# Importance of Retaining Sufficient Acetabular Depth

## Successful 2-Year Outcomes of Hip Arthroscopy for Patients With Pincer Morphology as Compared With Matched Controls

Claudia R. Brick,*† MBBS (Hons), BMedSci (Hons),
Catherine J. Bacon,*‡ BSc, BPhEd (Hons), MSc, PhD, and Matthew J. Brick,*§ MBChB, FRACS
*Investigation performed at Orthosports North Harbour, Auckland, New Zealand*

**Background:** Patients with pincer-type femoroacetabular impingement are commonly treated with arthroscopic reduction of acetabular depth as measured by the lateral center-edge angle (LCEA). The optimal amount of rim reduction has not been established, although large resections may increase contact pressures through the hip. A recent publication demonstrated inferior surgical outcomes in patients with acetabular overcoverage as compared with normal acetabular coverage. Casual observation of our database suggested equivalent improvements, prompting a similar analysis.

**Purpose:** To analyze patient-reported outcomes after hip arthroscopy for femoroacetabular impingement in patients with acetabular overcoverage who were matched with controls with normal coverage, as well as to analyze associations with reduction in LCEA.

**Study Design:** Cohort study; Level of evidence, 3.

**Methods:** Data were collected prospectively from patients with a minimum 2-year follow-up after receiving hip arthroscopy for femoroacetabular impingement by a single surgeon. Cases were reviewed to identify those with pincer-type morphology (LCEA >40°) and matched according to sex, age, chondral damage, and surgery date in a 1:1 ratio with controls with an LCEA of 25° to 40°. The surgical goal was to reduce the LCEA to the upper end of the normal range with minimal rim resection, usually 35° to 37°. Radiographic measurements of coverage, intraoperative findings, procedures, and patient-reported outcomes were recorded, including the 12-Item International Hip Outcome Tool, Non-arthritic Hip Score, Hip Disability and Osteoarthritis Outcome Score, visual analog scale for pain, rates of revision or reoperation, and conversion to total hip arthroplasty.

**Results:** A total of 114 hips (93 patients) for the pincer group were matched 1:1 from 616 hips (541 patients) for the control group. The pincer group (mean ± SD age, 34.5 ± 12.2 years) did not differ in age, body mass index, or follow-up from controls. LCEA was reduced in both groups pre- to postoperatively: the pincer group from 44.0° ± 2.8° to 34.2° ± 3.5° and the controls from 32.9° ± 3.9° to 31.0° ± 3.0°. No differences in improvement were observed: iHOT-12 improved by 35.7 points in both groups (*P* = .9 for analysis of variance interaction) and Nonarthritic Hip Score by 22.3 points (*P* = .6). From all eligible surgical procedures, 2-year follow up rates were 2.5% and 2.6% for the pincer and control cohorts, respectively, and 1.2% and 0.3% for conversion to total hip arthroplasty.

**Conclusion:** Arthroscopic management of acetabular overcoverage can achieve excellent results, equivalent to arthroscopy for other causes of symptomatic femoroacetabular impingement. A key finding was smaller rim resections producing a mean postoperative LCEA of 34.2° with a small standard deviation.

**Keywords:** hip arthroscopy; femoroacetabular impingement; FAI; pincer hip; acetabular overcoverage

That femoroacetabular impingement (FAI) can cause labral tears, cartilage damage, and joint degeneration is now well-documented.[10] The 2 mechanisms of this impingement are cam type and pincer type, although many patients demonstrate a combination of the 2. In pincer-type FAI, acetabular overcoverage causes impingement between the deep acetabular socket and the femoral neck, producing labral and articular cartilage damage.[2]

Pincer-type FAI is commonly treated with resection of the acetabular overcoverage.[21] This not only removes the pincer component of the impingement process, but also reduces or removes areas of grade 4 cartilage damage that may contribute to symptoms.

The American Journal of Sports Medicine
2020;48(10):2471–2480
DOI: 10.1177/0363546520937301

A clinically reliable measurement of hip socket depth is the lateral center-edge angle (LCEA).[17,27] An LCEA of 25° is commonly accepted as the lower limit of normal. An LCEA >40° is associated with acetabular overcoverage and pincer-type FAI.[27,29,30]

A question that has not been answered is the optimal amount of rim trimming for joint preservation. Too little and the pincer deformity may remain. Too much and iatrogenic acetabular dysplasia, increased loading of the remaining cartilage, and instability may occur. A cadaveric study of contact pressures through the hip joint after rim resection demonstrated that resecting >4 mm of the acetabular rim may increase contact pressures by 3 times at the acetabular base.[3] These unwanted effects have the potential to cause or accelerate degenerative changes, compromising patient outcomes in the short, medium, and long term.

