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Association of Cartilage Defects, and other MR Findings with Pain and Function in Individuals with Mild-Moderate Radiographic Hip Osteoarthritis and Controls

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Abstract

Objective—To evaluate the relationship of hip radiographic osteoarthritis (ROA) and MR findings of cartilage lesions, labral tears, bone marrow edema like lesions (BMEL) and subchondral cysts with self-reported and physical function.

Design—Eighty five subjects were classified as controls (n= 55, KL 0, 1) or having mild-moderate ROA (n = 30, KL 2, 3). T_2-weighted MR images at 3-Tesla were graded for presence of cartilage lesions, labral tears, BMELs and subchondral cysts. Posterior wall sign, cross-over sign, center-edge angle and alpha angle were also recorded. Function was assessed using Hip Osteoarthritis Outcome Score (HOOS), Timed-Up and Go (TUG) test and Y-Balance Test (YBT). Analysis compared function between subjects with and without ROA and those with and without femoral or acetabular cartilage lesions, adjusted for age. Non-parametric correlations were used to assess the relationship between radiographic scores, MR scores and function.

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Results—Subjects with acetabular cartilage lesions had worse HOOS (Difference = 5–10%, P = 0.036–0.004), but not TUG or YBT, scores. Acetabular cartilage lesions, BMELs and subchondral cysts were associated with worse HOOS scores (ρ= 0.23–0.37, P = 0.041–0.001). Differences in function between subjects with and without ROA or femoral cartilage lesions were not significant. Other radiologic findings were not associated with function.

Conclusions—Acetabular cartilage defects, but not femoral cartilage defects or ROA, were associated with greater self-reported pain and disability. BMELs and subchondral cysts were related to greater hip related self-reported pain and disability. None of the radiographic or MR features were related to physical function.

Keywords

BMEL; subchondral cyst; Kellgren-Lawrence; Balance; Y-Balance Test; Labral tears

INTRODUCTION

One in four individuals is at risk of developing symptomatic hip osteoarthritis (OA) in their lifetime. [1] People with hip OA have significant disability which impacts their quality of life with a large number eventually requiring total hip arthroplasty. [2, 3] Clinical diagnosis of hip OA is made using a combination of symptoms and radiographic findings characteristic of osteoarthritis. [4, 5] Although radiographs are inexpensive and easily available, they only allow gross visualization of changes in bone and joint space. [6] They also entail exposure to ionizing radiation and offer poor reproducibility for characterizing OA related degeneration. [7, 8] Finally, radiographs are insensitive to the earliest changes associated with OA [6] or to differences between the acetabular and the femoral cartilage. MRI offers greater soft-tissue contrast and allows direct visualization of cartilage, labrum, bone marrow edema like lesions (BMEL), subchondral cysts and other soft-tissue pathologies. [9, 10] Hence, there is a need to compare the association of radiographic and MR descriptors of disease severity with measures of pain and disability for hip OA.

MR imaging for OA related tissue degeneration is more established for knee [6, 11] and there is substantial literature investigating the relationship of radiographic and MR findings with patient pain, symptoms and function in populations with knee OA. [12, 13] Relatively fewer studies have investigated MR imaging for hip OA. [10, 11, 14, 15] The hip joint is functionally and structurally very different compared to the knee and it has been more challenging to develop clinical MR imaging which allows adequate visualization of hip structures due to the shape and location of the hip joint. [16] Hence, even though hip OA is associated with significant loss of function, there is not enough information on the relationships of radiographic and MR findings of hip OA with pain, disability and physical performance. [10, 17, 18] It is also unknown if cartilage defects in the femur and the acetabulum have different relationships with functional deficits. Furthermore, there have been reports of abnormal MR findings like cartilage lesions, labral tears and cam-type lesions being present in asymptomatic individuals which also necessitate understanding the clinical relevance of these imaging findings. [19–21]

Cartilage thinning and defects are the primary characteristic of the osteoarthritis disease process and radiographs are thought to provide an indirect measure of cartilage loss. Since MR imaging provides a direct visualization of femoral and acetabular cartilage, it needs to be seen if cartilage defects in these areas are associated with functional deficits. Hence, the primary purpose of this study was to evaluate the associations of radiographic OA (ROA) and MR evidence of femoral and acetabular cartilage lesions with self-reported pain and disability, and physical function in adults with mild-moderate hip ROA. Secondary purpose was to evaluate the association of MR evidence of BMELs, subchondral cysts, labral tears

and features of developmental dysplasia of the hip (DDH) and femoroacetabular impingement (FAI) with self-reported pain and disability, and physical function in adults with mild-moderate hip ROA.

