High Incidence of Soft Tissue Injury in Pediatric Proximal Tibia Fractures: A Systematic Review

Ethan Sanders, M.D., Anna-Lee Policicchio, M.D., and Lisa Phillips, M.D., F.R.C.S.C.

Purpose: The purpose of this study was to describe the incidence of soft tissue injuries associated with pediatric proximal tibial fractures (PPTF) and the frequency that magnetic resonance imaging (MRI) was used before surgery in this patient population. **Methods:** A systematic review of English literature, using EMBASE and PubMed, was completed. Articles reporting on soft tissue injury in PPTFs between 1980 and 2021 were identified. Associated pathology (meniscal tear, meniscal entrapment, cruciate ligament injury, extensor mechanism injury, and chondral injury) and use of MRI at time of diagnosis, were assessed in these studies. Twenty-three articles were included. **Results:** Extraction of data revealed 1046 patients and 1057 fractures, with a mean age of 12.3 ± 1.7 at the time of injury. Most patients were male (n = 757 [72.3%]). Most fractures were tibial eminence fractures (TEF) (n = 747 [70.7%]), followed by tibial tubercle (n = 218 [20.6%]) and then tibial plateau fractures (n = 92 [8.7%]). Associated soft tissue injuries were found in 58.8% (n = 621) of fractures overall. Meniscal entrapment was the most common, occurring in 22.1% (n = 234) of cases. Meniscal tears occurred in 18.6% of cases (n = 197), followed by ligament injury in 9.4% (n = 99), chondral injury in 6.5% (n = 69), and extensor mechanism injury in 2.1% (n = 22) of cases. All cases of tendinous extensor mechanism injury were seen in tibial tubercle fractures, with 22 injuries occurring in 10.1% of tibial tubercle fractures. At time of injury just 24.3% (n = 257) of fractures had an MRI performed before surgery. **Conclusions:** PPTFs are associated with a high incidence of associated injury (58.8%), particularly in TEFs (63.5%) and TPFs (100%). **Level of Evidence:** Systematic Review of Level III-IV studies

Pediatric proximal tibia fractures (PPTFs) are a heterogenous group of injuries, comprising tibial eminence fractures (TEFs), tibial tubercle fractures (TTFs), and tibial plateau fractures (TPFs). Each fracture shares the potential for intra-articular involvement and associated injury. TEFs, although relatively uncommon, have increasing incidence with injury, occurring in 3 in 100,000 per year.[1] This injury is more often found in children and adolescents aged 8 to 14 years, with avulsion injury because of the immature bone.[2,3] As the functional equivalent to an anterior cruciate ligament injury, this will occur through noncontact twisting or hyperextension injury in sport.[2] The incidence of associated soft tissue injury has been well studied in this population, specifically highlighting the incidence of meniscal tears and entrapment, as well as associated ligamentous injury based on mechanism.[2-6]

Less well studied is the potential for soft tissue injury in TTFs and TPFs, likely because of the uncommon nature of these injuries. TTFs account for <1% of all physeal injuries but are increasing in frequency because of participation in sport and avulsion caused by quadriceps contraction being the most common mechanism.[7,8] These injuries can have devastating consequences, with ongoing associated neurovascular injury, compartment syndrome, as well as under-recognized associated pathology.[8] Finally, although tibial plateau fractures are extremely rare in the pediatric population because of their intra-articular nature, there is certainly potential for associated soft tissue injury. Segond fracture, a fracture of the lateral tibial plateau, is essentially pathognomonic for an anterior cruciate ligament injury, as the site of attachment of

From the Cumming School of Medicine, University of Calgary, Calgary, Albert, Canada.

The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received February 2, 2023; accepted June 4, 2023.

Address correspondence to Lisa Phillips, M.D., F.R.C.S.C., Division of Orthopaedic Surgery, University of Calgary Sport Medicine Centre, 376 Collegiate Blvd NW, Calgary, AB, T2N 1A4, Canada. E-mail: phillila@ucalgary.ca

2666-061X/23115

https://doi.org/10.1016/j.asmr.2023.100771

the anterior longitudinal ligament stressed in internal rotation of the knee.[9] Meniscal pathology is also common in this population.[9]

It is possible that missed associated soft tissue injury in PPTFs can lead to morbidity. There is potential for ongoing disability, altered knee biomechanics, failure to return to pre-injury levels, as well as the sequelae of abnormal loading of a joint. The purpose of this study was to describe the incidence of soft tissue injuries associated with PPTF and the frequency that MRI was used before surgery in this patient population. We hypothesize that there will be a high incidence of intra-articular injury in proximal tibia fractures, with relatively low use of MRI before surgery.

