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OUTCOMES RESEARCH IN ORTHOPEDICS (O AYENI, SECTION EDITOR)

Proximal Hamstring Injuries: Management of Tendinopathy and Avulsion Injuries

Ryan M. Degen [1]

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Abstract

Purpose of Review To outline the typical presentation, physical examination, diagnostic imaging, and therapeutic treatment options for proximal hamstring injuries to improve awareness, expedient diagnosis, and definitive management.

Recent Findings Proximal hamstring tendinopathy and partial-thickness tears can often successfully be managed with a combination of non-operative modalities, including physiotherapy focused on eccentric strengthening, extracorporeal shock wave therapy, or peri-tendinous injections. Surgery is reserved for refractory cases, but can yield good outcomes. Contrastingly, non-operative treatment often leads to unsatisfactory outcomes in complete ruptures, with residual weakness and reduced function with poor return-to-sport rates. Instead, surgical repair can provide satisfactory outcomes, with good-to-excellent functional outcomes and strength, with acute treatment preferred over delayed, chronic repair.

Summary Hamstring tendinopathy and partial-thickness tears can be successfully treated non-operatively with good functional outcomes, with surgical repair reserved for refractory cases. Complete tears are best managed with surgical repair, allowing improved strength and functional outcomes.

Keywords Hamstring injuries · Tendinopathy · Avulsion injuries · Outcomes research · Orthopedics

Introduction

While hamstring injuries at the musculotendinous junction are relatively common with athletic participation, proximal hamstring injuries occur with lower frequency [1•, 2–4]. These injuries range from chronic insertional tendinopathy to partial-thickness tears to complete proximal avulsion injuries, with vastly different presentations. As a result of both their reduced incidence and variable presentation, these injuries are often misdiagnosed or missed altogether, resulting in prolonged periods of disability and delays in treatment. As such, the purpose of this review is to outline the typical presentation, physical examination, diagnostic imaging, and therapeutic treatment options for each of these entities to improve awareness, expedient diagnosis, and definitive management.

This article is part of the Topical Collection on *Outcomes Research in Orthopedics*

✉ Ryan M. Degen
ryan.degen@lhsc.on.ca

[1] Fowler Kennedy Sport Medicine Clinic, 3M Centre, Western University, 1151 Richmond Street, London, ON N6A 3K7, Canada

Functional Anatomy

The proximal hamstrings, excluding the short head of the biceps femoris, originate from the ischial tuberosity. Their origin is comprised of two tendinous insertions: the semimembranosus and the conjoint tendon, comprised of both the semitendinosus and long head of the biceps femoris. The semimembranosus insertion has been characterized as ventral and lateral relative to the conjoint tendon insertion, which lies dorsal and medial in relation to the semimembranosus [2, 5, 6]. The tibial portion of the sciatic nerve innervates all three muscles.

The hamstrings are active throughout the gait cycle, but primarily in terminal swing phase to slow knee extension and initiate hip extension [2]. They continue to function during early stance phase to assist in hip extension. Because they span both the hip and knee, the hamstrings are at a higher risk of injury due to the possibility for rapid muscle lengthening with combined hip flexion and knee extension noted during the swing phase of sprinting or running [2, 4, 7].

Chronic Insertional Tendinopathy

Clinical Presentation

First described as "hamstring syndrome" in 1988, chronic insertional hamstring tendinopathy is common among long-distance runners and hurdlers [8]. It is not typically associated with a single inciting event, but instead represents a chronic degenerative process produced by mechanical overload and repetitive stretch [7]. Predisposing factors include overuse, poor lumbopelvic stability, and relatively weak hamstrings [7, 9]. Tendinopathy often presents as an ill-defined posterior thigh pain, most notable when participating in running sports, where terminal hip flexion and knee extension elicits symptoms [7]. Alternatively, patients may experience symptoms with prolonged sitting or driving in a car [10]. Occasionally, symptoms of sciatic nerve irritation may also develop along with their posterior thigh pain, ranging from posterior thigh pain to radiating pains down the leg.

