Suture Versus Screw Fixation of Tibial Spine Fractures in Children and Adolescents

A Comparative Study

Mark Callanan,*† MD, Judd Allen,† MD, Brett Flutie,† BS, Francis Tepolt,† MD, Patricia E. Miller,† MS, Dennis Kramer,† MD, and Mininder S. Kocher,† MD, MPH

Investigation performed at Boston Children's Hospital, Boston, Massachusetts, USA

Background: Tibial spine fractures involve an avulsion injury of the anterior cruciate ligament (ACL) at the intercondylar eminence, typically in children and adolescents. Displaced fractures are commonly treated with either suture or screw fixation.

Purpose: To investigate differences in various outcomes between patients treated with arthroscopic suture versus screw fixation for tibial spine avulsion fractures in one of the largest patient cohorts in the literature.

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

Methods: A search of medical records was performed with the goal of identifying all type 2 and type 3 tibial spine avulsion fractures surgically treated between 2000 and 2014 at a pediatric hospital. All patients had a minimum of 12 months clinical follow-up, suture or screw fixation only, and no major concomitant injury.

Results: There were 68 knees in 67 patients meeting criteria for analysis. There were no differences with regard to postsurgical arthrofibrosis ($P = .59$), ACL reconstruction ($P = .44$), meniscal procedures ($P = .85$), instability ($P = .49$), range of motion ($P = .51$), return to sport ($P > .999$), or time to return to sport ($P = .11$). Elevation of the repaired fragment on postoperative imaging was significantly greater in the suture group (5.4 vs 3.5 mm; $P = .005$). Postoperative fragment elevation did not influence surgical outcomes. The screw fixation group had more reoperations (13 vs 23; $P = .03$), a larger number of reoperations for implant removal (3 vs 22; $P < .001$), and nearly 3 times the odds of undergoing reoperation compared with suture patients (odds ratio, 2.9; $P = .03$).

Conclusion: Clinical outcomes between suture and screw fixation were largely equivalent in our patients. Postoperative fragment elevation does not influence surgical outcomes. Consideration should be given for the greater likelihood of needing a second operation, planned or unplanned, after screw fixation.

Keywords: tibial spine; avulsion fracture; adolescent ACL; pediatric ACL; suture fixation; screw fixation

Tibial spine fractures involve an avulsion injury of the anterior cruciate ligament (ACL) at the intercondylar eminence and usually occur in children and adolescents.[11] They are classified based on the degree of displacement: type 1 fractures are minimally displaced; type 2 are partially displaced with an intact posterior hinge; type 3 are completely displaced; and type 4 are completely displaced, comminuted, or with rotation.[13] Type 1 fractures are typically treated nonoperatively, while type 2 and type 3 are typically treated with surgical reduction and fixation to ensure healing in an anatomic position to avoid knee instability or lack of extension.[11,12,21]

Although there are various arthroscopic and open surgical techniques reported, currently no consensus exists on the optimal method of fixation.[6,12,21] The most common repair techniques utilize arthroscopic reduction with suture or screw fixation. Previous biomechanical studies

*Address correspondence to Mark Callanan, MD, 7925 Youree Dr, Suite 200, Shreveport, LA 71105, USA (email: callana1@gmail.com).

†Boston Children's Hospital, Boston, Massachusetts, USA.

One or more of the authors declared the following potential conflict of interest or source of funding: J.A. has received educational support from Pylant Medical, Smith & Nephew, and Arthrex. D.K. has received educational support from Kairos Surgical. M.S.K. has received consulting fees and royalties from OrthoPediatrics and Ossur, nonconsulting fees from Smith & Nephew, and honoraria from Stryker. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from Boston Children's Hospital Office of Clinical Investigation (IRB-P00005943).

