Tibial Spine Fracture Management - Technical Tips and Tricks from the Tibial Spine Fracture Research Interest Group

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Abstract: Tibial spine/eminence fractures are uncommon fractures, usually seen in patients with open physes, and are considered as an equivalent to an ACL tear in adults. The aim of treatment is reduction of the fracture, restoring the ACL length for appropriate healing and avoiding complications. There are many techniques described to treat these fractures with no current consensus on the optimal method of fixation. The purpose of this paper is to describe and demonstrate treatment with video, pearls, technical tricks, and tips by members of PRiSM tibial spine fracture research interest group.

Key Points:

- Tibial spine fractures are uncommon fractures seen in patients between 8 to 14 years of age.
- During surgical management, after adequate fracture debridement, any obstructions to fracture reduction should be identified and tackled.
- Various techniques for fixation using screws, sutures, and anchors can be used, based on surgeon preference.
- Robust fixation is required for early mobilization to prevent arthrofibrosis, which is the most common complication.

Introduction

Tibial spine fractures (TSF) are a bony avulsion of a portion of the anterior cruciate ligament (ACL) from its attachment on the intercondylar tibial eminence usually seen in patients between 8 and 14 years of age.[1, 2] The treatment can be nonoperative or operative, depending on the fracture type and displacement (Figure1).

There are a variety of techniques described for operative fixation of these fractures, which include screw fixation, suture fixation, and suture anchor fixation. Each technique has its pros and cons.[1-8] The goals of fracture fixation are early restoration of knee range of motion, minimization of ACL laxity, adequate stability to allow

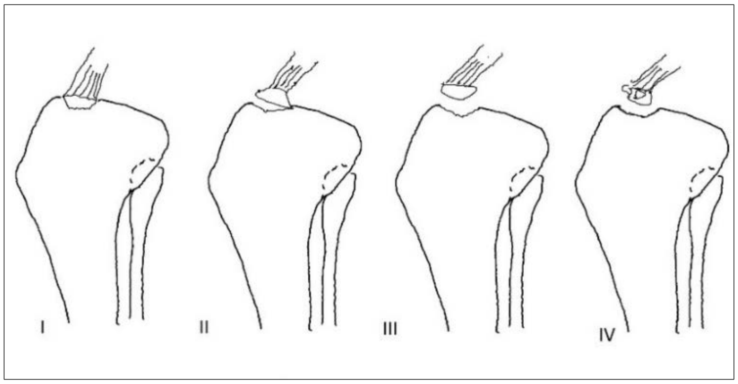


Figure 1. *Modified Meyers and McKeever classification of tibial eminence fractures: Type I - nondisplaced, Type II - displaced anterior margin and hinged posterior cortex, Type III - absence of any bony contact, Type IV - displaced and comminuted*

bony healing, and an ultimate return to normal function. Whether reduced open or arthroscopically, the existing literature does not indicate a gold standard for fixation of these fractures.[9-11] Therefore, the surgeon should be able to utilize different fixation techniques in different patients with variable fracture patterns and any associated injuries. In this article, members of the Pediatric Research in Sports Medicine (PRiSM) TSF Research interest group (RIG) describe pearls, technical tricks, and tips that can be used for TSF management.

Closed Reduction of Tibial Eminence Fractures

Although recent trends have suggested less than half of pediatric orthopaedic surgeons perform closed reduction on Type 2 fractures,[12] prior publications suggest value in a closed reduction maneuver for a displaced TSF.[13-15] An improved understanding of soft tissue entrapment,[16-18] risk for nonunion,[10] and concomitant injuries[18, 19] may have influenced surgeons to consider open or arthroscopic reduction and internal fixation over closed reduction.

A closed reduction can be attempted in any displaced tibial spine fracture. Some have suggested that less than 5mm of anterior displacement in Type 2 tibial spine fractures leads to a higher success rate of closed reduction.[14] However, a Type 3 tibial spine fracture, compared to Type 2, may have more concomitant injuries, decreased intrinsic bony stability, and increased and soft tissue entrapment. Thus, one should counsel families as such prior to performing the procedure[18, 19]. A closed reduction is more successful if performed within 48 hours of the injury, under adequate analgesia/sedation; an MRI is obtained following the reduction. An MRI will confirm the adequacy of the reduction, rule out meniscal injuries, and evaluate for any injury to the substance of the ACL. If any of these are present, then arthroscopic reduction and internal fixation are recommended.

