Comparison of arthroscopic reduction and suture fixation versus open reduction and screw fixation for anterior cruciate ligament tibial spine avulsion fractures

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Background
Tibial spine avulsion fractures are not uncommon injuries, with numerous published techniques for their management. However, there is no evidence suggesting the superiority of any single technique.

Aim and objectives
This study aims to evaluate the clinical and radiological outcomes of tibial spine avulsion fractures treated by arthroscopic reduction and suture fixation compared to those fixed by open reduction and screw fixation.

Patients and methods
This randomized comparative study included 26 cases of tibial spine avulsion fractures treated at the Arthroscopy and Sports Medicine Unit, Orthopedic Surgery Department, Mansoura University, between September 2020 and September 2021. Group A consisted of patients who underwent arthroscopic reduction and internal fixation with sutures, while group O included those who received open reduction and internal fixation with screws.

Results
Statistically significant differences were observed between the two groups. These differences included comparisons of the Lysholm score before and after surgery, subjective IKDC scores before and after surgery, anterior drawer test results before and after surgery, and preoperative and postoperative range of motion for both extension and flexion.

Conclusion
Our research findings indicate that patients who underwent arthroscopic reduction and suture fixation had better outcomes compared to those who underwent open reduction and screw fixation.

Keywords:
arthroscopic, internal fixation, open reduction, tibial spine

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Introduction

An avulsion fracture of the tibial spine with anterior cruciate ligament (ACL) attachment is not uncommon. It occurs more frequently in children aged 9–14 years. However, the incidence of this injury in older individuals is higher than previously thought. ACL tibial avulsion fractures can account for up to 13% of all knee fractures [1].

The anterior portion of the tibial plateau is distinguished by the close anatomical relationship between the ACL and the meniscal roots. The ACL attaches to the tibial spine, while the anterior root of the lateral meniscus is anchored near the tibial eminence, very close to the ACL's tibial insertion. These structures are so closely aligned that they often blend together anatomically [2].

Tibial spine fractures are categorized into four types [3]. Type I involves a nondisplaced fragment, type II features an anterior separation of the fragment with an intact posterior hinge, type III consists of a completely separated fragment, and type IV is a comminuted fracture with multiple bone fragments.

Displaced tibial spine avulsion fractures can compromise knee stability and lead to anteroposterior laxity. Additionally, such fractures may cause a mechanical blockage to knee extension, which, if not properly addressed, can limit the range of motion and lead to a flexion deformity. The displaced fragment may be difficult to reduce due to traction forces from the ACL or displacement of the meniscus or intermeniscal ligament beneath the fragment, which can obstruct the reduction [4].

Conservative treatment is generally recommended for nondisplaced tibial spine avulsion fractures of types I and II. Conversely, displaced fractures of type III and IV typically require surgical fixation. The optimal fixation method should ensure stable reduction while allowing early initiation of knee motion to prevent arthrofibrosis and expedite rehabilitation. Various fixation techniques have been proposed for tibial spine avulsion fractures, with no single method proving superior [5]. Management strategies can be divided between open and arthroscopic techniques. Fixation options include metal screws, anchors, transosseous sutures, and metal cerclage wires.

Arthroscopic management is particularly appealing due to its minimally invasive nature, which results in lower morbidity, earlier rehabilitation, and reduced pain [6]. High-tensile suture fixation is a viable option, allowing for the management of fragmented fractures by threading sutures through the ACL stump and utilizing small transosseous drills that minimize physis injury. However, this technique is technically demanding and may result in longer surgical times [7].

On the other hand, the arthroscopic approach offers several advantages. It not only facilitates the diagnosis and treatment of associated injuries – reported in up to 59% of cases, according to some studies – but also minimizes invasiveness. This approach tends to result in less postoperative pain, quicker recovery times, and reduced risk of complications. The ability to address concurrent injuries and perform a minimally invasive procedure makes arthroscopy a compelling alternative to open reduction and internal fixation (ORIF), particularly for managing complex cases [8].