The Orthopaedic Journal of Sports Medicine, 7(11), 2325967119881961
DOI: 10.1177/2325967119881961

have shown that in cadaveric models, sutures demonstrated higher peak failure and pull-out strength, with more consistent fixation after repetitive cycling in comparison with cannulated screws for the treatment of this injury.[1,3,18] Ultimately, previous studies comparing clinical outcomes between suture and screw fixation of tibial spine avulsion fractures have largely shown no difference in clinical or radiographic outcomes.[8,15,19] A recent systematic review concluded there is currently insufficient evidence in the literature to determine that arthroscopic surgery is superior to open surgery or that suture fixation is superior to screw fixation.[6]

The purpose of this study was to investigate differences in outcomes between patients treated with arthroscopic suture versus screw fixation for tibial spine avulsion fractures with respect to ability to return to sports, postoperative loss of motion, instability, reoperation, or any other surgical complications.

METHODS

After institutional review board approval, a computerized medical record search was performed to identify all type 2 and type 3 tibial spine avulsion fractures surgically treated between 2000 and 2014 at a tertiary care children's hospital. Inclusion criteria included the presence of a tibial spine avulsion fracture, surgical fixation with either arthroscopic suture or screw, and a minimum of 12 months clinical follow-up. Exclusion criteria included patients with inadequate follow-up, hybrid fixation, fixation other than sutures or screws, or any chondral injury or associated fracture that could potentially have a significant effect on recovery and outcomes compared with an isolated tibial spine avulsion injury. Patients with concurrent meniscal tears were not excluded from analysis.

Electronic medical records were reviewed for radiographic and clinical outcomes that included range of motion (ROM), postoperative fragment elevation, and return to sport. Postoperative fragment elevation was measured on all patients on lateral films and adjusted to 1× magnification. Measurements were made at the level of the tibial plateau up to the highest point of anterior elevation of the tibial spine fragment. Postoperative contracture was determined from clinical follow-up ROM documentation and was defined as per previously published work by Fabricant et al[5] as full, functional, or failure. ROM was extracted from the last documented clinical follow-up date, and measurements were then used to extrapolate patients into the 3 categories of full, functional, or failure, which were used for analysis purposes. As per Fabricant et al, full ROM was defined as achieving –5 to 130 degrees, and functional was defined as failure to reach –5 to 130 degrees of motion but did not require surgery to correct. Failure was defined as any patient who required revision surgery for arthrofibrosis. While goniometer use was specified in some clinical follow-up notes, not all clinical notes had this clearly documented. Postoperative instability was defined as a documented Lachman International Knee Documentation Committee (IKDC) grade C/D or greater than 5-mm difference in anterior drawer compared with the contralateral knee at the longest clinical follow-up date. Patients were dichotomized as stable or unstable based on this criterion for analysis purposes. All complications requiring reoperation were also recorded and included: (1) arthrofibrosis requiring manipulation under anesthesia (MUA) and/or lysis of adhesions (LOAs); (2) surgery for meniscal injury requiring meniscectomy or repair for retear or new tear; (3) instability from ACL incompetence or ACL rupture, requiring ACL repair or reconstruction; and (4) implant removal including deep suture removal (suture group) or screw removal (screw fixation group) that was further subclassified as either planned removal (plan made at time of implant insertion) or unplanned (removal because of symptoms).

Patient and injury characteristics were compared across treatment groups (suture vs screw fixation). Continuous characteristics were compared with Student t test or the Mann-Whitney U test, as appropriate, and categorical characteristics were compared using the chi-square test or Fisher exact test, as appropriate.

Postoperative outcomes including superior elevation of the repaired fragment (as measured on postoperative radiographs), postoperative ROM, residual pain, knee stability, reoperation rate, and return to sports rate were summarized and compared across treatment groups. Multivariable general linear modeling was used to analyze outcomes by treatment group and to assess the possible effects of age, sex, body mass index (BMI) (further stratified by underweight, healthy weight, overweight, and obese), injury mechanism, associated procedures/injuries, and prior surgical history on outcome.

