Do Larger Acetabular Chondral Defects Portend Inferior Outcomes in Patients Undergoing Arthroscopic Acetabular Microfracture? A Matched-Controlled Study

Edwin O. Chaharbakhshi, B.S., David E. Hartigan, M.D., John D. Spencer, B.A., Itay Perets, M.D., Ajay C. Lall, M.D., M.S., and Benjamin G. Domb, M.D.

Purpose: To elucidate the effect, if any, of acetabular chondral defect size on surgical outcomes after arthroscopic microfracture was performed with concomitant treatment for labral tears and femoroacetabular impingement (FAI) syndrome. **Methods:** The study period was between February 2008 and November 2014. Data were collected on patients who underwent hip arthroscopy. The inclusion criteria were acetabular microfracture; concomitant treatment for labral tears and FAI syndrome; and preoperative modified Harris Hip Score, Nonarthritic Hip Score, Hip Outcome Score—Sports Specific Subscale, and visual analog scale. Exclusion criteria were Workers' Compensation, preoperative Tönnis grade >1, or previous ipsilateral hip surgeries or conditions. Patients were grouped based on smaller chondral defects (SCDs) or larger chondral defects (LCDs), then matched 1:1 by age at surgery ±10 years, sex, body mass index ±5, labral treatment, capsular treatment, acetabuloplasty, and femoroplasty. Outcomes, secondary arthroscopies, and conversions to total hip arthroplasty (THA) were documented. **Results:** Of 131 eligible cases, 107 (81.7%) had minimum 2-year follow-up. Before matching, the conversion rate to THA was higher for LCDs (24.6%) than for SCDs (12.0%). Thirty-five patients were matched for each group. Mean follow-up time was 47.9 months (range, 24.0, 84.1) for the matched LCD group and 46.1 months (range, 24.0, 88.1) for the matched SCD group. Ligamentum teres debridement ($P = .03$) was performed more frequently in the LCD group. No other differences were found regarding demographics, intraoperative findings, procedures, traction time, preoperative scores, or follow-up scores. Both groups demonstrated significant improvements in all scores. Rates of revision or conversion to THA were similar between groups. The relative risk for conversion to THA was 2.33 for patients with defects $\geq$300 mm^2 compared with patients with defects $\leq$250 mm^2 ($P = .13$). Deep vein thrombosis occurred in 3 (5.3%) patients with LCDs. **Conclusions:** Matched patients with either SCDs or LCDs undergoing arthroscopic acetabular microfracture with concomitant treatment for labral tears and FAI syndrome demonstrated similar improvements at minimum 2-year follow-up. Patients with chondral defects approaching 300 mm^2 or greater may have a higher propensity toward conversion to THA. **Level of Evidence:** Level III, retrospective comparative therapeutic trial.

See commentary on page 2048

If left untreated, intra-articular chondral defects may lead to osteoarthritis and joint degeneration.[1] These defects generally have a low probability of healing without intervention. In the field of hip arthroscopy, it is understood that chondral defects are mostly a result of the complex interplay of several factors: femoroacetabular impingement (FAI) syndrome, trauma, genetics, inflammatory pathology, instability, chronic

From the American Hip Institute (E.O.C., J.D.S., I.P., A.C.L., B.G.D.), Westmont; and Loyola Stritch College of Medicine (E.O.C., J.D.S.), Chicago, Illinois; Department of Orthopedic Surgery and Sports Medicine, Mayo Clinic (D.E.H.), Phoenix, Arizona, U.S.A.; and Hadassah Hebrew University Hospital (I.P.), Jerusalem, Israel.

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Address correspondence to Dr. Benjamin G. Domb, American Hip Institute, 1010 Executive Court, Ste 250, Westmont, IL 60559, U.S.A. E-mail: DrDomb@americanhipinstitute.org

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microinstability, and/or articular pathology. Both the presence and severity of chondral defects have been associated with relatively inferior outcomes after hip arthroscopy.[2,3] Accordingly, there has been growing interest in both refining conventional and formulating new treatment options for these defects to maximize patient benefit.

There is currently no clearly established algorithm for addressing chondral defects in the hip. Notably, arthroscopic acetabular microfracture has become an increasingly popular treatment option for smaller full-thickness chondral defects, especially focal defects <400 mm^2 in area.[4] Philippon et al.[5] observed 95% to 100% coverage of previous isolated acetabular chondral damage after treatment with microfracture, and similar results were reported by Karthikeyan et al.[6] Significant improvements preoperatively to short-term follow-up have also been reported in case series and matched studies.[7-10] However, there is currently no controlled study in the literature that has examined the effect of acetabular chondral defect size on the outcomes of hip arthroscopic microfracture.[11,12] Furthermore, the literature search performed for the present study yielded no results regarding size criteria for classifying a chondral defect as small, average, or large.

The purpose of this study was to elucidate the effect, if any, of acetabular chondral defect size on surgical outcomes after arthroscopic microfracture was performed with concomitant treatment for labral tears and FAI syndrome. We hypothesized that patients with larger chondral defects (LCDs; $\geq$200 mm^2) have inferior outcomes after microfracture compared with those with smaller chondral defects (SCDs; $\leq$150 mm^2).