Physical Examination

Inspection often fails to identify any significant findings, as there is no associated bruising or any significant swelling in these cases. Palpation over the ischium can reproduce some tenderness in severe cases. Hip and knee range of motion is usually preserved. Specific physical examination maneuvers are then performed to elicit symptoms. The Puranen-Orava test is performed by flexing the hip to 90°, while the knee is then passively extended and supported on a foot rest (Fig. 1) [8]. Provocation of posterior thigh pain indicates a positive test. The bent-knee stretch test is performed with the patient supine and their knee and hip maximally flexed [2]. The knee is then gradually extended until symptoms develop (Fig. 2). The modified bent-knee stretch test, also known as the fast hamstring-stretch test, can also be performed [2, 10]. The hip is placed in extension, after which the hip and knee are maximally flexed and the knee is then rapidly extended. Provocation of posterior thigh pain indicates a positive test [2]. A standing heel drag test may also be performed, with provocation of pain indicating a positive test (Fig. 3). Lastly, resisted knee flexion may be tested with the patient prone, with pain indicating a positive test. This is often repeated at both 45° and 90° of flexion. Together, all tests have moderate to high validity and reliability in diagnosing chronic insertional tendinopathy.

Fig. 1 Puranen-Orava test for hamstring tendinopathy

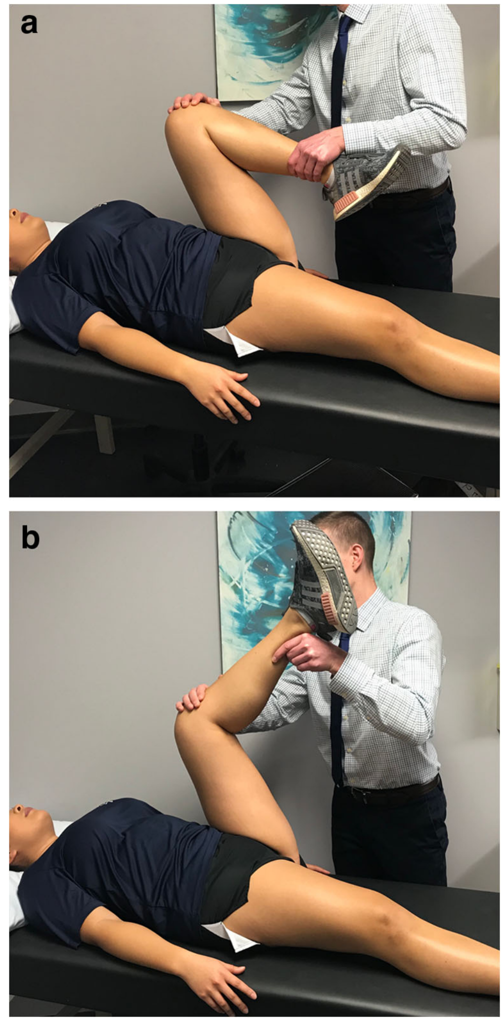

Fig. 2 Bent-knee stretch test for hamstring tendinopathy

Imaging

Plain radiographs are largely inconclusive for this diagnosis. Ultrasound (U/S) or magnetic resonance imaging (MRI) can be used; however, MRI has been shown to have higher sensitivity [11]. Interestingly, increased signal within the hamstring tendons on both T1- and T2-

Fig. 3 Standing heel drag test for hamstring tendinopathy

weighted images does not correlate with symptoms of tendinopathy and can be a normal finding [12]. More specific findings associated with tendinopathy include increased tendon size, peri-tendinous T2 signal, and ischial tuberosity edema [12].

Treatment

Non-operative Treatment

Initial management of chronic insertional hamstring tendinopathy consists of a variety of non-operative measures, including eccentric physiotherapy exercises, shock wave therapy, corticosteroid, or platelet-rich plasma injections [7].

Eccentric exercises have been considered the mainstay of treatment for chronic insertional hamstring tendinopathy, despite a lack of supportive literature [13•]. This has largely been extrapolated from supportive studies in the treatment of Achilles or patellar tendinopathy. More recently, heavy slow resistance (HSR) training, which consists of both concentric and eccentric exercises, has been investigated, showing some promise over eccentric exercises; however, further study is necessary to evaluate both forms of rehabilitation for this injury [14].

