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Original article

Knee laxity after anterior tibial eminence fracture in children: A 35-case series

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ABSTRACT

Introduction: Anterior tibial eminence (ATE) fractures are characterized by avulsion of the anterior cruciate ligament insertion. The aim of our study was to evaluate the long-term incidence of laxity and instability in the aftermath of these fractures. The secondary objective was to identify factors for instability.
Hypothesis: ATE fracture in children is responsible for laxity and instability in the medium and long term.
Material and methods: This retrospective, single-center study included 35 isolated fractures of the tibial intercondylar eminence during skeletal growth between January 2006 and January 2020. Analysis comprised demographics, laxity measured by GNRB™, range of motion and IKDC and Lysholm scores. Clinical reassessment was performed in 24 patients, the other 11 being interviewed by telephone.
Results: Mean laxity on GNRB™ was 1.46 mm, and 3 patients had > 3 mm differential with respect to the healthy knee. Mean IKDC score was 92.2 and mean Lysholm score 93.1. Four patients showed instability, 2 of whom required surgical management. There was no significant difference in occurrence of laxity according to fracture type or reduction quality. Mean follow-up was 5.9 years (range, 1.1–14.8).
Discussion: Our clinical and functional results were in accordance with the literature. The long-term clinical results were satisfactory. ATE fractures require long-term follow-up to screen for instability and laxity on GNRB™.
Level of evidence: IV, retrospective study.

1. Introduction

Anterior tibial eminence (ATE) fracture features avulsion of the anterior cruciate ligament (ACL) insertion. Annual incidence is 3/100,000 children, mainly between 8 and 14 years of age [1,2]. Before complete ossification, the ATE surface is cartilaginous, with lower resistance than the ligament. Thus, trauma more easily results in ATE fracture than in the ACL tears seen in adults, especially in younger children [2,3]. ATE fracture can lead to ACL laxity and loss of full knee extension, even when reduction is anatomic, and whatever the treatment applied [4]. KT 1000™ is the most widely used laximeter, but Robert et al. demonstrated significantly better reproducibility with the GNRB™ device (Genourob, Laval, France) [5]. However, few studies have used the GNRB™ in ATE fracture in children [6].

To confirm that ATE fracture induces medium- and long-term laxity and instability in children, the present study assessed incidence of laxity on GNRB™ and functional impact. The secondary objective was to identify risk factors for instability.

2. Material and methods

2.1. Patients

This single-center retrospective study included under-16 year-old patients with isolated ATE fracture between 2006 and 2020. Exclusion criteria comprised fused growth plate at trauma and history of ipsilateral or contralateral knee fracture or ACL tear.

2.2. Methods

Analysis concerned demographic data, trauma circumstances, body-mass index (BMI), length of follow-up, type of treatment, timing and duration of immobilization, and complications (Table 1). Last follow-up assessment included pain (visual analog scale: VAS),

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Table 1
Patient data.

		Total population (n = 35)	Reassessed (n = 24)
Gender	Female	11	6
	Male	24	18
Side	Right	22	15
	Left	13	9
Circumstances	2-wheel accident	18	10
	Sport	14	11
	Fall	3	3
Type of fracture	I	4	1
	II	13	12
	III	13	10
	IV	5	1
Weight	Normal	26	18
	Overweight	7	5
	Obese	2	1

instability, range of motion (decreased range defined as 5° extension loss and/or 15° flexion loss), functional assessment on IKDC and Lysholm scores, and ACL tear requiring reconstruction. On GNRB™, displacement at 134 Newton with ≥ 3 mm differential with respect to the healthy knee was counted as laxity [5,7,8].

Initial radiological assessment comprised AP and lateral knee radiographs and fracture classification following Meyers and McKeever as modified by Zaricnyj [9,10]. Complementary imaging was not systematic. For type I and II fractures, the first stage of treatment consisted in reduction by external maneuver under fluoroscopy, with hemarthrosis drainage as appropriate. If reduction was anatomic, non-operative treatment by cast immobilization was initiated; otherwise, surgery was performed, with medial parapatellar arthrotomy. Concomitant lesions were systematically screened for, the fracture site was hollowed out and the fracture was reduced by lacing under visual control. Intraoperative ACL testing assessed ligament tension. In type III and IV fractures, surgery was performed in first line, followed by cast immobilization (Fig. 1). Reduction was classified in 3 groups on postoperative X-ray: anatomic, < 2 mm deficit, and ≥ 2 mm deficit. Patients were followed up at 6 weeks, 3 months, 6 months and 1 year, plus a final consultation. If the final consultation was not possible, a telephone interview was made.