The depth of rim trimming undertaken may be radiologically measured by the LCEA, with a recent study finding that for 1 mm of rim reduction, 2.4° of reduction in center-edge angle can be expected, with 0.6° for each additional millimeter following (although this does not take into account far anterior rim trims, which may be masked by the LCEA measurement).[26]

Although arthroscopic treatment of pincer-type FAI seems to have conclusively demonstrated improvement in patient-reported outcomes (PROs),[6,28] a recent publication demonstrated inferior outcome improvement in patients with acetabular overcoverage undergoing hip arthroscopy in comparison with that of controls with normal acetabular coverage.[4] Superficial observation of our long-term database suggested equivalent improvements after arthroscopy between these groups. This study is a similar matched analysis to report on minimum 2-year outcomes of hip arthroscopic surgery for FAI in patients with acetabular overcoverage (defined as LCEA >40°) and matched controls with normal acetabular coverage (defined as LCEA of 25°-40°). We hypothesized that with lesser resection and a higher postoperative LCEA, good results can be obtained with pincer resection that are equivalent to results obtained in patients with normal socket depth.

## METHODS

### Patient Selection

This study was a matched-pair cohort analysis to compare the outcomes of hip arthroscopy for FAI between patients with acetabular overcoverage and a control group with normal coverage. We routinely collect prospective data on outcomes of all patients undergoing hip arthroscopic surgery. For this study, we extracted pre- and postoperative data from consenting patients undergoing hip arthroscopy for symptomatic FAI refractory to nonoperative measures between 2012 and December 2016.

Inclusion in the study required an LCEA >40° for the study group and an LCEA of 25° to 40° for the control group. All operations were performed by the senior surgeon (M.J.B.). Exclusion criteria were previous or coexisting hip or rheumatoid conditions, except for minor fractures or tears that did not require surgical intervention; previous or concurrent hip, pelvic, or buttock surgery in the operated hip; and grade 3 or 4 femoral head damage or a diagnosis at surgery of early osteoarthrosis. Patients without minimum 2-year follow-up of outcome scores, except those who had subsequent surgery on the same hip within 2 years, were also excluded. Patients were matched in a 1:1 ratio of priority by age within 5 years, depth of acetabular cartilage loss, sex, and surgery year.

### Physical Examination

All patients were examined in clinic by the senior surgeon pre- and postoperatively. Flexion and maximum internal and external rotation with the knee flexed to 90° were recorded. Positive quadrant test and flexion, abduction, and external rotation (FABER) signs, markers of impingement,[1] were recorded.

### Radiological Evaluation

Anterior-posterior pelvic radiographs and Dunn lateral views were obtained before and 3 months after surgery, all at the same on-site imaging provider. Measurements of the Wiberg LCEA,[31] Tönnis acetabular index angle, alpha angle[24] (Dunn lateral view), and Tönnis grade were recorded. The presence of a crossover sign and ischial spine sign were also reported.[13] The LCEA (measured to the lateral edge of the sourcil) and the presence of a crossover sign were recorded by the senior surgeon at the time of reviewing the patient in clinic preoperatively and approximately 3 months postoperatively. These measurements were rechecked by an independent rater (C.R.B.), and remaining measurements were measured and recorded at a separate time point by a trained member of the team. Imaging was accessed and measured using online tools on a national imaging database.

[§]Address correspondence to Matthew J. Brick, MBChB, FRACS, Orthosports North Harbour, AUT Millenium, 17 Antares Place, Rosedale, Auckland 0632, New Zealand (email: mat@orthosports.co.nz).

*Orthosports North Harbour, AUT Millennium, Auckland, New Zealand.

[†]Alfred Health, Melbourne, Australia.

[‡]Faculty of Medical and Health Sciences, University of Auckland, Auckland, New Zealand.

Submitted October 4, 2019; accepted April 27, 2020.

One or more of the authors has declared the following potential conflict of interest or source of funding: M.J.B. has received speaking fees from Stryker and royalties from Arthrex. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

TABLE 1
Patient Characteristics According to Study Group[a]

| | Pincer | Control | *P* Value |
|---|---|---|---|
| Patients eligible | 135 | 775 | |
| Surgical procedures | | | |
| Eligible | 162 | 924 | |
| Included with 2-y follow-up | 114 | 616 | |
| Matched | 114 | 114 | |
| Sex, female:male | 57:57 | 51:63 | .43 |
| Side, right:left | 56:58 | 66:48 | .28 |
| Age at surgery, y | 34.5 ± 12.2 (13-59) | 34.5 ± 12.2 (14-59) | .98 |
| Body mass index, $kg/cm^2$ | 25.35 ± 5.1 | 24.29 ± 6.2 | .32 |
| Tönnis grade | | | .43 |
| 0 | 97 | 101 | |
| 1 | 17 | 13 | |

[a]Values are presented as No. or mean ± SD (range).

