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A Prospective 2-Year Clinical Evaluation of Augmented Hip Abductor Tendon Repair

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Background: Hip abductor tendon (HAT) tearing is commonly implicated in greater trochanteric pain syndrome. Studies reporting surgical outcomes are often on small cohorts and with limited information on functional improvement.

Purpose: To report the 2-year clinical and functional outcomes in a series of patients undergoing HAT repair augmented with a ligament augmentation and reconstruction system (LARS) ligament.

Study Design: Case series; Level of evidence, 4.

Methods: Between October 2012 and December 2016, a total of 142 patients with symptomatic HAT tears underwent open bursectomy, V-Y lengthening, and reattachment of the tendon with suture anchors augmented with a LARS ligament. This included 132 women (93%) with a mean age of 64.3 years (range, 43-84 years), a mean body mass index of 28.2 kg/m^2 (range, 20.0-41.3 kg/m^2), and an average duration of symptoms of 4.0 years (range, 6 months-20 years). Following surgery, patients underwent a graduated rehabilitation program consisting of hydrotherapy and land-based exercises. Patient-reported outcome measures (PROMs) were evaluated preoperatively and at 3, 6, 12, and 24 months postoperatively with the Harris Hip Score, Oxford Hip Score, 12-item Short Form Health Survey, and visual analog scale (VAS) for pain. Hip range of motion, hip abduction strength, 30-s single-leg stance (SLS), and 6-minute walk test (6MWT) capacity were evaluated. Patient satisfaction and perceived global rating of change were evaluated postsurgery. Analysis of variance was employed to evaluate clinical improvement over time.

Results: A significant improvement ($P < .05$) was demonstrated up to 24 months in all PROMs and clinical scores, including hip range of motion in all planes, hip abductor strength limb symmetry indices (mean ± SD; presurgery, 90.1% ± 42.5%; 24 months, 102.6% ± 15.0%), and the 6MWT (presurgery, 421.8 ± 91.9 m; 24 months, 509.7 ± 105.1 m). Furthermore, several variables, including pain (VAS and pain scores during the 6MWT and 30-s SLS) and patient-perceived improvement (global rating of change), continued to improve from 12 to 24 months. At 24 months, 95.7% of patients were satisfied with their surgical outcome (excluding 3 patients who underwent reoperation within the 24-month period). There was a 5.6% (n = 8) failure rate over the study period.

Conclusion: HAT repair augmented with a synthetic ligament demonstrated significantly improved clinical and functional outcomes, high levels of patient satisfaction, and a relatively low failure rate up to 24 months postsurgery.

Registration: ACTRN12616001655437 (Australian New Zealand Clinical Trials Registry).

Keywords: hip abductor tendon; hip abductor tears; surgical repair; assessment; clinical outcomes

Greater trochanteric pain syndrome (GTPS) affects 10% to 25% of the general population[35,44,48] and is a generic term used to define the clinical condition of greater and peritrochanteric hip pain.[27-29,32,44,48] While a number of conditions are associated with GTPS, the common role of hip abductor tendon (HAT) tears is now better understood.[2,8,28] Despite first being reported in 1997 by Bunker et al,[4] a review[13] published in 2015 highlighted encouraging outcomes in patients embarking on HAT surgical repair via a range of surgical techniques, with numerous open, endoscopic, and augmented techniques reported since that time.[5,14,22,24-26,31,33]

Interestingly, only a few of these studies[14,22,37,47] actually documented outcomes in more than 30 patients, with a recent review summarizing the surgical outcomes of patients undergoing HAT repair reporting that many studies lack detail on the patient cohort, postoperative care, and clinical follow-up.[13] Furthermore, despite the encouraging published outcomes, satisfaction rates vary across studies, ranging from 66% to 90%,[3,10,36,38-40,42] and surgical failure rates as high as 31% and 33% have been cited.[9,40] Despite a lack of difference in clinical scores, a higher complication rate has been indicated with open repair techniques versus endoscopic surgical methods.[1,6] As recently noted in 2 reviews on the subject,

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overall surgical complication rates of 13% to 19% have been reported, with retear rates of 9% to 13% when employing open repair methods.[1,6]

Given the aforementioned concerns with respect to small sample sizes and the lack of meaningful clinical and functional outcome data, the aim of the current study was to present outcomes over a 24-month postoperative period in patients undergoing HAT repair. Furthermore, given the concerning high retear rates indicated in some studies, the current study employed a HAT repair surgical technique augmented with a synthetic ligament. The current study is an extension (in postoperative follow-up and patient numbers) of a previous patient cohort that underwent HAT repair with 12-month postoperative outcomes.[14] It was hypothesized that (1) patients in the current 24-month cohort would demonstrate significant clinical improvement over the study period, with a low rerupture rate (<10%) and a high satisfaction rate (>85%), and (2) no significant clinical differences would exist between 12 and 24 months.

