral recess and length the distance from the chondrolabral junction to the tip of the labrum (Fig. 2). For categorization, the size of the labrum was measured at the lateral acetabular rim on a frontal plane through the center of the femoral head. A labrum was considered hypotrophic when its length was less than half the height, normal when length and height were approximately equal and large when length was twice as large as the height. The categorization into 2:1, 1:1 and 1:2 automatically lead to a gap between the sizes which helped to obtain unambiguous, non-overlapping data. For groups 1 and 2, 20 hips were selected from the initial cohort according to the in-/exclusion criteria mentioned below. Because of the uniformity of the values in the large labrum group, all showing acetabular dysplasia, the analysis was discontinued after ten hips.

Inclusion criteria were a standardized anterior-posterior radiograph of the pelvis according to Siebenrock *et al.* [30] and closed physes on MRI (for cam deformity determination), as development of the cam-deformity is thought to take place during physeal closure [30, 31]. Exclusion criteria were lack of radial MR slices, inappropriate radiographs, severe labral changes on MRI (signal alterations Czerny 1B or higher, ganglia, ossifications, tears) in >50% of slices measured, and history of previous hip surgery, trauma or infection [32].

MRI's were obtained as follows: Intraarticular injection of contrast material with fluoroscopic guidance was performed prior to the MR examination in a standardized fashion in the radiology department. One to two milliliters of a local anaesthetic (lidocaine hydrochloride 10 mg/ml 1%, Rapidocain, Sintetica, Mendrisio, Switzerland), 1–2 ml of iodinated contrast media (Iopamiro 300, Bracco, Milano, Italy) and approximately 10 ml of MR contrast
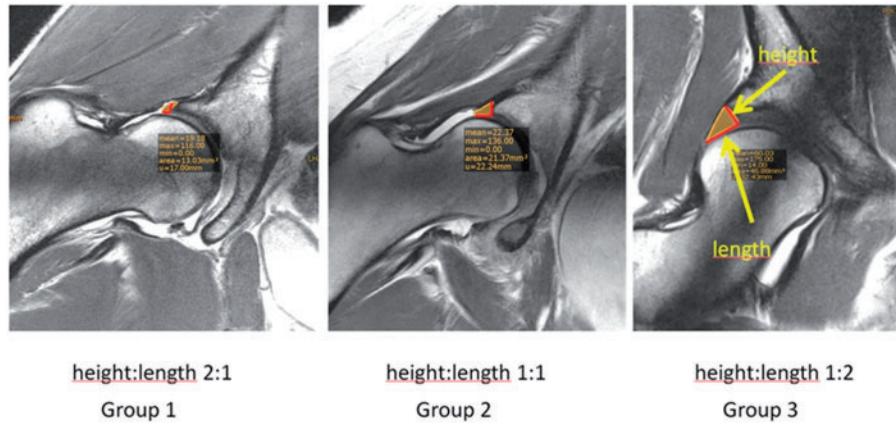

Fig. 1. MR-arthrography showing a hypotrophic labrum (arrow) in the anterosuperior area of the acetabulum.

height:length 2:1
Group 1

height:length 1:1
Group 2

height:length 1:2
Group 3

Fig. 2. Categorization of the labra.

agent (gadoteric acid, 0.0025 mmol/ml, Artirem, Guerbet, Villepinte, France) were applied. MR images were obtained on a 3 Tesla scanner (Achieva 3.0T; Philips Healthcare, Best, The Netherlands) with a six-channel SENSE cardiac coil (Philips Healthcare, Best, The Netherlands).

The routine protocol for MR arthrography included a transverse T1-weighted turbo spin-echo sequence, a coronal and sagittal intermediate-weighted turbo spin-echo sequence, a radial intermediate-weighted turbo spin-echo sequence, a transverse THRIVE (T1-weighted high resolution isotropic volume examination) or DESS (dual-echo steady state) sequence and a rapid transverse T1-weighted sequence over the proximal and distal femur for antetorsion measurement.

The radial sequence was planned on a scout image perpendicular to the long axis of the femoral neck using the center of the femoral neck as the axis of rotation, with a section thickness of 4 mm, which led to 25 slices.

For analysis only the 12 values corresponding to the clock system were used, 12 o'clock position being superior, 3 o'clock anterior, 6 o'clock inferior (transverse ligament) and 9 o'clock posterior (Fig. 3). For easier analysis and presentation, the data of the left hips were converted into right hips and presented in a clockwise fashion.

