Ligamentum Teres Injuries and Treatment

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16.1 Introduction

Since the nineteenth century, the anatomy and mechanical properties of the ligamentum teres (LT) have been studied. However, traditionally the LT has been considered a vestigial structure with no role in the biomechanics or vascularity of the adult hip [1]. In recent years, the LT has become the subject of increased attention due to its role in hip stability and a potential pain generator [2, 3]. Moreover, recent studies have suggested an association between LT tears and articular cartilage damage [4]. Previous studies reported the prevalence of LT tears to be 5–50% in patients undergoing hip arthroscopy [5, 6]. However, a recent study by Chahla et al. found LT abnormalities in up to 89.5% of hip arthroscopies ($N = 2213$) performed for femoroacetabular impingement (FAI), with complete tears more likely to be seen in women, lower body mass index, and lower central edge angles [7, 8]. Advancements in imaging modalities and increasing use of hip arthroscopy have led to a better understanding of the LT functions and pathologies and paved the way to the development of several treatment approaches and surgical techniques.

16.2 Anatomy and Histology

The normal LT is pyramidal in shape, along its acetabular aspect, gently transitioning into a round or ovoid shape near its femoral attachment [9, 10]. The LT arises from the transverse acetabular ligament and the posterior inferior portion of the acetabular fossa and attaches to the femoral head at the fovea capitis [11]. The fovea capitis is located slightly posterior and inferior to the center of the femoral, and it is ovoid in shape and is not covered by hyaline cartilage. The LT has a broad origin that blends with the entire transverse ligament of the acetabulum and is attached to the ischial and pubic sides of the acetabular notch by two bands. The overall length of the ligament is 30–35 mm [10, 12]. A recent cadaveric study by Mikula et al. found the broad acetabular origin of the LT to have six consistent anchoring points: pubic, ischial, iliac, anterior, posterior, and transverse attachment [13, 14]. The LT has three bundles: anterior, posterior, and medial. The posterior band is the longest, and the medial one is the thinnest [10]. The LT is tightened to limit abduction, and internal and external rotation [15]. Its arterial supply is provided by the anterior branch of the posterior division of the obturator artery. Vascular canals extend a short distance from the fovea capitis into the femoral head [16].Yet its contribution to the femoral head's blood supply varies as these canals are occluded in one-third of the adult population.

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N. Bonin et al. (eds.), *Hip Preservation Surgery*, https://doi.org/10.1007/978-3-662-61186-9_16

The LT is surrounded by a synovial membrane which is a thin layer, composed of a single layer of cuboidal epithelium, and lies over a subsynovial layer of vessels and adipose tissue. The LT is composed of parallel bundles of well-organized collagen fibers [17]. The major collagen type found in the mature LT is type I, but type III and type V are also typically present. The LT is similar in its collagen distribution to the collateral ligaments of the knee but differs in that the attachments of the LT to the femur and the acetabulum lack the fibrocartilage which is usually found around ligaments' insertion sights [18]. The dispersion of collagenous fibers at the cartilage surface and the lack of reach to the thin subchondral bone of some fibers may weaken the LT at its insertion to the femoral head [19].

Histological studies have found LT possesses both mechanoreceptors and nociceptors [10, 20], specifically type IVa receptors (unmyelinated nerve fibers), suggesting the LT plays a part in the integral reflex system which is involved in joint protection, sense of pain, and proprioception.

How the LT contributes to normal hip biomechanics and stability is still debatable. Some surgeons view the LT as having a negligible role in hip biomechanics and stability; for example, open surgical dislocations require transection of the ligament and are therefore based on the premise that sacrifice of the LT is inconsequential. In contrast, others believe that its role in the normal hip biomechanics and stability warrants its reconstruction. A recent cadaveric study by Jo et al. found that LT can minimally limit external rotation when the hip is in the flexed position but does not contribute to translation stability [21]. Another cadaveric study by Philippon et al. elucidated more on the LT biomechanic properties and found the mean load to failure of the LT was 204 N [22].

