Tibial Eminence Involvement With Tibial Plateau Fracture Predicts Slower Recovery and Worse Postoperative Range of Knee Motion

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Objectives: To examine 1-year functional and clinical outcomes in patients with tibial plateau fractures with tibial eminence involvement.

Design: Retrospective analysis of prospectively collected data.

Setting: Academic Medical Center.

Patients/Participants: All patients who presented with a tibial plateau fracture (Orthopaedic Trauma Association (OTA) 41-B and 41-C).

Intervention: Patients were divided into fractures with a tibial eminence component (+TE) and those without (−TE) cohorts. All patients underwent similar surgical approaches and fixation techniques for fractures. No tibial eminence fractures received fixation specifically.

Main Outcome Measurements: Short musculoskeletal functional assessment (SMFA), pain (Visual Analogue Scale), and knee range-of-motion (ROM) were evaluated at 3, 6, and 12 months postoperatively and compared between cohorts.

Results: Two hundred ninety-three patients were included for review. Patients with OTA 41-C fractures were more likely to have an associated TE compared with 41-B fractures (63% vs. 28%, $P < 0.01$). At 3 months postoperatively, the +TE cohort was noted to have worse knee ROM (75.16 ± 51 vs. 86.82 ± 53 degree, $P = 0.06$). At 6 months, total SMFA and knee ROM was significantly worse in the +TE cohort (29 ± 17 vs. 21 ± 18, $P \leq 0.01$; 115.6 ± 20 vs. 124.1 ± 15, $P = 0.01$). By 12 months postoperatively, only knee ROM remained significantly worse in the +TE cohort (118.7 ± 15 vs. 126.9 ± 13, $P < 0.01$). Multivariate analysis revealed that tibial eminence involvement was a significant predictor of ROM at 6 and 12 months and SFMA at 6 months. Body mass index was found to be a significant predictor of ROM and age was a significant predictor of total SMFA at all time points.

Conclusion: Knee ROM remains worse throughout the postoperative period in the +TE cohort. Functional outcome improves less rapidly in the +TE cohort but achieves similar results by 1 year.

Key Words: tibial plateau, tibial eminence, fractures, outcomes

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

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INTRODUCTION

Tibial plateau fractures comprise 1%–2% of all fractures of the extremities.[1,2] Despite the prevalence of this fracture, there is little literature regarding the association of tibial eminence involvement with tibial plateau fractures. Isolated fractures of the tibial eminence are less common and are typically discussed in the setting of either pediatric knee injuries or anterior cruciate ligament tears.[3–9] The combination of a tibial plateau fracture with an associated tibial eminence fracture suggests a more significant soft-tissue injury about the knee joint as is implies not only fracture deformity (varus or valgus angulation secondary to fracture displacement) but also anterior tibial translation because of disruption of the anterior cruciate ligament bony attachment.[10] Currently, there is very little literature regarding the association of combined tibial plateau and tibial eminence fractures and functional outcome. In this study, we sought to compare functional outcome and range-of-motion (ROM) of patients with this combined injury to patients with isolated tibial plateau fractures. We hypothesized that patients with tibial eminence fractures in the setting of tibial plateau fractures would have worse functional outcomes and ROM because of the combined bony and ligamentous injury.

PATIENTS AND METHODS

Using an IRB approved prospectively collected tibial plateau fracture database maintained by our institution between January 2005 and January 2016, we performed a retrospective analysis to identify patients who met the following inclusion criteria: age >18 years, operative treatment with plate and screw fixation, and ≥1-year postoperative

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follow-up. Exclusion criteria included patients younger than18 years, patients who underwent either nonoperative treatment or operative treatment with fixation other than plate and screws, and patients with less than 1-year postoperative follow-up. All patients were treated by 1 of 3 orthopaedic traumatologists and underwent similar surgical approaches and postoperative physical therapy protocols.[11] No tibial eminence fractures were fixed during this study period as it was the standard practice of the treating surgeons to treat the fractured tibial eminentia without surgical repair. Fractures were classified according to the OTA/AO classification system (41-C and 41-B).[12] Fractures were also classified according to the Moore fracture-dislocation scheme and reported for descriptive purposes only.[13] Functional outcome scores were measured using the Short musculoskeletal functional assessment (SMFA). Pain scores were measured using the Visual Analogue Scale (VAS) for pain. ROM was measured at the knee using standard flexion and extension measurements in degrees. These three primary outcomes were measured at 3 months, 6 months, and 12 months postoperatively.

