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Using the Scoring Hip Osteoarthritis With Magnetic Resonance Imaging (SHOMRI) System to Assess Intra-articular Pathology in Femoroacetabular Impingement

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Abstract

There is currently no widely accepted classification system of intra-articular damage in the setting of femoroacetabular impingement (FAI). The goal of this study is to correlate the Scoring Hip Osteoarthritis with Magnetic Resonance Imaging (SHOMRI) system with arthroscopic findings in symptomatic FAI patients to justify its use in this setting. Symptomatic FAI patients scheduled for hip arthroscopy were prospectively enrolled. Prior to surgery, radiographs, and an MRI were obtained of the affected hip and all patients completed the Hip disability and Osteoarthritis Outcome Score (HOOS) questionnaire. Each MRI was graded using the SHOMRI system. Intraoperatively, cartilage and labral injury grades were recorded. SHOMRI scores were then correlated with the intraoperative cartilage and labral grades as well as preoperative radiographic findings and HOOS scores. Forty-three patients were analyzed (mean age 35.7 years, 58.1% male). SHOMRI total scores correlated with intraoperative femoral cartilage grade ($\rho = 0.42$; $p = 0.002$), acetabular cartilage grade ($\rho = 0.30$; $p = 0.046$), and labral tear grade ($\rho = 0.42$; $p = 0.003$) as well as with preoperative Tönnis grade ($\rho = 0.37$, $p = 0.013$), HOOS pain score ($\rho = -0.33$; $p = 0.039$), HOOS ADL score ($\rho = -0.39$; $p = 0.007$), and HOOS sports score ($\rho = -0.30$; $p = 0.037$). In conclusion, total scores from the SHOMRI system showed significant correlation with arthroscopic findings as well as radiographic gradings and clinical symptoms in patients with FAI. Use of this quantitative system to assess the burden of chondrolabral damage in FAI appears valid.

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AUTHORS' CONTRIBUTIONS

TG is responsible for data curation, formal analysis, methodology, writing original draft, coordinating manuscript revisions, and implementing feedback from all authors. Will be first listed author. JN Assisted in conceptualization of project, data collection, methodology, revising draft. MAS has significant role in conceptualization of project, data collection, methodology, revising draft. RBS had supervisory role conceptualization of project, data collection, formal analysis, and investigation as well as assistive role in manuscript review/editing. SM responsible for conceptualization of project. Revised and targeted both the research question and project structure. TML supervised with imaging-based data collection and analysis and development of the quantitative system used in this study. ALZ Served as principle investigator, had leadership role in project initiation, refining the research question, identifying deficits in the literature, guiding project goals, ensuring proficient project methodology, and coordinating manuscript feedback and revisions.

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Keywords

femoroacetabular impingement; hip arthroscopy; magnetic resonance imaging; osteoarthritis

Over the past decade, non-arthroplasty treatment of intra-articular hip pathology has become more common as surgeons emphasize preservation of the native hip joint.[1–6] In particular, the incidence of hip arthroscopy has increased considerably, rising 250% between 2007 and 2011.[4] While hip arthroscopy is used to treat multiple hip pathologies,[7,8] its success in treating Femoroacetabular Impingement (FAI) is a large contributor to its growing popularity.[7,9,10] FAI is an increasingly recognized and treated condition involving abnormal morphologies of the femur and/or acetabulum that can damage the labrum and articular cartilage during physiologic hip motion,[11] and is considered a risk factor for the early development of degenerative hip arthritis.[12] Despite consistent evidence that hip arthroscopy can improve symptoms and function in FAI patients,[10] older patients and those with more advanced degenerative changes have less favorable outcomes postoperatively involving a higher rate of revision arthroscopy, continued pain, and earlier conversion to total hip arthroplasty (THA).[13–16] Appropriate patient selection thus remains a controversial but crucial part of FAI treatment, and characterizing the extent of joint damage preoperatively is needed when considering the benefits of hip arthroscopy for this population.

Multiple radiographic classification systems have been developed to quantify degenerative changes occurring in the hip, including the Kellgren–Lawrence and Tönnis classifications.[17,18] While these systems are often applied to the FAI population to assess the extent of joint degeneration, they emphasize late-stage osseous changes and remain insensitive to the soft tissue, cartilage, and labral changes that occur during the early stages of symptomatic FAI.[19] In comparison, magnetic resonance imaging (MRI) is a well-known imaging modality capable of accurately diagnosing soft tissue changes that occur in FAI.[20] However, widespread use of MRI-based classification schemes that stratify joint degeneration and help guide treatment decisions is lacking.