Figure 2. *Closed reduction technique part 1: A. Flex the knee to 90° to mobilize the tibial spine fragment. B. As the knee is extended to approximately 30°, perform a Lachman maneuver and hold anterior translation.*

Closed Reduction Technique

Following adequate analgesia with an oral agent (weight-based hydrocodone) and intra-articular aspiration of hematoma and injection of Ropivacaine (10 ml 0.75%); the patient is placed supine on a radiolucent table. A gentle passive range of motion is performed in order to ensure adequate analgesia. Next, flex the knee to 90° to mobilize the tibial spine fragment (Figure 2A). As the knee is extended to approximately 30°, perform a Lachman maneuver and hold anterior translation (Figure 2B). This will pull tension on the ACL, pulling the tibial eminence posteriorly while there is anterior translation of the tibia. This will promote mobility of any soft tissue entrapped (e.g., intermeniscal ligament) anteriorly to allow for reduction of the fragment. Maintain this anterior translation while further fully extending the knee (Figure 3C).

Hold the knee in terminal extension (Figure 3D). Following the reduction maneuver, lateral fluoroscopic imaging is used to confirm adequacy of the reduction. If an anatomic reduction is appreciated, then a long leg cast is placed in an extended (not hyperextended) position. Following reduction, an MRI is paramount to ensure adequate reduction and identify concomitant injures. After 3 weeks of cast immobilization, the patient should begin range of motion with a physical therapist and weight-bearing as tolerated with the extremity locked in extension for 3 additional weeks.

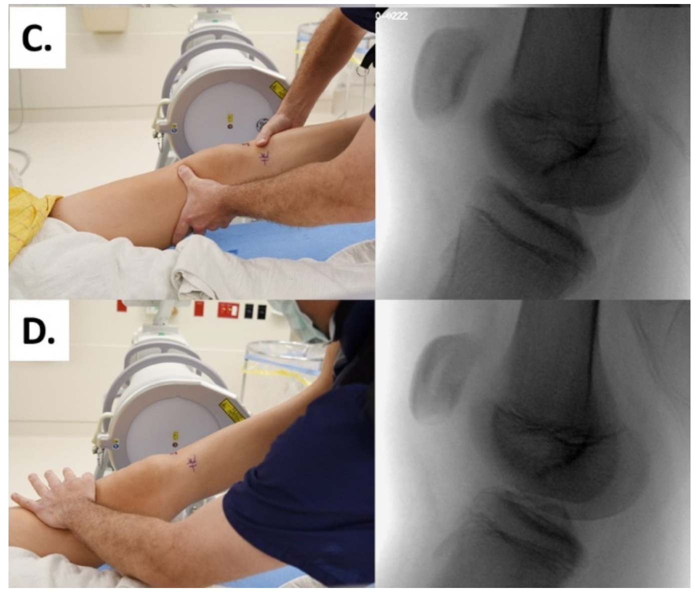


Figure 3. *Closed reduction technique part 2: C. Anterior translation is maintained while further fully extending the knee. D. The knee is held in terminal extension.*

Arthroscopic Techniques

While open reduction and fixation (see methods below) have been performed for many decades, arthroscopic reduction is considered by many as less morbid than open management for these fractures.[20] When performing this procedure, the following steps are utilized. Please see the associated video for the following technique.

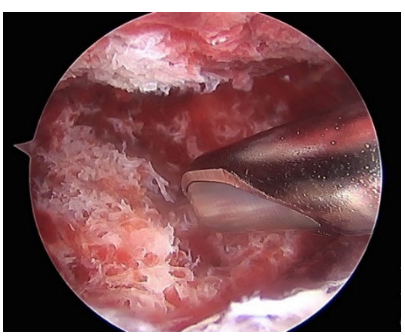


Figure 4. *Debridement of the fracture base with a shaver*

Evacuation of the hematoma. After establishing standard medial and lateral portals, the hematoma is evacuated with an arthroscopic shaver and can take up to 15 minutes depending on the acuity of the fracture. This should be done expeditiously, as longer surgical times have been associated with higher possibility of arthrofibrosis.[10, 21] It is advised to remove some of the infrapatellar fat pad when evacuating the hematoma to improve visibility of the inter-meniscal ligament for which can block reduction.

Assessment of the fracture and debridement of the base. One can use a probe/freer/elevator to elevate the fracture lip, which is usually anterior, and then use a shaver to debride the fracture hematoma (Figure 4). It is crucial to debride the fracture base to get rid of any bony debris with a shaver or curettes (or sometimes a burr if needed). Having contact between the fragment and its bed remains essential to ensure healing. Removing a little extra will allow one to slightly recess the fragment into the bed, which helps bring the ACL back to adequate tension after fixation (which is usually plastically stretched during the injury).

