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Clinical and functional outcomes after augmented hip abductor tendon repair

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ABSTRACT

Introduction: Hip abductor tendon (HAT) tearing is commonly implicated in greater trochanteric pain syndrome. Surgical studies are often reported in small cohorts and with limited information on functional improvement. This study reports the clinical and functional outcomes after HAT repair.

Methods: 112 patients with symptomatic HAT tears, diagnosed via magnetic resonance imaging, underwent open bursectomy, V-Y lengthening of the iliotibial band, debridement of the diseased tendon, decortication of the trochanteric foot-plate and reattachment of the tendon with suture anchors, augmented with a LARS ligament through a trans-osseous tunnel. Patients were evaluated pre-surgery and at 3, 6 and 12 months post-surgery using the Harris (HHS) and Oxford (OHS) Hip Scores, SF-12, hip range of motion, 6-minute walk and 30-second single leg stance tests. Maximal isometric hip abduction strength (HAS) was assessed and limb symmetry indices (LSIs) were calculated between the operated and non-operated limbs. Patient satisfaction and perceived global rating of change (GRC) was evaluated. Analysis of variance evaluated improvement over time.

Results: There was a significant improvement ($p<0.05$) in all clinical and functional measures. HAS significantly improved over time ($p<0.002$) and all LSIs were >85% at 12 months. At 12 months, a mean GRC score of 3.5 (range -1 to 5) was reported, while 96% of patients were satisfied with their surgical outcome. There was a 2.7% (n = 3) failure rate at 12 months.

Conclusions: HAT reconstruction, augmented with a synthetic ligament, demonstrated significantly improved clinical and functional outcomes, high levels of patient satisfaction and a low failure rate to 12 months post-surgery.

Keywords: Assessment, Clinical outcomes, Hip abductor tears, Hip abductor tendon

Introduction

Greater trochanteric pain syndrome (GTPS) is a condition of greater and peri-trochanteric hip pain and tenderness (1-6), affecting 10%-25% of the general population (5-7). While a number of conditions are associated with GTPS including trochanteric bursitis, external coxa saltans and gluteal tendinopathy (3, 4, 8), better understanding of the condition along with advanced imaging and surgical findings has revealed a common cause to be hip abductor tendon (HAT) tears (2, 9, 10). While Bunker et al (11) first reported on the high incidence of HAT tears in patients with femoral neck fractures, numerous open and endoscopic techniques have been presented since this time (12-35), with the majority of these over the past 5 years. Recent reviews highlighted a higher number of reported surgical complications with open repair techniques, though no differences in strength or clinical scores (36, 37). Another review reported that many of these studies presenting outcomes after HAT repair lacked detail on the patient cohort, post-operative care and clinical follow-up (38). Furthermore, only 2 of the aforementioned 24 studies report outcomes in more than 24 patients (12, 26).

Therefore, this study aimed to comprehensively evaluate the clinical and functional outcomes of a consecutive series of patients undergoing HAT repair augmented with a synthetic ligament. We hypothesised that patients failing prior conservative treatment and with evidence of HAT tearing diagnosed via magnetic resonance imaging (MRI), would demonstrate significant clinical improvement and a low re-tear rate up until 12 months post-surgery.

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Methods

Patients

Between October 2012 and May 2015, 146 patients presented to a single orthopaedic surgeon's private practice (G.C.J.) and subsequently enrolled into a prospective study (Fig. 1). All patients presented with HAT tears diagnosed via MRI, which included partial or full thickness tears of gluteus minimus in all cases, along with the anterior portion of gluteus medius. All patients had previously failed a course of nonoperative treatment including corticosteroid injections and physical therapy. Of these 146 patients, 23 did not elect to proceed toward surgical repair within the recruitment and evaluation period. 11 patients that did proceed to surgery had also undergone prior total hip arthroplasty (THA) and were excluded from this prospective analysis (Fig. 1). Of the remaining 112 patients, 2 withdrew from ongoing clinical follow-up after surgery due to reported time and travel restraints, prior to their first postoperative evaluation (Fig. 1). Therefore, this pre- and postoperative clinical analysis included 110 patients (101 females, 9 males), of which 8 were symptomatic bilaterally. However, these 8 patients only underwent HAT repair on a single limb throughout the recruitment and evaluation period, which was the most symptomatic hip, providing all surgical inclusion criteria were met. Furthermore, while the predominant presenting symptom was lateral-sided trochanteric pain with radiation down the lateral leg, and not below the knee joint line in all patients, 8 patients that underwent surgery presented with evidence of advanced (Grade 2-4) (39) and/or symptomatic hip osteoarthritis (OA) on MRI. A further 4 patients had undergone prior failed gluteal tendon repair (n = 2) or iliotibial band (ITB) release and/or bursectomy (n = 2), and these were retained in this analysis.

