Original Article

Thinner Tibial Spine Fracture Fragments Are Associated With Risk of Fixation Failure

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Purpose: To determine the rate of and risk factors for failure of tibial spine fracture (TSF) repair. **Methods:** This was a retrospective review of patients aged 18 years or younger with TSF who underwent arthroscopic repair performed by a single orthopaedic surgeon at a large tertiary academic hospital between 2015 and 2022. Demographic, clinical, injury, fracture, and surgical characteristics were collected. Coronal length and sagittal length and height of the fracture fragment were measured on preoperative plain radiographs and magnetic resonance imaging of the knee. **Results:** Of 25 patients who underwent arthroscopic reduction with internal fixation of TSFs, 2 (8%) experienced fixation failure. In 16 (64%), internal fixation was performed with suture anchors, whereas 8 (32%) underwent internal fixation with screws. There were 19 male patients (76%). There were no differences in demographic factors (age, race, sex, and body mass index), injury characteristics (laterality, mechanism of injury, and activity causing injury), modified Meyers-McKeever fracture classification, or method of internal fixation between the group with fixation failure and the group without failure. Coronal length (14.2 mm vs 18 mm, $P = .17$) and sagittal length (13.9 mm vs 18.7 mm, $P = .17$) of the fracture fragment also did not differ significantly between groups. Sagittal height of the fracture fragment was thinner in patients with failure of fixation (4.3 mm) than in those without failure (8 mm) ($P = .02$). **Conclusions:** Decreased bone thickness of the displaced fragment was associated with an increased likelihood of fixation failure. **Level of Evidence:** Level III, retrospective cohort study.

Tibial spine fracture (TSF), or tibial eminence fracture, is defined as osteochondral avulsion or detachment of the anterior cruciate ligament (ACL) at its tibial insertion site. It is an uncommon injury in the pediatric population, occurring at an estimated annual incidence of 3 per 100,000.[1] Children aged 11 to 14 years are at risk,[2] and the injury mechanism typically involves a pivoting or rotational motion with knee flexion or hyperextension.[1] Male patients have a greater peak incidence that also occurs at an older age.[3,4] Several reasons have been suggested to explain this biological phenomenon, including differences in the timing of bone maturation and variations in risk exposure.[3-5]

Treatment usually relates to the degree of displacement, with immobilization and rest for nondisplaced fractures and operative treatment for displaced injuries.[6] Magnetic resonance imaging (MRI) is often obtained to evaluate for concomitant intra-articular injury.[7] Various methods of operative fixation have been described for the treatment of TSF, including suture anchors, sutures, and screws.[8-10] Studies have not identified a superior method of fixation, given that most techniques have shown good clinical outcomes.[6,11] Despite this, a small percentage of patients may experience fixation failure or reinjury.[12,13]

The purpose of this study was to determine the rate of and risk factors for failure of TSF repair. We hypothesized that decreased bone stock in the displaced fragment would be associated with an increased likelihood of fixation failure.

Methods

Approval from our institutional review board was obtained.

Study Cohort

In this retrospective cohort study, we reviewed patients who presented with TSF and underwent

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Received August 15, 2023; accepted December 20, 2023.

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2666-061X/231163
https://doi.org/10.1016/j.asmr.2023.100878

