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TIBIAL SPINE AVULSION FRACTURES IN ADULTS TREATED WITH ACL RECONSTRUCTION

Orthopaedics

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ABSTRACT

Introduction: Tibial spine fractures are avulsion fractures of the anterior cruciate ligament (ACL). They are more frequent in children than in adults. Arthroscopic fixation methods for such fractures are technically demanding, and their outcomes are compromised due arthrofibrosis leading to knee stiffness, residual ACL laxity causing anterior instability, mal-union, non-union and protruding hardware, all of which may require subsequent surgery. **Material And Methods:** This is a retrospective study reporting medium-term results of a series of displaced tibial spine avulsion fractures in adults treated with arthroscopic ACL reconstruction using a quadrupled Semitendinosus-Gracilis graft. From January 2019 to June 2021, 9 patients treated using this technique with a minimum follow-up of 2 years were included in this study. There were 7 new fractures and 2 cases were of non-union of tibial spine avulsion fracture previously treated non-operatively. Clinically, all patients had anterior laxity of the knee pre-operatively. **Results:** At 6 months all patients had regained full range of movement of the knee, complete functional recovery and ability to return to work. At the last follow-up at 2 years or beyond, in all patients anterior drawer test, Lachman test and pivot shift test were negative, and all patients had returned to their pre-injury activity levels. Outcomes as per Modified Lysholm score and also, as per Tapper and Hoover grading were excellent in 5 cases and good in 4 cases. No patient required any form of reoperation. **Conclusion:** Arthroscopic ACL reconstruction using a quadrupled Semitendinosus-Gracilis graft is a satisfactory method of primary treatment for displaced tibial spine avulsion fractures in adults, and also for non-union of these fractures. Patients thus treated do not have residual ACL laxity or instability, they do not have knee stiffness, and they do not need any subsequent surgery.

KEYWORDS

Tibial spine avulsion fracture, anterior instability, ACL reconstruction

INTRODUCTION

Tibial spine avulsion fracture is usually avulsion fracture of the anterior cruciate ligament (ACL) and is a major intra-articular injury. These injuries are commonly encountered in children between the ages of 8 and 14 years, and are usually sports-related injuries occurring especially during cycling and skiing. In adults, the same traumatic mechanism usually causes ACL tears making tibial spine avulsion fractures quite infrequent during adulthood, although their incidence now appears to be higher than previously thought. Also, in adults, tibial spine avulsion fractures are usually due to high-velocity road traffic accidents.

Mayers and McKeever[14] classified these fractures based on the degree of displacement of the avulsed fragment.

Type I fracture: An undisplaced fracture of tibial eminence, where in the avulsed fragment is not displaced from the fracture crater.

Type II fracture: A 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: A completely displaced fracture and there is no contact of the avulsed fragment to the bone bed. Type III has been further subdivided into III-A and III-B.

Type III-A involves only ACL insertion and *Type III-B* involves entire intercondylar eminence.

Type IV fracture: Added later by Zariczynj[29] to include comminuted fractures of tibial spine.

There is a high incidence of associated injuries with tibial spine avulsion fractures. Concomitant tibial plateau fractures and osteochondral fractures can occur along with tibial spine avulsion fractures. Interstitial injury to the anterior cruciate ligament has been reported in these fractures[10,12]. Mayo et al.[12] reported concomitant ACL injuries in 25 of their 129 patients (19%), with higher rates in older male patients. Yamauchi et al.[27] reported a case of tibial eminence fracture with mid-substance tear of anterior cruciate ligament in a 10-year-old boy. Other concomitant non-osseous injuries like meniscal injury, cartilage injury and other ligamentous injury can also occur. Aderinto et al.[1] reported medial collateral ligament sprain and posterolateral corner injury with tibial spine avulsion fractures.

McMains et al.[13] reported associated rupture of patella tendon with tibial tubercle avulsion fracture in a skeletally mature patient with tibial spine avulsion fracture. MRI is useful in outlining such associated injuries[18,25]. However, Mayo et al.[12] found that pre-operative MRI had low sensitivity for recognizing ACL injury associated with tibial spine avulsion fractures compared with intra-operative assessment.

Treatment options for tibial spine avulsion fractures include cast immobilization, closed reduction with immobilization, open reduction with immobilization, open reduction with internal fixation, arthroscopic reduction with immobilization and arthroscopic reduction with fixation[9]. Surgical treatment is indicated for Type II, Type III and Type IV fractures. The goal of operative treatment is to restore full range of motion and knee stability.

Arthroscopic fixation of these fractures has the advantages of having better visualization, ability to deal with associated intra-articular pathologies and decreased morbidity when compared with open surgery due to being minimally invasive, Arthroscopic fixation may be accomplished with either sutures or hardware like metal screws, Herbert screws, staples, Kirschner wires, suture anchors, etc.. However, most arthroscopic fixation methods are technically demanding, and carry risks of comminution of the fracture fragment, partial detachment of ACL insertion during reduction/fixation of the fracture fragment, implant breakage, implant loosening and high failure rate. Outcomes of fixation of displaced tibial spine avulsion fractures are also compromised due to arthrofibrosis leading to knee stiffness, residual ACL laxity causing anterior instability, mal-union, non-union and protruding hardware, all of which may require subsequent surgery.