In 2015, the Osteoarthritis Research Society International (OARSI) set forth the most recent recommendations for hip imaging in research trials.[21] This report noted that while the use of MRI-based semi-quantitative scoring systems for knee osteoarthritis has been very successful in evaluating disease progression, the use of such systems in the hip remains limited. It thus advocates for use of such systems, including the Scoring Hip Osteoarthritis with Magnetic Resonance Imaging (SHOMRI) system, whenever possible in hip research. SHOMRI is a newly-developed, MRI-based tool designed to quantify the burden and progression of intra-articular changes that occur with hip osteoarthritis.[22] It has been shown to have excellent reproducibility and to correlate well with radiographic signs of hip arthritis as well as patient reported outcomes.[22,23]

While the SHOMRI system has never been used to characterize hip damage in FAI patients, expanding its use to this population may improve patient selection for hip arthroscopy and guide postoperative expectations. However, it remains unclear if this system accurately reflects degenerative joint changes in the FAI population. As such, the objective of this study is to utilize the SHOMRI system to assess intraarticular pathology in symptomatic FAI

patients and to correlate the SHOMRI scores with chondrolabral changes found during hip arthroscopy. We postulate that worsening SHOMRI scores will demonstrate significant correlations with more severe arthroscopic chondrolabral grades, radiographic changes, and patient reported outcome scores, and will justify the future use of this system in the FAI population.

MATERIALS AND METHODS

Patient Cohort

Patients were prospectively enrolled from the institution's hip preservation clinic for study inclusion after approval from the Institutional Review Board (IRB). Criteria for study inclusion involved patients with: (i) cam-type or cam-predominant mixed-type FAI; (ii) ages 18 years to 50 years; (iii) Body Mass Index (BMI) less than 30 kg/m^2; (iv) Lateral Center Edge Angle (LCEA)>20 degrees; and (v) hip pain or dysfunction refractory to at least 6-weeks of conservative therapies including activity modification, physical therapy, and/or corticosteroid injections. Patients were excluded if they had radiographic evidence of advanced arthritis (Tönnis grade 2 or higher) or had a history of prior hip surgery. Demographic data including age, gender, and BMI were recorded for all patients.

Image Acquisition

Complete radiographs of the affected hip including anteroposterior, frog lateral, and 45-degree Dunn lateral views were obtained on all patients. 3.0T MRI scans of the affected hip were also obtained prior to surgery using an 8-channel cardiac coil (GE Healthcare, Waukesha, WI). The MRI protocol included triplanar 2D intermediate-weighted (IW) fat-saturated fast spin echo (FSE).[22]

Image Grading

Hip radiographs were analyzed and both alpha angle (on Dunn lateral view) and Tönnis grade were recorded. Each MRI was then scored using the SHOMRI system. Three board certified radiologists, who were blinded to patient history and symptom severity, performed the image analyses. Each radiologist had at least 5-year of musculoskeletal experience and at least 2-year of experience using SHOMRI, including a 4-week initial consensus training meant to calibrate and standardize readings. Such consensus training has previously shown to produce excellent intra-reader and inter-reader correlation (Intra-Class Correlation Coefficient >0.9) for SHOMRI readings in both arthritic and non-arthritic patients.[22,23]

SHOMRI System

The SHOMRI system has been described previously but in brief involves the ordinal scoring of eight features of the hip joint including articular cartilage lesions, bone marrow edema pattern, subchondral cysts, labral abnormalities, paralabral cysts, intrarticular loose bodies, joint effusion, and ligamentum teres abnormalities.[22] The articular cartilage, bone marrow edema pattern, and subchondral cyst scores were determined for each of 10 subregions of the hip joint (four acetabular and six femoral), and added to create a total subscore in each category. The labrum score was graded in four different subregions, and added to create a total labrum subscore. A single paralabral cyst, intra-articular loose bodies, joint effusion,

and ligamentum teres subscore was determined for the entire hip joint. Subsequently, all eight subscores were added to create a total SHOMRI score, with higher scores reflecting a more severe magnitude of hip degeneration (Table 1).