The CSA of the labrum was measured on the radial images at each position around the acetabulum, except in the area of the transverse ligament, using the area-measuring-tool of the PACS-System-software (Phönix Merlin PACS, Phönix-PACS GmbH, Emmy-Noether-Straße 2, D-79110 Freiburg). At each position the mean area (±SD) was calculated and analysed. Differences of labral size at each of the positions were compared between the groups. In a second step, the mean circumferential CSA-values of the labrum for each group were averaged.
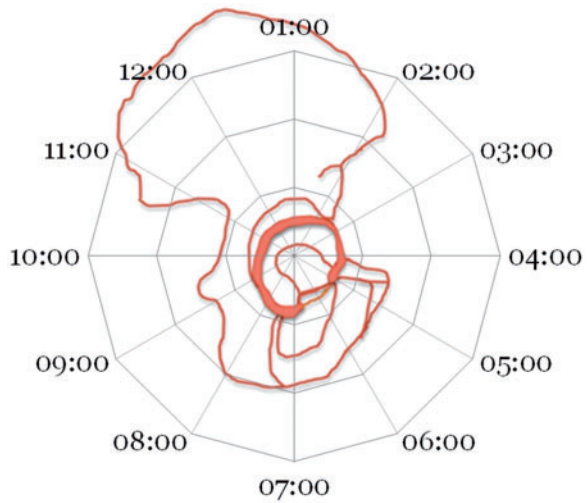

Fig. 3. Clockwise orientation of the analized planes around the acetabulum.

Changes of the acetabular rim and labrum were also recorded (labral base ossfications, ganglia, signal alterations and tears). To assess the presence of a cam deformity, the asphericity of the head neck junction was measured using the alpha angle as described by Nötzli at the 3 o'clock position and the asphericity angle at the 1:30 position as recommended by Rakhra and Pfirrmann [33–35]. The cutoff value for the angle of asphericity, representing a cam deformity, was set at 55° according to recent recommendations [36, 37].

Pelvic radiographs for each patient were analysed and the neck-shaft-angle (NSA), the lateral center-edge-angle (LCE), the acetabular index (AI) and the femoral extrusion index (FEI) were recorded [38–50]. Radiological signs of acetabular retroversion [crossing sign, posterior wall sign,

Table I. Demographics of the patients of the three groups

	Male	Female	n	Mean age
Hypotrophic	7	13	20	22.7 (15–31, ±4.6)
Normal	6	14	20	26.2 (16–35, ±6.6)
Hypertrophic	2	8	10	26.3 (17–40, ±7.1)
Σ =	15	35	50	25.1 (15–40, ±6.1)

ischial spine sign and acetabular retroversion index (ARI)] were also recorded [51, 53]. All measurements were done on the PACS-software (Phönix Merlin PACS, Phönix-PACS GmbH, Emmy-Noether-Straße 2, D-79110 Freiburg).

Statistical analyses were performed with IBM SPSS software program (version 20.1). Analyses of variance were used to determine differences in mean values between the three groups concerning all measured items, including *post hoc* Bonferroni correction. Simple and multivariate linear regression analyses were performed to investigate a correlation between the measured parameters and labral volume. Level of significance was set at $P < 0.05$.

RESULTS

Group 1 includes 20 hips with a very small (hypotrophic) labrum, group 2 includes 20 hips with normal labrum and group 3 includes 10 hips with a large labrum. There was no significant difference concerning mean age, although the average age in group 1 was slightly younger than in the other two groups (1:2: $P = 0.213$/1:3: $P = 0.382$/2:3: $P = 1.0$). There was no gender difference between group 1 and 2; however, there was a clear preponderance for female hips in the hypertrophic group. Patient characteristics are shown in Table I.

Mean overall labral CSA differed significantly (1:2: $P < 0.001$; 1:3: $P < 0.001$; 2:3: $P < 0.001$) between all groups (Table IV and Fig. 4).

In group 1 the averaged mean CSA over all clock positions was $12.1 \pm 2.9 \text{ mm}^2$ (range 6.2–16.1 mm²), in group 2 it measured $25.2 \pm 6.2 \text{ mm}^2$ (range 17.5–43.2 mm²) and in group 3 it was $41.1 \pm 12.3 \text{ mm}^2$ (range 24.3–61.6 mm²). The lowest single CSA value measured was 1.4 mm^2 in group 1, the highest 94.6 mm^2 in group 3. The mean size in mm² and distribution of the cross sectional area of the labrum around the circumference are presented in Table II and Fig. 5.

