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Open Repair of Acute Proximal Hamstring Avulsion: A Prospective, Mid-Term Follow-Up in Active Middle-Aged Adults

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Hamstring Avulsion; Proximal Hamstring Rupture; Hamstring Repair; Deep Gluteal Pain Syndrome

Level of Evidence:

Level IV; Prospective Case Series; Mid-Term Follow Up

Abbreviations:

MRI; Magnetic Resonance Imaging: PHAT; Perth Hamstring Assessment Tool: SD; Standard Deviation: VAS; Visual Analog Scale

1. Abstract

1.1. Background

Acute proximal hamstring ruptures can significantly impair function, particularly in active individuals. While conservative treatment may provide pain relief, it often fails to restore full strength and mobility. This study evaluates the mid-term functional outcomes of primary open surgical repair for acute complete proximal hamstring ruptures.

1.2. Materials and Methods

A prospective cohort of 29 patients (7 women, 22 men; mean age 44.9 ± 11.2 years) with acute complete proximal hamstring avulsions underwent open surgical repair. The mean time from injury to surgery was 1.8 ± 12.2 weeks. Functional outcomes were assessed preoperatively and postoperatively at six months, one year, and three years using the Perth Hamstring Assessment Tool (PHAT) and Visual Analog Scale (VAS). Isokinetic strength testing was performed at final follow-up to compare the operated limb with the contralateral side. Rehabilitation began immediately after surgery following a structured protocol. Results: At final follow-up (mean 3.1 years; range 3.1–5.3 years), the PHAT score improved from 27.4 ± 13.03 to 97.89 ± 7.55 ($P < 0.01$), and the VAS score decreased from 6.2 to 1.2 ($P < 0.01$). Isokinetic testing showed no significant strength difference between limbs (6.7% ± 3.18 deficit, P = 0.23). No patients required grafting or augmentation, and no major complications were reported. Conclusion: Early surgical repair provides superior functional recovery, preserving strength and mobility. These findings support early intervention as the preferred treatment for active individuals and athletes requiring optimal hamstring function.

2. Introduction

Hamstring pathology occurs frequently in athletes and most commonly occurs at the myofascial union [1]. Most hamstring injuries are successfully treated conservatively. However, there is no consensus regarding treatment when hamstring injuries involve and compromise the proximal insertion of this muscle group. It is reported that 1–12% of all hamstring injuries are complete proximal ruptures [2,3]. These lesions usually occur during sports participation or slip-and-fall accidents and can cause significant functional impairment that can greatly affect athletes [4].The hamstring complex is composed of three different muscles, namely semitendinosus, semimembranosus, and biceps femoris.The functions of the hamstring complex are knee flexion and secondary hip extension, and all its three constituent muscles have insertions on the ischium. The biceps femoris and semitendinosus are inserted through the joint tendon sheath on the medial and posterolateral aspects of the ischium, and the semimembranosus is inserted on the lateral facet of the ischium and is in close proximity to the sciatic nerve [5,6]. Although conservative treatment can yield acceptable results, persistent symptoms such as knee flexion and hip extension weakness, deformity, and the risk of hamstring syndrome with its associated pain, discomfort, and functional deficits pose significant challenges, making nonoperative management often incompatible with high-performance sports [7] . However, there are reports that primary surgical repair, especially in the acute phase of hamstring injury, is associated with better functional results, such as greater knee flexion force, and lower rate of neurological complications than conservative treatment [2,4,8].The aims of this study were to present a series of 29 patients with acute complete proximal hamstring rupture who were surgically treated in our center using the open technique and to evaluate the mid-term functional results. Our hypothesis is that primary surgical repair of acute proximal hamstring ruptures significantly improves functional outcomes and pain levels, with minimal mid-term strength deficits in middle-age active adults.

3. Materials and Methods

This prospective study included 29 otherwise healthy Caucasian patients diagnosed with acute complete proximal hamstring ruptures (types 4 and 5 according to the Wood et al. classification) [9] who underwent open surgical repair at our institution between March 2015 and January 2016. All patients were physically active, participating in sports such as soccer, water skiing, rugby, running, and motorcycle racing at least five times per week.The diagnosis of acute complete proximal hamstring rupture was based on standard radiographs (posterolateral and axial views) and confirmed by 2.0 Tesla magnetic resonance imaging (MRI), including thigh and pelvic views (Figure 1A). Written informed consent was obtained from all participants.

