Treatment of Severe Pincer-Type Femoroacetabular Impingement With Arthroscopic Significant Acetabular Rim Correction and Circumferential Labral Reconstruction Improves Patient-Reported Outcome Measures

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Purpose: To validate an arthroscopic approach for performing significant acetabular rim correction and circumferential labral reconstruction required to treat severe pincer-type femoroacetabular impingement. **Methods:** Using a minimum of 2-year follow-up, data from 48 hips, including 47 patients (11 male, 36 female; mean age of 42 years) having undergone significant arthroscopic acetabuloplasty for severe pincer impingement (center edge angle >45°) with concomitant circumferential allograft labral reconstruction were analyzed to determine improvements in patient-reported outcomes and degree of radiographic correction. **Results:** Findings demonstrated a 98% success rate, including substantial improvements on all radiographic measurements and patient-reported outcomes. Minimal clinically important differences were met with extremely strong measures of effect. The mean center edge angle improved from 49° to 36° (MΔ = 13.96, $P \leq .001$, standard deviation [SD] = 55.97, confidence interval [CI] 12.17- 15.62, $d = 2.33$) and the mean Tönnis angle improved from −6° to 0° (MΔ = 6.2, $P \leq .001$, SD = 2.76 CI −7.1 to −5.39, $d = 2.29$). Modified Hip Harris Scores improved by a mean of 34.45 points ($P \leq .001$, SD = 20.64, 95% CI 28.45-40.44, $d = 1.66$). Lower extremity functional scale scores improved by a mean of 27.35 points ($P \leq .001$, SD = 18.37, 95% CI 22.02-32.69, d =1.48). No complications were reported. One case converted to a total hip arthroplasty (2%). **Conclusions:** Findings validated that the significant acetabular rim correction required to treat severe pincer morphology is safe and feasible via an arthroscopic approach. This, in addition to concomitant circumferential allograft labral reconstruction, resulted in improvement in patient-reported outcomes and radiographic measurements. **Level of Evidence:** Level IV, therapeutic case-series.

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The authors report the following potential conflicts of interest or sources of funding: B.J.W. is an educational and product development consultant for Smith & Nephew, AlloSource, and Zimmer Biomet and receives royalties from Zimmer Biomet. ICMJE author disclosure forms are available for this article online, as supplementary material.

Received November 22, 2021; accepted May 27, 2022.

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0749-8063/211615

https://doi.org/10.1016/j.arthro.2022.05.014

Due to innovations in surgical techniques and an associated exponential increase in demand, the last 2 decades have seen extraordinary growth within the specialty of arthroscopic hip surgery.[1,2] The goal of modern hip arthroscopy has shifted focus from simply resecting painful, damaged tissue to restoring and preserving hip function.[3] Hip preservation is achieved by addressing the multifactorial etiopathogenic factors that result in abnormal force transmission and load distribution throughout the joint. This involves attending to the painful, diseased, or degraded labral tissue and restoring the fluid seal of the femoroacetabular joint,[3-6] as well as addressing the variants in osseous morphology that contribute to the pathologic biomechanics that generate pain and result in chondrolabral pathology.[3,7-15]

Regarding nonarthritic chondrolabral pathology, a growing body of evidence is supporting labral reconstruction as a viable option not only in the revision setting but as a primary treatment for symptomatic femoroacetabular impingement (FAI) wherein the surgeon has deemed the labral tissue to be irreparable, including labral tissue that is ossified, degenerative, diminutive, or otherwise concluded to be of poor tissue quality.[3,16-18] Within the last few years, 6 systematic reviews and meta-analyses and more than 2 dozen studies have been published pointing to superior results of labral reconstruction as both primary and revision procedures in terms replicating the function of native, healthy hip tissue by re-establishing the fluid seal and thereby restoring joint pressurization, stability, and normal biomechanics.[4-6,16-48]