## Surgical Technique

All hip arthroscopies were performed with a McCarthy hip distractor (Innomed), with the patient under general anesthesia and in the lateral position. Midtrochanteric, midanterior, and distal anterolateral accessory portals were used. A 35-mm crescentic interportal capsulotomy was created. The joint was inspected, and findings and interventions in the central and then peripheral compartments were photographed and documented. The labrum was mobilized using a radiofrequency device, and rim resection was undertaken using a 4-mm bur under imaging guidance. Anterior acetabuloplasty was performed for focal anterior overcoverage. A more general acetabuloplasty was performed for an LCEA >39°. The surgical goal was to reduce the LCEA to the upper end of the normal range with minimal rim resection, usually 35° to 37°. When there was sufficient-quality tissue, the labrum was repaired with 3-mm knotless PEEK anchors (Stryker) and labral base sutures. When there was insufficient or poor-quality tissue, labral reconstruction was employed using an iliotibial band autograft. Any grade 4 chondral loss was treated with curettage and microfracture. Traction was removed, and the peripheral compartment was inspected.

A dynamic impingement test was undertaken, and femoral osteoplasty was performed for offset <8 mm or evidence of intra-articular deformation of the labrum per a flexion, adduction, and internal rotation (FADIR) impingement test. The amount of resection was determined by the magnitude of the femoral cam deformity. The goal was to obtain a "light bulb"–shaped head-neck junction on multiple radiographic views and a negative FADIR impingement test result. The anterior two-thirds of the capsulotomy was routinely closed in patients with a stable capsule. Complete capsular closure or plication was employed in patients with hyperlaxity (Beighton score >4 of 9 or significant capsular laxity noted intraoperatively). The iliopsoas tendon at the level of the acetabular rim was lengthened only in cases of symptomatic snapping.

Postoperative rehabilitation included a minimum of 2 weeks partial weightbearing with crutches, increasing to 6 weeks for cases of microfracture and instability. Early active motion was begun on postoperative day 1 with pendulum and circumduction exercises, followed soon thereafter with stationary cycling.

## Outcomes

The PRO questionnaires used were the Non-Arthritic Hip Score (NAHS),[5] the Hip Disability and Osteoarthritis Outcome Score (Activities of Daily Living, Sports, Quality of Life),[15] the 12-item International Hip Outcome Tool (iHOT-12),[22] and the visual analog scale for pain. Scores were obtained preoperatively, at 6 months and 1 year, and annually thereafter. Any revision surgery, reoperations attributed to subsequent reinjury, and conversions to total hip arthroplasty (THA) as recorded on a comprehensive national joint registry were noted.

## Statistical Analysis

A minimum sample size of 100 per group was calculated with G*Power (v 3.1)[9] to detect a difference of 8 points in iHOT-12 or NAHS based on an SD of 20 points, a statistical power of >80%, and an alpha error rate of <.05.

Statistical analysis was undertaken with SPSS (v 25; IBM Corporation). Differences between case and control groups were determined using chi-square analysis for categorical variables and using unpaired *t* tests for continuous variables, corrected for inequality of variance via the Levene test, if this assumption was violated. Between-group differences in change over time for PROs were analyzed with 2-way analyses of variance, with consideration of the time × group interaction effect. The level of statistical significance was set at <.05.

# RESULTS

## Patient Characteristics

A total of 114 surgical procedures (93 patients) satisfied the inclusion and follow-up criteria for the pincer group

TABLE 2
Preoperative Clinical Examination Findings[a]

| | Pincer | Control | *P* Value |
|---|---|---|---|
| Flexion, deg | 100.2 ± 15.7 | 101.3 ± 14.4 | .60 |
| Rotation, deg | | | |
| Internal[b] | 16.4 ± 13.2 | 21.4 ± 14.9 | .01 |
| External | 50.2 ± 12.7 | 51.7 ± 10.7 | .37 |
| Positive sign | | | |
| Quadrant | 101 (96.2) | 109 (98.2) | .37 |
| FABER | 70 (74.5) | 59 (56.7) | .009 |

[a]Values are presented as mean ± SD or No. (%). FABER, flexion, abduction, and external rotation.
[b]Knee held at 90° of flexion.

and 616 (541 patients) for the control group. All pincer surgical procedures were matched with no resulting statistically significant differences between groups for age at surgery, body mass index, follow-up length, sex, side of surgery, or Tönnis grade (Table 1). In sum, 114 operations were matched in the control group from 108 patients.

## Examination and Radiological Findings

As displayed in Table 2, there were no significant differences between the groups in clinical examination of flexion or external rotation. Eighteen percent more of the pincer group than the control group had a positive FABER sign ($P = .009$).

Table 3 shows the pre- and postoperative radiological findings. As expected, the preoperative LCEA of the pincer group (mean ± SD, 44.0° ± 2.8°) was higher than that of the control group (32.9° ± 3.9°; $P < .001$). The pincer group had an 11.4% higher rate of ischial spine sign ($P = .03$) and more large-sized crossover signs, 15 (13.2%) in the pincer group as opposed to 2 (1.8%) in the control group ($P = .004$), although differences in the rates of any crossover sign were not statistically different between groups. Postoperatively, the LCEA of the pincer group decreased 9.8° (to 34.2° ± 3.5°), and the crossover signs were abolished, while the LCEA of the control group decreased by a far lesser extent (to 31.0° ± 3°). The pincer group had a smaller Tönnis angle pre- and postoperatively as compared with the control group ($P < .001$), although a slightly smaller average preoperative alpha angle did not attain statistical significance ($P = .06$).