Material and Methods

A systematic review of the literature was conducted to identify primary scientific articles reporting on the incidence of associated soft tissue injury among PPTFs. The search was conducted using PubMed and EMBASE. The search was performed in April 2021 using the following terms and strategy:(pediatric OR paediatric OR skeletally immature OR child*) AND (proximal tibia fracture* OR tibial tubercle fracture* OR tibial eminence fracture* OR intercondylar eminence fracture* OR anterior tibial spine fracture* OR tibial plateau fracture* OR tibial spine fracture*) AND (intraarticular injur* OR meniscal injur* OR meniscal entrapment OR cartilage injur* OR osteochondral injur* OR chondral injur* OR chondral pathology* OR meniscal tear*). References in relevant articles were reviewed to ensure completeness of the literature search. Articles were considered eligible if they report on the following: (1) patients under the age of 18, (2) minimum of 10 patients, and (3) the incidence of associated soft tissue injury. Review articles, case reports, and expert commentaries were excluded.

During our review, 149 articles were identified for review. Titles were screened, and abstracts reviewed (E.S., A.P.). Those with relevant information as per the inclusion criteria were included for full text review. This was done by 2 reviewers working independently using the Covidence software (Melbourne, Australia), followed by conflict resolution

From these articles demographic data was collected including age at time of injury and sex. Outcomes included fracture type (TEF, TTF, TPF), as well as associated soft tissue injury. Specific injuries included meniscal tear, meniscal entrapment, ligamentous injury, chondral injury, and complete tendinous extensor mechanism injury. The management strategy (operative vs nonoperative), as well the use the of MRI and arthroscopy for evaluation of soft tissue injuries, was reported.

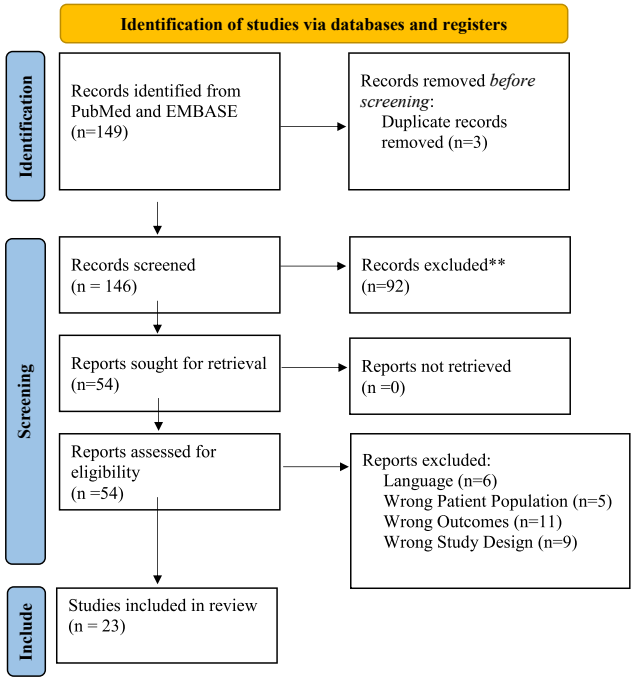

Fig 1. Process of completing the systematic review of the literature.

Results

Our search identified 149 articles to review. Of these, 23 were ultimately selected for inclusion (Fig. 1). Articles included in the systematic review of Level III-IV studies detailed in Table 1. The systematic review included 14 articles on TEFs, 7 articles on TTFs, and 2 articles on TPFs.

Demographic and Injury Characteristics

The systematic review included 1046 patients with 1057 PPTFs. The majority were TEFs (n = 779 [71.5%]), followed by TTFs (n = 218 [20.0%]) and TPFs (n = 92 [8.4%]). Of these patients, the mean age was 12.3 ± 1.7 years at the time of injury. Most patients were male (n = 757 [72.3%]).

Pretreatment Evaluation

Before undergoing definitive treatment, 24.3% (n = 257) of fractures underwent MRI. MRI was most common in the TEF group, with preoperative MRI in 80.1% of these injuries. Arthroscopy was done in 24.5% (n = 259) of patients. In total, 47.8% (n = 506) of patients had either MRI or arthroscopy done before or as a part of the definitive management of their injuries.