Several theories regarding the LT's function in the hip have been proposed. Having both nociceptors and mechanoreceptors, it has been postulated that the LT acts as a stabilizer to prevent excessive joint movement. The similarities between the LT and the anterior cruciate ligament (ACL) led to the theory that the LT serves a similar role in the hip as the ACL in the knee; acting as a strong intrinsic stabilizer that resists joint subluxation forces. Besides the similarities to the ACL in regard to mechanical strength, being an intra-articular structure, having free nerve endings, similar bundled appearance, and similar collagen distribution, it has also been shown in animal models that hips without LT have higher rates of dislocations [23]. Moreover, the understanding that the LT is tightened in flexion external rotation and extension internal rotation, in which the hip is the least stable, further supports the theory regarding its role as an intrinsic hip stabilizer. In addition to its contribution to normal hip biomechanics and stability, it has been theorized that the LT plays a role in the distribution of synovial fluid within the joint ('the windshield wiper') [24].

16.3 Classification of Injuries

The most common classification system used is that of Gray and Villar [24], they described three types of injuries to the LT: Type I—Complete, Type II—partial tears, and Type III—degenerative tears. They based their classification system on 472 hip arthroscopies where they identified a cohort of 20 patients with LT pathology.

A descriptive classification system was also proposed [5]: Type 0—intact ligament, Type 1—tear of less than 50% of the ligament fibers, Type 2—tear of more than 50% of the ligament fibers, but not a complete tear, Type 3—complete tear of the LT. The study included 284 patients with LT injuries, out of 558 patients undergoing primary hip arthroscopy.

Of note, both classifications have only fair interobserver reliability, with a higher absolute agreement rate for the descriptive classification. Normal, partial, and low-grade tears are prone to disagreement and major discrepancy in interpretation [25].

Combing the two classification systems would create a concise classification system that would be treatment oriented and consistent among surgeons.

A more recent classification by O'Donnel and Arora had incorporated the presence of synovitis and hypermobility. Hypermobility is defined by a

Beighton score ≥ 4. LT pathology is divided according to severity: 0 = normal, 1 = synovitis, 2 = partial tear, and 3 = complete tear. They have also proposed a treatment algorithm based on their classification and available literature [26].

16.4 Clinical History

The patient chief complaint should be obtained, specifically asking about pain, clicking, locking, catching, and giving way or any sense of instability. Making the differentiation between pain and instability is critical.

Duration of symptoms should be established and specifically the onset of symptoms; to delineate whether symptoms started after a traumatic event or had insidious onset is crucial. In cases of a traumatic event, the exact mechanism of injury should be revealed. Previously LT tears were mainly diagnosed in the rare event of acute hip dislocations, which usually results from high-energy trauma [27], whereas today, the majority of patients with LT tears report low energy injury or no injury at all [5, 6]. Proposed injury mechanisms which might cause LT tears are flexion adduction with axial loading, acute twisting injuries, hyperabduction, and excessive external or internal rotation [10, 28]. Participating in high-impact sports, such as American Football, hockey, rugby, Australian Football, or activities that require extreme range of motion, such as gymnastics, martial arts, and particularly ballet [29], predisposes the participant to these proposed injury mechanisms and the potential risk of sustaining an LT tear.

Additional intra-articular pathologies are often found with LT tears; therefore, a detailed account of past treatments for the symptoms is required including nonoperative treatment, injection, and surgery.

Medical and family histories should be investigated for connective tissue disorders such as Ehlers-Danlos syndrome, Arthrochalasis multiplex congenita, Marfan syndrome, and Down syndrome.

16.5 Physical Examination

There is no physical examination specific to the detection of LT tears, and the majority of the patients will have additional intra-articular pathology [6, 30], emphasizing the need for detailed clinical history, evaluation of the mechanism of injury, and a high level of suspicion. A complete examination of the hip should be obtained, including gait evaluation, active and passive range of motion (flexion, extension, internal, and external rotation), tenderness to palpation around the groin, greater trochanter, piriformis, and adductors. Required provocative tests include the anterior impingement test, lateral impingement test, posterior impingement test, and FABER test. Pain and apprehension are recorded in all tests. Assessment of muscle strength and general joint laxity is also mandatory.

Specific tests to evaluate hip stability include the Domb's test: the patient is positioned prone, the examined limb is flexed at the knee to 90°, and the hip is externally rotated and anterior pressure is applied to the hip. A positive response would be a sense of apprehension or anterior hip pain. Supine log roll test, evaluating for difference in the range of motion as well as apprehension during external rotation would indicate hip instability. The dial test: the patient lies supine; the examined limb is internally rotated. The limb is then released and allowed to externally rotate. The test is positive when the patient's limb passively rotates >45° from vertical in the axial plane and lacks a mechanical end-point. The contralateral limb is tested for comparison.