The purpose of this study is to present that displaced tibial spine avulsion fractures in adults usually have damage of ACL such as interstitial damage and mid-portion tears sustained at the time of injury, and therefore arthroscopic ACL reconstruction is a satisfactory method of primary treatment for these fractures as it removes all the above mentioned risks associated with fixation of these fractures including residual ACL laxity causing instability, arthrofibrosis leading to knee stiffness and need for reoperation. This study also confirms that arthroscopic ACL reconstruction is the treatment of choice for non-union of these fractures previously treated non-operatively.

MATERIAL AND METHODS

This is a retrospective study reporting medium-term results of a series of displaced tibial spine avulsion fractures in adults treated with arthroscopic ACL reconstruction using a quadrupled Semitendinosus-Gracilis graft. From January 2019 to June 2021, 9 patients were treated

Table 1

	Age Sex	Side	M-M Type	ACL Status On Pre-Op MRI	ACL Status On Arthroscopy	Associated Injury On MRI And Also On Arthroscopy	Tibial Spine Fragment	Injury-To-Surgery Time	Follow-Up In Months	Post-operative Complications	Modified Lysholm Score At Last Follow-Up	Outcome As Per Tapper & Hoover Grading
1	24 years Male	Right	III-A	Dispersed Fibers of Mid-portion of ACL	Bruising of ACL with Some Mid-portion Fraying	Lateral meniscus Tear	Fully Exiced	6 Days	29	None	92	Excellent
2	26 years Male	Right	III-A	Dispersed Fibers of Mid-portion of ACL	Mid-portion Tear With Fraying of ACL	None	Partly excised	13 Days	25	Early Minor Wound Infection with Cellulitis	89	Good
3	28 years Male	Right	III-A	Interstitial Altered Signal of ACL	Bruising and tear of mid-portion of ACL	Tear of lateral meniscus, red-red zone tear of medial meniscus, tear of MCL and tear of patellar tendon	Fully excised	5 Days	31	None	93	Excellent
4	27 years Male	Right	III-A	Interstitial Altered Signal of ACL	Bruising of ACL with Some Mid-portion Fraying	None	Partly excised	23 Days	24	None	96	Excellent
5	29 years Male	Right	III-A	Interstitial Altered Signal of ACL	Some Mid-portion Fraying of ACL	Red-red zone tear of medial meniscus and tear of MCL	Fully excised	12 Days	28	None	85	Good
6	25 years Female	Right	III-B	Interstitial Altered Signal of ACL	Bruising with Laxity And Elongation of ACL	Tear of lateral meniscus	Partly excised	7 Days	27	None	91	Excellent
7	23 years Female	Left	III-A	Interstitial Altered Signal of ACL	Bruising of Mid-portion of ACL	None	Partly exicesd	19 Days	33	Slightly Tender Scar Possibly due to Neuroma	89	Good
8	38 years Female	Left	III-A	Interstitial Altered Signal of ACL	Intact ACL, but was effectively lax due to the non-union of the tibial spine fragment	None	Fully excised	33 months	24	None	85	Good
9	19 years Male	Right	III-A	Interstitial Altered Signal of ACL	Intact ACL, but was effectively lax due to the non-union of the tibial spine fragment	None	Fully excised	30 months	28	None	96	Excellent

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using this technique.

We had 3 female and 6 male patients, of ages ranging 19 to 38 years with average age of 26.55 years. Left knee was involved in 2 cases and right knee in 7 cases. Details of these cases are outlined in Table 1.

Of the 9 cases, 8 had type III-A fracture and 1 had type III-B fracture. Of these 9 cases, 7 were new fractures who underwent the operation after an average interval of 12.14 days from the date of injury (range from 5 days to 23 days). 2 cases were non-union of tibial spine avulsion fractures previously treated non-operatively but had been left with pain and anterior instability of the knee; one of these 2 cases was a 38 year-old female patient who had sustained the injury 33 months earlier, and the other was a 19 year-old male patient who had sustained the injury 30 months earlier.

In those 7 cases with new fractures, pre-operative MRI showed dispersed fibers of mid-portion of ACL in 2 cases and interstitial altered signal of ACL in 5 cases. In the 2 cases with non-union of the tibial spine avulsion fracture pre-operative MRI showed interstitial altered signal of ACL in both cases. Pre-operative MRI of cases with new fractures also showed that 2 patients had concomitant lateral meniscal tears, 1 patient had associated complete tear of medial collateral ligament with peripheral red-red zone tear of medial meniscus, and another patient had associated complete tear of medial collateral ligament with peripheral red-red zone tear of medial meniscus, tear of lateral meniscus and tear of patellar tendon. 3 other patients with new fractures and the 2 cases with non-union of old tibial spine avulsion fractures did not have any meniscal tears or any other associated injuries.