METHODS

Patients

This was a prospective single-surgeon series of 180 patients between October 2012 and December 2016. All patients had a thorough clinical assessment, followed by magnetic resonance imaging (MRI) confirmation of a HAT tear, including high-grade partial delaminating (75%) or full-thickness (25%) tears of the gluteus minimus in all cases, with the anterior portion of the gluteus medius. Of the 180 patients who were recruited (Figure 1), 38 were excluded from the current analysis. Of these, 24 patients did not progress toward surgery within the designated period, 2 proceeded toward surgery but withdrew from the study before the first 3-month postoperative clinical review, and 12 underwent surgery but either had undergone prior total hip arthroplasty or proceeded toward total hip arthroplasty combined with HAT repair. Of the 142 patients remaining in the current study analysis, 132 (93%) were women. The cohort had a mean age of 64.3 years (range, 43-84 years), mean body mass index of 28.2 kg/m^2 (range, 20.0-41.3 kg/m^2), an average duration of symptoms of 4.0 years (range, 6 months-20 years), and had undergone a mean 3.2 (range, 1-8) prior corticosteroid injections. All patients had previously failed a course of nonoperative treatment, including corticosteroid injections and physiotherapy. Overall, 14 patients reported symptoms bilaterally, with 3 of these undergoing contralateral HAT repair (at 8, 13, and 14 months following their first surgical procedure). These patients were retained in the analysis over the 24-month period (though outcomes requiring comparison with the contralateral limb, such as strength, were omitted for these patients once contralateral surgery had been performed).

A total of 10 patients who underwent HAT repair presented with evidence of advanced (grades 2-4)[34] and/or symptomatic hip osteoarthritis on their preoperative MRI (not including those who underwent total hip arthroplasty combined with HAT repair who were excluded from the current analysis), though the predominant presenting symptom was lateral-sided trochanteric pain with radiation down the lateral leg in all patients. Excluding those with preexisting total hip arthroplasty who were excluded from this analysis, prior surgery included failed HAT repair that was not augmented per the current surgical technique (n = 3), iliotibial band release and/or bursectomy (n = 3), and labral debridement (n = 1), and these patients (n = 7) were all retained in the current analysis. All patients (n = 180) provided informed consent before study recruitment and preoperative clinical review, and ethics approval was obtained from the relevant hospital ethics committee.

Surgical Technique

The surgical technique has been described.[14] With the patient under general anesthetic in the lateral decubitus position, a 10-cm longitudinal incision is made over the lateral aspect of the greater trochanter, followed by a direct lateral approach through the tensor fascia lata. The thickened trochanteric bursa is excised, exposing the insertion of the gluteus medius tendon into the greater trochanter. It should be noted that the superficial fibers often appear normal as the tear begins on the deep surface. The gluteus medius and minimus are then elevated from the greater trochanter, usually revealing the presence of an enthesophyte and allowing for tear severity to be evaluated. The torn ends are debrided, leaving the intact, usually posterior, gluteus medius fibers on the bone. The underlying bone is decorticated to expose a bleeding bone surface. The delamination of the HAT tear is first dealt by using transtendinous sutures to equalize the length and retension the abductor complex (Figure 2). The broad end of a ligament augmentation and reconstruction system (LARS) ligament (ACTOR 10; Corin Group) is then sutured to the deep surface of the abductor tendon with No. 2 Ethibond sutures (Ethicon) (Figure 3). Two converging 4.5-mm bone tunnels are drilled to create a long curvilinear tunnel, first from the footprint of the gluteus minimus on the anterior facet of the greater trochanter to midway through the greater trochanter and

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Ethical approval for this study was obtained from the Hollywood Private Hospital Research Ethics Committee (HPH3448).

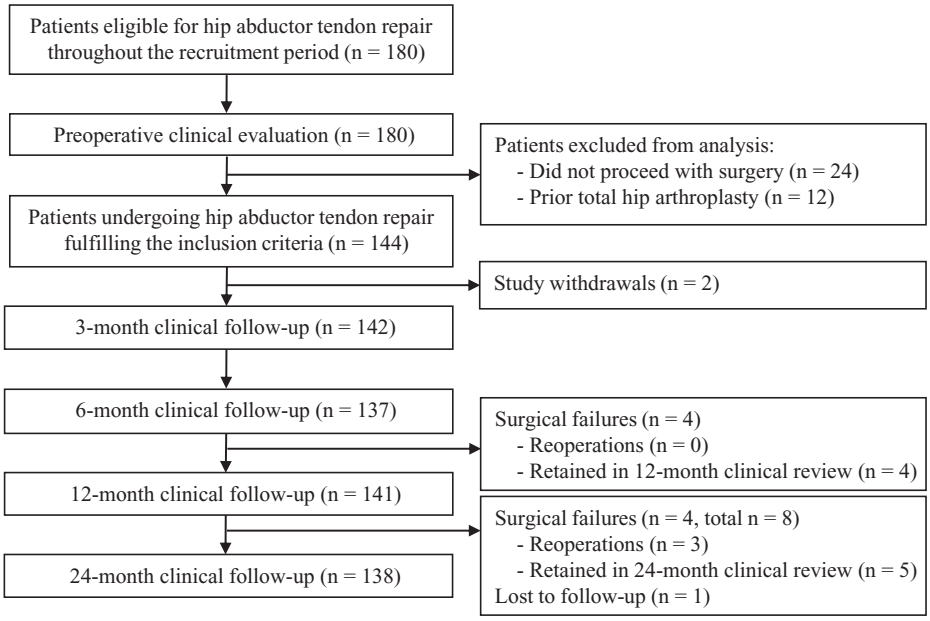

Figure 1. Study flowchart demonstrates patient recruitment and clinical evaluation over the 24-month period.