However, despite considerable advances in the techniques of hip-preservation surgery, significant acetabular overcoverage, such as severe pincer deformity (center edge angle [CEA] >45°), protrusio acetabuli, coxa profunda, and acetabular retroversion, continues to be recognized as a challenging problem in terms of arthroscopic treatment.[3,7,8,26,49-51] Due to the technical challenge of obtaining circumferential access to the joint, arthroscopists may opt to avoid arthroscopic hip surgery in patients with a CEA greater than 45°. Open surgical dislocation of the hip, which has been historically used as the standard approach for treating severe acetabular overcoverage, has been shown to be associated with an increased risk for significant morbidity and a more complicated recovery.[7-9,11,19,51-55]

While arthroscopic management of significant acetabular overcoverage, to include severe or global pincer-type FAI, protrusio acetabuli, coxa profunda, and acetabular retroversion, has been argued by field experts as presenting a significant technical challenge to an arthroscopic approach due to issues related to obtaining circumferential access to the joint,[7-9,26,51,52,56] findings from this study support the limited but growing body of evidence that has demonstrated safe and positive outcomes as they relate to the arthroscopic management of this complex problem. For example, when compared with cases that underwent open surgical dislocation of the hip, cases treated with arthroscopic methods were found to have significant correction in radiographic anomalies, improved scores on patient-reported outcomes (PROs), high rates of patient satisfaction, lower rates of major complications and patient morbidity, and low rates of failure or subsequent conversion to total hip arthroplasty.[7,9,52-54,57,58] Likewise, 2 relevant systematic reviews have been published in the last decade addressing the techniques used to treat the pathologic osseous morphologies that contribute to FAI of the hip. In 2011, Matsuda et al.[59] found that arthroscopic techniques were associated with lower rates of major complications and had equal or superior outcomes when compared to open or mini-open procedures. More recently, in 2018 Coughlin et al.[56] reported specifically on results as they pertain to FAI in the setting of global pincer morphology. Findings by Coughlin et al.[56] echoed those reported by Matsuda et al.[59] in terms of outcomes and complications. Likewise, both sets of authors also commented that in the hands of experienced surgeons, severe impingement morphologies can safely and successfully be treated arthroscopically[56,59]

The purpose of this large therapeutic case series was to validate an arthroscopic approach for performing significant acetabular rim correction and circumferential labral reconstruction required to treat severe pincer-type femoroacetabular impingement. Our study's hypothesis aimed to validate the arthroscopic management of severe pincer morphology with concomitant circumferential allograft labral reconstruction, contending that the procedure would be shown to be successful, safe, and associated with improved patient outcomes and radiographic measurements.

Methods

Patient Selection

Our therapeutic case series was composed of information queried from the lead author's prospective hip registry. Cases included in the study had undergone arthroscopic circumferential allograft labral reconstruction to treat symptomatic FAI performed by the lead author between January 2014 and December 2016 and were those also noted to have severe pincer morphology as evidenced by a CEA of greater than 45° and a Tönnis angle of zero degrees or less.[51,60−62] The study cohort included both male and female patients and did not exclude by age or other demographic features. Cases were excluded if they did not meet radiographic criteria for severe pincer deformity. Likewise, cases with less than a minimum of 2-year follow-up were excluded. This study was institutional review board approved.

Physical and Radiographic Examination

Symptomatic labral pathology and hip impingement were diagnosed using clinical examination, plain-film radiographs, magnetic resonance imaging, and, when applicable, diagnostic injections. A physical examination was performed on all included cases by the lead author, including measurements of range of motion and tests for anterior and posterior hip impingement. Patients were offered hip arthroscopy if they had positive examination findings in addition to hip pain refractory to nonoperative conservative care in the setting of well-preserved joint space (>2 to 3 mm). As has been described previously, it has been the surgical practice of the lead author since 2013 to perform arthroscopic circumferential allograft labral reconstruction of the hip