Pre-operative clinical examination confirmed that all 9 cases had positive anterior drawer test, positive Lachmann test and positive pivot shift test. The 2 cases with medial collateral ligament tear had significant laxity of the medial side on valgus stressing of the knee and severe bruising and swelling of the medial aspect of the knee, and one of these patients also had concomitant tear of the patellar tendon. The patient with medial collateral ligament tear and tear of the patellar tendon had sustained the knee injury due to fall from height of 15 feet, and the other patient with medial collateral ligament tear had sustained the knee injury in a high speed motorbike accident.

No patients had any major post-operative complication. 1 patient had early minor wound infection with cellulitis. A slightly tender scar possibly due to neuroma formation was seen in 1 another case.

Minimum follow-up of these cases was 2 years, ranging from 24 months to 33 months with average follow-up of 26 months.

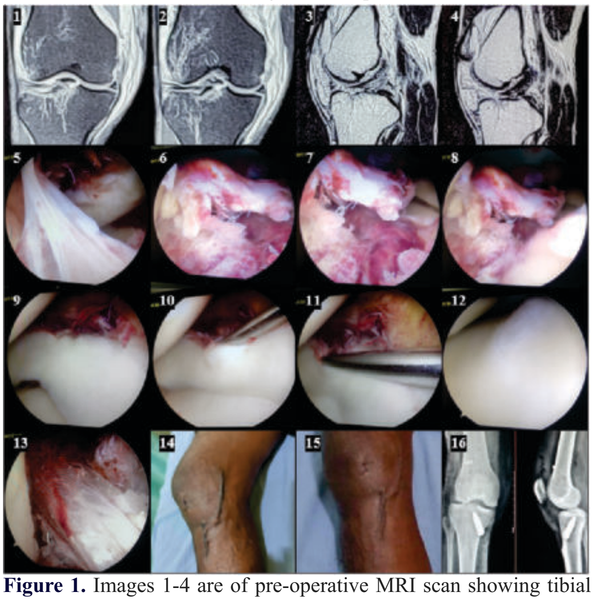

Figure 1. Images 1-4 are of pre-operative MRI scan showing tibial spine avulsion fracture, altered interstitial signal of ACL, complete tear of medial collateral ligament and peripheral detachment of medial meniscus. Image 5 shows initial arthroscopy finding of intact ligamentum mucosum. Images 6-8 show arthroscopy findings of displaced tibial spine avulsion fracture and bruised-torn ACL. Images 9-11 show arthroscopy findings of red-red zone tear of medial meniscus, tear of MCL and peripheral separation of medial meniscus from the MCL-capsular attachment. Image 12 shows arthroscopy finding of intact lateral meniscus. Image 13 shows arthroscopy picture of reconstructed ACL. Images 14-15 show post-operative wounds. Image 16 shows postoperative x-ray after ACL reconstruction.

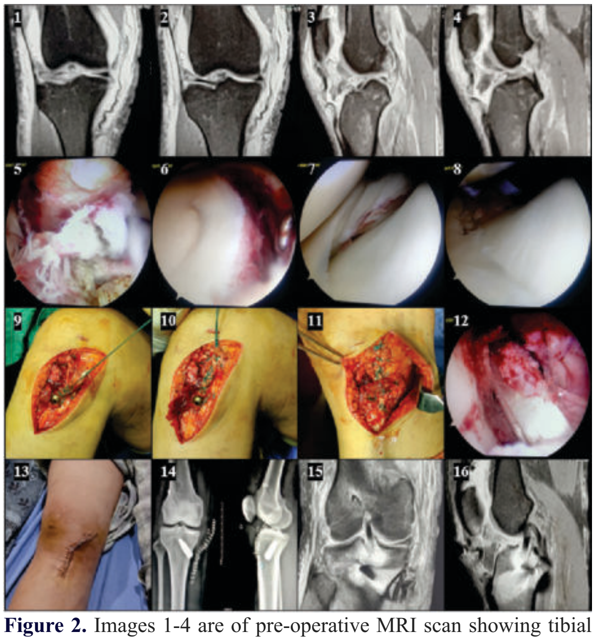

Figure 2. Images 1-4 are of pre-operative MRI scan showing tibial spine avulsion fracture, altered interstitial signal of ACL, complete tear of medial collateral ligament, peripheral detachment of medial meniscus and tear of patellar tendon. Image 5 shows arthroscopy findings of displaced tibial spine avulsion fracture and bruised-torn ACL. Image 6 shows arthroscopy findings of red-red zone tear of medial meniscus, tear of MCL and peripheral separation of medial meniscus from the MCL-capsular attachment. Image 7 shows arthroscopy finding of tear of lateral meniscus. Image 8 shows arthroscopy picture after excision of posterior horn tear of lateral meniscus. Images 9-11 show interference screw holding the STG graft of reconstructed ACL in the tibial tunnel, repaired patellar tendon, and open repair of MCL with its reinforcement by suturing the end of STG graft on to it. Image 12 shows arthroscopy picture of reconstructed ACL. Image 13 shows the wound closure. Image 14 shows post-operative x-ray after ACL reconstruction. Image 15-16 show post-operative MRI scan after ACL reconstruction.

