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Research Article

Initial Outcomes Following Femoral Head Osteochondral Allograft and Meniscus Allograft Labral Reconstruction: A Prospective Cohort Study

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Abstract

Purpose: To determine initial pain and function outcomes for patients undergoing hip preservation surgeries including Acetabular Labrum Reconstruction (ALR) and/or Femoral Head Osteochondral Allograft Transplantation (FHOCA).

Methods: Patients scheduled to undergo hip preservation surgery were prospectively enrolled into an IRB-approved registry. Patients were included for analyses when they underwent fresh meniscus ALR and/or FHOCA transplantation with a minimum of 1-year follow-up. Patient-Reported Outcome Measures (PROMs) were collected preoperatively and 3 months, 6 months and yearly post-operatively. Fisher's exact tests, Wilcoxon signed-rank tests and Kruskal-Wallis tests were used for statistical analysis, with $p < 0.05$ considered statistically significant.

Results: A total of 43 patients met inclusion criteria. Outcomes were deemed successful in 4 of 6 FHOCA patients (66.6%), 7 of 9 FHOCA+ALR patients (77.8%) and 27 of 28 ALR patients (96.4%) with no statistically significant difference based on cohort ($p = 0.051$). Only the ALR cohort demonstrated statistically significant improvements in outcome scores. There was no statistically significant risk for failure associated with undergoing concomitant procedures.

Conclusion: The findings of this study demonstrate an overall success rate of 86.8% for ALR and/or FHOCA hip preservation patients with a minimum of 1 year of follow up, with no significant difference in success rates based on undergoing FHOCA alone, ALR alone or FHOCA combined with ALR. All 3 cohorts demonstrated modest improvements in outcome scores from preoperative assessment to FFU, however, the ALR-only group alone demonstrated statistically significant improvements in hip function and pain scores by FFU.

Keywords: Acetabular Labral Reconstruction; Arthroscopic; Meniscus Allograft; Hip Preservation

Level of Evidence: III, prospective non-randomized controlled cohort study.

Introduction

Symptomatic femoral head articular cartilage lesions and irreparable acetabular labral tears can occur alone or in combination and are being diagnosed with increased frequency, especially among young, active individuals. In this patient population, these conditions are commonly caused by factors such as Femoroacetabular Impingement Syndrome (FAIS), hip dysplasia, trauma, overuse or avascular necrosis, significantly elevating the risk of early-onset hip Osteoarthritis (OA) [1-3]. While nonsurgical and surgical treatments aimed at alleviating pain and dysfunction and mitigating the development and progression of hip OA are

desirable, these conditions pose a challenge for preventative treatment. Total Hip Arthroplasty (THA) may be an effective surgical treatment option for patients with end stage hip OA, however, it is generally avoided in young, active individuals [4-6]. As such, surgical reconstruction procedures that restore articular tissue form and function may be necessary to preserve the native hip joint and delay the need for THA in affected patients [7-9].

Functional hyaline articular cartilage and acetabular labral fibrocartilage are essential for maintaining hip joint health through their crucial roles in loading, stability, suction-seal, lubrication and motion components of movement. Articular cartilage repair results in inferior fibrocartilage production and while acetabular labral repair can produce excellent outcomes, many defects are irreparable such that Acetabular Labral Reconstruction (ALR) should be prioritized over labral resection.10 There has been an evidence-based shift in practice to the use of fresh high-cell-viability Femoral Head Osteochondral Allograft (FHOCA) transplantation and/or Meniscus Allograft Transplantation (MAT) for the treatment of symptomatic femoral head articular cartilage lesions and irreparable acetabular labral tears, respectively [9-21]. The purpose of this study was to determine initial pain and function outcomes for patients undergoing hip preservation surgeries including ALR and/or FHOCA. It was hypothesized that patients undergoing FHOCA transplantation and MAT ALR alone or in combination would have high success rates and improvements in PROMs by 1 year.