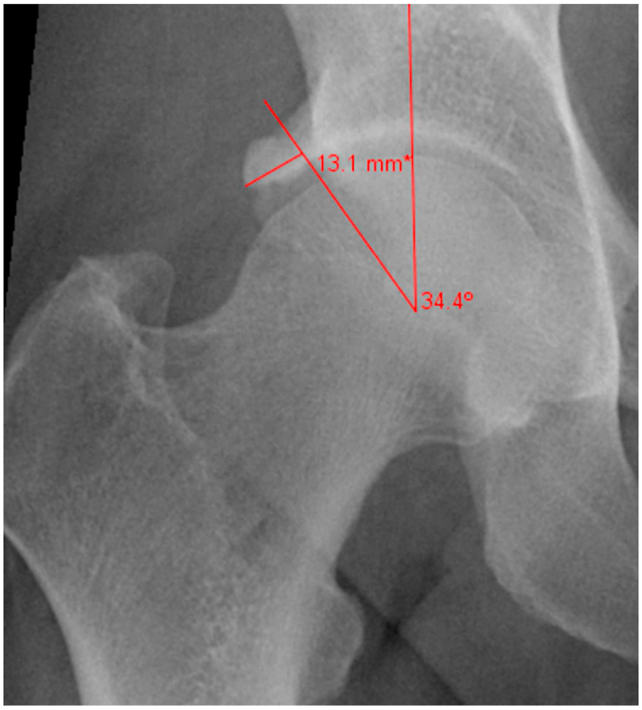

Fig 1. Anteroposterior image of a right hip with a severe pincer and CEA of 56° and Tönnis angle of −7°. The CEA was corrected to approximately 34° with a neutral Tönnis angle. Per this template, this required an approximately 13 mm resection. (CEA, center edge angle.)

both as primary and revision procedures, rather than labral repair, in any instance when the labrum is deemed irreparable.[3,16,18,37]

Preoperative radiographs were obtained, including standing and corrected anteroposterior (AP) pelvis, false-profile, and cross-table lateral views. Properly rotated and centered AP pelvis radiographs with 2 to 4 cm distance between the sacrococcygeal joint and the pubic symphysis were used to plan the amount and degree of correction required to create an acetabulum with more normal coverage. The CEA of Wiberg, which was measured to the lateral edge of the acetabulum, and the Tönnis angle were the 2 measurements used to numerically quantify the severity of the pincer and to assess and quantify the desired correction.[60-62] A cross-table lateral view was used to measure the alpha angle.

Data Collection and Outcomes Measures

Preoperative clinical and radiographic information and surgical data were recorded by the lead author, who was also the surgeon in all included cases. Data were then entered into the lead author's prospective hip registry database. Patient reported outcomes, including the Modified Hip Harris Score (mHHS), Lower Extremity Functional Scale (LEFS), visual analog scale (VAS) at rest, VAS with activities of daily living (ADLs), and VAS with sports were collected preoperatively, and at the most recent follow-up greater than 2 years from the date of surgery.[16-18,38,63] Patient satisfaction levels, rated on a scale of 1 to 10, where 10 was extremely satisfied, also were collected at the most recent follow-up. Intraoperative fluoroscopic images in the AP and lateral planes were used to assess the significant acetabular correction required to treat severe pincer-type morphology. Imaging obtained at follow-up in the lead author's office included plain film corrected AP-pelvis and cross-table lateral radiographs. Postoperative radiographs were obtained at the 2-week and 3-month postoperative appointments and were compared with those obtained preoperatively. Failure was defined per the practice of the lead author as a need for revision ipsilateral hip surgery, which included revision hip arthroscopy or conversion to total hip arthroplasty.

Surgical Technique

The operation begins with templating the original AP radiographs to determine the amount of necessary resection and to develop an appropriate intraoperative plan. Using the AP pelvis radiograph, the CEA is adjusted from its high preoperative value to a desired correction in the mid-30° and to the location where the Tönnis angle is improved from a negative number to zero-degrees. The distance in millimeters from the original lateral edge of the acetabulum or pincer to the desired edge of the acetabulum with both the corrected CEA and Tönnis angle is measured (Fig 1). This measurement is then used intraoperatively to determine the

Fig 2. Postoperative right hip radiograph of the same patient after the planned pincer resection with a final center edge angle of 34° and Tönnis angle of zero degrees in the setting of a circumferential allograft labral reconstruction.