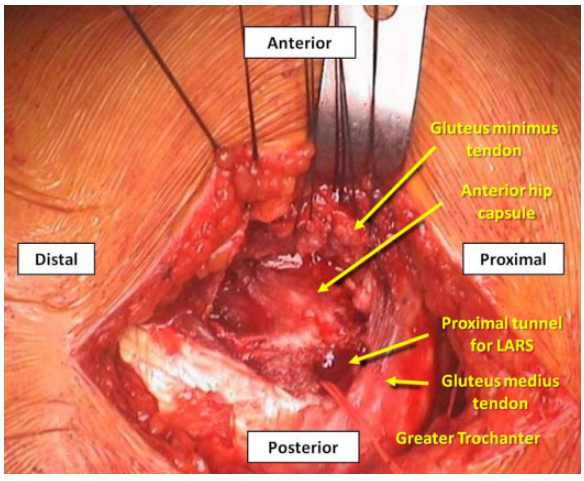

Figure 2. The delamination of the hip abductor tear is visualized and reduced, with transtendinous sutures employed to equalize the length and retension the abductor complex.

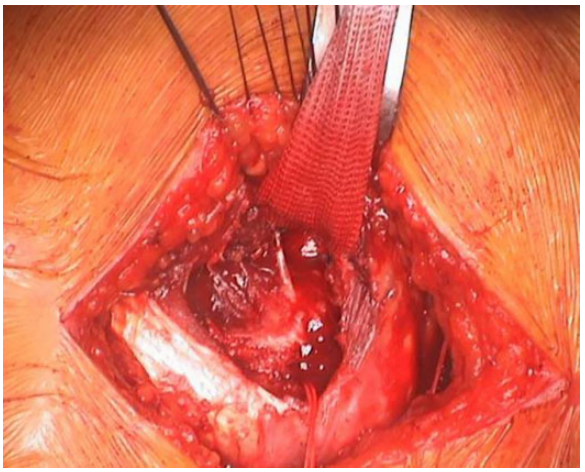

Figure 3. The broad end of the LARS ligament is sutured to the deep surface of the abductor tendon.

the second from posterodistal on the lateral prominence of the greater trochanter to meet the first. A flexible looped wire is passed retrograde, and the LARS ligament is passed through the greater trochanter (Figure 4), with the tension created by the LARS approximating the tendon back to the trochanter and with a 5.2-mm interference screw (Corin Group) used distally to secure the tension in the ligament-bone interface (Figure 5A). The repair is finally augmented with a single row of interosseous sutures (Figure 5B) and occasional bone anchors if required. The final repair construct is shown before (Figure 5C) and after (Figure 5D) the excess LARS ligament is trimmed. In all figures, the cranial end is to the right of image. The wound is closed in layers, without drains, in a standard fashion.

Postoperative Management

Patients were discharged from the hospital 3 to 5 days after surgery with 2 weeks of subcutaneous low molecular weight heparin to reduce the risk of developing deep vein thrombosis. All patients were discharged partial weightbearing with crutches, but no abduction bracing was employed. Following hospital discharge, all patients commenced an outpatient exercise rehabilitation program from 2 to 4 weeks postsurgery. This consisted of hydrotherapy and land-based exercises.[14] The early focus of the rehabilitation program was on managing postoperative pain and swelling, improving mobility, and increasing weightbearing capacity. Specific structured exercises were prescribed as of 2 to 4 weeks postsurgery (to progress from those provided

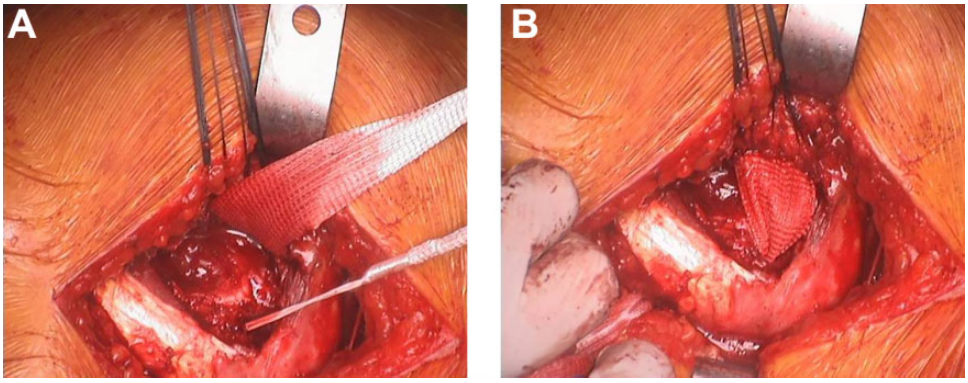

Figure 4. (A) The initial stages of passing the LARS ligament through the greater trochanter bone tunnel. (B) The final stages of drawing the LARS ligament through the greater trochanter bone tunnel.