With the Oxford Hip Score (OHS) as the primary outcome variable, a previous study reported that a sample size of 22 patients would have over 99% power to detect a mean change of 5 points (34), which has been suggested as the minimal clinically important difference for the OHS (40), assuming a standard deviation (SD) of the change score of 10, corresponding to a moderate effect size of 0.5. Given the early success and steady flow of patients requiring and undergoing the surgical procedure we continued recruitment. Patients provided written informed consent prior to study enrolment and subsequent preoperative clinical evaluation, and ethics approval was obtained from the relevant hospital ethics committee. This study conformed to the STROBE checklist, and was undertaken according to the Declaration of Helsinki.

Surgical technique

The procedure was performed using general anaesthesia, prophylactic antibiotics and an indwelling urinary catheter. In the lateral decubitus position, a 10-cm longitudinal incision was made over the lateral aspect of the greater trochanter. The tensor fascia lata (TFL) was divided longitudinally, the same length as the skin incision. A 1-2 cm V-Y lengthening of the TFL investing fascia was performed. The thickened trochanteric bursa was excised to expose the insertion of the gluteus medius tendon into the lateral facet of the anterior

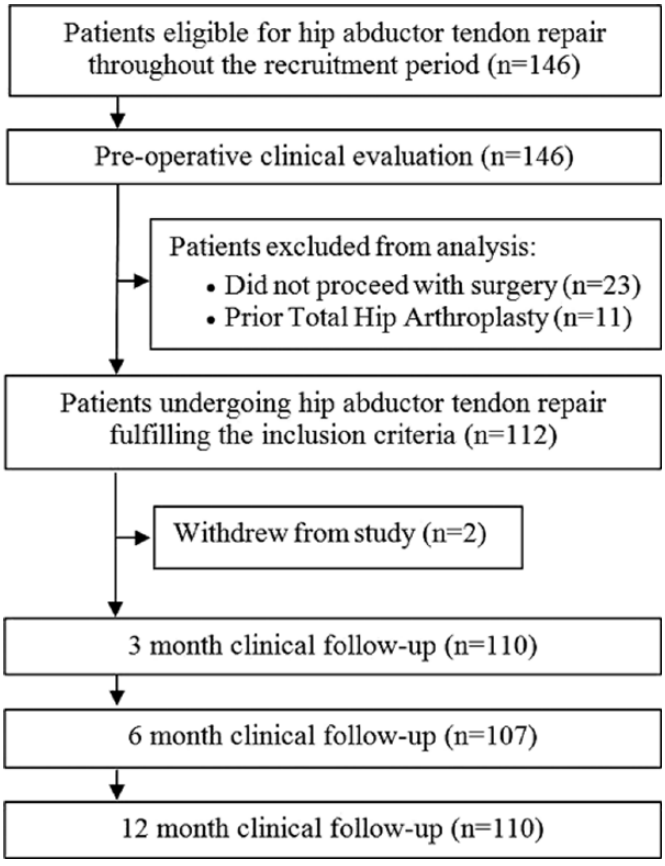

Fig. 1 - Flowchart demonstrating recruitment and evaluation over the 12-month period.

greater trochanter. Subsequent evaluation of the tendon was performed for the extent of the tear and the presence or otherwise of an associated enthesiophyte (Fig. 2A). The tear always involved gluteus minimus and the anterior fibres of gluteus medius. The involved portions of those tendons were elevated from the anterior greater trochanter. Any intact, generally posterior, fibres of the gluteus medius were not dissected from bone. The underlying bone on the foot-print of the tendon insertion was decorticated with an osteotome to remove sclerotic reactive bone and enthesiophytes, exposing a bleeding bone surface ready to receive the prepared tendon. Tendinopathic tissue was excised from the tendon end. Any de-laminations of the tendons were then repaired. The repair in all cases was augmented with a LARS (ACTOR 10, Corin Group) ligament which was cut longitudinally along the seam allowing the tube to fan. The flattened portion was sutured onto the under-surface of medius, or reflected minimus. Stay sutures in the reflected tendon ends aided retraction during LARS attachment. The LARS ligament was secured using 2-Ethibond sutures (Ethicon Inc., Johnson and Johnson).

A 4.5-mm bone tunnel was drilled from the foot-print of gluteus minimus on the anterior facet of the greater trochanter, which exits posterodistal to the lateral prominence of the greater trochanter (Fig. 2B). A flexible looped wire passed through the bone tunnel (Fig. 2C) permitted passing of the