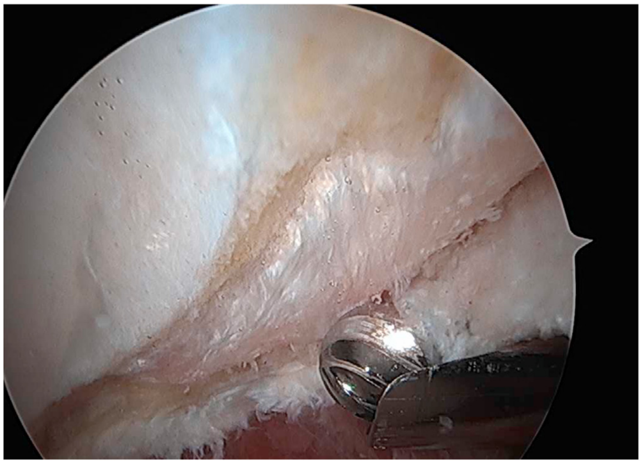

Fig 3. Arthroscopic view from the anteromedial portal of the posterolateral acetabulum in a left hip with a planned 8-mm resection. A 5-mm round burr is used for scale and measuring.

amount of the acetabular edge resection needed to achieve the desired correction. The amount of anterior and posterior resection relative to the lateral edge of the acetabulum is determined by the assessment of the acetabular walls on the original radiographs and balancing the correction around the entire acetabulum.

At the start of each procedure, an intraoperative fluoroscopic AP pelvis is obtained, centered, and rotated to match the preoperative radiograph upon which the template is based. Arthroscopically, labral tissue is removed between the 9:00 and 4:30 position in right hips and 7:30 and 3:00 positions in left hips. Labral tissue is removed even more posteriorly and inferiorly if the pincer deformity requires more extensive resection. Complete resection of the labrum allows for excellent exposure of the acetabular rim and understanding the full extent of the pincer deformity. Radiofrequency ablation is used to mark the amount of bone that is to be removed (Fig 2). It is important that the surgeon recognizes the location on the acetabulum that corresponds to the lateral edge of the acetabulum on radiograph as it is often more posterior than one might think. Anterior and posterior resection is then typically judged from the preoperative radiographic assessment of acetabular walls and volume, as well as based upon surgeon experience (Fig 3). Once the acetabulum is optimally reshaped, an intraoperative AP fluoroscopic image is obtained and compared to the preoperative fluoroscopic image, as well as the planned template (Fig 4).

Following the completion of adequate acetabular resection, and after the cam deformity is removed and the femoral neck is anatomically reshaped, a circumferential allograft labral reconstruction is performed. The technique for the arthroscopic circumferential allograft labral reconstruction has been described in our previous publications in detail and includes the use of Smith & Nephew Q-FIX and SUTUREFIX anchors, as well as an AlloSource frozen fascia lata allograft.[37,38] As noted in our previous publications, graft length is determined by measuring the rim and adding 3 to 4 cm.[37,38]

It is of critical importance that the labral graft is both fixed and originates at the origin of the anterior transverse acetabular ligament. With some severe pincer deformities, even after adequate resection, it is not possible to access the anteroinferior aspect of the acetabulum in traction. In such cases, low anterior anchors are placed, and the graft is transported into the joint and secured in the peripheral compartment out of traction. Access is made possible by introducing the camera through a canula placed in an anteromedial (AM) portal after all the anchors are placed. The AM poral is located approximately 6 cm medially and 1 cm distally to the anterolateral portal.[3,37] The anterior sutures are pulled through the AM portal and kept on tension so that the graft can functionally be transported across the joint from the anterolateral portal to the anteroinferior aspect of the acetabulum without catching or becoming tangled in the other sutures. The graft is then secured at the first anchor position and progressive fixation is performed from the front to the back of the joint (Figs 5-7) as has been previously described.[37]