MATERIALS AND METHODS

Subjects

Subjects were recruited from the community using flyers and advertisements. The inclusion criteria for ROA (n = 30) patients (+ROA) were Kellgren-Lawrence (KL) grade of 2 or 3 at the hip on weight-bearing anterior-posterior radiographs.[22] The side with greater KL grade was selected as the “index hip”. The control (n= 55) subjects (-ROA) had a radiographic KL grade of 0 or 1 at both hips, and were without history of diagnosed OA or previous hip injuries. Exclusion criteria for all subjects were a any contra-indications to MR imaging, KL grade of 4, a total joint replacement of any lower extremity joint, previous hip trauma, pain at any other lower extremity joint, radiographic evidence of any knee or ankle joint OA, systemic inflammatory arthritis or any other spine or lower extremity condition that would affect their ability to complete the functional tests. All subjects signed a written informed consent approved by the University of California, San Francisco Committee on Human Research.

MRI acquisitions

All imaging was performed with a 3-Tesla MR scanner (GE MR750, GE Healthcare, Waukesha, WI, USA) and an 8 -channel cardiac coil (GE Healthcare, Waukesha, WI, USA). Patient positioning aids were used to immobilize and support patients, and ensure a consistent, reproducible, and comfortable hip positioning during scanning. Patients were positioned supine with their feet taped together, their knees supported by cushions to prevent movement. The imaging protocol and parameters are shown in Table 1.

Image analysis

Clinical MR grading for features of hip OA—Experienced board-certified musculoskeletal radiologists (TML, LN, SL) performed the clinical grading for each subject on the coronal and sagittal MR studies. The features scored included cartilage defects, labral tears, bone marrow edema like lesions (BMEL) and subchondral cysts. For cartilage lesions, BMEL and subchondral cysts, the femoral and acetabular segments were divided into six subregions (4 femoral, 2 acetabular) on the coronal studies and 4 subregions (2 femoral, 2 acetabular) on the sagittal studies, for a total of 10 subregions (Fig 1). The mid portion of the femoral head was defined on the sagittal images and subdivided into four subregions on the coronal images, from lateral to medial (Fig 1a,b). The landmark for division was lateral acetabular rim for lateral and superolateral, a vertical line from center of femoral head for superolateral and supermedial, and ligamentum teres for supermedial and inferior subregions. On the sagittal MR study, the anterior subregion represented the anterior 1 cm of the femoral head and the posterior subregion represented the posterior 1 cm of the femoral head (Fig 1c,d). The division was based on a simplified version of the geographic zone method described by Ilizaliturri Jr. et al. for hip arthroscopy which showed superior inter-observer reproducibility compared to the clock-face method. [23] Cartilage defects were graded as 0 (no defect), 1 (partial thickness) and 2 (full thickness). BMEL were graded as 0(absent), 1 (< or= 0.5 cm), 2 (0.5–1.5 cm) and 3 (> or = 1.5 cm). Subchondral cysts were graded as 0 (absent), 1 (< or = 0.5 cm) and 2 (> 0.5 cm). The labrum was graded on the sagittal images in the anterosuperior region, coronal images in the superolateral regions and on the axial images in the anterior and posterior regions. Labral tears were graded as 0 (normal or normal variant), 1 (fraying or signal abnormality), 2 (simple tear), 3 (labor-cartilage sepeartion), 4 (complex tear) and 5 (maceration). Total scores were calculated for

cartilage lesions (femoral and acetabular), labral tears, BMELs and subchondral cysts. Consensus readings were performed in case of a disagreement.