Extracorporeal shock wave (ECSW) therapy has been utilized as an adjunctive therapy for insertional hamstring tendinopathy. Cacchio et al. completed a level I, randomized controlled trial comparing ECSW therapy with traditional conservative treatment (NSAIDs, physiotherapy), demonstrating superiority with ECSW [10]. The ECSW group exhibited greater improvement in pain scores and higher rates of return to sport than the traditional conservative treatment group.

Ultrasound-guided corticosteroid injections have also been utilized. Two studies have demonstrated significant improvements in pain scores immediately following injections, with no reported short- or long-term complications [11, 15]. However, the durability of the results is unclear, as it appeared that only a minority (< 38%) of patients exhibited sustained relief 6 months after the injection. Nevertheless, it may represent a viable option in the initial non-operative treatment regimen.

More recently, PRP injections have been utilized for the treatment of chronic insertional hamstring tendinopathy; however, the quality of literature to support its use is relatively poor. The available evidence stems from three studies, two of which are small cohort series with no control group reporting a positive effect in reducing pain scores [16, 17]. The other study was a double-blind, randomized controlled trial comparing injections of whole blood with PRP for the treatment of chronic insertional tendinopathy [18]. Both groups demonstrated improvements in all pain and functional outcome measures at 6 months, with no significant differences between groups. Without studies comparing PRP with conventional non-operative therapy, it is challenging to say where it falls in the treatment algorithm, but it may represent a potential option should other non-surgical modalities fail.

Operative Treatment

In refractory cases, where all non-surgical treatments yield unsatisfactory results, surgical debridement and repair represents a viable solution. Surgical indications include chronic, disabling symptoms despite conservative treatment [19]. Puranen and Orava, who first described "hamstring syndrome," reported on the successful operative management of this entity by releasing the "taut, tendinous structures of the proximal hamstrings muscle over the nerve" near the ischium [8]. The authors felt that this effectively decompressed the sciatic nerve by releasing the taut structures that may have been causing compression of the nerve, thus generating pain. They reported complete relief of pain in 88% (52/59) patients. Lempainen et al. also reported on the outcomes of 90 patients (103 cases) with proximal hamstring tendinopathy treated with surgical release of the semimembranosus off of the ischium, which was then sutured to the conjoint tendon [19]. They, too, noted a good or excellent result in 89% of patients, with high rates of return to sport. Their justification for the surgical approach was that the semimembranosus tendon was most commonly involved in tendinopathy, corroborated on the MRI. They also felt that the lateral margin of the semimembranosus was synonymous with the "tight band" causing sciatic irritation referred to by Puranen and Orava in their initial study. With both techniques, surgical treatment provided effective relief of refractory insertional hamstring tendinopathy and should be considered in these cases.

Partial-Thickness Hamstring Tears

Clinical Presentation

Partial-thickness hamstring tears can occur in two different ways. Firstly, they can occur without a specific inciting event as a continuation of insertional tendinopathy. This most commonly involves the central fibers of the semimembranosus origin, producing a tear with minimal retraction [20]. Alternately, they may occur in the same manner as a complete avulsion with a strong eccentric contraction, often with the hip flexed and knee extended [20, 21]. This can be associated with a "popping" sensation and immediate posterior thigh pain and bruising. This mechanism can produce injuries involving 1 to 3 tendons. The most commonly injured tendons include the semitendinosus and biceps, while the semimembranosus is the least commonly injured [22]. The most common pattern of partial-thickness injury is an avulsion of the conjoint tendon, while the semimembranosus remains intact. This often prevents significant retraction, and can occasionally produce a "hidden lesion," where injury to the conjoint tendon is not evident at the time of repair unless the semimembranosus is incised [1•].

Physical Examination

Partial-thickness tears should first be evaluated with observation of the patient's gait. Depending on the severity of the injury, they may have a "stiff-legged" gait, to avoid simultaneous hip flexion and knee extension [2]. For an acute injury, the posterior thigh should also be inspected for any notable bruising or swelling. Palpation over the ischium may elicit pain, and a palpable defect may be noted with some injuries. Additionally, palpation over the mid-thigh may help to identify any avulsed or retracted tendons. After evaluating hip and knee range of motion, similar special tests can be performed as detailed above for chronic insertional tendinopathy. The popliteal angle may also be measured [2]. Similar to the bent-knee stretch test, this test starts with the hip flexed to 90° and the knee flexed to 90°. The knee is then gradually extended until posterior thigh pain is elicited or there is significant guarding. This angle is then compared with the contralateral leg. A higher angle suggests a proximal hamstring injury (Fig. 4).