## Intraoperative Diagnoses and Procedures

The intraoperative diagnoses for both groups are displayed in Table 4. There was a 10.5% higher rate of labral tears in the pincer group as compared with the control group ($P = .04$). The labral tears in the pincer group were also larger and involved a more posterior position. There were no significant differences in acetabular or femoral head cartilage grades between the groups.

Table 5 displays the intraoperative procedures. The pincer group had higher rates of labral repair (13.1%; $P = .002$) and acetabuloplasty (33.3%) than the control group ($P < .001$). The control group had more than double the rate of acetabular microfracture (21.9% higher than the pincer group; $P < .001$). There was no significant difference in femoroplasty, ligamentum teres treatment, or capsular repair.

## Patient-Reported Outcomes

With a minimum 2-year follow-up (mean, 5.36 ± 1.89 years) in patient-reported outcome scores, the 2 groups had no significant differences in preoperative scores, score improvements (interaction effect), or postoperative scores (Table 6). Both groups showed a clear pattern of improvement from 6 months (Figure 1). The PRO scores isolated from patients who underwent revision or reoperation also demonstrated no significant difference in change between groups, although there were significant improvements in some scores after the secondary operation for both groups (Table 7).

## Secondary Procedures

As displayed in Table 8, 2 patients in the pincer group (1.8%) and 1 in the control group (0.9%) required conversion to THA within 2 years of their initial operation, with time to conversion ranging from 10.8 to 22.6 months and

TABLE 3
Pre- and Postoperative Radiological Findings[a]

| | Preoperative | | | Postoperative | | |
|---|---|---|---|---|---|---|
| | Pincer | Control | *P* Value | Pincer | Control | *P* Value |
| Angle, deg | | | | | | |
| Lateral center edge | 44.0 ± 2.8 | 32.9 ± 3.9 | <.001 | 34.2 ± 3.5 | 31.0 ± 3.0 | <.001 |
| Tönnis | –1.6 ± 3.1 | 3.7 ± 3.8 | <.001 | 1.8 ± 4.5 | 4.3 ± 3.1 | <.001 |
| Alpha | 45.8 ± 6.6 | 47.6 ± 7.5 | .06 | 38.0 ± 5.8 | 38.0 ± 4.3 | ≥.999 |
| Sign | | | | | | |
| Crossover, any | 48 (42.1) | 36 (31.6) | .10 | 0 | 2 (1.8) | .10 |
| Ischial spine | 30 (26.3) | 17 (14.9) | .03 | 29 (25.4) | 15 (13.2) | .08 |

[a]Values are presented as mean ± SD or No. (%).

TABLE 4
Intraoperative Diagnoses[a]

| | Pincer Group | Control Group | *P* Value |
|---|---|---|---|
| Labral tear | 100 (87.7) | 88 (77.2) | .04 |
| Seldes type | | | .19 |
| 1 | 34 (29.8) | 65 (57.0) | |
| 2 | 40 (35.1) | 2 (1.7) | |
| 1 and 2 | 26 (22.8) | 21 (18.4) | |
| Size, mm | 33.3 ± 13 | 25.5 ± 11 | <.001 |
| Clockface position of labral tear, h:min | | | |
| Most posterior | 11:24 ± 1:15 | 12:10 ± 1:07 | <.001 |
| Most anterior | 2:43 ± 0:37 | 2:41 ± 0:39 | .71 |
| Acetabular chondral lesion grade | | | .97 |
| None | 19 (16.7) | 19 (16.7) | |
| Early delamination or wave sign | 34 (29.8) | 32 (28.1) | |
| Delamination one-third from rim to fossa | 31 (27.2) | 30 (26.3) | |
| Delamination two-thirds from rim to fossa | 30 (26.3) | 33 (28.9) | |
| Femoral head chondral lesion grade | | | ≥.999 |
| None | 112 (98.2) | 112 (98.2) | |
| Grade 1 | 1 (0.9) | 1 (0.9) | |
| Grade 2 | 1 (0.9) | 1 (0.9) | |
| Ligamentum teres tear | 4 (3.5) | 3 (2.6) | .70 |

[a]Values are presented as mean ± SD or No. (%).

with age at conversion ranging from 49.5 to 60.8 years. No further patients required conversion in the remaining follow-up period of 5.09 ± 1.87 years. The reasons for THA were unexplained pain with maintenance of chondral surfaces on magnetic resonance imaging for 1 patient in the pincer group and symptomatic progression of osteoarthritic changes for the other 2 patients. At primary hip arthroscopy, 1 patient in the pincer group had a 2-cm$^2$ grade 4 acetabular rim defect that was removed using pincer resection, causing a significant reduction in the LCEA, which may have contributed to rapid osteoarthritic progression. The patient in the control group had severe cam-dominant FAI at the time of surgery with widespread grade 1 femoral head changes and 2-cm$^2$ grade 4 acetabular defects requiring microfracture. Rates for conversion to THA for the larger group of all those eligible for the study were 1.2% and 0.8% in the pincer and control groups for the total follow-up period (mean, 5.09 years; *P* = .5) and 1.2% and 0.3% at 2 years (*P* = .1), respectively.