Methods

Patient Selection Criteria

Data were collected and retrospectively reviewed on all patients reported on in this study. The study period was defined to be between February 2008 and November 2014. The inclusion criteria were as follows: hip arthroscopy with acetabular microfracture; full-thickness acetabular chondral defect (Outerbridge grade 4); concomitant treatment for labral tears and FAI syndrome; and preoperative patient-reported outcomes scores including modified Harris Hip Score (mHHS), Nonarthritic Hip Score (NAHS), Hip Outcome Score—Sports Specific Subscale (HOS-SSS), and visual analog scale (VAS). The exclusion criteria for possible confounding variables were Workers' Compensation claims, preoperative Tönnis osteoarthritis grade >1, avascular necrosis, slipped capital femoral epiphysis, rheumatoid arthritis, systemic lupus erythematosus, frank dysplasia, or previous ipsilateral hip surgery. All patients participated in the American Hip Institute Hip Preservation Registry. While the present study represents a unique analysis, data on some patients in this study may have been reported in other studies. All data collection received Institutional Review Board approval.

Grouping and Matching

Patients were first grouped based on smaller ($\leq$150 mm^2) or larger ($\geq$200 mm^2) chondral defects. The following criteria were used to perform 1:1 matching between groups: age at surgery $\pm$10 years, sex, body mass index (BMI) $\pm$ 5, labral treatment type, capsular treatment type, acetabuloplasty, and femoroplasty. To limit possible bias, matching was performed blinded to all data points except the matching criteria. The matched patients' data were then retrieved for analysis.

Clinical Evaluation

All patients were examined by the senior surgeon (B.G.D.). A comprehensive physical examination was conducted to evaluate range of motion (ROM), strength, and instability. The anterior, lateral, and posterior impingement tests were used to aid in diagnosis of labral tears and FAI syndrome. Anterior capsular laxity was evaluated for via the dial test, with the hip in extension and in the supine position.[13] The leg was internally rotated, released, and allowed to externally rotate. The dial test was considered positive if the external rotation of the symptomatic hip was greater when compared with that of the contralateral leg. Anterior apprehension was tested with the patient in the prone position, hip externally rotated, and anterior force directed such that the femoral head was translated anteriorly. Pain was indicative of a positive test result.

All patients underwent standard pre- and postoperative radiographic evaluation including anteroposterior pelvis in both supine and upright positions, Dunn view, and false profile view. The anteroposterior pelvis radiograph was used to measure the lateral center-edge angle of Wiberg; evaluate joint space; and assess for crossover sign, prominent ischial spine sign, and posterior wall sign. The Dunn radiograph was used to measure the alpha angle, with measurements $>60^\circ$ suggesting femoral cam-type deformities. All measurements were performed using GE Healthcare's Picture Archiving and Communication System (GE-PACS; Fairfield, CT). Radiographs were scrutinized and graded for signs of osteoarthritis using the Tönnis scale. All patients underwent preoperative magnetic resonance arthrogram to assist in confirming the diagnosis of labral tear and FAI syndrome and to further evaluate the hip for intra- and extra-articular pathologies.

Indications for Hip Arthroscopy

Prior to recommendation for surgery, all patients in this study first underwent conservative treatment including a combination of rest, nonsteroidal

anti-inflammatory drugs, and at least 3 months of physical therapy. The patients with continued symptoms and evidence of labral tears and FAI syndrome, who had also failed the period of conservative treatment, were recommended for arthroscopic intervention by the senior surgeon.

Surgical Technique

The specifics of the procedure have been described elsewere.[14] Prophylaxis for deep vein thrombosis (DVT) was not routinely administered. In brief, arthroscopy was performed with each patient in the modified supine position. Two or more portals were established, primarily including standard midanterior and anterolateral portals. The capsule was cut parallel to the labrum using a beaver blade under direct visualization. Diagnostic arthroscopy was performed to evaluate the labrum, intra-articular cartilage, and the ligamentum teres. Labral tears were classified using the Seldes classification.[15] Acetabular chondral defects were classified using the acetabular labrum articular disruption and Outerbridge classifications.[16,17] Femoral head cartilage defects were classified using the Outerbridge classification.[16]

All concomitant procedures were performed with extra attention to preserve capsular tissue when necessary for plication. Ligamentum teres fraying or tearing was treated with debridement using a radiofrequency device to remove all unstable fibers. Acetabular pincer-type deformities were trimmed using a burr to restore anatomy and to create a healing surface for the labrum. Under fluoroscopic guidance, femoral head-neck deformities were also corrected using a burr. Iliopsoas fractional lengthening was performed to treat painful internal snapping of the hip.

Irreparable labral tears were treated with selective debridement of torn labral tissue and attempting to leave a stable rim of tissue. Unstable portions were carefully removed using an arthroscopic shaver while preserving as much of the labrum as possible. Labral repairs were performed using 2.9-mm push-lock suture anchors (Arthrex, Naples, FL) using a labral base refixation or circumferential suture technique based on both labral quality and thickness.

Acetabular microfracture was performed for full-thickness chondral lesions according to principles previously described by Steadman et al.[18] The dimensions of chondral defects were noted using a 5-mm probe in units of square millimeters. The location of each defect was noted using the clockface method.[19] Loose cartilage flaps and delaminated cartilage were excised with an arthroscopic shaver, followed by creation of stable borders and removal of the calcified cartilage layer with a ring curette (Fig 1A). Chondro picks (Arthrex) with a 1.5-mm diameter, 220-mm shaft, and 40°, 60°, and 90° tips were used perpendicular to the exposed subchondral bone and advanced with a mallet (Fig 1B). Multiple holes were created 3 to 4 mm apart, at a depth of greater than 4 mm, in the exposed bone adjacent to the healthy rim of cartilage (Fig 1C). Irrigation was temporarily stopped to confirm bleeding from the microfracture holes.