Fig. 4 Popliteal angle

Imaging

Ultrasound is a useful bedside modality that can be used in the emergency department or clinic to help identify any appreciable regions of tendon discontinuity, suggesting a partial-thickness or complete avulsion that may require surgical repair [23]. However, it may not identify pathology in more subtle cases, such as a partial-thickness tear involving only the semimembranosus. In this scenario, MRI is more sensitive. A commonly noted finding on MRI is the presence of a "sickle sign," which is a crescent-shaped linear signal at the bone-tendon interface on T2-weighted images, suggestive of a partial-thickness tear (Fig. 5) [21].

Treatment

Non-operative Treatment

For partial-thickness tears, treatment options include non-surgical and surgical treatment. Non-surgical treatment is typically indicated for single-tendon tears, or 2-tendon tears with less than 2 cm of retraction. Conventional non-operative treatment with activity modification, anti-inflammatories, and physiotherapy can yield good results. Additional modalities, including shock wave therapy and injections (corticosteroid or PRP), can also be added. Piposar et al. reviewed a cohort of 25 patients with partial-thickness tears managed non-surgically [1•]. Forty percent of patients ultimately required surgical intervention after a failed trial of non-surgical treatment with persistent pain or limited function. Comparing the results of the sustained non-operative group ($n = 15$) with the group that converted to surgical management ($n = 10$), they noted that

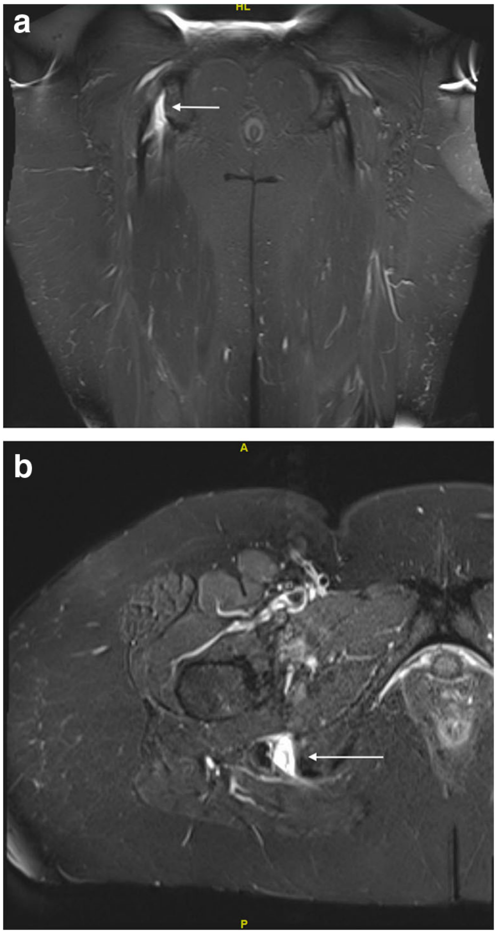

Fig. 5 "Sickle sign" demonstrating partial-thickness hamstring tear of the proximal origin. **a** Coronal T2-weighted MRI image. **b** Axial T2-weighted MRI image

both groups had comparable functional outcomes with a single-leg hop test and isokinetic evaluation. However, the surgical group demonstrated superiority in their lower extremity function score (LEFS) and SF-12 compared with the non-operative group. The authors concluded that for partial-thickness tears, a trial of non-surgical management was reasonable, as improved outcomes could still be obtained in the group that failed and required eventual surgical management.

Operative Treatment

Surgical treatment is indicated for partial-thickness tears after a failure of non-operative treatment, for 2-tendon injuries with 2+ cm of retraction, or complete 3-tendon injuries [2]. Lempainen et al. first reported on surgical management of partial tears of the proximal hamstrings [24]. They retrospectively reviewed the results of 48 patients, with 42 patients treated after failed non-operative treatment and 6 treated acutely. They performed a suture anchor–based repair to the ischium, with routine sciatic neurolysis. At a mean follow-up of 3 years, 87.5% of this cohort reported good-to-excellent outcomes, with 85.4% returning to their pre-injury level of sport participation. The authors concluded that surgical repair yielded improved function, even after a failed trial of non-operative treatment.