Demographic information collected included age, sex, smoking status, education level, Charlson comorbidity index score, body mass index (BMI), and workman's compensation status. Injury characteristics collected included OTA fracture classification, residual articular depression after surgical fixation, postoperative mechanical axis alignment, ligamentous laxity on examination, reoperation rate, and wound complications. Residual articular depression was measured from the plane of the preinjury joint line, parallel to the femoral condyles, to the point of maximum joint depression. As full-length standing films were not present, mechanical axis was measured in the coronal plane using the distal femoral condyles as a reference horizontal axis and measuring the angle in comparison to the tibial shaft.

Statistical Analysis

Patients were divided into a tibial eminence fracture cohort (+TE) and no tibial eminence fracture cohort (−TE). Chi-square test was used to compare ordinal values and students *t* test was used to compare means for demographic and injury characteristics between the cohorts. Significance was determined at $P \leq 0.05$ threshold, and approaching significant was determined at $P < 0.10$ threshold. Outcome measures were compared at 3, 6, and 12 months using the same statistical tests. Subgroup univariate analysis was performed to determine the contribution of OTA fracture classification to tibial eminence fracture outcomes (SMFA and ROM). In this analysis, the primary outcome measures for the several subgroups were compared (refer to Table 2 for a list of subgroups). A multivariate regression analysis was performed to determine independent predictors of 3, 6, and 12 months SMFA and ROM for all patients combined.

RESULTS

Two hundred ninety-three patients met the inclusion criteria and were included in all subsequent analysis. The mean age of the cohort was 49.5 ± 14.7 years and there were 155 men and 138 women. The mean BMI was 27.1 ± 5.5. There were 65 (22.2%) smokers and 12 (4.1%) workman's compensation patients. The mean Charlson comorbidity index for all patients was 0.2 ± 0.5. There were 202 (68.9%) OTA 41-B and 91 (31.1%) OTA 41-C fractures. There was a total of 112 fractures with tibial spine involvement of which 56 (50.0%) were in OTA 41-B fractures and 56 (50.0%) were in OTA 41-C fractures (see **Figures, Supplemental Digital Content 1 and 2**, http://links.lww.com/BOT/A928 and http://links.lww.com/BOT/A929 for a breakdown of OTA 41-B and 41-C fracture with and without TE fracture). Patient's who had moore 2 and moore 5 classification were more likely to have tibial spine fractures, while moore 4's were less likely to have a concomitant spine fracture ($P <$ 0.01, Table 1).

The mean residual articular depression was 0.6 ± 1.1 mm and mean the overall mechanical axis alignment was 86.7 ± 5.7 degrees. The mean time to healing for all patients was 3.9 ± 1.9 months. There were 18 (6.1%) reoperations total and 9 (3.1%) wound complications (Table 1). Nine of these reoperations were for removal of hardware. Only three patients required stability surgery for laxity on examination (2 from −TE, 1 +TE). The remaining six patients required surgery for wound I&D (2), total knee replacements (2), PCL reconstruction (1), and a knee arthroscopy (1).

The mean total SMFA at 3, 6, and 12 months was 36.2 ± 16.5, 23.9 ± 18.2, and 19.0 ± 17.8, respectively. The mean ROM at 3, 6, and 12 months was 82 ± 53, 120.9 ± 17.5, and 123.9 ± 14.3 degree, respectively. The mean VAS (pain) at 3, 6, and 12 months was 2.8 ± 2.5, 3.0 ± 2.6, and 2.9 ± 2.6, respectively.

