

Received: 2018.10.25

Accepted: 2018.12.07

Published: 2018.12.27

Avulsion Fractures of the Ischial Tuberosity: Progress of Injury, Mechanism, Clinical Manifestations, Imaging Examination, Diagnosis and Differential Diagnosis and Treatment

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Source of support: Effect of Epimedium on the Differentiation and Apoptosis of Chondrocytes in Osteoarthritis (Bethune Special) (No. 20160101027J/C)

Avulsion fracture of the ischial tuberosity (AFIT) is a rare adolescent sports injury. At present, there is no consensus on its therapeutic paradigm, but conservative treatment appears to be the predominate choice. Furthermore, the degree of fracture displacement (DFD) remains as an important factor in determining whether AFIT needs internal fixation. The aim of the present study was to review and update the injury mechanism, clinical manifestations, imaging examination, diagnosis and differential diagnosis, and treatment of AFIT.

A literature search was performed on a variety of databases using text words, and the results were limited to the English language.





This review provides an important reference for the diagnosis and treatment of AFIT.

AFIT can be easily misdiagnosed. Therefore, a detailed medical history and imaging examination are crucial for a correct diagnosis and differential diagnosis. For the choice of treatment of AFIT, it is necessary to consider not only the size of the fracture and DFD, but also the long-term functional needs of the patient.

MeSH Keywords: **Fractures, Bone • Ischium • Surgical Procedures, Operative**

Abbreviations: **AFIT** – avulsion fracture of ischial tuberosity; **ORIF** – open reduction and internal fixation; **ISI** – the inability score index; **DFD** – degree of fracture displacement; **ROM** – range of motion

Full-text PDF: <https://www.medscimonit.com/abstract/index/idArt/913799>

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Background

Avulsion fracture of the ischial tuberosity (AFIT) is a rare adolescent sports related injury [1]. Since the epiphysis of ischial tuberosity has not been closed in puberty, it can also be called avulsion fracture of the epiphysis of the ischial tuberosity [2]. In 1912, Berry [3] reported the first AFIT, and subsequent reports have appeared in the form of case reports [4,5]. However, there is presently no consensus on how to treat AFIT [6].

This study used the terms “Ischium”, “Fractures, Bone”, “Ischial Tuberosity” and “Avulsion Fracture” as keywords to search the PubMed, Embase, Cochrane Library, Web of Science, and other databases for literatures from 1912 to October 2018. A total of 369 articles were found. The subsequent selection process (Figure 1) narrowed the final literature search to 40 relevant papers. The aim of the present study was to review the research progress for the injury mechanism, clinical manifestations, imaging examination, diagnosis and differential diagnosis, and treatment of AFIT. To the best of our knowledge, the present study is the first to conduct an extensive literature review of AFIT.

Mechanism of Injury

Before the occurrence of the secondary ossification center of the ischial tuberosity, the ischial bone is mainly cartilage and has a certain degree of shock absorption. At the age of 13 to 15 years old, the ossification of the ischial tuberosity begins. Thereafter, the elasticity of the epiphysis gradually decreases. During this period of time, this structure is 2 to 5 times weaker than the normal tendon and ligament [7], and becomes the weakest part of the muscle-ischial tuberosity structure. Therefore, a sudden pull can easily lead to the separation of the epiphyses from the tarsal plate, until the remaining ischial nodules are fused between the age of 20 and 25 years old [8]. Rossi et al. [9] reported that the average age of pelvic avulsion fractures was 13.8 years old, while Porr et al. [10] indicated that the average age of pelvic avulsion fractures were 16.8 years old. Although these reported ages were slightly different, both of these reports indicated that the fragile characteristics of adolescent osteophytes are prone to avulsion fractures [11]. The ischial tuberosity is the starting point of the hamstring muscle, which includes the long head of the biceps femoris, semitendinosus, and semimembranosus of the biceps femoris. The semitendinosus and biceps femoris have a common tendon on the ischial bone, and the semimembranosus originates from the outside of the ischial tuberosity [12,13]. Furthermore, the long head of the biceps femoris ends in the capitulum fibulae, inserts on the fibular head, and has a small branch that inserts on the posterior-lateral aspect of the tibial condyle, and the semitendinosus and semimembranosus