In the setting of subtle capsular laxity or lack of preoperative stiffness in athletic patients, capsular plication was performed at the conclusion of arthroscopy using a previously described technique.[20] After plication, the operative limb was brought into extension with arthroscopic viewing to ensure that the repaired capsule remained intact.

Rehabilitation Protocol

Postoperative restoration of strength and ROM was initiated with physical therapy the day after surgery. Physical therapy lasted a duration of 3 months. During the first 8 weeks, patients used crutches with partial weight bearing (20 pounds [9 kg]) and a low-profile abduction brace (Donjoy X-Act ROM hip brace; DJO Global, Vista, CA). This brace served to limit hip flexion to 90° and extension to 0°.

Surgical Outcomes

All patients completed preoperative questionnaires within 1 month prior to surgery to establish baseline mHHS, NAHS, HOS-SSS, and VAS for pain. VAS was scored from 0 to 10, with 10 being extreme pain. Follow-up scores and patient satisfaction with the results of surgery (0-10) were collected at each annual follow-up time point. All scores were automatically calculated, stored, and encrypted in our institution's hip preservation database. The iHOT-12 was implemented at our institution's database after the study period began. Thus, only follow-up iHOT-12 scores were documented for patients in this study. Revisions and conversions to total hip arthroplasty (THA) were routinely documented during collection of follow-up data. Patients with hips that were either reinjured or had continued symptoms after the index arthroscopy were clinically and radiographically evaluated and offered conservative treatment prior to recommendation for revision. THA was offered as a final solution for patients with unresolved symptoms and/or progression toward moderate to severe osteoarthritis. Minimum 2-year follow-up was defined as having either all minimum 2-year scores or required conversion to THA or both. Follow-up outcomes scores, revisions, and conversions to THA were routinely documented during appointments and/or via online questionnaires.

Statistical Analysis

Assuming a mean difference of 8 points in follow-up mHHS between groups was clinically significant, an a priori power analysis determined that 25 patients were

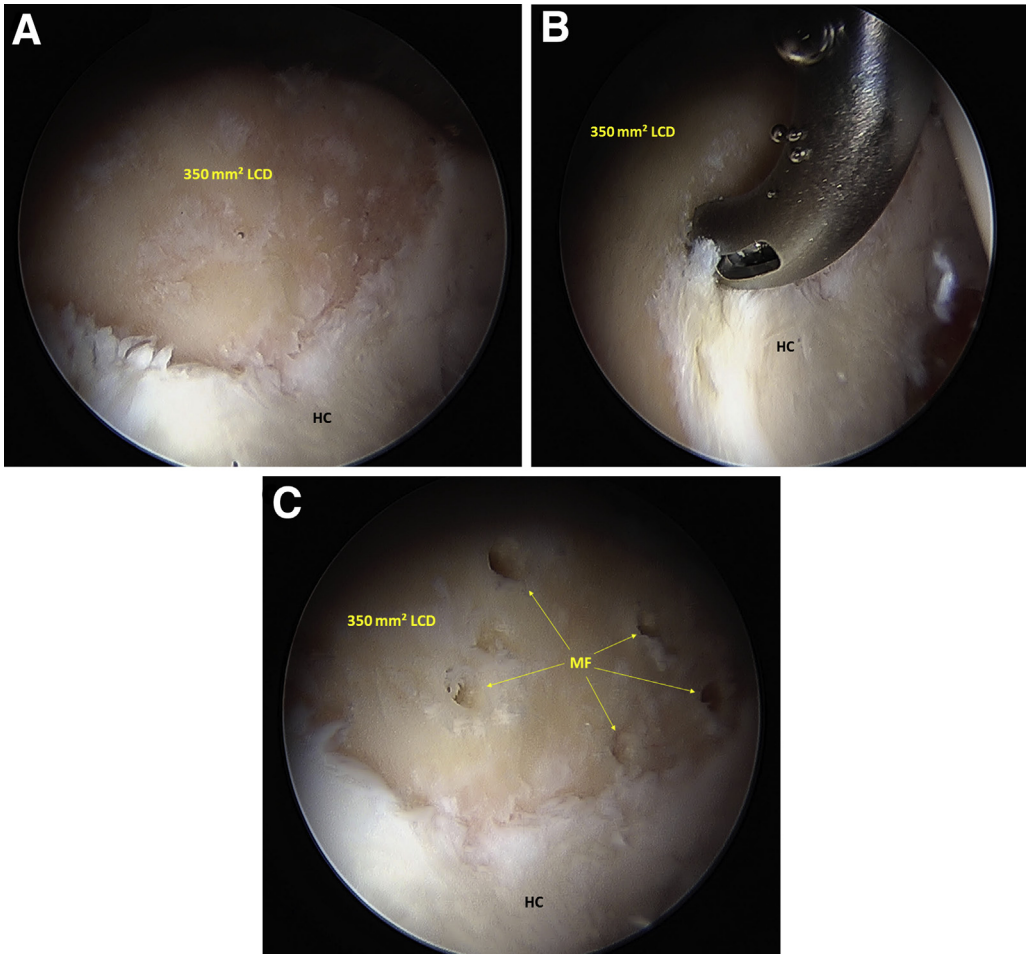

Fig 1. (A-C) Arthroscopic microfracture performed to treat a full-thickness 350 mm^2 LCD of the right hip. (A) The cartilage flap was excised to expose the subchondral bone. (B) Several perforations were created 3 to 4 mm apart and 3 to 4 mm deep for optimal release of bone marrow contents. (C) The exposed subchondral bone will demonstrate cartilage filling approximately 8 weeks after microfracture. HC, healthy cartilage; LCD, large chondral defect; MF, microfracture.