Bowman et al. reported on the outcomes of a cohort of 17 patients with partial-thickness tears managed operatively, with release, debridement, and reattachment to the ischium [21]. They did not routinely perform sciatic neurolysis unless the patient exhibited pre-operative symptoms. They reported satisfactory improvements in post-operative LEFS score and Marx activity scale, suggesting improved function and return to athletics, with 93% of patients satisfied with their outcome. The authors suggested that this procedure should be reserved until failure of a trial of extended non-operative management.

Barnett et al. evaluated the outcomes following repair of both partial and complete proximal hamstring tears [25]. Their cohort study included 36 patients with partial injuries that underwent suture anchor repair to the ischium. The majority of these patients (~ 75%) reported good-to-excellent outcomes following surgical repair, making this an acceptable treatment option for partial-thickness tears.

Complete Proximal Hamstring Avulsions

Clinical Presentation

Complete proximal avulsion injuries typically occur following an eccentric contraction with the hip in a flexed position with concurrent knee extension [2, 26]. This often occurs with higher energy ballistic activities, such as weight lifting or water skiing. Patients will usually report hearing or feeling a popping or snapping sensation, accompanied by extensive bruising over the posterior thigh. Patients may also present with symptoms of sciatic nerve irritation, which can range from posterior buttock pain to parasthesias, or even symptoms of sciatica with burning or shooting pains down the leg [2].

Physical Examination

As detailed above, patients with complete avulsion injuries will often present with a stiff-legged gait. Inspection should be performed for ecchymosis or swelling. Similar tests can be utilized as detailed above for chronic insertional tendinopathy or partial-thickness tears. More importantly, a careful neurologic evaluation should be performed to assess for sciatic nerve irritation, including posterior thigh sensation and distal motor and sensory function of the tibial and peroneal nerves.

Imaging

Radiographs are often negative; however, they are prudent to do in this population to rule out a bony avulsion injury. It is not uncommon to see an apophyseal avulsion in skeletally immature patients, which is important to identify if you are considering repair or for the potential complications that can occur with non-operative treatment, such as ischiofemoral impingement [27].

Ultrasound is useful to evaluate for complete proximal avulsions, particularly in the acute setting where MRI may not be practical. It can be used to accurately identify complete avulsions to allow appropriate referral and care. When surgical treatment is being considered, MRI is also useful to allow further characterization of the injury. It can help to identify the number of tendons involved, and the extent of distal retraction, which is helpful for potential surgical management of these injuries (Fig. 6).

Treatment

Non-operative Treatment

Since the description of this injury, most literature has been supportive of early operative intervention, particularly in active, athletic patients [3, 28, 29••]. However, non-operative management is still an option. The typical indications for non-operative treatment include a relatively sedentary patient, someone with significant medical comorbidities, or patients that are unable to comply with post-operative restrictions [2]. However, a trial of non-operative management can still be considered outside of these indications. Similar to partial-thickness tears, non-operative treatment consists of activity modification, anti-inflammatories, and physiotherapy. Additional adjuncts, including injections or shock wave therapy, can also be used to manage symptoms.

Hofmann et al. reported on the largest series of patients with complete proximal avulsion injuries managed non-operatively [30]. In a series of 19 patients with an average follow-up duration of 31 months, the most notable finding was a persistent