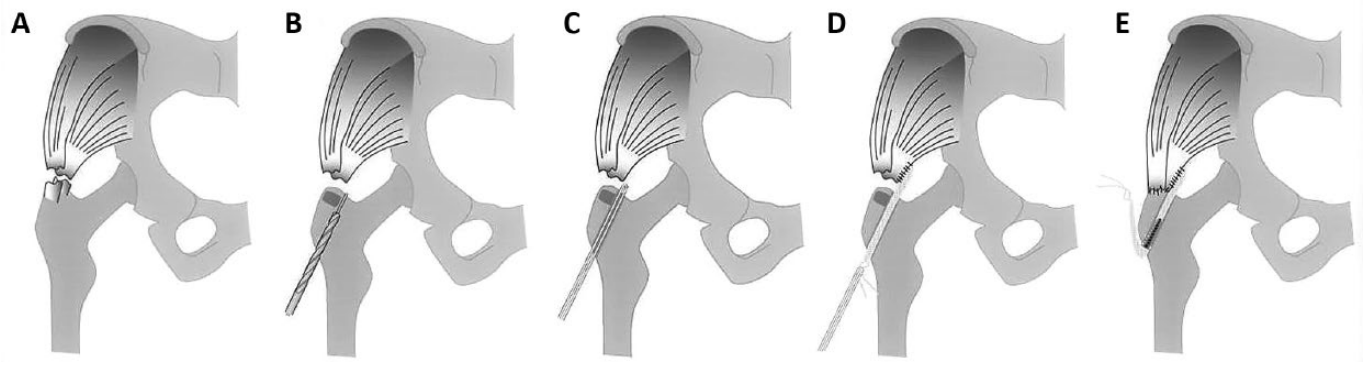

Fig. 2 - The surgical procedure, including identification and evaluation of the tendon tear (**A**), drilling of the bony tunnel (**B**), passing of the flexible looped wire (**C**) and LARS ligament (**D**), and placing of the interference screw into the bone tunnel to secure the tension in the ligament/bone interface, along with subsequent formal repair of the gluteal tendons to the greater trochanter (**E**).

draw-string on the free end of the LARS ligament through from anteromedial (deep) to lateral (superficial), and the deep surface of the tendon was drawn onto the footprint (Fig. 2D). A 5.2-mm interference screw (Corin) was placed into the bone tunnel to secure the tension in the ligament/bone interface (Fig. 2E). The excess tail of the LARS ligament was trimmed. Subsequently formal repair of the gluteal tendons to the anterior greater trochanter was performed with interosseous suture and bone anchors as indicated (Fig. 2E). The wound was closed in layers excluding the proximal fascia lata decompression. Patients were discharged from hospital 3-5 days after surgery, and 2 weeks of subcutaneous DVT prophylaxis was administered in all patients.

Postoperative rehabilitation

All patients underwent a coordinated postoperative rehabilitation programme of graduated weight-bearing and progressive exercise over at least 12 weeks, while further education and advice was provided up until the 12-month time-point (Tab. I).

Clinical assessment

A number of patient-reported outcome measures (PROMs) were employed. Firstly, the Harris Hip Score (HHS) (41) and OHS (39, 42) have been previously reported as the 2 most common clinical tools used to evaluate the outcome of patients before and after HAT repair (38). Secondly, the 12-item Short Form Health Survey (SF-12) evaluated the general health of the patient producing a mental (MCS) and physical component subscale (PCS). Thirdly, a visual analogue pain scale (VAS) evaluated the frequency (VAS-F) and severity (VAS-S) of pain on a scale of 0-10 (0 = no pain, 10 = constant/worst pain). Finally, a global rating of change (GRC) scale evaluated the patient's perceived status compared to before their surgery, while a patient satisfaction questionnaire was used to evaluate satisfaction with the surgery overall, as well as satisfaction with the surgery to relieve hip pain, improve the ability to perform normal daily and work activities, and improve the ability to return to recreational activities (1 = very satisfied, 2 = somewhat satisfied, 3 = somewhat dissatisfied, 4 = very dissatisfied).

Patients also underwent a series of functional tests in the following order, undertaken by a single experienced physical therapist. Active hip range of motion (ROM) was evaluated on the affected/operated limb in all planes using either a hand-held bubble inclinometer (hip flexion in supine, internal and external rotation in prone) or a Jamar® long arm goniometer (hip adduction and abduction in supine, extension in standing). A 30-second single leg stance (SLS) test was employed on the affected/operated limb, almost identical to that previously reported in patients with gluteal tendinopathy (4). However, while the originally published test requires patients to report the presence (or not) of hip pain within 0-5 seconds (immediate), 6-15 seconds (early) and/or or 16-30 seconds (late), we asked patients to verbally report their severity of pain immediately prior to the test and then at 10, 20 and 30 seconds into the test, on a VAS of 0-10. Patients underwent a 6-minute walk test (6 MWT) to assess the maximum comfortable distance they could walk in 6 minutes (43). A VAS (0-10) was again employed immediately prior to the test and then at 2, 4 and 6 minutes into the test, to evaluate pain severity. Finally, maximal isometric hip abduction strength was assessed on both the affected/operated and unaffected limb, using a T5 Cable Tensiometer (Pacific Scientific Company). In an upright standing position, with the patient able to bear as much weight as was required through their upper body supported alongside their trunk, patients were asked to abduct their leg as hard as they could against the cable anchored just above their lateral malleolus. The patient was instructed to maintain an upright trunk and not force their hips out with the test leg and, therefore, to ensure this was the case the hands of the assessor were placed on either hip of the patients during the test. The test was undertaken 3 times for each limb, initiated on the unaffected limb and then alternated between the unaffected and affected side, with the maximum score used. In addition to absolute peak values, a Limb Symmetry Index (LSI) for hip abductor strength was calculated by dividing the peak values on the affected/operated limb by that recorded on the unaffected limb.