When comparing the +TE versus −TE cohort, there were no differences in demographic characteristics. There were significantly more + TE within the OTA 41C cohort compared with the OTA 41-B cohort (63% vs. 28%, $P <$ 0.01). A breakdown of the +TE fractures by OTA-fracture type revealed 14 OTA 41-B1, 1 OTA 41-B2, and 41 OTA 41-B3 and 5 OTA 41-C1, 19 OTA 41-C2, and 32 OTA 41-C3. The only injury characteristic that was significantly different between the +TE and −TE cohort was residual articular surface depression after operative fixation (0.8 ± 1.2 vs. 0.4 ± 1.0 mm, $P = 0.04$) (refer to Table 1 for comparison of all demographic and injury characteristics). At 3 months postoperatively, there was no difference in total SMFA or VAS scores; however, the +TE cohort was noted to trend toward significantly worse knee ROM (75.2 ± 51.8 vs. 86.8 ± 53.82 degree, $P = 0.06$). At 6 months, total SMFA and ROM was significantly worse in the +TE cohort (28.5 ± 17.4 vs. 20.9 ± 18.2, $P < 0.01$; 115.62 ± 20.6 vs. 124.1 ± 14.5, $P < 0.01$), but there was no difference in VAS. By 12 months postoperatively, there was no significant difference in SMFA or VAS; however, difference in knee ROM in the +TE cohort remained significant (118.73 ± 15.2 vs. 126.9 ± 12.9, $P < 0.01$). See Figure 1 for differences over time in total SMFA and Figure 2 for differences over time for knee ROM.

Refer to Table 2 for subgroup analysis. Significant differences and values approaching significant difference are highlighted. For SMFA, only group 5 at 6 mo (OTA 41B −TE vs. OTA 41C +TE) demonstrated a significant difference in functional outcome (19.9 vs. 30.2, $P < 0.01$). This

TABLE 1. Comparison of Demographic and Injury Characteristics Between Tibial Plateau Fractures With and Without Tibial Eminence Fracture

	+TE (n = 112) (%)	−TE (n = 181) (%)	*P*
Demographics			
Male	67 (59.8)	88 (48.6)	0.07
Smoker	22 (19.8)	43 (23.8)	0.43
BMI	27.2 ± 5.2	27.0 ± 5.7	0.76
CCI	0.2 ± 0.4	0.2 ± 0.4	0.64
WC	6 (5.3)	6 (3.4)	0.40
Injury characteristics			
OTA 41-B	56 (50.0)	146 (79.4)	<0.01*
OTA 41-C	56 (50.0)	35 (18.3)	<0.01*
Moore 1	5 (4.5%)	6 (3.3%)	0.62
Moore 2	30 (26.8%)	11 (6.1%)	<0.01*
Moore 3	2 (1.8%)	5 (2.8%)	0.60
Moore 4	2 (1.8%)	17 (9.4%)	0.01*
Moore 5	45 (40.2%)	16 (8.8%)	<0.01*
Fibula fracture	26 (23.2)	23 (12.7)	0.07
Open fracture	8 (7.7)	6 (3.6)	0.14
Postoperative articular depression, mm	0.8 ± 1.2	0.4 ± 1.0	0.02*
Mechanical axis alignment, degrees	86.0 ± 8.7	86.9 ± 1.9	0.38
Reoperation	9 (8.0)	9 (5.0)	0.26
Wound complications	6 (5.4)	3 (1.7)	0.07

*$p < 0.05$.
CCI, Charlson comorbidity index; OTA, orthopaedic trauma association; WC, workman's compensation.

difference was not significant at 1 year (18.1 vs. 21.0 *P* = 0.42). For ROM, at 6 mo group 3 (OTA 41-B +TE vs. OTA 41-C +TE), group 4 (OTA 41B −TE vs. OTA 41C −TE), and group 5 (OTA 41B −TE vs. OTA 41C +TE) demonstrated significant differences in ROM. The difference in ROM for group 3 and group 5 remained significant at 12 months, while group 4 leveled off at this time point. A significant difference was also found at 12 months for group 2, with OTA 41-C fractures with TE involvement having worse ROM compared with OTA 41-C without TE fractures (114.7 vs. 125.0, $P < 0.01$).

Multivariate analysis revealed that independent predictors of SMFA were age (3, 6, and 12 months) and +TE (6 months only). Independent predictors of ROM were +TE (6 and 12 months), BMI (6 and 12 months), and OTA 41-C classification (12 months only) (Table 3).