For residual symptoms and knee stability (obtaining a Lachman grade B or higher on clinical examination), ordinal logistic regression was used. For reoperation and return to sport rates, binomial logistic regression was used. Estimates of effect or odds ratios were estimated for significant coefficients along with 95% CIs. All tests were 2-sided, and P values $<.05$ were considered significant.

The technique for suture fixation of tibial spine avulsion fracture first involves direct arthroscopic visualization, followed by removal of any interposed meniscus, intermeniscal ligament, or soft tissue that could block reduction. Once anatomic reduction can be confirmed, a suture is passed through the posterior base of the ACL near the insertion on the tibial spine using a suture-passing device. Typically, No. 1 polydioxanone suture, No. 2 orthocord, or a No. 2 or a No. 5 fiberwire suture would be used. A second suture can be passed in a similar fashion just anterior to the first suture at the base of the ACL. A small incision is made over the proximal tibia to allow placement of the ACL guide, which can be adjusted to avoid physeal perforation in younger patients. The ACL guide is then used to drill medial and lateral holes near the edges of the fracture border on the tibial plateau, through which a suture retriever is then inserted from the tibia into the knee joint. Using the suture retriever, the medial and lateral suture limbs are respectively pulled out through the drilled medial and lateral tunnels. Tension is placed on the sutures, and then quality

TABLE 1
Patient and Injury Characteristics for all Patients and by Treatment Type

Characteristics	All Patients (N = 68) Frequency, %	Suture Fixation (n = 33) Frequency, %	Screw Fixation (n = 35) Frequency, %	P
Age at surgery, y, mean ± SD	11.8 ± 2.99	12.4 ± 2.55	11.2 ± 3.29	.11
Sex (% male)	49 (72)	22 (67)	27 (77)	.42
BMI percentile (n = 49)[a]				
Underweight	2 (4)	1 (3)	1 (6)	.05
Healthy weight	34 (69)	22 (67)	12 (34)	
Overweight	7 (14)	7 (21)	0 (0)	
Obese	6 (12)	2 (6)	4 (11)	
Injury from sport (including football, soccer, dance, skiing, biking, skating, horseback riding, baseball, and kickball)	58 (85)	30 (91)	28 (80)	.15
Mechanism of injury (n = 63)[a]				
Contact	37 (59)	15 (45)	22 (63)	.07
Noncontact	26 (41)	17 (51)	9 (26)	
McKeever class (n = 64)[a]				
II	14 (22)	5 (15)	9 (26)	.23
III	50 (78)	28 (85)	22 (63)	

[a]The number in parentheses represents the number of patients with available data for the given characteristic unless specified otherwise. BMI, body mass index.

and stability of the reduction are confirmed before sutures are tied down over the anterior tibia.

The technique for screw fixation of tibial spine avulsion fracture also involves direct arthroscopic visualization, followed by removal of any interposed meniscus, intermeniscal ligament, or soft tissue that could block reduction. Using either a superomedial or a superolateral portal, provisional wire fixation of the reduced fragment is first achieved. On the basis of the size of the fragment, a second wire may be used to aid fixation in the preparation for a second screw, although typically only 1 screw is used for fixation. A cannulated drill is then used to drill over each wire in preparation for screw fixation. A cannulated screw that is typically 3.5 to 4.5 mm in diameter is then passed over the guide wire and tightened down until adequate reduction and compression of the avulsed fragment is achieved. The screw is epiphyseal and does not cross the proximal tibial physis. Fluoroscopic imaging is used during the case. Quality and stability of reduction are again confirmed after screws are placed.