16.6 Imaging

Evaluation of all hip suspected of intra-articular hip pathology should begin with radiographic imaging: an anteroposterior (AP) pelvic view, Dunn view, cross-table lateral view, and a false-profile view [31–33], to assess for any bony abnormalities. We recommend obtaining bilateral imaging at least in AP view, to allow comparison and the differentiation between bony pathology and normal variants. Measurements performed on these views include the Tonnis angle (acetabular inclination angle (AI)) using the method described by Jessel et al. [34] and the lateral center edge (CE) angle of Wiberg [35]. These two measurements allow the calculation of the lateral coverage index (LCI): LCI = CE − AI. The LCI has been shown to correlate with the presence of LT tears [6]. The presence of arthritis should be evaluated and can be graded using the Tonnis classification of osteoarthritis [36].

In cases of traumatic hip injury or dislocation, computed tomography (CT) is useful in detecting small nondisplaced acetabular fracture as well as small LT avulsion fractures and intra-articular loose bodies.

When an intra-articular source of pain is suspected, magnetic resonance imaging (MRI) allows for a detailed evaluation of soft tissue structures. MR arthrogram provides superior accuracy over plain MRI [37] in detecting LT tears. However, it may still be challenging to differentiate between an intact ligament to a partially torn one [38]. Partial LT tears are characterized by abnormal intrasubstance signal intensity, focal partial loss of continuity, thickening of the ligament due to scar tissue formation, and abnormal ligament attenuation [9, 38]. Acute complete tears are not as challenging to detect as the partial tears and may be detected using plain MRI or MR arthrogram. Signs of a complete tear include discontinuity of the ligament fibers, wavy contour, and increased signal intensity on T2.

16.7 Treatment

In general, a traumatic LT tears are initially managed nonsurgically with rest and activity modification followed by physical therapy. In cases where the above-mentioned nonsurgical modalities are unsuccessful, intra-articular injection may be considered. Surgical intervention is considered after nonsurgical treatments have failed or in cases of an avulsion fracture of the LT with an intra-articular osteochondral fragment.

The effect a torn LT has on the hip is still debatable, whether it creates micro-instability that causes additional joint damage or whether there is micro-instability or predisposing factors leading to LT tears [6, 39].

Currently, the surgical treatment options for LT tears are performed arthroscopically, including arthroscopic debridement, shrinkage, augmentation, and reconstruction. Since in the majority of patients, LT tears are accompanied by additional intra-articular pathologies, arthroscopy offers the opportunity to address them concomitantly.

Arthroscopy is carried out under general anesthesia, the patient is placed in the supine position on a traction table or fracture table, both feet are well secured and padded, and a perineal post is used to protect the genitalia. The hip is prepped and draped in the usual fashion. Traction is applied and a spinal needle, under fluoroscopic visualization, is inserted into the joint and the joint is vented. After venting of the joint, additional traction is applied. The needle is retracted, and Marcaine is injected into the subcutaneous tissues. Correct portal placement is located using fluoroscopic visualization. The anterolateral portal is first established using an 11 blade for the skin. A spinal needle is inserted through the incision and into the joint, taking care to avoid the labrum and the femoral head. An over-the-guidewire technique is used to insert a 70-degree scope through a 4.5 mm cannula. A mid-anterior portal is established using the same over-the-guidewire technique. A beaver blade is used to perform capsulotomy, incising the capsule parallel to the acetabular rim in order to connect the two portals.

Arthroscopic debridement and shrinkage are carried out in a similar fashion: evaluation is performed by visualizing the LT through the anterolateral portal and probing using the mid-anterior portal. In cases of complete tears, the stump is debrided using a curved shaver. In partial tears the curved shaver is used to debride any frayed or torn portion followed by shrinkage of the partially torn ligament, which is carried out using a long, thin, flexible radiofrequency ablation probe. Debridement of the ligament is best performed when the hip is externally rotated, this will increase the tension on the ligament as well as deliver it anteriorly. Shrinkage should be performed when the hip is in a neutral position and should be performed sparingly in order to avoid limiting internal rotation.

Arthroscopic augmentation of the LT with suture tape had also been described in a technical note [40], but we are unaware of any data regarding the outcomes of the procedure.

LT reconstruction has been reported in case reports [41], surgical techniques [42–45], and small case series [46, 47]. Techniques for LT reconstruction are evolving and further studies reporting outcomes data are required.