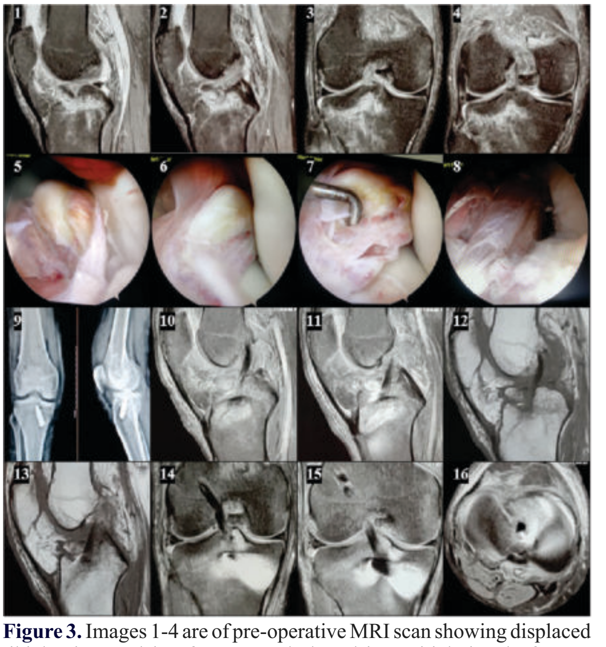

Figure 3. Images 1-4 are of pre-operative MRI scan showing displaced tibial spine avulsion fracture and altered interstitial signal of ACL. Images 5-6 show arthroscopy findings of displaced tibial spine

avulsion fracture and bruised-torn ACL. Image 7 shows interstitial mid-substance tear of ACL on probing. Image 8 shows arthroscopy picture of the reconstructed ACL. Image 9 shows post-operative x-ray after ACL reconstruction. Images 10-16 are of post-operative MRI scan after ACL reconstruction. These post-operative x-ray and post-operative MRI scans show that a large portion of the avulsed tibial spine fracture fragment is left behind to heal to its bed and the reconstructed ACL lies fully behind the large tibial spine fracture fragment.

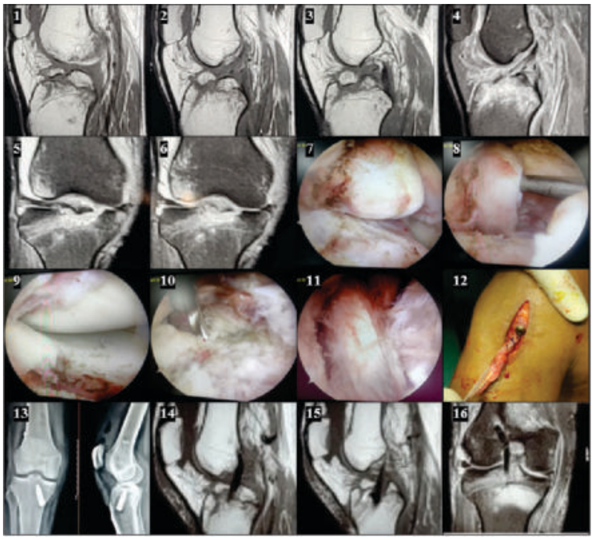

Figure 4. Images 1-6 are of pre-operative MRI scan showing displaced tibial spine avulsion fracture and altered interstitial signal of ACL. Images 7 shows arthroscopy finding of bunched up ACL attached to the displaced tibial spine avulsion fracture. Image 8 shows arthroscopy finding of lax and bruised ACL on probing. Image 9 shows the displaced tibial spine avulsion fracture and its bed. Image 10 shows arthroscopy picture of the tibial guide wire coming out into the tibial intercondylar area after removal of ACL and some of the tibial spine avulsion fracture fragment. Image 11 shows arthroscopy picture of the reconstructed ACL. Image 12 shows the interference screw fixing the STG graft in the tibial tunnel. Image 13 shows post-operative x-ray after ACL reconstruction. Images 14-16 are of post-operative MRI scan pictures after ACL reconstruction. These post-operative x-ray and post-operative MRI scans show that large portion of the avulsed tibial spine fracture fragment is left behind to heal to its bed and the reconstructed ACL lies fully behind the large tibial spine fracture fragment.