RESULTS

There were 162 knees that underwent surgical repair for tibial spine avulsion fractures between 2000 and 2014. Of these, 68 knees in 67 patients met criteria for analysis, including 49 (72%) males. Surgical procedures were performed by a total of 11 experienced surgeons at a single institution. The large majority of patients who were ineligible for the study had inadequate follow-up or a disqualifying fixation method with a hybrid technique or smart nails. There were 3 patients excluded because of concurrent chondral injury, and 1 was excluded because of a concurrent tibial plateau fracture. Mean age at surgery was 11.8 ± 2.99 years. Patients were followed for a median of 26 months (interquartile range, 17-47 months). Suture fixation was performed in 33 knees (33/68 knees; 49%) and screw fixation was performed in 35 knees (35/68 knees; 51%). Meniscal entrapment at the time of surgery was noted in 21 of 68 (31%) of patients. There were 17 meniscal tears noted at time of surgery in 15 (22%) patients, with 8 (47%) meniscal repairs performed and 9 (53%) meniscectomies performed. BMI data of 49 patients were recorded (32 in the suture group, 17 in the screw fixation group), among which there were 2 underweight, 34 healthy weight, 7 overweight, and 6 obese patients based on US Centers for Disease Control and Prevention classification of obesity via BMI. We noted a significant difference ($P = .05$) in the number distribution of patients who were treated with suture versus screw fixation in the overweight (7/7; 100% suture) and obese (2/6 [33%] suture vs 4/6 [66%] screw fixation) groups. There were no differences across treatment groups with respect to age ($P = .11$), sex ($P = .42$), injury sports participation ($P = .15$), mechanism of injury ($P = .07$), McKeever class ($P = .23$), or associated injuries ($P = .94$) (Table 1).

Patients treated with suture fixation had a shorter mean follow-up (2.1 vs 4.3 years; $P = .002$) and a reported shorter time to radiographic union (3.2 vs 5.3 months; $P = .03$).

The patients in the suture group had increased superior elevation of the repaired fragment on postoperative imaging (suture fixation, 5.4 ± 2.32 mm; screw fixation, 3.5 ± 1.54 mm; $P = .005$) (Table 2). Fragment elevation was also found to be the only factor independently associated with reoperation, demonstrating an inverse likelihood of reoperation based on fragment elevation, even when adjusting for patient age, BMI, fixation type, and McKeever classification. There were no differences across treatment groups with respect to LOAs/MUA ($P = .59$), ACL reconstruction ($P = .44$), meniscal procedures ($P = .85$), residual symptoms

TABLE 2
Outcomes by Treatment Type[a]

Outcome	Suture (n = 33) Frequency (%)	Screw (n = 35) Frequency (%)	P
Duration of follow-up, y, median (IQR)	2 (1-2)	4 (2-5)	.002
Time to radiographic healing, mo, median (IQR)	3 (2-3)	5 (3-6)	.03
Return to sports (n = 57)[b]	30 (91)	26 (74)	≥.999
Time to RTS, mo, median (IQR) (n = 50)[b]	8 (6-13)	6 (4-8)	.11
Postoperative elevation of the fragment, mm, mean ± SD (n = 50)[b]	5.4 ± 2.32	3.5 ± 1.54	.005
Range of motion			
Full (achieved –5 to 130 degrees or better)	25 (76)	23 (66)	.51
Functional (did not reach –5 to 130 degrees, but did not meet failure criteria)	0 (0)	1 (3)	
Failure (required revision surgery for arthrofibrosis)	8 (24)	11 (31)	
Lachman			
Stable	33 (100)	33 (94)	.49
Unstable	0 (0)	2 (6)	
Hardware/implant removal	3 (9)	22 (63)	<.001
Reoperation data (n = 39[b])			
LOA/MUA	8 (24)	12 (34)	.59
ACL reconstruction	3 (9)	3 (9)	.44
Meniscal procedure	2 (6)	3 (9)	.85
(suture: 2 menisectomies, screw: 1 meniscal repair, 2 menisectomies)			
Reoperation	13 (39)	23 (66)	.03
Number of reoperations			
1	13 (39)	17 (49)	
2	0 (0)	5 (14)	
3	0 (0)	1 (3)	

[a]Data are expressed as frequency (%) unless otherwise indicated. ACL, anterior cruciate ligament; IQR, interquartile range; LOA, lysis of adhesion; MUA, manipulation under anesthesia; RTS, return to sport.