Intra and inter-rater reliability for the measures was established on a subset of 30 subjects by 2 radiologists. The intra- and inter-reader reliability per observation was rated with Cohen Kappa values and percent agreements. Linear weighted kappa was used for features with point-scale greater than two. Intra-reader kappa values were between 0.70 – 0.79 (cartilage = 0.70, BMEL = 0.79, cyst = 0.78, labrum = 0.73) and percent agreement was between 74%–98% (cartilage = 85%, BMEL = 96%, cyst =98%, labrum = 74%). Inter-rater kappa values were between 0.55 – 0.71 (cartilage = 0.57, BMEL = 0.55, cyst = 0.71, labrum = 0.65) and percent agreement was between 66%–97% (cartilage = 78%, BMEL = 91%, cyst =97%, labrum = 66%).

Clinical assessment of features of DDH and FAI—Presence or absence of the posterior wall sign and the cross-over sign, and the center-edge angle were recorded from the radiographs.[24] Additionally, alpha angle [25] was measured on the oblique axial MR images.

Self report function

Self-reported function was assessed using Hip disability and Osteoarthritis Outcome Score (HOOS).[26] The HOOS covers 5 separate dimensions of hip function: Pain, Symptoms, Activities of Daily Living (ADL), Sport and Recreation Function (Sport), and Hip-Related Quality of Life (QOL). All dimensions are scored from 0 to 4, and then scores are transformed to a percentage score of 0 to 100, with 0 representing extreme hip problems and 100 representing no hip problems. The HOOS has been shown to be a valid, reliable, and responsive measure of overall hip joint function in people with OA. [26] For this study HOOS subscales of Pain, Symptoms and ADL were used in the analyses.

Physical Function Tests

Two tests were used.

Timed-up and Go Test—The TUG requires a subject to rise from a chair, walk 3 m, turn and come back to sit down. Participants were instructed to walk as quickly as they felt safe and comfortable. A stopwatch was be used to measure the time to complete the TUG within the nearest one hundredth of a second. In a recent review TUG has been shown to be one of the 2 tests with best measurement properties among the sit to stand tests for people with hip or knee OA. [27]

Y-Balance Test (YBT)—YBT is a modification of the valid and reliable Star Excursion Balance Test (SEBT) which eliminates the redundancy in the directions of SEBT and overcomes some of its limitations [28]. The test was devised after Plisky et al [29] incorporated the anterior (A), postero-medial (PM) and postero-lateral (PL) directions of the SEBT. The YBT requires the participant to stand barefeet on an elevated central plastic footplate 1 in (2.54 cm) off the ground and push a rectangular reach indicator block with the foot along a 1.5-m length of plastic tubing in each of the 3 directions. The *reach distance* is recorded in half centimeters as farthest distance the participant is able to push the reach indicator. The YBT takes less time to complete, has a standard protocol and high inter-rater (0.99–1.00) and intra-rater reliability (0.85–0.91).[30] Three repetitions were performed for each of these 3 directions on both extremities and the greatest reach distance recorded. The difference in the greatest reach distance from each direction between right and left extremities was used to calculate a symmetry score. For this study the reach distance from

PM and PL directions were used in the analyses which have been shown to have the greatest agreement with SEBT. [28]

Statistical Analysis

Primary analyses were to compare self –report and physical function measures between +ROA and –ROA groups (adjusted for age) and those without (grade = 0) and with (grade >0) cartilage lesions in the femur and in the acetabulum (adjusted for age) using ANOVA. Additionally, non-parametric Spearman's ρ correlations were used to assess the relationship between KL scores, cartilage scores (femoral and acetabular), labral scores, BMEL scores and subchondral cyst scores; and between these scores and functional metrics (HOOS, TUG, YBT).

Exploratory analyses were performed to compare function (HOOS, TUG, YBT) with subjects stratified those with (grade >0) and without (grade = 0) BMELs, those with (grade > 3) and without (grade <= 3) complex labral tears and with (grade >0) and without (grade =0) subchondral cysts, adjusting for age, using ANOVA. Finally, Pearson's correlations were used to evaluate the relationships of center-edge angle and alpha angle with function (HOOS, TUG, YBT); and non-parametric Spearman's ρ correlation was used to assess their relationship with other imaging scores (KL, cartilage, labral, BMEL, subchondral cyst scores).