2.3. Data collection

Data were collected by a single independent investigator. The protocol was approved by the CNIL national data protection commission (#PI2021_843-0103).

2.4. Statistics

Statistical analysis used EasyMedStat software (www.easymedstat.com; Neuilly-Sur-Seine, France). Qualitative variables were compared on Fisher exact test and quantitative variables on Mann-Whitney test. The Kruskal-Wallis test was used for comparison between 2 or more groups. Subgroup analysis concerned only patients seen at the final consultation. The α risk was set at 5%.

3. Results

Thirty-five of the 52 patients with isolated ATE fracture were analyzed, and 24 were reassessed at final follow-up (Fig. 2). Mean age at trauma was 11.8 years (range, 6.1–15.8). Mean follow-up was 5.9 years (range, 1.1–14.8).

Ten patients underwent non-operative treatment in theater, and 25 underwent surgery. On postoperative radiographs, reduction was anatomic in 22 patients, 10 showed < 2 mm reduction deficit, and 3 showed ≥ 2 mm deficit. Mean immobilization time was 6.3 weeks (range, 3.3–11). There were no postoperative complications.

Mean displacement on GNRB™ was 1.46 mm (range, 0.1–4.6), with ≥ 3 mm displacement in 3 patients (12.5%) (Table 2).

Four patients (11.4%) showed instability (Table 3). One showed laxity and instability but declined further surgery. One showed instability with 2.7 mm laxity, and was followed up annually. The two others required revision surgery (5.7%). One, with type III fracture, underwent reconstruction for ACL tear 2 years after the fracture. The other, with type I fracture, underwent treatment for non-union by lacing and medial meniscus suture 3 years after the fracture.

GNRB™ curves for the healthy versus the operated knee were superimposable in patients without laxity and divergent in those with laxity and/or instability (Fig. 3). In the latter case, there was also an initial differential, increasing with increasing force.

There was no significant difference in laxity according to operative versus non-operative management on any item (Table 4).

One of the 24 patients reassessed at final follow-up showed decreased range of motion. Mean flexion was 135.4° (range, 100°–140°), with no extension deficit.

Thirteen patients (54.2%) had normal objective IKDC scores (category A), 5 (20.1%) scored B, 5 scored C and 1 (4.2%) scored D.

In 25 of the 35 patients (71.4%), Lysholm score was excellent, in 6 (17.1%) good, in 4 (11.5) moderate, and poor in none. Mean Lysholm score was 93.1 (range, 66–100). Mean subjective IKDC score was 92.2 (range, 70.1–100). Eleven patients (31.4%) reported occasional knee pain, with a mean rating of 2.3/10. Subgroup analysis is shown in Table 4.

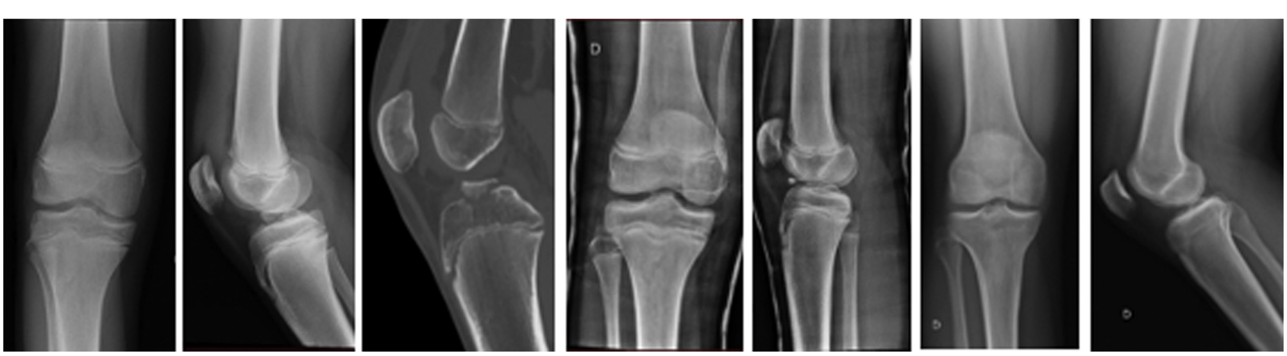

Fig. 1. Radiologic assessment of a 15 year-old boy with type III fracture. Left to right: AP, lateral radiograph, and sagittal CT slice. Preoperative, postoperative and final follow-up.