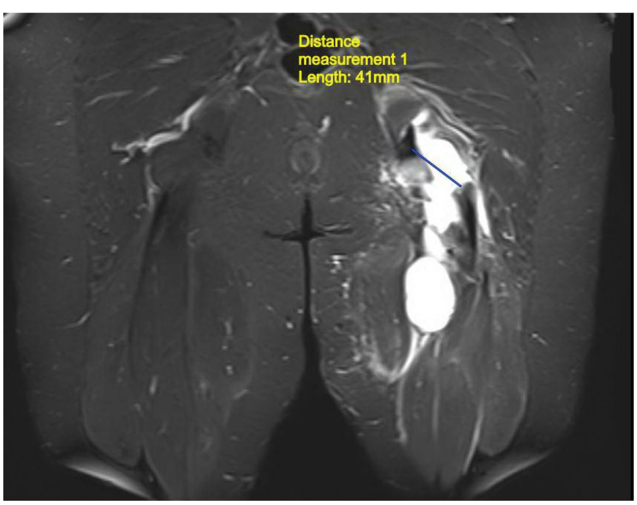

Fig. 6 Coronal T2-weighted MRI demonstrating a complete proximal avulsion injury with 4 cm of distal retraction

strength deficit. The injured leg demonstrated 62% and 66% flexion strength compared to the uninjured leg at 45° and 90° flexion; however, the hop test demonstrated only a 2.2% deficit compared with the uninjured leg. Importantly, 30% of patients were unable to return to the same level of sport participation. Forty-seven percent of this cohort wished they had undergone operative treatment at the time of the injury. The authors caution that non-operative treatment can lead to noticeable subjective and objective functional deficits.

Shambaugh et al. corroborated the above results in their comparative retrospective review of 11 patients treated non-operatively and 14 patients treated with operative repair [31••]. They, too, reported significant deficits in isometric hamstring strength in the non-operative group (58% and 68%) at 45° and 90° flexion, and a lower rate of return to sport compared to the operative group (73% vs. 100%). In addition to the reported persistent functional deficits in these studies, there is also concern about the possibility of "hamstring syndrome" with late sciatic nerve irritation in non-operatively treated avulsion injuries, as described by Takami et al. [32]. These findings have swung the pendulum more towards operative treatment of complete avulsion injuries.

Operative Treatment

Surgical repair of a proximal hamstring avulsion is performed with the patient in the prone position. The incision can be oriented horizontally along the gluteal fold, or longitudinally from the ischial tuberosity distally. The choice for the orientation is often varied based on the amount of tendon retraction and the need for a sciatic neurolysis, where greater retraction and the need for a neurolysis favor the use of a longitudinal incision [3, 33, 34]. Careful elevation of the inferior border of the gluteus maximus is performed to expose the posterior hamstring fascia, taking care to avoid injuring the posterior femoral cutaneous nerve. A large hematoma/seroma is often evacuated after opening the fascia if the repair is done in the acute setting. Depending on the acuity, the hamstring tendons may either be easily identified and mobilized after evacuating the hematoma/seroma, or may require careful dissection of scar tissue between the retracted tendons and sciatic nerve in chronic cases [2, 34]. A formal sciatic neurolysis is usually reserved for cases with pre-operative symptoms of nerve irritation, or chronic cases where the retracted tendons need to be mobilized off the nerve to allow repair to the ischium (Fig. 7).

After mobilizing the tendon, the ischial tuberosity should be carefully exposed and debrided of any remaining tissue. Motorized instruments should be avoided and a manual awl is suggested for placement of anchors. Two to five anchors can be utilized for repair, with the author's preferred technique being 3 anchors placed in an inverted triangle configuration (Fig. 8). Running, locking sutures, or mattress sutures may be used with high strength suture to complete the repair. The knee

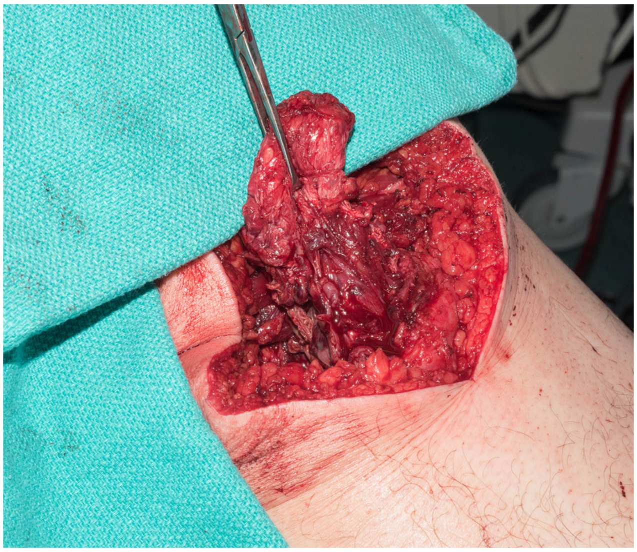

Fig. 7 Intra-operative image after sciatic neurolysis and tendon mobilization

is usually flexed to approximately 30° to relieve tension while sutures are tied to complete the repair.