required in each group to achieve at least 80% power using a 1:1 matching ratio.[21] Normally distributed data were identified using the Shapiro-Wilk test. The F-test was used to identify equal variances for comparisons of continuous data. The paired or unpaired 2-tailed *t*-tests were performed to compare continuous data sets. Categorical data were compared using the χ^2-test or Fisher's exact test when appropriate. Descriptive statistics including means, standard deviations, proportions, and ranges were reported when appropriate. The threshold for statistical significance was set to .05. All statistical analyses were performed using Microsoft Excel.

Results

Matched Comparisons of Patient Demographics

A total of 2,279 primary and revision arthroscopies were performed by the senior surgeon during the study period. Of these, 131 cases met the inclusion criteria, and 107 (81.7%) of these patients had minimum 2-year follow-up and were eligible for matching (Fig 2). Fifty-seven (53.3%) patients had LCDs and 50 (46.7%) had SCDs. Table 1 summarizes the demographics and preoperative radiographic measurements compared between the matched LCD and SCD groups. Each group had 23 (65.7%) male patients and 12 (34.3%) female patients. No differences were found when comparing age, BMI, and preoperative radiographic measurements. The LCD group had a mean follow-up time of 47.9months ±21.3 (range, 24.0-84.1), and the SCD group had a mean follow-up time of 46.1months ±21.4 (range, 24.0-88.1).

Matched Comparisons of Intraoperative Findings

Table 2 details the matched comparisons of intraoperative findings documented during diagnostic arthroscopy. The LCD group had a mean chondral defect size of 250.0 ± 73.7 mm^2 (range, 200-450 mm^2), and the SCD group had a mean chondral defect size of 116.9 ± 35.2 mm^2 (range, 50-150 mm^2; $P = .0001$). No differences were identified between the matched groups in terms of Seldes-type labral tears, acetabular labrum articular disruption grade, acetabular Outerbridge grade, or femoral head Outerbridge grade.