In this chapter, we describe our preferred technique which had been published by the senior author [48]. In the development of this technique, numerous procedures were performed in cadaver hips and were followed by open dissections to assess the proximity of the bone tunnels to the obturator vessels and identify additional challenges. The result was a technique that was found to be both feasible and reproducible. We describe our technique for reconstruction of the ligamentum teres herein.

16.8 Surgical Technique

16.8.1 Patient Positioning and Portals

Under general anesthesia, the patient is placed in the supine position on a traction table or fracture table, both feet are well secured and padded, and a perineal post is used to protect the genitalia. The hip is prepped and draped in the usual fashion. Traction is applied and a spinal needle, under fluoroscopic visualization, is inserted into the joint and the joint is vented. After venting of the joint, additional traction is applied. The needle is retracted, and Marcaine is injected into the subcutaneous tissues. Correct portal placement is located using fluoroscopic visualization. The anterolateral portal is first established using an 11 blade for the skin. A spinal needle is inserted through the incision and into the joint, taking care to avoid the labrum and the femoral head. An over-the-guidewire technique is used to insert a 70-degree scope through a 4.5-mm cannula. A mid-anterior portal is established using the same over-the-guidewire technique. A beaver blade is used to perform capsulotomy, incising the capsule parallel to the acetabular rim in order to connect the two portals.

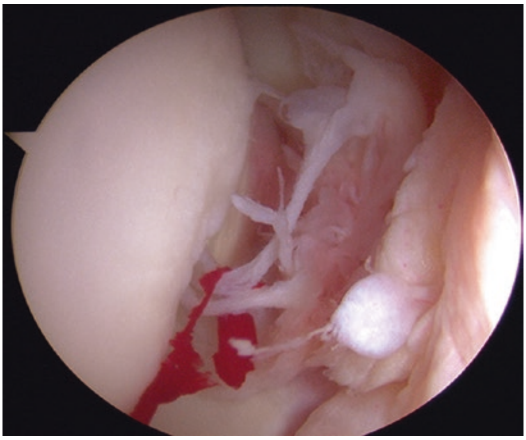

Fig. 16.1 Arthroscopic view of the left hip demonstrating complete tear of the ligamentum teres

A diagnostic arthroscopy is performed, switching portals frequently to access all parts of the joint. Any additional pathology in the joint is addressed prior to LT reconstruction. Care should be taken to identify central acetabular osteophytes or a prominent posterior acetabular fossa edge. Both pathologies have been associated with an LT tear and resection of these bony prominences should be performed prior to LT reconstruction [49, 50]. The LT is examined and probed upon identification of a complete tear (Fig. 16.1); the stump in the acetabular fossa is cleared using the Nav X ablation device (Arthrex, Naples, FL) and a shaver (Fig. 16.2).

16.8.2 Graft Preparation

The graft choice may include a semitendinosus autograft or allograft. The double-stranded graft is prepared with maximal length on a Retro-Button (Arthrex, Inc., Naples, FL), with the graft sutured to the button using a 2 mm loop. The graft should be prepared prior to tunnel preparation.

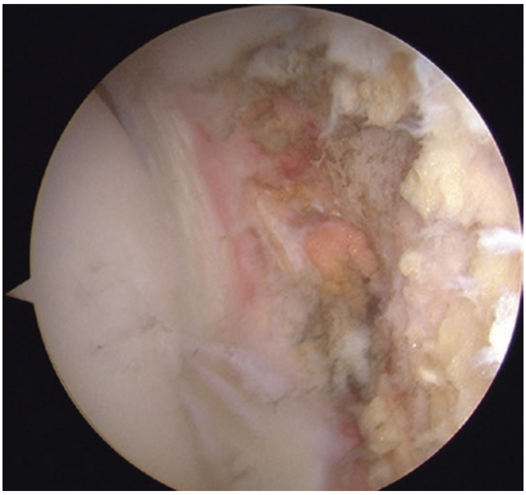

Fig. 16.2 Arthroscopic view of the left hip after debridement of the LT stump from fossa

Fig. 16.3 Fluoroscopic intraoperative image. After reaming the femoral tunnel over a guidewire, the guidewire is passed through the femoral tunnel into the desired location of the acetabular tunnel. The guidewire is drilled into the acetabular footprint, with care not to penetrate the medial cortex of the acetabulum

16.8.3 Femoral and Acetabular Tunnels

A lateral 2 cm incision is made to approach the femoral transtrochanteric tunnel; the location is determined using fluoroscopy. A 3.2 mm guidewire is passed through the lateral cortex of the greater trochanter, exiting through the center of the fovea in the footprint of the LT. This is done in a “freehand” technique using fluoroscopic assistance and direct visualization of the guide’s exit point in the fovea. Over the guidewire, a cannulated reamer is used to create the femoral tunnel. The reamer size used is determined by the graft size, which is measured during graft preparation. A shaver and wand are inserted through the femoral tunnel to complete the preparation of the footprint at the base of the acetabular fossa.

