Pediatric Tibial Spine Fractures: Current Research and Debates

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Introduction

Tibial spine fractures (TSFs) are avulsion fractures at the tibial intercondylar eminence.[1] They are relatively rare, occurring in about 3 per 100,000 individuals per year.[2] They are more common in males than females and in children than adults. Common mechanisms of injury include contact, hyperextension, and rotational or pivoting injuries with the knee flexed.[3] Commonly reported injury causes include falls from bicycles and injuries during sports.[4]

The most used TSF classification system is that by Meyers and McKeever, which characterizes nondisplaced fractures as Type I, minimally displaced fractures with an intact posterior hinge as Type II, and completely displaced as Type III.[5] Later, Zaircznyj introduced Type IV to describe comminuted fractures.[5,6] Treatment for TSFs can be operative or nonoperative and depends on factors including fracture severity, pain, range of motion, presence of soft tissue entrapment and/or concomitant injuries, and surgeon and patient/family preference. Research regarding the epidemiology, classification, and optimal treatment for TSFs has increased in recent years.

Epidemiology

Two large epidemiological database studies on TSFs were published in 2021.[7,8] In one, U.S. Healthcare Cost and Utilization Project databases were queried for patients aged 7-18 years with TSFs in 2016 in New York, Florida, or Maryland. They found 185 cases, 69.7% male. The incidence peak was 9.3 per 100,000 individuals at age 14 for males and 3.4 per 100,000 individuals at age 9 for females.[7] In the second study, the U.S. Truven Health Marketscan Database was queried for individuals aged 7-18 with TSFs between 2016-2018.8 They found 878 cases with a male to female case burden ratio of 2.2:1.8 In this study, cases peaked at age 13-14 in boys and 11-12 for girls.[8] Both studies demonstrated that TSFs are more common in males than females and that they peak at a later age for males.[7,8]

Classification Systems

In 2021, Ellis et al. assessed the reliability of the Meyers and McKeever classification system. Deidentified radiographs from 40 patients with TSFs were classified on two separate occasions by pediatric sports medicine surgeons, and intra- and interrater reliability was assessed.[9] They found only fair intra- and interrater agreement ($\kappa = 0.47$ and 0.35, 0.33, respectively) when classifying by Meyers and McKeever type.[9]

Additionally, an alternative classification system was proposed by Green et al. in 2018 which makes use of MRI, rather than radiographs.[10] In this system, non or minimally displaced (< 2 mm) are Grade 1, posterior hinged fractures are Grade 2, and displaced fractures, those that result in meniscus or intermeniscal ligament entrapment, and those that extend to the articular surface are Grade 3. However, this study also showed only fair to moderate inta- and interrater reliability ($\kappa = 0.66$ and 0.34, 0.41, respectively).[10]

Treatment Options

Nonoperative Treatment

There is some debate regarding when nonoperative treatment is indicated for TSFs. An oft-cited convention is that Type 1 fractures are treated nonoperatively, but one multicenter, retrospective cohort study found that 25% (n = 12/48) of patients with reported Type 1 fractures were treated surgically.[11] When the authors reassessed the fracture classification, the number of "true Type 1" fractures was reduced from 48 to 40, but they still found that 15% (n = 6/40) were treated surgically, and 23% (n = 9/40)

had concomitant injuries.[11] Another study by the same group compared outcomes between patients with Type 2 fractures treated operatively (n = 123) and nonoperatively (n = 41).[12] They found that the overall complication and reoperation rates did not differ between groups. However, the nonoperative group had a higher rate of subsequent ACL injury or TSF requiring surgery (4.9% vs. 0.0%), and the operative group had a higher rate of arthrofibrosis (8.9% vs. 0.0%).[12]

A systematic review identified 18 studies regarding the nonoperative treatment of 369 TSFs (n = 173 Type 1, n = 124 Type 2, n = 72 Type 3). The most common complications were persistent stiffness (33.9%) and persistent instability (13.4%). The authors note that few studies stratified complications by fracture grade, but there was a "modestly higher rate" of arthrofibrosis and persistent laxity with higher grade fractures.[13] Taken together, this research suggests that more information is needed to determine when nonoperative treatment should be pursued.