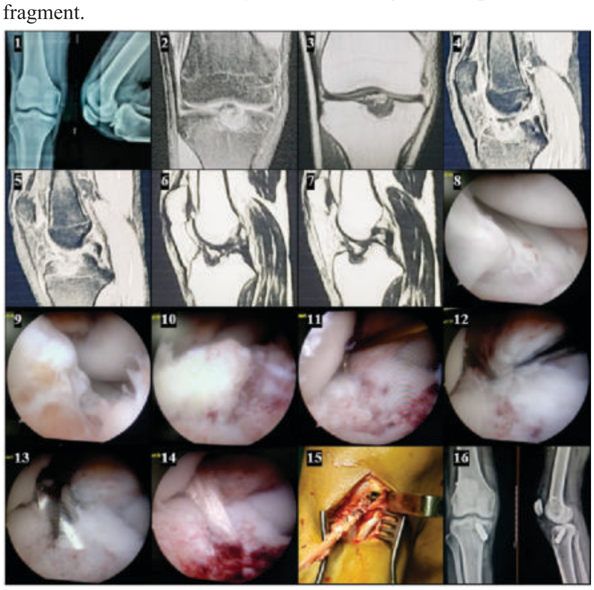

Figure 5. Image 1 shows x-ray of non-union of tibial spine fracture in a 19 year old male patient. Images 2-7 are of pre-operative MRI scan showing non-union of displaced tibial spine avulsion fracture and altered interstitial signal of ACL. Images 8-9 show arthroscopy finding of non-union of the displaced tibial spine avulsion fracture held to its bed with fibrous tissue. Image 10 shows arthroscopy finding of the tibial spine fragment after removal of fibrous tissue at the non-union site. Image 11 shows the arthroscopy picture of the tibial intercondylar area after removal of the tibial spine avulsion fracture fragment and the placement of ACL-tibial jig posterior to the bed of the tibial spine fracture. Images 12 and 13 show the arthroscopy pictures of the tibial intercondylar area with the tibial guide wire (image 12) and the tibial dril1 (image 13), both being posterior to the bed of the tibial spine fracture. Image 14 shows arthroscopy picture of the reconstructed ACL. Image 15 shows the interference screw fixing the STG graft in the tibial tunnel. Image 16 shows post-operative x-ray after ACL reconstruction.

Surgical Technique

All knees were treated with arthroscopic ACL reconstruction using a quadrupled Semitendinosus-Gracilis graft performed by the senior author[*1]. All cases had operation done under spinal anesthesia. Tourniquet was used in all the cases. Standard medial and lateral para-patellar portals were established and diagnostic arthroscopy was carried out. Some of the fat pad was removed with a shaver or RF probe to allow good visualization of the intercondylar notch with the knee in flexion.

During arthroscopy the size and displacement of the tibial spine avulsion fracture fragment and the integrity of ACL attachment to it were initially assessed. Then ACL was carefully probed to ascertain injury associated with these fractures such as mid-portion tear and interstitial injury of fibers of ACL with bruising and elongation of ACL.

Arthroscopy of the 7 cases with new fractures showed some mid-portion tear with fraying of ACL fibers in 2 cases, some mid-portion fraying in 1 case and bruising of ACL in 4 cases. In these 7 cases with new fractures no attempt was made to reduce and fix the fracture fragment as the aim in these cases was to perform ACL reconstruction as the primary treatment. The ACL attachment of the tibial spine avulsion fracture fragment was taken down with RF probe. Rest of the ACL was then excised right up to its femoral attachment using a combination of punch forceps, shaver and RF probe. The tibial spine avulsion fracture fragment was then again carefully assessed for its size and stability. If the fragment was small and loose, it was entirely removed from the joint. If the fragment was large and stable, it was only partly removed so as to ascertain the correct positioning of the tibial tunnel and the rest of the fragment was left behind to heal to its bed. Of the 7 cases with new fractures, the tibial spine fracture fragment was partly excised in 4 cases and fully excised in 3 cases. In all cases the opening of the ACL tibial tunnel in the joint was posterior to the fracture fragment and its bed.

Arthroscopy of the 2 old cases with non-union of the tibial spine fracture, the fragment was small in size possibly due to some bone loss and was not stable once the ACL attached to it and scarring around the non-union were removed. Therefore, in these cases the entire tibial spine fragment was excised along with the ACL and then ACL reconstruction was performed.

Semitendinosus and gracilis tendons were harvested by a 3 cm longitudinal incision placed over pes anserinus on the anteromedial surface of the proximal metaphysis of tibia starting at the level of the prominence of tibial tuberosity and extending downward. All muscle fibres were removed from the STG graft and sizing of the quadrupled tendon graft was done.

Thereafter, arthroscopy was resumed to locate the over-the-top position of the lateral femoral condyle and that area was then prepared by removing its soft tissue attachments using RF probe. The remaining bony landmarks in the intercondylar region of tibia were then carefully assessed for the placement of the pointer of standard tibial jig. Tibial guide wire was then passed using the tibial jig. Tibial tunnel was then made using a cannulated tibial drill of appropriate size (usually 8mm and rarely 9 mm) depending on the size of the quadrupled STG graft.

