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Tibial Spine Avulsion Fractures: Current Concepts and Technical Note on Arthroscopic Techniques Used in Management of These Injuries

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1. Introduction

Avulsion fractures of tibial spine, leading to discontinuity of anterior cruciate ligament fibers has been well described in literature in both pediatric and adult population. These fractures are also called as tibial eminence fractures or ACL avulsion fractures. They represent a variant of anterior cruciate ligament injury. Poncet in 1895 was probably the first person to document these types of injuries and it was only in 1959 that Meyers and McKeever described an account of surgical management of type II injuries of tibial spine. These injuries are commonly seen in children aged between 8-13 years and are usually sports related injuries occurring especially during cycling and skiing [1-3]. In adults these injuries are commonly related to high energy trauma usually road traffic accidents [31] and have high incidence of associated injuries. The cause of increased incidence amongst children is hypothesized as being secondary to relative weakness of incompletely ossified tibial eminence compared to native ACL fibres [4]. It has also been proposed that injury occurs secondary to greater elasticity of ligaments in young people [5].

2. Relevant anatomy

Tibial eminence is anatomically the eminent confluence of the medial and lateral plateaus and contains two spines. The medial spine bears the broad attachment of the ACL. The broad insertion of ACL fans out from the tibial eminence and coalesces with the attaching fibers of the anterior horn of medial meniscus anteriorly and the anterior horn of the lateral meniscus posterolaterally. The anatomy of these attachments also known as transverse intrameniscal

ligament is important as they may get interposed between the fracture bed and the fractured fragment thereby preventing a successful reduction.

2.1. Classification

Mayer and Mc Keevers first described the method of classification in their article in 1959 [2]. They classified these fractures based on degree of displacement of avulsed fragment.

- *Type I* fracture is an undisplaced fracture of tibial eminence, where in the avulsed fragment is not displaced from the fracture crater.
- *Type II* fracture is partially displaced fracture, in which the anterior part of the avulsed fragment is displaced superiorly from the bone bed and gives a beak like appearance on the lateral x-rays.
- *Type III* fracture is completely displaced fracture and there is no contact of avulsed fragment to the bone bed. Type III has been further subdivided into IIIA and B.
- *Type III* involves only ACL insertion and
- *Type III B* involves entire Intercondylar eminence.
- *Type IV* was later added by Zariczyj [8] to include comminuted fractures of tibial spine.

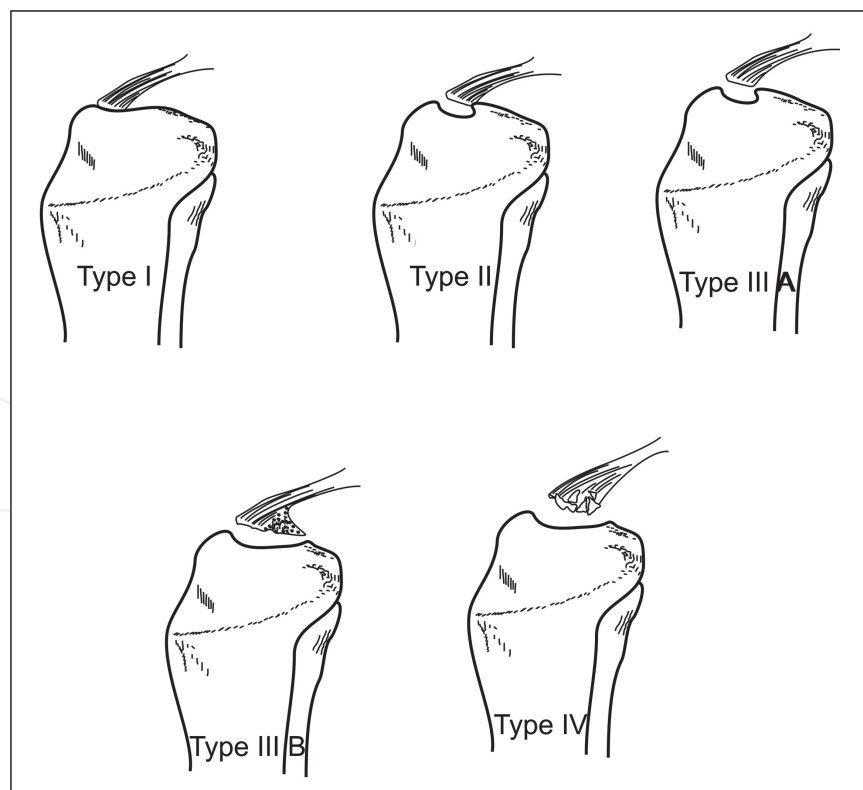


Figure 1. Mayer and Mc Keevers classification of tibial spine avulsion fracture. Type IV Comminuted fracture was added later by Zariczyj