Data and statistical analysis

Means (SD and range) were presented for all measures. To investigate the progression of clinical (HHS, OHS, VAS-F,

TABLE I - Overview of postoperative management of patients undergoing hip abductor tendon repair outlining specific goals, weight-bearing (WB) graduation, hip range of motion (ROM) and exercise prescription

Phase	Postoperative goals	Patient education and exercise prescription
Phase 1 (1-2 weeks)	1. Reduce postoperative pain/oedema. 2. Avoid excessive WB (>20% BW). 3. Avoid provocative postures and positions that may adversely stretch/load the repair site. 4. Maintain lower limb joint	• Educate on strategies to reduce pain/inflammation. • Education and practice in proficient heel-toe WB ambulation (≤20% BW), using 2 crutches. • Education on provocative postures and positions that may adversely stretch/load the repair site. • Passive and active-assisted hip ROM exercises within a pain-free ROM (avoidance of hip flexion >90°, internal rotation beyond neutral and/or hip adduction beyond the midline). • Active ankle dorsi- and plantar-flexion exercises. mobility, muscle tone and circulation. • Isometric contraction of the quadriceps, hamstrings, adductor and gluteal musculature.
Phase 2 (2-4 weeks)	1. Pain and oedema well managed. 2. Proficient heel-toe gait at 50% BW with 1-2 crutches. 3. Proficiency in undertaking home-exercise programme.	• Progress from ≤20% BW (1-2 weeks) to 50% BW (4 weeks), using 1-2 forearm crutches. • Education on quality of gait, particularly with the progression toward a single forearm crutch. • Introduce gentle stretching of the hip flexors. • Introduce additional home-based exercises, such as: knee extensions, prone knee flexion, multi-plane isometric hip adduction, bilateral supine bridging, resisted knee flexion, heel raises and standing hip extension. • Introduce hydrotherapy, including: deep water walking (forwards, backwards, sideways), heel raises, mini squats, straight leg hip flexion and extension, cycling, scissor kicks.
Phase 3 (4-8 weeks)	1. Pain-free full WB gait by 8 weeks (1 crutch permitted for protection, stability and/or safety as required. 2. Pain-free during low demand daily tasks. 3. Proficiency in performing all new home-based exercises. 4. Near full and comfortable hip ROM (≥75% hip ROM in all planes compared to the contralateral hip).	• Progress from 50% BW (4 weeks) to full WB as tolerated from 6 weeks, using 1 forearm crutch as required. • Progress toward full pain-free passive and active hip ROM. • Education on quality gait required. • Increase demand of home based exercises, including: isometric and isotonic external hip rotation (using theraband), clam exercises, supine hip flexion, straight leg raises, bilateral supine bridging (with added theraband resistance) and standing hip abduction (without resistance). • Introduce stationary cycling (week 4-6) and gentle freestyle swimming for hip ROM and/or cardiovascular fitness. • Hydrotherapy: add shallow water walking (waist depth), straight leg hip abduction and circumduction, deep squats, step ups/downs, lunges, single leg balance and proprioception exercises. • Gentle remedial massage and soft tissue mobilisation.
Phase 4 (8-12 weeks)	1. Pain-free and full active hip ROM (≥90% hip ROM in all planes compared to contralateral hip). 2. Pain-free 6-minute walk test without the use of walking aids (gait speed patient dependent). 3. Ability to single leg stand for 15-30 seconds, with VAS ≤3/10. 4. Proficiency in performing home- and clinic-based exercises for the independent continuation of post-discharge rehabilitation.	• Full WB as tolerated, crutch/cane for stability as required. • Education on quality gait and undertaking functional activities (i.e. rising from sitting) required. • Increase demand of home based exercises, including: trunk flexion and core stability activities, prone hip extension, quadruped exercises with hip extension, standing resisted (theraband) hip extension and abduction, side-lying hip abduction. • Introduce WB functional activities as permitted (week 11-12), including: bilateral wall and free-standing squats (with assistance if required), single leg stance balance and weight shift activities, proprioceptive WB exercises.