The mean NSA was significantly higher ($P < 0.009$) in group 3 compared with group 2. No significant difference was found between group 1 and 3 ($P < 0.107$) or 1 and 2
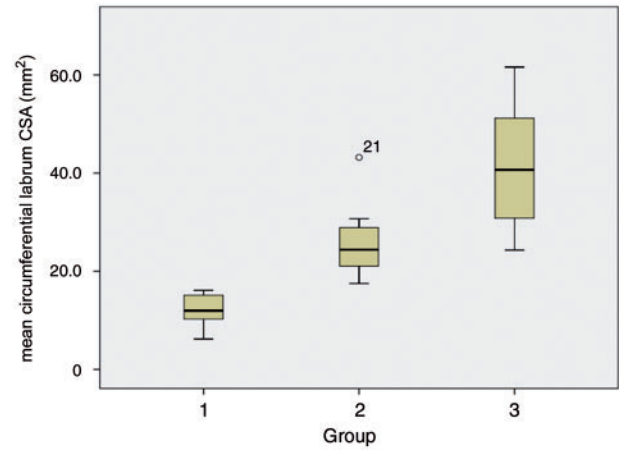
Fig. 4. Boxplot of the size of the labrum of the three groups. 1) hypotrophic, 2) normal, 3) hypertrophic.

($P < 0.7$). The lowest NSA was 121° measured in group 2, and the highest 156° in group 3.

The mean LCE was significantly lower ($P < 0.001$) in group 3 than in the two other groups. The highest value measured was 40° in group 1, and the lowest −17° in group 3. No significant difference was found between groups 1 and 2 ($P = 0.827$).

The mean AI was also significantly higher ($P < 0.001$) in the dysplastic hips group than in group 1 or group 2. Again, group 1 and 2 did not differ significantly. The lowest AI-value measured was −8.8° in group 1, and the highest 30.6° in group 3.

The mean FEI was significantly higher ($P < 0.001$) in group 3 compared with the other groups. Once more, no significant difference was found between group 1 and 2. Sixty-three percent in group 3 was the highest value measured, 0% in group 1 the lowest.

The radiographic parameters are summarized in Table IV.

Most labral disorders were found between 1 and 4 o'clock, representing the antero-superior quadrant. Ossifications were found more often in the hypoplastic group (20 slices versus 9 slices versus 1 slice) while signal alterations and lesions were equally distributed. The distribution of labral disorders is shown in Fig. 6.

Signs of acetabular retroversion (ARI > 20%) were seen in five hips in group 1 (25%) versus five hips in group 2 (25%) versus two hips in group 3 (20%) (Table III) [51–53].

A cam-deformity was found in none of the hips in group 1 (0%), in 11 hips of group 2 (55%) and in 4 hips in group 3 (40%). The absence of a cam deformity at the 01:30 position was statistically significant ($P = 0.031$). No difference

Table II. Size of the labrum in mm² at the various clock positions. At 6:00 is the transverse ligament, therefore no data was available

Position	Hypotrophic	Normal	Hypertrophic	P value (1:2/1:3/2:3)
12:00	14.4 ± 5	23 ± 5.3	42.4 ± 7.7	0.0001/0.0001/0.0002
01:00	11.5 ± 6.2	22.4 ± 9.3	36.1 ± 13.7	0.0002/0.0001/0.002
02:00	9.6 ± 4.4	19.9 ± 10.6	24.2 ± 16	0.003/0.002/0.035
03:00	15 ± 6	19.8 ± 5.8	22.7 ± 9.4	0.037/0.008/0.078
04:00	13.1 ± 4.9	18.4 ± 6.4	29.6 ± 1.7	0.19/0.045/0.075
05:00	14 ± 4.8	17 ± 6.9	38.8 ± 2.6	0.27/0.0007/0.0012
06:00	0	0	0	
07:00	8.7 ± 2.8	13 ± 1.3	22.1 ± 9.4	0.028/0.0045/0.05
08:00	10.3 ± 2.1	14.1 ± 4.3	18.8 ± 5.6	0.008/0.0014/0.09
09:00	13 ± 4.4	15.8 ± 4.9	30.4 ± 12.1	0.11/0.003/0.009
10:00	16.1 ± 7.7	19.1 ± 6.6	32.8 ± 10.5	0.35/0.004/0.008
11:00	19.6 ± 5.6	22.7 ± 4	34.4 ± 17.3	0.079/0.0006/0.0016
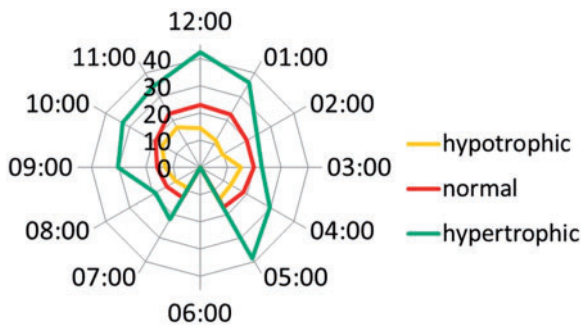
Fig. 5. Schematic representation of the size of the labrum for hypotrophic, normal and hypertrophic labra (in mm²).
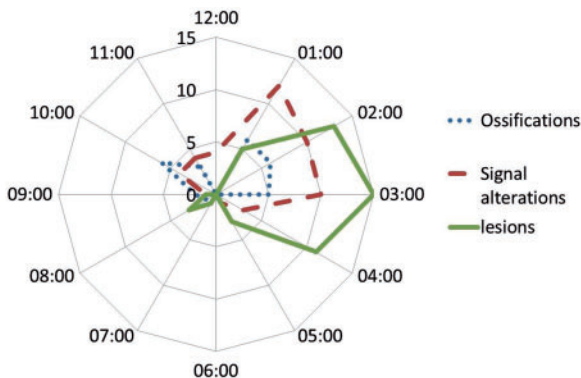
Fig. 6. Distribution of labral disorders.