Methodology

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed to include institutional review board approval (#2003053) and documented informed consent for all patients to undergo allograft transplantation in the hip and be prospectively enrolled into a registry established to follow hip preservation surgery outcomes.

Study Patients

All patients included in this study underwent pre-operative Magnetic Resonance Imaging (MRI) and/or diagnostic hip arthroscopy to determine the extent and severity of femoral head and labral pathology. All patients had large (>2.5 cm^2) grade III or IV focal articular cartilage defects of the femoral head and indicated for FHOCA transplantation and/or had irreparable acetabular labrum deficiency and indicated for MAT ALR. Patients selected FHOCA transplantation and/or MAT ALR after comprehensive preoperative assessment and counseling, insurance approval and documentation of their informed consent to proceed with surgery. The 3 treatment groups in this study consisted of patients who underwent FHOCA transplantation alone, patients who underwent MAT ALR alone and those who underwent combined MAT ALR with FHOCA transplantation. All patients included had a minimum of 1-year of follow-up data available. Those patients excluded from the study were pregnant, incarcerated or underwent previous acetabular or femoral head cartilage repair procedures. All procedures were performed between June 2016 to May 2024.

Allograft Recovery and Processing

Based on extensive evidence, fresh (viable) allografts documented to have high-cell-viability at the time of transplantation were used for all cases in this study [11,19,20]. Osteochondral and meniscal allografts used in these procedures were recovered from eligible organ and tissue donors for processing, testing and storage at an American Association of Tissue Banks (AATB)-accredited tissue bank (MTF Biologics, Edison, NJ, USA) using a commercially available preservation method (Missouri Osteochondral Preservation System, MOPS®). Once cleared for use based on completion of all required safety testing, allografts were used in conformance with the FDA's classification of human cell and tissue products under Section 361 of the Public Health Service Act within 56 days after recovery [11,19,20].

FHOCA Transplantation [22-24]

All FHOCA transplantations were performed via surgical hip dislocation [23]. A step-cut greater trochanteric osteotomy was performed [22]. FHOCA transplantations were performed using either cylindrical grafts ("plugs") or custom-cut, patient-specific shell grafts, depending on the defect's size and shape. Size-matched cylindrical OCAs were fashioned from donor tissues using commercially available tools, while custom-cut shell OCAs were shaped using a sagittal saw. Subchondral OCA bone was drilled, irrigated and saturated with autogenous BMC [24]. Cylindrical grafts were implanted using press-fit fixation, while custom-cut shell grafts were secured with bioabsorbable nails (SmartNail, ConMed; Largo, FL, USA). When MAT ALR was performed in combination with FHOCA transplantation, the FHOCA transplantation procedure was completed first.

Acetabular Labrum Reconstruction [22-28].

Open ALRs were performed via surgical hip dislocation [23]. A step-cut greater trochanteric osteotomy was performed [22]. Irreparable labral tissue was resected and the recipient bed was prepared. Meniscal allografts were prepared by sharp dissection and trimmed to size. Passing sutures were placed along the peripheral margin of the meniscus allograft at 1 cm intervals such that each entered and exited at the inferior and superior margins to engage the meniscal circumferential fibers. Knotless labral-based suture anchors and a posterior junctional suture anchor were placed at 1 cm intervals along the recipient from anterior to posterior. The hip was reduced and all anchor sutures were passed into the meniscus allograft using the pre-placed passing sutures. Lastly, the posterior junctional anchor suture was used to attach the allograft to the remaining native labrum and all sutures were tightened.