To be continued

TABLE I - Continued

Phase	Postoperative goals	Patient education and exercise prescription
Phase 5 (3-6 months)	1. Normal, pain-free and unaided gait. 2. Hip abductor strength ≤75% on MMT and/or HHD, compared with the contra-lateral limb. 3. Comfort in ambulating stairs (ascent and descent) and gradients. 4. Return to work (dependent on occupational demands). 5. Proficiency in performing all full WB strengthening, functional and proprioception activities.	• Education and exercises pertinent to the training of daily activities for the individual patient is required. • End range and multi-plane stretching and soft tissue therapy of surrounding hip musculature, including: gluteus medius, minimus, iliotibial band and tensor fascia lata. • Increase demand of home based exercises, including: single limb supine bridge exercise, side and prone bridging, pelvic drops and lateral band walks. • Increase demand of WB functional activities as required, including: single limb squat, lunge, single leg balance and stepping activities. • Outdoor road cycling is permitted, while rowing ergometry and elliptical trainers can be introduced. • Please note: graduation in WB activities should be based upon the assumed healing and maturation of the surgical repair, as well as the individuals' surgical details, lower limb strength/function and tolerance to exercises (pain and control).
Phase 6 (6 months onwards)	1. Ability to tolerate pain-free walking distances of any length/duration. 2. Hip abductor strength ≥90% on MMT and/or HHD, compared with the contra-lateral limb. 3. Ability to perform all activities of daily living pain-free. 4. Ability to effectively negotiate uneven terrain and soft sand. 5. Return to pre-operative low-impact recreational activities and/or sport as required.	• Ongoing education may be required in undertaking specific work, recreational and/or sporting activities, with particular reference to optimal ergonomic and/or technique modification to avoid provocative positions and/or movements that could be implicated in a recurrence of symptoms. • Exercises employed should begin to replicate what is required for the patient's individual activity goals, which may include sport specific activities.

BW = body weight; HHD = hand held dynamometry; MMT = manual muscle testing; ROM = range of motion; VAS = visual analogue pain scale; WB = weight-bearing.

VAS-S, SF-12 PCS and MCS) and functional (hip ROM, 6 MWT, pain during 6 WMT and 30-second stance tests, absolute hip abductor strength and hip abductor strength symmetry) outcomes over time, repeated measures analysis of variance (ANOVA) was used. Statistical analysis was performed using SPSS software (SPSS, Version 17.0, SPSS Inc.), while statistical significance was determined at $p<0.05$.

Results

The 110 patients (101 females, 9 males) included in this analysis had a mean age of 63.2 years (range 43-82 years) and body mass index (BMI) of 27.8 (range 20.0-40.2). Patients had undergone an average of 3.3 (range 1-8) corticosteroid injections and reported a mean duration of symptoms (DOS) of 3.6 years (range 6 months - 18 years). All 110 patients were evaluated pre-surgery and at 3 and 12 months post-surgery, with only 107 patients being evaluated at the 6-month assessment time point (an intention to treat analysis was performed for these 3 missing cases at 6 months post-surgery using the "last value carried forward" technique) (Fig. 1). However, 1 patient was unable to complete maximal isometric hip abduction strength assessment pre-surgery, while 5 patients were unable to undertake the 30-second SLS and/or 6 MWT preoperatively due to the requirement of a single forearm crutch. 8 patients were unable to ambulate through the entire 6 MWT at 3 months post-surgery without the crutch, so this data was omitted from the analysis. Finally, maximal isometric hip abduction strength data were omitted from the analysis in the 8 patients that were symptomatic bilaterally, due to potential bias in limb symmetry measures.

A significant postoperative improvement ($p<0.05$) was observed in all PRO scores (Tab. II). We observed a significant improvement in all planes of active hip ROM ($p<0.0001$) (Tab. III) and 6-minute walk capacity ($p<0.0001$) (Tab. IV), while patients reported significantly less ($p<0.0001$) pain throughout, and upon completion, of the 6 MWT (Tab. IV). Throughout the 30-second SLS test, postoperative reported hip pain was significantly lower ($p<0.0001$) at all test points (prior to test onset and at 10, 20 and 30 seconds into the test) (Tab. V). Finally, patients displayed a significant postoperative improvement ($p = 0.002$) in maximal isometric hip abductor strength on their operated limb, while hip abductor strength symmetry also significantly improved ($p<0.0001$) over time (Tab. VI).

As time progressed patients perceived themselves to be better than their pre-surgery status, with GRC mean scores of 2.2 (range -5 to 5), 2.6 (range -3 to 5) and 3.5 (range -1 to 5) reported at 3, 6 and 12 months post-surgery, respectively. Of the 110 patients who completed the patient satisfaction questionnaire at 12 months post-surgery, 96% (n = 106) were

TABLE II - Patient-reported outcomes throughout the pre- and postoperative timeline