Time to revision or reoperation ranged from 7.5 to 78.9 months, and age at this operation ranged from 20.1 to 59.0 years. Four patients in the pincer group (3.5%) and 5 in the control group (4.4%) required revision or reoperation within 2 years. Two patients, 1 from each group, required subsequent endoscopic sciatic neurolysis for deep gluteal syndrome but no further hip arthroscopy. Of the remaining patients, the main indication for revision or reoperation within 2 years was capsulolabral adhesions: 1 patient in the pincer group and 3 in the control group. In addition, 1 patient in the pincer group developed recurrent pain after reinjury, causing a disruption to the primary capsule repair; 1 patient in the pincer group had bony regrowth at the femoral osteoplasty site, causing recurrent impingement; and 1 patient in the control group had persistent impingement, with findings of a recurrent labral tear and chondral damage at the site of the previous microfracture. Patients requiring revision or reoperation increased to 10 and 12 patients in the pincer and control groups, respectively, within the follow-up period. The majority (4 of 6 in the pincer group and 5 of 7 in the control group) were due to capsulolabral adhesions, despite immediate postoperative range of motion including circumduction to reduce this risk.[32] Rates of revision or reoperation for all those eligible were 6.8% and 8.4% for the follow-up period (*P* = .5)

TABLE 5
Intraoperative Procedures[a]

| | Pincer Group | Control Group | *P* Value |
|---|---|---|---|
| Labral | | | |
| Repair | 108 (94.7) | 93 (81.6) | .002 |
| Reconstruction | 4 (3.5) | 2 (1.8) | .41 |
| Capsular repair | 94 (82.5) | 93 (81.6) | .86 |
| Acetabuloplasty[b] | 108 (94.7) | 70 (61.4) | <.001 |
| Acetabular microfracture | 22 (19.3) | 47 (41.2) | <.001 |
| 1 hole | 2 (1.8) | 5 (4.4) | |
| 2 holes | 5 (4.4) | 11 (9.6) | |
| 3 holes | 7 (6.1) | 11 (9.6) | |
| 4 holes | 2 (1.8) | 13 (11.4) | |
| 5 holes | 3 (2.6) | 6 (5.3) | |
| >5 holes | 3 (2.6) | 1 (0.9) | |
| Femoroplasty (cam resection) | 102 (89.5) | 104 (91.2) | .65 |
| Ligamentum teres treatment | 1 (0.9) | 2 (1.8) | .56 |
| Iliopsoas fractional lengthening | 2 (1.8) | 7 (6.1) | .09 |

[a]Values are presented as No. (%).
[b]Detachment with rim trim or pincer resection.

TABLE 6
Patient-Reported Outcomes at Baseline and Minimum 2-Year Follow-up[a]

| | Preoperative | | | Postoperative | | | |
|---|---|---|---|---|---|---|---|
| | Pincer | Control | *P* Value | Pincer | Control | *P* Value | Interaction *P* Value |
| NAHS | 62.4 ± 19.5 | 64.1 ± 17.1 | .52 | 84.7 ± 16.5 | 86.5 ± 14.6 | .40 | .84 |
| iHOT-12 | 39.6 ± 20.2 | 39.7 ± 19.6 | ≥.999 | 74.5 ± 23.9 | 75.4 ± 23.4 | .56 | .55 |
| HOOS | | | | | | | |
| ADL | 69.6 ± 21.9 | 69.5 ± 19.1 | .97 | 88.4 ± 17.9 | 90.7 ± 14.7 | .30 | .34 |
| Sports | 44.8 ± 21.9 | 44.9 ± 22.5 | .97 | 74.8 ± 23.0 | 79.5 ± 21.1 | .12 | .22 |
| QoL | 33.8 ± 18.8 | 32.5 ± 19.1 | .66 | 68.1 ± 23.2 | 70.3 ± 23.3 | .48 | .35 |
| VAS pain | 60.9 ± 24.2 | 59.2 ± 24.3 | .48 | 22.4 ± 23.5 | 22.8 ± 26.0 | .90 | .69 |

[a]Values are presented as mean ± SD. ADL, Activities of Daily Living; HOOS, Hip Disability and Osteoarthritis Outcome Score; iHOT-12, 12-Item International Hip Outcome Tool; NAHS, Non-Arthritic Hip Score; QoL, Quality of Life; VAS, visual analog scale.