Postoperative Procedures

All patients were instructed on the lead author's postoperative recovery protocol. In patients in whom microfracture was not performed, this included 30% weight-bearing for 4 weeks with continuous passive motion for 2 weeks. If a microfracture procedure was performed, patients were limited to 20% weight-bearing for 6 weeks. All patients were limited to external rotation of the hip to neutral for 2 weeks. No patients were placed in postoperative hip braces. All

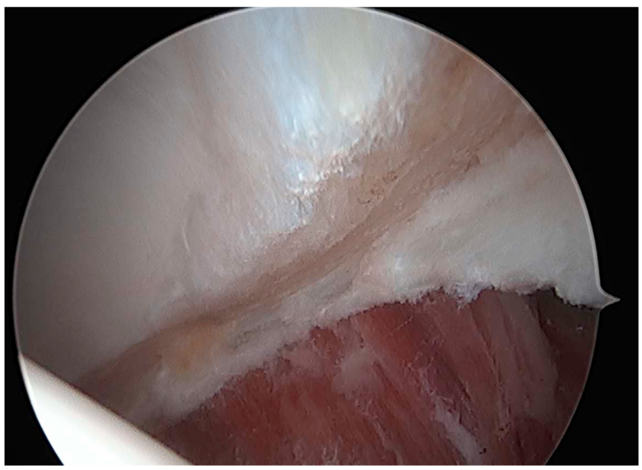

Fig 4. Arthroscopic view from the anteromedial portal in a left hip after the 8-mm resection.

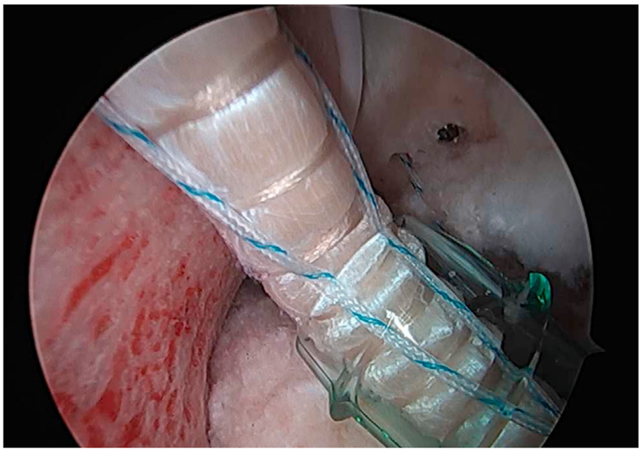

Fig 5. View from the anteromedial portal with the canula in the anterolateral portal in a left hip: transporting the graft into the joint via the peripheral compartment.

patients were prescribed 325 mg of aspirin once daily for 10 days in addition to sequential compression devices for the prevention of deep-vein thrombosis. All patients were prescribed naproxen 500 mg twice daily for 2 weeks for heterotopic ossification prophylaxis. Physical therapy was initiated per our protocol within 1 week and continued for several months postoperatively, stopping when the patients' goals and expectations were met.

Statistical Analysis

G-Power (http://www.gpower.hhu.de/) was used to conduct a power analysis. To obtain a power of ≥80%, it was determined that a sample size of 34 cases would be needed to obtain modest to large effects with statistical significance. 48 cases met criteria for inclusion, thus validating that the study had adequate power per demonstrated results. For all continuous data, distributions were assessed for outliers. If means and medians were found to be similar, indicating normal distribution of the data, standard deviations (SDs) were reported. Because data were generally found to be normally distributed, paired samples *t*-tests were used to assess the changes in mean scores on radiographic measurements and PROs. These findings were confirmed by computing new variables representing the change between preoperative and postoperative scores on radiographic measurements and PROs. Due to the limited nature of research on this topic, no comparable studies were found by which to create a precedent for measuring the minimal clinically important differences (MCIDs). Therefore, and in addition to the normality of the data distribution, the MCID was calculated using Cohen's *d*, which is a recognized distribution-based MCID model measuring effect, or magnitude, or an intervention or variable.[64-66] As this was a therapeutic case series/methodologic validation study, there was no control or comparison groups. Due to the nature of the study design, we did not assess for a prospective differential effect of changes over time and did not create a multivariate model to control for extraneous factors or covariates. Likewise, as comparisons were made only from one group (preoperative versus postoperative), we did not adjust for multiple comparisons. Statistical analysis was performed using IBM SPSS Statistics, version 28 (IBM Corp., Armonk, NY). A *P*-value of $< .05$ was considered statistically significant. A Cohen's *d* of > 0.8 was considered of large magnitude or effect.