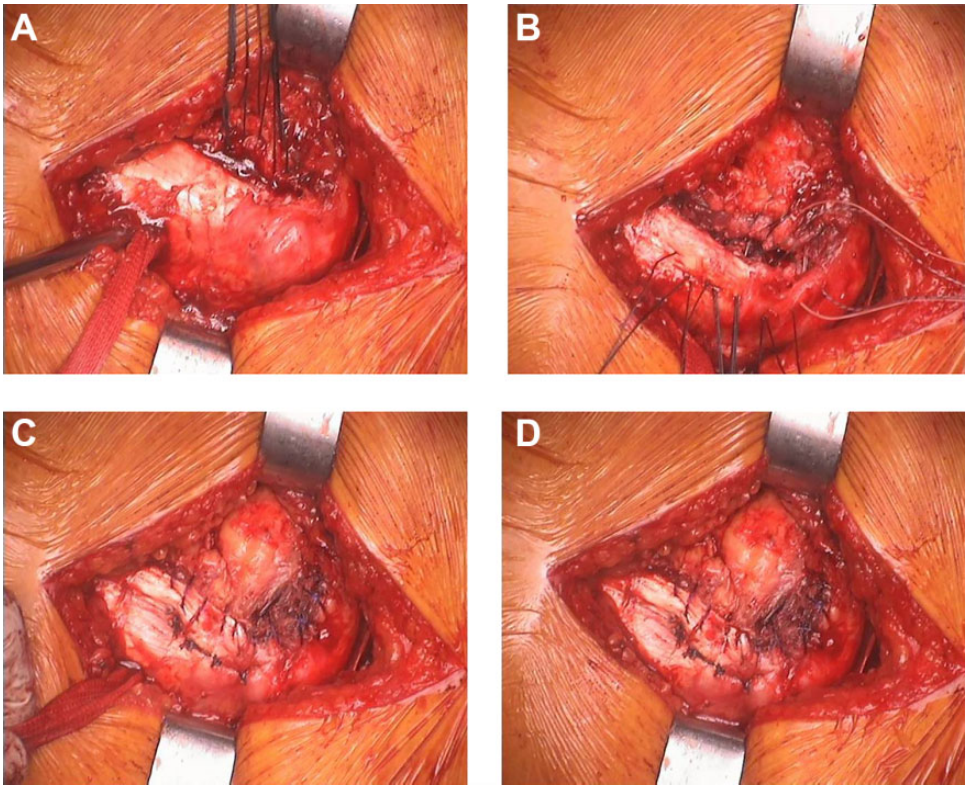

Figure 5. (A) The tension created by the LARS approximates the tendon back to the trochanter, and a 5.2-mm interference screw is fixed distally to secure the tension in the ligament-bone interface. (B) The repair is formally undertaken with a single row of interosseous sutures. (C) The final repair construct before the excess LARS ligament is trimmed. (D) The final repair construct following the trimming of the excess LARS ligament.

postoperatively in the hospital), stationary cycling from 4 to 6 weeks, and full weightbearing permitted as of 6 to 8 weeks, though this was providing that a normal gait pattern had returned. While weightbearing functional exercises such as squats were often advocated before 8 weeks, resisted hip abduction exercises were introduced as of 8 weeks postsurgery. Exercises prescribed beyond 12 weeks were largely dictated by individual progression and patient activity goals. However, ongoing guidance and exercise prescription were provided as needed until 12 months postsurgery.

Clinical Assessment

Patients were assessed preoperatively and at 3, 6, 12, and 24 months postsurgery with a number of patient-reported outcome measures (PROMs), including the Harris Hip Score,[23] the Oxford Hip Score,[11,41] the 12-item Short Form Health Survey (SF-12) producing Mental and Physical Component Subscales, a visual analog scale (VAS) evaluating the frequency and severity of pain on a scale of 0 to 10 (0 = no pain, 10 = constant/worst pain), and a global

TABLE 1
Patient-Reported Outcome Measures Throughout the Assessment Period[a]

Measure	Presurgery	3 mo	6 mo	12 mo	24 mo	*P* Value
HHS	59.0 (17.6)	76.9 (15.6)	83.9 (13.2)	88.5 (12.1)	90.3 (10.7)	<.0001
	15.3-90.0	42.7-100.0	43.6-100.0	41.8-100.0	52.8-100.0	
OHS	25.9 (8.2)	35.0 (8.0)	38.2 (7.6)	41.1 (6.1)	43.1 (5.8)	<.0001
	5-46	12-48	11-48	23-48	22-48	
SF-12: PCS	34.0 (8.5)	37.5 (9.6)	40.8 (9.4)	44.3 (9.0)	45.4 (9.5)	<.0001
	9.0-57.8	10.8-57.2	10.8-61.4	14.9-58.1	18.7-58.1	
SF-12: MCS	48.7 (11.5)	54.1 (11.3)	52.7 (11.3)	54.4 (9.6)	55.2 (8.9)	.039
	20.4-70.8	25.6-70.9	27.3-69.7	27.3-69.5	28.9-69.5	
VAS: frequency	8.0 (2.5)	3.5 (2.8)	2.9 (2.5)	2.2 (2.2)	1.5 (1.9)	<.0001
	1-10	0-10	0-10	0-9	0-9	
VAS: severity	6.4 (2.2)	2.6 (1.8)	2.4 (2.1)	1.7 (1.5)	1.5 (1.6)	<.0001
	1-10	0-7	0-9	0-6	0-7	
GRC	NA	2.3 (2.0)	2.8 (1.8)	3.4 (1.7)	3.7 (1.6)	<.0001
	NA	–5 to 5	–4 to 5	–5 to 5	–5 to 5	