An alternate method for performing proximal hamstring repairs is to use an endoscopic approach. This has previously been described in two studies reporting primarily on surgical technique [35, 36]. While these studies propose that it can be utilized to treat both partial-thickness and complete tears, others have questioned the ability to perform endoscopic repairs with full-thickness tears with distal retraction [35–37]. In this case, it may be best reserved for partial-thickness tears, or full-thickness tears with minimal retraction.

Fig. 8 Post-operative radiograph demonstrating the author's preferred anchor configuration

Post-operative care following operative repair of complete avulsions is highly variable, ranging from non-weight-bearing with an orthosis to limit hip or knee flexion, to full weight-bearing without any orthosis [38]. The author's preferred approach is to utilize a knee orthosis with a 30° extension block, limiting weight-bearing to foot-flat (~ 20 lb) for the first 6 weeks. Physiotherapy is initiated following the 6-week visit, starting with gait retraining, hip and knee range of motion, and isometric strengthening. Concentric strengthening is introduced between 3 and 4 months, starting the closed chain kinetic exercises, with open-chain exercises reserved for the final stages of rehabilitation. While there is significant heterogeneity between centers regarding the rehabilitation protocols, on average patients resumed sport specific training at approximately 4 months (21.5 weeks), with return to athletic competition at approximately 6.5–7 months (28.3 weeks) [38].

Operative repair of complete proximal avulsion injuries is largely successful for restoration of strength and return to sport, as reported in multiple cohort series' [25, 28, 31, 39]. Bodendorfer et al. performed a systematic review of both operative and non-operative treatment of these injuries [29••]. They reported significantly higher patient satisfaction (91% vs. 53%), LEFS score (73 vs. 70), and single-leg hop distance (119 cm vs. 57 cm) in the operative group compared with the non-operative group. However, operative repair was associated with a 23% complication rate. Perhaps, a more important subgroup comparison was subsequently performed, comparing those treated acutely (< 4 weeks) versus those treated late, with chronic injuries (> 4 weeks). Acute repairs tended to have improved patient satisfaction (95% vs. 84%), less pain (1.1 vs. 3.7), greater strength (85.2% vs. 82.8%), and greater LEFS (75.6 vs. 71.5) compared with the chronic repairs.

Along the same lines, Subbu et al. reported on the outcomes following surgical repair in early (< 6 weeks), delayed (> 6 weeks), and late (> 6 months) intervention [40••]. They identified more expedient return to sport in the early intervention group (16 weeks) compared with the delayed (25 weeks) and late (29 weeks) intervention groups. Twelve athletes had sciatic nerve symptoms post-operatively with a significantly higher rate in the delayed and late groups—specifically, two patients in the early group (2.6%), five in the delayed group (20.8%), and five in the late group (50%) experienced neurologic complications.

Collectively, results of these studies would support that operative treatment provides good-to-excellent outcomes in terms of both subjective function, objective strength evaluation, and patient reported outcome measures, with acute repair favored over delayed/chronic repair.

Conclusion

Proximal hamstring injuries are increasingly common and have varying presentations. For chronic insertional tendinopathy and partial-thickness tears, non-operative treatment consisting of physiotherapy, extracorporeal shock wave therapy, and injection therapy should be the mainstay of treatment. Operative treatment, in the form of debridement and reattachment to the ischium, should be reserved for refractory cases where unsatisfactory results occur following an extended course of non-operative treatment. For active patients, or high-level athletes, operative treatment is favored in complete proximal avulsion injuries, with improved subjective and objective functional outcomes, with improved return-to-sport rates. Acute repair (< 4 weeks following injury) is favored over chronic repair (> 4 weeks), yielding higher patient reported outcome measures and lower post-operative complications.

Compliance with Ethical Standards

Conflict of Interest Ryan M. Degen declares no potential conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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•• Of major importance

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