Suture vs. Screw Fixation

In one laboratory study on Yorkshire porcine knees, screw and suture fixation constructs were compared between skeletally mature and immature groups.[14] A standardized TSF was created in 8 mature and 8 immature knees. Then 4 knees in each group underwent fixation with 2 screws, and 4 underwent fixation with a dual-suture technique. The knee specimens then underwent 200 cycles of cyclic loading, followed by load-to-failure testing. In the immature knees, load to failure was not significantly different between groups. In the mature knees, load to failure was 1.9 times higher in the suture group. Displacement and stiffness were also not different between the fixation groups after cyclic loading. The authors' conclusion was that the two fixation constructs appear equivalent in the skeletally immature, and suture fixation may be superior for those skeletally mature.[14]

Open vs. Arthroscopic Fixation

Both open (ORIF) and arthroscopic (ARIF) fixation methods have been used for TSF treatment. In one multicenter, retrospective cohort, 420 patients treated with ARIF and 57 treated with ORIF were compared.[15] They found that ARIF was most often performed by surgeons with sports subspecialty training (85% of cases) and ORIF was more often performed by surgeons without sports subspecialty training (56.1% of cases). Importantly, they found similar rates of short-term complications and return to the operating room between the two groups.[15]

Conclusion

Despite an increase in recent research, there remains no true gold standard for TSF treatment, likely due to their rare nature. Many additional controversies exist as well, including the use of pretreatment MRI, preoperative mobilization, rehabilitation protocols, and the amount of acceptable residual displacement. Prospective research is needed to answer these questions, and CHOP serves as the data coordinating center for a prospective cohort study with 15 other institutions with the objective of beginning to answer these questions.

References

1. Cruz AI, JR, Lee RJ, Kushare I, *et al.* Tibial Spine Fractures in Young Athletes. *Clin Sports Med.* 2022;41:653-670.

2. Hargrove R, Parsons S, Payne R. Anterior tibial spine fracture – an easy fracture to miss. *Accid Emerg Nurs.* 2004;12:173-175.

3. Lafrance RM, Giordano B, Goldblatt, J, *et al.* Pediatric tibial eminence fractures: evaluation and management. *J Am Acad Orthop Surg.* 2010;18(7):395-405.

4. Aderinto J, Walmsley P, Keating JF. Fractures of the tibial spine: Epidemiology and outcomes. *The Knee.* 2008;15:164-167.

5. Meyers, MH, McKeever, FM. Fracture of the intercondylar eminence of the tibia. J Bone *Joint Surg Am.* 1970;52(8):1677–1684.

6. Zaricznyj B. Avulsion fracture of the tibial eminence: treatment by open reduction and pinning. *J Bone Joint Surg Am.* 1977;59:1111-1114.

7. DeFrancesco CJ, Tananbaum A, LeBrun DG, *et al.* The Incidence of Pediatric Tibial Spine Fractures Is Greater and Peaks Later in Male Patients. Arthroscopy, Sports Medicine, and Rehabilitation. 2021;4(2):e639-43.

8. DeFrancesco CJ, Wilson L, Lebrun DG, *et al.* Pediatric Tibial Spine Fractures: Exploring Case Burden by Age and Sex. *Orthop J Sports Med.* 2021;9(9): 23259671211027237.

9. Ellis HB, Zynda AJ, Cruz AI, Jr, *et al.* Classification and Treatment of Pediatric Tibial Spine Fractures: Assessing Reliability Among a Tibial Spine Research Interest Group. *J Pediatr Orthop.* 2020;41(1):e20-e25.

10. Green D, Tuca M, Luderowski E, *et al.* A new, MRI-based classification system for tibial spine fractures changes clinical treatment recommendations when compared to Myers and Mckeever. *Knee Surg Sports Traumatol Arthrosc.* 2019;27:86-92.

11. Shimberg JL, Leska TM, Cruz AI, Jr, *et al.* Is Nonoperative Treatment of Appropriate for All Patients With Type 1 Tibial Spine Fractures? A Multicenter Study of the Tibial Spine Research Interest Group. *Orthop J Sports Med.* 2022;10(6): 23259671221099572.

12. Tibial Spine Research Group, Prasad N, Aoyama JT, *et al.* A Comparison of Nonoperative and Operative Treatment of Type 2 Tibial Spine Fractures. *Orthop J. Sports Med.* 2021;9(1):2325967120975410.

13. Zhang K, Catapano M, Carsen S, *et al.* Management and Complications in Nonoperative Fractures of the Tibial Spine: A Systematic Review. *J Pediatr Orthop.* 2021;41:e272–e278.

14. Thome AP, Jr, O'Donnell R, DeFroda SF, *et al.* Effect of Skeletal Maturity on Fixation Techniques for Tibial Eminence Fractures. *Orthop J Sports Med.* 2021;9(11): 23259671211049476.

15. Shimberg JL, Leska TM, Cruz AI, Jr, *et al.* A Multicenter Comparison of Open Versus Arthroscopic Fixation for Pediatric Tibial Spine Fractures. *J Pediatr Orthop.* 2022;42:195–200.