Variable		Pre-surgery	3 months	6 months	12 months	p value
HHS	Mean (SD)	57.6 (18.9)	74.5 (16.1)	80.8 (14.9)	85.8 (13.6)	<0.0001
	Range	15.3-90.0	42.7-100.0	43.6-100.0	41.8-100.0	
OHS	Mean (SD)	25.3 (8.7)	33.8 (8.4)	37.3 (7.9)	39.9 (6.7)	<0.0001
	Range	5-46	12-47	11-48	23-48	
SF-12 (PCS)	Mean (SD)	33.2 (9.2)	36.4 (10.5)	40.6 (10.1)	44.1 (9.4)	<0.0001
	Range	9.0-57.8	10.8-57.2	10.8-61.4	14.9-58.1	
SF-12 (MCS)	Mean (SD)	49.3 (11.5)	53.5 (11.4)	52.4 (11.4)	54.9 (9.8)	0.008
	Range	20.4-70.8	25.6-70.9	27.3-69.7	27.3-69.5	
VAS-Frequency	Mean (SD)	7.9 (2.6)	3.8 (2.8)	3.1 (2.6)	2.2 (2.0)	<0.0001
	Range	1-10	0-10	0-10	0-6	
VAS Severity	Mean (SD)	6.5 (2.2)	2.8 (1.8)	2.7 (2.1)	1.9 (1.5)	<0.0001
	Range	1-10	0-7	0-9	0-5	

HHS = Harris Hip Score; OHS = Oxford Hip Score; SF-12 = 12-item Short Form Health Survey; PCS = physical component score; MCS = mental component score; VAS = visual analogue pain scale; SD = standard deviation.

TABLE III - Pre- and postoperative active hip range of motion (degrees)

Plane of hip motion		Pre-surgery	3 months	6 months	12 months	p value
Flexion	Mean (SD)	101.8 (18.4)	112.1 (13.4)	116.1 (13.8)	118.0 (12.9)	<0.0001
	Range	55-135	70-145	70-145	80-155	
Extension	Mean (SD)	14.8 (5.8)	18.3 (5.7)	20.3 (6.0)	21.6 (6.3)	<0.0001
	Range	5-28	8-35	10-35	10-35	
Abduction	Mean (SD)	31.3 (12.4)	40.0 (12.4)	44.8 (12.6)	47.6 (13.8)	<0.0001
	Range	5-50	7-70	22-70	20-70	
Adduction	Mean (SD)	14.6 (6.2)	21.9 (7.2)	23.4 (6.4)	25.0 (7.2)	<0.0001
	Range	5-40	10-40	12-40	12-40	
External rotation	Mean (SD)	29.5 (10.1)	36.6 (9.8)	37.3 (8.7)	39.4 (8.2)	<0.0001
	Range	0-50	5-55	12-55	12-62	
Internal rotation	Mean (SD)	28.7 (11.8)	34.7 (10.4)	36.4 (9.7)	37.8 (9.5)	<0.0001
	Range	0-55	8-60	12-60	12-60	

SD = standard deviation.

TABLE IV - Pre- and postoperative 6-minute walk distance (m) and pain reported (0-10) throughout the 6-minute walk test

Time point		Distance (m)	Pain (0-10) 0 mins	Pain (0-10) 2 mins	Pain (0-10) 4 mins	Pain (0-10) 6 mins
Pre-surgery	Mean (SD)	405 (109)	2.8 (2.4)	3.6 (2.7)	4.3 (2.7)	4.9 (2.9)
	Range	105-705	0-9	0-10	0-10	0-10
3 months	Mean (SD)	417 (112)	1.3 (1.7)	1.9 (1.9)	2.33 (2.2)	2.6 (2.3)
	Range	190-730	0-9	0-9	0-9	0-10
6 months	Mean (SD)	460 (103)	0.9 (1.54)	1.4 (1.8)	1.7 (2.0)	2.0 (2.2)
	Range	190-723	0-7	0-8	0-8	0-9
12 months	Mean (SD)	495 (102)	0.5 (1.0)	1.0 (1.4)	1.4 (1.7)	1.6 (2.0)
	Range	190-723	0-6	0-7	0-7	0-9
p value		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

SD = standard deviation.

TABLE V - Pain reported (0-10) throughout the 30-second single leg stance test (prior to onset and at 10, 20 and 30 secs), at the designated pre- and postoperative assessment time points

Time point		Pain (0-10) 0 secs	Pain (0-10) 10 secs	Pain (0-10) 20 secs	Pain (0-10) 30 secs
Pre-surgery	Mean (SD)	2.2 (2.3)	3.6 (2.8)	4.4 (3.1)	4.9 (3.1)
	Range	0-9	0-9	0-10	0-10
3 months	Mean (SD)	1.0 (1.4)	1.8 (2.0)	2.3 (2.2)	2.7 (2.4)
	Range	0-5	0-8	0-8	0-10
6 months	Mean (SD)	0.6 (1.0)	1.3 (1.7)	1.6 (2.0)	1.9 (2.2)
	Range	0-7	0-9	0-9	0-9
12 months	Mean (SD)	0.4 (0.7)	0.7 (1.0)	1.0 (1.2)	1.2 (1.4)
	Range	0-4	0-5	0-5	0-5
p value		<0.0001	<0.0001	<0.0001	<0.0001

SD = standard deviation.