TABLE 2. Subgroup Analysis of OTA 41B and OTA 41C Fractures With and Without Tibial Spine Fracture: Comparison of SMFA and ROM at 3, 6, and 12 Months

	Group 1, OTA 41-B +TE versus OTA 41-B −TE	Group 2, OTA 41-C +TE versus OTA 41-C −TE	Group 3, OTA 41-B +TE versus OTA 41C +TE	Group 4, OTA 41-B −TE versus OTA 41-C −TE	Group 5, OTA 41B −TE versus OTA 41C +TE	Group 6, OTA 41-B +TE versus OTA 41-C −TE
SMFA 3 mo	34.1 versus, 35.4 (*P* = 0.70)	40.2 versus 36.9.0 (*P* = 0.40)	34.1 versus 39.6 (*P* = 0.12)	35.4 versus 37.3 (*P* = 0.61)	35.4 versus 39.6 (*P* = 0.15)	34.1 versus 37.3 (*P* = 0.50)
SMFA 6 mo	26.5 versus 19.8 (*P* = 0.07)*	30.85 versus 26.3 (*P* = 0.33)	26.5 versus 30.2 (*P* = 0.37)	19.8 versus 25.0 (0.20)	**19.9 versus 30.2 ($P < 0.01$)†**	26.5 versus 25.0 (0.77)
SMFA 12 mo	20.0 versus 18.1 (*P* = 0.65)	21.6 versus 16.4 (*P* = 0.31)	20.0 versus 21.0 (*P* = 0.84)	18.1 versus 18.3 (0.96)	18.1 versus 21.0 (0.42)	20.0 versus 18.3 (*P* = 0.78)
ROM 3 mo	73.6 versus 88.3 (*P* = 0.08)	75.8 versus 80.4 (*P* = 0.69)	73.6 versus 76.8 (*P* = 0.75)	88.3 versus 83.5 (*P* = 0.63)	88.3 versus 76.8 (*P* = 0.16)	73.57 versus 83.5 (*P* = 0.41)
ROM 6 mo	122.7 versus 125.5 (*P* = 0.31)	108.8 versus 118.2 (*P* = 0.09)*	**122.7 versus 109.5 ($P < 0.01$)†**	**125.5 versus 119.1 (*P* = 0.05)†**	**125.6 versus 109.5 (*P* = 0.01)†**	122.7 versus 119.1 (*P* = 0.37)
ROM 12 mo	124.4 versus 127.1 (*P* = 0.36)	**114.7 versus 125.0 ($P < 0.01$)†**	**124.4 versus 114.3 ($P < 0.01$)†**	127.2 versus 125.9 (*P* = 0.69)	**127.2 versus 114.3 ($P < 0.01$)†**	124.4 versus 125.9 (*P* = 0.60)

*Denotes approaching significance.
†Denotes statistically significant difference.
Mo, months; OTA, orthopaedic trauma association.

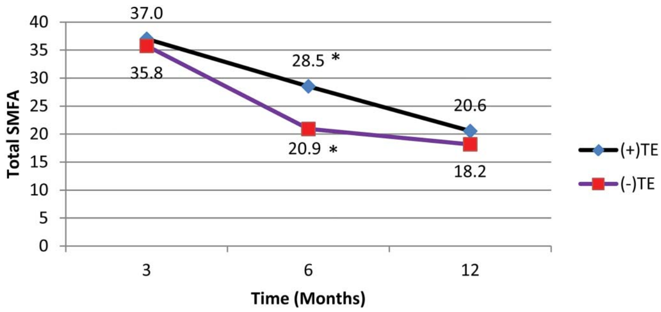

FIGURE 1. Total SMFA scores in tibia plateau fractures with and with tibial eminence fractures. +TE, tibial eminence fracture; −TE, no tibial eminence fracture. *denotes significant difference ($P \leq 0.05$). **Editor's note**: A color image accompanies the online version of this article.