4. Inclusion and Exclusion Criteria

4.1. Inclusion Criteria

- History of forced eccentric contraction of the hamstring muscle complex, occurring with the knee in extension and the hip in hyperflexion.
- Diagnosis of acute complete traumatic hamstring rupture (types 4 and 5, Wood et al. classification) confirmed by posterolateral and axial radiographs and 2.0 Tesla MRI of the affected thigh and pelvis.
- Retraction of less than 40 mm and absence of radiographic signs of osteoarthritis in the affected hip.
- Time from diagnosis to surgical treatment < 6 months.
- All procedures were performed by the same surgical team, following a standardized surgical technique, anesthetic approach, and pain management protocol.

Exclusion Criteria:

- Radiological evidence of hip and/or knee osteoarthritis, including joint space narrowing, osteophyte formation, subchondral sclerosis, subchondral cysts, or joint deformity (10).
- Hip instability, characterized by excessive movement or misalignment leading to pain, weakness, or a sensation of instability (11).
- Prior intra-articular injection of corticosteroids or other substances near the hamstring insertion site within six months prior to rupture.
- Chronic corticosteroid use (>3 months).
- Concurrent conditions affecting hip biomechanics, such as hip dysplasia, identified by a decreased acetabular index or abnormal femoral head coverage, or prior hip surgery.
- Rheumatic disease, diabetes mellitus, or hematologic/oncologic disorders (current or past).
- Inability to provide informed consent.

All statistical analyses were performed using SPSS v.25 for Mac (IBM, Armonk, NY, USA). Data distribution was assessed using the Shapiro-Wilk test to determine normality. For comparisons between groups, independent t-tests were conducted, with the level of significance set at $p \leq 0.01$. Continuous variables are reported as mean ± standard deviation (SD).

4.2. Surgical Technique

Under general anesthesia and with the surgical field prepared, the patient is positioned prone on a surgical table with an angled central section to achieve an anterior pelvic tilt of 20°. The affected lower limb is extended and supported on a brace secured to the distal portion of the table, maintaining a knee flexion angle of 10°. This positioning allows for intraoperative adjustments, enabling increased knee flexion if needed to approximate the hamstring tendons to their anatomical footprint. The central table angulation facilitates identification of the ischial tuberosity, which lies anterior to the sciatic nerve at the injury site, aiding in both precise localization and protection of the nerve throughout the procedure.A sub-gluteal incision is made following the lines of force, extending 2 cm medially and 8 cm laterally from the ischium. The subcutaneous tissue is dissected, and the gluteus maximus is identified and proximally released to prevent neurological injury. Blunt retractors are used to retract the gluteus maximus, providing clear exposure of the ischial fascia, which is then incised longitudinally and distally from the center of the ischium. Hematoma evacuation occurs spontaneously or via aspiration, as hamstring-related hematomas are typically extensive, often exceeding 250 mL in volume [12].Upon entering the hamstring compartment, the ischial footprint is located using two bone retractors placed medially and laterally at the superior border of the ischium, along with a blunt distal retractor. This setup optimizes visualization of the surgical field and facilitates identification of the sciatic nerve, which lies lateral to the ischium and shifts to an anterior position when the hip is flexed, as illustrated in Figure 1B. A cross-sectional exposure of the ischium is performed, revealing the avulsed proximal tendon ends. In all cases, the avulsed tendons were found to be clustered together and adhered to their pseudo-capsular structures in the posterior and lateral regions.With controlled manual dissection, the distal end of the avulsed hamstring stump is carefully freed from its adhesions. Transient tensile sutures using 1.0 Vicryl are placed to facilitate controlled traction of the tendon towards the ischium. Once the bone bed is prepared, three to four separate 3.5 mm anchors are inserted approximately 1–2 cm apart, creating an extensive reattachment surface with high-strength double sutures. This configuration allows for the placement of six to eight sutures in a geometric pattern, ensuring anatomical reinsertion from distal to proximal.