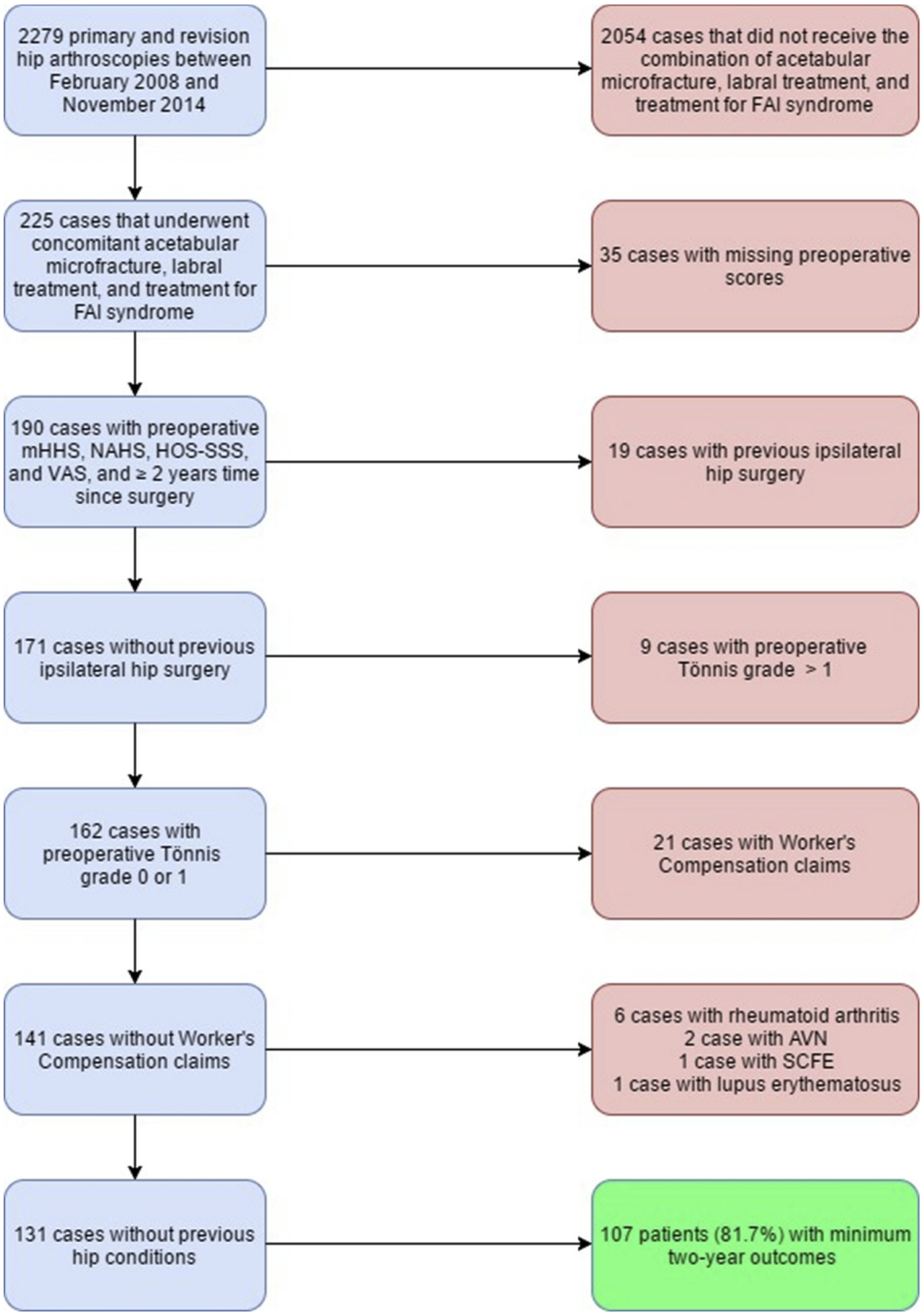

Fig 2. Flow chart demonstrating the application of inclusion and exclusion criteria to arrive at the 107 patients who had follow-up and were eligible for matching.

Regarding the positioning of the acetabular cartilage defects, the mean clockface center was 13.5 ± 0.5 for the matched LCD group and 13.2 ± 1.0 for the matched SCD group. There were no significant differences between groups when comparing the mean clockface positions most anterior, most posterior, and center.

Matched Comparisons of Intraoperative Procedures

Table 3 compares the intraoperative procedures performed in the matched LCD and SCD groups. A total of 21 (60%) patients in each group had combined pincer-type and cam-type lesions and underwent combined acetabuloplasty and femoroplasty. The only

Table 1. Demographics and Preoperative Radiographic Measurements Compared Between the Matched Larger Chondral Defects (LCDs) and Smaller Chondral Defects (SCDs) Groups

	LCD (≥200 mm^2)	SCD (≤150 mm^2)	*P* Value
No. of cases eligible for matching	57	50	—
No. of cases matched	35	35	—
Sex, male:female	23:12	23:12	1.00
Age at surgery, years, mean ± SD (range)	41.6 ± 9.8 (21.2, 61.3)	42.7 ± 9.9 (20.2, 58.4)	.20
Body mass index, mean ± SD (range)	26.6 ± 3.9 (20, 36)	27.7 ± 4.5 (21, 35.6)	.31
Preoperative Tönnis osteoarthritis grade, n (%):	—	—	.79
0	24 (68.6)	26 (74.3)	—
1	11 (31.4)	9 (25.7)	—
Alpha angle, degrees, mean ± SD (range)	72.9 ± 11.9 (56, 98)	68.5 ± 12.4 (46, 104)	0.20
Tönnis angle, degrees, mean ± SD (range)	5.2 ± 6.0 (0, 24)	4.9 ± 5.4 (-2, 19)	0.83
LCEA, degrees, mean ± SD (range)	29.5 ± 5.7 (18, 37)	28.0 ± 5.9 (18, 38)	0.76
Follow-up time, mo, mean ± SD (range)	47.9 ± 21.3 (24.0, 84.1)	46.1 ± 21.4 (24.0, 88.1)	0.68

difference in procedures between groups was ligamentum teres debridement, which was performed more frequently in the LCD group (54.3%) compared with the SCD group (25.7%; $P = .03$). Traction time was not significantly different between groups.

Matched Comparisons of Outcomes Scores

Changes in outcomes scores from preoperatively to latest follow-up were compared between the matched LCD and SCD groups (Table 4). Within both matched groups, all outcomes scores and VAS demonstrated significant improvements at latest follow-up. For the LCD group, mean improvements were as follows: mHHS (67.9-80.5; $P = .001$), NAHS (65.9-80.9; $P = .0002$), HOS-SSS (51.2-68.1; $P = .003$), and VAS (4.7-3.1; $P = .01$). Mean improvements for the SCD group were as follows: mHHS (64.5-80.6; $P = .0001$), NAHS (58.9-79.4; $P = .0001$), HOS-SSS (40.7-63.9; $P = .0001$), and VAS (5.5-2.8; $P = .0001$). Mean patient satisfaction was 7.6 for the matched LCD group and 8.1 for the SCD group ($P = .17$). Table 5 details the comparisons performed between groups at the preoperative and latest follow-up time points. No statistically significant differences were identified at either time point, but mean preoperative NAHS ($P = .10$) and HOS-SSS ($P = .07$) were lower in the matched SCD group and also trended toward significance. Twenty-two patients (62.9%) in the matched SCD group met the patient acceptable symptomatic state with mHHS ≥74, compared with 18 patients (51.4%) in the matched LCD group ($P = .47$).