TABLE VI - Pre- and postoperative maximal isometric hip abductor strength (kg) for the affected/operated and unaffected limbs, along with hip abductor strength symmetry (the affected/operated limb as a percentage of the unaffected limb)

Time point		Affected limb	Unaffected limb	Strength symmetry
Pre-surgery	Mean (SD)	35.7 (7.2)	38.0 (8.9)	94.8%
	Range	24.4-59.1	26.2-82.5	62.9-110.0%
3 months	Mean (SD)	36.2 (8.2)	36.4 (8.0)	99.4%
	Range	23.8-78.9	23.9-72.1	71.7-117.5%
6 months	Mean (SD)	38.8 (8.0)	38.1 (8.1)	101.9%
	Range	23.9-68.8	23.9-73.8	73.6-121.1%
12 months	Mean (SD)	39.9 (8.6)	39.2 (8.8)	101.3%
	Range	23.9-68.9	23.9-72.1	86.8-128.5%
p value		0.002	0.220	<0.0001

SD = standard deviation.

satisfied with the results of the surgery to relieve their hip pain, 96% (n = 106) were satisfied with the improvement in their ability to undertake daily and work activities and 90% (n = 99) to improve their ability to return to recreational activities. Overall, 96% (n = 106) of patients at 12 months were satisfied with their surgical outcome.

A number of postoperative complications were reported. Firstly, up until 12 months post-surgery we have encountered 3 surgical failures, all of which presented with increasing lateral hip pain and symptoms similar to their preoperative condition, and all of which were subsequently confirmed on repeat postoperative MRI. The 1st of these failures was confirmed at 11 months post-surgery in a patient that had failed gluteal tendon repair 5 years prior. She continues to be prospectively followed though is being managed conservatively. A partial re-tear was confirmed in the other 2 failures at 7 and 9 months post-surgery, and both patients have since undergone revision surgery. 1 patient developed a postoperative haematoma and 2 developed superficial wound infections, which were treated with oral antibiotics and subsided accordingly. 1 patient developed a deep venous thrombosis and pulmonary embolism at 3 weeks post-surgery, was treated accordingly and recovered without sequelae.

Discussion

GTPS encompasses a range of conditions, though HAT tears are a common cause (2, 9, 10). While a number of surgical options have been presented in addressing these tears (38), studies often lack detail on the patient cohort, postoperative care and clinical follow-up, with only 2 previous published studies reporting outcomes in more than 24 patients (12, 26). In this study, significant improvement was observed in PROM and functional measures, along with a low re-tear rate (2.7%) and high levels of satisfaction, in a large consecutive cohort undergoing HAT repair augmented with a LARS ligament.

All PROMs significantly improved after surgery. The HHS has been the most commonly employed PROM evaluating HAT repair, and the postoperative improvement demonstrated in this study appears consistent with prior studies that have employed the HHS, at a variety of postoperative time points (12, 13, 15, 21, 23-25, 28, 30, 32, 33). The significant OHS improvement observed was also similar to previously reported HAT repair studies (20, 34). A significant improvement in the frequency and severity of hip pain was reported in this prospective study. The VAS has been reported in several

studies reporting the outcomes of HAT repair (12, 20, 30, 32, 34), and our outcomes are also consistent with those previously reported.

With the reported physical disability observed with HAT tears, poor preoperative scores for the PCS of the SF-12 were expected, albeit better than that previously reported (20, 34). Nevertheless, the PCS significantly improved with 12-month postoperative outcomes similar to that reported in other studies (20, 34). We also observed a significant improvement in the MCS subscale of the SF-12, reflective of the positive psychological benefit HAT repair may offer these patients. Previous studies that have employed the MCS to evaluate outcome after HAT repair have also reported improvement in this PRO (20, 34), with 1 study showing a non-significant improvement (20). A study by Fearon et al (44) demonstrated that people with GTPS demonstrated high levels of pain and dysfunction, low levels of full time work participation and a reduced quality of life, which was indistinguishable from people with severe hip OA. The improved MCS in this study highlights the improvement in the patient's perceived level of disability and quality of life.

Overall, the significant postoperative clinical improvement correlated with the high level of satisfaction reported by patients in this study. At 12 months post-surgery, 96% of patients were satisfied with the overall results of their surgical outcome, with 96% also satisfied with their hip pain relief and ability to undertake daily and work activities. Furthermore, 90% were satisfied with their ability to return to recreational activities, though the type of activities was not evaluated. These satisfaction rates are encouraging and appear better than what has been documented in the existing literature, with satisfaction rates of 66%-90% reported (13, 15, 18, 21, 23, 25, 34).

Despite observing a significant postoperative improvement in active hip ROM in all planes of motion, it has been previously reported that hip movement is generally not affected in GTPS patients (3). These earlier reports may be due to the fact these patients often do not have OA hips, though extremes of hip movement may be limited due to pain with increased gluteal activation and/or compression over the greater trochanter. Limited (and/or painful) hip ROM may well limit the individual's ability to undertake simple daily activities, such as sitting in a low chair or riding a bike with restricted hip flexion. Therefore, these improvements may translate to an improvement in functional capacity, though the true clinical significance of these improvements remains unknown.