[a]Values are presented as mean (SD) and range. GRC, global rating of change; HHS, Harris Hip Score; MCS, Mental Component Subscale; NA, not applicable; OHS, Oxford Hip Score; PCS, Physical Component Subscale; SF-12, 12-item Short Form Health Survey; VAS, visual analog scale.

rating of change (GRC) scale (postsurgery only) to evaluate patient-perceived status (vs presurgery). A patient satisfaction questionnaire was employed at 24 months to evaluate satisfaction with the surgery overall, as well as satisfaction with the surgery to relieve pain and improve the ability to perform normal daily and work activities and return to recreational activities (eg, swimming, cycling, dancing, golf). A Likert response scale was employed with the following descriptors: very satisfied, somewhat satisfied, somewhat dissatisfied, and very dissatisfied.

Objectively, patients first had their active hip range of motion (ROM) assessed pre- and postsurgery (on only the operated limb) with either a handheld bubble inclinometer (hip flexion in supine, internal and external rotation in prone) or a long arm goniometer (hip adduction and abduction in supine, extension in standing).[14,16] Second, a 30-s single-leg stance (SLS) test[32] was employed on the operated limb, evaluating the presence and severity of pain following 10-, 20-, and 30-s SLS tests (on a VAS of 0-10).[14,16] Third, patients underwent a 6-minute walk test (6MWT) to assess the maximum distance that they could walk in a 6-minute period,[17] with a VAS pain scale (0-10) again employed to evaluate pain severity before and at 2, 4, and 6 minutes into the test.[14,16] Finally, maximal isometric hip abduction strength was assessed on the operated and unaffected limbs with a T5 Cable Tensiometer (Pacific Scientific Company) per the technique and procedure previously reported.[14,16] All evaluations were undertaken by a single experienced physical therapist.

Data and Statistical Analysis

Means (SD and range) were presented for all scores, while a limb symmetry index was calculated for peak isometric hip abductor strength (reported as the strength of the operated limb as a percentage of the unaffected limb). Repeated-measures analysis of variance was employed to investigate the pre- and postoperative change in PROMs (Harris Hip Score, Oxford Hip Score, VAS frequency, VAS severity, and SF-12 Physical and Mental Component Subscales) and functional outcomes (hip ROM, 6MWT, pain during 6WMT and 30-s SLS tests, absolute hip abductor strength, and hip abductor strength symmetry) over time. Analysis of variance was also employed to evaluate the postoperative change in the GRC, and *t* tests were employed to evaluate any change from 12 to 24 months. Where appropriate, statistical analysis was performed with SPSS software (Version 17.0; IBM). Statistical significance was determined at $P < .05$.

RESULTS

Of the 142 patients retained in the current analysis, all were assessed clinically at 3 months postsurgery (Figure 1). A total of 137, 141, and 138 patients underwent their 6-, 12-, and 24-month clinical reviews, respectively. An intention-to-treat analysis was performed with the patient's last visit for the missed clinical reviews at 6- and 12-month postoperative time points. At 24 months postsurgery, 1 patient could no longer be located for review, while 3 patients who had failed had proceeded to revision HAT repair and so were omitted from 24-month clinical review. With respect to hip abductor strength assessment, 2 patients were unable to undertake preoperative strength assessment, while 5 were unable to undertake (or complete) the 30-s SLS test and/or 6MWT preoperatively. Postoperatively, 6MWT data were omitted from the analysis in 10 patients, given that they were unable to ambulate for the time required without crutch assistance. Finally, maximal isometric hip abduction strength data were omitted from the analysis in the 8 patients who were symptomatic bilaterally, owing to potential bias in limb symmetry measures. Hip abductor strength data were omitted for the 14 patients who reported bilateral GTPS symptoms (given the comparison required with the unaffected limb), though all other scores for these patients were retained.

A significant improvement ($P < .05$) over the 24-month postoperative period was observed for all PROMs (Table 1),

TABLE 2
Clinical Outcomes Throughout the Assessment Period[a]