Table 2. Comparisons of Intraoperative Findings Noted During Diagnostic Arthroscopy for the Matched Larger Chondral Defects (LCDs) and Smaller Chondral Defects (SCDs) Groups

Intraoperative Findings	LCD (≥200 mm^2)	SCD (≤150 mm^2)	*P* Value
Seldes-defined labral tear, n (%)	35	35	1.00
Type 1	12 (34.3)	15 (42.9)	.62
Type 2	6 (17.1)	7 (20.0)	1.00
Combined types 1 and 2	17 (48.6)	13 (37.1)	.47
Mean chondral defect size, mm^2, mean ± SD (range)	250.0 ± 73.7 (200, 450)	116.9 ± 35.2 (50, 150)	.0001
Acetabular labrum articular disruption grade, n (%):			
0	0	0	1.00
1	0	0	1.00
2	0	0	1.00
3	15 (42.9)	19 (52.3)	.47
4	20 (57.1)	16 (45.7)	.47
Acetabular Outerbridge grade, n (%):			
0	0	0	1.00
1	0	0	1.00
2	0	0	1.00
3	0	0	1.00
4	35 (100)	35 (100)	1.00
Femoral head Outerbridge grade, n (%)			
0	27 (77.1)	26 (74.3)	1.00
1	0	0	1.00
2	5 (14.3)	5 (14.3)	1.00
3	2 (5.7)	3 (8.6)	1.00
4	1 (2.9)	1 (2.9)	1.00

Table 3. Comparisons of Intraoperative Procedures Noted During Hip Arthroscopy for the Matched Larger Chondral Defects (LCDs) and Smaller Chondral Defects (SCDs) Groups

Intraoperative Procedures	LCD ($\geq$200 mm^2)	SCD ($\leq$150 mm^2)	*P* Value
Labral treatment:	35 (100)	35 (100)	1.00
Repair	21 (60)	21 (60)	—
Debridement	14 (40)	14 (40)	—
Acetabular microfracture	35 (100)	35 (100)	1.00
Capsular treatment:	35 (100)	35 (100)	1.00
Release	29 (82.9)	29 (82.9)	—
Plication	6 (17.1)	6 (17.1)	—
Ligamentum teres debridement	19 (54.3)	9 (25.7)	.03
Isolated femoroplasty	13 (37.1)	13 (37.1)	1.00
Isolated acetabuloplasty	1 (2.9)	1 (2.9)	1.00
Combined acetabuloplasty and femoroplasty	21 (60)	21 (60)	1.00
Iliopsoas fractional lengthening	7 (20)	8 (22.9)	1.00
Synovectomy	3 (8.6)	4 (11.4)	1.00
Notchplasty	7 (20)	7 (20)	1.00

NOTE. Data are reported as n (%). All patients underwent arthroscopic microfracture, labral treatment, and treatment for femoroacetabular impingement syndrome.

Comparisons of Outcomes Scores Without Matching

The unmatched groups demonstrated no significant differences in mean age at surgery, proportions of each sex, mean BMI, or intraoperatively defined cartilage damage. The mean size of the acetabular chondral defects was 246.5 mm^2 in the unmatched LCD group and 120.8 mm^2 in the unmatched SCD group ($P = .0001$). The outcomes scores were compared between the unmatched LCD and SCD groups in Table 6. The follow-up time was 43.6 months for the unmatched LCD group and 40.2 months for the unmatched SCD group ($P = .39$). Preoperatively, the unmatched SCD group trended toward significantly worse preoperative scores, and the preoperative HOS-SSS was significantly lower ($P = .02$). No trends or differences were observed at follow-up.

Future Revisions and Conversions to THA

Table 7 summarizes the rates of revision with and without matching. In both matched and unmatched comparisons, no statistically significant differences were noted regarding revision rates, time to revision, conversion rate to THA, or time to THA. One revision was performed in the matched (2.9%) and unmatched (1.8%) LCD group. These rates were not statistically lower than the 4 revisions noted in the matched (11.4%) and unmatched (8.0%) SCD groups. Time to revision was similar in both comparisons.

Table 7 also summarizes the rates of conversion to THA with and without matching. Mean time to THA was similar between matched and unmatched groups. Seven (20%) conversions to THA were documented in the matched LCD group, and 6 (17.1%) were documented in the matched SCD group. Fourteen (24.6%) conversions to THA were documented in the

Table 4. Improvements in Patient-Reported Outcomes and Patient Satisfaction at Latest Follow-up

Patient-Reported Outcomes	Preoperative (mean, SD)	Follow-up (mean, SD)	*P* Value
LCD ($\geq$200 mm^2):			
Modified Harris Hip Score	67.9 ± 14.8	80.5 ± 17.9	.001
Nonarthritic Hip Score	65.9 ± 15.8	80.9 ± 17.3	.0002
Hip Outcome Score—Sports Specific Subscale	51.2 ± 20.0	68.1 ± 26.2	.003
iHOT-12	—	66.0 ± 28.3	—
Visual analog scale	4.7 ± 2.2	3.1 ± 2.8	.01
Patient satisfaction	—	7.6 ± 2.4	—
SCD ($\leq$150 mm^2):			
Modified Harris Hip Score	64.5 ± 14.9	80.6 ± 18.4	.0001
Nonarthritic Hip Score	58.9 ± 15.8	79.4 ± 18.8	.0001
Hip Outcome Score—Sports Specific Subscale	40.7 ± 21.7	63.9 ± 27.1	.0001
iHOT-12	—	69.5 ± 24.3	—
Visual analog scale	5.5 ± 2.5	2.8 ± 2.6	.0001
Patient satisfaction	—	8.1 ± 2.2	—

NOTE. Comparisons are performed independently within groups.