RESULTS

Subjects

A total of 180 people were screened for this study and 95 met the eligibility criteria. Out of them 10 were excluded due to various reasons (changed their mind = 7, missed appointment = 1, unable to complete testing = 1, claustrophobia = 1).

Age, BMI and gender distribution are shown in Table 2. The +ROA subjects were older ($P < 0.001$) compared to −ROA. Similarly, subjects with femoral cartilage lesions ($P = 0.008$) and those with acetabular cartilage lesions ($P = 0.001$) were older than subjects without cartilage lesions.

Function

The HOOS, TUG and YBT scores are shown in Table 3. The HOOS scores for all subscales were no different between +ROA and −ROA groups ($P > 0.05$), and those with and without femoral cartilage lesions ($P > 0.05$). Subjects with acetabular cartilage lesions had worse scores ($P < 0.05$) on all HOOS subscales. The differences in TUG and YBT scores were not significant for any of the comparisons ($P > 0.05$).

In the exploratory analyses, no significant differences were seen ($P > 0.05$) on comparing the HOOS data between subjects with and without labral tears. Subjects with BMEL had worse Symptom ($P = 0.003$) but not Pain ($P = 0.268$) or ADL ($P = 0.453$) scores, compared to subjects without BMELs. Subjects with subchondral cysts had worse scores on all subscales - Symptom ($P = 0.001$), Pain ($P = 0.006$), ADL ($P = 0.019$), compared to those without cysts. No significant differences ($P > 0.05$) were seen in TUG of YBT scores for any of these comparisons.

Relationships

Results from non-parametric tests are shown in Table 4. KL score was not significantly related with any functional measure. Greater total score of femoral cartilage lesions had a close to significance negative association with HOOS Symptom and ADL scores but not

with Pain score. Total acetabular cartilage score was negatively related with all HOOS scores. Total BMEL and subchondral cysts scores were also related to worse scores on all HOOS subscales. Greater severity of labral tears was not associated with any HOOS score. None of the MR measures showed a significant association with any of the physical performance test scores in this cohort.

Exploratory analyses showed that the center-edge angle and alpha angle were not associated with any of the functional measures ($P > 0.05$).

Prevalence of pathologies on MR

There were associations between worsening KL score and increasing number and severity of femoral cartilage defects ($\rho = 0.338$, $P = 0.002$), acetabular cartilage defects ($\rho = 0.347$, $P = 0.001$), subchondral cysts ($\rho = 0.303$, $P = 0.005$) labral tears ($\rho = 0.405$, $P < 0.001$) and a trend for BMELs ($\rho = 0.192$, $P = 0.079$). There was a greater prevalence of acetabular cartilage lesions and subchondral cysts in subjects with hip OA (Table 5). Subjects with cartilage lesions in the femur or acetabulum had higher prevalence of BMELs and subchondral cysts. Furthermore, subjects with cartilage lesions in the acetabulum had greater prevalence of labral tears.

The prevalence of the subjects with a positive cross-over sign (overall prevalence = 20%) or a positive posterior wall sign (overall prevalence = 39%) were not different between +ROA and –ROA groups, or those with and without femoral or acetabular cartilage lesions. Additionally, the center-edge angle (overall = 31.8±8.6°) did not have a significant relationship with KL grade, or with cartilage, labral, BMEL and cyst scores ($P > 0.05$). However, alpha angle (overall = 56.9±14.2°) had a positive association with KL grade ($\rho = 0.27$, $P = 0.012$), total femoral cartilage score ($\rho = 0.38$, $P < 0.001$), total acetabular cartilage score ($\rho = 0.45$, $P < 0.001$)total BMEL score ($\rho = 0.23$, $P = 0.034$) and close to significance association with total cyst score ($\rho = 0.20$, P = 0.071) but not with total labral score ($\rho = 0.17$, P = 0.117).