Symptom Assessment

All patients completed the Hip disability and Osteoarthritis Outcome Score (HOOS) questionnaires preoperatively. These HOOS questionnaires produce scores in five separate subscales: pain, symptoms, activities of daily living (ADLs), sport, and recreation function (sports), and hip related quality of life (QOL). Each subscale ranges from 0 to 100, with higher scores representing a better clinical status in that category. Originally intended to quantify symptom improvement after hip replacement,[24] the HOOS questionnaires have since been validated for use in patients with FAI who have consistently demonstrated worse scores than non-FAI controls.[25,26]

Surgical Protocol

Arthroscopic treatment was subsequently performed for all patients as standard of care for their indicated pathology, including osteochondroplasty, labral debridement, labral repair, microfracture of chondral defects, or loose body removal as needed. All procedures were performed with the patient in the supine position by a single surgeon board-certified in Sports Medicine (Initials-blinded for review). After placement of standard mid-anterior and anterolateral portals, a diagnostic arthroscopy was performed and both femoral and acetabular cartilage as well as labral injury grades were recorded using the Beck classification.[27] Originally developed for use during open surgical dislocation of the hip, the Beck classification has since been demonstrated to have substantial interobserver and intraobserver reliabilities in hip arthroscopy.[28] Higher grades on the Beck scale portend worse subjective outcomes and hip function postoperatively.[29] The Beck scale grades labral damage as (0) normal, (1) degeneration, (2) full thickness tear, (3) detachment, and (4) ossification whereas it grades articular cartilage as (0) normal, (1) malacia, (2) debonding, (3) cleavage, and (4) full defect.[28]

Statistical Analysis

SHOMRI total and sub-scores were correlated with the intraoperative cartilage and labral grades in addition to patient age, preoperative Tönnis grades, and preoperative HOOS scores. Spearman rank correlation coefficients were obtained, and all significant correlations were determined. All statistical analyses were performed using STATA software (Version 15.0; Statacorp, College Station, TX), with significance set to $p < 0.05$. A power analysis was performed a priori to determine the sample size needed for a moderate Spearman correlation ($\rho > 0.4$), which was previously demonstrated using SHOMRI scores for patients with osteoarthritis.[22] Based on an alpha of 0.05, a power of 0.80, and a r of 0.4 using a one-tailed test, a sample size of 38 was required to identify such a relationship should one exist.

RESULTS

Baseline Characteristics

A total of 43 patients met inclusion and exclusion criteria and were analyzed (mean age 35.7 years, mean BMI 23.8 kg/m^2, 58.1% male) (Table 2). The mean SHOMRI total score for all patients was 11.7 (range 2–38). All patients had labral tears, including 45.7% grade 2 tears and 54.3% grade 3 tears. There were 60.5% patients with Tönnis grade 0 and 39.5% patients with Töonnis grade one hip radiographs.

Correlations With Age, Symptoms, and Radiographic Findings

Both the labrum subscores and total scores from the SHOMRI system correlated well with clinical symptoms and radiographic Tönnis grade (Table 3). Specifically, the SHOMRI labrum subscores demonstrated significant correlation with the HOOS pain scale (ρ = – 0.50; p < 0.001), the HOOS ADL scale (ρ = – 0.47; p < 0.001), the HOOS sports scale (– 0.38, p 0.01), and the Tönnis grade (0.31, p = 0.038). Similarly, the SHOMRI total score demonstrated significant correlation with the HOOS pain scale (ρ = – 0.33; p = 0.039) (Fig. 1, the HOOS ADL scale (ρ = – 0.36; p = 0.007), the HOOS sports scale (ρ = – 0.30, p = 0.037), and the Tönnis grade (ρ = 0.47, p < 0.001) (Fig. 2). There were also strong correlations between age and multiple SHOMRI scores, including the articular cartilage score (ρ = 0.48, p < 0.001), labrum subscore (ρ = 0.49, p < 0.001), and total score (ρ = 0.57, p < 0.001). Other significant correlations included the articular cartilage subscore with alpha angle (ρ = 0.42, p = 0.001) and Tönnis grade (ρ = 0.43, p = 0.001); the bone marrow edema subscore with the HOOS ADL scale (ρ = —0.23, p = 0.045); and the subchondral cyst score with the HOOS pain scale (ρ = 0.22, p = 0.024) (Table 3).