The two most common structures that can block reduction are the anterior horn of the medial meniscus and the inter-meniscal ligament. A knee that does not fully extend passively may suggest incarcerated tissue. The authors have observed incarcerated meniscus and inter-meniscal ligament even in Type 1 fractures. For the inter-meniscal ligament, a trick is to use a suture to pull

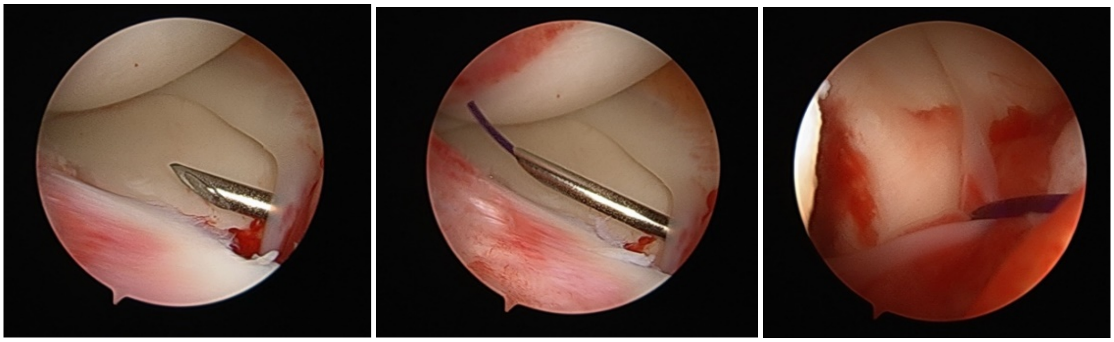


Figure 5 (left). *Retraction of meniscus step 1 – passing of spinal needle through the patellar tendon;* **Figure 6 (middle).** *Retraction of meniscus step 2 – passing of a suture through the spinal needle;* **Figure 7 (right).** *Retraction of the meniscus (obstruction to reduction) with suture*

the structure out of the way. An 18G spinal needle can be inserted outside-in underneath the anterior of the meniscus (Figure 5) through which a suture can be passed (Figure 6), which can be used to retract the meniscus anteriorly and thus facilitates reduction of the eminence fracture (Figure 7).

Fixation of fractures. Use of accessory portals with a plastic cannula (for better visualization and fixation of fractures[22]) are recommended for suture management (to avoid suture entanglement). Once the obstacles to reduction have been removed, the fracture is reduced. A 0.045-in K-wire is placed from a superomedial or superolateral entry for temporary fixation of the fracture after reduction (Figure 8).

The fracture tends to be slightly laterally translated, so consider a more lateral to medial trajectory for the K-wire to allow you to joystick the fracture medially to anatomically reduce it. Many different techniques and modalities have been used for fixation of TSF.[3, 4, 6, 8, 9, 20] The most common methods are:

Screw Fixation. After fracture reduction, a superior medial portal is created with the knee in 80-90° of flexion, and two guidewires are placed across the fracture. The reduction is confirmed arthroscopically and fluoroscopy. To avoid bending the K-wire, care must be taken not to flex or extend the knee while obtaining the lateral fluoroscopic image which is needed to avoid placing a screw across the physis in skeletally immature patients. In patients closer to maturity, the physis can be crossed to obtain better screw purchase. Fixation is performed with two partially threaded, self-tapping, cannulated 4.0-mm screws inserted over the guidewires. A washer can be used to distribute compressive forces. For large fracture fragments, an additional third screw can be placed through a superior lateral accessory portal (Figure 9 and 10).

Once the K-wires are removed, take the knee through a full range of motion to ensure the screws properly reduce the fracture and are a safe distance from the femoral condyles during extension (Figure 11). Screw fixation is not the first choice in small or comminuted tibial spine fractures as screws may split a fracture fragment during insertion. If this occurs, one might need to resort to suture fixation.