Arthroscopic ALRs were performed using anterolateral, modified mid-anterior, Distal Anterolateral (DALA), anterior proximal medial and posterior portals [25]. Traction was applied to distract the hip joint. Nonviable appearing labral tissue was debrided, the acetabular rim was prepared, an anchor was placed at the lateral and medial extent of the labral deficiency and pilot holes for knotless anchors were drilled. Meniscal allografts were prepared and trimmed to size. The meniscus allograft was delivered into the joint through the posterior portal using the Kite technique [26]. One suture from the anterior/medial most and from the posterior/lateral most anchor were retrieved. The anterior-most and posterior shuttle stitches were passed through the meniscus. The sutures through the meniscus body were retrieved via the accessory proximal medial portal. A knotted anchor suture was tied anteriorly. The sutures within the meniscus were retrieved via the DALA portal and placed into knotless suture anchors tensioned sequentially to allow for appropriate fixation and contouring. A posterior knotted anchor was used to fix the meniscus allograft. Traction was released, the suction seal was restored and capsular plication of the capsulotomy was performed [27,28].

Rehabilitation Protocols

Each patient was provided with procedure-specific postoperative rehabilitation instructions, delivered both verbally and in written form. Instructions were shared with outpatient physical therapists involved in the patient's recovery. Post-operative rehabilitation protocols are outlined in Fig. 1. Patient adherence to the postoperative rehabilitation protocol were recorded when patients significantly deviated from the prescribed protocol during the first year following surgery.

Outcome Measures

PROMs collected included the Visual Analog Scale (VAS) for pain, the Hip Disability and Osteoarthritis Outcome JR Score (HOOS-JR) and the Patient-Reported Outcomes Measurement Information System (PROMIS) Physical Function [29-31]. These were evaluated preoperatively, at 3 months, 6 months and annually after surgery. Demographic data, surgical details, postoperative complications, concurrent surgeries and reoperation records were gathered from patients' electronic medical records. Treatment failure was defined as need for revision surgery to address any issue with the primary allograft transplants or conversion to total hip arthroplasty at any time point during follow-up. Revisions were defined as any reoperation to revise any previously implanted allografts and decisions to pursue revision were based on discussion between surgeon and patient regarding failure mechanism, treatment options, prognosis and patient preference. Outcomes were deemed successful if patients reported that they resumed activities of daily living without needing revision or arthroplasty at FFU. The Final Follow-Up (FFU) was defined as the final in-person visit with the hip preservation team or the last timepoint for completing PROMs.

Statistical Analysis

Descriptive statistics were employed to summarize means, ranges and percentages. Fisher's exact tests were conducted to identify significant differences in proportions. For comparisons showing significant differences, odds ratios were calculated. Wilcoxon signed-rank tests was used to compare failure rates based on patient characteristics. Kruskal-Wallis tests were used to evaluate for cohort differences in medians. The value of $p < 0.05$ was considered statistically significant. Minimum clinically significant difference (MCID) for VAS pain score was defined as 1.86, for HOOS-JR was 8.0 and for PROMIS Physical Function was 5.0 [32,33].

	Standard Postoperative Rehabilitation Protocols by Procedure		
	Any Patient With Operation Including FH OCA Transplantation	**Open ALR - Only Patients**	**Arthroscopic ALR - Only Patients**
Weight Bearing and Range of Motion Restrictions	Restricted to 25 pounds for six weeks and prohibited from performing active hip abduction		Restricted to 25 pounds for two weeks
Physical Therapy	Begin within the first two weeks after surgery. Continue for up to six months.		
Stationary Bike	Use was allowed starting one week after surgery.		
Reintroduction of Weight Bearing Activities	Gradually reintroduced after six-week clinical examination and radiographs		Gradually reintroduced after two-week clinical examination
Discontinue Crutches Use	Once cleared by surgeon and gait is normal and pain free		
Return to Sport and High Level Activity Permitted	At least 12 months postoperatively. Advancement contingent upon evidence of OCA remodeling on imaging.	About six months postoperatively	

Post-operative protocols based on treatment cohort.

Figure 1: Post-operative rehabilitation protocols.