DISCUSSION

The aim of this study was to investigate the association of hip ROA, femoral and acetabular cartilage lesions with self-reported and physical function. We found that individuals with acetabular cartilage defects reported worse pain and disability compared to those without acetabular cartilage defects. Such differences were not seen between +ROA and –ROA groups, or between those with and without femoral cartilage lesions. Additionally the results show that even complex labral tears are not associated with functional deficits where as acetabular cartilage lesions, BMELs and subchondral cysts are associated with worse self-report disability. Radiologic features of DDH and FAI were also not found to be associated with function in this cohort. These results highlight the importance of MR imaging to guide diagnosis and prognosis for people with hip related disability, and highlight the strengths of MR imaging over radiography for investigating the osteoarthritis disease process at the hip. The findings also enhance the understanding of clinical significance of degeneration of different soft-tissues of the hip in the osteoarthritis disease process.

We did not observe worse disability in individuals with ROA or an association of ROA with function. Earlier reports on the relationship of ROA and function have been inconclusive [31], similar to the results of much more extensive evaluations of association of radiographic knee OA and symptoms. [31, 32] This is further complicated by the differences in radiographic definitions of hip OA and the reproducibility of the radiographic measures. [4, 22, 33] MR imaging could therefore provide an alternative to radiographic imaging since it

allows a more detailed characterization of the OA disease process and in the current study was found to be significantly related to self-reported functional impairments.

Worse self-reported disability in individuals with acetabular cartilage lesions and association of acetabular cartilage lesions with HOOS scores, suggests that lesions in the acetabular cartilage may hold greater clinical significance than those in the femur. The reason for this is not clear from this cross-sectional analysis. Overall the prevalence of femoral cartilage lesions (61%) was greater than acetabular cartilage lesions (40%) but all of the acetabular cartilage defects were in the anterior and superior acetabular regions. Using arthroscopy, Nepple et al. reported majority of acetabular cartilage defects to be present in the anterior and superior regions. [34] Finite element modeling work has shown higher contact stresses in the anterior and superior regions than the posterior regions. [35] Further investigation in our cohort shows worse self-reported disability (results not shown) in people with femoral cartilage defects in the superior and anterior regions compared to those without femoral cartilage lesions in these subregions. Hence, it is possible that cartilage defects in the anterior and superior regions of both femur and acetabulum have greater clinical significance. Operative treatment of cartilage defects [36] in this population may reduce pain and improve function. Conservative to prevent further cartilage damage could also be considered for people with cartilage defects. Future studies in larger samples would be needed to confirm this. The results highlight the strength of MR imaging at being able to differentiate acetabular from femoral cartilage defects which would not be possible from conventional radiography.

We did not observe any association between complex labral tears or macerated labrum and disability. We also found a high proportion of our subjects (~ 88%) to have at least simple labral tear and upto 45% to have a complex labral tear or a macerated labrum. Recent studies have reported similar prevalence of 70–86% in asymptomatic population. [37] [38] Roemer et al. also did not find an association between any grade of labral tears and self-reported function in their study. [10] The labral score did show positive correlation with radiographic OA, consistent with recent literature suggesting labral tear may contribute to early OA. [39] MRI is known to offer limited sensitivity towards detecting labral lesions at the hip with arthroscopic evaluation being the gold standard. [40] However, recently optimized non-contrast hip MRI has shown favorable results. [41] The ability to visualize the labrum in our study was enhanced by the use an optimized non-contrast hip MRI protocol, using a small field of view on a 3-Tesla scanner. Surgical treatment is often recommended for labral tears [42] and future work should investigate the presence of other abnormalities which may be related to patient symptoms.

Exploratory analysis in the study showed worse hip related symptoms in subjects with BMELs, and worse self-reported pain, symptoms and function in subjects with subchondral cysts. Furthermore, worse BMEL and cyst scores were associated with worse self-reported disability in our cohort, similar to what has been found in knee OA. [12, 13] We also found higher KL grade associated with worse femoral and cartilage scores, labral scores and subchondraly cysts scores even in this cohort of individuals with mild-moderate hip OA, similar to the findings of Roemer et al.[10] Hence, radiographs may have some utility towards providing indirect evidence of tissue pathologies characteristic of OA. Considering the small number of subjects with BMELs and cysts in the study, replication of these results in larger samples is warranted.