The tendon is secured by sequentially suturing its proximal end after being repositioned using the Vicryl tension sutures. Definitive fixation is performed in a distal-to-proximal manner, ensuring full utilization of the ischial footprint (Figure 2). In cases of significant tendon retraction, knee flexion and surgical table adjustments may be required to optimize fixation.Following tendon reattachment, all sutures are meticulously reviewed. The hip and knee are then returned to their extended and flexed positions, respectively, to confirm suture integrity and resistance to future rehabilitation stresses. Finally, the gluteal fascia is closed with separate absorbable sutures.The subcutaneous tissue is closed in a similar manner, ensuring meticulous hemostasis to prevent hematoma formation. Given the proximity to the perianal region, hematomas pose an increased risk of infection, while excessive accumulation of fluid may contribute to compartment syndrome and potential sciatic nerve injury [13]. The skin is closed using separate non-absorbable sutures, and occlusive dressings are applied to maintain a clean surgical field.In our series, sciatic neurolysis was not performed, as direct visualization of the sciatic nerve was achieved. However, in cases where significant adhesions are encountered, neurolysis should be considered to ensure nerve decompression.Postoperative pain management followed a standardized protocol for all patients. Nonsteroidal anti-inflammatory drugs (NSAIDs) were administered intravenously, with 300 mg of ketoprofen diluted in 500 mL of Ringer's solution at a continuous infusion rate of 10 mL/hour for the first 24 hours. Subsequently, patients received 1 g of acetaminophen every 8 hours for 15 days. To reduce the risk of thromboembolism and heterotopic ossification, all patients were prescribed 10 mg of rivaroxaban and 550 mg of naproxen daily for four weeks. Notably, no epidural block, femoral block, or opioid rescue analgesia was utilized.

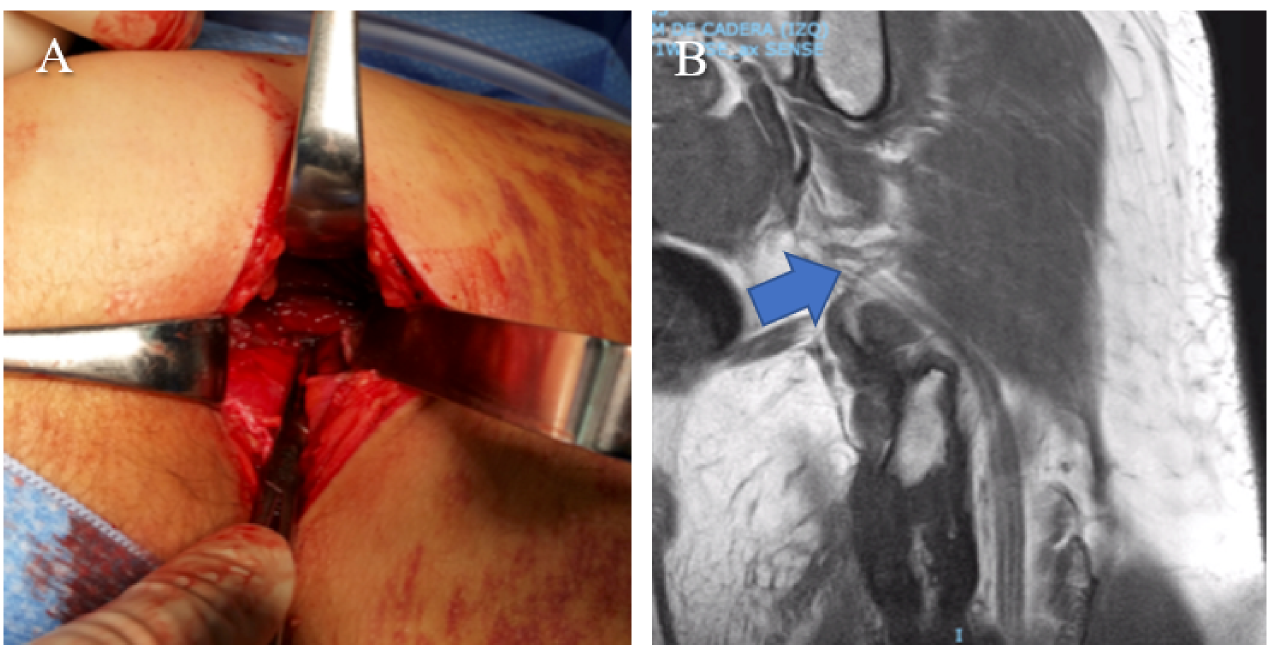


Figure 1: (A) Complete acute proximal hamstring rupture (Wood 5a) in a 24-year-old male. **(B)** T1 sagittal MRI showing complete proximal hamstring rupture [blue arrow] in the same patient (Wood 5a).

