

# A Comparison of Nonoperative and Operative Treatment of Type 2 Tibial Spine Fractures

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**Background:** Tibial spine fractures (TSFs) are typically treated nonoperatively when nondisplaced and operatively when completely displaced. However, it is unclear whether displaced but hinged (type 2) TSFs should be treated operatively or nonoperatively.

**Purpose:** To compare operative versus nonoperative treatment of type 2 TSFs in terms of overall complication rate, ligamentous laxity, knee range of motion, and rate of subsequent operation.

**Study Design:** Cohort study; Level of evidence, 3.

**Methods:** We reviewed 164 type 2 TSFs in patients aged 6 to 16 years treated between January 1, 2000, and January 31, 2019. Excluded were patients with previous TSFs, anterior cruciate ligament (ACL) injury, femoral or tibial fractures, or grade 2 or 3 injury of the collateral ligaments or posterior cruciate ligament. Patients were placed according to treatment into the operative group ( $n = 123$ ) or nonoperative group ( $n = 41$ ). The only patient characteristic that differed between groups was body mass index (22 [nonoperative] vs 20 [operative];  $P = .02$ ). Duration of follow-up was longer in the operative versus the nonoperative group (11 vs 6.9 months). At final follow-up, 74% of all patients had recorded laxity examinations.

**Results:** At final follow-up, the nonoperative group had more ACL laxity than did the operative group ( $P < .01$ ). Groups did not differ significantly in overall complication rate, reoperation rate, or total range of motion (all,  $P > .05$ ). The nonoperative group had a higher rate of subsequent new TSFs and ACL injuries requiring surgery (4.9%) when compared with the operative group (0%;  $P = .01$ ). The operative group had a higher rate of arthrofibrosis (8.9%) than did the nonoperative group (0%;  $P = .047$ ). Reoperation was most common for hardware removal (14%), lysis of adhesions (6.5%), and manipulation under anesthesia (6.5%).

**Conclusion:** Although complication rates were similar between nonoperatively and operatively treated type 2 TSFs, patients treated nonoperatively had higher rates of residual laxity and subsequent tibial spine and ACL surgery, whereas patients treated operatively had a higher rate of arthrofibrosis. These findings should be considered when treating patients with type 2 TSF.

**Keywords:** arthrofibrosis; complications; nonoperative treatment; tibial spine fracture

Tibial spine fractures (TSFs) are relatively rare, with an annual incidence of approximately 3 fractures per 100,000 children in the United States.<sup>11</sup> TSFs typically occur in children aged 8 to 14 years and are associated with bicycle falls as well as sports, such as soccer, rugby, and skiing.<sup>2,3,10</sup> TSFs are classified according to the Meyers and McKeever system as type 1 (nondisplaced), type 2 (hinged), or type 3 (completely displaced).<sup>12</sup> The tibial spine is the attachment point for the anterior cruciate ligament (ACL) and is thought to fracture before the ACL ruptures in certain situations secondary to loading rates of the complex and the elastic properties of the ACL.<sup>14,24</sup> TSFs are also associated with concomitant meniscal and ligamentous injuries and ACL deficiency.<sup>7,17</sup>

Currently, there is no consensus on the best treatment for type 2 TSFs. It is generally agreed that type 1 fractures

should be treated nonoperatively using immobilization and type 3 fractures should be treated operatively.<sup>12,18</sup> However, the treatment approaches to type 2 TSFs vary. Jackson et al<sup>9</sup> surveyed surgeon members of the Pediatric Orthopaedic Society of North America and found that 68% of respondents recommended operative treatment for type 2 TSFs. In contrast, Adams et al<sup>1</sup> conducted a discrete-choice experiment using 40 case vignettes and found that pediatric orthopaedic surgeons selected operative treatment for 85% of the presented type 2 fractures, with significant variability in their threshold to pursue surgery. With this variation of opinion about appropriate treatment of type 2 TSFs, research is needed to compare outcomes between operative and nonoperative treatment.

Our objective was to compare operative versus nonoperative treatment of type 2 TSFs in terms of overall complication rate, ligamentous laxity, knee range of motion (ROM), and rate of reoperation. We hypothesized that the treatment types would not differ by complication rate or measured outcomes.