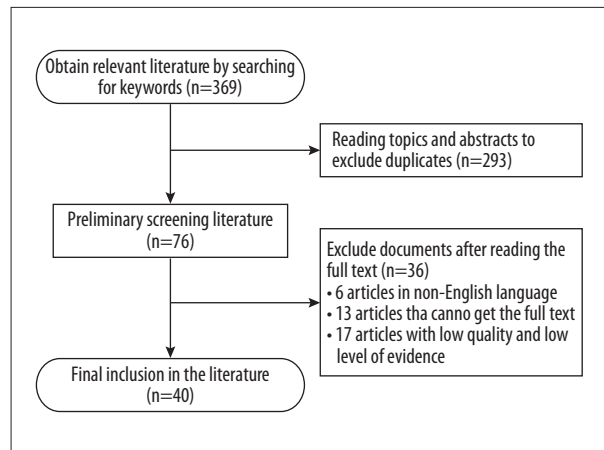


Figure 1. Document retrieval flow chart.

terminate in the medial aspect of the tibia with multiple insertion points. The main function of their contraction is to bend the knee and extend the hip joint. This position places the hamstring in a mechanically advantageous position, leading to increased forces at the ischium, which might contribute to AFIT [4,14].

AFIT is closely associated with competitive sports, such as football and track and field [15,16]. However, ischial tuberosity damage can also be caused by long-term chronic strain, such as ischial tuberculosis [16], and this disorder can be further developed to avulsion fracture. Even though AFIT occurs mostly in adolescents, adult injuries have also been reported [17,18]. In these cases, most of their fractures are caused by strong external forces. In addition, in special cases, the presence of AFIT could lead to the pathological damage without trauma [19].

Clinical Manifestation

Patients often present with sudden pain in the back of the thigh or hip, followed by abnormal gait or the inability to walk. Furthermore, the patient may feel or hear a “pop” click on the hip. Physical examination often reveals the following: swelling of the buttocks, accompanied by ecchymosis, tenderness at the ischial tuberosity when touching the bones, inability to sit, and disorders of hip and knee flexion or extension. If accompanied by nerve damage, it can be expressed as pain in the hips and large hind legs, and the most obvious symptom is extreme pain of the hip extension, adduction and external rotation [1].

Imaging Examination

X-ray examination is usually required when AFIT is suspected, and fractures with a significant displacement can be easily diagnosed (Figure 2A). Computed tomography (CT) scans may