Results

A total of 43 consecutively treated patients met inclusion criteria (24M, 19F). There were no significant differences in sex, Body Mass Index (BMI), nicotine use or patient adherence among cohorts. The mean patient age was significantly higher in the ALR cohort at 33.2 compared to the FHOCA cohort and FHOCA+ALR cohort ($p = 0.006813$). There were no significant differences in pre-operative HOOS-JR score, VAS pain score or PROMIS Physical Function among cohorts. The mean FFU was 48.3 ± 27.2 months in the FHOCA cohort, 38.3 ± 16.3 months in the FHOCA+ALR cohort and 37.8 ± 19.3 in the ALR cohort ($p = 0.1703$).

Successful outcomes were documented in 4 of 6 patients in the FHOCA cohort, 7 of 9 patients in the FHOCA+ALR cohort and 27 of 28 patients in the ALR cohort ($p = 0.05068$) (Table 1). There were no differences in sex, mean age, mean BMI, nicotine use or adherence between successful and failed cohorts. The mean FFU was 38.4 ± 19.1 in the successful cohort and 47 ± 25.4 in the failed cohort ($p < 0.0005$) (Table 2,3).

At 1 year post-operatively, there were no significant differences among cohorts for HOOS-JR, VAS pain or PROMIS Physical Function. At FFU (mean > 3 years), there were no significant differences among cohorts in HOOS-JR, VAS pain or PROMIS Physical Function. When comparing pre-operative to 1-year post-operative PROMs, there were statistically significant improvements reported in the ALR cohort for HOOS-JR ($p = 0.002$), VAS Pain ($p = 0.0008$) and PROMIS Physical Function ($p = 0.006$) scores. Improvements in these scores did not reach statistical significance in either the FHOCA or FHOCA+ALR cohorts. When comparing pre-operative to FFU PROMs, there were statistically significant improvements reported in the ALR cohort for

HOOS-JR (p = 0. 004), VAS Pain (p = 0.026) and PROMIS Physical Function (p = 0.019) scores. Improvements in these scores from preop to FFU did not reach statistical significance in either the FHOCA or FHOCA+ALR cohorts (Table 4). Of the FHOCA patients with complete pre-operative and FFU data, 2 out of 4 met MCID for PROMIS Physical Function, 1 out of 3 met MCID for VAS pain and 3 out of 4 met MCID for HOOS-JR. Of the FHOCA+ALR patients with complete pre-operative and FFU data, 3 out of 5 met MCID for PROMIS Physical Function, 3 out of 5 met MCID for VAS pain and 5 out of 5 met MCID for HOOS-JR. Of the ALR patients with complete pre-operative and FFU data, 12 out of 23 met MCID for PROMIS Physical Function, 16 out of 28 met MCID for VAS pain and 13 out of 21 met MCID for HOOS-JR.

A total of 39 patients (90.6%) underwent at least 1 concurrent procedure. All 6 FHOCA patients underwent femoral head and neck osteoplasty, 1 patient underwent autologous bone grafting to fill in small defects adjacent to a large femoral head osteochondral allograft and 1 underwent labral repair and acetabular chondroplasty. All 9 patients in the FHOCA + ALR underwent femoral head and neck osteoplasty, 1 underwent Anterior Inferior Iliac Spine (AIIS) decompression, 4 underwent acetabuloplasty, 1 underwent labral repair, 2 underwent acetabular chondroplasty and 1 underwent proximal femur rotational osteotomy. Within the ALR only cohort, 19 of 28 patients underwent concurrent femoral head and neck osteoplasty, 10 underwent acetabuloplasty, 3 underwent AIIS decompression, 4 underwent proximal femur rotational osteotomy, 4 underwent hardware removal, 1 underwent acetabular chondroplasty and 1 underwent femoral head microfracture. There was no statistically significant risk for failure associated with undergoing the most common concomitant procedures including femoral head and neck osteoplasty, pincer lesion resection or AIIS decompression (Table 5).