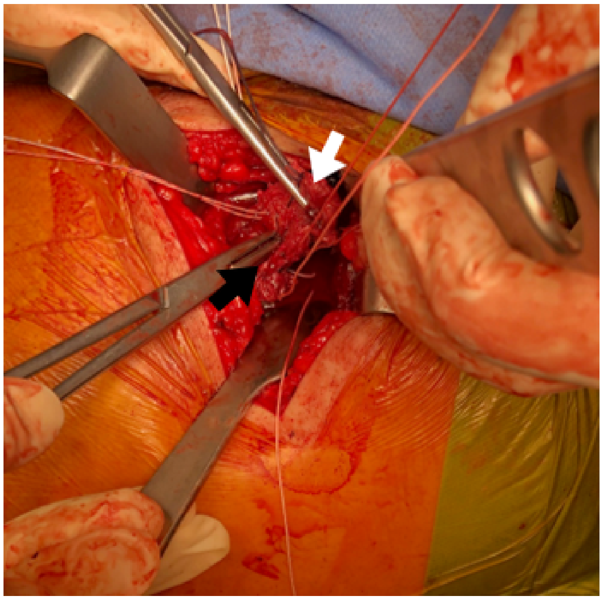


Figure 2: Definitive sutures in a 19-year-old male, placed from distal (black arrow) to proximal (white arrow), ensuring full utilization of the ischial footprint.

Figure 3: First-stage postoperative protocol demonstrating protection and articular block with a knee brace locked at 40º of flexion and an harness. This setup restricts hip flexion during the first four weeks to safeguard the surgical repair.

5. Rehabilitation Protocol

All patients followed a standardized rehabilitation protocol, structured into three progressive stages to ensure optimal recovery while protecting the surgical repair.

5.1. Early Stage (Weeks 0–4) – Protection Phase

During the initial four weeks, the primary objective was to protect the surgical repair. Patients were fitted with a knee brace locked at 40° of flexion and an articular block to restrict hip flexion (Figure 3). Toe-touch weight-bearing was permitted, but full weight-bearing and active hip flexion were strictly avoided to prevent excessive strain on the repair.

Intermediate Stage (Weeks 4–12) – Progressive Mobilization and Strengthening. From postoperative week 4, patients gradually transitioned to partial weight-bearing while beginning articular range-of-motion (ROM) exercises and hip flexibility and stability training. High-impact activities such as running and jumping were strictly prohibited for the first six months to prevent reinjury. During weeks 6–8, sciatic neuromobilization exercises were introduced alongside progressive hamstring and total lower-limb strengthening with controlled resistance. By week 8, patients were expected to achieve full ROM, with continued strengthening exercises to enhance muscle activation and neuromuscular coordination.

5.2. Advanced Stage (Weeks 12–24+) – Functional Restoration and Sports Reintegration

By postoperative week 12, patients were able to perform daily activities without restrictions and began a gradual return to low-impact aerobic exercises as tolerated. Rehabilitation focused on progressive functional training tailored to each patient's activity level, including sports-specific exercises and progressive running and jumping drills between months 3 and 6. Before resuming full sports participation, all patients underwent isokinetic strength testing to evaluate hamstring recovery. Return to sports was permitted once strength asymmetry between the injured and contralateral hamstring was ≤8%. This structured approach ensured a safe and effective return to function while minimizing the risk of reinjury [14,15].Clinical outcomes were assessed using the Perth Hamstring Assessment Tool (PHAT)[16] and the Visual Analog Scale (VAS) at four time points: preoperatively, six months postoperatively, one year postoperatively, and at the three-year follow-up.Preoperative imaging included magnetic resonance imaging (MRI) performed using a 2.0 Tesla system. All MRI scans were reviewed by a musculoskeletal radiologist, who classified the proximal hamstring injuries according to the Wood et al. classification [9].

6. Results

Initially, 37 patients were deemed eligible for inclusion; however, six were excluded based on the study's exclusion criteria (four due to diabetes mellitus and two due to hip osteoarthritis). Additionally, two patients were lost to follow-up, resulting in a final study population of 29 patients (7 women and 22 men), all of whom underwent surgical repair.