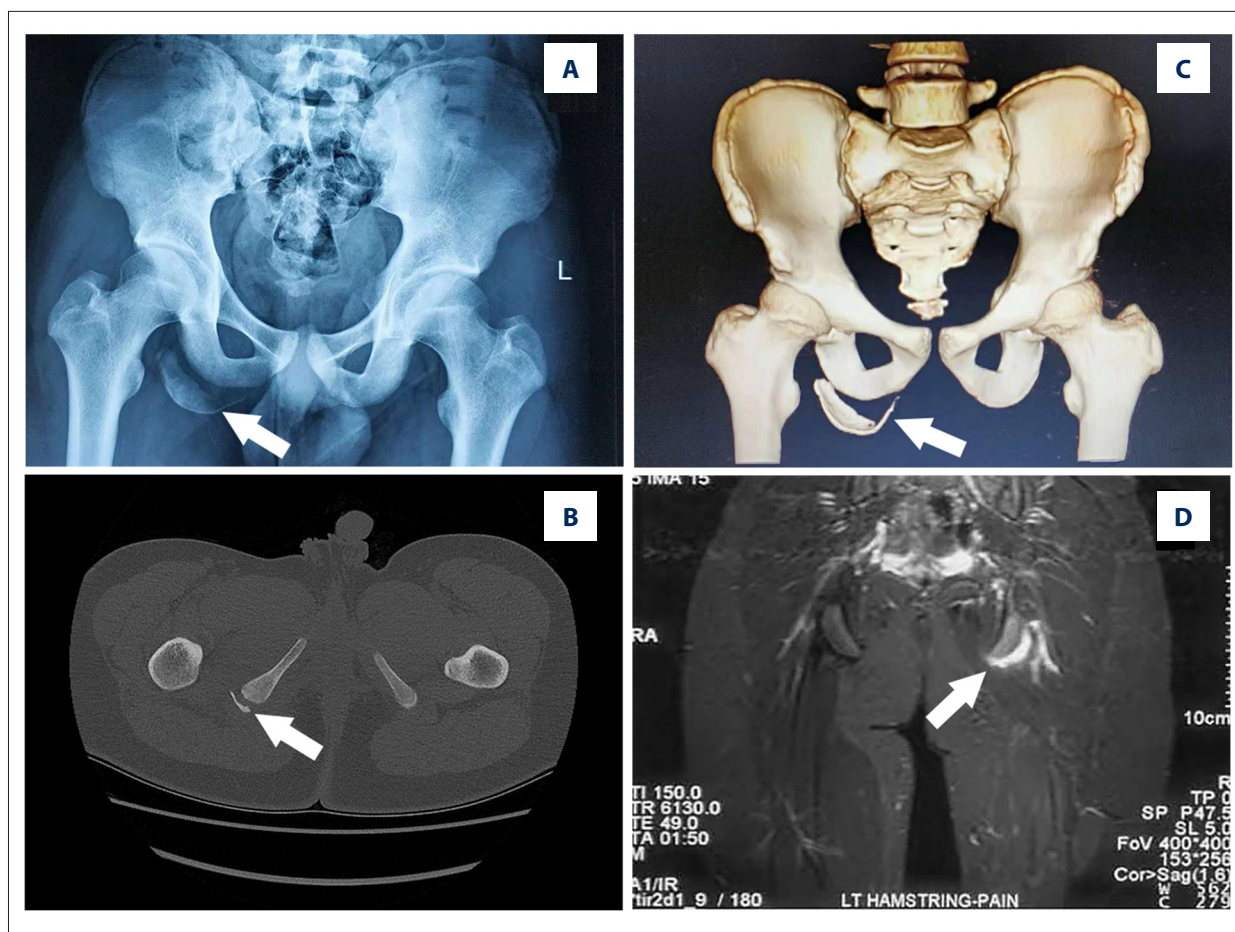


Figure 2. (A) X-ray of the right hip showing the avulsed ischial tuberosity. Note that the x-ray can detect larger displaced fracture blocks. (B) Typical computed tomography (CT) image of the avulsion fracture of the ischial tuberosity. Note that CT can easily detect small displaced fracture blocks. (C) The 3D-CT clearly depicts the shell-like fragment of the displaced fracture block. Note that the 3D-CT scan can more intuitively show the avulsion fractures. (D) Typical coronal magnetic resonance imaging (MRI) scan of the pelvis/thigh demonstrating the displaced ischial tuberosity. Note that MRI can detect occult fractures through the edema-like signal intensity and subperiosteal fluid volume of the sciatic nerve nodules and surrounding soft tissues. (Figure from *J Pediatr Orthop* 2013;33: e72–e76 [27]).

be required for further confirmation of fractures with minor displacements. CT is an important examination for AFIT [20]. It can be used to distinguish fractures with small displacement or partial avulsion (Figure 2B), and CT 3-dimensional reconstruction can more intuitively show the avulsion fractures (Figure 2C). However, magnetic resonance imaging (MRI) is required when AFIT is occult [21,22]. MRI has its unique advantage in AFIT. It can detect occult fractures of the AFIT through the edema-like signal intensity of the ischial tuberosity and surrounding soft tissue, and the amount of subperiosteal fluid [22] (Figure 2D). Some investigators [15] have considered that ultrasound is also a useful diagnostic tool that can be used to identify whether nerve damage is present. However, the investigators in the present study consider that ultrasound was not as good as MRI in the diagnosis of AFIT [23].