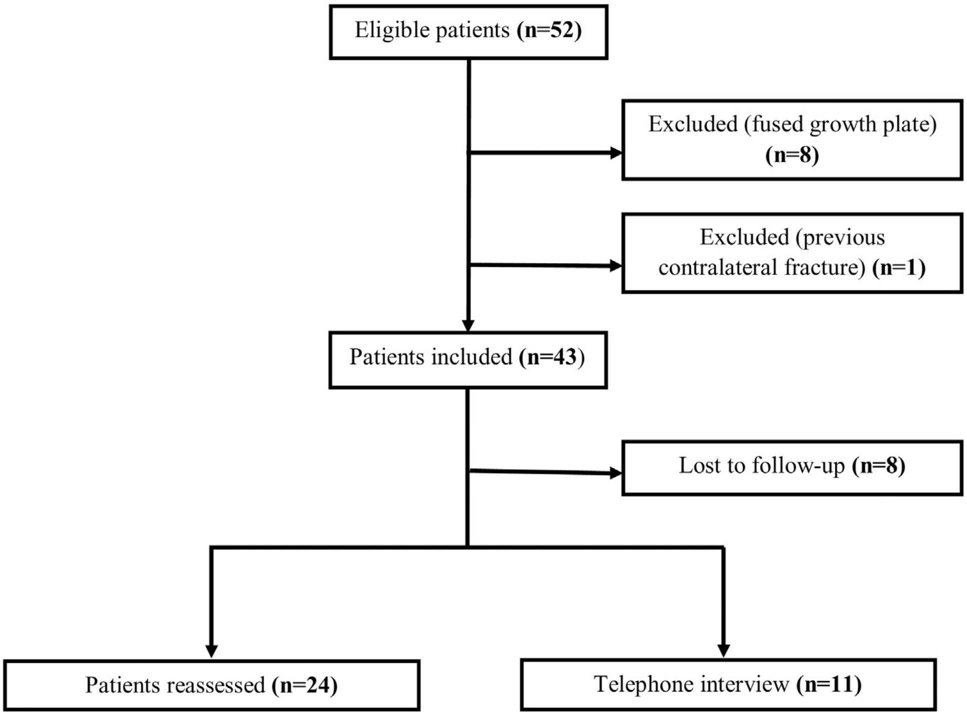

Fig. 2. Recruitment flowchart.

Table 2
Patients with GNRB ≥ 3 mm.

	Age (years)	Gender	Type of fracture	BMI	Type of treatment	Reduction quality	Instability	Subjective IKDC	Lysholm
1	8.1	F	III	N	A-L	A	Yes	87.4	84
2	9.3	M	III	N	A-L	A	No	96.6	99
3	12.2	M	III	O	A-L	A	No	89.7	95

F: female; M: male; BMI: body-mass index; N: normal; O: obese; A-L: arthrotomy-lacing; A: anatomic.

Table 3
Patients with instability.

	Age (years)	Gender	Type of fracture	BMI	Type of treatment	Reduction quality	Revision surgery	GNRB	Subjective IKDC	Lysholm
1	8.1	F	III	N	A-L	A	No	3.1	87.4	84
2	10.2	F	III	N	D-R	< 2 mm	Yes	NR	95.4	94
3	12.8	M	I	N	D-R	A	Yes	NR	95.7	99
4	12.9	M	II	N	D-R	< 2 mm	No	2.7	71.3	66

F: female; M: male; BMI: body-mass index; N: normal; A-L: arthrotomy-lacing; D-R; drainage-reduction; A: anatomic; NP: not performed (patient absent at final follow-up).