The mean age at the time of surgery was 44.9 ± 11.2 years, and the mean time from diagnosis to surgery was 1.8 ± 12.2 weeks. The minimum follow-up period was 3.1 years, with a range of 3.1–5.3 years.Details regarding the location, size, and classification of proximal hamstring injuries (Wood et al. (9)) are summarized in

Table 1, while patient demographic characteristics are presented in Table 2. The sports associated with proximal hamstring avulsions in this cohort are outlined in Table 3.Overall, both clinical and radiological outcomes showed significant improvement across all patients. The mean preoperative PHAT score was 27.4 ± 13.03, which increased to 84.6 ± 5.1 at the six-month follow-up ($P < 0.01$). At the one-year follow-up, the mean PHAT score further improved to 95.2 ± 4.2 ($P < 0.01$). By the final follow-up at three years, the mean PHAT score reached 97.89 ± 7.55, representing a significant improvement compared to the preoperative values ($P < 0.01$) (Table 4). Preoperatively, the mean VAS score was 6.2, with significant variability among patients. By the three-year follow-up, the score had significantly decreased to 1.2 ($P < 0.01$), indicating a substantial reduction in pain. At the final follow-up, isokinetic testing revealed no statistically significant difference in hamstring strength between the affected and contralateral limbs. The mean strength deficit in the operated limb was 6.7% ± 3.18 compared to the contralateral side ($P = 0.23$), indicating near-complete recovery of muscular function.

Table 1: Characteristics of proximal hamstring injuries in patients operated between March 2015 and January 2016 at the Clinical MEDS Center, Chile.

Wood Classification	Numberofpatients	Retraction (cm)	BoneAvulsion
Grade 4	8	0.5 (SD 0.23)	0
Grade 5a	19	2.3 (SD 1.32)	2
Grade 5b	2	2.86 (SD 1.14)	0

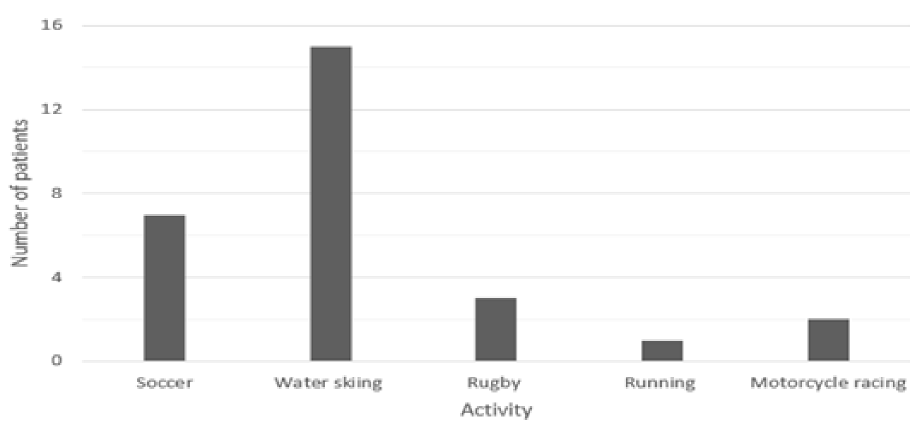
Note: From the data base of *"Open repair of acute proximal hamstring avulsion: A prospective, mid-term follow-up in active middle-aged adults"*.Data are expressed as mean ± standard deviation (SD). Wood classification of the proximal hamstring injuries [9].

Table 2: Demographic characteristics of patients with proximal hamstring injuries operated between March 2015 and January 2016 at the Clinical MEDS Center, Chile.

