Lesions of the abductors in the hip

Eustathios Kenanidis1,2,3
George Kyriakopoulos1,4
Rajiv Kaila1
Panayiotis Christofilopoulos1

- Abductor tendon lesions and insertional tendinopathy are the most common causes of lateral thigh pain. Gluteal tendon pathology is more prevalent in women and frequency increases with age.
- Chronic atraumatic tears result in altered lower limb biomechanics. The chief complaint is lateral thigh pain. Clinical examination should include evaluation of muscle strength, lumbar spine, hip and fascia lata pathology. The hip lag sign and 30-second single leg stance tests are useful in diagnosing abductor insufficiency.
- Magnetic resonance imaging (MRI) is the gold-standard investigation to identify abductor tendon tears and evaluate the extent of muscle fatty infiltration that has predictive value on the outcome of abductor repair.
- Abductor tendinosis treatment is mainly conservative, including non-steroidal anti-inflammatory medications, activity modification, local corticosteroid injections, plasma-rich protein, physical and radial shockwave therapy. The limited number of available high-quality studies on treatment outcomes and limited evidence between tendinosis and partial ruptures make it difficult to provide definite conclusions regarding the best management of gluteal tendinopathy.
- Surgical management is indicated in complete and partial gluteal tendon tears that are unresponsive to conservative treatment.
- There are various open and arthroscopic surgical procedures for direct repair of abductor tendon tears. There is limited evidence concerning surgical management outcomes. Prerequisites for effective tendon suturing are neurologic integrity and limited muscle fatty infiltration. Chronic irreparable tears with limited muscle atrophy and limited fatty infiltration can be augmented with grafts. Gluteus maximus or vastus lateralis muscle transfers are salvage reconstruction procedures for the management of chronic end-stage abductor tears with significant tendon insufficiency or gluteal atrophy.

Keywords: arthroscopy; gluteal muscles; gluteus medius; gluteus minimus; greater trochanteric pain syndrome; hip abductors; lateral thigh pain; muscle transfer; tendinopathy; tendon tears

Cite this article: EFORT Open Rev 2020;5:464-476.
DOI: 10.1302/2058-5241.5.190094

Introduction

Many terms describe persistent lateral hip pain around the greater trochanter, including trochanteric bursitis, greater trochanteric pain syndrome, and lateral thigh pain.1 However, the cause of pain encompasses many different pathologies. Lateral thigh pain is frequently associated with trochanteric bursitis, but the use of advanced imaging methods has provided greater awareness that hip abductor injuries can be causative.1,2 It is now supported that abductor tendon lesions and non-inflammatory insertional tendinopathy of gluteus medius (GMed) and gluteus minimus (GMin) are the most common cause of lateral thigh pain in both native and prosthetic hips.3 Hip abductor tendinopathy can range from tendinosis to complete tendon rupture, frequently complicated by muscle fat atrophy.4 This instructional review aims to present an outline of current literature evidence regarding the anatomy, diagnosis and treatment of hip abductor tendon lesions and specifically of GMed and GMin.

Anatomy and function of gluteal muscles

The hip abductors comprise the GMed, GMin and tensor fasciae latae.4 The GMed originates from the anterior superior iliac spine and the outer border of the iliac crest towards the posterior superior iliac spine.5 A recent cadaveric study demonstrated three distinct GMed origins: gluteal fossa and aponeurosis, and the posteroinferior edge
of the iliac crest. The GMin originates from between the anterior and posterior inferior iliac spines along the middle gluteal line. Both of these are innervated by the superior gluteal nerve; however, variable primary innervation patterns have been reported. The GMed has three distinct parts, the anterior, middle and posterior. The muscle fibres of the anterior and middle segments are perpendicularly oriented, initiating hip abduction, while the posterior fibres of the GMed and GMin have a horizontal orientation, stabilizing the hip joint during gait.

Two discrete GMed insertion sites with different shapes have been recognized (Fig. 1). The posterior aspect of the GMed and a section of the middle portion are inserted on the posterosuperior facet of the greater trochanter (Fig. 1C). This facet is thick and almost round with a diameter less than 10 mm. The remaining middle and anterior GMed parts are inserted on the lateral trochanteric facet (Fig. 1D). This is wider and trapezoidal with a mean length of 3.5 cm inclined to the femoral axis. The GMin has fascicular attachments to the anterior hip capsule (Fig. 1B) and the anterior and lateral facets of greater trochanter (Fig. 1A) beneath the GMed. The insertional facets of the GMed and GMin are separated from an area bare of tendon attachments, the so-called ‘bald area’ (Fig. 1E), serving as an anatomic landmark, particularly for hip arthroscopy.

**Epidemiology**

The prevalence of abductor tendon lesions cannot be accurately estimated. Abductor tendinopathy has been historically under-reported under the term greater trochanteric pain syndrome (GTPS) which has included both trochanteric bursitis and external coxa saltans (snapping hip syndrome). However, half of patients suffering from GTPS demonstrate gluteal tendinosis or ruptures. Also, less than 20% have ultrasound-detected bursitis, which is usually a secondary feature. Besides, less than 10% of patients suffer from bursitis without any other pathology.

GTPS is more prevalent in women than men and demonstrates peak prevalence between the fourth and sixth decades of life. The rate of gluteal tendinosis and ruptures increases with age. In an observational study of 185 patients over 50 years old with non-hip-related problems, the incidence of gluteal ruptures increased from 10% in the under the sixties to 50% in the over seventies groups. Importantly, after the age of 70 years, the prevalence of tendinopathy can be over 80% and 60% can demonstrate partial tears.

**Aetiopathogenesis**

Abductor tendon insufficiency can result in altered lower limb biomechanics. Patients suffering from knee or hip osteoarthritis demonstrated a higher prevalence of abductor pathology. Twenty five per cent of patients undergoing total hip arthroplasty (THA) for end-stage hip osteoarthritis also suffer from gluteal tendon ruptures. Abductor pathology appears related to ageing, mainly attributed to diminished tendon vascularity.