Table 5. Comparisons of Preoperative and Follow-up Scores Between the Matched Larger Chondral Defects (LCDs) and Smaller Chondral Defects (SCDs) Groups

	LCD ($\geq$200 mm^2)	SCD ($\leq$150 mm^2)	*P* Value
Preoperative:			
Modified Harris Hip Score	67.9 ± 14.8	64.5 ± 14.9	.39
Nonarthritic Hip Score	65.9 ± 15.8	58.9 ± 15.8	.1
Hip Outcome Score—Sports Specific Subscale	51.2 ± 20.0	40.7 ± 21.7	.07
iHOT-12	—	—	—
Visual analog scale	4.7 ± 2.2	5.5 ± 2.5	.19
Follow-up:	—	—	—
Modified Harris Hip Score	80.5 ± 17.9	80.6 ± 18.4	.99
Nonarthritic Hip Score	80.9 ± 17.3	79.4 ± 18.8	.76
Hip Outcome Score—Sports Specific Subscale	68.1 ± 26.2	63.9 ± 27.1	.56
iHOT-12	66.0 ± 28.3	69.5 ± 24.3	.58
Visual analog scale	3.1 ± 2.8	2.8 ± 2.6	.65
Patient satisfaction	7.6 ± 2.4	8.1 ± 2.2	.17

unmatched LCD group compared with 6 (12.0%) in the unmatched SCD group ($P = .14$). Of these, 3 (21.4%) in the unmatched LCD group and 1 (16.7%) in the unmatched SCD group had a preoperative Tönnis grade 1.

One patient (7.1%) in the unmatched LCD group that converted to THA had a femoral head Outerbridge defect of grade 3, 5 patients (35.7%) had a defect of grade 2, and 8 patients (57.1%) had no femoral head Outerbridge defects. These proportions were not significantly different from the patients who did not undergo THA. Using the matched patients, the relative risk for conversion to THA was 2.33 for patients with chondral defects $\geq$300 mm^2 when compared with patients with chondral defects $\leq$250 mm^2 ($P = .12$).

Postoperative Complications

The overall complication rate was 7.0% (4 patients) in the unmatched LCD group and 8.0% (4 patients) in the unmatched SCD group. The 4 complications in the LCD group included 3 cases of DVT and 1 case of superficial numbness at the site of surgery. The 4 complications in the SCD group included 3 cases of superficial numbness at the site of surgery and 1 case of postoperative wound infection that was resolved with topical treatment. The complication rates and the types of complications were not found to be significantly different between groups.

Discussion

This study demonstrated similar outcomes after arthroscopic microfracture, labral treatment, and treatment for FAI syndrome in patients with either LCDs ($\geq$200 mm^2) or SCDs ($\leq$150 mm^2). In matched and unmatched comparisons, both groups demonstrated significant improvements in outcomes scores preoperatively to latest follow-up. Mean patient satisfaction was also high in both groups. The conversion rates to THA and complication rates were not significantly different between groups.

Microfracture encompasses the penetration of subchondral bone such that pluripotent mesenchymal stem cells within the bone marrow are released into the joint space. These mesenchymal stem cells can differentiate into chondrocytes, with optimal repair observed as early as 6 weeks after microfracture in a rabbit model.[22] Recent clinical literature has already demonstrated that

Table 6. Comparisons of Preoperative and Follow-up Scores Between the Unmatched Larger Chondral Defects (LCDs) and Smaller Chondral Defects (SCDs) Groups

	LCD ($\geq$200 mm^2)	SCD ($\leq$150 mm^2)	*P* Value
Preoperative, n:	57	50	—
Modified Harris Hip Score	68.9 ± 14.5	63.0 ± 16.3	.08
Nonarthritic Hip Score	67.8 ± 16.9	60.9 ± 16.7	.06
Hip Outcome Score—Sports Specific Subscale	51.5 ± 22.0	39.5 ± 24.1	.02
iHOT-12	—	—	—
Visual analog scale	4.3 ± 2.2	5.3 ± 2.5	.07
Follow-up, n:	57	50	—
Modified Harris Hip Score	81.3 ± 16.2	79.7 ± 17.8	.66
Nonarthritic Hip Score	81.3 ± 15.3	80.2 ± 18.2	.76
Hip Outcome Score—Sports Specific Subscale	64.3 ± 24.7	61.7 ± 27.8	.65
iHOT-12	68.1 ± 25.2	67.7 ± 23.7	.84
Visual analog scale	2.7 ± 2.4	2.8 ± 2.5	.77
Patient satisfaction	7.5 ± 2.5	7.8 ± 2.1	.49

Table 7. Comparisons of Matched and Unmatched Rates of Revision, Time to Revision, Rates of Conversion to Total Hip Arthroplasty (THA), and Time to THA

Future Procedures	LCD ($\geq$200 mm^2)	SCD ($\leq$150 mm^2)	*P* Value
Matched, n:	35	35	—
Revision arthroscopies, n (%)	1 (2.9)	4 (11.4)	.36
Time to revision, mo, mean ± SD (range)	30.1	35.9 ± 36.7 (3.7, 83.3)	—
Conversion to THA, n (%)	7 (20)	6 (17.1)	1.00
Time to THA, mo, mean ± SD (range)	28.2 ± 11.6 (15.0, 40.2)	33.7 ± 24.2 (7.8, 72.6)	.68
Unmatched (n)	57	50	—
Revision arthroscopies, n (%)	1 (1.8)	4 (8.0)	.18
Time to revision, mo, mean ± SD (range)	30.1	35.9 ± 36.7 (3.7, 83.3)	—
Conversion to THA, n (%)	14 (24.6)	6 (12.0)	.13
Time to THA, mo, mean ± SD (range)	31.4 ± 14.4 (15.0, 60.7)	33.4 ± 24.2 (7.8, 72.6)	.85

arthroscopic microfracture plays important roles in the prevention of osteoarthritis and successful clinical outcomes at short-term follow-up. In 2004, Byrd et al.[7] reported improvements after acetabular microfracture was used to treat grade 4 chondral defects in 21 patients. More recently, Domb et al.[8] reported significant short-term improvements in patients undergoing microfracture with labral tears and/or FAI syndrome. The results of their microfracture group were similar to the results of their control group that did not undergo microfracture. Notably, their conversion rate to THA was 11.4% in the microfracture group versus 6.3% in the control group, which the authors explained may have been due to the lack of grade 4 defects in their control group.[8]