Drilling of the acetabular tunnel is performed through the femoral tunnel in order to achieve correct tunnel positioning in the cotyloid fossa. Optimization of the acetabular tunnel can be achieved by 15° of internal rotation and 15° of abduction [51, 52]. The anatomic insertion of the LT in the cotyloid fossa is made in the inferior portion of the fossa. In order to maintain a safe distance from the obturator vessels, the tunnel is placed slightly posterior to the center of the base of the fossa. The concept of safe acetabular drilling and safe zones is well-established and has been in use by surgeons performing hip arthroplasty for screw placement in the acetabular component. It was first described by Wasielewski et al. [16, 17, 53], in which they described the posteroinferior and posterosuperior quadrants to be safe for drilling, whereas the anterior quadrants were not. The structures at risk while drilling in the posteroinferior portion of the cotyloid fossa are the obturator artery and vein, but they are at a safe distance from the exit point of the drill [15].

A guidewire is placed through the femoral tunnel and into the posteroinferior portion of the fossa; its position is verified by direct visualization. Upon achieving the correct position, the guide is drilled to the medial cortex, without penetrating it, using fluoroscopic assistance (Fig. 16.3). Over the guidewire, a cannulated reamer is used to create the acetabular tunnel. The reamer used is determined by the graft size which is measured during graft preparation. Fluoroscopic assistance is used to assure the guidewire is not penetrating into the pelvis, and the drilling is performed cautiously to avoid plunging through the medial cortex of the acetabular fossa.

16.8.4 Graft Placement

Once both tunnels are prepared, the graft is passed through the tunnels. Graft placement is performed using direct visualization and fluoroscopic assistance. Two knot pushers are used to lead the graft/button complex through the tunnels; one knot pusher is used to lead the button through the tunnel, and the second knot pusher is used to flip the button over the medial cortex. Once the button has been flipped, tension is placed on the graft and fluoroscopy is used to assure that the button has flipped and is secure.

The motion and tension of the graft are examined in internal and external rotation while the hip is in traction. The traction of the leg is then released while maintaining traction on the graft. The leg is positioned in 10° of hyperextension and 60° of external rotation, and a PEEK interference screw (Arthrex, Inc., Naples, FL) is used for femoral fixation. Once the graft is secured, traction is reapplied, the arthroscope is reintroduced, and the graft is again examined (Fig. 16.4) throughout the range of motion. The excess graft is cut flush with the lateral cortex of the femur.

The portals are closed using 3–0 monocryl, and the distal incision is closed using #1 Vicryl for the fascia, 2–0 Vicryl for the subcutaneous layer, and 3–0 monocryl for the skin. The patient is placed in a X-Act ROM hip brace (DJO Global, Vista, CA) and an abduction pillow.