Diagnosis and Differential Diagnosis

AFIT can be easily misdiagnosed [2,21], and is often misdiagnosed as a muscle strain in the proximal thigh [5,24]. Early diagnosis requires doctors to have highly skeptical awareness, especially for the pain of adolescent athletes at the ischial tuberosity. In addition, detailed medical history and physical examination are required, and imaging examination is also essential. As mentioned earlier, AFIT should be first differentiated from hamstring injury [25]. In addition, the diagnosis of piriformis syndrome, intervertebral disc disease, and ischial tuberosity bursitis should also be excluded [4]. Some patients may have missed the acute phase at the time of treatment. At this time, AFIT can form a pseudoarticular joint, in which the bone mass is overgrown, similar to a bone tumor [26]. The histopathological examination of the pseudojoint shows

the original bone-like tissue, which usually contains normal trabecular bones and cartilage tissues, and these needs to be differentiated from osteosarcoma and osteochondroma [20].

Treatment

There is no consensus on the treatment of avulsion fractures of the ischial tuberosity. The general view is to choose the treatment method based on the degree of fracture displacement (DFD). Conservative treatment is considered for patients with small DFD, while surgical treatment options would be considered for patients with large DFD. However, some scholars have considered that this is unscientific. The choice of treatment methods also needs to take into account the patient's requirements for functional recovery, which requires individualized treatment options [27]. For surgical treatment options, early and late, open reduction and internal fixation (ORIF) are the main options [28].

Surgical Indication

The opinion of most scholars [29-30] is that conservative treatment should be considered for patients with DFD <2 cm, while some investigators [14,31] have required surgery for a DFD of >1.5 cm. Ferlic et al. [14] studied 13 patients with AFIT, and found that patients with a DFD of >1.5 cm and underwent surgery recovered well. Conservative treatment was selected for some patients with a DFD of >1.5 cm, but half of them formed a pseudoarticular joint. Sikka et al. [27] treated 3 patients, and 2 of these patients had a fracture shift of <5 mm. However, the conservative treatment did not achieve satisfactory results. In the end, the patient was restored to daily activities through surgical treatment. Sundar et al. [32] treated 12 patients with mild AFIT with conservative treatment, and these patients were followed for an average of 44 months. It was found that 8 of these patients had a significant decline in exercise capacity. Consistently, Kaneyama et al. reported a case of an avulsion fracture of the ischial tuberosity treated with a new surgical approach early after injury. In this case report, the authors used the subgluteal approach, which is relatively simple and safe. Therefore, they recommended it for treating AFITs, especially when the fragment is displaced by >2 cm and the sciatic nerve is not involved [33].

This suggested that it is unscientific to judge the treatment according to the DFD. With this, it cannot be denied that the DFD is an important reference factor for determining whether surgery should be performed.

A number of scholars [2,18] have pointed out that many patients who received the conservative treatment ended up in

chronic disability, such as long-term pain, muscle weakness, decreased exercise capacity and sciatica. They also indicated that once a neurological injury occurs, either early or late, surgery must be performed. For example, in one case, conservative treatment did not relieve the patient's sustained pain and neurological symptoms, but the surgery achieved long lasting satisfactory results (observed for 10 years postoperatively) [12]. On the other hand, some investigators [34,35] have considered that since the results of early surgery and late surgery are similar, they suggested that regardless of the size and extent of the fracture, the patient should initially receive conservative treatment, and subsequently choose surgery if the first treatment fails. Nevertheless, some investigators [14,36] have suggested that early surgery should be performed as long as the indications for surgery are met.

From all the cases reported in literatures, it is not difficult to observe that it appears that all patients who have undergone surgery, whether early or late, have recovered to pre-injury levels. Therefore, it can be concluded that: 1) if DFD is <1.5 cm, conservative treatment should be first given, and close follow-up should be subsequently given. If the fracture is not healed or persistent pain is observed, surgery should be chosen. 2) If DFD is between 1.5–2.0 cm, and the patient has high expectation and requires quick functional recovery, early surgery is recommended to achieve anatomic reduction of the fracture. 3) If a patient with a DFD of 1.5–2.0 cm is unwilling to undergo surgery, this patient can be temporarily given conservative treatment, and surgery can be subsequently considered when the conservative treatment fails. 4) If the DFD is >2 cm, early surgical treatment is recommended. 5) If nerve damage is present, emergency surgery is recommended. 6) If the patient missed the early diagnosis or was misdiagnosed in the early stage, or the patient was diagnosed with AFIT and complications occurred in the later stage, surgical treatment is recommended as soon as possible (Figure 3).