Soft Tissue Injury

Accounting for the nonuniversal use of MRI or direct visualization (arthroscopy) before definitive treatment, 53.7% (n = 568) of PPTFs had associated soft tissue

Table 1. Details of Studies Included in the Systematic Review of the Literature

Reference	Year of Publication	Level of Evidence	Fracture	Number of Patients	Age of Patients (Yr)	Sex (M:F)
Shelton and Canale[12]	1979	IV	TPF	38	14.2	37:1
Ogden et al.[13]	1980	IV	TTF	14	14.3	13:1
Bolesta and Fitch[14]	1986	IV	TTF	16	15.2	16:0
Wiss et al.[15]	1991	IV	TTF	15	15.2	15:0
Mah et al.[16]	1998	IV	TEF	10	15.3	8:1
Kocher et al.[17]	2003	IV	TEF	80	11.6	45:35
Mosier and Stanitski[18]	2004	IV	TTF	18	13.7	17:1
Ishibashi et al.[3]	2005	IV	TEF	13	11.7	9:4
Shea et al.[6]	2011	IV	TEF	20	12.0	16:4
Pandya et al.[8]	2012	IV	TTF	40	15.0	40:0
Johnson et al.[19]	2014	IV	TEF	20	12.5	12:8
Mitchell et al.[2]	2015	IV	TEF	58	12.0	34:24
Chotel et al.[20]	2016	IV	TEF	15	6.5	9:6
Najdi et al.[21]	2016	IV	TEF	24	11.0	17:7
Feucht et al.[4]	2017	III	TEF	54	12.5	35:19
Rhodes et al.[5]	2018	IV	TEF	163	11.8	109:54
Shin et al.[1]	2018	IV	TEF	27	10.1	19:8
Mayo et al.[22]	2019	IV	TEF	129	10.5	85:44
Callanan et al.[23]	2019	III	TEF	67	11.8	49:18
Formiconi et al.[24]	2020	IV	TTF	12	14.1	11:1
Jardaly et al.[25]	2021	IV	TTF	95	14.2	84:11
Quinlan et al.[26]	2021	IV	TEF	97	10.7	33:33
Kushare et al.[9]	2021	IV	TPF	53	15.4	44:9

Details of studies published in systematic review, organized by year of publication.

injury. The most common was meniscal entrapment (n = 234 [22.1%]), whereas tendinous extensor mechanism disruption was the least common (n = 22 [10.1%]) outside of the TTF population. The details are outlined in Table 2.

Among TTFs, 15.1% (n = 33) of fractures were associated with soft tissue injury. The most common associated injury was tendinous extensor mechanism disruption, occurring in 10.1% (n = 22) of fractures. Other injuries were relatively uncommon, with meniscal tear occurring in 4.1% (n = 9) of fractures.

TEFs were the largest cohort included in this review of PPTFs. They also represented the greatest incidence of associated soft tissue injury (n = 474), present in 63.5% of these fractures. The most common was meniscal entrapment, occurring in 30.1% of cases. Meniscal pathology (tears/entrapment) represents 79.3% (n = 376) of associated soft tissue injuries in this group, and overall risk of meniscal pathology is 50.3% among TEFs.

Although TPFs represent the smallest cohort in this systematic review, they account for the highest risk of associated soft tissue injury (n = 99). Among these, 60.9% had associated ligament injury (n = 56), followed by meniscal tears occurring in 40.2% (n = 37) of fractures. This cohort also represented the highest proportion of chondral injury, occurring in 13.0% (n = 12) fractures.

Discussion

The most important finding of this study is that 58.7% of PPTFs are associated with soft tissue injury. Associated injury was most common among TPFs and TEFs. Meniscal pathology was the most common across all groups, except for the tibial tubercle fractures. Meniscal entrapment was present in 22.1% of patients and meniscal tears in 18.6%. Despite the incidence of associated pathology, just 47.8% of patients underwent preoperative MRI or were managed with arthroscopy to facilitate intra-articular assessment and determination of the true incidence of disease.

There is limited literature highlighting the incidence of associated soft tissue injuries with proximal tibia fractures in the pediatric population. This association has been well studied in the adult population, with associated soft tissue injury occurring in 71% to 73% of patients.[10,11] This is comparable to what was found in our study in the pediatric population. Similarly, meniscal injury was the most common across both groups.[10,11] Although the fracture patterns may differ somewhat between adults and children, the similar incidence of associated soft tissue pathology suggests generalizability. The differences in injury pattern despite similar mechanism are owed to the relative weakness of pediatric ligamentous attachments and the vulnerability of ossifying physes.