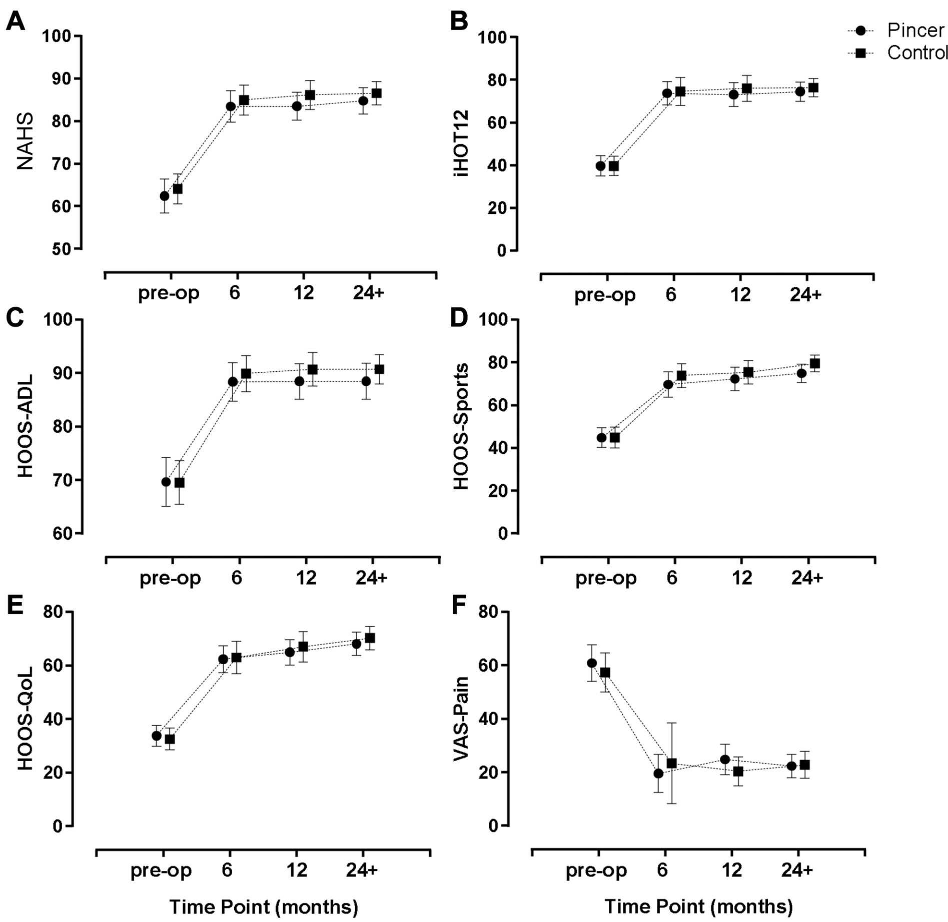


**Figure 1.** Pre- and postoperative outcome scores in the pincer and control groups. Error bars are 95% CIs. No interaction (time × group) effects attain statistical significance. (A) Non-Arthritic Hip Score (NAHS). (B) 12-Item International Hip Outcome Tool (iHOT12). Hip Disability and Osteoarthritis Outcome Score (HOOS): (C) Activities of Daily Living (ADL), (D) Sports, (E) Quality of Life (QoL). (F) Visual analog scale (VAS) for pain.

TABLE 7
Patient-Reported Outcomes of Patients Who Underwent Secondary Procedures[a]

| | Before Primary Operation | Secondary Operation | | *P* Value | |
|---|---|---|---|---|---|
| | | Before | After | Change | Interaction |
| Pincer (n = 10) | | | | | |
| NAHS | 46.4 ± 24.5 | 60.1 ± 19.6 | 75.0 ± 18.4 | .02 | |
| iHOT-12 | 30.6 ± 19.8 | 34.2 ± 21.0 | 64.4 ± 28.4 | .39 | |
| HOOS | | | | | |
| ADL | 55.0 ± 27.8 | 69.1 ± 21.6 | 81.1 ± 20.7 | .11 | |
| Sports | 43.8 ± 34.6 | 37.6 ± 22.9 | 60.6 ± 24.4 | .21 | |
| QoL | 18.9 ± 22.0 | 23.4 ± 11.1 | 50.2 ± 18.1 | .07 | |
| VAS pain | 65.8 ± 27.0 | 72.5 ± 10.9 | 42.3 ± 28.1 | —[c] | |
| Control (n = 12) | | | | | |
| NAHS | 60.4 ± 19.7 | 61.7 ± 22.3 | 77.8 ± 22.1 | .24 | .39 |
| iHOT-12 | 30.9 ± 22.1 | 36.3 ± 24.1 | 71.3 ± 30.8 | .02 | .63 |
| HOOS | | | | | |
| ADL | 57.9 ± 18.2 | 69.2 ± 23.9 | 82.8 ± 22.2 | .02 | .92 |
| Sports | 37.0 ± 19.0 | 49.5 ± 25.7 | 68.1 ± 32.3 | .09 | .33 |
| QoL | 28.9 ± 11.8 | 38.6 ± 22.8 | 63.1 ± 28.6 | .04 | .97 |
| VAS pain | 77.3 ± 11.1 | 51.4 ± 30.2 | 30.0 ± 29.3 | .16 | .57 |

[a]Values are presented as mean ± SD. ADL, Activities of Daily Living; HOOS, Hip Disability and Osteoarthritis Outcome Score; iHOT-12, 12-Item International Hip Outcome Tool; NAHS, Non-arthritic Hip Score; QoL, Quality of Life; VAS, visual analog scale.
[b]Group × Change interaction, represents the between-group difference in change.
[c]Insufficient number.