Demographiccharacteristics	Mean ± SD
Sex	Men = 22; Women = 7
Age (years)	44,9 ±11,2
BMI (kg/m^2)	26,1 ± 2,1
Weight (kg)	71,7±11,3
MRI retraction (cm)	1,8 ±1,24
PHAT Preoperative	27,4 ± 13,03
PHAT At least 3 yearsfollow up	95,22±6,2

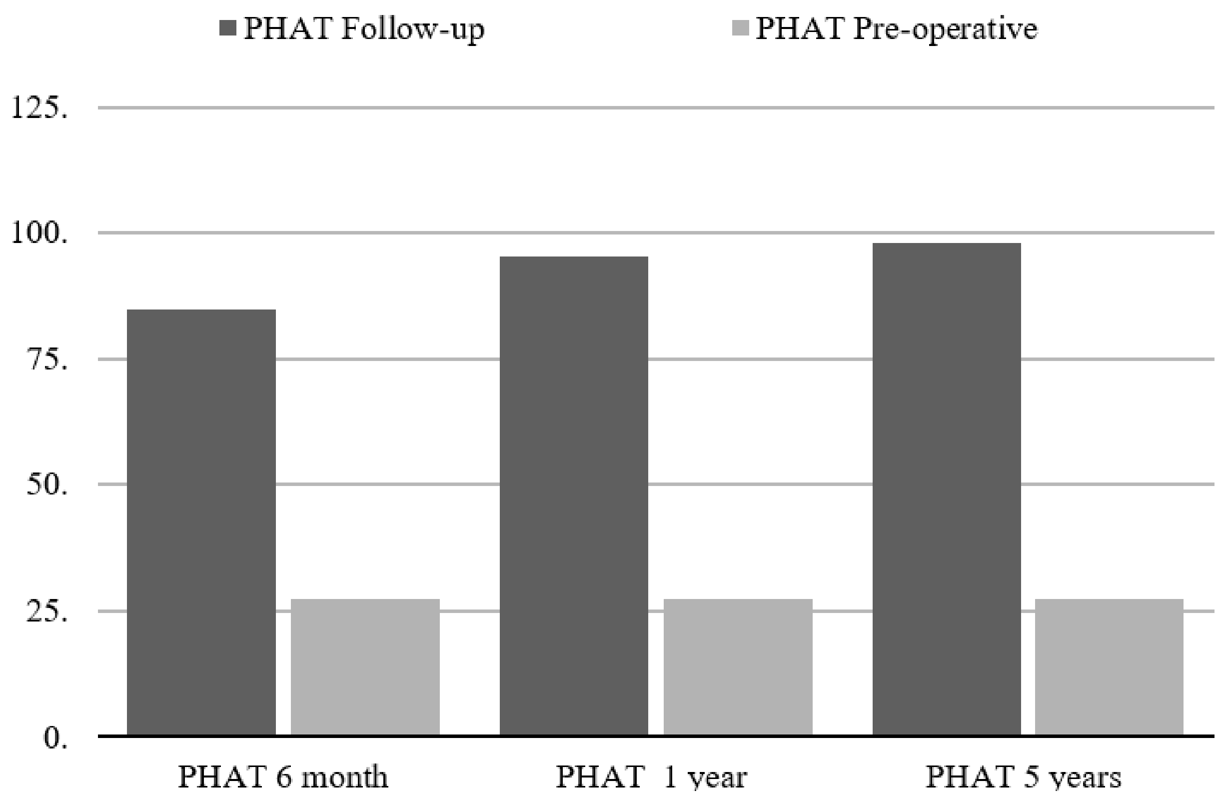
Note: From the data base of *"Open repair of acute proximal hamstring avulsion: A prospective, mid-term follow-up in active middle-aged adults"*.
Data are expressed as Mean ± Standard Deviation (SD).
BMI, body mass index; PHAT, Perth Hamstring Assessment Tool [6]; MRI, magnetic resonance imaging.

Table 3: Graphic of the sports involved of patients (n=29) with proximal hamstring injuries operated between March 2015 and January 2016 at the Clinical MEDS Center, Chile.



Note: From the data base of *"Open repair of acute proximal hamstring avulsion: A prospective, mid-term follow-up in active middle-aged adults"*. Presented as number of patients (Soccer = 7, Water skiing = 15, Rugby = 3, Running = 1, Motorcycle racing = 2).

Table 4: Change in PHAT score of patients (n=29) with proximal hamstring injuries operated between March 2015 and January 2016 at the Clinical MEDS Center, Chile.



Note: From the data base of *"Open repair of acute proximal hamstring avulsion: A prospective, mid-term follow-up in active middle-aged adults"*. The increase of PHAT was statistically significant in all of follow up. (*p<0,01)
PHAT, Perth Hamstring Assessment Tool.