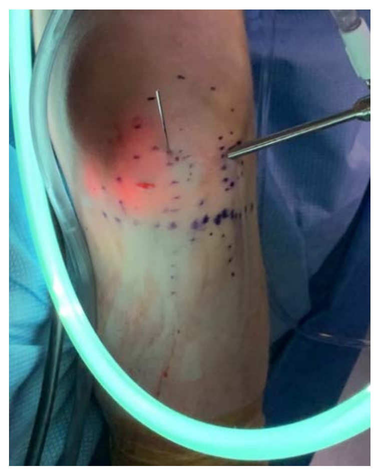
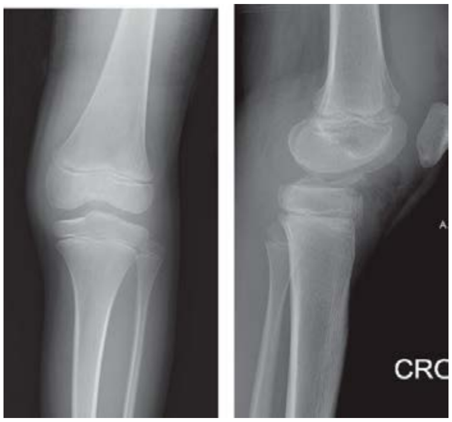


Figure 8. *Temporary K-wire fixation*

If the patient has growth remaining and the screws cross the proximal tibial physis, screw removal should be performed. Arthroscopic screw removal can be challenging and different techniques have been described to prevent complications.[23] A nonabsorbable suture can be tied between the screw and washer during insertion with few centimeters of suture left in the joint, which can be used to retrieve the screw during second-look arthroscopy. A K-wire can be inserted in the cannulated screw and as the screw is being withdrawn with a cannulated screwdriver, the



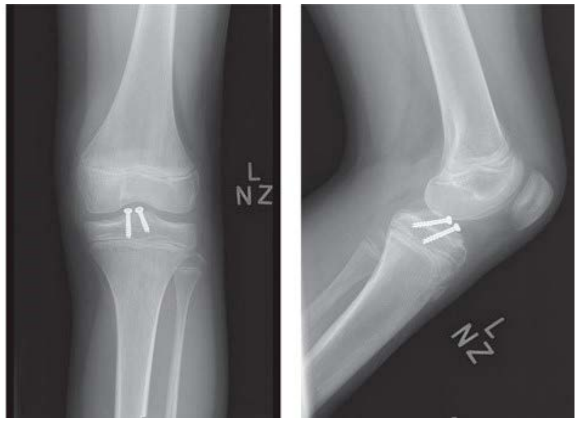


Figure 9 (left). *Screw fixation preoperative radiographs;* ***Figure 10 (right).*** *Screw fixation postoperative radiographs*

K-wire tip can be bent slightly so that the screw does not fall off in the joint as it is gradually removed.[23, 24]

Suture Fixation: One of two approaches for stabilization can be used. If the avulsion fracture is quite small, one can simply grab the base of the ACL with an arthroscopic suture passing device and pass two sutures, then plan to drill bone tunnels through the base of the tibial spine fracture bed. These sutures are then shuttled through the bone tunnels and tied over a bone bridge or otherwise fixed to the proximal tibia. If the avulsion is a larger fragment, the prior stabilization method with a K-wire is used; with the fracture reduced, one can drill a tunnel that travels through the avulsion itself and is directly in line with the anterior aspect of the ACL base. A small transpatellar tendon portal can be created for suture shuttling.

Using the ACL tibial guide to plan drill holes (Figure 12) for placing suture around the displaced fracture fragment can be useful, though all-epiphyseal trajectories are technically challenging both to position and to lasso passing sutures and pull the fragment into the recessed bed (described below).

Transphyseal sutures provide a better trajectory, but future growth should be assessed. The ACL tibial guide is used to pass two to three guidewires to make tunnels from the anteromedial aspect of the tibia to the base of the fracture. One must make sure to leave an adequate bone bridge at the anteromedial cortex of the tibia to tie the sutures. The locations where these tunnels exit intra-articular can be spread out medial and lateral or anterior and posterior to the tibial spine fracture depending on the fracture pattern and size. Each wire is carefully removed and replaced with suture passing devices.

Options to pass the sutures through tibial drill holes are semi-rigid plastic tube vs. metallic suture passing device vs. Hewson suture passer, which is done under direct intra-articular visualization. The suture passing loops sit on either side of the ACL footprint. If using a curved suture passer, three or more sutures are passed and retrieved out of the transpatellar tendon portal. For a Type 3 fracture, one drill hole should be placed in the center of the ACL tibial footprint, one posterior, and one anterior, in order to create a broad-based suture bridge. Anterior-based tunnels are acceptable for Type 2 fractures with an intact posterior hinge. Suture fixation can be performed with high strength nonabsorbable suture or a heavy absorbable suture. The absorbable suture could be considered if there is a desire for temporary fixation to minimize the possibility of growth-plate tethering.