Then a 5 mm or 7 mm over-the-top femoral jig was then inserted into the knee through the tibial tunnel and its flange was placed above the over-the-top position. Femoral guide wire was then passed through the femoral jig into the femur at the femoral ACL footprint with the knee in 70-80 degrees of flexion. Femoral jig was then pulled out of the knee through the tibial tunnel. Then the initial femoral tunnel was made using a 4.5 mm cannulated drill over the femoral guide wire. Length of the femoral tunnel was measured and appropriate sized endobutton loop was then chosen. Quadrupled STG graft was then prepared by passing the STG tendons through the chosen endobutton loop and stitching the ends of the tendons together. Length and diameter of the prepared graft were measured and markings were made on the graft using a marker pen.

Femoral tunnel was then completed by over-drilling an appropriate length of the initial femoral tunnel over the guide wire with a larger femoral drill usually of the size of the tibial drill used earlier. The endobutton with the graft was then pulled through the tibial tunnel and into the femoral tunnel. The endobutton was then flipped over the femoral cortex and the graft was then securely fixed to the tibial tunnel with an appropriately sized titanium interference screw (usually 2-3 mm larger than the size of the tibial tunnel) with the graft under proper tension. The reconstructed ACL was then assessed for impingement with the femoral intercondylar notch when the knee is fully extended.

Meniscal tears were also identified and treated appropriately. Arthroscopy confirmed lateral meniscal tear in 2 cases as shown on the pre-operative MRI, and these lateral meniscal tears were treated by partial lateral meniscectomy.

Arthroscopy of a case with tear of the medial collateral ligament showed extensive peripheral red-red zone tear of mid-portion of medial meniscus. This patient underwent open repair of the peripheral red-red zone tear of the medial meniscus to restore its capsular attachment along with repair of the torn medial collateral ligament.

Arthroscopy of another case with tear of the medial collateral ligament showed extensive peripheral red-red zone tear of mid portion of medial meniscus, tear of posterior horn of lateral meniscus, bruising and mid-portion tear of ACL and tear of the patellar tendon. This patient underwent open repair of the peripheral red-red zone tear of the medial meniscus to restore its capsular attachment along with repair of the torn medial collateral ligament, excision of posterior horn of lateral meniscus, excision of tibial spine fracture fragment and open repair of tear of patellar tendon. Also, in this case, after ACL reconstruction, the remaining excess portion of lower end of the STG graft was turned upward from the outer end of the tibial tunnel and stitched over the repaired medial collateral ligament to reinforce the repaired medial collateral ligament.

Post-operatively patients were advised to use a locking knee brace and were allowed to bear weight as tolerated with a pair of elbow crutches. Patients were asked to start knee exercises to improve range of movement, muscle strength and proprioception. During the initial phase up to 3 weeks patients were asked to do closed kinetic chain exercises like heel slides on bed for ROM and static quads, heel press and SLR in a knee immobilizer splint. As weight bearing improved, partial squats were included for gaining strength. From 6-8 weeks onward patients were encouraged to progress on to more intensive exercises and gradually return to pre-injury activity levels. Griffin et al.[6], Heijne et al.[7] and Nicholas et al.[16] have shown that proprioceptive training plays important role in ACL rehabilitation. Initial proprioceptive training exercises included balance on rocker board progressing to balance on wobble board. When the patients regained adequate muscle strength, they were advised to start agility training like zigzag running, figure of eight running and hops.

RESULTS

Patients were followed-up at 2 weeks, 6 weeks, 3 months, 6 months and after 2 years.

Tapper and Hoover grading system[22] (Table 2) as well as Modified Lysholm score[23] were used to assess the result at the time of last follow-up. Patients were asked about the level of their activities. All results were then graded into Excellent, Good, Fair or Poor as per Tapper and Hoover grading system and Modified Lysholm score.

Table 2 The Tapper & Hoover Grading System

Excellent	An effective and completely normal knee.
Good	A knee giving minor symptoms, but no disability, i.e. the knee is functional in all activities including vigorous sports, but with some ache or swelling afterwards.
Fair	A knee giving definite symptoms and some disability, preventing vigorous sports.
Poor	A knee giving symptoms, e.g., aching while kneeling or climbing stairs, which interferes with daily activities. Definite mechanical symptoms, e.g. locking, also indicates a poor grade.

At the 6 months, all patients had regained full range of movement of the knee, complete functional recovery and ability to return to work.

At the last follow-up at 2 years or beyond, in all patients anterior drawer test, Lachman test and pivot shift test were negative, and all patients had returned to their pre-injury activity levels.

Modified Lysholm Score at the last follow-up ranged from 85 to 96 with an average of 90.66. Outcomes as per Modified Lysholm score and also as per Tapper and Hoover grading were excellent in 5 cases and good in 4 cases.