between groups was observed concerning the alpha-angle at 03:00 (Tables III and IV).

Multivariate regression analyses showed a significant correlation between all radiographic parameters (NSA, LCE, AI and FEI) and overall mean labral CSA with a corrected R^2 value of 0.278. Simple linear regression analyses showed a significant correlation between LCE value and overall mean labral CSA ($P < 0.001$) with a corrected R^2-value of 0.301.

DISCUSSION

Our study aimed to investigate if hips with hypotrophic labra have deeper hips with more bony acetabular coverage, so that the small size could be explained as a consequence of increased coverage and thus decreased forces acting at the labro-acetabular-interface, possibly thereby disincentivizing the labrum to further hypertrophy during its development. According to our data, this hypothesis could not be confirmed in means of statistical significant differences in bony morphology between groups 1 and 2. Statistical regression analyses showed a weak but significant correlation between LCE and mean labral CSA. Interestingly, the group with the hypotrophic labra did not reveal any cam-deformities, speaking in favor of an isolated pincer-FAI. Acetabular retroversion did not have an influence on labrum size and was equally distributed among all groups.

A study by Cobb *et al.* [54] showed a difference in bony acetabular morphology between Pincer- and Cam-type hips. They found Cam-type hips to be shallower than normal hips, which in turn were again shallower than Pincer-type hips [54]. In how far this circumstance has an influence on labral morphology was not reported.

A study by Corten *et al.* [29] showed that in 'deep' hips, an existing pincer impingement leads to a bony apposition at the acetabular rim, which displaces the labrum, mimicking a small or absent labrum on MR imaging [29]. The study population though was older than ours (mean 41.9 years for tissue sample group), and patients with ossifications were significantly older than those without (43 years versus 33 years). In our study, we could not identify any labral or acetabular rim ossifications on the AP radiographs, whereas scrutinizing the MRI's revealed some ossifications as described by Corten *et al.* [29] but there were also hypotrophic labra without any signs of acetabular rim changes or signal alterations. In addition, also dysplastic hips and hips with normal acetabular labrum showed these ossifications.

As the labrum is thought to have several biomechanical functions, the capability to accomplish these is likely to depend on its integrity and also on its size.

It is questionable in how far the hypotrophic labra are able to perform the assigned biomechanical function of a seal. Patients with hypotrophic labra do not show a vacuum effect while performing a surgical dislocation of the hip, suggesting an insufficient or at least remarkably diminished sealing effect.

Assumed that a hypotrophic labrum is not able to maintain the synovial liquid in the central compartment at load-bearing, higher forces distributed across the cartilage would be the consequence, thus enhancing cartilage and joint degeneration. This would mean that in hips with a hypotrophic labrum osteoarthritis would develop earlier, however, up to date, there is no data confirming a correlation between labral absence and earlier onset of osteoarthritis or FAI.