Correlations With Arthroscopic Findings

The articular cartilage SHOMRI subscore demonstrated significant correlation with intraoperative femoral cartilage (ρ = 0.38, p = 0.006), acetabular cartilage (ρ = 0.36, p = 0.005), and labral tear grades (ρ = 0.50, < 0.001). Similarly, the total SHOMRI score correlated well with intraoperative femoral cartilage (ρ = 0.42, p = 0.002) (Fig. 3), acetabular cartilage (ρ =0.30, p = 0.046), and labral tear grades (ρ = 0.42, p = 0.003). Other significant correlations with intraoperative findings included the bone marrow edema subscore with acetabular cartilage grade (ρ = 0.47, p < 0.001) and labral tear grade (ρ =0.33, p = 0.013); the subchondral cyst subscore with acetabular cartilage grade (ρ = 0.49, p < 0.001); and the labrum subscore with femoral cartilage grade (0.42, p = 0.005) (Table 4).

DISCUSSION

Hip arthroscopy is an increasingly common procedure that has demonstrated consistent success in the treatment of Femoroacetabular Impingement (FAI), although proper patient selection for this procedure remains a controversial challenge.[1–8] While evidence suggests certain patient characteristics such as older age and more advanced degenerative changes portend worse postoperative outcomes,[15,16] there is no widespread scoring system used to guide patient selection for hip arthroscopy. The present study validates the Scoring Hip Osteoarthritis with Magnetic Resonance Imaging (SHOMRI) scoring system for future

investigations in the FAI population, as it shows significant correlation with degenerative changes seen on direct visualization during arthroscopy as well as with preoperative radiographic findings and clinical symptom scores.

The SHOMRI system was developed in 2015 as a non-invasive, MRI-based, quantitative tool meant to characterize the degenerative changes of hip osteoarthritis and monitor disease progression.[22] While another MRI scoring system, the Hip Osteoarthritis MRI Scoring (HOAMS) system, had been developed previously, this system did not demonstrate significant correlations with clinical symptoms and was burdensome as it required the grading of over a dozen hip characteristics.[22,30] The SHOMRI system was thus designed to include eight of the most cardinal features of hip osteoarthritis, and was shown to have moderate to excellent reproducibility, in addition to significant correlations with clinical parameters and radiographic findings for patients with hip osteoarthritis.[22] Despite the promising use of SHOMRI in osteoarthritis and its ability to assess longitudinal disease progression,[23] its ability to characterize hip joint damage related to FAI has never been explored.

Currently, evidence suggests outcomes after hip arthroscopy for FAI are best for younger patients,[15,16] patients with lower Tönnis grades,[31] and those with less severe cartilage injury grades seen during arthroscopy.[13,29,32] While age and radiographs are easily obtained prior to surgery and can help guide appropriate patient selection for this procedure, arthroscopic grading of chondrolabral damage is only possible after proceeding with surgery. As such, patients found to have advanced chondrolabral degeneration during arthroscopy may have undergone a surgical procedure that ultimately offers limited benefit, and may not alter their trajectory toward total hip arthroplasty (THA).[16] However, the significant correlations between the SHOMRI system and arthroscopic findings (in addition to radiographic and clinical parameters) found in this study suggest this quantitative system may serve as a non-invasive proxy for chondrolabral changes in FAI patients, and could assist in guiding surgical decision-making, expectations, and prognosis.

While multiple subscores of the SHOMRI system demonstrated significant correlations with various patient characteristics, the total SHOMRI score was correlative with multiple parameters including clinical symptoms (HOOS pain, ADL, and sports scales), arthroscopic findings (femoral cartilage, acetabular cartilage, and labral tear grades), and radiographic changes (Tönnis grade). The total SHOMRI score represents the sum of all eight subscores, including articular cartilage lesions, bone marrow edema pattern, subchondral cysts, labral abnormalities, paralabral cysts, intra-articular loose bodies, joint effusion, and ligamentum teres abnormalities.[22] The significant correlations demonstrated with total SHOMRI score are thus logical, as it is a parameter that represents an aggregation of the overall magnitude of the degenerative process in the hip joint. Furthermore, worsening total scores (in addition to articular cartilage and labral subscores) strongly correlated with advancing patient age, which further validates this system in the FAI population as older age is a known predictor of more severe degenerative changes.

The present study is strengthened by the utilization of a quantitative MRI-based classification system known to involve excellent interobserver and intraobserver reliability.