Results

Demographics

Data from 52 patients in the lead author's prospective patient registry met the primary inclusion criteria of

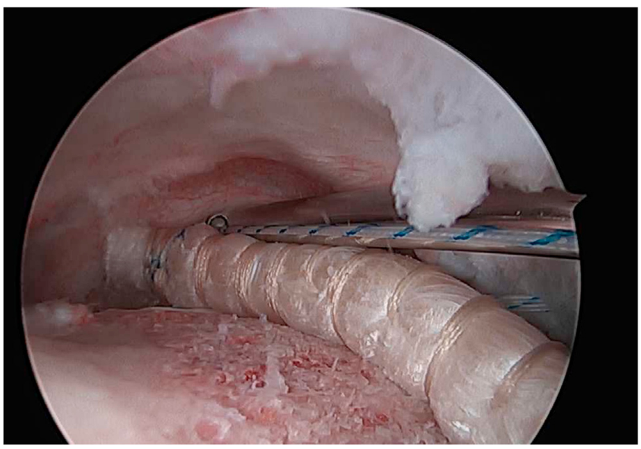

Fig 6. View from the anteromedial portal securing the first anchor with a knot pusher from the anterolateral portal in the left hip.

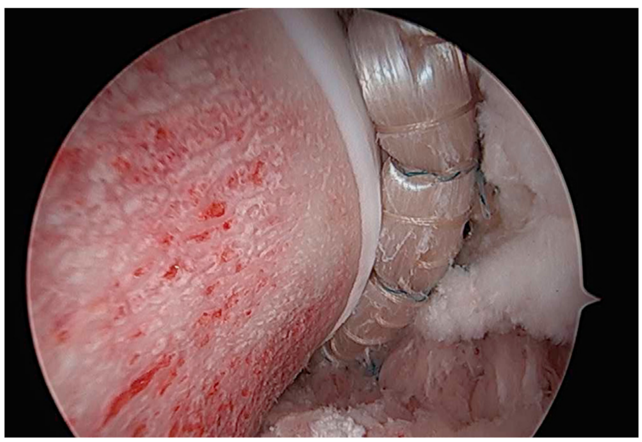

Fig 7. Final view from the anteromedial portal of the completed 14 cm circumferential allograft labral reconstruction in a left hip, forming a complete seal with the femoral head.

Table 1. Demographic Characteristics

Patients meeting criteria	47
Hips meeting criteria	48
Right	33
Left	15
Sex	
Male	11
Female	36
Age at surgery, y	42.2 (15-57)
Follow-up, mo	46.2 (27-68)
Anchors used	8 (7-10)
Graft length, cm	11 (8-13)
Graft width, mm	5-5.5
Conversion to THA	1 (2%)

THA, total hip arthroplasty.

having preoperative severe pincer-type FAI. Four cases were lost to follow-up. The remaining 47 patients (48 hips, 92%) met inclusion criteria of 2-year minimum follow-up. This included 11 male and 36 female patients with a mean age of 42.2 years (range 15-57 years) at the time of surgery. In total, 44 were primary surgeries and 3 were revision operations. The mean time of last follow-up was 46.2 months (range 27-68 months). As was described in the surgical technique, all patients underwent arthroscopic correction of severe pincer-type impingement morphology with concomitant circumferential allograft labral reconstruction. The average graft length was 11 cm (range 8-13 cm), with an average width of 5 to 5.5 mm. An average of 8 anchors (range 7-10 anchors) were used. One patient failed and was converted to a total hip replacement (2%), resulting in a success rate of 98% for this operation. This case, which converted to a total hip arthroplasty, was not 1 of the 3 revision operations. Table 1 describes demographics.