7. Discussion

The most important finding was that in our series of 29 patients, we observed excellent mid-term results of open hamstring repair with a mean PHAT score of 97.89. Our results show functional improvements similar to those recently reported by other authors. In terms of strength, endurance, and chronic deep gluteal pain, open surgical treatment of types 4 and 5 lesions according to the classification by Wood et al. [9] generally yields better results than conservative therapy, especially in patients who participate in sports [6,17].

There are limited reports on the treatment of severe avulsive hamstring injuries with retractions greater than 2 cm, particularly regarding their association with sciatic nerve inflammation [18]. Although these injuries are relatively common and often transient, adhesions formed during healing can sometimes lead to chronic sciatic irritation and functional impairment [12].Patients typically experience strength deficits when the joint tendon or the tendinous insertions of all three hamstring muscles are compromised. However, an isolated complete rupture with retraction of the semimembranosus does not appear to cause significant functional deterioration in the medium or long term [19].

In our selected patient cohort, none of the aforementioned complications were observed. We believe that early surgical intervention, combined with meticulous sciatic nerve neurolysis, may help reduce the incidence of mid- to long-term sciatic symptoms.Our findings highlight the importance of proper surgical exposure, precise anatomical identification, and controlled tension during tendon reinsertion to optimize outcomes in proximal hamstring avulsion repair. Consistent with previous reports [20], complete visualization of the ischium using soft tissue retractors is essential for accurate footprint identification, while direct visualization of the sciatic nerve remains crucial to minimize the risk of iatrogenic injury.Hip flexion was used intraoperatively to facilitate anterior displacement of the sciatic nerve, effectively moving it away from the surgical field and reducing the likelihood of adhesions or nerve entrapment. Although intraoperative neuromonitoring was initially employed in early cases not included in this study, it was ultimately discontinued due to its lack of additional clinical benefit. However, its use may still be warranted for less experienced surgeons or in complex chronic cases requiring extensive dissection and repair [21].A clear understanding of the anatomical footprint is fundamental to achieving stable tendon fixation. As previously described by Hamming et al. [20], the ischial footprint can be divided into a lateral insertion site for the semimembranosus and a posteromedial site for the conjoint tendon. Based on these anatomical considerations, most cases in our series required four anchors (3.5 mm titanium, Smith & Nephew, London, UK), with the number adjusted according to the size of the ischium. The avulsed tendon stumps were reapproximated and secured under controlled tension to prevent excessive strain and potential re-rupture.In one case, a tendon retraction greater than 7 cm necessitated an extended incision. To ensure adequate fixation, two posterolateral anchors were placed for the semimembranosus and a portion of the conjoint tendon, while two posteromedial anchors were positioned to secure the conjoint tendon, achieving a functional anatomical reinsertion. However, it was not always possible to differentiate individual tendons, particularly in cases of extensive soft tissue damage. In such instances, reconstruction was guided by anatomical landmarks to ensure the most physiological repair possible.The decision to pursue surgical intervention was based on prior evidence indicating that nonoperative management often results in suboptimal outcomes, including persistent weakness, reduced endurance, and chronic deep gluteal pain [6,17]. Given these findings, early surgical repair should be considered in appropriately selected patients to restore function and minimize long-term complications.The timing of surgical intervention is a critical factor in achieving favorable outcomes. Surgical repair beyond 12 weeks post-injury is generally considered to fall within the chronic phase, as tendon retraction and adhesion to surrounding structures may complicate anatomical reinsertion, often necessitating grafting [22] . In our series, reinsertion was successfully performed up to 14 weeks post-injury. Although these cases required more meticulous dissection, including external sciatic neurolysis, no instance of tendon retraction was encountered that precluded direct anatomical reinsertion. To date, none of our patients have required augmentation or grafting, as described in previous literature. These findings suggest that, while delayed repair increases surgical complexity, anatomical reinsertion remains feasible in properly selected cases, reinforcing the importance of early intervention whenever possible.A systematic review concluded that although the quality of the reviewed studies is poor, surgical repair of proximal hamstring avulsions appeared to result in satisfying outcomes based on subjective patient reporting [4]. In our prospective series, the results were much better with a lower rate of complications, including significant muscle deficits, deep gluteal pain syndrome, ischial pain, and sciatic complications of varying degrees, than those reported in studies on conservative treatment [4,23].The rehabilitation protocol outlined in this study is contingent upon achieving anatomical and stable tendon reinsertion, which allows for progressive elongation and mobility from the fourth postoperative week. Ensuring a secure fixation is fundamental to enabling early, controlled rehabilitation without compromising structural integrity.