2.2. Imaging

Standard imaging for tibial spine fractures include anteroposterior (AP) and lateral radiographs. Lateral radiographs should be true lateral radiographs which are particularly useful to assess degree of displacement and type of fracture. In skeletally immature patients the actual size of fragment may be significantly larger than what they appear on a radiograph owing to presence of cartilage in the fragment. A notch view is sometimes useful to better visualize the fragment in an AP plane. CT scan is useful in better assessment of fracture anatomy and degree of comminution [9, 14]. MRI is useful in outlining the non-osseous concomitant injuries like meniscal injury, cartilage injury and other ligamentous injury [10, 11].

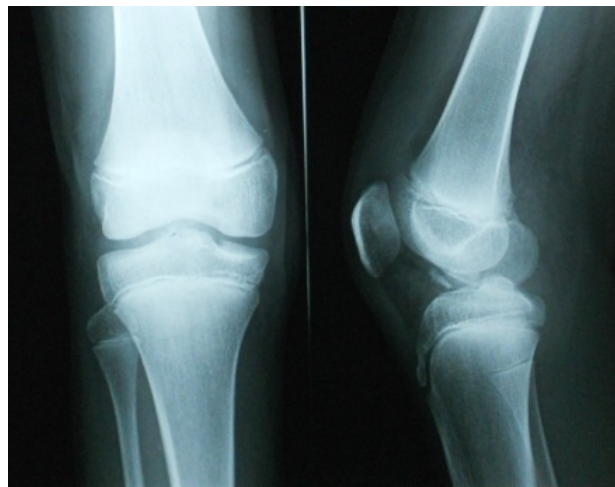


Figure 2. Anteroposterior and lateral view of tibial spine avulsion fracture in immature skeleton



Figure 3. Lateral view of tibial spine avulsion fracture in mature skeleton



Figure 4. MRI of knee showing tibial spine avulsion fracture in immature skeleton

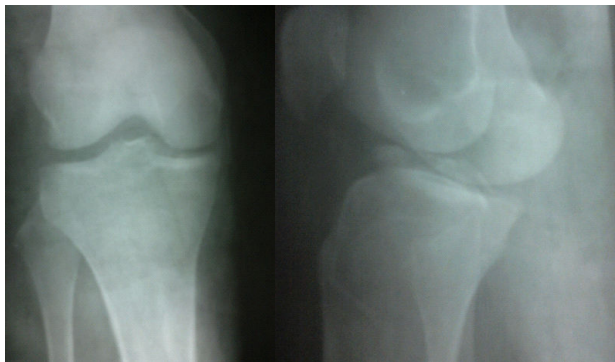


Figure 5. Radiograph of knee showing tibial spine avulsion fracture in Mature skeleton

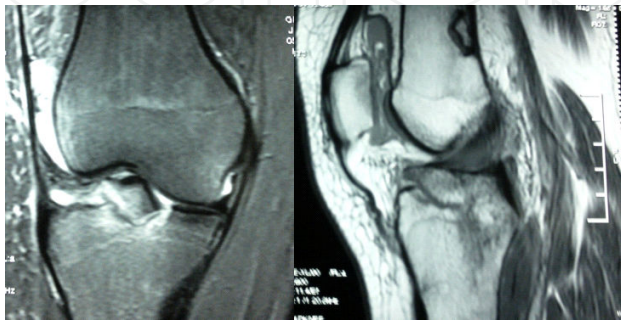


Figure 6. MRI of knee showing tibial spine avulsion fracture in Mature skeleton

2.3. Treatment

Treatment of tibial spine fractures depends on type of fracture, entrapment of soft tissues at fracture site and associated knee injuries.