Measures of physical performance did not show any significant relationships with MR or radiographic findings in this report. Our cohort was relatively high functioning with mean HOOS scores being > 80% across all subscales. The discordance between the relationship of hip degeneration with self-reported vs. physical function suggests that there may be an

interaction of structural, socio-economic and psychological factors which affects the magnitude of disability. [18, 43, 44] Another possibility could be that the performance based tests used here are not sensitive enough to evaluate physical function for this population. Using 3-D motion analysis techniques, it has been shown the people with mild-moderate hip OA walk with reduced joint excursion and reduced hip flexion moment in late stance. [45] Motion discontinuity (MD) in the sagittal plane has been proposed as a biomarker of hip OA since it is associated with presence and severity of hip OA. [46] It is possible that a more objective evaluation of functional movement patterns using biomechanical techniques may be more sensitive than the functional tests used in this study. Future work is needed to evaluate the association of hip MR abnormalities and biomechanical descriptors of hip movement patterns.

In this cohort of individuals with mild-moderate hip OA, we did not observe an association between center-edge or alpha angle and hip function. The prevalence of subjects with a positive posterior wall or cross-over sign was not different between +ROA and −ROA groups, or those with and without femoral or acetabular cartilage lesions. These features are common descriptors of DDH and FAI, both of which are known risk factors for development of hip OA. [47, 48] Considering the positive association of alpha angle with ROA and cartilage scores, by excluding individuals with KL = 4, it is possible that those with more severe cam-type FAI may have been excluded. Also, we excluded individuals with previous hip surgeries which would have excluded symptomatic individuals with DDH and FAI who underwent surgery, perhaps biasing our sample. Findings of DDH and FAI are not uncommon in asymptomatic individuals [21, 49] and not all these individuals progress to hip OA. [49, 50] Bony morphology, soft-tissue morphology, amount and types of physical activity) and other unknown factors are likely related to the individuals with a FAI or DDH being symptomatic or progressing to OA. [50]

This study has limitations which need to be taken into consideration while interpreting the results. Radiographic OA was defined only using KL grade since it is the most common definition of OA. Other definitions including minimum joint space width measures may lead to different findings. Also the sample size and inclusion of only individuals with mild-moderate radiographic hip OA limit the generalization of the findings. Further analysis related to the location of the different MR features including cartilage defects, BMELs, subchondral cysts and labral and functional outcomes was not done due to the small sample size. Future studies would be needed to evaluate the effect of the location of cartilage lesions etc. with pain and disability in these individuals. Also, longitudinal studies would be needed to study the effect of various tissue pathologies on symptomatic progression of hip OA.

To conclude we found that individuals with acetabular cartilage defects had greater self-reported disability compared to those without, and acetabular cartilage defects were associated with worse self-reported disability. Such differences and associations were not observed with ROA or femoral cartilage lesions. Additionally, presence of BMELs and subchondral cysts was related to greater hip related pain and disability. None of the radiographic or MR features of OA, DDH or FAI were related to physical function in this cohort. MRI may serve as a useful tool towards evaluating the effect of osteoarthritis disease process on the structure of the hip joint.

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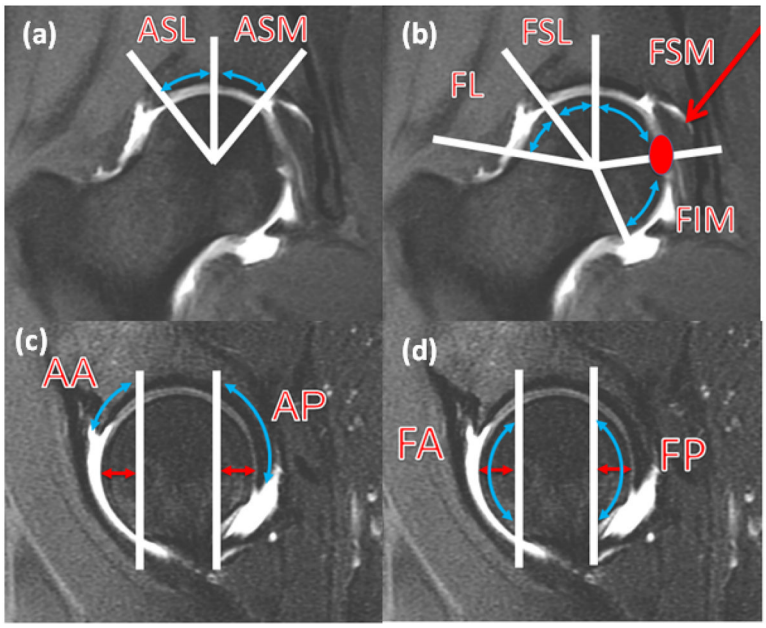