Outcome	Presurgery	3 mo	6 mo	12 mo	24 mo
Active hip range of motion, deg					
Flexion	101.9 (17.3)	111.3 (12.8)	115.1 (13.1)	116.4 (12.3)	116.4 (11.3)
	55-135	70-145	70-145	80-155	80-155
Extension	14.6 (5.4)	18.5 (5.4)	20.6 (5.6)	21.5 (6.0)	21.8 (5.8)
	5-28	8-35	10-35	10-35	10-34
Abduction	32.6 (11.1)	41.4 (11.7)	45.1 (12.6)	46.8 (12.9)	46.9 (12.6)
	5-50	7-70	22-70	20-70	20-70
Adduction	13.7 (5.7)	22.2 (6.1)	22.6 (5.9)	23.0 (6.3)	22.6 (5.9)
	5-40	10-40	12-40	12-40	12-35
External rotation	30.5 (9.3)	37.7 (9.4)	38.4 (8.8)	40.3 (8.3)	39.4 (9.4)
	0-50	5-55	12-55	12-62	12-60
Internal rotation	29.8 (10.7)	34.9 (9.8)	36.6 (8.7)	38.6 (9.3)	38.7 (9.1)
	0-55	8-60	12-60	12-60	12-58
6-min walk test					
Distance, m	421.8 (91.9)	433.1 (99.0)	472.1 (91.9)	497.4 (92.2)	509.7 (105.0)
	105-705	190-730	190-723	190-723	185-720
Pain (0-10)					
0 min	2.5 (2.3)	1.0 (1.5)	0.7 (1.2)	0.6 (1.0)	0.6 (1.2)
	0-9	0-9	0-7	0-6	0-7
2 min	3.5 (2.5)	1.5 (1.7)	1.2 (1.5)	1.0 (1.5)	0.8 (1.3)
	0-10	0-9	0-8	0-7	0-7
4 min	4.2 (2.5)	2.0 (2.0)	1.4 (1.8)	1.3 (1.7)	1.0 (1.4)
	0-10	0-9	0-8	0-7	0-7
6 min	4.7 (2.7)	2.2 (2.1)	1.7 (1.9)	1.5 (2.0)	1.0 (1.5)
	0-10	0-10	0-9	0-9	0-9
30-s single-leg stance test					
Pain (0-10)					
0 s	2.0 (2.1)	0.8 (1.2)	0.5 (1.0)	0.4 (0.8)	0.4 (0.9)
	0-9	0-5	0-7	0-4	0-5
10 s	3.3 (2.6)	1.4 (1.8)	1.1 (1.6)	0.7 (1.0)	0.4 (0.9)
	0-9	0-8	0-9	0-5	0-5
20 s	4.0 (2.9)	1.8 (2.0)	1.4 (1.9)	0.9 (1.2)	0.6 (1.1)
	0-10	0-8	0-9	0-5	0-5
30 s	4.5 (3.0)	2.1 (2.2)	1.7 (2.1)	1.0 (1.4)	0.8 (1.3)
	0-10	0-10	0-9	0-5	0-6
Peak hip abductor strength					
Limb symmetry index, %	90.1 (42.5)	99.8 (25.3)	106.5 (26.2)	105.8 (27.0)	102.6 (15.0)
	62.9-140.0	71.7-138.1	73.6-121.1	86.8-128.5	82.1-135.3

[a]Results are presented as mean (SD) and range. $P < .0001$ for each outcome row.

as well as all functional measures employed (and pain scores associated with these functional measures) ($P < .001$) (Table 2). While the VAS frequency ($P = .001$) and GRC ($P = .021$) significantly improved from 12 to 24 months, as did patient-reported pain severity reported at 4 ($P = .002$) and 6 ($P < .001$) minutes into the 6MWT and at 10 ($P < .001$), 20 ($P < .001$), and 30 ($P = .012$) seconds into the 30-s SLS test, no other clinical measures significantly changed ($P > .05$) after 12 months. In the 141 patients at 12 months postsurgery, 95.7% (n = 135) were satisfied with the surgery to relieve their hip pain, 95.7% (n = 135) were satisfied with the improvement in their ability to undertake daily activities, and 91.4% (n = 129) were satisfied with their ability to participate in recreational activities. Satisfaction rates were relatively unchanged at 24 months postsurgery (n = 138), with 96.4% (n = 133) satisfied with pain relief, 95.7% (n = 132) satisfied with the improvement in activities of daily living, and 93.5% (n = 129) satisfied with recreational activity participation. Overall, 95.7% (n = 132) of patients were satisfied overall with their 24-month outcome. The 24-month satisfaction rates are shown in Table 3.

Complications were recorded for all patients during their follow-up period. Of the 142 patients included in the review, there were 8 surgical failures (5.6%), defined as patients presenting postoperatively with increasing lateral hip pain and symptoms similar to their preoperative condition. Retear was confirmed in all patients on MRI, which included 4 patients within the first 12 postoperative months (of which 1 had previously failed HAT repair via a nonaugmented approach) and 4 patients between 12 and 24 months surgery (presenting with a recurrence of symptoms at 12.5, 14, 14, and 16 months postsurgery). Within the 24-month postoperative period, 3 of the 8 patients who

TABLE 3
Patients Within Each Grading for the 4 Satisfaction Items at 24 Months Postsurgery[a]

Satisfaction Item	Pain Relief	Improving Ability to Undertake ADLs	Improving Ability to Participate in Recreational Activities	Overall Satisfaction
Very satisfied	113 (81.9)	106 (76.8)	92 (66.7)	107 (77.6)
Satisfied	20 (14.5)	26 (18.8)	37 (26.8)	25 (18.1)
Dissatisfied	4 (2.9)	4 (2.9)	6 (4.3)	4 (2.9)
Very dissatisfied	1 (0.7)	2 (1.4)	3 (2.2)	2 (1.4)
Satisfied (overall)	133 (96.4)	132 (95.7)	129 (93.5)	132 (95.7)

[a]Values are presented as number (%). Results are shown for 138 patients (out of 142) with 24-month review (excluding 1 patient lost to follow-up and 3 patients who had undergone reoperation). ADLs, activities of daily living.

had demonstrated symptomatic retear progressed toward reoperation, and while patient clinical data for the reoperations (n = 3) were not retained in the 24-month analysis, the results for the 5 patients with retear who had not undergone reoperation were included at all time points.