	Femoral Head OCA - Only		**Combined Femoral Head OCA with Acetabular Labrum Reconstruction**		**Acetabular Labrum Reconstruction - Only**		**p value**
# of Patients	6		9		28		
Sex	5M	1F	6M	3F	13M	15F	0.1839
Final Follow Up (Months)	48.3 ± 27.2		38.3 ± 16.3		37.8 ± 19.3		0.1703
Success at 1 Year	4 Successful	2 Failed	7 Successful	2 Failed	27 Successful	1 Failed	0.0507
Mean BMI	28.0 ± 5.27		28.2 ± 4.27		27.9 ± 6.27		0.8493
Mean Age	23.2 ± 6.55		23.9 ± 2.71		33.2 ± 9.98		**0.0068**
Nicotine Use	1 Yes	5 No	0 Yes	9 No	1 Yes	27 No	0.3023
Adherence	5 Adherent	1 Non-Adherent	7 Adherent	2 Non-Adherent	24 Adherent	4 Non-Adherent	0.8353
Insurance	6 Commercial	0 Other	9 Commercial	0 Other	23 Commercial	5 Federal/Military	
Patient demographics are reported for respective cohorts. Standard deviations are provided with cohort means when appropriate. P values are reported to compare cohorts when appropriate, with statistically significant p values in bold.							

Table 1: Patient demographics by cohort.

	Pre-Operative				**One-Year Post-Operative**				**Final Follow Up**			
	FHOCA	**FHOCA+ALR**	**ALR**	**p value**	**FHOCA**	**FHOCA+ALR**	**ALR**	**p value**	**FHOCA**	**FHOCA+ALR**	**ALR**	**p value**
HOOS-JR	67.4	62.1	55.6	0.399	79.9	75.9	74.9	0.753	78.8	85.2	72.6	0.295
Std Dev	20.0	15.4	14.1		17.5	14.1	14.1		14.1	14.8	13.2	
VAS Pain Score	3.3	5.2	5.7	0.209	1.2	1.7	3.2	0.134	2.7	1.3	3.5	0.411
Std Dev	2.9	2.9	1.9		1.8	1.4	2.5		2.5	0.6	2.7	
PROMIS Physical	36.8	36.9	40.0	0.270	48.4	44.1	45.	0.611	47.8	55.3	46.	0.113

Function							0				0	
Std Dev	6.3	6.4	6.5		9.8	7.4	5.8		1.1	5.9	6.5	
Patient demographics are reported for successful and failure cohorts. Standard deviations are provided with cohort means when appropriate. P values are reported to compare cohorts when appropriate, with statistically significant p values in bold.												

Table 2: Patient demographics by success or failure.

	Success Group		**Failure Group**		**p value**
# of Patients	38		5		
Sex	21 M	17F	3M	2F	1.000
Final Follow Up (Months)	38.4 ± 19.1		47 ± 25.4		**< 0.005**
Mean BMI	27.9 ± 5.75		28.9 ± 6.06		0.769
Mean Age	30.3 ± 9.68		26.4 ± 9.07		0.426
Nicotine Use	2 Yes	36 No	0 Yes	5 No	0.243
Adherence	31 Adherant	7 Non-Adherant	5 Adherant	0 Non-Adherant	0.542
Patient demographics, preceding injury, timeline and mechanism of failure are reported for all patients deemed to have a failed outcome in this study.					

Table 3: Hip preservation failures.