Three distinct clinical scenarios have been described for abductor tendon tears. First, they may be chronic tears. These are often found in the over 70-year-old age group, in patients with persistent lateral hip pain, non-responsive to conservative treatment. The other two scenarios involve atraumatic chronic tears of the anterior GMed part found unexpectedly during hip surgery and iatrogenic avulsion tears of abductor tendons following THA using a transgluteal approach, due to deficient healing of the disruption site. Svensson et al followed 97 patients for a year undergoing THA through the transgluteal approach using metal markers on both sides of gluteal repair. Twenty-three patients had a separation > 1 cm at two weeks, and 54 had a split > 2.5 cm at one-year postoperatively. Traumatic tears in young adults have also been reported. Excessive wear, osteolysis and especially metallosis following THA may lead to fatigue, inflammatory process and excessive abductor tendon damage and atrophy of the hip abductors. The amount of femoral...
offset produced following THA often affects abductor function. A reduction in offset over 5 mm results in reduced abductor strength.²²

**Clinical presentation**

The effect of abductor tendon pathology on quality of life (QoL) may be similar to or even worse than symptoms from end-stage hip osteoarthritis.²⁰,²³ The chief complaint is lateral thigh pain aggravated by lying on the affected limb, walking or climbing stairs.⁵ Pain radiating over the fascia lata may also be problematic. Tenderness over the superior and lateral facets of the greater trochanter is typically found on examination. Although described, anterior groin pain is less common, and other reasons for pain should be excluded.²⁴

The patient often shows a slight or moderate limp and a positive Trendelenburg sign. These simple clinical findings have shown sensitivity and specificity of between 73% and 76%, to diagnose abductor tendon tears, respectively.²⁵ The sensitivity and specificity to diagnose abductor tendon tears have been shown to be superior to resisted abduction testing and internal rotation in a study of 24 cases with GTPS.²⁵ A gait analysis study showed increased adduction in single leg stance before lift-off and lowered contralateral hemipelvis position in patients with symptomatic glutaeal tendinopathy.²⁶

A detailed clinical examination should be performed including evaluation of muscle strength, neurologic status, lumbar spine and hip or fascia lata pathology. The passive hip range of motion is usually not limited, but hip abductor muscle strength is decreased compared with asymptomatic individuals.²⁷ In patients with THA, the integrity of the prosthetic joint must also be checked.

The hip lag sign is a useful test in diagnosing abductor insufficiency. It is performed with the patient in the lateral position with the affected side up. The clinician passively extends the hip 10 degrees, abducts 20 degrees, and then maximally internally rotates the hip with the knee in 45 degrees of flexion. The leg is then released, and the patient is asked to hold it in an upright position. If the leg drops more than 10 cm, the test is considered positive.²⁸ Hip lag sign demonstrated sensitivity and specificity of 89% and 96% respectively for abductor tendon ruptures, insufficiency and tendinopathy.²⁸

Additional useful tests are the 30-second single leg stance and external derotation tests. In the former, the patient is asked to perform a 30-second single leg stance and no trunk deviation; the test is positive if lateral thigh pain occurs.²⁹ The latter is tested with the patient lying supine with the hip and knee flexed at 90° and the hip in external rotation; the test is positive if pain arises after resisted derotation of the leg.²⁹ Single leg stance test and resisted external derotation test in supine position had a sensitivity of 100% and 88% respectively and specificity of 97.3% in diagnosing gluteal tendinopathy.²⁹ Internal rotation lag sign showed a weaker correlation to diagnose abductor tears.³⁰

**Imaging**

Magnetic resonance imaging (MRI) is the gold-standard examination in evaluating abductor muscles and tendon anatomy.⁴ Metal artefact reduction sequences (MARS) and multiple acquisitions with variable-resonance image combinations MRI (MAVRIC) are advanced MRI protocols that enable improved assessments when prosthetic hips are present. The size and shape of muscles, tendinosis, partial or complete tendon defects and fatty infiltration of glutaeal muscles can be assessed. An area of hyperintense signal superior or lateral to the greater trochanter, separating the tendon from its attachment on T2 MRI sequence, is reported to have 75% sensitivity and 95% specificity to predict GMed tendon tears.³¹ GMed tendon elongation³¹ or Tensor Fasciae Latae (TFL) hypertrophy³² are other indirect MRI findings related to abductor tendon tears. MRI may under-report tears when compared to intraoperative findings.²⁴ Also, peritrochanteric abnormalities on MRI may be present in 50% of asymptomatic patients, elucidating that clinical presentation should guide treatment³³ (Fig. 2).

---

**Fig. 2** Magnetic resonance imaging (MRI) sequence pictures demonstrating a chronic glutaeus medius rupture with extended fatty infiltration of the muscle.
Lesion of Hip Abductors

The extent of abductor muscle fatty infiltration has a predictive value on repair outcomes. The Goutallier–Fuchs classification rates the degree of abductor fatty infiltration on MRI using a four-scale range. Grade 1 relates to some muscle fatty streaks. Grades 2 and 3 involve muscle fatty infiltration with more muscle and fat, or equal muscle and fat, respectively. Grade 4 demonstrates more fat than muscle on MRI. Bogunovic et al correlated greater muscle fatty infiltration (Grade 3–4), higher postoperative pain and failure rate and the lower functional outcomes. The prognostic value of abductor muscle fatty infiltration has been confirmed both for open and endoscopic repair. Although gluteal tears may be present in asymptomatic individuals, they are more common in symptomatic individuals. Fatty infiltration is almost exclusively seen in symptomatic patients.

Standard hip and pelvic radiographs should also be performed and have an essential role in the initial evaluation. Greater trochanter enthesophytes or surface irregularities > 2 mm have a 90% prognostic value of gluteal tendinopathy (Fig. 3). In patients with prosthetic hips, additional radiographs should also evaluate concomitant THA pathology.

Ultrasound also has a role and can effectively diagnose tendinopathy and tears. Fearon et al reported 79% sensitivity and 100% positive predictive value for abductor tears using preoperative ultrasound in 19 patients who underwent open abductor repair. In the setting of THA and the absence of available advanced MRI protocols for artefact reduction, it is useful. However, ultrasound is user-dependent and inferior to MRI in recognizing the degree of fatty infiltration. In patients with painful THA, ultrasound was found to be superior in detecting joint effusion but inferior in evaluating muscle atrophy and pseudotumours compared to MARS MRI.

Treatment

Conservative treatment

Initial treatment of abductor tendon pathology is conservative and can include short-term use of non-steroidal anti-inflammatory medications, activity modification, physical therapy and local injections of corticosteroid plus anaesthetic into the trochanteric bursa. If conservative management fails to relieve the symptoms after three months of therapy, surgical treatment may follow. However, the limited availability of high-quality studies and the elusive evidence between tendinosis and partial ruptures cannot provide definite conclusions regarding the best management of gluteal tendinopathy. Randomized controlled trials (RCTs) are needed to test the proposed treatment modalities.

Modification of load and mechanical stimulation with exercises is considered beneficial for tendon biochemical processes. However, there are limited clinical studies and no RCTs to assess specific exercise programmes in gluteal tendinopathy. Rompe et al compared a four-month exercise programme including stretching of the iliobibial band and piriformis and strengthening of muscles in the sagittal plane with corticosteroid and shock-wave therapy (SWT) for gluteal tendinopathy. This exercise programme was ineffective during the first weeks, and less than half of the patients were improved at four months; however, the response was positive at 15 months for 80% of patients. Further research and better-quality studies are needed.