[22,23] It is also the first to apply this quantitative system to a large cohort of patients with FAI, and to correlate it with arthroscopic findings that are known to accurately predict outcomes after hip arthroscopy.[29] However, this study is limited by its exclusion of patients with more advanced stages of radiographic arthritis, which was necessary as these patients were not eligible for hip arthroscopy. Furthermore, the SHOMRI measurements were performed by three separate musculoskeletal radiologists, and no specific inter-rater or intra-rater reliabilities were determined for this FAI population. However, each radiologist had at least 2 years of familiarity with SHOMRI, including an initial consensus training that has been previously shown to produce excellent intrareader and inter-reader correlation for both arthritic and non-arthritic patients.[22,23] This study also lacks long-term postoperative outcomes including rates of conversion to THA, radiographic progression of degeneration, and postoperative symptom assessment. However, the goal of the current study is to validate the use of SHOMRI in the FAI population. Future studies will be aimed to characterize how preoperative SHOMRI scores predict outcomes after hip arthroscopy to further define its role in guiding optimal patient selection for this procedure. It is possible that SHOMRI scores may be a more sensitive predictor for outcomes after hip arthroscopy than Tönnis grade. Investigations should also establish the ability of the SHOMRI system to longitudinally assess the progression of degenerative changes in FAI with and without arthroscopy. Such a tool would be invaluable in determining if hip arthroscopy successfully alters the natural history of this condition, in addition to its known benefit of improving pain and function.

CONCLUSION

Total scores from the SHOMRI system showed significant correlation with arthroscopic findings as well as radiographic gradings and clinical symptoms in patients with FAI. Use of this quantitative scoring system to assess the burden of chondrolabral damage in the FAI population appears valid, and warrants further longitudinal investigation.

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Figure 1.
Correlation of preoperative Hip disability and Osteoarthritis Outcome Score (HOOS) pain scores with SHOMRI total scores. A HOOS score of 100 is normal, with lower HOOS scores suggest worsening clinical status in this category.

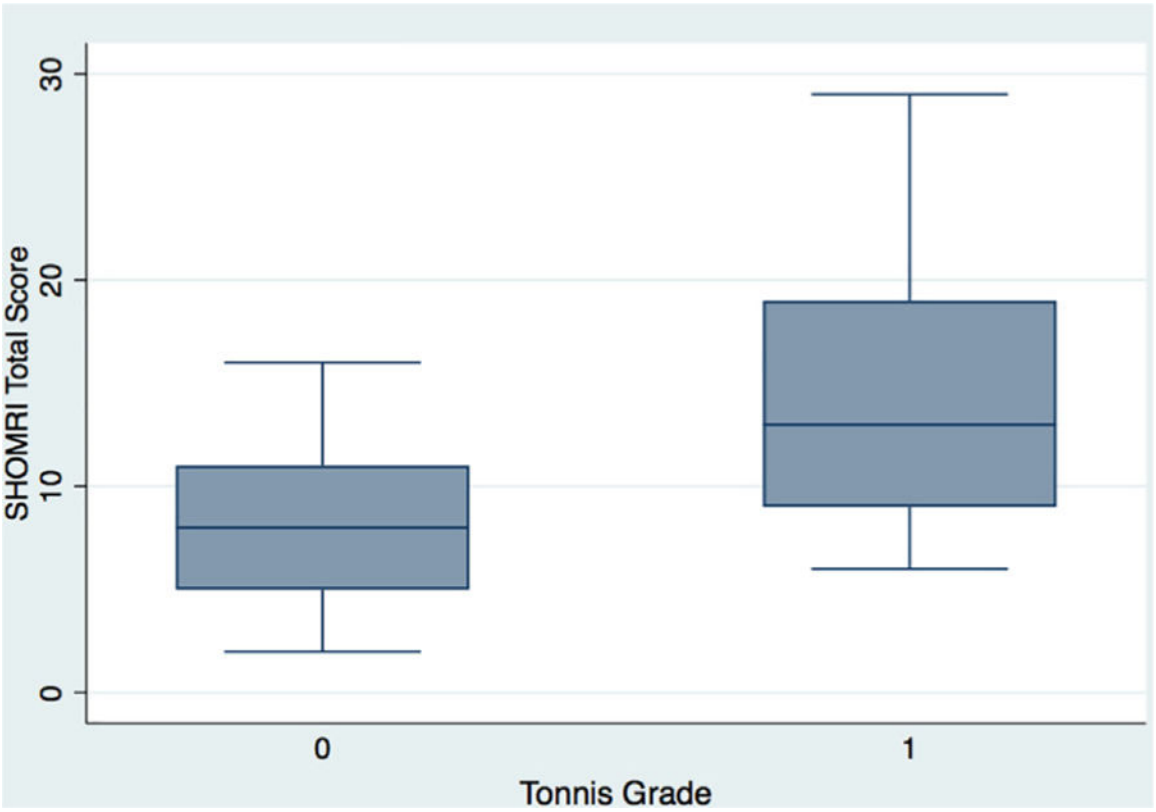

Figure 2.