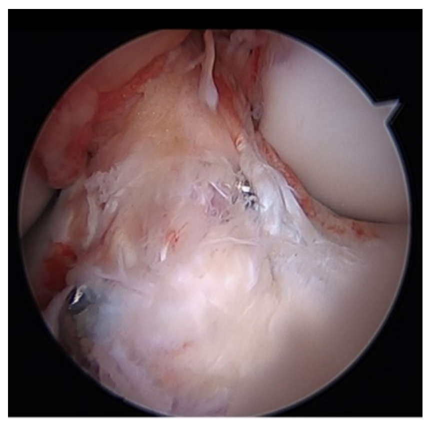


Figure 11*. Screw fixation arthroscopic view*

The sutures are tensioned at the anteromedial aspect of the tibia while the fragment is directly visualized, confirming anatomic reduction and slight recession into the fracture bed. The arthroscope is removed, and the knee brought to 30° of flexion for final tensioning and tying of the sutures. Other methods to secure the sutures include:

1. If multiple tunnels were not utilized and if there is only a single tunnel used due to smaller size of the fragment or if the bone bridge is inadequate, the sutures can be tied over a button.
2. As a fixation method by itself or to supplement all of the above three options after tying, the free suture ends may be fixed to the proximal tibial metaphysis using a screw or suture anchor with eyelet as a back-up fixation to prevent loosening
3. Suture anchor fixation can be used based on the location of displacement similar to a Bankart repair of the shoulder.

The knee is reexamined for stability using the Lachman maneuver. The scope is then introduced into the joint for inspection of the fracture and ACL to confirm robust fixation when ranging the knee.

All-epiphyseal tibial spine fracture fixation versus transphyseal suture fixation should be considered for younger patients to prevent growth plate injury. This method can be challenging in the young patient. Since the ACL itself is intact, the tunnel drilled for passing sutures tends to be slightly more anterior than a tunnel for ACL reconstruction. As such, the bony real estate available for an anterior epiphyseal tunnel tends to be rather minimal, even when drilling at 30°. In order to allow for more robust fixation, we favor the principles described in the original fixation technique for all-epiphyseal ACL reconstruction described by Allen Anderson.[25]

In this method, the tunnel is all epiphyseal and exiting out the anterior cortex of the epiphysis, the sutures are then brought distally over the anterior cortex of the tibia, with fixation distal to the tibial physis.

Technique Details

Prior to starting the arthroscopic portion of the procedure, fluoroscopy is used to estimate the position of the tibial physis as a reference for tunnel placement.

Figure 12. *ACL guide to drill at the base of the fracture*

Sutures with a loop at one end can be used to make two "luggage tag" configuration suture knots at the base of the ACL, one medially and one laterally, and placed through each portal respectively using an arthroscopic suture passing device. In very rare cases, one may find it difficult to use an all epiphyseal guide and have sufficient anterior bone. In these cases, consideration can be made for a freehand technique with a second K-wire using the first wire as a guide. It is important to note that the tunnel does not become either too steep or too posterior such that the guide pin enters the footprint of the ACL. The ends of the sutures after shuttling are fed through the eyelet of a knotless suture anchor and then while holding tension, confirm suture anchor location that is distal to the physis. Secure the anchor and confirm a satisfactory Lachman exam. Final fluoroscopic images can be taken to confirm and document reduction radiographically. There is often some degree of anterior lip displacement of the fracture. While this does not affect the structural integrity of the reduction, it is helpful to establish baseline fluoroscopic images for later purposes of comparison.

Postoperative Rehabilitation

To date, there are no evidence-based guidelines for postoperative rehabilitation following treatment of a pediatric tibial spine fractures. Historically, initiation of knee motion within 4 weeks of treatment resulted in a lower frequency of arthrofibrosis (0% vs. 36%; p=0.04) and earlier clearance for full activity (103 vs. 218 days; p=0.02). Children in whom the knee was immobilized longer than 4 weeks were at 12 times higher odds of developing arthrofibrosis (p=0.03)[26]. Treatment of arthrofibrosis, typically with arthroscopic lysis of adhesions and/or manipulation under anesthesia, may not always be benign. In one study, three of thirty-two patients that underwent manipulation for arthrofibrosis sustained distal femoral fractures with subsequent growth arrest.[21] Given the existing body of literature, we recommend early motion following fracture fixation.