[b]The number in parentheses represents the number of patients with available data for the given characteristic.

($P = .80$), instability ($P = .49$), postoperative ROM ($P = .51$), return to sport (suture fixation, 91%; screw fixation, 74%; $P \geq .999$), or the time taken to return to sport (suture fixation, 8 months [range, 6-13 months]; screw fixation, 6 months [range 4-8 months]; $P = .11$) (Table 2). The sports that patients returned to included football, soccer, dance, skiing, biking, skating, horseback riding, baseball, and kickball.

The screw fixation group had a larger number of reoperations that included implant removal (3 [9%] vs 22 [62%]; $P < .001$) and overall reoperations (13 [39%] vs 23 [65%]; $P = .03$). Of the patients who underwent reoperation for implant removal in the suture group, 2 of 3 (66%) were planned versus 10 of 22 (45%) that were planned in the screw fixation group. When planned implant removal reoperations were excluded, we noted no significant difference between reoperations between the 2 groups, with 11 in the suture group and 13 in the screw fixation group. Overall, screw fixation patients had nearly 3 times the odds of undergoing reoperation compared with suture patients (OR, 2.9; 95% CI, 1.10-7.91; $P = .03$). All 6 patients who required 2 or more reoperations were treated with screw fixation (Table 2). Additional reasons for unplanned reoperations included LOAs/MUA for arthrofibrosis (suture, 8 [24%]; screw, 12 [34%]), ACL reconstruction for instability and tear (suture, 3 [9%]; screw, 3 [8%]), and repeated meniscal procedure for retear versus new meniscal tear (suture, 2 [6%]; screw, 3 [8%]). Of the ACL reconstructions performed, all 3 in the suture group occurred after ACL rupture when patients returned to sports, none of which had documented clinical instability leading up to rupture. Of the ACL reconstructions performed in the screw fixation group, 1 was performed because of rupture after return to sport, and the other 2 were performed because of documented clinical instability and ACL incompetence.

DISCUSSION

This study is one of the largest comparative studies in the literature comparing clinical and radiographic outcomes of suture versus screw fixation of tibial spine avulsion fractures in adolescents and children. Previous literature has described advantages of suture fixation including the ability to reduce and stabilize even small, thin, bony fragments to restore ACL length and allow for early postoperative mobilization while avoiding a second surgery for removal of hardware.[7,17,25] The literature has also determined that suture fixation reduces neurovascular injury risk, prevents fragment comminution because of screw insertion, and can be used in cases of fragment comminution where a screw could not have adequate purchase.[22] However, an outcome comparison study determined that arthroscopic screw fixation yielded significantly better IKDC scores, lower incidence of postoperative glide pivot shift, and shorter operative times in comparison with suture fixation.[16] A recent study[20] has also determined that screw fixation was an effective method for treatment of tibial spine avulsion fractures with good clinical outcomes and few complications, although 100% of patients in the study (n = 27) underwent planned reoperations for hardware removal. A prior study[23] has also described a notable occurrence (5/13; 38%) of postoperative stiffness with suture fixation of tibial spine avulsion fractures, albeit this was in a young adult population in a small cohort of patients.

Our data demonstrated no significant differences between return to sports, residual symptoms, postoperative knee contracture (as defined by Fabricant et al[5]), knee instability (objectively via Lachman examination or greater than 5-mm documented difference in anterior drawer compared with the contralateral knee at the longest clinical follow-up date), or complications (not including reoperation) between patients treated with suture versus screw fixation. This is consistent with previous literature[6,8,15,16,19] that found no significant differences in clinical outcome measures between suture versus screw fixation of tibial spine avulsion fractures.