Table 2. Associated Soft Tissue Injury in Different Fracture Types

Fracture Type	Number of Fractures	Associated Soft Tissue Injury	Meniscal Tear	Meniscal Entrapment	Ligamentous Injury	Chondral Injury	Tendinous Extensor Mechanism Disruption
TTF	218	33 (15.1%)	9 (4.1%)	0 (0.0%)	1 (0.5%)	1 (0.5%)	22 (10.1%)
TEF	747	474 (63.4%)	151 (20.2%)	225 (30.1%)	42 (5.6%)	56 (7.5%)	0 (0.0%)
TPF	92	114 (100%)	37 (40.2%)	9 (9.8%)	56 (60.9%)	12 (13.0%)	0 (0.0%)
Total	1057	621 (58.8%)	197 (18.6%)	234 (22.1%)	99 (9.4%)	69 (6.5%)	22 (2.1%)

Summary of the soft tissue injuries associated with different fracture patterns, as well as overall incidence.

Overall, we believe that our study is valid and generalizable, providing valuable information on the incidence of associated soft tissue injuries in PPTFs. This was the goal of the systematic review, because we identified that 58.8% of patients had associated soft tissue injury. Going forward, further research should be conducted into PPTFs, to identify the true incidence of associated injuries with these fracture patterns. A prospective study to identify outcomes, and the significance of these lesions would be useful to inform practice and management decision.

Ultimately, these injuries should prompt consideration by treating physicians for intra-articular assessment before definitive treatment in the form of MRI or arthroscopy. This will allow for informed decision making based on the likely presence of associated soft tissue injury. It is hoped that this will prove useful in preventing morbidity, reoperation, and lost sport years among pediatric patients sustaining these injuries.

Limitations

This systematic review is not without limitations. These are partially pertaining to the design, such that data are collected retrospectively from pre-published articles without access to the complete data set. As such we are also limited by the quality of articles produced, such that all data were gathered from Level III/IV evidence, which were retrospective cohort studies and case series. The level of evidence limits the strength of recommendations that can be drawn from this article. This could lead to reporting bias, because there is a lack of homogeneity to the data. This led to the inability to differentiate between patients who underwent both MRI and arthroscopy in their evaluation and treatment, but rather just the ability to report on the number of patients undergoing each. Finally, although the goal of this study was to define the incidence of associated soft tissue injuries, we did not quantify the significance of these lesions. Not all soft tissue injuries require operation or even lead to substantial morbidity. However, this was outside the scope of our study because we aim to improve recognition of these injuries for treatment consideration.

In addition, in our systematic review there is bias toward TEFs, with 70.6% of fractures included being TEFs. We believe that this is partly due to the mechanism of injury and the nature of a TEF being a functional anterior cruciate ligament injury, such that associated injury is often suspected by treating physicians. We believe that our study underestimates the incidence of associated pathology because of the limited nature of intra-articular assessment, with 47.8% of patients undergoing assessment before definitive management. Despite this underestimation, the high association of intra-articular injury deserves consideration for further assessment in these injuries, with either MRI before surgery or arthroscopy at the time of surgery.

Conclusions

PPTFs are associated with a high incidence of associated injury (58.8%), particularly in TEFs (63.5%) and TPFs (100%).

References

1. Shin CH, Lee DJ, Choi IH, Cho TJ, Yoo WJ. Clinical and radiological outcomes of arthroscopically assisted cannulated screw fixation for tibial eminence fracture in children and adolescents. *BMC Musculoskelet Disord* 2018;19:41.
2. Mitchell JJ, Sjostrom R, Mansour AA, et al. Incidence of meniscal injury and chondral pathology in anterior tibial spine fractures of children. *J Pediatr Orthop* 2015;35:130-135.
3. Ishibashi Y, Tsuda E, Sasaki T, Toh S. Magnetic resonance imaging aids in detecting concomitant injuries in patients with tibial spine fractures. *Clin Orthop Relat Res* 2005;434:207-212.
4. Feucht MJ, Brucker PU, Camathias C, et al. Meniscal injuries in children and adolescents undergoing surgical treatment for tibial eminence fractures. *Knee Surg Sports Traumatol Arthrosc* 2017;25:445-453.
5. Rhodes JT, Cannamela PC, Cruz AI, et al. Incidence of meniscal entrapment and associated knee injuries in tibial spine avulsions. *J Pediatr Orthop* 2018;38(2):e38-e42.
6. Shea KG, Grimm NL, Laor T, Wall E. Bone bruises and meniscal tears on mri in skeletally immature children with tibial eminence fractures. *J Pediatr Orthop* 2011;31:150-152.
7. Pretell-Mazzini J, Kelly DM, Sawyer JR, et al. Outcomes and complications of tibial tubercle fractures in pediatric patients: A systematic review of the literature. *J Pediatr Orthop* 2016;36:440-446.