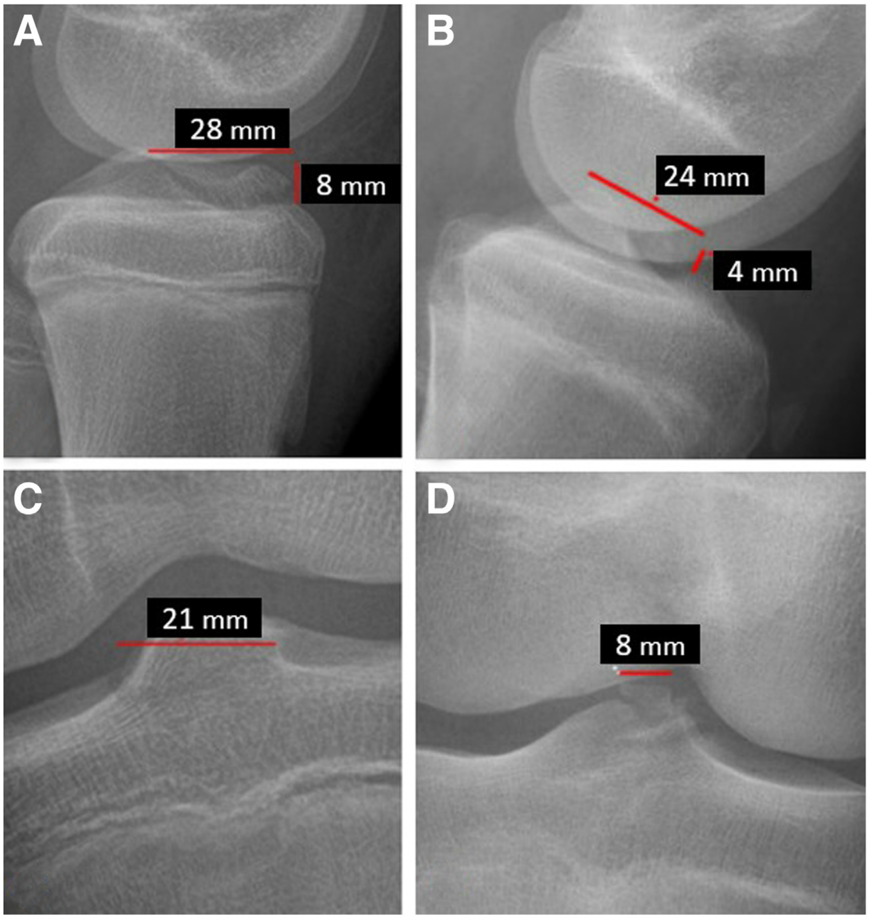

Fig 1. Coronal (A, C) and sagittal (B, D) measurements of type II tibial spine fractures on plain knee radiographs: lateral radiographs of 8-mm sagittal height fragment (A) and 4-mm sagittal height fragment (B) and anteroposterior radiographs of 21-mm fragment (C) and 8-mm fragment (D).

operative treatment between 2015 and 2022 performed by a single orthopaedic surgeon at a large tertiary academic hospital. All patients aged 18 years or younger who had at least 9 months' follow-up were included. Fixation selection was determined based on radiographic and arthroscopic size of the avulsion fragment and fracture pattern. Sutures were used if the fragment size was thin and could potentially fragment or result in poor screw purchase. Screws were used for thicker avulsion fragments. Repair failure was defined as radiologic recurrence of ipsilateral tibial spine avulsion. Patients were categorized into failure and nonfailure groups for comparison after TSF fixation.

During the study period, all patients were recommended to follow the same postoperative protocol for clinical and radiographic evaluation. The protocol consisted of appointments at the following time points after index repair: 2 weeks for clinical and radiographic evaluation, 2 months for clinical evaluation only, 4 months for clinical and radiographic evaluation, and 1 year for clinical and radiographic evaluation.

Data Collection

Data were extracted from institutional electronic medical records, which included clinical and radiographic records. Patient demographic characteristics (age, race, sex, and body mass index [BMI]), injury characteristics (laterality, mechanism of injury, and activity), and fracture and surgery variables were collected. All patient charts were evaluated to determine the incidence of tibial spine avulsion recurrence during follow-up.

Imaging assessment included evaluation of preoperative plain radiographs and MRI scans. Fractures were classified according to the Meyers-McKeever classification system[14] with modification by Zaricznyj,[15] which added type IV to describe comminuted fractures. Type I fractures are nondisplaced, type II fractures involve displacement of the anterior one-third to one-half of the eminence with an intact posterior hinge, and type III fractures are completely displaced.[2] Measurements of TSF fragments included coronal length and sagittal length and height because these parameters have been shown to have moderate interobserver and intraobserver reliability (Fig 1).[6,16] Coronal length was measured as the distance

Table 1. Clinical and Injury Characteristics

Variable	Total (N = 25)	Repair Failure (n = 2)	No Failure (n = 23)	*P* Value
Sex				.43
Male	19	1 (5)	18 (95)	
Female	6	1 (17)	5 (83)	
Race				.15
White	12	1 (8)	11 (92)	
Black	10	0 (0)	10 (100)	
Other	3	1 (33)	2 (67)	
Age, yr	13.4 ± 3.9	11.9 ± 0.9	13.5 ± 4	.29
Body mass index	21.9 ± 6.7	17.8 ± 5.6	22.3 ± 6.7	.19
Injured side				.70
Left	14	1 (7)	13 (93)	
Right	11	1 (9)	10 (91)	
Mechanism of initial injury				.61
Contact	9	0	9	
Twisting	8	1 (13)	7 (88)	
Hyperextension	5	1 (20)	4 (80)	
Uncertain	3	0	3	
Activity causing initial injury				.91
Sports	17	2 (12)	15 (88)	
Bicycling	3	0	3	
Motor vehicle collision	2	0	2	
Fall from height	2	0	2	
Other	1	0	1	

NOTE. Data are expressed as number, number (percentage), or mean ± standard deviation.

from the medial-most to lateral-most aspect of the fracture fragment. Sagittal length and height were measured from the most anterior to most posterior aspect and from the most superior to most inferior aspect, respectively, of the fracture fragment.