ORIF allow for direct visualization of the avulsed fragment and are generally more straightforward and quicker to perform. Nonetheless, this method is often associated with greater postoperative pain, a slower recovery period, and difficulties in managing fragmented fractures [8].

This study aimed to evaluate and compare the early outcomes of arthroscopic reduction and suture fixation versus open reduction and screw fixation for ACL tibial avulsion fractures, and to document the incidence of associated injuries. We hypothesize that the arthroscopic approach will yield superior results compared to the open approach.

Patients and methods

Study design

This is a randomized study that evaluates the outcomes of managing pediatric and adolescent patients with tibial spine avulsions using either open reduction and screw fixation or arthroscopic reduction and suture fixation. The management details and anticipated outcomes were thoroughly explained to the patients and their parents, and informed consent was obtained. The study was conducted at the Arthroscopy and Sports Medicine Unit, Orthopedic Surgery Department, Mansoura University, from January 2019 to December 2021. The study protocol was submitted to and approved by the Institutional Review Board (IRB) under approval number MS.20.09.1244.R1.R1.R2-2020/11/04.

Patients

The study included all patients with ACL avulsion fractures classified as types III and IV presented to our institute during the study period. Exclusions were made for patients with type I fractures and type II fractures that could be reduced with a full extension cast. Pediatric and adolescent patients with open physis were eligible, with no minimum age limit, while adult patients with closed epiphyseal plates were excluded. Patients with chronic injuries exceeding 3 weeks, as well as those requiring revision surgery, those with multiligament injuries, and patients with incomplete follow-up, were also excluded from the study.

Preoperative assessment

All patients were evaluated preoperatively to determine the mechanism and timing of the injury. A physical examination was conducted to assess knee instability and identify any mechanical block during knee extension. Imaging studies, including MRI and plain radiographs, were performed for all patients. For those with severely comminuted fragments, a computed tomography scan was also used to enhance evaluation. Clinical assessments were carried out using the Lysholm score and the IKDC score. Following the assessment, patients were randomized into two groups using block randomization. Group A underwent arthroscopic reduction and transosseous suture fixation with screws and washers, while group O received open reduction and screw fixation of the fragment.

Surgical technique

For group A

Diagnostic arthroscopy was performed using anterolateral and anteromedial portals to document and manage associated injuries. The fracture pattern was assessed, and the avulsed fragment was elevated with a hook to inspect the underlying surface. The bed of the fragment was prepared with an arthroscopic shaver and burr until a fresh bleeding surface was achieved. The provisional reduction was evaluated to ensure anatomical alignment of the ACL fibers under appropriate tension and to confirm no notch impingement in full extension.

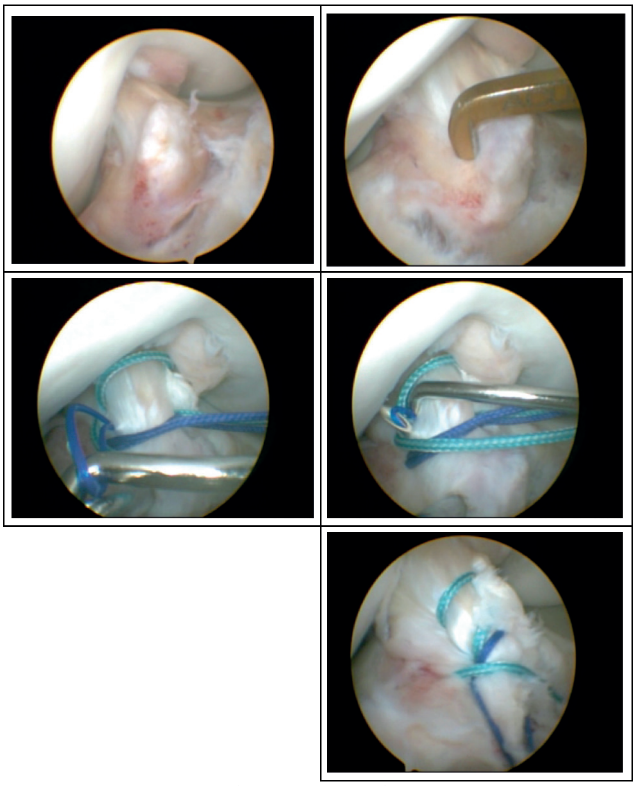
Two high-tensile, nonabsorbable (Ethibond No. 2) sutures were then passed through the ACL fibers near their tibial attachment using a shuttle suture passing device. An anteromedial incision was made and with the aid of an ACL C-guide aimer, two 1.5 mm wires were drilled through the fragment bed, followed by over-drilling with a 2.2 mm cannulated drill. The wires were removed, leaving the cannulated drills in place to facilitate the passing of shuttle proline sutures inside the joint.