We noted an overall low incidence of postoperative instability with both suture (0%) and screw (6%) fixation. Only 6 of 68 (8%) of our total patients went on to eventual ACL reconstruction (range, 11.1-114.7 months after initial fixation). Our postoperative instability is lower in comparison with that described in previous literature, which determined the rates of instability to range from 14% to 83%.[2,6,9] The incidence of residual laxity that has been noted in our data and previous literature after tibial spine fixation may be representative of plastic deformation of the ACL occurring from the injury. Given the retrospective nature of our study, we did not have a homogeneous method of measurement or documentation for clinical instability at follow-up. However, all patients who were included in the study had appropriate follow-up and clear objective clinical documentation of laxity at follow-up. As such, we feel our numbers confidently reflect the true incidence in our patients.

As previously stated, we noted no difference between our 2 groups in the development of postoperative contracture as defined by Fabricant et al[5] (24% suture vs 31% screw fixation). A recent study[20] reported only a 4% incidence (1/27 patients) of postoperative contracture with screw fixation, which was defined as 1 patient with a 10-degree flexion contracture. Another study[17] reported only a 8% incidence (2/26 patients) of contracture after arthroscopic suture fixation, which was documented as 1 patient with a 40-degree loss of extension and 1 patient with a 10-degree flexion contracture. The study, however, was a fairly small number of patients that included a wide range of ages from adolescents to adults. A prior study[24] published rates up to 75%, albeit the study used both arthroscopic and open methods for fixation. A systematic review[6] comparing suture versus screw fixation outcomes found a 6.3% rate of postoperative contracture after arthroscopic suture fixation based on their defined criteria of a 10-degree extension deficit or a 25-degree flexion loss. Similarly, a previous study[14] found an 8.3% prevalence of arthrofibrosis in children and adolescents after ACL reconstruction. The higher rate of arthrofibrosis found in our study could be attributed to the large majority of the patients having type 3 fractures, which prior meta-analysis has determined to be a significant factor for loss of motion postoperatively.[6] We also used a strict methodology for defining contracture, which may have contributed to the higher reported rate in our patients and the larger number of patients than the previously mentioned studies.[5]

We had 17 concomitant meniscal injuries in 15 (22%) patients in our patient cohort. A recent study[20] found a similar 22% incidence of meniscal tear at the time of tibial spine avulsion repair in a smaller number of overall patients. However, a prior study found concurrent meniscal injury to be as low as 3.8%.[9] Our finding of 21 of 67 (31%) patients found with meniscal entrapment at the time of surgery fell within the range of previously published incidences (28%-54%).[10,20]

The time to radiographic union of the fragment postoperatively was also noted to be significantly different between suture and screw fixation (3.2 vs 5.3 months; $P = .03$), with a longer time to radiographic union in the screw fixation group. The reasons for this are not clear. We also noted a more significant degree of superior fragment displacement in our patients treated with suture versus screw fixation (5.4 vs 3.5 mm; $P = .005$). This may be a consequence of the fixation forces utilized in the suture repair technique in which the suture typically grabs and reduces the base of the ACL to the donor site, which may cause some superior elevation of the anterior-most portion of the bony fragment that does not have any ACL fibers attached to it. The fragment elevation appears to be inconsequential and a statistical oddity in our series. Fragment elevation was found to be the only factor independently associated with reoperation; however, it showed an inverse likelihood of reoperation based on fragment elevation. This likely means that small 1- to 2-mm amounts of fragment elevation after fixation do not affect the overall outcome. Ultimately, the differences in postoperative fragment elevation were minimal. Given that there were no differences in outcomes between the 2 fixation methods, there, again, does not appear to be clinical relevance to the noted degree of postoperative superior fragment displacement. The lack of clinical difference is likely because of the ACL healing in anatomic position, with the postoperative elevation of the fragment not being great enough to block extension.