	Failures							
Failure Patient	**Cohort**	**BMI**	**Sex**	**Age at FHOCA/ALR**	**Laterality**	**Revision/THA**	**Time to THA/ revision**	**Mechanism**
1	FHOCA+ ALR	27.0	M	24	R	THA	38 months	Prior to FHOCA+ALR, the patient sustained bilateral femur fractures, had pain and ROM with femoral head AVN and a labral tear. This patient went onto THA 38 months after FHOCA+ALR due to persistent pain that limited his daily function.
2	FHOCA only	25.0	F	21	L	THA	38 months	This patient had femoral head AVN. Went onto THA 38 months FTER FHOCA due to significant pain interfering with ambulation and daily activity.
3	FHOCA+ ALR	22.5	F	22	R	THA	9 months	This patient had femoral head AVN with an irreparable labral tear preoperatively and they subsequently went onto THA 9 months after FHOCA+ALR due to significant pain interfering with ambulation and daily activity.
4	FHOCA only	16.0	M	20	R	THA	14 months	Prior to FHOCA, patient was in an MVC and

								sustained a posterior wall acetabular fracture and femoral head fracture, among other injuries. Nine months after FHOCA, he underwent removal of trochanteric hardware and then went onto THA 14 months after FHOCA due to significant arthritis and pain that interfered with daily activities
6	ALR only	33.0	M	34	L	THA	52 months	This patient had an irreparable labral tear prior to ALR. They went onto lysis of adhesions 52 months after ALR and then subsequently went onto THA 79 months after ALR.
Patient reported outcomes were compared between treatment cohorts at the pre-operative, one-year post-operative and final follow up timepoints. Values reported represent means, with respective standard deviations italicized below. P values are reported to compare means between cohorts at each respective timepoint, with statistically significant p values in bold.								

Table 4: Patient reported outcome measures by cohort.

	Femoral Head OCA - Only	**Combined Femoral Head OCA with Acetabular Labrum Reconstruction**	**Acetabular Labrum Reconstruction - Only**
# of Patients	6	9	28
Femoral Head and Neck Osteoplasty	6	9	19
Autologous Bone Grafting	1	0	0
Labral Repair	1	1	0
AIIS Decompression	0	1	3
Acetabuloplasty	0	4	10
Acetabular Chondroplasty	0	2	1
Proximal Femur Rotational Osteotomy	0	1	4
Hardware Removal	0	0	4
femoral Head Microfracture	0	0	1
Concomitant procedures are summarized. While most patients underwent at least one concomitant procedure, there was no statistically significant risk for failure associated with undergoing the most common concomitant procedures.			

Table 5: Concomitant procedures.

Discussion

The results of this study demonstrate that, in patients who underwent FHOCA and/or ALR hip preservation operations with at least 1 year of follow up, the overall success rate was 86.8%. Outcomes were deemed successful in 4 of 6 FHOCA patients (66.6%), 7 of 9 FHOCA+ALR patients (77.8%) and 27 of 28 ALR patients (96.4%) with no statistically significant difference in success or failure based on cohort ($p = 0.05068$). There were modest improvements in all outcome scores for all cohorts from pre-operative to the 1-year post-operative and FFU timepoints, however, outcome score improvements met statistical significance in only the ALR cohort. Demographic and lifestyle factors such as sex, age, BMI, nicotine use or adherence were not significantly associated with having a successful versus a failed outcome. While the majority of patients (90.6%) underwent at least 1 concurrent procedure, there was no statistically significant risk for failure associated with undergoing the most common concomitant procedures.

Hip pathology affecting the femoral head and/or acetabular labrum has been increasingly recognized in young, active individuals from a variety of causes [4,6]. The purpose of hip preservation is to restore and maintain a healthy hip joint while limiting patient symptoms and preserving function. Based on prior research, our hip preservation center has implemented an evidence-based shift in practice to the use of fresh high-cell-viability Femoral Head Osteochondral Allograft (FHOCA) transplantation and/or Meniscus Allograft Transplantation (MAT) for the treatment of symptomatic femoral head articular cartilage lesions and irreparable acetabular labral tears, respectively [9,11-21]. Previous studies have provided initial outcomes data in support of these procedures for mitigating hip pain and dysfunction in indicated patients [10,12,17-19]. The results from this current study build on prior research, suggesting an overall failure rate less than 15% for patients who underwent FHOCA and/or ALR with at least 1 year of follow-up. There was no significant risk for failure associated with undergoing ALR or FHOCA alone or in combination, though the success rate for ALR alone (96.4%) was higher than the success rates observed in both groups including FHOCA (66.6% and 77.8%). All groups demonstrated modest improvements in PROMs from pre-operative to FFU, though statistical significance was met only for patients who underwent ALR alone. Lack of statistical significance in PROM improvements at FFU in cohorts that underwent FHOCA and lack of statistical significance in success rates between cohorts may be due in part to relatively small cohort sizes and in part because patients undergoing FHOCA have significant cartilage pathology warranting these procedures.