Figure 1.

Subregions of articular cartilage. for femur on coronal (a) and sagittal (c) images. Subregions for acetabulum on coronal (b) and sagittal (d) images. (a) coronal MR image demonstrating acetabular superolateral (ASL) and superomedial (ASM) subregions divided by vertical line extending from femoral head center.(b) coronal MR image demonstrating femoral lateral (FL), superolateral (FSL) and superomedial (FSM) and inferior (FIM) subregions divided by line extending from femoral head center, to the lateral acetabular rim, to straight vertical direction and to the ligamentum teres attachment. (c) sagittal MR image demonstrates acetabular anterior (AA) and posterior (AP) subregion, demarcated by vertical line 1 cm from the most anterior and posterior aspect of the femoral head. (d) sagittal MR image demonstrates femoral anterior (FA) and posterior (FP) subregion, demarcated by vertical line 1 cm from the most anterior and posterior aspect of the femoral head.

Table 1

MR sequence parameters.

Sequence	Parameters
Coronal Fast Spin Echo – T2 weighted Fat Suppressed	TR/TE = 2496/60, Echo Train Length = 16, Matrix = 288 × 224, # of slices = 16, Field of View = 20, Slice Thickness = 4, Bandwidth = 50.0, Acquisition Time = 4 min 40 sec
Sagittal Fast Spin Echo – T2 weighted Fat Suppressed	TR/TE = 3678/60, Echo Train Length = 16, Matrix = 288 × 224, # of slices = 24, Field of View = 14, Slice Thickness = 4, Bandwidth = 50.0, Acquisition Time = 4 min
Axial Fast Spin Echo – T2 weighted Fat Suppressed	TR/TE = 2800/60, Matrix = 288 × 224, # of slices = 18, Field of View = 18, Slice Thickness =3, Bandwidth = 50.0, Acquisition Time = 3 min 50 sec

Table 2

Group characteristics for age, BMI and gender distribution

	Control (n = 55)	Osteoarthritis (n = 30)	*P*	No-FemCL (n = 33)	FemCL (n = 52)	*P*	No- AceCL (n = 51)	AceCL (n = 34)	*P*
Age (years) *	43.3 (13.6)	53.9 (11.2)	**<0.001**	42.0 (13.2)	50.1 (13.3)	**0.008**	43.1 (13.8)	52.7 (11.7)	**0.001**
BMI (kg/m^2) *	23.8 (3.3)	23.8 (3.3)	0.954	23.6 (3.9)	24.0 (2.9)	0.615	23.5 (3.5)	24.4 (2.9)	0.234
Male: Female **	27:28	17:13	0.504	17:16	27:25	0.971	25:26	19:15	0.535

FemCL = cartilage lesion in the femur

AceCL = cartilage lesion in acetabulum

* P value from independent samples T-test

** P value from Chi-square test

Table 3

Mean (95 % Confidence Intervals) for self-report measures and physical function tests across groups.