The 6 MWT has not previously been used to evaluate the functional improvement provided by HAT repair, despite walk capacity being reported as a key component of many activities of normal daily living, as well as a foundation for functional independence (45). Not only did we observe a 25% improvement in distance walked, but a significant reduction in patient-reported pain throughout and upon completion of the test at 12 months, compared with pre-surgery. A significant reduction in pain throughout and upon completion of the 30-second SLS test was also reported post-surgery. Some studies do report the presence (or not) of a positive Trendelenburg sign (38), though not necessarily pain during SLS. We modified a test reported previously in patients with gluteal tendinopathy (4), with mean preoperative VAS scores upon test completion of almost 5/10 reported in the current patient cohort, which had reduced to 1.2/10 at 12 months.

Several studies have evaluated the improvement in hip abductor muscle strength after tendon repair (21, 23, 24, 30, 32) and, while all studies reported improvement, manual muscle testing was employed to assess preoperative deficiencies and postoperative improvement. Voos et al (24) suggested that a weakness of their study was the lack of quantitative strength testing and, therefore, we attempted to quantify maximal isometric hip abductor strength. While we observed a significant improvement in strength of the operated limb from pre- to post-surgery, with a subsequent improvement in strength symmetry between the operated and asymptomatic contralateral limb, we did not undertake a thorough evaluation of pain during the evaluation which could affect strength. Nevertheless, mean hip abductor strength symmetry in this study had been attained as early as 6 months post-surgery, maintained at 12 months and, in addition to restoration of the hip abductor mechanism, this may be in part due to the progressive rehabilitation programme that has been developed to accommodate this surgery. It should also be noted that existing studies have evaluated strength of the affected/operated limb only in the lateral decubitus position, while evaluating hip abduction strength in side lying has been frequently employed in clinical settings (46). However, we aimed to also evaluate limb symmetry which limited the applicability of using the side lying position due to compression pain when lying on the affected/operated limb, whilst evaluating the nonoperated limb.

Recent reviews have highlighted a higher number of complications with open repair techniques, compared with endoscopic methods, despite no overall differences in strength or clinical scores (36, 37). A review by Alpaugh et al (37) reported a re-tear rate of 9% in open repairs, with an overall 13% complication rate. Chandrasekaran et al (36) reported a 13% re-tear rate with open repairs, with a 19% overall complication rate that included infection (0.8%), haematoma (2.3%), deep vein thrombosis (DVT) (4.7%) and pulmonary embolism (0.8%). Failure rates as high as 16% (18), 31% (20) and 33% (23) have been reported in prospective studies. At 12 months, we have observed a 2.7% re-tear rate, with an overall complication rate of 6.3% which included the 3 re-tears, 1 haematoma, 2 superficial wound infections, and 1 DVT with a pulmonary embolism. The rationale for the LARS employed in this surgical technique was to reinforce the early repair, providing immediate additional mechanical strength to support the healing tissue and potentially reduce the incidence of early re-tear.

We acknowledge several limitations in this study. Firstly, a number of validated hip PROMs exist and we chose to employ the HHS and OHS to evaluate hip pain, symptoms and disability. This was in part due to the lack of a validated PROM for patients with GTPS and/or HAT tears at study onset, though more recently a PROM specific to evaluating the pain and disability associated with GTPS has been developed and validated (47), and could be employed in future research. However, the HHS has been the most commonly employed clinical tool to evaluate the outcome of patients before and after HAT repair (38). Other PROMs have been employed including the

Lequesne index (12), Merle D'Aubigne Postel Score (20), Hip Outcome Score (15, 24, 26, 32), Hip disability and Osteoarthritis Outcome Score (27), the Non-Arthritic Hip Score (32, 33), and the Lower-Extremity Activity Scale (21), making comparison of different studies more difficult.

Secondly, several studies have employed MRI to evaluate the status of the repair in the majority (or a sample) of patients post-operatively (12, 13, 23, 24). We only employed postoperative MRI if patients presented with increasing lateral hip pain and symptoms similar to their pre-operative condition and, given the high satisfaction rates and no evidence of clinical failure, it was not deemed necessary otherwise. Finally, this prospective study lacked a control cohort of patients, though given the long duration of symptoms and failed prior attempts at other conservative treatments to no avail, these patients may serve as their own internal control.

Our hypothesis was supported, in that this augmented HAT repair technique demonstrated good clinical and functional outcomes to 12 months, along with a low re-tear rate (2.7%) and high levels of patient reported satisfaction. While the clinical improvements appear consistent with current literature reporting HAT repair, long-term follow-up of these patients will continue to confirm the durability of the repair and longevity of improved patient clinical outcome and quality of life.

Disclosures

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