TABLE 8
Secondary Procedures According to Study Group[a]

| | Pincer (n = 114) | Control (n = 114) | *P* Value |
|---|---|---|---|
| Follow-up, y | 5.03 ± 1.87 | 5.15 ± 1.86 | .62 |
| Conversion to THA | 2 (1.8) | 1 (0.9) | .56 |
| Within 2 y | 2 (1.8) | 1 (0.9) | .56 |
| Time to THA, y | 1.39 ± 0.69 | 1.13 | .81 |
| Age at THA, y | 53.3 ± 5.3 | 61.1 | .44 |
| Revision or reoperation | 10 (8.8) | 12 (10.5) | .65 |
| Within 2 y | 4 (3.5) | 5 (4.4) | .52 |
| Time to surgery, y | 2.82 ± 1.79 | 2.86 ± 1.35 | .95 |
| Age at surgery, y | 35.6 ± 11.8 | 33.7 ± 11.9 | .71 |

[a]Values are presented as mean ± SD or No. (%). THA, total hip arthroplasty.

and 2.5% and 2.6% within 2 years (*P* = .9) for the pincer and control groups, respectively.

## DISCUSSION

This study demonstrated that patients with acetabular overcoverage and those with normal acetabular coverage can experience equivalent improvements in PROs at a minimum of 2 years after hip arthroscopic surgery. There was a low rate of reoperation and conversion to THA that did not significantly differ between the groups. In addition, the postoperative LCEA of the overcoverage group remained significantly larger than that of the control group, at 34.2° ± 3.5° versus 31.0° ± 3.0°.

Recent studies have demonstrated successful outcomes for patients with pincer-type FAI treated using acetabular rim resection during arthroscopic intervention.[6,20,28] Sanders et al[28] reported on a cohort of 42 patients with pincer-type FAI with a mean postoperative LCEA correction of 30.8° ± 1.8° from a preoperative LCEA of 39.9° ± 2.4°, with a mean iHOT-12 score of 69.7 points postoperatively. Matsuda et al[20] demonstrated equivalent improvement in 2-year outcomes for cohorts with global pincer FAI (LCEA >40°) and focal pincer FAI (LCEA, 25°-39° with a crossover sign), with a conversion rate to THA of 5% to 6%, although postoperative radiological findings were not reported. The authors found a mean improvement in NAHS of 21 to 22 points across both groups to a mean 24-month score of 77.3 in the focal group and 74.1 in the global group.

However, there are fewer studies directly comparing the outcomes of patients with pincer-type FAI and a hip arthroscopy control group with a normal LCEA. The first such study may be that of Chandrasekaran et al,[4] who compared 36 hips with an LCEA >40° with a matched control group with a normal LCEA at 2-year follow-up. In the overcoverage group, the LCEA decreased from 45° ± 4.69° to 28.8° ± 5.31°, while in the control group, it reduced from 31.3° ± 3.72° to 26.3° ± 4.07°. The SD of postoperative LCEA for the overcoverage group (5.31°) would indicate that a number of patients would have a postoperative LCEA that was at the lower end of the normal range or even borderline dysplastic. Although both groups improved, the authors found inferior improvements across all PROs in patients with acetabular overcoverage as compared with those with normal coverage (mean improvement in modified Harris Hip Score: 13.5 in the pincer group vs 21.7 in the control group) as well as significantly lower mean patient satisfaction scores. They also found a significantly higher rate of conversion to THA in the pincer group, with 4 conversions (11.1%, $P$ = .04) in a mean of 13.1 months as compared with 0 in the control group. The authors suggested that this could be related to technical difficulties with more challenging access or the different pattern of labral damage occurring in pincer FAI. Our study is in accordance with the literature regarding this different pattern of labral damage occurring in patients with acetabular overcoverage,[2] with a more posterior location of tears on the acetabulum and a greater proportion of intrasubstance tearing as compared with the control group.

A key question posed is the optimal amount of rim trimming for joint preservation, as radiologically determined by the LCEA. Our finding of equivalent functional outcomes between the pincer group and the control group contrasts with the findings of Chandrasekaran et al[4] in a similar matched-cohort analysis. Chandrasekaran et al showed more modest increases in the NAHS in their pincer group from a mean of 61 ± 23 preoperatively to 76 ± 20 postoperatively, while their control group increased from 59 ± 19 to 81 ± 20. Here we showed improvements in the same measure in both groups from 62 to 64 preoperatively to 85 to 87 postoperatively. Our results for iHOT-12, an outcome measure designed for patients undergoing hip arthroscopy,[22] showed marked increases in both groups from 40 preoperatively to 75 postoperatively (see Table 6). We also found a low conversion rate to THA of 0.9% to 1.8% over a mean follow-up of 5.36 years. These results may be in part attributable to a lesser resection of the acetabulum and a higher postoperative LCEA of 31° to 34°, and we suggest that this technique may be associated with better results and lower conversion rates.