DISCUSSION

The importance of tibial eminence fractures in the setting of tibial plateau fractures has been poorly defined in the current literature. This is the first study to our knowledge to provide a comprehensive assessment of the relationship of these 2 injury patterns. Regarding functional outcome, our data revealed that tibial plateau fractures with and without tibial eminence fractures have similar 3-month functional outcome scores; however, by 6 months, there is a significant difference in the trajectory of improvement demonstrating a lag in recovery of the patients with tibial spine fractures. By 12 months, this effect has decayed (Fig. 1). Because both cohorts underwent similar postoperative physical therapy programs, it is not surprising that during the initial 3-month postoperative period during which all patients are routinely made non–weight-bearing, there is no significant difference in functional outcome. At this point, therapy is focused primarily on knee ROM and quadriceps strengthening. Once the patient has advanced to weight-bearing as tolerated at 3 months postoperatively, it seems that the effect of the tibial eminence fracture becomes evident. By 6 months, +TE patients have not made the same improvement that −TE patients have. This discrepancy in the 6-month functional outcome can be attributed in part to worse knee ROM at this time point. This likely makes the process of ambulatory recovery more difficult.

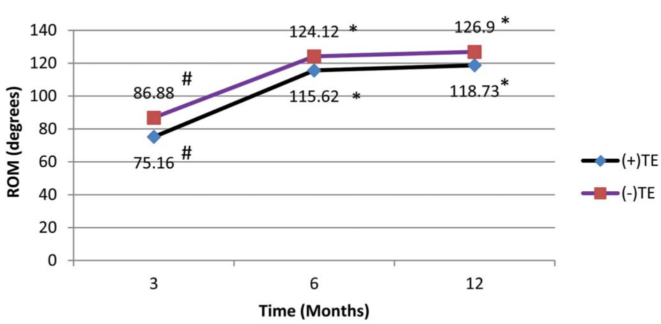

FIGURE 2. Knee ROM in tibial plateau fractures with and without tibial emincence fractures at 3, 6, and 12 months postoperatively. +TE, tibial eminence fracture; −TE, no tibial eminence fracture. *denotes significant difference ($P \leq 0.05$). #denotes approaching significant difference ($P \leq 0.10$). **Editor's note**: A color image accompanies the online version of this article.

Regarding knee ROM, our data reveal that the +TE cohort approaches significantly worse knee ROM at 3 months postoperatively and is significantly worse at 6 and 12 months postoperatively. This finding may help explain part of the discrepancy in 6-month SMFA scores as +TE patients must struggle more during the 3–6 months phase of physical therapy (Fig. 1). This larger hurdle that the +TE cohort must overcome may lead to worse SMFA scores at 6 months.

The multivariate analysis revealed that tibial eminence fracture was an independent predictor of functional outcome and ROM at 6 months and remained a predictor of worse ROM at 12 months. We previously showed in the overall +TE versus −TE cohort that these are the same time points at which the +TE cohort exhibits significant differences from the −TE cohort. The presence of a tibial eminence fracture was noted to have a moderately strong correlation to OTA 41-C fracture classification for 12 month-ROM as well (Table 2). Therefore, the correlation of tibial eminence fracture to OTA 41-C fracture type regarding predicting ROM lends credence to the fact that a contributing factor in the slower recovery of +TE patients is the more complex OTA 41-C fracture type. Although we do note that at 12 months postoperatively both OTA 41C fracture classification and tibial eminence fractures are independent predictors of knee ROM, a confounding factor is the fact that 30 patients (33%) had a dual incision technique for fixation and this may have predisposed them to increase postoperative knee stiffness. Therefore, we cannot definitively say that it is solely the fracture classification and/or the tibial eminence fracture that resulted in worse outcomes.

Our subgroup analysis revealed that within OTA 41-B fractures, there was no significant difference between + TE and −TE patients regarding function and ROM. Comparison of +TE between OTA 41-B and 41-C cohorts (group 3) revealed that although there is no difference in functional outcome, 6 and 12 month-knee ROMs are significantly worse in the 41-C cohort, which again demonstrates the contribution of fracture classification to outcome (Table 2). The inability to demonstrate a significant difference in functional outcome at any time point may be due to inadequate sample size. This is supported by the fact in group 5, where OTA 41-C +TE fractures have poor knee ROM at 6 and 12 months postoperatively compared with OTA 41-B −TE. In this analysis, only SFMA scores at 6 months were found to be statistical different.