Conservative Treatment

In the early stage of conservative treatment, the main tasks include rest and pain control. Although, again, different groups used slightly different programs. However, there is some general trend in treatment approaches: from easy to hard, from using orthosis to without using orthosis, strengthened muscle or even jogging, subsequently. For example, Ceretti et al. [30] proposed a 4-stage rehabilitation program. During the first phase (0–3 weeks), when inability score index (ISI) was approximately 590, the patient received RICE (rest, ice, compression and elevation), nonsteroid anti-inflammatory therapy, and 1 week of careful passive mobilization with soft stretching. During the second phase (3–8 weeks), when $50 \leq \text{ISI} < 90$, the patient underwent progressive agility and trunk stabilization exercises

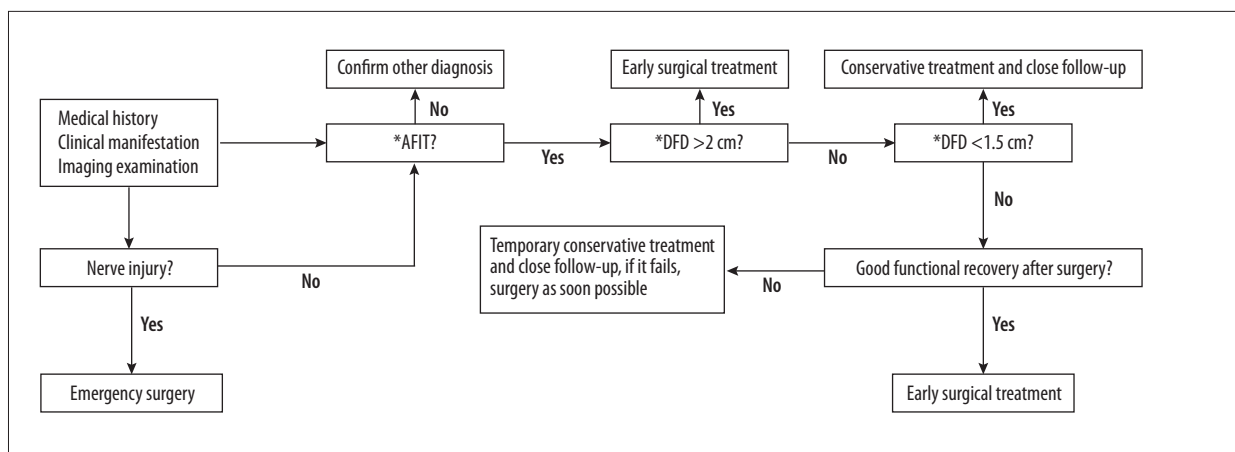


Figure 3. AFIT diagnosis and treatment flowchart. * AFIT – avulsion fracture of ischial tuberosity, DFD – degree of fracture displacement.

with low to moderate intensity. During the third phase (8–16 weeks), when $10 \leq \text{ISI} < 50$, progressive agility and trunk stabilization exercises with high intensity (velocity of movement similar to sport activity) were performed. During the fourth phase (16–24 weeks), when ISI was < 10 , the exercises initially focused on static stretching and isometric strengthening, and subsequently on dynamic stretching with concentric and eccentric hamstring strengthening.

Metzmaker et al. [37] similarly proposed a 4-stage rehabilitation program, which was not expanded in the present study. Furthermore, the studies all judged the recovery of patients according to similar, but slightly different, evaluation systems, allowing the exercise intensity to be gradually intensified until the maximum value of recovery was reached [38].

Surgical Treatment

Early ORIF

For the choice of surgical location, most investigators [15,39] selected the special position of prone, hip and knee flexion, which was considered conducive for the exposure of ischial tuberosity. However, other investigators [14] preferred the lateral position. They believed that the lateral position helped the surgeon to move the patient's hip and knee joints, which made it easier to reset the fracture.