Table 4
Subgroup analysis of the 24 reassessed patients.

		n	%	GNRB > 3 mm Mean score	*p*	Subjective IKDC Mean score	*p*	Lysholm Mean score	*p*
Type of fracture	Type I	1	4.2	0.9	$p = 0.3$	90.8	$p = 0.35$	95	$p = 0.42$
	Type II	12	50	1.11		92.7		92.6	
	Type III	10	42	1.91		89.31		91.6	
	Type IV	1	4.2	1.9		82.7		79	
Weight	Normal	18	75	1.31	$p = 0.13$	90.4	$p = 0.77$	93.1	$p = 0.98$
	Overweight	5	21	1.42		92.4		92.9	
	Obese	1	4.2	4.6		89.6		95	
Surgery	Yes	19	79	1.47	$p = 1$	92.6	$p = 0.093$	93.1	$p = 0.068$
	No	5	21	1.46		83.6		89.4	
Reduction quality	Anatomic	17	71	1.38	$p = 1$	92.7	$p = 0.41$	93.7	$p = 0.61$
	< 2 mm	4	17	1.93		84.2		85.5	
	≥ 2 mm	3	12	1.37		88.5		88	
Instability	Yes	2	8.3	2.9	$p = 0.24$	79.3	$p = 0.083$	75	$p = 0.058$
	No	22	92	1.34		91.8		93.2	
Rehabilitation	Yes	17	70.8	1.6	$p = 0.48$	89.5	$p = 0.388$	90.6	$p = 0.797$
	No	7	29.2	1.14		93.9		94.6	

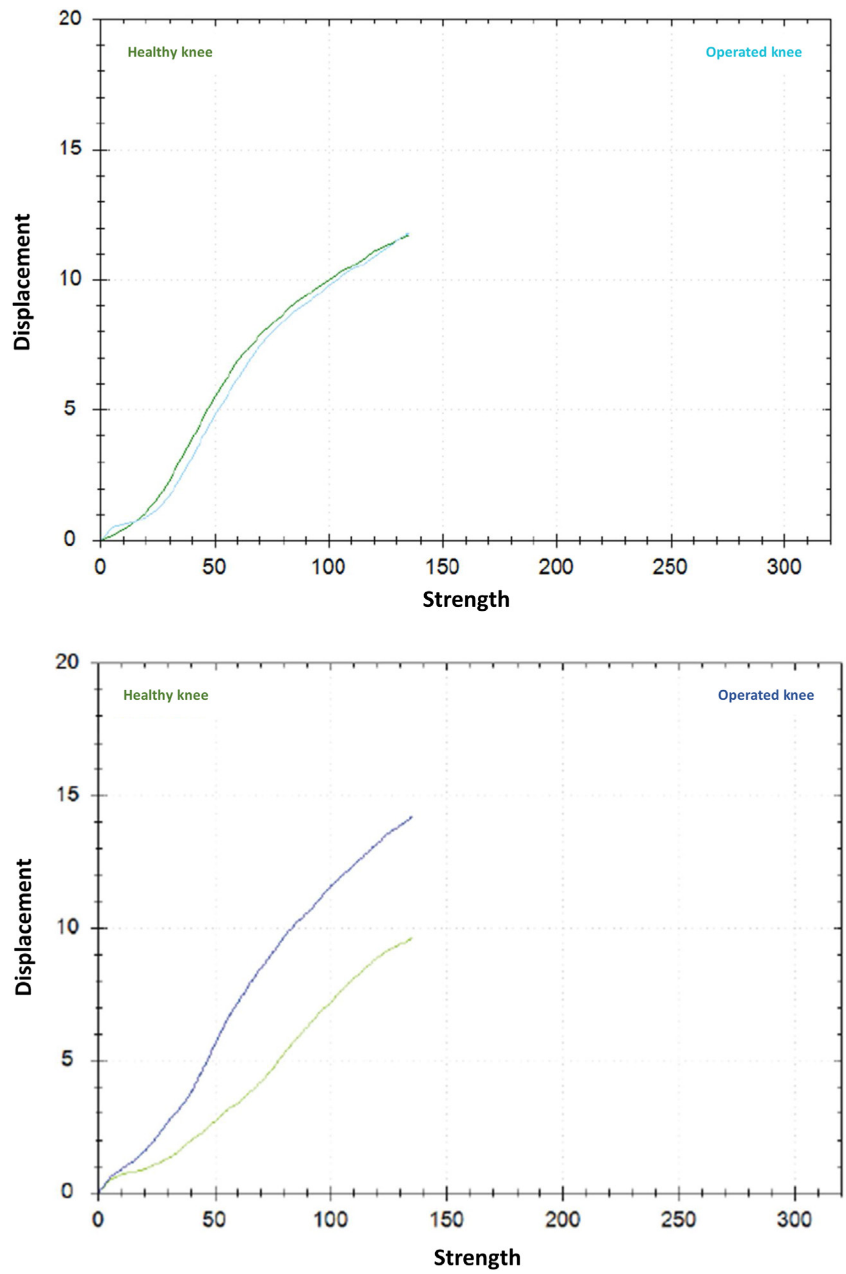

Fig. 3. GNRB curves. A. Left: stable patient. B. Right: patient with laxity.