All retears occurred at the tendon-bone interface, and in the 3 patients who had undergone reoperation, the LARS was torn in all cases with some retraction of the tendon. The reasons for the retears were varied. While 4 patients could recollect a specific incident (ie, a fall in 3 patients and a motor vehicle accident in 1 patient) that created a recurrence of symptoms that failed to resolve, 4 patients were unable to recollect a specific incident for the recurrence of their symptoms. There was a 4.2% (n = 6) early complication rate: 4 patients with superficial wound infections, 1 with postoperative hematoma, and 1 with a lower limb deep vein thrombosis who developed a pulmonary embolism (at 3 weeks postsurgery). All of these complications were treated accordingly with no ongoing issues. When combined with the surgical failures (6 surgical complications, 8 retears), an overall complication and adverse event rate of 9.8% (14 of 142) was observed.

DISCUSSION

While published evidence grows and encouraging clinical outcomes have been reported in patients undergoing HAT repair for symptomatic HAT tears, these studies[14,22,37,47] generally have small patient cohorts with only a few reporting outcomes in more than 30 patients. These studies[3,10,36,38-40,42] often lack meaningful patient clinical review and present varied satisfaction levels, some[9,40] with high surgical failure rates beyond 30%. While a pilot study[3] has been published utilizing this surgical HAT repair technique in a separate cohort with early promising (albeit limited) outcomes, the current study is an extension (in postoperative follow-up and patient numbers) of another patient cohort reporting positive 12-month clinical outcomes after HAT repair.[14] The most important findings from the current study investigating outcomes in patients undergoing an open HAT repair procedure augmented with LARS were good clinical and functional improvement over a 24-month period, combined with high levels of patient satisfaction (95% overall) and low rates of complication (4.2%) and retear (5.6%). However, while it was hypothesized that no further significant benefit would exist between 12 and 24 months, improvement was reported in pain (VAS frequency and pain scores during the 6MWT and 30-s SLS test) and patient-perceived improvement (GRC) over this later period.

While all PROMs employed significantly improved over the 24-month postoperative period, there were no significant differences observed beyond 12 months postsurgery. The full (or modified) Harris Hip Score and the Oxford Hip Score have been reported as the more commonly employed PROMs to evaluate HAT repair,[13] and the postoperative improvement demonstrated in the current study demonstrates consistent (if not better) scores as compared with prior studies that employed these PROMs.[‖] Of no surprise, the SF-12 Physical Component Subscale improved over time, though the significant improvement in the Mental Component Subscale highlights the positive psychological benefit that HAT repair may offer these patients with symptomatic and often debilitating pathology that has often been left for a significant period. Studies have previously demonstrated the high levels of pain, dysfunction, and reduced quality of life in patients with GTPS that are comparable[18] or worse[16] than those presenting with hip osteoarthritis. Also in alignment with the other PROMs,[3,9,12,37,43] the frequency and severity of pain significantly improved, employing a VAS score to evaluate pain changes in HAT repair cases over time. However, of interest in the current study was the significant improvement from 12 to 24 months (in pain frequency). It is also important to note that the GRC significantly improved from 12 to 24 months postsurgery, suggesting that the ongoing resolution in pain in these patients is at least a 2-year process and that patient-perceived improvement (as reported via the GRC) continues to improve with pain reduction. This is also important from the perspective of patient preoperative counseling and education, and patients should be fully informed that this procedure progresses very differently to hip arthroplasty and that patients undergoing HAT repair should expect a lengthier period of recovery. Reflected in the high mean PROMs at 2 years postsurgery, patients in the current study reported a high level of satisfaction in all domains (93.5%-96.4%), which compares favorably to the wide range

[‖]References 3, 9, 10, 12, 21, 22, 25, 37-40, 42, 43, 45, 46.

of previously published outcomes ranging from 66% to 90%.[3,10,36,38-40,42]

While existing studies investigating the outcomes after HAT repair often employ PROMs to present improvement, very few have employed objective measures that may be just as, if not more, important to patients who are seeking an improvement in pain and functional capacity. While it had been reported that active hip ROM was not affected in patients with GTPS,[29] likely given that these patients are not generally burdened by osteoarthritic hips, more recent reports would suggest that hip ROM is affected.[16] While hip ROM in all planes of motion was shown to be worse on the affected limb as compared with the unaffected limb in patients with HAT tear,[16] it would make sense that movements/positions that may act to increase hip abductor muscle activation and/or increase trochanteric compression may increase pain and limit movement. It may well be that the improvement in hip ROM, particularly toward end ranges, may assist daily tasks such as sitting in low chairs, getting into and out of a car, and even cycling.