The authors' preference is for immediate protected motion in a hinged brace following stable fracture fixation. A continuous passive motion (CPM) machine may be utilized if needed. Motion is typically limited to 0-90° degrees for the first 3 weeks unless a concomitant meniscus repair is performed, in which case this limitation lasts for 6 weeks. Foot-flat weight-bearing is typically only prescribed for the first 2 weeks but may last for 6 weeks if a meniscus repair was performed. A wide variety of rehabilitation protocols are described in the literature, with most protocols emphasizing closed chain exercises in the early phases of rehabilitation. The authors prefer to avoid any open chain knee extension for at least 6 weeks after surgery. Clearance for return to sports is typically between 4 and 6 months after surgery but is based on fracture healing, full-motion, strength within 90% of the uninjured limb, and functional testing with consideration of the anticipated demands on the knee. Further research is necessary to develop evidence-based guidelines.

Complications

Arthrofibrosis after surgical treatment of tibial spine fractures is the most common complication with a rate of about 10-29%.[21, 27] Stiffness is primarily related to the amount of time of postoperative immobilization[21] and the authors recommend that postoperative casting be avoided. The authors have also identified that concomitant ACL tears and case duration greater than 2 hours are also associated with arthrofibrosis. Besides early postoperative motion, routine arthroscopic screw removal and debridement at 3 months postoperatively has been advocated.[28] Method of fixation (screws or sutures) or approach (arthroscopic or open) are not associated with the development of knee stiffness.[10, 14] When arthrofibrosis is encountered, dynamic splinting for both extension and flexion has been successful as an adjunct to physical therapy.[29] If splinting is unsuccessful, surgical treatment with appropriate rehab can also improve ROM. Importantly, surgical outcomes are not hindered by preoperative splinting.[30] When treatment under anesthesia is undertaken, arthroscopic lysis of adhesions is recommended along with manipulation in order to prevent physeal fracture.[21]

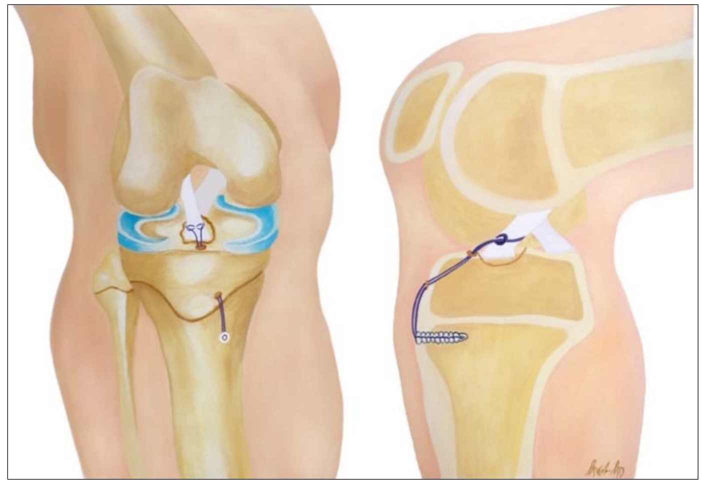


Figure 13. *All-epiphyseal technique of fracture fixation*

ACL laxity is common after tibial spine fracture treatment. The anterior drawer and Lachman tests are positive in 20-60% of patients after fracture healing, and the pivot shift test is positive in 8-40% of patients. There is an association between postoperative laxity and the severity of the initial injury.[10] ACL reconstruction for residual laxity or new injury after tibial spine fracture can be seen at a rate of nearly 20%.[31] However, residual laxity seems to be well tolerated in most cases.[32]

Nonunion is seen in <2% of cases and is reported more commonly in nonoperatively treated fractures.[10] Surgical treatment is generally successful in achieving union.[33]

Conclusion

Tibial spine fractures are relatively uncommon injuries seen in patients with open physes. Surgical management commonly consists of screw or suture fixation, and the technique can vary depending on the surgeon's preference and nature of the fracture. The goal of surgery is adequate reduction of the fracture, restoring the ACL length for appropriate healing. This should be achieved with secure fixation so that early knee range of motion can be initiated to prevent arthrofibrosis, which is the most common complication. The tips and tricks mentioned in this paper from the members of the PRiSM TSF research interest group are presented to help orthopedic surgeons plan their surgery and avoid any pitfalls during management of these uncommon fractures.

Acknowledgement: We would like to thank Aristides I. Cruz, Jr. MD, MBA for help with pictures and videos, and to other members of the PRiSM tibial spine fracture research interest group for their input.

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