One of the most important findings in our study was the significant difference in the number of reoperations between the suture (13; 39%) and screw fixation (23; [66%) groups and the increased odds of reoperation with screw fixation. Notably, 2 of 3 (66%) of the suture fixation isolated implant removal operations were planned versus 10 of 22 (45%) that were planned in the screw fixation group. When planned reoperations for implant removal were removed from the analysis, there was no significant difference in the number of reoperations between 11 in the suture group versus 13 in the screw fixation group. While the clinical outcomes between suture and screw fixation are largely equivalent, the overall greater likelihood of needing a second operation, planned or unplanned, when utilizing a screw fixation technique should be considered. Our findings are consistent with previously published studies including one that described a 44% secondary reoperation rate in patients treated with screw fixation, primarily for removal of hardware.[4] Another study described a group of patients treated exclusively with screw fixation reporting good clinical and functional outcomes; however, 100% of patients underwent reoperation for removal of hardware.[20] As with many of the patients that were in our series, the decision for hardware removal with screw fixation can typically come down to surgeon preference. The choice to avoid intra-articular hardware, concern for physeal tethering in a growing patient, or because the patient was experiencing impingement from the screw head secondary to position of the screw for fixation are the most common reasons for removal. However, in the asymptomatic patient with no impingement or physeal concerns, the screw may often be left in and a second surgery may be avoided altogether.

The primary limitations of this study include those inherent in any retrospective database study. The clinical measures documented were not standardized and were performed by a variety of practitioners at a single institution. For statistical purposes, many continuous variables were also converted to ordinal or dichotomous variables for ease of analysis, which could potentially affect conclusions. We were unable to obtain any significant yield of validated patient-reported outcomes to include in the analysis with the clinical outcomes. We also had a large number of patients with both suture and screw fixation who were excluded from the study because of insufficient clinical follow-up (<12 months), which could represent a bias in our patient study group.

On the basis of our results and conclusions, the authors now routinely employ suture fixation for surgical repair of tibial spine fractures. The data presented support the use of suture fixation over screw fixation, given the lower likelihood of reoperation for screw removal, studies showing biomechanical superiority, ability to cinch up the ACL with repair especially in cases of fragment comminution, and less imaging artifact with postoperative magnetic resonance imaging. Ultimately, a more definitive conclusion advocating only suture over screw fixation would still need to be clarified via higher level studies with prospective data collection and follow-up outcome analysis.