SHOMRI total scores for patients with Tönnis Grade 0 (normal) and Tönnis Grade 1 (mild sclerosis of femoral head and acetabulum, mild joint space narrowing) on preoperative hip radiographs.[31]

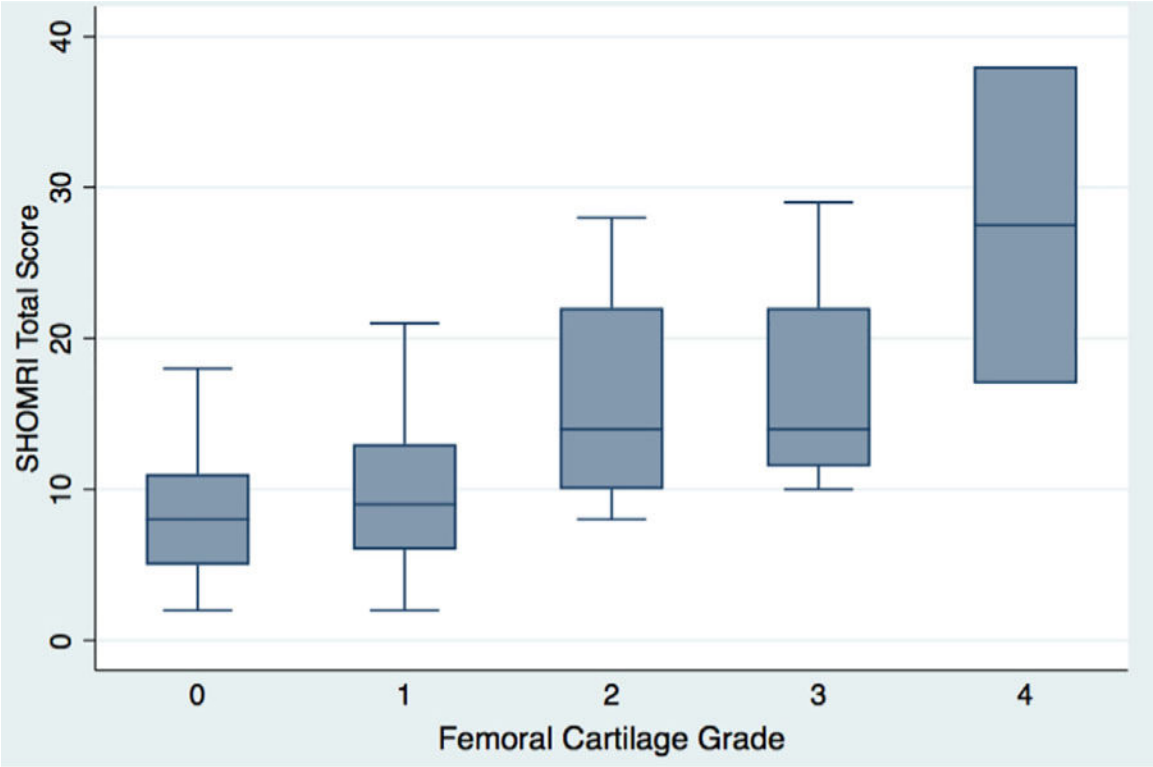

Figure 3.
SHOMRI total scores for progressive femoral cartilage grades observed arthroscopically using the Beck classification.[28]

Table 1.