DISCUSSION

Surgical treatment is indicated for displaced tibial spine avulsion fractures (Types II, III and IV fractures). The goal of operative treatment is to restore full range of motion and knee stability. Arthroscopic fixation of tibial spine avulsion fractures is technically demanding and although many techniques of fixation of these fractures have been described, none has been accepted as the gold standard technique to date[4]. This is because no technique has been entirely successful in preventing the various problems that can occur after fixation of these fractures, especially knee joint instability and knee stiffness.

Fixation of displaced tibial spine avulsion fractures can cause arthrofibrosis leading to knee stiffness. Also, after fixation of these fractures a large proportion of patients are left with residual ACL laxity. This can be due to interstitial injury to the ACL sustained at the time of the original injury causing elongation and laxity of ACL. Partial detachment of ACL insertion can occur during reduction and fixation of these fractures. Blood supply of ACL can also be compromised during fixation of these fractures. Mal-union and non-union of these fractures and loosening of implant can also cause ACL laxity resulting in instability. All these problems and also protruding hardware may require subsequent surgery.

Sun et al.[21] stated that risk factors for postoperative stiffness include long immobilization period, complete fracture displacement, mal-union, hardware protrusion, more than one surgical intervention and increasing age.

May et al.[11] retrospectively studied the outcome of fixation of tibial spine fractures in 22 patients. In their series patients above 18 years had worse functional outcomes than those below 18 years. They concluded that age older than 18 years was a statistically significant factor for lower outcome scores which they attributed to postoperative stiffness, fracture displacement, need for secondary surgery and longer post-operative immobilization requirement with increasing age. They also found that those with comminution had lower Tegner scores, and those with screw fixation had a higher reoperation rate due to symptomatic hardware removal. They reported an average loss of extension between 7-10 degrees in 22 patients treated with arthroscopic screw fixation, and 57% of patients in their series underwent symptomatic hardware removal.

Bram et al.[3] reported on risk factors for arthrofibrosis in tibial spine fractures in a multicenter study. They concluded that risk of arthrofibrosis is higher in younger patients with concomitant ACL tears and traumatic injuries not resulting from athletics and with postoperative immobilization in a cast. They also concluded that concomitant ACL injury is associated with a higher return to the operating room for MUA.

Vander Have et al.[26] reported a series of patients who developed knee stiffness after operative treatment for displaced tibial eminence fractures. Of 32 patients, they reported that 24 patients required reoperation for loss of flexion (n=9), loss of extension (n=4), or both (n=11). Manipulation under anesthesia resulted in distal femoral fractures and subsequent growth arrest in 3 patients.

Thaunat et al.[24] reported high prevalence of knee stiffness after arthroscopic bone suture fixation of tibial spine avulsion fractures in adults. They concluded that two most common complications after fixation are residual laxity due to technical errors during surgery and post-operative stiffness secondary to arthrofibrosis. 38% of their patients had knee stiffness after surgery.

Aderinto et al.[1] reported functional outcome in 83 knees with tibial spine fractures with mean age at injury of 35 years. They reported 60% knee stiffness due to arthrofibrosis following fixation of tibial spine fractures in adults. They also reported 10% incidence of instability due to ACL laxity. They concluded that tibial spine fracture in a skeletally mature patient is associated with a significant risk of knee stiffness and instability. They also stated that relatively high rate of persistent anterior laxity has caused some to question whether it would lead to future ligament, chondral, or meniscal injuries.

Yin et al.[28] reported on arthroscopic fixation of anterior cruciate ligament avulsion fractures with pull-out suture technique. They stated that residual laxity of ACL is the most common complication.

Kocher et al.[9] evaluated laxity and functional outcome of displaced tibial spine fractures in skeletally immature patients treated with arthroscopic reduction and internal fixation. They concluded that arthroscopic fixation of type III tibial spine fractures in skeletally immature patients resulted in persistent laxity but excellent functional outcomes. Physical examination showed persistent laxity, with an abnormal Lachmann test in 5 of their 6 patients and an abnormal pivot-shift test in 2 of 6 patients. Instrumented knee laxity (KT-1000) showed greater than 3-mm manual-maximum side-to-side difference in 4 of 6 patients. However, they concluded that arthroscopic reduction and internal fixation of type III tibial spine fractures in skeletally immature patients results in persistent laxity but excellent functional outcome.

Osti et al.[17] carried out a systematic review of different arthroscopic fixation methods of tibial eminence fractures. They reported ACL laxity in 30% of cases. They stated that the ACL intrasubstance damage and stretching during injury lead to permanent deformation and laxity, independent of the treatment method.