Our institution takes a multidisciplinary approach to hip preservation, with several steps taken in recent years in pursuit of optimizing outcomes for patients. First, all grafts are preserved in MOPS, which has been validated to significantly preserve higher viable chondrocyte density at time of transplantation compared to standard-preservation grafts, with grafts able to be stored at room temperature for up to 56 days [11,19,20]. Second, fresh meniscus allografts were used for all ALRs, which have been associated with higher initial success rate, PROMs and MRI findings when compared to fresh frozen tendon allografts in ALR patients, as well as superior function outcomes compared to fresh-frozen tendon allografts in a preclinical canine model.10,18 Third, there have been evidence-based shifts in OCA transplantation and ALR techniques [24,25,27,28,34-36]. Fourth, our institution's hip preservation team has been developed to support patients throughout their care journey.

Limitations

Limitations should be considered when interpreting and applying the results of this study. First, this study had a relatively small sample size of 43, putting our data analysis at an elevated risk for encountering type II errors. Second, this study is limited to a short-term minimum follow-up for inclusion of 1 year; however, the goal of this study was to present available initial outcome data. Third, variation between cohorts existed regarding rehabilitation and limitation protocols, possibly resulting in unquantifiable variations in patient-reported outcomes. Fourth, patients in the ALR alone cohort were significantly older than those who received FHOCA transplantation with or without ALR. Fifth, we were unable to determine whether all patients met MCIDs from pre-operative to FFU timepoints, largely because several patients did not have complete pre-operative data.

Conclusion

The findings of this study demonstrate an overall success rate of 86.8% for ALR and/or FHOCA hip preservation patients with a minimum of 1 year of follow up, with no significant difference in success rates based on undergoing FHOCA alone, ALR alone or FHOCA combined with ALR. All 3 cohorts demonstrated modest improvements in outcome scores from preoperative assessment to FFU, however, the ALR-only group alone demonstrated statistically significant improvements in hip function and pain scores by FFU.

Conflict of Interest

Author disclosures are as follows:

John R. Baumann MD: has no conflicts to report.

Kylee Rucinski, PhD, MHA reports the following:

- National Institutes of Health, Research support
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- Orthopediatrics: Paid consultant
- Osteocentric: Paid consultant
- RomTech: Stock or stock Options
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Data Availability Statement
Data will be available through a genuine email request to the corresponding author.

Ethical Statement
This study was approved and executed under #2003053 from the University of Missouri Institutional Review Board.

Informed Consent Statement
Documented informed consent was obtained for all patients who underwent allograft transplantation in the hip that were prospectively enrolled into our registry that was established to follow hip preservation surgery outcomes.

Authors' Contributions
Conceptualization: K.R., J.L.C., B.D.C. and S.F.D.; Formal analysis: J.R.B., K.R., J.L.C., B.D.C., C.R.C. and S.F.D.; Investigation: J.R.B., K.R., J.L.C., B.D.C., C.R.C. and S.F.D.; Resources: K.R., J.L.C., B.D.C. and S.F.D.; Supervision: K.R., J.L.C., B.D.C. and S.F.D.; Writing - original draft: J.R.B., K.R., J.L.C. and S.F.D.; Writing - review and editing: J.R.B., K.R., J.L.C., B.D.C., C.R.C. and S.F.D.

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