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## METHODS

## Patient Selection

Institutional review board approval and reliance were granted for the 10 participating pediatric hospitals in the United States. We included patients aged 6 to 16 years who presented with a TSF to any of the 10 hospitals between January 1, 2000, and January 31, 2019. The modified Meyers and McKeever classification system<sup>12</sup> was used to classify fractures, and only patients with type 2 TSFs were included. Patients with previous TSF or ACL injury; associated femoral or tibial fracture; or concomitant grade 2 or 3 injury of the medial collateral ligament, lateral collateral ligament, or posterior cruciate ligament were excluded.

## Study Groups

Patients were categorized into the operative or nonoperative group depending on their treatment. Operative treatment consisted of open reduction and internal fixation or arthroscopic reduction and internal fixation. Nonoperative treatment consisted of 1 or more of the following: immobilization in a cast, brace, or knee immobilizer with or without a formal attempt at reduction; physical therapy; activity restrictions; or weightbearing restrictions. Of 164 patients who met our inclusion criteria, 41 (25%) underwent nonoperative treatment, and 123 (75%) underwent operative treatment.

## Patient and Injury Characteristics

The cohorts did not differ significantly by patient age or sex; however, patients in the nonoperative group had a higher mean body mass index (22) than did patients in the operative group (20;  $P = .02$ ) (Table 1). We found no differences between groups by mechanism of injury (twisting, contact, or hyperextension of the knee;  $P = .63$ ) or the activity causing injury (bicycling, motor vehicle collision, sports, horseplay, fall from height;  $P = .25$ ). Only 64 patients (39%) underwent magnetic resonance imaging before treatment to evaluate for concomitant injuries: 15 (37%) in the nonoperative group and 49 (40%) in the operative group. The operative group had a significantly higher rate of concomitant injuries (39%) than did the nonoperative group (2.6%;  $P < .0001$ ). Of these concomitant

TABLE 1  
Characteristics and Pretreatment Details for 164 Patients Aged 6-16 Years With Type 2 TSFs (2000-2019) by Treatment Type<sup>a</sup>

Characteristic	Treatment Group, No. (%) or Mean $\pm$ SD		P Value
	Nonoperative (n = 41)	Operative (n = 123)	
Sex			.59
Male	28 (68)	87 (71)	
Female	13 (32)	36 (30)	
Age, y	11 $\pm$ 2.5	12 $\pm$ 2.7	.36
Body mass index	22 $\pm$ 5.5	20 $\pm$ 4.0	.02
Injured side			.01
Right	27 (66)	53 (43)	
Left	14 (34)	69 (56)	
Mechanism of injury <sup>b</sup>			.63
Twisting	8 (31)	43 (43)	
Contact	12 (46)	37 (37)	
Hyperextension	3 (12)	7 (7.1)	
Uncertain	3 (12)	12 (12)	
Activity causing injury <sup>c</sup>			.25
Sports	19 (49)	73 (59)	
Motor vehicle collision	3 (7.7)	3 (2.4)	
Bicycling	3 (7.7)	17 (14)	
Running	0 (0)	2 (1.6)	
Horseplay	2 (5.1)	2 (1.6)	
Fall from height	5 (13)	13 (11)	
Other	7 (18)	13 (11)	

<sup>a</sup>TSF, tibial spine fracture.

<sup>b</sup>Data available for 125 patients (26 in the nonoperative group and 99 in the operative group).

<sup>c</sup>Data available for 162 patients (39 in the nonoperative group and 123 in the operative group).

injuries, 8 patients had soft tissue entrapment; 4, partial ACL tears; 6, medial meniscal tears; 24, lateral meniscal tears; 5, chondral injury; and 1, another ligamentous injury. In the nonoperative group, 1 patient had a concomitant ligamentous injury.

Mean duration of follow-up with an orthopaedic surgeon was significantly longer in the operative group (11 months; 95% CI, 8.9-14) than in the nonoperative group (6.9 months; 95% CI, 3.9-10). At final follow-up, 74% of all patients had a recorded laxity examination.

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Ethical approval for this study was obtained from Children's Hospital of Philadelphia (institutional review board 17-013853).