The ends of the high-tensile sutures were threaded through the shuttle sutures and the drilled holes in a crossing pattern: the medial end was guided through the lateral drill hole, and the lateral end was shuttled through the medial drill hole. The sutures were secured over the tibial surface using a post and washer. Arthroscopic control was maintained throughout the fixation process to ensure anatomical reduction and proper alignment (Fig. 1).

For group O

A medial parapatellar incision was made with the knee in 90° flexion. The patellar tendon was retracted laterally, and the joint was irrigated with saline to enhance exposure to the fracture. The fracture was stabilized initially using two small K-wires. After confirming proper reduction, the fragment was secured with two antegrade screws.

Figure 1



Arthroscopic technique of reduction and fixation.

Postoperative rehabilitation

Postoperative radiographs were obtained to evaluate the reduction and positioning of the hardware. Patients in both groups were immobilized in full extension using a knee brace. They were permitted to walk with crutches after 3 weeks, and range of motion exercises were introduced at that time and progressively increased.

Postoperative assessment

At the end of the follow-up period, postoperative evaluations included Lysholm scores, subjective IKDC scores, visual analog sclae pain scores, and range of motion assessments. Additionally, the healing time was monitored through serial radiographs. Postoperative complications, including stiffness, persistent pain, and infection, were also assessed.

Statistical analysis

Descriptive statistics for qualitative data were presented in terms of counts and percentages. Parametric data were subjected to a normality assessment using the Kolmogorov–Smirnov test, and quantitative data were then summarized using the mean and SD. The significance of the findings was assessed at the 0.05 significance level.

Results

The study included a total of 26 patients, who were randomly assigned by block randomization to two groups: group A, which underwent arthroscopic reduction and suture fixation (14 patients), and group O, which received open reduction and screw fixation (12 patients). The study population comprised 25 male patients and one female patient. In the arthroscopic reduction internal fixation (ARIF) group, the average age was 15.21 years, while in the ORIF group, the mean age was 14.58 years. Statistical analysis revealed no significant differences between the groups regarding age and sex (P=0.144 and 0.345, respectively). The mean duration since injury was 2.5 weeks for the ARIF group and 3 weeks for the ORIF group, with no statistically significant difference noted between the groups in terms of injury duration (P=0.052). Demographic data are shown in Table 1.

In the ARIF group, the mean follow-up duration was 73.43 weeks, compared to 55.33±6 weeks in the ORIF group. Postoperative assessments revealed significant

Table 1 Demographic data and fracture pattern by treatment group

	Levels	ARIF (*N*=14)	ORIF (*N*=12)	Test of significance
Age (years)	Mean±SD	15.21±4.46	14.58±12.43	*t*=1.511 *P*=0.144
Sex (male/female)	*n* (%)	13 (92.9)/1 (7.1)	12 (100.0)/0	χ^2=0.891 *P*=0.345
Mechanism of injury	Levels	ARIF (*N*=14)	ORIF (*N*=12)	Test of significance
Motor car accident (high energy trauma)	*n* (%)	10 (71.4)	10 (83.3)	χ^2=0.516 *P*=0.473
Twisting trauma (low-energy trauma)	*n* (%)	4 (28.6)	2 (16.7)	
Side	Levels	ARIF (*N*=14)	ORIF (*N*=12)	Test of significance
Right	*n* (%)	5 (35.7)	8 (66.7)	χ^2=2.476 *P*=0.116
Type of fracture	Levels	ARIF (*N*=14)	ORIF (*N*=12)	Test of significance
III	*n* (%)	5 (35.7)	7 (58.3)	χ^2=1.330 *P*=0.249
IV	*n* (%)	9 (64.3)	5 (41.7)	
	Levels	ARIF (*N*=14)	ORIF (*N*=12)	Test of significance
Duration since injury (weeks)	Mean±SD	2.5 (1.0–2.5)	3.0 (2.2–3.0)	*t*=2.049 *P*=0.052