Cortisone is one of the most commonly prescribed treatment methods for gluteal tendinopathy. Both blind and ultrasound-guided cortisone infiltration of the peritrochanteric region have been used. However, most studies are case series with no controls, and studies with sufficient power are scarce. Besides the pathology of the abductor tendon is rarely confirmed with MRI. Corticosteroid injection usually provides substantial immediate pain relief during the first month; however, pain is not entirely alleviated with a positive response for less than half of patients at mid to long term. An RCT of 120 patients with lateral trochanteric pain for more than one week compared cortisone injection with conservative treatment. Cortisone had superior outcomes regarding pain at three months but no difference at one year. The absence of MRI to specify diagnosis by primary care physicians was a limitation. Labrosse et al reported 50% pain reduction and 72% improvement in QoL scores at one month following ultrasound-guided cortisone infiltration in 54 patients with symptomatic gluteal tendinopathy. However, abductor lesions were not confirmed by MRI. In an RCT comparing fluoro-guided vs. blind cortisone injection for GTPS in 65 cases, no outcome difference was found at one and three months. Although the use of fluoroscopy increased the
cost, it did not necessarily improve outcomes. Poor patient outcomes were related to the diagnosis not being confirmed by MRI. Other potential drawbacks of corticosteroid injections are the unknown mechanism of action and safety regarding repeated use. Probably the primary mode of action is local analgesic than anti-inflammatory action, interacting with local neuropeptides and neurotransmitters. The recurrence of pain following injection usually reflects the inability of corticosteroids to address the underlying pathology.

Data concerning the use of plasma-rich protein (PRP) to manage gluteal tendinopathy are limited. Mautner et al performed ultrasound-guided PRP injections in 16 patients with chronic GMed tendinopathy. They reported 82% moderate to complete lateral thigh pain resolution at six months. However, the diagnosis was unclear and not refractory for abductor tendinopathy. In a non-controlled retrospective study, leukocyte-rich ultrasound-guided PRP injections in 21 patients with tendinosis or partial tendon rupture without atrophy also improved QoL at a mean of 20 months follow-up. Saltzman et al showed that platelet-rich fibrin matrix post glutei repair was superior to repair alone in terms of early postoperative QoL scores but had otherwise no difference in GMed tendon repair in terms of pain or clinical evidence of retears. In an RCT comparing ultrasound-guided triamcinolone and PRP in 20 patients with GTPS, triamcinolone had better outcomes but no superiority versus PRP at two months. In a higher-quality prospective RCT that investigated only partial ruptures, ultrasound-guided injection of PRP was superior to cortisone in 70 patients at 12 weeks in terms of modified Harris Hip Score (mHHS).

Radial SWT is an alternative treatment modality for gluteal tendinopathy. Shock waves can penetrate soft tissues up to 4 cm, providing both analgesia and healing of abductor tendons. In a non-randomized comparative study, weekly sessions of SWT for three weeks were more beneficial than exercise and corticosteroid injections at four weeks and better than corticosteroids at 15 months. In a case-control study, Furia et al compared 66 patients with GTPS responsive to lidocaine infiltration who received low energy extracorporeal SWT with 33 controls who underwent traditional conservative treatment. The SWT group had superior HHS and pain scores during the first 12 months. Although SWT was considered beneficial for the management of GTPS, the information for the control group was unclear.

**Preoperative evaluation**

Candidates for surgical repair of gluteal tendon tears must undergo a thorough preoperative clinical and radiological evaluation. Special care is needed concerning the following:

**Neurologic evaluation**

Neurologically intact abductor muscle is a prerequisite for surgical management of abductor tendon tears. Lumbar spine pathology or other sources of neurologic impairment of gluteal muscles should be routinely screened preoperatively. Management of neurologically impaired gluteal muscles usually involves complex reconstruction techniques with muscle transfers.

**Fatty infiltration of gluteal muscles**

The direct repair of extensively fatty infiltrated abductor muscles (Goutallier classification > 2) is related to inferior outcomes. More complex reconstruction techniques such as muscle flaps or grafts are necessary to overcome fatty infiltration.

**Existing THA**

Infection, aseptic loosening or any other concomitant pathology should be excluded in the presence of THA. Prosthetic infection or excessive wear may inevitably affect the quality of gluteal tendons, and augmented repair or muscle transfer may be needed. Excessive osteolysis of the greater trochanter can make tendon fixation on cancellous bone ambiguous or insufficient.

**Fascia lata or iliotibial band tightness**

Preoperative and intraoperative evaluation of iliotibial band tightness and fascia lata should be performed, and appropriately corrected with lengthening during abductor tendon repair.

**Types of procedures**

Various open and arthroscopic procedures for direct repair of abductor tendon tears have been reported. Prerequisites for an efficient non-augmented direct suturing of abductor tendons are neurologic integrity and limited fatty infiltration of muscles. Chronic irreparable tears without atrophy and limited fatty infiltrated abductor tendons can be augmented with synthetic grafts or allografts. Reconstruction techniques are salvage procedures for the management of chronic end-stage abductor tears with significant tendon insufficiency or gluteal atrophy. Unfortunately, the level of evidence of studies concerning surgical management of abductor tears is low and mainly consists of case series. A proposed treatment algorithm for the management of abductor tendon tears is illustrated in Fig. 4.

**Surgical treatment**

Surgical management is indicated for full gluteal tendon ruptures and partial tears that are non-responsive to conservative treatment, eliciting pain and disability for patients. Analgesia, preservation of function and better QoL of patients are the main goals of surgical treatment.
Direct open or endoscopic non-augmented repair using bone tunnels or suture anchors

Open or arthroscopic direct non-augmented repairs of full-thickness tears of gluteal tendons have been described (Fig. 5). During open procedures, the patient is usually placed in the lateral decubitus position, and an incision centred over the greater trochanter or a posterolateral approach is used. Following the exposure of the gluteal attachment, the quality, type and extent of the rupture of the gluteal tendons are assessed. Partial-thickness GMed tears often develop in the tendon undersurface, and recognition of the lesion is difficult. Saline injection under the insertion of gluteal tendons may elevate tendinous insertion indicating an undersurface rupture (‘bubble sign’). Doubtful lesions are assessed by splitting GMed fibres in line to gain access to the tendon undersurface. In cases of severe tendinosis, an aggressive debridement should be avoided to preserve maximal tendon length and width, preventing tensioning or non-anatomic repair. Once the tendon tears have been recognized, the bone bed area should be prepared with a burr or nibbler, taking care not to remove excessive bone, weakening bone adjacent to anchor holes.