**TABLE 2**  
Complications Among 164 Patients Aged 6-16 Years With Type 2 TSFs (2000-2019) by Treatment Type<sup>a</sup>

Complication	Treatment Group, No. (%)		P Value
	Nonoperative (n = 41)	Operative (n = 123)	
Any complication	7 (17)	17 (14)	.61
Arthrofibrosis	0 (0)	11 (8.9)	.047
Instrumentation complication	0 (0)	1 (0.81)	.56
Ipsilateral new ACL injury	2 (4.9)	0 (0)	.01
Ipsilateral new TSF	2 (4.9)	0 (0)	.01
Leg-length discrepancy	0 (0)	2 (1.6)	.41
Nonunion	1 (2.4)	0 (0)	.08
Persistent pain	1 (2.4)	2 (1.6)	.74
Superficial infection	0 (0)	1 (0.81)	.56

<sup>a</sup>ACL, anterior cruciate ligament; TSF, tibial spine fracture.

### Outcomes of Interest

The primary outcome of interest was overall complication rate. Complications included new TSFs, new ACL injuries, nonunion, hardware complications, superficial infections, leg-length discrepancies, persistent pain, and arthrofibrosis. Arthrofibrosis was considered present if it was diagnosed by the treating surgeon or if the patient had a loss of 10° of extension or 25° of flexion in the injured compared with the uninjured leg. Secondary outcomes were post-treatment laxity on final clinical examination, final post-operative ROM, and the rate of subsequent surgical procedures. Functional ROM was defined as <130° of flexion and/or >5° of extension loss without a need for revision.

### Statistical Analysis

Descriptive, univariate, and bivariate statistics were used to evaluate and compare the 2 treatment groups. Statistical analyses were performed using Stata Version 15.0 (StataCorp LLC). Significance was set at  $P < .05$ .

## RESULTS

### Complication Rates

The complication rates were 17% (7 patients) in the nonoperative group and 14% (17 patients) in the operative group, which were not significantly different ( $P = .61$ ). Two patients treated nonoperatively (4.9%) and no patients treated operatively experienced new ipsilateral TSFs and ACL injuries ( $P = .01$ ). The new TSFs in the nonoperative group occurred, on average, 5.2 months after the initial injury. The operative group had a higher rate of arthrofibrosis (8.9%) than did the nonoperative group (0%;  $P = .047$ ). No other complication rates differed significantly between treatment groups (Table 2).

**TABLE 3**  
Final Outcomes for 164 Patients Aged 6-16 Years With Type 2 TSFs (2000-2019) by Treatment Type<sup>a</sup>

Outcome	Treatment Group		P Value
	Nonoperative (n = 41)	Operative (n = 123)	
Follow-up, mo, mean (95% CI)	6.9 (3.9-10)	11 (8.9-14)	.05
Laxity present, No. (%) <sup>b</sup>			
Anterior drawer	1 (4)	1 (1)	.32
Posterior drawer	1 (4)	0 (0)	.05
Lachman test	7 (28)	7 (7.2)	<.01
Pivot shift	1 (4)	1 (1)	.32
None	19 (76)	89 (92)	<.01
Range of motion, deg, mean ± SD <sup>c</sup>			
Flexion	126 ± 28	134 ± 13	.86
Extension	-0.87 ± 3.9	0.13 ± 3.9	.27
Total arc	127 ± 27	134 ± 14	.89

<sup>a</sup>TSF, tibial spine fracture.

<sup>b</sup>Data available for 122 patients (25 in the nonoperative group and 97 in the operative group).

<sup>c</sup>Data available for 144 patients (33 in the nonoperative group and 111 in the operative group).

### Laxity

Of the patients who had available data for a laxity examination, a significantly greater proportion of the nonoperative group (28%) had laxity in the injured knee based on the Lachman test as compared with the operative group (7.2%;  $P < .01$ ). A greater proportion of patients in the operative group (92%) had stability on all testing when compared with the nonoperative group (76%;  $P < .01$ ) (Table 3).