8. Pandya NK, Edmonds EW, Roocroft JH, Mubarak SJ. Tibial tubercle fractures: Complications, classification, and the need for intra-articular assessment. *J Pediatr Orthop* 2012;32:749-759.
9. Kushare I, McHorse G, Ghanta R, Kastan K, Stone T, Wunderlich NA. High incidence of intra-articular injuries with segond fractures of the tibia in the pediatric and adolescent population. *J Pediatr Orthop* 2021;41:514-519.
10. Stannard J, Lopez R, Volgas D. Soft tissue injury of the knee after tibial plateau fractures. *J Knee Surg* 2010;23:187-192.
11. Warner SJ, Garner MR, Schottel PC, et al. The effect of soft tissue injuries on clinical outcomes after tibial plateau fracture fixation. *J Orthop Trauma* 2018;32:141-147.
12. Shelton W, Canale S. Fractures of the tibia through the proximal tibial epiphyseal cartilage. *J Bone Joint Surg* 1979;61:167-173.
13. Ogden JA, Tross RB, Murphy MJ. Fractures of the tibial tuberosity in adolescents. *J Bone Joint Surg Am* 1980;62A(2):205-215.
14. Bolesta M, Fitch R. Tibial tubercle avulsions. *J Pediatr Orthop* 1986;6:186-192.
15. Wiss D, Schilz J, Zionts L. Type III fractures of the tibial tubercle in adolescents. *J Orthop Trauma* 1991;5:475-479.
16. Mah J, Adili A, Otsuka N, Ogilvie R. Follow-up study of arthroscopic reduction and fixation of type III tibial-eminence fractures. *J Pediatr Orthop* 1998;18:475-477.
17. Kocher MS, Micheli LJ, Gerbino P, Hresko MT. Tibial eminence fractures in children: Prevalence of meniscal entrapment. *Am J Sports Med* 2003;31:404-407.
18. Mosier S, Stanitski C. Acute tibial tubercle avulsion fractures. *J Pediatr Orthop* 2004;24:181-184.
19. Johnson A, Wyatt J, Treme G, Veitch A. Incidence of associated knee injury in pediatric tibial eminence fractures. *J Knee Surg* 2014;27:215-219.
20. Chotel F, Raux S, Accadbled F, et al. Cartilaginous tibial eminence fractures in children: Which recommendations for management of this new entity? *Knee Surg Sports Traumatol Arthrosc* 2016;24:688-696.
21. Najdi H, Thévenin-lemoine C, Sales de gauzy J, Accadbled F. Arthroscopic treatment of intercondylar eminence fractures with intraepiphyseal screws in children and adolescents. *Orthop Traumatol Surg Res* 2016;102:447-451.
22. Mayo M, Mitchell J, Axibal D, et al. Anterior cruciate ligament injury at the time of anterior tibial spine fracture in young patients: An observational cohort study. *J Pediatr Orthop* 2019;39:668-673.
23. Callanan M, Allen J, Flutie B, et al. Suture versus screw fixation of tibial spine fractures in children and adolescents: A comparative study. *Orthop J Sports Med* 2019;7(11):2325967119881961.
24. Formiconi F, D'Amato RD, Voto A, Panuccio E, Memeo A. Outcomes of surgical treatment of the tibial tuberosity fractures in skeletally immature patients: An update. *Eur J Orthop Surg Traumatol* 2020;30:789-798.
25. Jardaly A, Conklin M, Ashley P, Gilbert SR. Closed reduction in the treatment of tibial tubercle fractures. *Injury* 2021;52:1336-1340.
26. Quinlan NJ, Hobson TE, Mortensen AJ, et al. Tibial spine repair in the pediatric population: Outcomes and subsequent injury rates. *Arthrosc Sports Med Rehabil* 2021;3(4):e1011-e1023.