The use of both drill holes and suture anchors through the greater trochanter have been described for open techniques. Optimally, four pairs of bone tunnels are drilled on the lateral facet of greater trochanter for full-thickness GMed tears. The number of tunnels is modified accordingly for partial thickness tears. An additional pair of tunnels is drilled on the anterior tubercle of the greater trochanter for GMin tears. Bone tunnels for GMed reattachment should be performed perpendicularly to the long axis of footprint, while tunnel(s) for GMin should be done obliquely. Thick non-absorbable sutures passing through tendon ends, and bone tunnels are used to tie down under maximum tension and reapproximate tendons to their footprint. Additional thin sutures are usually needed to enhance the repair.

The use of suture anchors instead of bone tunnels may preserve the vascular supply of the femoral head in native hips. Two to three proximal anchors are used in a proximal row and another two distally to make a double-row effect; 5–6.5 mm diameter anchors are usually preferred to overcome the tension of the underlying cancellous bone. Following trochanteric footprint preparation, proximal anchors are placed; sutures are then passed through the GMed flap and tightened, transferring the flap onto the major trochanter with the hip in slight abduction.
abduction. Suture placement should account for final tendon positioning and row width, usually 5–10 mm from the tendon edge. After tendon approximation, the distal-row anchors are placed, and new sutures increase tendon compression on the bone. GMMin tears are similarly managed using fewer anchors due to the smaller insertion area and capsular attachments of muscle. When needed, the blunt release of gluteal muscles is performed, taking care to preserve the superior gluteal nerve or elongation of fascia lata using a V-Y technique. Postoperatively, non-weight-bearing or partial weight-bearing walking for six weeks, avoiding active hip abduction, is followed.

Direct open non-augmented repair with sutures is a straightforward technique. However, inadequate mechanics and substantial delay of the repair is related to a high reported failure rate up to 25%. Davies et al reported improved QoL and muscle strength and no re-tears for five years for open gluteal tendon repairs using transosseous sutures and anchors. Poor results were found for highly atrophic and fatty infiltrated muscles. In one of the largest open gluteal tendon repair series using transosseous sutures, Walsh et al followed 72 patients with different tear types for a minimum of one year. Ninety-five per cent of patients improved in pain and function with a low 5.5% re-tear rate and 8.3% Deep Venous Thrombosis (DVT) rate, although no thromboprophylaxis was used. Davies et al reported improvement in pain and five failures out of 16 patients who underwent open repair using double-row suture anchors at one-year follow-up. The level of fatty infiltration of muscles was not provided. A re-rupture rate of 8.25% was reported for 12 patients undergoing double-row open repair for partial and complete abductor tendons ruptures followed for a mean of 19 months. Outcomes worsen for higher Goutallier classification scores. McConagle et al demonstrated no improvement in tendon and muscle quality postoperatively in 15 patients who underwent open repair with anchors. Again, no preoperative Goutallier grading was provided and tendon quality intraoperatively was not mentioned.

In one of the longest follow-up studies (mean 4.6 years) after open double-row repair for abductor tears in 67 patients, Makridis et al demonstrated improvement in pain and QoL but a 16% re-tear rate. Other studies showed outcomes of open techniques for abductor tears with an existing THA. Davies et al reported improvement in pain and five failures out of 16 patients who underwent open repair using double-row suture anchors following THA using the lateral Hardinge approach with sutures passing through bone tunnels. Half of the cases had substantial improvement in limping and pain at 38 months, but a 25% failure rate was reported when treating tendon avulsion using a posterior-lateral THA approach with sutures. Several studies also reported good mid-term results with endoscopic non-augmented repair methods for partial and full-thickness abductor tendon ruptures. Direct distal lateral and proximal portals, as well as accessory anterolateral and posterolateral portals, are usually used to access the peritrochanteric space, facilitate instrumentation and anchor placement. The endoscopic repair has been described even for ruptures found at the musculotendinous junction. Good results have been reported in the endoscopic double-row repair of full-thickness tears in 10 patients at one-year follow-up and partial undersurface ruptures in 25 patients with a minimum of 24 months follow-up. Chandrasekaran et al reported improvement in pain and QoL at two years in 34 patients undergoing endoscopic double-row repair for complete and partial ruptures with no re-tears. In one of the longest follow-up studies, 14 patients demonstrated good outcomes at midterm (five years) follow-up following endoscopic repair with concomitant labral repair. However, the study population was inhomogeneous, including both partial and full tears as well as labral repair and excision.

The superiority of anchors vs. transosseous sutures, with decortication or not, single vs. double-row repair and open vs. endoscopic methods is unclear due to the absence of high-quality comparative studies. A biomechanical study...
showed that double-row repair led to better footprint coverage and a trend for a higher load to failure than single-row constructs.\textsuperscript{72} A cadaveric biomechanical study demonstrated inferior pullout strength in cases with excessive decortication or low Bone Mineral Density (BMD), suggesting caution for osteoporotic patients and avoidance of excessive decortication.\textsuperscript{71} Unfortunately, no comparative study between open and endoscopic methods of gluteal tear suturing exists in the literature. Two recent systematic reviews reported similar patient-reported outcomes, pain scores, and improvement in abduction strength using open and endoscopic methods for the management of abductor tendon repair.\textsuperscript{74,75} However, open techniques had a higher complication rate (re-tears) than endoscopic ones.\textsuperscript{74}

**Direct open augmented repair with synthetic grafts or allografts**

Synthetic grafts or allografts are used for the management of chronic irreparable abductor tendon tears of non-atrophied muscles with limited fatty infiltration. Grafts cover the repair site, ensuring effective hold on healthy tendon proximally and healthy tendon or bone distally. Either a standard transosseous or suture anchor repair is performed. Different types of synthetic grafts or allografts have been proposed:

**Synthetic ligament**

Following debridement of the diseased tendon and decortication of the trochanteric footprint, the flattened portion of the synthetic ligament is sutured onto the undersurface of the muscles. Combined transosseous tunnel and suture anchors are used to reattach the augmented GMed.\textsuperscript{76} Bucher et al\textsuperscript{76} reported on clinical and functional results of 22 patients with GMed and GMin tears that were augmented with Ligament Augmentation and Reconstruction System (LARS) synthetic ligament following the previous failure of conservative treatment. However, the degree of atrophy and tendon degeneration was not described. Oxford Hip Score, Short Form (SF)-36 and Visual Analogue Scale (VAS) scores were significantly improved, and all patients were at least satisfied at 12 months postoperatively. There was a minimal complication rate; the LARS was removed from one patient due to lateral thigh pain.\textsuperscript{76} In another prospective cohort study, 110 patients with native hips followed-up for a year following open abductor tendon repair of full-thickness GMed tears were augmented with LARS ligament, bursectomy and iliobibial band lengthening. All scores and strength were improved, and 96% of the patients were satisfied with a 3% failure rate.\textsuperscript{77}

**Collagen patch**

A collagen patch is an appropriately sized non-absorbable graft which is secured over the abductor tendon tear repair with running non-absorbable suture.\textsuperscript{78} This can be partly secured to the vastus lateralis tendon distally to enhance mechanical integrity.