Chief goals in treating tibial spine avulsion [12-16] are:

- Anatomical reduction of displaced fragment and achieving continuity of ACL fibers. While removing any block to reduction like bone fragments, blood clots, intermeniscal ligament or meniscus.
- Adequate rigid fixation which allows early range of motion exercises
- Eliminate the extension block and impingement due to displaced fragments

2.4. Type I

Type 1 fractures are treated with long leg cast immobilization for a period of 4-6 weeks. Radiographs are done immediately post immobilization to ensure that fragment is not displaced. Follow-up radiographs are done 2 weekly until 6 weeks. Position of knee immobilization in varying angles of flexion, extension and hyperextension has been described in the literature [2, 17]. There is no consensus amongst the researchers as to what should be the knee position during immobilization. We prefer to immobilize in full extension for a period of 4-6 weeks. Hyperextension stretches posterior neurovascular structures and hence should be avoided. Aggressive rehabilitation is required post immobilization to prevent knee stiffness.

2.5. Type II

Treatment of type II fractures has been controversial. In most cases closed reduction and immobilization may be attempted after aspirating knee haemarthrosis. Knee extension allows femoral condyles to reduce the displaced fragment. If acceptable reduction is achieved conservative management should be continued. Loss of reduction is common after conservative management of Type II fractures and should be closely monitored [18]. If there is persistent superior displacement of the fragment seen on lateral radiographs then it is preferable to do arthroscopic reduction and internal fixation because there are high chances that there might be soft tissue entrapment at the fracture site.

2.6. Type III /IV

Treatment of displaced tibial spine avulsion fractures has evolved over a period of time from conservative management to open reduction and internal fixation to arthroscopic reduction and internal fixation. Various methods of fixation are used in operative treatment of these fractures varying from retrograde wires [8] /screws [26], antegrade screws [19], sutures [20, 21, 22, 23, 42], suture anchors [24], and a recently described suture bridge [44] and K wire and tension band wiring [25] technique.

There are only few comparative studies in literature to recommend which is the best technique of fixation for these fractures. Seon and Park [27] did a clinical comparative study of screw

fixation and suture fixation method for tibial spine avulsion fractures and concluded that there is no significant clinical difference in terms of clinical outcome and stability. Bong and coworkers [28] in their biomechanical comparative study of screw versus fibrewire fixation concluded that fibrewire fixation was significantly stronger than cannulated screw fixation. Biomechanical comparison of 4 different methods of fixation was done by Mahar and colleagues [29] on immature bovine knees. They concluded that 2 single-armed #2 Ethibond sutures, 3 bio absorbable nails, a single resorbable screw, or a single metal screw do not have any significant mechanical advantage over other. Tsukada [30] and coworkers did a biomechanical comparative study of antegrade screw fixation, retrograde screw fixation, and pullout suture fixation. They compared the initial fixation strength in response to a cyclic tensile load and found that antegrade screw is most effective in providing initial fixation strength.

2.7. Surgical technique–Pull through suture method

Patient is placed supine with affected leg secured on a leg holder. Standard arthroscopic setup and instruments are required for the surgery. Few instruments, which are specific to suture fixation technique, are 90-degree suture lasso with wire loop (Arthrex), epidural needle no.16 and suture retriever. Though image intensifier is not usually required it should be kept ready so that whenever it is required intraoperatively it can be used.

After giving IV antibiotics leg is exsanguinated and tourniquet is inflated. Standard antero-medial (AM) and anterolateral (AL) portals are made, adequate lavage is given to drain hematoma and clear the vision. The organized hematoma at the fracture site is removed with aggressive shaver blade and fat pad is removed if required. In all cases calf should be palpated at regular interval of time to assess compartment pressure.

Diagnostic arthroscopy is carried out assess additional injuries like meniscal injury, chondral injury or other ligament tears. Fracture crater is adequately cleaned, additional cancellous bone can be curetted to achieve better reduction. After achieving temporary reduction of fragment with 2mm kirschner wire from superomedial portal assess the reduction. Entrapped soft tissue or intermeniscal ligament are released if they are hindering the reduction.