The relationship between hip arthroscopic microfracture outcomes and chondral defect size is limited to data from 1 study, making decision-making algorithms difficult to establish. The recent study by Trask and Keene[12] reported on a case series of 70 patients who underwent microfracture with treatment for labral tears and/or FAI syndrome. Their mean chondral defect size was 143 mm^2, compared with 116.9 and 250.0 mm^2, respectively, in our matched SCD and LCD groups. They also reported a conversion rate to THA of 17% (12 patients), which was similar to that seen in our matched comparisons. The authors cautioned that in general, full-thickness chondral defects may portend a high rate of conversion to THA after microfracture. Most notably, they found that chondral defect size had no significant bearing on outcomes. However, their lack of a control group makes it difficult to elucidate the true effect. Our study, which was adequately powered for clinical significance and controlled for several confounding variables, provides a more refined framework for surgical decision-making. The present study suggests that patients with SCDs or LCDs may demonstrate similar and significant improvements in outcomes at $\geq$2 years postoperatively when controlled for several confounding variables. While the subgroup with defects approaching $\geq$300 mm^2 showed a higher risk of conversion to THA, our study did not attain enough statistical power to determine significance.

Philippon et al.[23] recently reported the minimum 10-year outcomes of athletic patients who underwent hip arthroscopy for both FAI and labral tears. Notably, their multivariate Cox regression identified an association between acetabular microfracture and conversion to THA. Another recent study demonstrated that microfracture outcomes may be enhanced with autologous matrix-induced chondrogenesis (AMIC), a technique that combines the microfracture technique with a resorbable collagen I/III matrix.[24] Compared with microfracture alone, AMIC demonstrated superior outcomes at each annual time point between 2 and 5 years and also demonstrated more durability. Given this evidence and our results, we suspect that AMIC may be an appropriate implementation to maximize the benefit gained via microfracture.

Another interesting finding in this study was that the incidence of DVT was exclusive to the patients with LCDs. A recent review of 6,395 hip arthroscopies reported a 0.08% incidence of DVT.[25] Another recent study by Cvetanovich et al.[26] similarly reported a 0.1% rate of DVT within 30 days postoperatively in 1,338 patients who underwent hip arthroscopy. Given the markedly higher incidence of DVT in our study, its exclusivity to the LCD group, and no significant differences in traction time between groups, this relationship may warrant further investigation. Importantly, the present study was neither powered nor designed to investigate differences in complication rates.

Our study has several strengths. First, data were collected on all patients in this study using a series of outcomes tools including mHHS, NAHS, HOS-SSS, iHOT-12, VAS, patient satisfaction, revision procedures, conversions to THA, and surgical complications. It is important to use a diverse group of reporting measures, as it has been shown that there is no single tool that is adequate for reporting outcomes after hip arthroscopy and it also allows our results to be more

easily compared to other literature.[27] Second, several confounding variables were controlled for via the inclusion criteria, exclusion criteria, and pair matching: acetabular microfracture, labral treatment type, capsular treatment type, acetabuloplasty, femoroplasty, age at surgery, sex, BMI, Tönnis grade >1, Workers' Compensation, and previous ipsilateral hip conditions or surgeries. Additionally, all surgeries were performed by the senior surgeon. Furthermore, matching was performed blinded to all data except the matching criteria to limit bias. Controlling for these confounding variables enhances our confidence in the results reported. Third, an a priori power analysis was performed to ensure that our group sizes were adequate to detect clinically significant differences in mean mHHS. Although only 25 patients were required in each matched group for a minimum of 80% power, 35 patients were successfully matched into each group, thus lowering the probability of type II error regarding mHHS.

Limitations

Our study has several limitations to consider. First, although adequately powered for clinically significant differences in mHHS, our study was underpowered for detection of statistically significant differences in rates of revision, conversion to THA, and complications. A much larger sample of patients for each group is necessary for these analyses. Additionally, arthroscopic microfracture tends to be less prevalent at our high-volume hip preservation center. Attaining an appropriate sample size was considered with an a priori power analysis before investigation. Second, the outcomes reported in this study were mostly restricted to the short term. Thus, we were unable to confidently predict the durability of these outcomes at the midterm (≥5 years). Third, the proportions of debrided ligamentum teres tears were found to be significantly different between the matched groups, which may be a confounding variable, as ligamentum teres tears are known sources of intra-articular dysfunction and pain.[28] Lastly, the chondral defects measured in the present study were not validated by 2 observers at 2 different time points.

Conclusions

Matched patients with either SCDs or LCDs undergoing arthroscopic acetabular microfracture with concomitant treatment for labral tears and FAI syndrome demonstrated similar improvements at minimum 2-year follow-up. Patients with chondral defects approaching 300 mm^2 or greater may have a higher propensity toward conversion to THA.

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