4. Discussion

This study showed that ATE fracture can induce residual laxity, although no risk factors were identified. Laxity is also reported in the literature, and is the most frequent complication. Rates vary between studies from 0% to 67% (Table 5). Neither the literature nor the present study can determine the origin. One hypothesis is that it is secondary to the ACL being stretched at the moment of trauma just before the fracture; it would therefore be recommended to lower the insertion by making a hollow, as in the present series, although this may not be enough to restore satisfactory ACL tension [11–13]. Examining the present curves for patients with laxity and/or instability revealed a pre-existing differential (possibly due to a question of length and insufficient ACL tensioning), increasing with increasing force (possibly due to a question of elasticity following ligament fiber elongation at trauma). Woo et al. showed that the ACL elasticity coefficient and tear resistance decrease significantly with age [14]. Mayo et al. found almost 19% of patients with ACL lesions in case of ATE fracture [15]. Shaw et al. reported that a wide intercondylar eminence predicted ATE fracture rather than ACL tear [16].

All the patients operated on in the present series underwent medial parapatellar arthrotomy. Arthroscopy (bone suture, screwing, K-wire with adjustable stop, etc.) has recently been developed in this indication, with very good results, reducing morbidity and allowing earlier mobilization and shorter hospital stay [30–32]. However, residual laxity was comparable to open surgery [33,34]. Whatever the technique, depending on the surgeon's habits, the aim must be anatomic reduction, stable fixation and ACL retensioning [35].

Laxity does not systematically lead to instability, and here the present results match those of the literature (Table 5) [36]. Absence of instability may be due to ACL nerve fiber integrity, conserving proprioceptive function and neuromuscular control [22]. Ursei et al.

Table 5
Reports on childhood ATE fracture, with objective laxity.

Article	Date	Number of patients/ patients assessed	Type of fracture (I/II/III-IV)	Type of treatment Non-op/op (O/A)	Laxity measurement	Mean laxity (mm)	Complications				Mean functional scores	
							Laxity > 3 mm	Unstable	RoM	N-U	IKDC	Lysholm
Kocher et al. [17]	2003	6/6	0/0/6	0/6 (A)	KT-1000	6.33	4	0	0	0		99.5
Senekovic et al. [18]	2003	14		0/14 (A)	KT-1000	0.7	0		0			99.6
Louis et al. [19]	2008	17	0/17/0-0	0/17 (CO)	KT-1000	1.05	0	0				99.7
Vega et al. [20]	2008	7		0/7 (A)	KT-1000	2		0			92	94
Hirschmann et al. [21]	2009	6/6	0/2/3-1	0/6 (A)	KT-1000	2		0	0	0		97
Perugia et al. [22]	2009	10		0/10 (A)	KT-1000	3	5	0	0	0	92.4	95.9
Liljeros et al. [23]	2009	23/13	7/2/14-0	16 (A)	KT-1000	1.23	1	0	4	0		93.7
Casalonga et al. [24]	2010	32/13	8/17/5-2	14/18 (CO)	KT-1000	0.67	2	2	3	0	84.8	
Wouters et al. [25]	2011	12/12		0/12 (A)	KT-1000		1	0	0	0		
Franqueville et al. [26]	2014	12/7	0/1/9/2	0/8(CO) 4(A)	KT-1000	0.3			2			
Le Reun et al. [6]	2015	17	2/8/6-1	9/5(CO) 3(A)	GNRB							
Shin et al. [27]	2018	27/17	0/12/13-2	0/27 (A)	KT-1000	1.8	3		2	1		94.8
Stallone et al. [28]	2020	42/23	13/16/12-1	26/16 (CO-A)	KT-1000	0.4	3	1	3	1	96.4	
Kristinsson et al. [29]	2021	16/13	0/9/2-2	0/16 (A)	KT-1000	0.8	1	0	1	0		
D'Ambrosio et al. [30]	2021	25/20	0/19/12-3	0/34 (A)	KT-1000	0.7	5	4	0	0	93.8	93.1
Present study	2022	35/24	4/13/13-5	10/25 (CO)	GNRB	1.46	3	4	1	1	92.2	93.1

O: open; A: arthroscopic; N-U: non-union; blank cell: no data.