Two reviewers (G.B., D.B.) performed the measurements and classifications independently. Any discrepancies in measurements or classifications were resolved by the senior author. In cases in which both plain radiographs and MRI scans were available, radiographs were used for obtaining measurements.

Statistical Analysis

Descriptive statistics were presented as mean ± standard deviation for continuous variables and number (percentage) for categorical variables. Statistical analysis was performed using the Student *t* test for continuous data and Pearson χ^2 and Fisher exact tests for categorical data. The level of significance was defined as $P < .05$. Analysis was conducted using Stata statistical software (release 17 [2021]; StataCorp, College Station, TX). In 5 (20%) patients, only preoperative MRI scans of the knee were available. To assess agreement between radiographic and MRI measurements, we performed analysis using the Lin concordance correlation coefficient (CCC), a statistical test that evaluates the degree of concordance between 2 continuous variables and provides an estimate of their correlation and accuracy.

Results

From 2015 to 2022, 25 patients underwent arthroscopic reduction with internal fixation of TSF. One patient was excluded because of lack of available imaging. Of these 25 patients included in this study, 2 (8%) experienced TSF fixation failure, 1 due to a noncontact, twisting injury while playing with his pet at 147 days postoperatively and the other due to a noncontact injury while playing field hockey at 311 days postoperatively. Postoperatively, no patient exhibited residual laxity or instability requiring ACL reconstruction. Both patients with fixation failure underwent index repair and subsequent reoperation with sutures and anchors. All patients had at least 9 months of follow-up (range, 9-57 months). Preoperative plain knee radiographs with at least 2 views were available in 20 patients (80%). Of these patients, 14 (70%) also underwent preoperative MRI of the knee.

Patient and Injury Characteristics

Most patients were male (19 [76%]) and white (11 [44%]), with an average age of 13.4 years and BMI of 21.9 (Table 1). The cohorts did not differ significantly in patient age, sex, race, or BMI. We found no between-group differences in laterality of injury, mechanism of injury (contact, twisting, or hyperextension of the knee; $P = .61$), or activity causing injury (sports, bicycling, motor vehicle collision, or fall from height; $P = .91$).

Table 2. Fracture and Surgery Characteristics

Variable	Total (N = 25)	Repair Failure (n = 2)	No Failure (n = 23)	*P* Value
Fracture type				.57
Type II	6	0 (0)	6 (100)	
Types III and IV	19	2 (11)	17 (90)	
Treatment				.57
Suture and anchors	16	2 (13)	14 (88)	
Screws	8	0 (0)	8 (100)	
Arthroscopy and debridement only	1	0 (0)	1 (100)	

NOTE. Data are expressed as number or number (percentage).

Fracture and Surgery Characteristics

Of the 25 patients, 6 (24%) had type II fractures, 18 (72%) had type III fractures, and 1 (4%) had a type IV fracture (Table 2). During arthroscopic examination, 1 patient was found to have a well-healed fracture in the elevated position and underwent only debridement of the anterior part of the fracture to prevent anterior impingement. In 16 patients (64%), arthroscopic reduction with internal fixation was performed using suture anchors, whereas 8 patients (32%) underwent arthroscopic reduction and internal fixation with screws. There were no differences in repair failure based on the classification of the index fracture or treatment.

Fracture Fragment Size

Coronal length (14.2 mm vs 18 mm, $P = .17$) and sagittal length (13.9 mm vs 18.7 mm, $P = .17$) of the fracture fragment did not differ significantly between the failure and nonfailure groups (Table 3). However, sagittal height of the fracture fragment was thinner in patients with recurrence of tibial spine avulsion than in patients without failure (4.3 mm vs 8 mm, $P = .02$). The Lin CCC analysis showed a high level of agreement between radiographic and MRI measurements for sagittal height, with a CCC value of 0.89 (95% confidence interval [CI], 0.77-1.0; $P < .001$; asymptotic CI).