Most studies mentioning the normal thickness of a labrum being 2–3 mm refer to an article by Barham S. who does not outline the source of this statement [55]. The indicated sources, to our knowledge, do not contain information about the labrum thickness [13, 56]. Aydingöz and Oztürk examined the labra of 180 asymptomatic volunteers in five age groups on MR-scans [25]. They found above mentioned labrum shapes and a size difference of over 25% between left and right hips in the same patients in one-fourth of volunteers. Average labrum area was mentioned to range between 7.8 and 13.5 mm^2, but the labra were indirectly measured only on midcoronal slices at the largest appearance using different formulas to determine the area according to its shape. Another effort to evaluate labral size was made by Kantarci *et al.* [57], measuring the cross sectional area of labra by ultrasound visualization. Again, the CSA was measured only on one single ultrasound image considered to display best the largest area of the labrum. Few cadaver studies mentioned the height of the labrum at certain points ranging from 1 to 33.6 mm

Table III. Presence of acetabular retroversion and cam deformity within the three different groups

	Acetabular retroversion	Cam
Hypotrophic	5 (25%)	0
Normal	5 (25%)	11 (55%)
Hypertrophic	3 (30%)	4 (40%)

Table IV. Overview of the different radiographic parameters in relation to the three groups

	G1: hypotrophic	G2: normal	G3: hypertrophic	P value (1:2/1:3/2:3)
Mean labrum CSA (range)	12.1 ± 2.9 mm^2 (6.2–16.1)	25.2 ± 6.2 mm^2 (17.5–43.2)	41.1 ± 12.3 mm^2 (24.3 to 61.6)	<0.001
NSA	134 ± 6.8	132 ± 5.9	140 ± 7.9	0.7/0.107/0.009
LCE	30.2 ± 5.2	27.6 ± 6.6	11 ± 5.2	0.827/0.001/0.001
AI	3.3 ± 5.2	4.7 ± 4.2	16.3 ± 9	1.0/0.001/0.001
FEI	17 ± 7.2	19 ± 5.9	33.9 ± 12.6	1.0/0.001/0.001
Angle alpha (3 o'clock)	43.5 ± 5.6	48.8 ± 8.4	48.4 ± 6.8	0.064/0.234/1.000
Asphericity angle (1'30 o'clock)	46.2 ± 6.9	54.8 ± 13.1	46 ± 8.9	0.031/1.000/0.094

(mean 5.9 mm) [14, 58]. Won *et al.* [58] also distinguished four types of shapes of labra and attachments to the acetabulum in their cadaveric study. They described small labra mainly in the posterior and inferior parts of the acetabulum with an incidence of 6.9%.

The small labra in our study showed a more or less circumferentially hypotrophic appearance, especially in the superior parts. In order to gain complete information about the acetabular shapes and corresponding labral CSA or volumes, combined 3D computed tomography and radial—MRI would be favorable.

Radial MR-arthrography has been described as the best method to detect labral pathology, and, in addition, is capable of showing the labrum circumferentially in its cross section [59–65].

The radiological parameters were chosen because of their reliability to show the degree of acetabular coverage of the femoral head, respectively, the acetabular depth. NSA were gained to determine if coxa valga had also influence on the labrum size, as this pathology leads to additionally increased loading forces on the superoanterior rim in dysplastic hips [39, 40, 43–46, 50].

The difficulty to recruit convenient MRI is the main reason for the small number of patients included in our study. Most patients who undergo arthro-MRI for the hip show labral changes such as signal alterations, ganglia, tears, cysts etc. even at young ages. As labrum MRI signals and labrum forms change during aging, only young patients with almost no symptoms are likely to have an intact labrum, which can be measured circumferentially [24–28]. The prevalence of labral pathology on MRI among 45 asymptomatic young participants was reported to be as high as 69%, underlining above mentioned problem [66]. Furthermore, finding intact hypotrophic and/or hypertrophic labra is an even harder challenge.

Another limitation of our study is selection bias, as our study population was recruited from symptomatic young patients attending our clinic and not from asymptomatic volunteers. In addition, our study population is not representative for the general public due to the selection process (estimated height:length-ratio). In order to determine the normal distribution of labrum sizes for categorization of small, normal or hypertrophic labra, either prospective or cross-sectional studies would be necessary with representative study populations.

CONCLUSION

Labral CSA correlates with the LCE. No statistically significant difference between hips with normal labra and hypotrophic labra concerning the radiological parameters reflecting the amount of acetabular coverage could be identified. However, the absence of a cam deformity leads to the conclusion, that hypotrophic labra are predominantly found in pure pincer FAI. Nevertheless, the group with the hypotrophic labra had the highest mean coverage of all groups, the dysplastic group the lowest. Probably a higher number of patients is necessary to yield a significant difference between groups 1 and 2.

CONFLICT OF INTEREST STATEMENT

None declared.

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