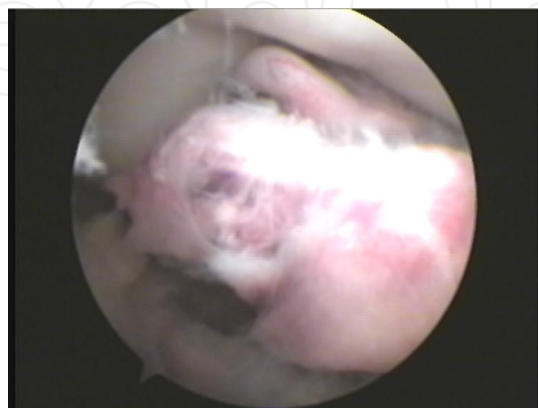


Figure 7. Avulsed fragment of tibial eminence

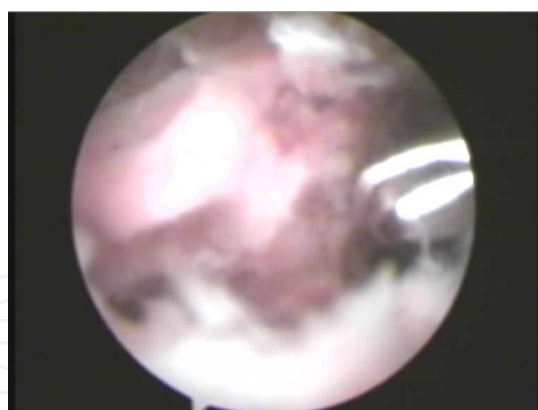
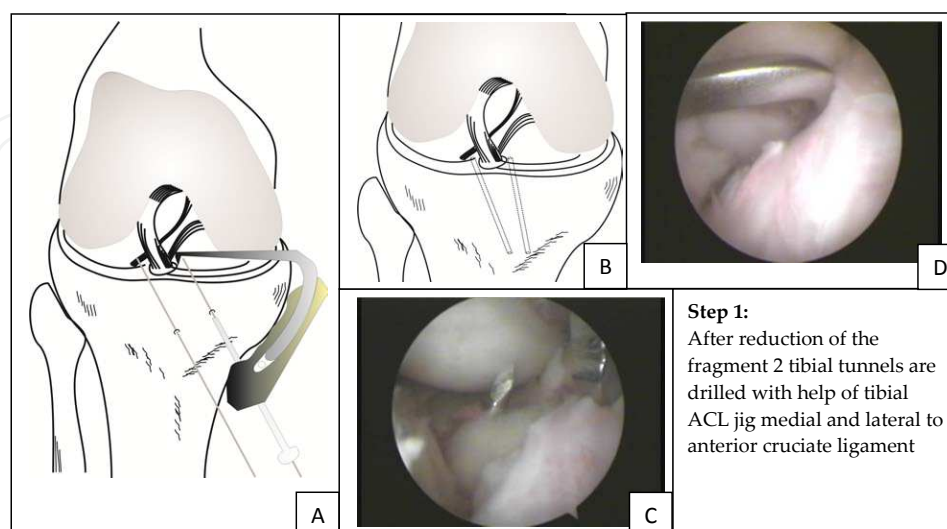


Figure 8. Avulsed fragment of tibial eminence being debrided with shaver

Two drill holes are made with 2.7 mm guide wire with the help of tibial ACL jig medial and lateral to anterior cruciate ligament (ACL) and exiting out on medial tibial cortex. With the scope in lateral portal and 90 degree suture lasso through medial portal a bite is taken in posterior half of ACL substance as close to fragment as possible and retrieve the cable loop through accessory lateral portal or by slightly enlarging lateral portal. Pass a fiber wire no. 2 through the loop and take it out through medial portal. This step is repeated by taking a suture bite through anterior half of substance of ACL.

Epidural or spinal needle no.16 is passed through medial tibial drill hole. Once epidural needle is seen in joint no.1 prolene loop is passed through the needle for suture shuttle. Prolene loop is retrieved through the medial portal. Both the fibrewire threads are passed through the prolene loop outside the joint and then prolene is pulled after holding lateral end of fibre wire with hemostat. Both fibre wire medial sutures will be shuttled through the medial tibial tunnel. This step is repeated for lateral sutures also and retrieved through lateral tibial tunnel.



Step 1:
 After reduction of the fragment 2 tibial tunnels are drilled with help of tibial ACL jig medial and lateral to anterior cruciate ligament

Figure 9. A,B,C,D: Formation of medial and lateral tibial tunnels

Both ends of fibre wire are held under traction and reduction is assessed. In full extension roof impingement is checked.If there is no obstruction to full extension sutures are tied independently over the bone bridge or if bone bridge is inadequate sutures can be tied over endobutton or suture wheel in extension.