Guide to the Scoring Hip Osteoarthritis With MRI (SHOMRI) System

		Description of Scores							
Subscore Categories	**Range**	**0**	**1**	**2**	**3**	**4**	**5**	**Number of Sub-Regions[a]**	**Total Subscore**
Articular cartilage	0–2	No Loss	Partial Thickness Loss	Full thickness loss	–	–	–	10[a]	0–20
Bone marrow edema pattern	0–3	No Lesion	Lesion < than 0.5 cm	Lesion 0.5–1.5 cm	Lesion >1.5 cm	–	–	10[a]	0–30
Subchondral cysts	0–2	Absent	<0.5 cm	>0.5 cm		–	–	10[a]	0–20
Labrum	0–5	Normal	Abnormal signal or fraying	Simple tear	Labro-cartilage separation	Complex tear	Maceration	4[b]	0–20
Paralabral cysts	0 or 1	Absence	Presence	–	–	–	–	N/A	0–1
Intra-articular bodies	0 or 1	Absence	Presence	–	–	–	–	N/A	0–1
Effusion/synovitis	0 or 1	Absence	Presence	–	–	–	–	N/A	0–1
Ligamentum teres	0–3	Normal	Signal abnormalities or fraying	Partial tear	Complete tear	–	–	N/A	0–3
Total score									0–96

[a]Articular cartilage, bone marrow edema pattern, subchondral cyst scores were made in each of four acetabular and six femoral sub-regions, as described previously.

[b]Labrum scores were made in four sub-regions, as described previously.[22]

Table 2.

Demographic and Surgical Data

	Mean (SD)
Number of patients	43
Age (years)	35.7 (10.1)
BMI (kg/m^2)	23.8 (3.0)
Male	58.1%
Alpha angle (degrees)	61.9 (4.8)
LCEA (degrees)	33.3 (6.2)
Labral tear grade	3 (2–3)[a]
Tonnis€grade	0 (0–1)[a]
Acetabular cartilage grade	3 (2–3)[a]
Femoral cartilage grade	1 (0–1)[a]

[a]Median (Interquartile Range); BMI, body mass index; LCEA, lateral center edge angle.

Table 3.

Spearman Rank Correlation Coefficients (*p*-value) Between SHOMRI Scores and Age, Patient Reported Outcomes, and Radiographic Findings

		Patient Reported Outcomes			Radiographic Findings		
SHOMRI Feature	**Age**	**HOOS Pain**	**HOOS ADL**	**HOOS Sports**	**Alpha Angle**	**Lateral CEA**	**Tönnis Grade**
Articular cartilage score	**0.48 (<0.001)**	−0.10 (0.57)	−0.14 (0.40)	−0.23 (0.14)	**0.42 (0.001)**	0.02 (0.91)	**0.43 (0.001)**
Bone marrow edema score	0.09 (0.61)	−0.15 (0.25)	**−0.23 (0.045)**	−0.19 (0.12)	0.11 (0.44)	−0.04 (0.79)	0.13 (0.41)
Subchondral cyst score	0.01 (0.94)	**0.22 (0.024)**	0.08 (0.45)	0.065 (0.64)	0.18 (0.11)	−0.05 (0.78)	0.09 (0.56)
Labrum score	**0.49 (<0.001)**	**−0.50 (<0.001)**	**−0.47 (<0.001)**	**−0.38 (0.01)**	−0.20 (0.19)	0.15 (0.40)	**0.31 (0.038)**
Total score	**0.57 (<0.001)**	**−0.33 (0.039)**	**−0.36 (0.007)**	**−0.30 (0.037)**	0.12 (0.45)	0.13 (0.46)	**0.47 (<0.001)**

p-value listed in parenthesis; SHOMRI, scoring hip osteoarthritis with magnetic resonance imaging; CEA, center edge angle; HOOS, hip disability and osteoarthritis outcome score; ADL, activities of daily living. Bold values in table represent statistically significant values.

Table 4.

Spearman Rank Correlation Coefficients (*p*-value) Between SHOMRI Scores and Intraoperative Findings

	Intraoperative Findings		
SHOMRI Feature	**Femoral Cartilage Grade**	**Acetabular Cartilage Grade**	**Labrum Grade**
Articular cartilage score	**0.38 (0.006)**	**0.36 (0.005)**	0.50 (<0.001)
Bone marrow edema score	0.21 (0.18)	**0.47 (<0.001)**	**0.33 (0.013)**
Subchondral cyst score	0.07 (0.43)	**0.49 (<0.001)**	0.26 (0.085)
Labrum score	**0.42 (0.005)**	0.12 (0.48)	0.09 (0.58)
Total score	**0.42 (0.002)**	**0.30 (0.046)**	**0.42 (0.003)**

p-value listed in parenthesis; SHOMRI, Scoring Hip Osteoarthritis with Magnetic Resonance Imaging. Bold values in table represent statistically significant values.