Fink et al\textsuperscript{78} evaluated the postoperative outcomes of 30 patients with a mean age of 76 years suffering from large GMed tears. Nine patients had a spontaneous tear of the gluteal muscle, and 21 had suffered tearing following THA using the transgluteal approach. The tears were repaired with transosseous fixation using a modified Mason-Allen technique that was augmented with a non-resorbable collagen patch (Covidien, Trèvoux, France). At a mean 24 months, the VAS, HHS and GMed muscle force were significantly improved; 25 patients had mild or no limp at all but five retained a severe limp. Fatty degeneration of muscle > 50% was related to suboptimal functional results, suggesting treatment for these situations should involve such a repair for Goutallier grade < 3 cases.\textsuperscript{78} Good to excellent results for pain and muscle strength were also reported for 11 out of 12 cases of gluteal avulsion post THA that were augmented with a dermal matrix at a mean 22-months follow-up. However, fatty degeneration and tendon stump condition were not specified.\textsuperscript{56}

**Achilles tendon allograft**

This technique is accomplished using fresh-frozen Achilles tendon with an attached calcaneal bone allograft block measuring 2 x 1.5 x 1 cm. The block is fashioned using a saw appropriately to dovetail into a trough made in the greater trochanter outlined to match the allograft size.\textsuperscript{79} Fibrous remnants of tendon insertion are cleaned to create a vascularized bed to increase integration. The GMed and GMin are then mobilized and translated inferiorly. The tendinous part of allograft passes through the GMed almost 3 cm proximal to the ruptured end and is then looped back on itself. Following maximum leg abduction, the bone block is placed into the trough with a press-fit technique and secured with 16-gauge wire or cables. The tendinous allograft part is secured to the GMin, anterior capsule and intact GMed tendon with non-absorbable sutures.\textsuperscript{79} A hip abduction brace is used for six weeks with partial weight-bearing.

Fehm et al\textsuperscript{79} reported the functional results of seven patients who underwent reconstruction of a deficient abductor mechanism following THA with the aforementioned surgical technique. All but one patient had substantial improvement concerning HHS and pain scores at two years; however, five patients still had a positive Trendelenburg sign.\textsuperscript{79}

**Reconstruction for chronic end-stage abductor tears using muscle transfer**

Two main surgical techniques have been proposed using either gluteus maximus (GMax)\textsuperscript{80–83} or vastus lateralis (VL) muscle transfer.\textsuperscript{84,85}
Reconstruction with GMax transfer flap

Whiteside originally described this technique for transferring the anterior part of the GMax to replace irreparable tears of hip abductors in five patients. They had a vast improvement in limping and pain. However, this study did not report on functional scores and muscle strength. Modifications of this technique have been reported. One of these was a two-limb technique where the anterior half of the gluteus maximus was transferred to the greater trochanter and sutured under the vastus lateralis and a separate posterior flaps was transferred under the primary flap to substitute for the GMin and capsule in patients during THA. In another modification, the anterior portion of the gluteus maximus and the entire TFL were transferred to the greater trochanter to substitute GMed and GMin for native hips. Chandrasekaran et al proposed a simpler modification of the previous technique. The anterior third of the GMax and posterior third of the TFL were transferred in a flap to the greater trochanter to manage irreparable abductor tears with excessive fatty degeneration in three patients. Postoperatively, two patients had no Trendelenburg gait, and all patients were relieved from pain.

The authors’ preference is the Geneva technique. This is a more straightforward modification of the aforementioned GMax transfer techniques. A triangular flap including the anterior third of the GMax is sharply divided anteriorly from fascia lata and posteriorly in line with GMax fibres. The length of the flap is 12 to 15 cm, extending roughly to the middle of the GMax. The proximal part of the VL is incised off the vastus lateralis ridge and mobilized for 2–4 cm. The footprint of GMax re-insertion on the lateral side of the greater trochanter is prepared with a round burr to reveal cancellous bone, facilitating healing. Three 2.6-mm bicortical corkscrew suture anchors, double-loaded with a row of high-strength sutures, are inserted at the anterior and posterior margins of the footprint to transfer and tighten the GMax flap. Alternatively, six 1.8-mm diameter drill holes are made at the margins of the footprint and large non-absorbable sutures passed through holes and the GMax flap is transferred onto the greater trochanter. Pie-crust incisions can be performed to the flap to obtain proper tension. Finally, the upper part of the VL is sutured over the distal end of the GMax with absorbable sutures forming a united flap. Partial weight-bearing and no active abduction is allowed for the first eight postoperative weeks.

Reconstruction with VL flap

Use of a VL flap is another salvage technique to manage non-reparable chronic end-stage abductor tears. The entire VL is mobilized proximally to distally taking care not to injure the neurovascular pedicle of muscle. The plane between the VL and vastus intermedius must be dissected carefully, preserving the nerve supply of the vastus intermedius. Once the VL insertion into quadriceps tendon is divided, the VL is mobilized, and the neurovascular pedicle is left within the surrounding fatty tissue. The VL is then sutured proximally to the remaining abductors and with transosseous sutures to the proximal femur with the leg abducted. Abductor splint and partial weight-bearing are necessary for six postoperative weeks, and abductor exercises are then allowed.

In the largest series using this technique, 11 patients with abductor insufficiency were treated with VL advancement, demonstrating a moderate improvement of functional scores, pain and strength at two-year follow-up. There was a failure in one patient. Loss of quadriceps strength was a common adverse outcome. Advantages of this method include the partial restriction of hip flexion, separate neurovascular pedicle, and VL activation in the same part of the gait cycle as hip abductors. The main drawbacks are the complexity of the procedure, decreased quadriceps muscle strength and potential neurovascular damage. Grob et al demonstrated in cadavers that the proximal VL transfer is limited to 13 mm due to overstretching of the neurovascular bundle beyond this. Betz et al reported fair to functional outcomes in nine patients with a mean follow-up of 33 months. Sixty-nine per cent had reduced pain medication and the use of walking aids. However, the functional results were modest, and the loss of quadriceps strength was reported.

Considerable progress has been made concerning the study of anatomy, epidemiology, clinical presentation and imaging modalities of gluteal tendon lesions; however, further advancement is needed in treatment protocols. The advantages of corticosteroid injections over other conservative treatment, the effectiveness of regenerative treatments such as PRP and the superiority of open vs. endoscopic repair needs further in-depth investigation. The limited current evidence is mainly attributed to the absence of high-level comparative studies and limited studies directly comparing treatment modalities. Table 1 demonstrates current understanding.