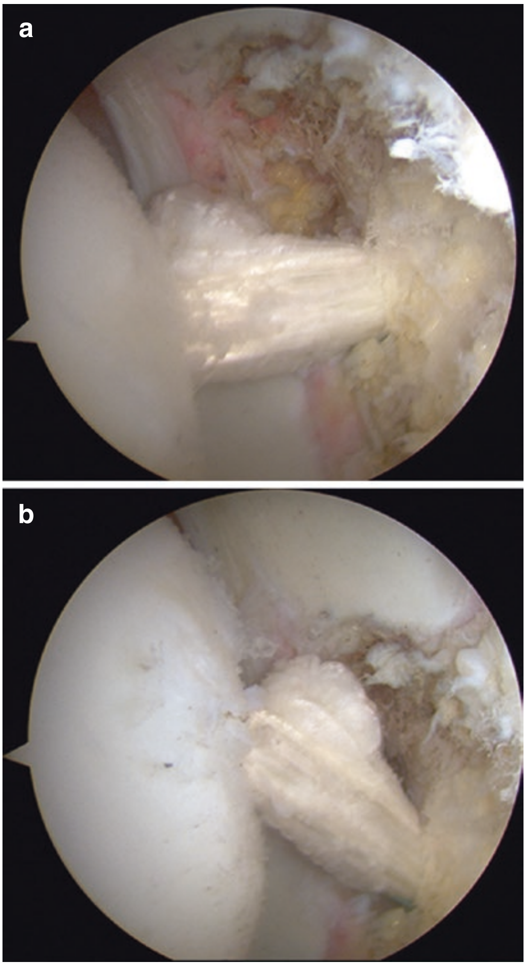

Fig. 16.4 Arthroscopic view, after graft fixation, evaluating the graft through the range of motion; (**a**) hip in neutral position, (**b**) hip in external rotation

16.9 Rehabilitation and Recovery

For the first 6 weeks, the patient is kept in a hip brace locked at 0–90° of flexion at all times and is restricted to 20 lb foot-flat weight-bearing. In addition, an abduction pillow is used at night for the same period. The patient starts physical therapy on the first postoperative day and is instructed to refrain from adduction and external rotation. Six weeks postoperatively, the brace and crutches are discontinued, and the patient continues physical therapy with an emphasis on strengthening the gluteus medius and core muscles as well as on gradual progression in range of motion and activities.

16.10 Discussion

The LT has been studied since the nineteenth century, but only in recent years have we started understanding its true function. Today we know that the LT is as strong as the ACL, is tight in flexion, external rotation, and abduction, and plays a role in hip proprioception and pain (nociceptors and mechanoreceptors) [9]. Also, studies have reported preliminary data suggesting the presence of an LT tear is associated with chondral damage [39, 54].

The evidence is growing in regard to the clinical implications of an LT tear. Chaharbakhshi et al. performed a matched-controlled study

($N = 68$), evaluating the effect of an LT tear on outcomes of patients with borderline dysplasia undergoing hip arthroscopy. Following a minimum 2-year follow-up, they found the concurrent presence of an LT tear may indicate advanced instability and portend slightly inferior outcomes. They also suggested that in these patients, the presence of an LT tear may have increased propensity toward revision arthroscopy and conversion to arthroplasty [55]. Maldonado et al. also performed a match-controlled study ($N = 54$) of patients with complete LT tears vs. patients with an intact LT undergoing primary hip arthroscopy for FAI. They found significant improvement in patient-reported outcomes (PROs) in both groups. However, with a complete LT tear were three times more likely to require an eventual total hip arthroplasty [56].

The current standard surgical treatment for LT tears consists of debridement, with several studies reporting good outcomes [57]. Byrd et al. reported on 23 patients who underwent debridement of LT tears with good outcomes. However, 15 patients in their study group had additional pathologies that were addressed during surgery [11]. Haviv and O'Donnell in a series of 29 patients reported on isolated LT tears, reporting improvement of 16 points in the modified Harris Hip Score (mHHS); however, five patients (17%) required revision surgery. Despite the good results reported with debridement, a subset of patients was experiencing residual pain and instability following LT debridement [58]. Pergaminelis et al. performed a retrospective study reporting improved clinical outcomes with a minimum of 6-month follow-up after radiofrequency debridement of solitary LT tears [59]. Amenabar et al. also reported improvement in PROs following debridement of isolated partial-thickness LT tears in their prospective case series [60].

Economopoulos et al. found posterior bony impingement of a prominent posterior acetabular fossa edge to be an uncommon cause for LT tears. They reported good outcomes with LT debridement in combination with resection of the impinging bone [50].

There is limited literature regarding clinical outcomes following LT reconstruction. Philippon et al. described a case series of four patients who underwent LT reconstruction with an iliotibial band autograft with early promising clinical results [46]. Chandrasekaran et al. reported a case series of four patients with connective tissue disorders and generalized ligamentous laxity undergoing arthroscopic reconstruction of the LT. They found improvement in patient-reported outcomes in three of the four patients with a 2-year follow-up [47].

Currently, the indications for LT reconstruction have yet to be established; however, it may be considered for patients with isolated complete LT tears [61] who report subjective hip instability and have increased external rotation.

We have found this technique of LT reconstruction to be safe and reproducible. Further studies on LT reconstruction are required to establish the exact role and recommendations for the use of LT reconstruction in the treatment of tears of the ligamentum teres.

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