Literature on tibial eminence fractures is sparse. At early an follow-up, we speculate that knee ROM may be worse in the setting of tibial eminence as a result of scarring in the intercondylar notch.[14] Rademakers et al[15] evaluated long-term follow-up of isolated tibial spine fractures and found that median 1-year knee ROM was 125 degrees (110–140 degrees). The authors reported long-term follow-up of 16 years and found that knee ROM did not significantly increase with a median knee ROM of 130 degrees (115–140 degrees). In this study, we found that mean 1-year knee ROM in the +TE cohort was 119 degrees which is comparable to the 1-year knee ROM reported by Rademakers.

TABLE 3. Multivariate Analysis Revealing Independent Predictors of SMFA and ROM at 3, 6, and 12 Months Postoperatively

	Model Variables	R^2	Coefficient	*P*	95% CI	Pearson's Correlation With +TE
SMFA 3 mo	Age	0.043	0.186	0.020	0.03 to 0.342	0.032
SMFA 6 mo	TE+	0.117	6.43	0.028	0.149 to 0.512	
	Age		0.257	0.001	0.149 to 0.512	−0.031
SMFA 12 mo	Age	0.038	0.219	0.034	0.017 to 0.442	−0.051
ROM 6 mo	TE+	0.214	−6.359	0.014	−11.418 to −1.301	
	BMI		−0.296	<0.001	−1.288 to −0.492	0.031
ROM 12 mo	TE+	0.174	−6.178	0.011	−10.911 to 1.445	
	BMI		−0.590	0.002	−0.951 to 0.228	0.001
	OTA41-C		−5.418	0.029	−10.279 to 0.558	0.406

Mo, months; OTA, orthopaedic trauma association.

Increasing age was found to be correlated with improved SMFA at all time points. This is counterintuitive to the notion that elderly patients are more frail and therefore are less likely to recuperate well after major injuries. However, Houben et al[16] have shown that younger patients tend to idealize preinjury functional status, whereas older patients are more likely to set realistic goals to obtain a functional rather than idealized baseline postoperatively.

Interestingly, BMI was found to be an independent predictor of ROM at 6 and 12 months. No previous studies that we are aware of have identified BMI as an independent predictor of knee ROM in tibial plateau fractures. While obesity is associated with worse outcomes throughout orthopaedics,[17–19] BMI has been shown to have a negative influence in knee ROM only in patients who have undergone total knee arthroplasty.[20,21] Several factors may play a role in the correlation of increasing BMI to worse knee ROM. Pua et al[22] have reported that patients with higher BMIs have slower improvement in quadriceps strength after total knee arthroplasty. Weak quadriceps function may be directly related to poor knee ROM. Further investigation into the relationship between BMI and knee ROM is warranted.

This study is limited because of its retrospective nature. It would have been ideal to obtain additional data points regarding functional outcome and ROM at pre-3 months to see how these outcomes improve during the immediate postoperative period. Advanced postoperative imaging, either in the form of full leg–length plain X-rays or CT scanograms, was not obtained and could have provided a more accurate assessment of leg alignment. In addition, postoperative CT would have provided a more accurate assessment of articular surface depression. It is not the routine practice of the study authors to obtain these advanced imaging. In addition, because of the small sample size, we may not have been powered to detect differences in SMFA and ROM in the subgroup analysis. Future studies may attempt to evaluate a larger cohort of patients to detect these differences.

CONCLUSION

Tibial eminence fractures in the setting of tibial plateau fractures are more common in high-energy–type fracture patterns (OTA 41-C), but they still occur in a third of lower energy plateau fractures (OTA 41-B). Although discrepancy in early (3 months) knee ROM approaches significance, the +TE cohort had significantly worse ROM by 6 and 12 months. The functional outcome improves less rapidly in the +TE cohort but achieves similar results by 1 year. The presence of a tibial eminence fracture in an OTA 41-B fracture results in a functional outcome similar to that of OTA 41-C fracture with tibial eminence involvement; however, knee ROM is worse in the OTA 41-C fracture type. Ultimately, combined tibial eminence and tibial plateau fractures are associated with slower recovery but do achieve comparable functional outcomes to patients without tibial eminence fractures at 1-year follow-up.

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