REFERENCES

1. Anderson CN, Nyman JS, McCullough KA, et al. Biomechanical evaluation of physeal-sparing fixation methods in tibial eminence fractures. *Am J Sports Med*. 2013;41(7):1586-1594.
2. Bogunovic L, Tarabichi M, Harris D, Wright R. Treatment of tibial eminence fractures: a systematic review. *J Knee Surg*. 2015;28(3): 255-262.
3. Bong MR, Romero A, Kubiak E, et al. Suture versus screw fixation of displaced tibial eminence fractures: a biomechanical comparison. *Arthroscopy*. 2005;21(10):1172-1176.
4. Coyle C, Jagernauth S, Ramachandran M. Tibial eminence fractures in the paediatric population: a systematic review. *J Child Orthop*. 2014;8(2):149-159.
5. Fabricant PD, Tepolt FA, Kocher MS. Range of motion improvement following surgical management of knee arthrofibrosis in children and adolescents. *J Pediatr Orthop*. 2018;38(9):e495-e500.
6. Gans I, Baldwin KD, Ganley TJ. Treatment and management outcomes of tibial eminence fractures in pediatric patients: a systematic review. *Am J Sports Med*. 2014;42(7):1743-1750.
7. Huang TW, Hsu KY, Cheng CY, et al. Arthroscopic suture fixation of tibial eminence avulsion fractures. *Arthroscopy*. 2008;24(11): 1232-1238.
8. Hunter RE, Willis JA. Arthroscopic fixation of avulsion fractures of the tibial eminence: technique and outcome. *Arthroscopy*. 2004;20(2): 113-121.
9. Kocher MS, Foreman ES, Micheli LJ. Laxity and functional outcome after arthroscopic reduction and internal fixation of displaced tibial spine fractures in children. *Arthroscopy*. 2003;19(10): 1085-1090.
10. Kocher MS, Micheli LJ, Gerbino P, Hresko MT. Tibial eminence fractures in children: prevalence of meniscal entrapment. *Am J Sports Med*. 2003;31(3):404-407.
11. Lafrance RM, Giordano B, Goldblatt J, Voloshin I, Maloney M. Pediatric tibial eminence fractures: evaluation and management. *J Am Acad Orthop Surg*. 2010;18(7):395-405.
12. May JH, Levy BA, Guse D, Shah J, Stuart MJ, Dahm DL. ACL tibial spine avulsion: mid-term outcomes and rehabilitation. *Orthopedics*. 2011;34(2):89.
13. Meyers MH, Mc KF. Fracture of the intercondylar eminence of the tibia. *J Bone Joint Surg Am*. 1959;41-A(2):209-220.
14. Nwachukwu BU, McFeely ED, Nasreddine A, et al. Arthrofibrosis after anterior cruciate ligament reconstruction in children and adolescents. *J Pediatr Orthop*. 2011;31(8):811-817.
15. Osti L, Buda M, Soldati F, Del Buono A, Osti R, Maffulli N. Arthroscopic treatment of tibial eminence fracture: a systematic review of different fixation methods. *Br Med Bull*. 2016;118(1):73-90.
16. Pan RY, Yang JJ, Chang JH, Shen HC, Lin LC, Lian YT. Clinical outcome of arthroscopic fixation of anterior tibial eminence avulsion fractures in skeletally mature patients: a comparison of suture and screw fixation technique. *J Trauma Acute Care Surg*. 2012;72(2): e88-e93.
17. Pandey V, Cps S, Acharya K, Rao SK. Arthroscopic suture pull-out fixation of displaced tibial spine avulsion fracture. *J Knee Surg*. 2017; 30(1):28-35.
18. Senekovic V, Balazic M. Bioabsorbable sutures versus screw fixation of displaced tibial eminence fractures: a biomechanical study. *Eur J Orthop Surg Traumatol*. 2014;24(2):209-216.
19. Seon JK, Park SJ, Lee KB, et al. A clinical comparison of screw and suture fixation of anterior cruciate ligament tibial avulsion fractures. *Am J Sports Med*. 2009;37(12):2334-2339.
20. 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(1):41.
21. Shin YW, Uppstrom TJ, Haskel JD, Green DW. The tibial eminence fracture in skeletally immature patients. *Curr Opin Pediatr*. 2015;27(1): 50-57.
22. Strauss EJ, Kaplan DJ, Weinberg ME, Egol J, Jazrawi LM. Arthroscopic management of tibial spine avulsion fractures: principles and techniques. *J Am Acad Orthop Surg*. 2018;26(10):360-367.
23. Thaunat M, Barbosa NC, Gardon R, et al. Prevalence of knee stiffness after arthroscopic bone suture fixation of tibial spine avulsion fractures in adults. *Orthop Traumatol Surg Res*. 2016;102(5): 625-629.
24. Vander Have KL, Ganley TJ, Kocher MS, Price CT, Herrera-Soto JA. Arthrofibrosis after surgical fixation of tibial eminence fractures in children and adolescents. *Am J Sports Med*. 2010;38(2): 298-301.
25. Wang J, Weng X, Li J, Chen X. Effectiveness of arthroscopic ultrabraid suture plane fixation for anterior cruciate ligament tibial eminence avulsion fractures [in Chinese]. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi*. 2015;29(11):1353-1357.