A recent computed tomography–based evaluation of acetabular coverage in a large asymptomatic population supported retaining greater postoperative coverage, finding a mean "normal" LCEA of 31°, excluding those with an LCEA >40° or <20°.[18] In contrast, a previously accepted lower limit of LCEA for pincer resection has been 20°,[8] although most authors now suggest that rim trimming should be performed minimally with an LCEA <25°.[26,31] As a guide to the amount of rim trimming to undertake, Philippon et al[26] correlated the amount of rim resection with changes in LCEA, finding that for the first millimeter of acetabular bone resection, the LCEA decreased by 2.4°, with a decrease of 0.6° for each further millimeter of resection.

An important cadaveric study found that acetabular rim resection dramatically increases contact pressures through the hip joint, demonstrating a 300% increase in the acetabular base contact pressure with 6 mm of rim resection.[3] The authors found that this increase occurred in hips with a preoperative LCEA of >30°, so no postresection hip in the study had an LCEA of <23°. Thus, this large increase in articular surface loading with resection is not limited to joints traditionally considered dysplastic.[31] It is widely accepted that in the knee joint, greater stress on cartilage surfaces secondary to removal of meniscal tissue is the strongest predictor of long-term osteoarthritis.[25] Similarly, the rapid escalation of joint contact pressures in the hip through large rim resection may accelerate joint arthrosis.

It may be that it is the size of the rim resection, as evidenced by the radiological change in LCEA, that is more important than individual pre- and postoperative LCEA measurements. As suggested by Coughlin et al,[6] there is likely to be an LCEA unique to each individual for maximum joint preservation. We suggest that this may lie close to the patient's original LCEA, and a large reduction in LCEA during arthroscopic intervention may hasten joint degeneration.

We also note that other studies have been more liberal with acetabuloplasty, performing this frequently when the LCEA was in the normal range: Chandrasekaran et al[4] stated that acetabuloplasty was performed on 100% of patients with acetabular overcoverage and normal coverage. Rim resection has been universally performed to remove damaged areas of articular cartilage, typical of cam and pincer lesions, with acetabular microfracture used in remaining areas of full-thickness chondral damage. In the same study, acetabular microfracture was performed for 5.6% of the overcoverage group and 8.3% of the control group.[4] In a study of 3022 cases from the Danish Hip Arthroscopy Registry, Lund et al[19] found that acetabular rim trimming was performed in 85.8% of all cases and microfracture in 5.4%. In contrast, in the current study acetabuloplasty was undertaken for 95% of the overcoverage group but only 61% of the control group, where it was performed with the aim of reducing areas of full-thickness chondral damage without significant reduction in acetabular depth, often achieved by minor beveling of the rim. Nonetheless, the higher microfracture rate reported here, 19% of the overcoverage group and 41% of the control group, likely reflects greater areas of remaining acetabular chondral damage attributed to the reduced amount of rim resection and lower acetabuloplasty rate. Despite this difference in surgical technique, comparable postoperative PRO scores were obtained. Given that Gupta et al[11] found acetabuloplasty itself to be a predictor of conversion to THA, we suggest that removal of areas of acetabular rim cartilage damage should not take precedence over the preservation of acetabular socket depth.

A major strength of the current study is the large sample size of 228 hips (from 201 patients) from a single surgeon with a long mean follow-up period of >5 years. The conversion rate to THA for the entire control population eligible for matching (n = 924) was 0.8%; thus, the group chosen for matching seems to be representative of and generalizable to the overall patient population. This conversion rate was collected from the National Joint Registry, a database that captures all hip replacements performed nationally. The matched-pair analysis format allowed for control of factors known to influence outcomes after hip arthroscopy: age, extent of articular cartilage loss, and sex.[11,23] We also matched by the year of surgery to control for the effect of increasing surgical experience.[7,12,16] We used multiple PRO scores that have been validated for use in populations undergoing hip arthroscopy, particularly the Hip Disability and Osteoarthritis Outcome Score and iHOT-12.[14]

This study had several limitations. The LCEA measurement was based on pre- and postoperative radiographs, which are a 2-dimensional measure of a 3-dimensional structure and thus would be more accurately assessed with computed tomography imaging.[18] However, the LCEA has been shown to have high intraobserver reliability and to correlate with pincer-type FAI.[17,27] All operations were performed by a high-volume experienced hip arthroscopic surgeon; therefore, findings may not apply in all other settings. Finally, almost a third (33%) of all eligible surgical procedures were excluded from matching given the lack of follow-up scores, and it is possible that those excluded in this way are not representative of the group as a whole.

## CONCLUSION

Arthroscopic management of symptomatic FAI can achieve equivalent excellent results when normal acetabular morphology is compared with acetabular overcoverage. A key finding was that our results were associated with smaller-than-previous acetabular rim resections, producing a mean postoperative LCEA of 34.2° with a small SD (3.5°). A very low conversion rate to hip replacement was also achieved.

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