### Range of Motion

ROM was recorded for 88% of patients at final follow-up. We found no significant differences between the nonoperative and operative groups in flexion (126° and 134°, respectively;  $P = .86$ ), extension (-0.87° and 0.13°, respectively;  $P = .27$ ), or total arc of motion (127° and 134°, respectively;  $P = .89$ ) (Table 3).

### Subsequent Surgical Procedures

The rates of subsequent surgical procedures did not differ significantly between the nonoperative group (9.8%) and the operative group (21%) ( $P = .10$ ). Reasons for a subsequent surgical procedure in the nonoperative group were as follows: 1 new TSF with a lateral meniscal tear, 1 new TSF with a partial ACL tear, 1 treatment failure caused by an incarcerated meniscus, and 1 nonunion. Patients in the nonoperative group who eventually underwent operative treatment did so at a mean 5.7 months (range, 2.4-10 months) after the initial injury. In the operative group, indications for reoperation were isolated implant removal (n = 13), lysis of adhesions and/or manipulation under

anesthesia (n = 7), lysis of adhesions or manipulation under anesthesia with removal of implant (n = 4), nonunion (n = 1), and chondroplasty for a new cartilage injury (n = 1). A significantly larger proportion of patients underwent surgery for a new TSF in the nonoperative group (4.9%) when compared with the operative group (0%;  $P = .01$ ) (Table 4).

#### Patients With Arthrofibrosis

Eleven patients in the operative group were diagnosed with arthrofibrosis by the treating surgeon after index surgery. Of these patients, 4 had an extension deficit, 3 had extension and flexion deficits, and 4 lacked ROM data. Lysis of adhesions and/or manipulation under anesthesia were performed in 6 patients, and 1 additional patient underwent removal of

hardware only. At the final visit, 6 patients achieved full ROM, 3 had functional ROM, and 2 had an unknown final ROM. Final ROM data are summarized in Table 5.

#### DISCUSSION

Although the overall rate of complications was not significantly different between patients treated operatively versus nonoperatively for type 2 TSF, those treated nonoperatively were more likely to experience a new ipsilateral TSF and ACL injury, and patients treated operatively were more likely to develop arthrofibrosis. Furthermore, patients treated nonoperatively had more residual laxity on clinical examination at final follow-up. We found no difference in the overall rate of subsequent surgical procedures. The most common reasons for a subsequent surgical procedure were a new ipsilateral TSF in the nonoperative group and removal of instrumentation in the operative group.

ACL laxity has been reported after operative and non-operative treatment of TSFs.<sup>16,22</sup> TSFs are often caused by mechanisms of injury similar to those that cause ACL injuries. Thus, it has been proposed that laxity may develop because of secondary interstitial damage of the ACL during the original injury that persists despite anatomic reduction of the fracture.<sup>23</sup> Laxity, which can be asymptomatic, is typically diagnosed through physical examination maneuvers.<sup>23</sup> Aderinto et al<sup>2</sup> analyzed functional outcomes 1 year after TSF in 83 adult knees, 76% of which were treated nonoperatively. The authors found that 22% of non-operatively treated knees had symptomatic instability, defined as a positive anterior drawer or Lachman test, whereas only 10% of operatively treated patients had such instability. In a systematic review, Bogunovic et al<sup>4</sup> analyzed data from 308 patients aged 12 to 37 years, of whom 6% had nonoperatively treated TSFs. A total of 60% of patients had type 2 TSFs. The authors found that rates of patient-reported instability were 54% in the nonoperative group and 1.2% in the operative group. Rates of

TABLE 4

Subsequent Operation/Reoperation for 164 Patients Aged 6-16 Years With Type 2 TSFs (2000-2019) by Treatment Type<sup>a</sup>

Reason for Procedure	Treatment Group, No. (%) <sup>b</sup>		P Value
	Nonoperative (n = 41)	Operative (n = 123)	
Any reason <sup>c</sup>	4 (9.8)	26 (21)	.10
Cartilage injury	0 (0)	1 (0.8)	.56
Instrumentation removal	0 (0)	17 (14)	.01
Lateral meniscal tear	1 (2.4)	0 (0)	.08
Lysis of adhesions	0 (0)	7 (5.7)	.09
Manipulation under anesthesia	0 (0)	7 (5.7)	.09
New ACL partial tear	1 (2.4)	0 (0)	.08
New TSF	2 (4.9)	0 (0)	.01
Nonunion	1 (2.4)	1 (0.8)	.41
Other	1 (2.4)	1 (0.8)	.41

<sup>a</sup>ACL, anterior cruciate ligament; TSF, tibial spine fracture.