Janarv et al.[8] reported a study of anterior tibial spine fracture in young rabbits. They stated that tibial spine fracture may affect the mechanical properties of the ACL for which they gave several explanations. They found that rigid immobilization with various types of external fixation or extensive casts for 8–12 weeks is known to affect the ACL with changes at the cellular level, reduced cross-sectional area of the ACL, as well as reduced ultimate load and stiffness. They also stated that damage to the blood supply of the ACL caused by the operation is another possible explanation, and quoted Robinson et al.[19] who devascularized the ACL in NZW rabbits by synovial stripping without damaging the ligament fibers which caused a gradual worsening of the mechanical properties of the ligament as shown by reduced ultimate tensile strength. They also stated that inflammatory reaction in the operated knees may have contributed to the reduced ultimate load to failure and the increased number of ruptures in the substance of the ACL, and quoted Goldberg et al.[5] who reported similar changes in the properties of the femur-ACL-tibia complex in rabbits after induction of an immune synovitis in the knee joint.

Mitchell et al.[15] reported the incidence of delayed instability or ACL ruptures requiring delayed ACL reconstruction in young patients with prior fractures of the tibial eminence. In their study 19 percent of all patients evaluated underwent delayed ACL reconstruction after a previous tibial spine fracture on the ipsilateral side. They concluded that a subset of young patients with all types of tibial spine fractures will require later ACL reconstruction, and that there is a need to counsel patients that a delayed ACL rupture is a potential risk after a tibial spine fracture, especially as children approach skeletal maturity.

Arroume et al.[2] evaluated knee laxity after anterior tibial eminence fracture in children in a 35-case series with a mean follow-up of 5.9 years (range 1.1-14.8). Mean laxity in their series was 1.46 mm, and 3 patients had more than 3 mm differential with respect to the healthy knee. Four patients showed instability, 2 of whom required surgical management. They also found that there was no significant difference in occurrence of laxity according to fracture type or reduction quality.

Review of literature shows that there is ample evidence of various problems that can occur after fixation of tibial spine avulsion fractures leading to poor outcomes especially in adults. Damage to ACL sustained at the time of injury and also during fixation of these fractures leading to ACL laxity has also been well documented. Despite this we have not come across any study in the literature which has recommended anterior cruciate ligament reconstruction as the primary treatment option for tibial spine avulsion fractures.

Levy et al.[10] reported anterior cruciate ligament reconstruction in 2 cases of Type III tibial avulsion fracture with associated anterior cruciate ligament injury.

In this study we present a series of 7 new displaced tibial spine avulsion fractures and 2 non-unions of tibial spine avulsion fractures in adults treated with arthroscopic ACL reconstruction using a quadrupled Semitendinosus-Gracilis graft. Pre-operative MRI showed some form of damage of ACL such as dispersed fibers of mid-portion of ACL and interstitial altered signal of ACL in all of the 9 cases in our study. Arthroscopy confirmed different forms of damage of ACL such as mid-portion tear, mid-portion fraying, bruising and laxity with elongation in all of the 7 cases of new fractures in our study. With such concomitant damage to ACL, considering the evidence in literature that fixation of such fractures in adults gives poor outcomes, we feel that were justified in treating all the 7 cases of new tibial spine avulsion fractures in our study with arthroscopic ACL reconstruction using a quadrupled Semitendinosus-Gracilis graft as the primary treatment. The 2 cases of non-union of tibial spine avulsion fracture in our series were suffering from pain and knee instability, and they were also treated satisfactorily with the same technique of ACL reconstruction. There were no major complications in these patients.

All patients had regained full range of movement of the knee, complete functional recovery and ability to return to work at 6 months. At the last follow-up at 2 years or beyond, no patient had knee stiffness or ACL laxity, and all patients had returned to their pre-injury activity levels. Outcomes of our cases as per Modified Lysholm score and also as per Tapper and Hoover grading were excellent in 5 cases and good in 4 cases despite the fact that 3 patients had concomitant lateral meniscal tears requiring partial lateral meniscectomy, 2 patients had concomitant tear of medial collateral ligament with peripheral red-red zone tear of medial meniscus requiring repair of these structures and one patient having had repair of the tear of patellar tendon. No patient in our series required any form of re-operation. Also, type of fracture, injury-to-surgery time, sex of the patient and side (right or left) of the affected knee did not have any bearing on the outcome in our series.

Our results are therefore comparable or even better than those reported in any study of fixation of these fractures in adults, and we have no hesitation in recommending arthroscopic ACL reconstruction using a quadrupled Semitendinosus-Gracilis graft as the primary treatment for displaced tibial spine avulsion fractures in adults, and also for previously treated patients with these fractures who have been left with anterior instability either due to non-union of the fracture or due to any other cause such as intrinsic damage of the ACL or mal-union of the fracture.

CONCLUSION

We conclude that arthroscopic ACL reconstruction using a quadrupled Semitendinosus-Gracilis graft is a satisfactory method of primary treatment for displaced tibial spine avulsion fractures in adults, and that it is also the treatment of choice for previously treated patients with these fractures who have been left with anterior instability either due to non-union of the fracture or due to any other cause such as intrinsic damage of the ACL or mal-union of the fracture. Patients thus treated do not have residual ACL laxity or instability, they do not have knee stiffness, and they do not need any subsequent surgery.

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