Conclusions

Abductor tendon lesions are the most common cause of lateral thigh pain. A high degree of clinical suspicion is demanded for middle-aged or older women with lateral thigh pain. A thorough clinical examination should be performed to exclude lumbar spine, hip, fascia lata or prosthetic joint pathology. MRI is the gold-standard investigation to evaluate lesions and the extent of fatty infiltration of the abductor muscles. The treatment of abductor tendinopathy is mainly conservative, including non-steroidal anti-inflammatory medication, activity
LESIONS OF HIP ABDUCTORS

modification, local corticosteroid injections, plasma-rich protein, physical and radial shockwave therapy. However, the limited available high-quality studies and limited evidence of treatment comparisons for tendinosis, partial and complete ruptures mean the best management remains inconclusive. Full gluteal tendon ruptures and partial tears that are non-responsive to conservative treatment may be surgically treated. Chronicity of the lesion, the neurologic integrity and extent of fatty infiltration of gluteal muscles determines the type of surgical treatment. Direct tendon suturing is indicated for recent tendon tears with neurologic integrity and limited gluteal muscle fatty infiltration. Chronic irreparable tears without abductor muscle atrophy and limited fatty infiltration can be augmented with grafts. Salvage reconstruction techniques with muscle transfers are needed for the management of chronic end-stage abductor tears with significant tendon insufficiency or gluteal atrophy.

ICMJE CONFLICT OF INTEREST STATEMENT
PC reports consultancy for MORE Institute and Medacta International, outside the submitted work. The other authors declare no conflict of interest relevant to this work.

FUNDING STATEMENT
No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

LICENSE
©2020 The author(s) This article is distributed under the terms of the Creative Commons Attribution-Non Commercial 4.0 International (CC BY-NC 4.0) licence (https://creativecommons.org/licenses/by-nc/4.0/) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed.

REFERENCES
1. Grimaldi A, Mellor R, Hodges P, Bennell K, Wajswelner H, Vicenzino B. Gluteal tendinopathy: a review of mechanisms, assessment and management. Sports Med 2015;45:1107–1119.
2. Albers IS, Zwerwer J, Diercks RL, Dekker JH, Van den Akker-Scheek I. Incidence and prevalence of lower extremity tendinopathy in a Dutch general practice population: a cross-sectional study. BMC Musculoskelet Disord 2016;17:16
3. Long SS, Surrey DE, Nazarian LN. Sonography of greater trochanteric pain syndrome and the rarity of primary bursitis. AJR Am J Roentgenol 2013;201:1083–1086.
4. Pierce TP, Issa K, Kurowicki J, Festa A, McInerney VK, Scillia AJ. Abductor tendon tears of the hip. JBJS Rev 2018;6:66.
5. Lachiewicz PF. Abductor tendon tears of the hip: evaluation and management. J Am Acad Orthop Surg 2011;19:385–391.
6. Flack NA, Nicholson HD, Woodley SJ. The anatomy of the hip abductor muscles. Clin Anat 2014;27:241–253.
walking in individuals with gluteal tendinopathy. Scand J Med Sci Sports 2018;28:686–695.

8. Robertson WJ, Gardner MJ, Barker JU, Boraih S, Lorich DG, Kelly BT. Anatomy and dimensions of the gluteus medius tendon insertion. Arthroscopy 2008;24:130–136.

9. Kong A, Van der Vliet A, Zadow S. MRI and US of gluteal tendinopathy in greater trochanteric pain syndrome. Eur Radiol 2007;17:1772–1783.

10. Redmond JM, Chen AW, Domb BG. Greater trochanteric pain syndrome. J Am Acad Orthop Surg 2016;24:231–240.

11. Segal NA, Felson DT, Torner JC, et al; Multicenter Osteoarthritis Study Group. Greater trochanteric pain syndrome: epidemiology and associated factors. Arch Phys Med Rehabil 2007;88:988–992.

12. Chi AS, Long SS, Zoga AC, et al. Prevalence and pattern of gluteus medius and minimus tendon pathology and muscle atrophy in older individuals using MRI. Skeletal Radiol 2015;44:1727–1733.

13. Redmond JM, Gupta A, Cregar WM, Hammarstedt JE, Gui C, Domb BG. Arthroscopic treatment of labral tears in patients aged 60 years or older. Arthroscopy 2015;31:1921–1927.

14. Lustenberger DP, Ng YY, Best TM, Ellis TJ. Efficacy of treatment of trochanteric bursitis: a systematic review. Clin J Sport Med 2011;21:447–453.

15. Howell GE, Biggs RE, Bourne RB. Prevalence of abductor mechanism tears of the hip in patients with osteoarthritis. J Arthroplasty 2001;16:121–123.

16. Hendry J, Biatt LC, Breusch SJ. Abductor mechanism tears in primary total hip arthroplasty. Arch Orthop Trauma Surg 2012;132:1619–1623.

17. Lubowitz JH. Editorial commentary: rotator cuff tears of the hip. Arthroscopy 2015;31:2068.

18. Svensson O, Sköld S, Blomgren G. Integrity of the gluteus medius after the transgluteal approach in total hip arthroplasty. J Arthroplasty 1990;5:57–60.

19. Yi SR, Kwon J, Cho JH. Acute isolated tear of gluteus medius in young male. Hip Pelvis 2017;29:291–293.

20. Fearon AM, Cook JL, Scarvell JM, Neeman T, Cormick W, Smith PN. Greater trochanteric pain syndrome negatively affects work, physical activity and quality of life: a case control study. J Arthroplasty 2014;29:383–386.

21. Berber R, Khoon M, Cook E, et al. Muscle atrophy and metal-on-metal hip implants: a serial MRI study of 74 hips. Acta Orthop 2015;86:353–357.

22. Mahmood SS, Mukka SS, Cronal S, Wretenberg P, Sayed-Noor AS. Association between changes in global femoral offset after total hip arthroplasty and function, quality of life, and abductor muscle strength: a prospective cohort study of 222 patients. Acta Orthop 2016;87:36–41.

23. Ebert JR, Retheesh T, Mutreja R, Janes GC. The clinical, functional and biomechanical presentation of patients with symptomatic hip abductor tendon tears. Int J Sports Phys Ther 2016;11:725–737.

24. Lindner D, Shohat N, Botser I, Agar G, Domb BG. Clinical presentation and imaging results of patients with symptomatic gluteus medius tears. J Hip Preserv Surg 2015;3:310–315.

25. Bird PA, Oakley SP, Shnier R, Kirkham BW. Prospective evaluation of magnetic resonance imaging and physical examination findings in patients with greater trochanteric pain syndrome. Arthritis Rheum 2001;44:2138–2145.

26. Allison K, Bennell KL, Grimaldi A, Vicenzino B, Wrigley TV, Hodges PW. Single leg stance control in individuals with symptomatic gluteal tendinopathy. Gait Posture 2016;49:108–113.

27. Allison K, Vicenzino B, Wrigley TV, Grimaldi A, Hodges PW, Bennell KL. Hip abductor muscle weakness in individuals with gluteal tendinopathy. Med Sci Sports Exerc 2016;48:346–352.