Regarding the choice of surgical approach, most investigators preferred the transverse incision under the gluteal approach. They argued that the transverse incision was good for aesthetics, and the exposed field of view was thus broad, which was conducive to fracture reduction and internal fixation. In 2012, Saka et al. [39] proposed an improved subgluteal approach for the treatment of AFIT. The advantages of

this surgical approach were presented as follows: 1) it has a wide surgical field of view; 2) if necessary, the surgical incision can be expanded; 3) the risk of iatrogenic injury of the sciatic nerve can be reduced; 4) the nerve damage can be easily revealed; and 5) it can also be applicable to the ORIF of chronic avulsion fracture.

Regarding the choice of internal fixation, the options included metal screws, absorbable screws, bone anchors, Kirschner wires and steel wires. In cases with larger fractures, some investigators also chose steel plate and screw fixation. However, there was no consensus for the internal fixation material due to the small number of surgical cases. Nevertheless, from the available data, there were many cases in which metal screws and bone anchors were used.

Late ORIF

The Kocher-Langenbeck approach is the preferred surgical approach for the treatment of AFIT in advanced nonunion [2,21]. This surgical approach facilitates the fixation of the plate to the outer edge of the ischial tuberosity, avoiding direct contact between the internal fixation and stool during sitting. However, when this surgical approach is taken, the ischial tuberosity is located at the deepest part of the incision, which is not conducive to the reduction and fixation of the fracture. Therefore, as mentioned earlier, the subgluteal surgical approach advocated by Saka et al. [39] can also be a good choice for the advanced surgery for AFIT. Regarding the choice of surgical procedure, Pilichou et al. [15] chose to remove the fibrous tissue surrounding the avulsed fracture block, and reset the bone mass. Sikka et al. [27] chose to directly remove the avulsion fracture block, and use the bone anchor to reattach the hamstring tendon to the ischial tuberosity. Putman et al. [2] treated a patient with atrophic fracture of the atrophic ischial tuberosity by wedge osteotomy and plate screw internal fixation.

All of the aforementioned patients had good recovery after surgery. Hence, the choice of surgical method should vary according to the size and fracture, and each individual's plan.

Rehabilitation Exercise

The postoperative rehabilitation plan and conservative treatment are basically the same. However, since surgery has already reduced the fracture, the time to start weight bearing and functional exercises after surgery can be earlier, when compared to conservative treatment. In the rehabilitation exercises, it is worth mentioning that core stability may provide several benefits to the musculoskeletal system, from maintaining low back health to preventing knee ligament injury. Core stability is the ability of the lumbopelvic hip complex to prevent buckling and return to equilibrium after perturbation. Present evidence suggests that decreased core stability may predispose to injury, and that appropriate training may reduce injury [40].

Functional Evaluation

The functional evaluation of AFIT after recovery is mostly based on pain relief and recovery of exercise capacity [21,26]. In order to examine the patient's condition, in 2013, Ceretti et al. [30] proposed a new index, the ISI, which was based on the hip range of motion (ROM) and scores of rest, walking and running pain, as well as other parameters, such as the edema area and fragment diastasis evaluated by x-ray and CT. Since ISI can correctly guide rehabilitation exercises and scientifically

judge recovery, ISI is highly recommended as a routine functional evaluation tool. On the other hand, Ferlic et al. [14] selected the modified Harris hip score to assess recovery. This includes the testing of the total strength, ROM, neurological examination, and the assessment of subjective complaints of the hamstring and adductor muscles, when compared to the contralateral side. In 2018, Tyberghein et al. [5] also proposed the functional assessment by isokinetic dynamometry, which can objectively reflect the recovery of muscle strength.

Conclusions

Due to the low incidence of avulsion fractures of AFIT, there is presently no consensus on its treatment, and a large number of clinical studies are needed to provide a clear guidance. Based on available data and the experiences of this study's investigators, in general, early diagnosis and early surgical treatment are preferred (if necessary) over conservative treatment for AFIT. However, there is presently no single AFIT-specific diagnostic tool/criterion available. Therefore, early diagnosis requires doctors to be highly vigilant, especially for the pain of adolescent athletes, in ischial tuberosity. In addition, detailed medical history, physical examination, and imaging examination are crucial for early and accurate diagnosis. Moreover, we also consider that the development of an individualized treatment plan based on the patient's condition is also crucial.

Conflicts of interest

None.

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