In our series, we opted for three or, in most cases (26 patients), four separate 3.5 mm metal anchors rather than using a smaller number of larger-diameter anchors. This approach aligns with findings from a cadaveric study by Hamming et al. [20], which demonstrated that repairs using four or five small anchors yielded biomechanical strength comparable to that of the intact tendon and were significantly superior to repairs utilizing only two large or two small anchors in cases of complete proximal hamstring avulsion [24]. These findings reinforce the importance of optimizing anchor distribution to enhance fixation strength and facilitate a rehabilitation protocol that progressively restores function while minimizing the risk of re-rupture.Based on existing data and our findings, we recommend anatomical surgical repair for acute and subacute hamstring avulsions. These injuries typically result from forced eccentric contraction of the hamstring muscle complex with the knee extended and the hip in hyperflexion. They are commonly associated with high-impact sports requiring eccentric hamstring activation, such as water skiing, motorcycle racing, soccer, and rugby [1,3,25]. In our series, water skiing and soccer had the highest incidence of injury (Table 3), consistent with previous reports.While conservative management of proximal hamstring avulsions can provide pain relief and some functional improvement, it often fails to restore full strength and range of motion, particularly in high-performance athletes [4]. The inability to regain optimal muscle function may compromise long-term athletic performance and increase the risk of reinjury. In contrast, primary surgical repair, especially when performed in the acute phase, consistently leads to superior functional outcomes. This approach is particularly beneficial for active individuals who rely on optimal hamstring function for sustained athletic performance, reinforcing the importance of timely surgical intervention.Fenn et al. [26] compared open and endoscopic surgical repair of proximal hamstring tears with a minimum follow-up of five years . Their findings demonstrated favorable outcomes with both techniques, supporting the effectiveness of surgical intervention in preserving long-term functional performance. However, our study specifically focused on open surgical repair of acute complete proximal hamstring ruptures, with a shorter minimum follow-up of 3.1 years. Despite this difference in follow-up duration, our results reinforce the advantages of early surgical intervention. The significant improvement in preoperative PHAT scores by the end of the follow-up period underscores substantial functional recovery, while the marked reduction in VAS scores highlights effective pain relief. These findings further support the role of early surgical repair in achieving near-complete functional restoration, particularly in active patients, and emphasize its superiority over nonoperative treatment in terms of both strength recovery and pain reduction. This study had several limitations. First, it was not controlled and may have been underpowered, meaning that statistical analysis primarily highlighted trends rather than establishing definitive significance. Second, the follow-up period was limited to three years, which may not have been sufficient to detect long-term complications such as relapse, late-onset sciatic symptoms, or progressive strength deficits. A longer follow-up could provide a more comprehensive understanding of the durability of surgical outcomes. Third, correct visualization of the enthesis is not possible with ultrasonography or MRI, limiting the ability to objectively assess tendon healing. The criteria for return to sports participation were based solely on clinical and biomechanical evaluations rather than standardized imaging assessments of proper healing. Additionally, although the PHAT and VAS scoring systems were the most commonly used tools at the time of the study, the lack of additional validated outcome measures may have restricted the ability to capture certain functional and quality-of-life aspects relevant to these patients.Another limitation is the absence of a direct comparison between surgical and nonoperative treatment, which could have provided further insight into the benefits of early intervention. Additionally, while all procedures were performed by the same surgical team using a standardized technique, potential variability in rehabilitation adherence among patients may have influenced functional outcomes. Finally, isokinetic strength assessment was performed only at the final follow-up, rather than at multiple time points, which may have limited the ability to track progressive strength recovery over time.

8. Conclusion

Primary surgical repair of acute proximal hamstring ruptures, especially when performed in the acute phase, yields favorable functional outcomes at a minimum follow-up of three years. Timely intervention is crucial for preserving strength, mobility, and overall function, particularly in athletes and active individuals. Early anatomical reinsertion not only facilitates recovery but also supports long-term performance and career continuity. Further research with longer follow-ups is needed to refine treatment strategies and confirm these findings.

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