In skeletally immature individuals tibial tunnels are made only through epiphysis. Entrance of the drill tip is confirmed under image intensifier before making tibial tunnels. Growth plate is not damaged with this method of fixation.

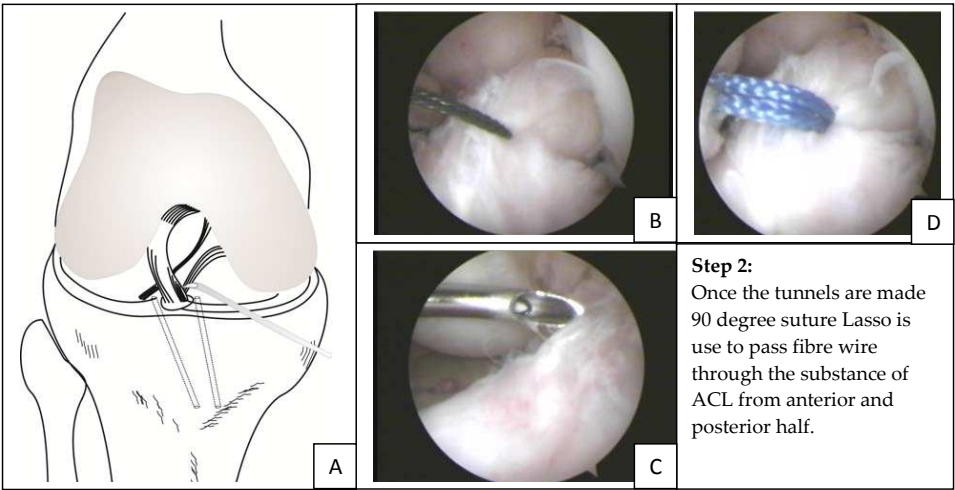


Figure 10. A,B,C,D: passage of lasso loop through the substance of ACL and exchanged with suture

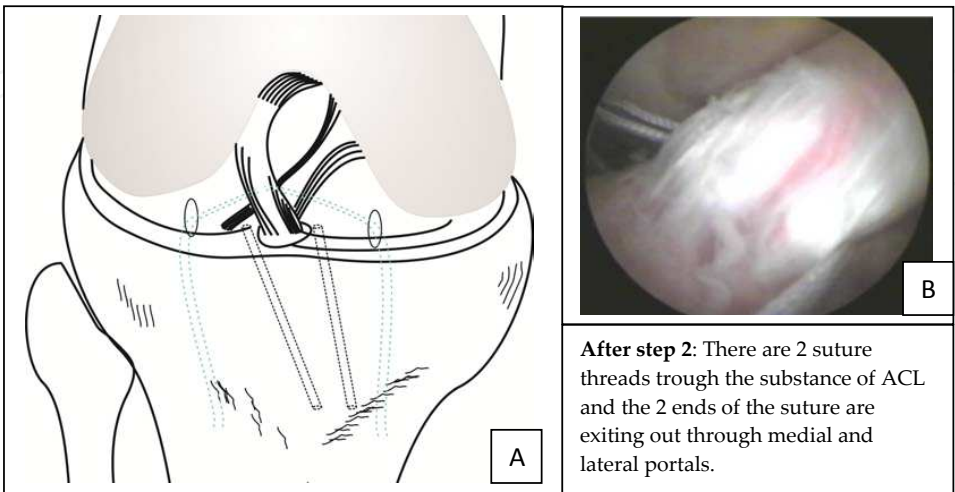


Figure 11. A,B: 2 sutures through the substance of ACL

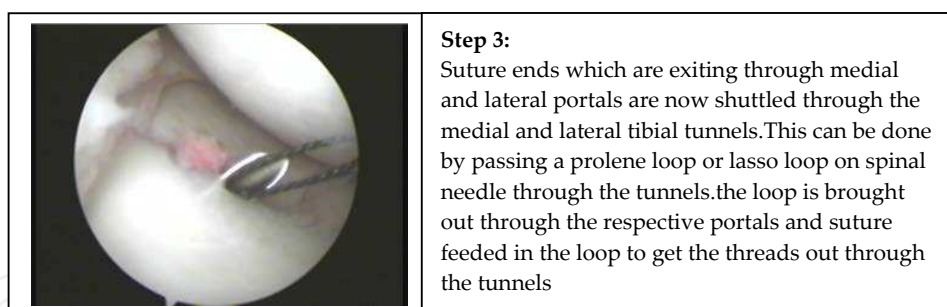


Figure 12. Lasso loop seen through spinal needle passed from one of tibial tunnels