28. Kaltenborn A, Bourg CM, Gutzeit A, Kalberer F. The hip lag sign: prospective blinded trial of a new clinical sign to predict hip abductor damage. PLoS One 2014;12:e91560.

29. Lequese M, Mathieu P, Vuillemin-Bodaghi V, Bard H, Djian P. Gluteal tendinopathy in refractory greater trochanter pain syndrome: diagnostic value of two clinical tests. Arthritis Rheum 2008;59:241–246.

30. Ossendorf C, Bohnert L, Mamisch-Saupe N, et al. Is the internal rotation lag sign a sensitive test for detecting hip abductor tendon ruptures after total hip arthroplasty? Patient Saf Surg 2011;5:7.

31. Civitanic O, Henzie G, Skezas N, Lyons J, Minter J. MRI diagnosis of tears of the hip abductor tendons (gluteus medius and gluteus minimus). AJR Am J Roentgenol 2004;182:137–143.

32. Sutter R, Kalberer F, Binkert CA, Graf N, Pfirrmann CW, Gutzeit A. Abductor tendon tears are associated with hypertrophy of the tensor fasciae latae muscle. Skeletal Radiol 2013;42:627–633.

33. Blankenbaker DG, Ulrick SR, Davis KW, De Smet AA, Haaland B, Fine JP. Correlation of MRI findings with clinical findings of trochanteric pain syndrome. Skeletal Radiol 2008;37:903–909.

34. Bogunovic L, Lee SX, Haro MS, et al. Application of the Goutallier/Fuchs rotator cuff classification to the evaluation of hip abductor tendon tears and the clinical correlation with outcome after repair. Arthroscopy 2015;31:2145–2151.

35. Davies JF, Stiehl JB, Davies JA, Geiger PB. Surgical treatment of hip abductor tendon tears. J Bone Joint Surg Am 2013;95:1420–1425.

36. Thauat M, Clowez G, Desseaux A, et al. Influence of muscle fatty degeneration on functional outcomes after endoscopic gluteus medius repair. Arthroscopy 2018;34:1816–1824.

37. Pfirrmann CW, Notzli HP, Dora C, Hodler J, Zanetti M. Abductor tendons and muscles assessed at MR imaging after total hip arthroplasty in asymptomatic and symptomatic patients. Radiology 2005;235:969–976.

38. Steinert L, Zanetti M, Hodler J, Pfirrmann CW, Dora C, Saepe N. Are radiographic trochanteric surface irregularities associated with abductor tendon abnormalities? Radiology 2010;257:754–763.

39. Connell DA, Bass C, Sykes CA, Young D, Edwards EE. Sonographic evaluation of gluteus medius and minimus tendinopathy. Eur Radiol 2003;13:1339–1347.

40. Fearon AM, Scarvell JM, Cook JL, Smith PN. Does ultrasound correlate with surgical or histologic findings in greater trochanteric pain syndrome? A pilot study. Clin Orthop Relat Res 2010;468:1838–1844.

41. Siddiqui IA, Sabah SA, Satcithananda K, et al. A comparison of the diagnostic accuracy of MARS MRI and ultrasound of the painful metal-on-metal hip arthroplasty. Acta Orthop 2014;85:375–382.

42. Rome JD, Segal NA, Cacchio A, Furia JP, Morral A, Maffulli N. Home training, local corticosteroid injection, or radial shock wave therapy for greater trochanter pain syndrome. Am J Sports Med 2009;37:1981–1990.
43. Brinks A, van Rijn RM, Willemsen SP, et al. Corticosteroid injections for greater trochanteric pain syndrome: a randomized controlled trial in primary care. Ann Fam Med 2011;9:226–234.

44. Labrosse JM, Cardinal E, Leduc BE, et al. Effectiveness of ultrasound-guided corticosteroid injection for the treatment of gluteus medius tendinopathy. AJR Am J Roentgenol 2010;194:202–206.

45. McEvoy JR, Lee KS, Blankenbaker DG, del Rio AM, Keene JS. Ultrasound-guided corticosteroid injections for treatment of greater trochanteric pain syndrome: greater trochanter bursa versus subgluteus medius bursa. AJR Am J Roentgenol 2013;201:W313–W317.

46. Cohen SP, Strassels SA, Foster L, et al. Comparison of fluoroscopically guided and blind corticosteroid injections for greater trochanteric pain syndrome: multiscint randomised controlled trial. BMJ 2009;338:b1088.

47. Coombes BK, Bisset L, Brooks P, Khan A, Vicenzino B. Effect of corticosteroid injection, physiotherapy, or both on clinical outcomes in patients with unilateral lateral epicondylalgia: a randomized controlled trial. JAMA 2013;309:461–469.

48. Rio E, Moseley L, Purdam C, et al. The pain of tendinopathy: physiological or pathophysiological? Sports Med 2014;44:9–23.

49. Mautner K, Colberg RE, Malanga G, et al. Outcomes after ultrasound-guided platelet-rich plasma injections for chronic tendinopathy: a multicenter, retrospective review. PMR 2013;5:169–175.

50. Lee JJ, Harrison JR, Boachie-Adjei K, Vargas E, Moley PJ. Platelet-rich plasma injections with needle tenotomy for gluteus medius tendinopathy: a registry study with prospective follow-up. Orthop J Sports Med 2016;4:23259671667062.

51. Saltzman BM, Ukwuani G, Makhni EC, Stephens JP, Nho SJ. The effect of platelet-rich fibrin matrix at the time of gluteus medius repair: a retrospective comparative study. Arthroscopy 2018;34:832–841.

52. Ribeiro AG, Ricioli W Jr, Silva AR, Polesello GC, Guimarães RP. PRP in the treatment of trochanteric syndrome: a pilot study. Acta Orhop Bras 2016;24:208–212.

53. Fitzpatrick J, Bulsara MK, O’Donnell J, McCrory PR, Zheng MH. The effectiveness of platelet-rich plasma injections in gluteal tendinopathy: a randomized, double-blind controlled trial comparing a single platelet-rich plasma injection with a single corticosteroid injection. Am J Sports Med 2018;46:933–939.

54. van der Worp H, Zwerver J, Hamstra M, van den Akker-Scheek I, Diercks RL. No difference in effectiveness between focused and radial shockwave therapy for treating patellar tendinopathy: a randomized controlled trial. Knee Surg Sports Traumatol Arthrosc 2014;22:2026–2032.

55. Furia JP, Rompe JD, Maffulli N. Low-energy extracorporeal shock wave therapy as a treatment for greater trochanteric pain syndrome. Am J Sports Med 2009;37:1806–1813.

56. Rao BM, Kamal TT, Vafaye J, Taylor L. Surgical repair of hip abductors: a new technique using Graft Jacket allograft acellular human dermal matrix. Int Orthop 2012;36:2049–2053.