Patient-Reported Outcomes

Results demonstrated both statistically significant improvement as well as extremely large measures of effect that met the MCID for each PRO as reflected in the Cohen's d. 100% of cases reported improvement on the mHHS. mHHS scores improved by a mean of 34.45 points, from 50.26 to 84.7 (95% confidence interval [CI] 40.44-28.46, SD = 20.64, $P \leq .001$, $d = 1.67$), and 96% of cases reported improvement on the LEFS. LEFS scores improved by a mean of 27.35 points, from 40.44 to 67.79 (95% CI 32.69-22.02, SD = 18.37, $P \leq .001$, $d = 1.48$). VAS at rest decreased from a mean of 4.73 of 10 to 2 of 10 (MΔ = 2.71, SD = 2.1, 95% CI 2.1-3.32, $P \leq .001$, $d = 1.2$). VAS with ADLs decreased from a mean of 6.27 of 10 to 2.56 of 10 (MΔ = 3.71, SD = 2.41, 95% CI 3.01-4.41, $P \leq .001$, $d = 1.54$). VAS with sports decreased from 7.81 of 10 to 3.38 of 10 (MΔ = 4.43, SD = 2.33, 95% CI 3.85-5.22, $P \leq .001$ $d = 1.94$). Additionally, 19 patients (nearly 40%) reported a satisfaction level of 10 of 10 at most recent follow-up. The average postoperative satisfaction level was rated as 8 of 10. Table 2 summarizes PRO findings.

Radiographic Findings

Table 3 describes the radiographic findings, which demonstrated significant correction of severe pincer-type impingement morphology. There were statistically significant improvements from all preoperative to postoperative measurements, as well as effect sizes of extremely large magnitude. The average CEA improved from a mean of 49.21° to a mean of 35.4° (MΔ = 13.96°, SD = 5.97, 95% CI 12.17-15.61, $P \leq .001$, $d = 2.33$). The average Tönnis angle improved from a mean of −5.76° to 0.47° (MΔ = 6.2°, SD = 2.76, 95% CI −7.1 to −5.39, $P \leq .001$, $d = 2.29$). The average alpha angle improved from a mean of 62.44° to 42.87° (MΔ = 19.49°, SD = 7.47, 95% CI 17.34-21.68, $P \leq .001$, $d = 2.61$).

Complications

No complications, such as surgical-site infections, venous thromboembolism, lasting neurologic deficits, or other patient morbidities were noted. All patients underwent both general and spinal anesthesia without complication. On average, patients were intermittently on traction during surgery for an approximate total of 90 minutes. No lasting cases of traction neuropraxia were reported.

Table 2. Patient-Reported Outcomes

	Mean	SD	95% CI Upper/ Lower	2-Tailed P	Cohen's d
LEFS					
Preoperative	40.44	17.85			
Postoperative	67.79	16.12			
Change	27.35	18.37	32.69-22.02	≤.001	1.48
mHHS					
Preoperative	50.26	16.38			
Postoperative	84.7	17.7			
Change	34.45	20.64	40.44-28.46	≤.001	1.66
VAS at rest					
Preoperative	4.73	2.18			
Postoperative	2	1.87			
Change	2.71	2.1	2.1-3.32	≤.001	1.2
VAS w/ADLs					
Preoperative	6.27	2.09			
Postoperative	2.56	2.37			
Change	3.71	2.41	3.01-4.41	≤.001	1.54
VAS w/sport					
Preoperative	7.81	1.56			
Postoperative	3.38	2.61			
Change	4.53	2.33	3.85-5.22	≤.001	1.94
Satisfaction					
Postoperative	8.19	2.38			

ADLs, Activities of Daily Living; LEFS, Lower Extremity Functional Scale; mHHS, Modified Hip Harris Score; SD, standard deviation; VAS, visual analog scale.