Discussion

In this study, we found that decreased bone fragment thickness was associated with failure after arthroscopic fixation (mean sagittal height, 4.3 ± 1.0 mm vs 8.0 ± 2.3 mm; $P = .02$). These findings suggest that a different treatment method, such as ACL reconstruction, may be more appropriate for such fractures with decreased bone fragment thickness.

Table 3. Tibial Spine Fracture Fragment Radiographic Measurements

Radiographic Factor	Repair Failure (n = 2)	No Failure (n = 23)	*P* Value
Coronal length, mm	14.2 ± 2.6	18 ± 5.4	.17
Sagittal length, mm	13.9 ± 0.1	18.7 ± 6.7	.17
Sagittal height, mm	4.3 ± 0.9	8 ± 2.3	.02*

NOTE. Data are expressed as mean ± standard deviation.
*Statistically significant.

Previous studies evaluating the utility of open and arthroscopic treatment of TSFs have shown good outcomes for both treatment options.[6,11] In 2 systematic reviews of studies investigating treatment methods for TSFs, outcomes after operative treatment of displaced TSFs were superior to those of conservative management, including better clinical knee stability, decreased laxity, and a much lower rate of ACL reconstruction (10-fold decrease).[6,11] However, no consistent differences were found between arthroscopic and open fixation or between suture anchor and screw fixation. The rate of persistent laxity leading to ACL reconstruction for all methods of operative fixation was around 0.5% to 2.6%.[6,11,17] As such, the higher failure rate in our cohort, represented by the 2 patients with decreased bone fragment height, may indicate the need for alternative treatment approaches when the bony avulsion fragment is insufficient for true bone-to-bone healing.

The term "cartilaginous TSF" has recently been used in 3 articles to describe an entity that reportedly differs from traditionally understood TSFs.[18-20] The term was used to describe a cartilaginous avulsion of the ACL insertion site that may occur in younger patients with immature ossification. In a series of 15 patients with cartilaginous TSFs treated conservatively or with suture fixation, most patients had good outcomes, but 3 eventually required ACL reconstruction.[19] Green et al.[21] evaluated the reliability of TSF diagnosis on radiographs and MRI scans and found that 6.9% of fractures were not visible on radiographs. A fracture not being visible on radiographs points to a thin bony avulsion or an injury similar to the cartilaginous TSF. Our study highlights the unique characteristics of TSFs with limited bone stock, which may fall on the spectrum between bony TSFs and purely cartilaginous TSFs. Our study also suggests that the traditional techniques used to treat bony TSFs may not achieve the same results in fractures with less bone stock available, given that decreased bone thickness was directly associated with the risk of failure after fixation. Repairing these TSFs with low bone stock may be more comparable to ACL avulsions that undergo ligament-to-bone repair. These primary ACL repairs have been shown to a have a high rate of failure. Gagliardi et al.[22] reported a series of ACL repairs with a 48% rate of failure in a pediatric population. As in our low–bone stock TSFs, primary ACL reconstruction may be the better option in these patients.[22] Future studies are needed to understand this subset of TSFs and its best treatment option.

Limitations

This study has several limitations. First, we measured bone size using different imaging modalities (radiography vs MRI) in different patients depending on availability. This may have introduced measurement biases, but we did try to rule that out by showing consistency of measurement (Lin CCC = 0.89) in patients who had both radiographs and MRI scans. Second, our sample size was limited, and our study may have been underpowered to detect other variables associated with failure. The limited sample size also precluded multivariate analyses to control for potential confounders. Nonetheless, observational biases typically cause a decrease in the likelihood of detecting differences. Therefore, the differences in bone thickness that we did detect are likely true findings. Considering our sample size, future multicenter studies are warranted to produce a larger data set. Last, as with all retrospective observational studies, we can establish only correlation and not causation. As such, although mechanically feasible, it is not clear if low bone stock is a causative risk factor for failure.

Conclusions

Decreased bone thickness of the displaced fragment was associated with an increased likelihood of fixation failure.

Disclosure

The authors report the following potential conflicts of interest or sources of funding: R.J.L. reports research support from Vericel and education support other from Arthrex and Supreme Orthopedics, outside the submitted work. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Acknowledgment

For editorial assistance, we thank Denise Di Salvo, M.S., Sandra Crump, M.P.H., and Rachel Box, M.S., in the Editorial Services group of the Johns Hopkins Department of Orthopaedic Surgery.

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