<sup>b</sup>Data are presented as No. (%) of complications per treatment group unless otherwise indicated.

<sup>c</sup>Expressed as No. (%) of patients.

TABLE 5

Characteristics of 11 Patients With Arthrofibrosis Treated Operatively for Type 2 Tibial Spine Fractures (2000-2019)<sup>a</sup>

No.	Sex	Age, y	Extension Deficit and/or >25° of Flexion Lost	ROM Before Treatment, deg <sup>b</sup>	Treatment	ROM at Final Visit, deg <sup>b</sup>
1	Female	10	Unknown	NR	LOA, MUA	125, 5, 120
2	Female	8	Extension deficit	140, 2, 138	LOA, ROH	140, 0, 140
3	Female	8	Extension deficit	NR	None	140, 5, 135
4	Male	12	Extension deficit	145, 10, 135	LOA, MUA	135, 10, 125
5	Female	11	Both	NR	None	60, 10, 50
6	Female	10	Extension deficit	NR	None	135, 5, 130
7	Male	12	Unknown	NR	LOA, MUA, ROH	NR
8	Male	13	Unknown	NR	MUA	145, 0, 145
9	Female	10	Both	100, 5, 95	ROH	140, 0, 140
10	Female	14	Unknown	NR	LOA, MUA	NR
11	Male	11	Both	85, 5, 80	None	95, 0, 95

<sup>a</sup>LOA, lysis of adhesions; MUA, manipulation under anesthesia; NR, not recorded; ROH, removal of hardware; ROM, range of motion.

<sup>b</sup>ROM expressed as flexion, extension, total arc of motion.

clinical instability were even higher: 70% in the nonoperative group and 14% in the operative group. Our cohorts were similar to those in the study by Aderinto et al, with a significantly higher rate of objective laxity in the nonoperative group per the Lachman test. However, neither Aderinto et al nor Bogunovic et al classified TSFs by type, so our ability to make comparisons with their findings is limited. Furthermore, we found that 6 children had laxity according to the Lachman test but not the pivot-shift test. This difference may be attributable to differences between the tests in sensitivity for diagnosing ACL laxity. In a meta-analysis by van Eck et al,<sup>19</sup> the sensitivity of the Lachman test without anesthesia was 0.81 versus 0.28 for the pivot-shift test. However, with anesthesia, the sensitivity of both tests was comparable (0.91 for Lachman test and 0.73 for pivot-shift test).

Two patients in the nonoperative group experienced new ACL injuries after TSF treatment, 1 of whom underwent surgical fixation and the other of whom pursued nonoperative treatment. In contrast, no patients in the operative group experienced a recurrent ACL injury. These results are consistent with the findings of Bogunovic et al,<sup>4</sup> who reported that patients treated nonoperatively were more likely to undergo subsequent ACL reconstruction surgery in the ipsilateral knee (10%) than were patients treated operatively (1%;  $P = .04$ ). Mitchell et al<sup>13</sup> studied 73 pediatric patients, 19% of whom underwent delayed ACL reconstruction after previous TSF. Twenty-eight patients had type 2 TSFs, of whom 29% were treated nonoperatively. Eight patients with type 2 TSFs underwent ACL reconstructions, 4 of whom were initially treated nonoperatively. However, these patients treated nonoperatively did not sustain a new injury before reconstruction but rather had persistent instability. ACL laxity is often asymptomatic and does not warrant intervention, but it is important to counsel patients about the risk of residual laxity and delayed ACL rupture. Additionally, the nonoperative group in our study had a significantly higher rate of new ipsilateral TSFs treated operatively. Although the new TSFs occurred, on average, 5.2 months after the initial injury, it is impossible to determine whether these injuries were truly new or were undiagnosed nonunions. However, nonunion is a rare complication. In a meta-analysis by Gans et al,<sup>8</sup> only 10 (1.7%) of 580 patients with TSFs had nonunion. Two nonunions occurred in patients with type 2 fractures treated using immobilization; 6, in patients with type 3 fractures treated using immobilization; and 2, in patients with type 3 fractures treated using open reduction and internal fixation. In our study, 3 (7.3%) of 41 patients in the nonoperative group had either a new TSF or nonunion, which is higher than the proportion reported by Gans et al. The higher rate of nonunion and new TSF for nonoperative cases should be considered when deciding which type of treatment to recommend to patients.