57. Walsh MJ, Walton JR, Walsh NA. Surgical repair of the gluteal tendons: a report of 72 cases. J Arthroplasty 2001;16:1544–1549.

58. Lübbeke A, Kampfen S, Stern R, Hoffmeyer P. Results of surgical repair of abductor avulsion after primary total hip arthroplasty. J Arthroplasty 2008;23:646–649.

59. Schröder JH, Geßlein M, Schütz M, Perka C, Krüger D. [Open repair of gluteus medius and minimus tendons tears with double-row technique: clinical and radiological results]. Orthopade 2018;47:238–245.

60. Miozzari HH, Dora C, Clark JM, Nötzel HP. Late repair of abductor avulsion after the transgluteal approach for hip arthroplasty. J Arthroplasty 2010;25:450–457 e1.

61. Davies H, Zhaeentan S, Tavakkolizadeh A, Janes G. Surgical repair of chronic tears of the hip abductor mechanism. Hip Int 2009;19:372–376.

62. McGonagle L, Haebich S, Breidahl W, Fick DP. MRI and clinical analysis of hip abductor repair. Hip Int 2015;25:24–27.

63. Makridis KG, Lequesne M, Bard H, Dijan P. Clinical and MRI results in 67 patients operated for gluteal tendinitis and minimus tendon tears with a median follow-up of 4.6 years. Orthop Traumatol Surg Res 2014;100:849–853.

64. Weber M, Berry DJ. Abductor avulsion after primary total hip arthroplasty: results of repair. J Arthroplasty 1997;12:202–206.

65. McCormick F, Alpaugh K, Nwachukwu BU, Yanke AB, Martin SD. Endoscopic repair of full-thickness abductor tendon tears: surgical technique and outcome at minimum of 1-year follow-up. Arthroscopy 2012;29:1941–1947.

66. Hartigan DE, Perets I, Ho SW, Walsh JP, Yuen LC, Domb BG. Endoscopic repair of partial-thickness undersurface tears of the abductor tendon: clinical outcomes with minimum 2-year follow-up. Arthroscopy 2018;34:1193–1199.

67. Yanke AB, Hart MA, McCormick F, Nho SJ. Endoscopic repair of a gluteus medius tear at the musculotendinous junction. Arthrosc Tech 2013;2:669–672.

68. Byrd JWT, Jones KS. Endoscopic repair of hip abductor tears: outcomes with two-year follow-up. J Hip Preserv Surg 2017;4:80–94.

69. Thaunat M, Chatellard R, Noil E, Sonnery-Cottet B, Nové-Josserand L. Endoscopic repair of partial-thickness undersurface tears of the gluteus medius tendon. Orthop Traumatol Surg Res 2013;99:853–857.

70. Chandrasekaran S, Gui C, Hutchinson MR, Lodhia P, Suarez-Ahedo C, Domb BG. Outcomes of endoscopic gluteus medius repair: study of thirty-four patients with minimum two-year follow-up. J Bone Joint Surg Am 2015;97:1340–1347.

71. Perets I, Mansor Y, Yuen LC, Chen AW, Chaharbakhshi EO, Domb BG. Endoscopic gluteus medius repair with concomitant arthroscopy for labral tears: a case series with minimum 5-year outcomes. Arthroscopy 2017;33:2194–2197.

72. Kahlenberg CA, Nwachukwu BU, Jahandar H, Meyers KN, Ranawat AS, Ranawat CS. Single- versus double-row repair of hip abductor tears: a biomechanical matched cadaver study. Arthroscopy 2019;35:818–823.

73. Putnam JG, Chhabra A, Castañoeda P, et al. Does greater trochanteric decompaction affect suture anchor pullout strength in abductor tendon repairs? A biomechanical study. J Am Sports Med 2018;46:1668–1673.

74. Alpaugh K, Chilelli BJ, Xu S, Martin SD. Outcomes after primary open or endoscopic abductor tendon repair in the hip: a systematic review of the literature. Arthroscopy 2017;33:530–540.

75. Chandrasekaran S, Lodhia P, Gui C, Vemula SP, Martin TJ, Domb BG. Outcomes of open versus endoscopic repair of abductor muscle tears of the hip: a systematic review. Arthroscopy 2015;31:2057–2067 e2.

76. Bucher TA, Darcy P, Ebert JR, Smith A, Janes G. Gluteal tendon repair augmented with a synthetic ligament: surgical technique and a case series. Hip Int 2014;24:187–193.

77. Ebert JR, Bucher TA, Mullan CJ, Janes GC. Clinical and functional outcomes after augmented hip abductor tendon repair. Hip Int 2018;28:74–83.
78. Fink B, Braun L. Treatment of extensive gluteus muscle tears with transosseous fixation and a nonresorbable collagen patch. *J Arthroplasty* 2018;33:555–559.

79. Fehm MN, Huddleston JI, Burke DW, Geller JA, Malchau H. Repair of a deficient abductor mechanism with Achilles tendon allograft after total hip replacement. *J Bone Joint Surg Am* 2010;92:2305–2311.

80. Whiteside LA, Nayfah T, Katerberg BJ. Gluteus maximus flap transfer for greater trochanter reconstruction in revision THA. *Clin Orthop Relat Res* 2006;453:203–210.

81. Whiteside LA. Surgical technique: transfer of the anterol portion of the gluteus maximus muscle for abductor deficiency of the hip. *Clin Orthop Relat Res* 2012;470:503–510.

82. Whiteside LA. Surgical technique: gluteus maximus and tensor fascia lata transfer for primary deficiency of the abductors of the hip. *Clin Orthop Relat Res* 2014;472:645–653.

83. Chandrasekaran S, Darwish N, Vemula SP, Lodhia P, Suarez-Ahedo C, Domb BG. Outcomes of gluteus maximus and tensor fascia lata transfer for primary deficiency of the abductors of the hip. *Hip Int* 2017;27:567–572.

84. Kohl S, Evangelopoulos DS, Siebenrock KA, Beck M. Hip abductor defect repair by means of a vastus lateralis muscle shift. *J Arthroplasty* 2012;27:625–629.

85. Grob K, Monahan R, Gilbey H, Ackland T, Kuster MS. Limitations of the vastus lateralis muscle as a substitute for lost abductor muscle function: an anatomical study. *J Arthroplasty* 2015;30:2338–2342.

86. Beck M, Leunig M, Ellis T, Ganz R. Advancement of the vastus lateralis muscle for the treatment of hip abductor discontinuity. *J Arthroplasty* 2004;19:476–480.

87. Betz M, Zingg PO, Peirrmann CW, Dora C. Advancement of the vastus lateralis muscle for irreparable hip abductor tears: clinical and morphological results. *Acta Orthop Belg* 2012;78:337–343.