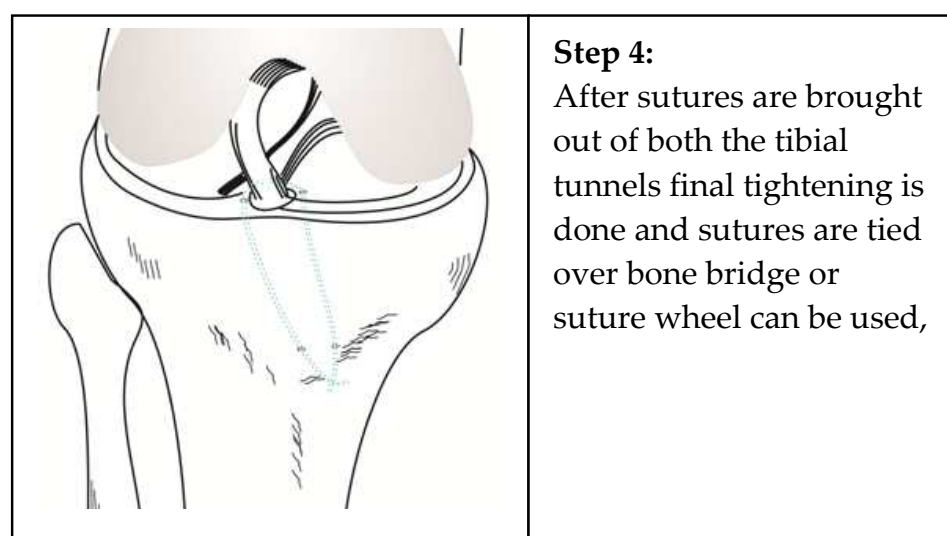


Figure 13. Sutures are seen passing from substance of ACL through tibial tunnels and final tightening is done over suture bridge

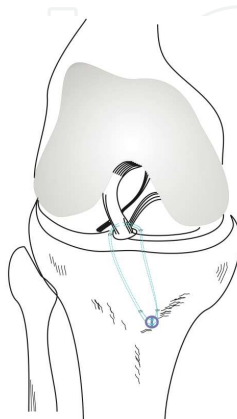


Figure 14. Lasso loop passed through the substance of ACL is tied over a suture disc, alternatively it can be tied over the bone bridge.



Figure 15. Post-operative X-ray showing reduction using pull through suture technique.

Suture fixation is preferable for comminuted fractures. Few authors have recommended suture fixation for all cases due to less risk of neurovascular involvement and less problem of implant prominence [12, 32]

2.8. Screw fixation

Patient is placed under supine position with affected leg on leg holder after administering general or regional anesthesia. Leg is exsanguinated after applying tourniquet.

Standard AM and AL portals are made and knee is adequately lavaged to clear the vision. Arthroscopic shaver is used to resect fat pad and organized hematoma at the fracture site.

Once the fracture site has been debrided reduction is attempted with ACL guide or 90 degree chondroplasty awl. In case intermeniscal ligament hinders the reduction and also cannot be mobilized resection is performed.

After achieving temporary reduction a guide wire from 4mm cannulated cancellous (C.C) screw is inserted through superomedial portal to temporarily hold the reduction. Reduction and guide wire placement is confirmed under image intensifier. This temporary fixation guide wire can be used for screw fixation or an additional wire under image guidance can be introduced. Cannulated cancellous drill bit is drill hole 4mm screw. 4 mm cc screw of appropriate length which is just holding the posterior cortex is used for fixation. Placement of screw is confirmed under image. A second screw can also be placed in provisional fixation wire if fragment is large enough.

Once adequate fixation is done guide wires are removed and knee is gently moved through gentle range of motion. Terminal extension is verified and arthroscopically assessed for notch impingement.

For skeletally immature individuals guide wire is stopped before entering the tibial physis. Drilling is done under image guidance to avoid crossing the tibial physis. Screw length should be just short of tibial physis.