Although the overall rates of complications were not significantly different between the nonoperative and operative groups in our study, we found significant differences by type of complication. Most notably, 8.9% of patients in the operative group developed arthrofibrosis versus 0% in the nonoperative group. Arthrofibrosis is the most commonly

reported complication causing knee stiffness after TSF.<sup>9</sup> The reported incidence is approximately 9% to 11% in all TSFs and 7.1% in type 1 and type 2 fractures.<sup>5,8</sup> However, the true incidence of arthrofibrosis is unclear because of differences in its definition. Risk factors for arthrofibrosis include age >18 years, immobilization for >4 weeks, delayed ROM rehabilitation, delayed surgery >7 days, and operative time >2 hours.<sup>2,9,15,21</sup> In a separate analysis of our 10 US hospitals' database, significant predictors of arthrofibrosis included concomitant ACL injury; nonsport traumatic injury; cast immobilization; and, in contrast to other series, younger age. Arthrofibrosis is typically treated using physical therapy, static or dynamic bracing, or manipulation under anesthesia with lysis of adhesions.<sup>20</sup> Fabricant et al<sup>6</sup> analyzed improvements in ROM for 90 adolescents with arthrofibrosis after lysis of adhesions and/or manipulation under anesthesia, with a mean 42 months of follow-up. After treatment, 62% of patients had full ROM at final follow-up, 28% had functional ROM, and 10% required revision. Six patients in our study underwent lysis of adhesions and/or manipulation under anesthesia to treat arthrofibrosis. Furthermore, 55% of patients with arthrofibrosis in our cohort achieved full ROM, and 27% achieved functional ROM. Although arthrofibrosis is typically associated with type 3 TSFs, patients with type 2 TSFs that are operatively treated are also at risk of developing this complication. Patients should be counseled that although operative treatment presents less risk of residual laxity and the need for ACL reconstruction, it presents greater risk of arthrofibrosis and the need for another surgical procedure.

The limitations of this study include the retrospective design and multicenter nature of the data. Different hospitals and providers may have used different criteria for determining laxity, measuring ROM, selecting nonoperative management protocols, and recommending subsequent surgical procedures. There is likely variation among surgeons and centers in the classification of type 2 fractures. Not every patient underwent preoperative magnetic resonance imaging to evaluate for concomitant injuries, which may have led to selection bias. The operative group had more diagnosed concomitant injuries (and thus more surgical interventions), which may have influenced decisions about treatment and fracture classification. The difference in diagnosed concomitant injuries could also be secondary to diagnoses made during the intraoperative examination in the operative group. All of these factors could have resulted in heterogeneity between the nonoperative and operative groups. Moreover, this study presents short-term follow-up data, and longer-term results are needed to determine the presence of late instability, reinjury, and need for subsequent intervention. Some patients were missing final measurements of laxity and ROM, which may have led to underestimation of the number of patients in either group with residual laxity and ROM deficits. Despite these limitations, the data collected from this large multicenter cohort of patients reinforce our current understanding of TSFs and serve as a basis for further study. These findings provide a foundation for studying a larger cohort of patients who have a relatively rare

fracture type. Furthermore, the inclusion of patients from multiple centers in different geographic locations increases the generalizability of the study.

## CONCLUSION

We believe this to be the largest analysis of nonoperative versus operative treatment of type 2 TSFs. Although complication rates were not significantly different between patients treated nonoperatively and operatively, those treated nonoperatively were more likely to develop residual laxity and to undergo future tibial spine and ACL surgery, whereas those treated operatively were more likely to develop arthrofibrosis. These factors should be considered in the clinical decision making for treatment of type 2 TSFs.

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