ORIF, open reduction and internal fixation.

Table 2 Clinical and radiological results

Subjective IKDC score	Levels	ARIF (*N*=14)	ORIF (*N*=12)	Test of significance
Preoperative	Mean±SD	32.09±23.93	10.13±2.92	*Z*=0.339 *P*=0.735
Postoperative	Mean±SD	99.26±1.24	98.86±1.88	*Z*=0.244 *P*=0.807
Comparison of preoperative and postoperative (paired *t* test)		*t*=12.406 *P*<0.001*	*t*=14.824 *P*<0.001*	
Lysholm score	Levels	ARIF (*N*=14)	ORIF (*N*=12)	Test of significance
Preoperative	Mean±SD	26.28±30.05	12.01±25.46	*Z*=1.709 *P*=0.087
Postoperative	Mean±SD	98.78±2.19	99.17±1.53	*Z*=0.243 *P*=0.808
Comparison of preoperative and postoperative (paired *t* test)		*t*=9.195 *P*<0.001*	*t*=11.796 *P*<0.001*	
Range of extension	Levels	ARIF (*N*=14)	ORIF (*N*=12)	Test of significance
Preoperative	Mean±SD	11.43±3.06	9.58±3.34	*t*=1.470 *P*=0.154
Postoperative	Mean±SD	0.0±0.0	0.0±0.0	*P*=1.0
Comparison of preoperative and postoperative (paired *t* test)		*t*=13.99 *P*<0.001*	*t*=9.931 *P*<0.001*	
Range of flexion	Levels	ARIF (*N*=14)	ORIF (*N*=12)	Test of significance
Preoperative	Mean±SD	116.43±4.97	115.83±7.93	*t*=0.373 *P*=0.712
Postoperative	Mean±SD	135.36±6.92	134.17±12.4	*t*=0.575 *P*=0.570
Comparison of preoperative and postoperative (paired *t* test)		*t*=7.848 *P*<0.001*	*t*=7.374 *P*<0.001*	
Operative time (min)	Mean±SD	83.92±7.64	75.0±10.66	*Z*=2.323 *P*=0.020*
Duration for full radiological bone healing (weeks)	Mean±SD	10.86±2.44	11.33±3.75	*Z*=0.166 *P*=0.868

ORIF, open reduction and internal fixation.

improvements in IKDC and Lysholm scores compared to preoperative values (*P*<0.001). While the arthroscopic group showed greater improvement, the differences between the groups were not statistically significant (*P*=0.735 for IKDC scores and *P*=0.807 for Lysholm scores). The mean time for radiological bone healing, defined as the complete resolution of fracture lines on plain radiographs, was 10.86 weeks in the ARIF group and 11.33 weeks in the ORIF group. Computed tomography scans, employed in four cases where plain radiographs were inconclusive, provided a better assessment of bony healing. The mean operative time was 83.92 min for the ARIF group and 75 min for the ORIF group, with a statistically significant difference observed between the groups (*P*=0.020). Detailed scores and data are presented in Table 2.

Associated injuries and complications

The incidence of associated injuries in this study was 20%, with four patients presenting with grade 2 chondral lesions and three patients having a lateral meniscal tear. Chondral lesions were managed by debridement of the cartilage fragment, while meniscal tears were treated with all-inside meniscal repair in two cases and partial meniscectomy in one patient.