Figure 16. Temporary fixation achieved through guide wire passed from superomedial portal



Figure 17. Screw fixation achieved for avulsed fragment

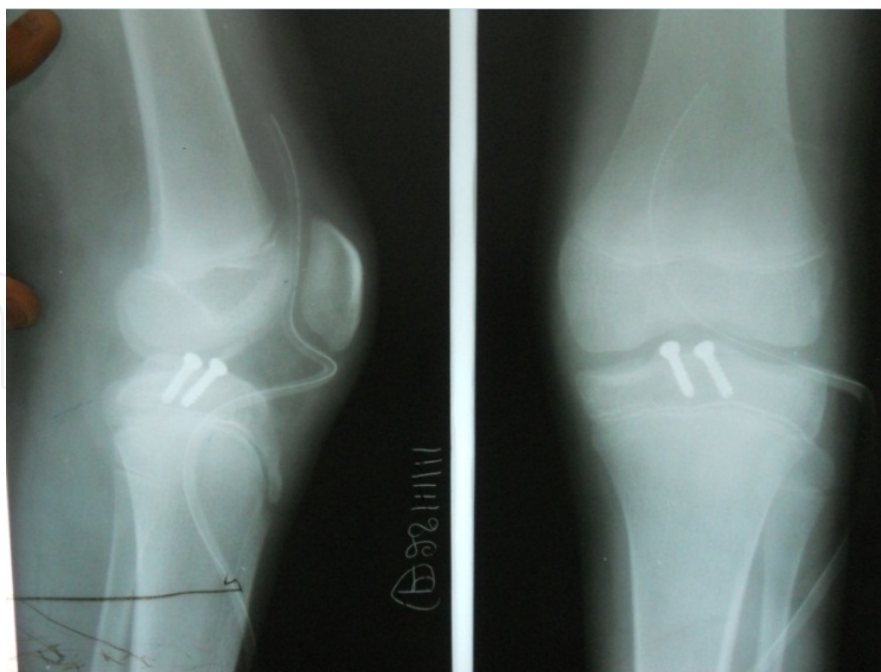


Figure 18. Screw fixation post op x-rays

3. Post-operative rehabilitation

Tibial eminence fractures have excellent prognosis. Previously, prolonged immobilization may lead to arthrofibrosis and a permanent loss of full extension. Therefore, earlier rehabilitation is crucial as it encourages a faster recovery and prevents the development of secondary complications [33]. Rehabilitation is similar to ACL tear protocols activities include static cycling, leg presses, elastic theraband or tubing exercises [34]. Patient is allowed to bear weight through a pair of elbow crutches and as per tolerance. Initial phase include closed kinetic chain exercise like heel slides on bed for ROM and static quads, heel press and SLR in long knee brace. As weight bearing improves, partial squats are included for gaining strength. Studies show that proprioceptive training plays important role in ACL rehabilitation [35-37]. Initial exercise includes balance on rocker board progressed to balance on wobble board. This can further be complicated with tossing the ball between the therapist and the patient while the patient balances himself on the wobble board. After achieving grade four of muscle strength, agility training like zigzag running, karaoke, figure of eight running, hops, etc can be incorporated. Along with training of lower limb muscles emphasis is also given on core strengthening exercises.

4. Complications

Main complications associated with tibial spine avulsion fractures are residual laxity, arthrofibrosis, implant prominence and growth deformity in pediatric patients.

Residual laxity [38] is most common complication of tibial spine avulsion fractures in both conservative and operative method of treatment. Despite the presence of residual laxity most patients are clinically asymptomatic [38, 39]. Few authors have recommend countersinking of the fragment to decrease the residual laxity [38, 40].

Arthrofibrosis results due to prolonged immobilization following a conservative treatment or malunion of the fragment [41]. Aggressive rehab protocol is advised after operative treatment of these fractures to prevent arthrofibrosis. While doing arthroscopic reduction and internal fixation it is recommended to assess the notch in extension to rule out notch impingement and inadequate reduction which can lead to extension loss.

Hardware prominence is common with screw fixation device. Hardware prominence can lead to notch impingement and extension loss. For symptomatic implant prominence implant removal is treatment of choice.

Growth disturbance after fixation of these fractures is uncommonly seen. It is recommended for patients with immature skeleton to undergo physis sparing fixation method [42, 43].

5. Conclusion

Tibial spine avulsion injuries are frequently seen by arthrosocopic surgeons. It is important that they are diagnosed promptly. Various treatment options exist and generally the results are good if an anatomic reduction is obtained.

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