The current study also sought to evaluate hip abductor strength, with improvements observed similar to those studies[10,12,40,43,46] that also measured strength. Strength limb symmetry indices in the current study demonstrated an improvement over time that largely peaked at 6 months postsurgery and was then sustained over the subsequent 18 months to final follow-up (despite the change in the limb symmetry index ranges demonstrating that those patients with worse limb symmetry indices continued to improve over the 24-month period). Given the improvement in pain and hip abductor strength, it was of no surprise that 6MWT and SLS capacity, as well as pain specifically throughout the 6MWT and 30-s SLS test, improved. However, similar to the VAS frequency, it was interesting that patient-reported pain scores during the 6MWT and 30-s SLS test showed continued significant improvement between 12 and 24 months, reiterating the longer-term benefit and lengthier recovery time that may be expected from HAT repair versus other hip surgery. Given the long mean duration of symptoms reported by these patients, this may also account for the longer functional recovery period observed. It is also worth noting that improvement in functional capacity is an important goal of any rehabilitation program, and patients underwent a coordinated and progressive program to complement the surgery.

Despite the encouraging outcomes of the current cohort, retear over the 24-month evaluation period was observed in 8 patients (including 4 patients before 12 months and a further 4 patients between 12 and 16 months postsurgery), and a range of additional complications was encountered. First, while 1 patient experienced deep vein thrombosis and pulmonary embolism in the early postoperative period, considered a more significant adverse event, this complication, with the others noted, was managed effectively without further issue. In the current study, there was a retear rate of 5.6%, which, when combined with a complication rate of 4.2%, gave an overall 9.8% complication rate. Alpaugh et al[1] cited a retear rate of 8.9% in open HAT repairs with an additional complication rate of 12.6%, giving an overall complication rate of 21.5%. Chandrasekaran et al[6] documented a retear rate of 7.9% in open HAT repairs with an additional surgical complication rate of 10.9%, giving an overall complication rate of 18.8%. Of the open HAT repair studies reported per the Alpaugh et al and Chandrasekaran et al reviews, none of these were augmented, and the retear and complication rates were higher than those of the current study, employing an augmented surgical technique. Of the failures in the current study, 4 occurred within the first 12 months, and 4 occurred after 12 months. While there were no retears beyond 16 months, it still suggests that patients must remain somewhat sensible with their physical activity up to and beyond 12 months postsurgery.

We acknowledge some limitations in the current study. First and most important, it was a prospective study with no control group or comparative cohort. While the current outcomes appear superior (clinical scores, satisfaction rates, retear rates) as compared with many smaller-cohort studies published on HAT repair, they are indeed comparable to some (at least with respect to the limited outcomes published by many of these other cohorts). Despite the encouraging outcomes observed thus far, a larger blinded randomized controlled trial comparing HAT repair with or without augmentation will better evaluate the additional benefit of synthetic augmentation.

Second, the primary PROMs employed (Harris Hip Score and Oxford Hip Score) demonstrated significant clinical improvement over time, although these were not developed and validated for patients with GTPS and therefore must be interpreted as such. Other GTPS-specific PROMs are emerging, such as the Victorian Institute for Sport Assessment for Gluteal Tendinopathy score, which has demonstrated reliability and validity in patients with GTPS[19] and recently has been shown to be more resistant to ceiling effects in patients undergoing HAT repair.[15] This may also explain why the PROMs did not significantly improve beyond 12 months, though various other pain scores (such as those reported during the 6MWT and the 30-s SLS test) did demonstrate further improvement.

Third, while the rationale behind the augmented synthetic ligament is to provide protection as the tendon-bone interface heals, thereby aiming to reduce the rate of surgical retears that have been reported, it is unknown whether there may be an element of stress shielding resulting from the use of the LARS augmentation. Furthermore, past concerns in using LARS have focused on reactions and/or particulate debris that may occur with abrasion or rupture. In the 3 patients who underwent reoperation, the proximal end of the LARS was still intimately attached to the undersurface of the gluteal tendons and had to be dissected. Evidence of nonspecific inflammation was observed at this time, with moderate fluid present with synovitis within the bursa. However, samples were not sent for histopathology, and further and longer-term follow-up would be required to ascertain any long-term effects of using LARS in this clinical setting. Finally, unlike some studies,[37,39,40,46] MRI was not employed in this analysis to evaluate the status of the repair. Given the cost of imaging postoperatively and the inability to justify imaging in patients who were largely asymptomatic, this was purely a clinical review, although MRI was used in cases where a

retear was suspected. Future research, including that of a blinded randomized controlled trial comparing HAT repair with and without augmentation, may include MRI or even postoperative ultrasound to image the repair, with the less costly ultrasound potentially holding some promise in the imaging of GTPS.[7,20,30]

Our first hypothesis was supported, whereby significant clinical improvement was observed over 24 months, a high level of patient satisfaction was reported in all domains (93.5%-96.4%), and a relatively low retear rate of 5.6% was observed. However, our second hypothesis was only partially supported. While the majority of scores did not improve from 12 to 24 months as proposed, significant improvement was reported in some pain measures (VAS frequency and pain scores during the 6MWT and 30-s SLS test) and patient-perceived improvement (GRC) beyond 12 months. The outcomes of this prospective study would suggest that open HAT repair augmented with LARS is a good option for patients with symptomatic HAT tears unresponsive to conservative treatments. Longer-term follow-up of this cohort should continue to confirm sustained clinical improvement and ascertain what factors in time may be associated with failure and/or recurrence of symptoms.

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