At the end of the follow-up period, six patients had not achieved full range of motion: five from the open reduction group and one from the arthroscopic group. All patients with incomplete range of motion underwent arthroscopic lysis, resulting in full extension and 130° of knee flexion for all individuals. No postoperative infections were reported in this study.

Discussion

Our study found no statistically significant differences between the two groups in terms of clinical outcomes, functional results, or complications. Demographic data were similar between the groups. However, the open reduction group exhibited a higher incidence of stiffness and a longer duration required to regain range of motion compared to the arthroscopic group.

A recent study compared clinical and radiographic outcomes between suture fixation and screw fixation for tibial spine avulsion fractures. The study included 68 knees from 67 patients and concluded that both groups showed equivalent results after 2 and 4 years of follow-up in the suture and screw fixation groups, respectively [9].

In our study, the rate of associated injuries with tibial spine avulsion fracture was only 20%. Conversely, the rate of associated injuries with ACL tibial avulsion is reported to be high. Rhodes *et al.* [10] studied 163 patients with tibial spine avulsions; 144 patients were operated on, and surgically diagnosed meniscus, chondral, and non--ACL ligamentous injury was found in 34.7, 33.3, and 5.6% of patients, respectively.

The incidence of associated lesions was minimal for type I fractures. In contrast, 29% of patients with minimally displaced fragments had associated injuries. Completely displaced fragments demonstrated a higher rate, with 48% of patients presenting with associated lesions [11].

In a series of 54 patients, Feucht and colleagues discovered that 37% of all ACL avulsion fractures were accompanied by meniscal tears. Tears were 90% in the lateral meniscus and 10% in the medial meniscus. Longitudinal tear of the lateral meniscus, as well as injury to anterior fibers of the lateral meniscus, were the most common [12].

Our results did not show a statistically significant difference between the two groups in terms of fracture types according to the Meyers and McKeever classification (P=0.249). In the ARIF group, type IV fractures were more common, comprising 64.3% of cases compared to 35.7% for type III fractures. In contrast, the ORIF group had a higher prevalence of type III fractures, with 58.3% compared to 41.7% for type IV fractures.

Additionally, our analysis did not find any statistically significant differences between the two fracture types (types III and IV according to the Meyers and McKeever classification) concerning clinical and functional outcomes. Specifically, there were no significant differences in postoperative range of motion for flexion, subjective IKDC scores, or Lysholm scores (P=0.184, 0.309, and 0.416, respectively).

Consistent with our findings, Watts and colleagues conducted a study with 31 patients, comparing two treatment methods: open reduction and screw fixation in 13 patients and arthroscopic reduction and fixation in 18 patients. The two groups were comparable in sex distribution (P=0.73), average age (11.5 years, ranging from 7 to 16 years, vs. 12.9 years, ranging from 7 to 18 years) with a P value of 0.18, and the proportion of type III fractures (30.8 vs. 27.8%, P=0.58) [13].

In a cohort of 36 patients, Huang *et al.* [14] demonstrated that arthroscopic reduction and suture fixation of ACL avulsion injuries resulted in a significant improvement in the Lysholm score after 2 years of follow-up (P<0.001).

Most of the patients in our study were males (25 out of 26). Consistent with our findings, a recent study investigating the incidence of tibial spine avulsions in a national American database found that the incidence peaked for male patients at age 14 (9.3 per 100 000). For female patients, the incidence peaked at a lower magnitude and an earlier age, at 3.4 per 100 000 at age 9. This could be partly due to higher sports participation among males compared to females in our locality [15].

This study had several limitations, including a small sample size and a relatively short follow-up period. However, a strength of the study was the consistent application of the management technique across all patients within each group, ensuring uniformity in treatment.

In conclusion, both open reduction with screw fixation and arthroscopic reduction with suture fixation for ACL tibial avulsion resulted in significant improvement and good functional outcomes. The study did not find an incidence of associated lesions with tibial spine avulsions to be 20%. Open management was associated with a more delayed return of knee motion and increased risk of arthrofibrosis, but it also had a shorter operative time.

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Nil.

Conflicts of interest
The are no conflicts of interest.

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