Table 3. Radiographic Findings

	Mean	Range	SD	95% CI Upper/ Lower	2-Tailed *P*	Cohen's *d*
Tönnis angle						
Preoperative	−5.76	−10 to 0	2.62			
Postoperative	.47	−4 to 5	1.96			
Change	6.2	−13 to 0	2.76	−7.1 to −5.39	≤.001	2.29
Center edge						
Preoperative	49.21	45-68	5.37			
Postoperative	35.4	47-32	1.96			
Change	13.96	6-33	5.97	12.17-15.61	≤.001	2.33
Alpha angle						
Preoperative	62.44	43-69	6.66			
Postoperative	42.87	39-48	2.35			
Change	19.49	−3 to 28	7.47	17.34-21.68	≤.001	2.61

CI, confidence interval; SD, standard deviation.

Discussion

While severe pincer-type FAI (CEA >45°) is seen as presenting a challenge within the specialty of hip arthroscopy, the results from this study affirmed our hypothesis that the significant acetabular rim correction required to treat severe pincer-type FAI and concomitant circumferential allograft labral reconstruction are not only feasible but are safe and result in highly positive patient outcomes when performed using an arthroscopic technique. At a minimum of 2 years' follow-up, average mHHS scores improved by 34 points, average LEFS scores improved by 27 points, significant improvements were noted with VAS scores at rest, with ADLs, and with sports, and patients overwhelmingly reported high degrees of postoperative satisfaction. Radiographically, arthroscopic management of severe pincer morphology resulted in correction from an average CEA of 49° to 36° and correction of an average Tönnis angle from −5.76° to near zero degrees (0.47°). Additionally, arthroscopic management of this complex issue proved to be exceedingly safe and resulted in no reported postoperative complications.

Results from this large therapeutic case series validated a minimally invasive method for improving pain and restoring hip function. As such, surgeons can avoid exposing patients to the potential risks and complications related to the large incision and trochanteric osteotomy associated with open surgical dislocation of the hip.[9,52,54,59] Using the described arthroscopic technique, which includes working out of traction in the peripheral compartment, the experienced hip arthroscopy specialist can overcome challenges related to severe pincer-type FAI, correct the over coverage of the acetabulum, and complete a circumferential labral reconstruction. Future research is recommended including prospective, experimental designs, and inclusion of broader patient populations treated by more than a single surgeon with longer-term follow-up intervals.

Limitations

Limitations to this research should be acknowledged. Being a therapeutic case series, our study lacked the control that would be seen with an experimental design. We could not control for the confounding variables of persons-vectors,[67] variances in hip pathology, concomitant procedures, individual history of disease or injury, and surgeon and technological-dependent improvements that occurred over the 2 years' data in which were collected. Outcome measures did not include range of motion. Additionally, due to the limited nature of research on this topic, no comparable studies were found by which to create a precedent for measuring MCID; as such a distribution-based model was used incorporating Cohen's *d*. It is of salient importance to note that labral reconstruction is a technically demanding procedure that requires a certain degree of experience and proficiency in hip arthroscopy. Therefore, and in consideration of the limitations, we realize that results may not be generalizable to all patients with severe pincer-type FAI or to other surgeons.

Conclusions

Findings validated that the significant acetabular rim correction required to treat severe pincer morphology is safe and feasible via an arthroscopic approach. This, in addition to concomitant circumferential allograft labral reconstruction, resulted in improvement in PROs and radiographic measurements. The described technique allows for accurate and complete acetabular correction. Working out of traction in the peripheral compartment can enhance circumferential exposure, access the anteroinferior acetabulum, minimize traction issues, and can be used to transport the graft into the joint. Previously described positive outcomes with allograft labral reconstruction can be applied to the patient with very challenging severe pincer-type FAI. The results from this study make a strong case for experienced hip arthroscopists in providing a safe and effective option in managing patients with severe pincer-type FAI and labral pathology.

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