		Control	Osteoarthritis	*P**	No-FemCL	FemCL	*P**	No- AceCL	AceCL	*P**
HOOS	**Symptoms**	90.0 (85.8, 94.2)	87.6 (81.6, 93.6)	0.709	92.3 (88.0, 96.6)	87.3 (82.5, 92.1)	0.265	93.6 (90.6,96.5)	83.0 (76.4, 89.7)	**0.004**
	Pain	92.0 (88.0, 96.0)	89.2 (83.0, 95.5)	0.406	92.2 (87.0, 97.5)	90.3 (85.8, 94.7)	0.549	93.7 (90.2, 97.2)	87.2 (80.9, 93.5)	**0.036**
	ADL	94.9 (91.7, 98.1)	93.0 (88.0, 97.4)	0.527	95.1 (91.2, 98.9)	93.7 (90.1, 97.3)	0.678	96.5 (94.0, 98.9)	91.0 (85.7, 96.3)	**0.037**
TUG (sec)		6.3 (5.9, 6.7)	6.4 (6.0, 6.7)	0.387	6.4 (5.9, 6.9)	6.3 (6.0, 6.6)	0.232	6.3 (5.9,6.6)	6.4 (6.0, 6.8)	0.671
YBT (cm)	**Posteromedial**	3.8 (2.9,4.7)	3.5 (2.3, 4.7)	0.460	3.2 (2.0, 4.4)	4.0 (3.1, 4.9)	0.421	3.4 (2.5, 4.3)	4.1 (2.9, 5.3)	0.432
	Posterolateral	4.6 (3.5, 5.8)	5.5 (3.7, 7.3)	0.927	4.1 (3.0, 5.3)	5.5 (4.1, 6.9)	0.387	4.8 (3.6, 5.9)	5.2 (3.4,7.0)	0.747

FemCL = cartilage lesion in the femur

AceCL = cartilage lesion in acetabulum

* *P* values adjusted for age.

Table 4

Non-parametric Spearman's ρ correlations and associated *P* values between KL score, MR findings and functional measures.

		HOOS			Y Balance Test	
	Timed Up and Go Test	**Symptoms**	**Pain**	**ADL**	**Posteromoedial**	**Posterolateral**
KL Score	0.15 (0.216)	−0.17 (0.147)	−0.12 (0.307)	−0.12 (0.287)	0.07 (0.58)	0.05 (0.704)
Total Femoral Cartilage Score	0.04 (0.741)	−0.22 (0.058)	−0.17 (0.146)	−0.2 (0.055)	0.14 (0.247)	0.06 (0.626)
Total Acetabular Cartilage Score	0.11 (0.328)	**−0.34 (0.003)**	**−0.25 (0.026)**	**−0.32 (0.004)**	0.16 (0.179)	−0.01 (0.970)
Total Labral Score	−0.05 (0.658)	−0.18 (0.126)	−0.10 (0.378)	−0.12 (0.316)	0.10 (0.437)	0.10 (0.443)
Total BMEL Score	0.06 (0.595)	**−0.26 (0.021)**	**−0.29 (0.010)**	**−0.23 (0.041)**	−0.008 (0.949)	0.21 (0.084)
Total Subchondral Cyst Score	0.15 (0.199)	**−0.35 (0.001)**	**−0.37 (0.001)**	**−0.31 (0.006)**	0.11 (0.360)	0.11 (0.38)

KL = Kellgren- Lawrence grade; BMEL = Bone Marrow Edema Lesion; HOOS = Hip osteoarthritis outcome score; ADL = Activities of Daily Living

Table 5

Prevalence of different pathologies in controls and hip OA, and different cartilage lesion groups. *P* values are from chi-square tests.

	Control	Osteoarthritis	*P*	No-FemCL	FemCL	*P*	No- AceCL	AceCL	*P*
Cartilage Lesion Femur (%)	54.6	73.3	0.089	NA	NA	NA	37.3	97.1	**<0.001**
Cartilage Lesion Acetabulum (%)	30.9	56.7	**0.021**	3.0	63.5	**<0.001**	NA	NA	NA
Complex Labral Tear or maceration (%)	40.0	53.3	0.237	33.3	51.9	0.093	35.3	58.8	**0.033**
BMEL (%)	10.9	23.3	0.128	0	25	**0.002**	**2.0**	**35.3**	**<0.001**
Subchondral Cyst (%)	9.1	26.7	**0.031**	3.0	23.1	**0.012**	**3.9**	**32.4**	**<0.001**

FemCL = cartilage lesion in the femur

AceCL = cartilage lesion in acetabulum