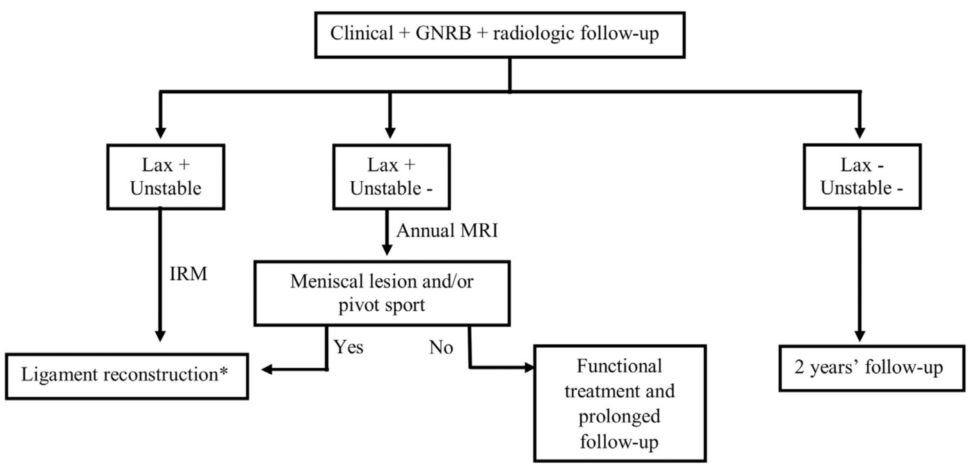

Fig. 4. ATE fracture follow-up algorithm. * ACL reconstruction proposed to adolescents à skeletal maturity; functional treatment in the meantime.

showed that patients with instability following an ACL lesion compensated with adaptations in the foot and ankle during gait [37]. Mitchell et al. found that 19% of patients required ACL reconstruction after ATE fracture, which was a higher rate than the 1% to 12% reported elsewhere [12]. O'Donnell et al. reported more frequent ACL tear in the later course of ATE fracture than at the moment of trauma itself: 21.7% versus 2.6%, over less than 2 years' follow-up [38]. Neither of the 2 reviews of childhood ATE fracture focused on ligament reconstruction [4,36].

In the light of the present results and of the literature, preventive ligament reconstruction in the same surgical step as the fracture repair seems not to be indicated in children and adolescents. On the other hand, ATE fracture requires at least 2 years' follow-up with GNRB™ assessment. Fig. 4 shows an algorithm for ATE fracture follow-up [3,39].

The present functional scores testified to good outcome: mean IKDC score, 92.2; mean Lysholm score, 93.1. The Lysholm category distribution was identical to that reported by Rademakers et al. in their long-term study, with persistent occasional knee pain [40]. Edmond et al. reported a 33.33% rate of pain, with a mean intensity of 3.7, similar to the present findings [41]. Another often overlooked complication of ATE fracture is osteoarthritis of the knee; Gans et al. reported a rate comparable to ours, with 10 cases in 580 fractures [4].

5. Study limitations

The first study limitation was the retrospective design, with 19% loss to follow-up. This is a familiar selection bias in pediatric studies, increasing with length of follow-up, which was up to 14 years in the present series. Even so, the rate of reassessment was high, at 69% (Table 5). The sample was small and heterogeneous in terms of management, without randomization, limiting statistical power; this was due to the relative rarity of the indication. Another bias was that assessment was not blinded, although this drawback was attenuated by using an objective and reproducible laxity measurement and standardized questionnaire. A prospective multicenter study could overcome these biases.

6. Conclusion

Childhood ATE fracture can lead to laxity and/or instability, which need screening for on long-term follow-up. Functional scores were satisfactory, and few patients required surgical revision for instability.

Disclosure of interest

The authors declare that they have no competing interest.

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None.

Author contributions

AA and CK: study design; RG and FD: critical revision for intellectual content; MP and FM: data acquisition.

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