Short-term outcomes of anterior cruciate ligament tibial insertion avulsion fractures treated with a single tunnel using a double-strand suture anchor under arthroscopy: a single-center retrospective study

Dan Guo (ab81821689@163.com)
Northern Jiangsu People's Hospital (NJPH)
Hansheng Hu
Northern Jiangsu People's Hospital (NJPH)

Research Article

Keywords: Anterior cruciate ligament tibial insertion avulsion fracture, arthroscopy, single tunnel

Posted Date: April 19th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1559762/v1

Abstract

Background

Anterior cruciate ligament (ACL) tibial insertion avulsion fractures cause instability of the knee joint, and minimally invasive techniques are the first choice for treating this type of intra-articular injury. The aim of this study was to investigate the clinical effect of a minimally invasive technique which treated ACL tibial insertion avulsion fractures under arthroscopy by a single tunnel with a double-strand suture anchor.

Methods

A retrospective analysis was performed on 29 patients with ACL tibial insertion avulsion fractures treated with this minimally invasive technique from January 2014 to June 2018. All patients were followed up for 12 months. X-ray were taken intermittently to determine fracture reduction and healing. During the follow-up period, CT and MRI were performed to evaluate reduction and healing. The Lachman test and ADT were performed by the same doctor to determine knee joint stability. The IKDC subjective score were used to evaluate postoperative knee function recovery

Results

All patients healed well without infection fracture nonunion and instability. The preoperative IKDC subjective score was 51.24 ± 3.16; the IKDC subjective score at the last follow-up was 92.93 ± 2.59 ($P < 0.05$).

Conclusions

Within the limitations of this study, a single tunnel with a double-strand suture anchor under arthroscopy for the treatment of ACL tibial insertion avulsion fracture was a simple procedure. The procedure caused minimal trauma,had firm fixation, ensured quick recovery and provided satisfactory clinical results.

Introduction

Anterior cruciate ligament (ACL) tibial insertion avulsion fractures are relatively uncommon and most often encountered in young patients between 8 and 14 years old, with an incidence of approximately 3 per 100,000 per year. This fracture typically occurs in the skeletally immature patient.A tibial insertion avulsion fracture of the ACL may result in instability of the joint [1, 2]. According to the Meyers-McKeever classification [3], ACL tibial insertion avulsion fractures can be divided into the following three types: type I: no or slight displacement of the fracture and no limitation to knee extension; type II: the first 1/3 or second 1/2 of the avulsed fracture block is lifted, but the anterior or posterior 1/3 is still connected to the humeral shaft to form a hinge; and type III: the fracture block is completely free and rotated. Type III fractures can be further divided into two types: Type IIIA fractures are completely separated and partially displaced, and type IIIB fractures are rotated or misaligned or the fracture block is completely separated. Zaricanyj later proposed type IV, which describes a completely displaced and comminuted fracture with rotation [4]. It is difficult to reduce the fracture block with conservative treatment and leads to loss of reduction ,this can result in nonunion or malunion of the fracture and ACL relaxation, which can cause knee instability and dysfunction. Most scholars [5–8]suggest that the displaced fractures (typeII, type III and IV fractures) are often operated,they also recommend accurate surgery and firm fixation. Surgical methods offer superior outcomes. However, this leads to further questions for surgeons regarding which surgical techniques offer the best outcomes.Although traditional open surgery can provide stable fixation, the procedure causes a large amount of trauma; additionally, the incidence of joint stiffness is high and it is difficult to effectively control the possibility of combined injury, which affects the surgery outcomes[8]. With the development of minimally invasive techniques and biomaterials, arthroscopy and double-strand suture anchors have been gradually adopted for the treatment of intra-articular fractures. ACL tibial insertion avulsion fractures are generally treated with arthroscopic surgery, which is gradually replacing traditional surgical methods. Arthroscopic surgical fixation methods include double-tunnel suture fixation, Kirschner wires, screws, and single-tunnel suture fixation[5–8]. Screw fixation is suitable for large avulsion fractures of the bone, but comminuted bones or bone blocks that are very small or very thin cannot be fixed. If the screw cap hinders knee extension, it needs to be removed with a second operation. Wire fixation surgery is difficult, especially when the wire is introduced or worn out, which is likely to cause secondary damage. In addition, steel wire is prone to fatigue fracture and interferes with magnetic resonance imaging (MRI) evaluations. The double-tunnel method requires a tunnel that is not very wide, which inevitably results in limited operation space and difficulty in pulling the fixed and traction lines. Additionally, this method cannot avoid the dispersion of double tunnel mechanics. Some other methods severely disrupt bone development in children. The above disadvantages can be avoided using the single-tunnel suturing method. Therefore, the aim of this study was to investigate the clinical effect of a single tunnel with a double-strand suture anchor in the treatment of ACL tibial insertion avulsion fractures.

Methods

Patients

A retrospective analysis was performed involving 29 patients who visited the North Jiangsu People's Hospital with tibial insertion avulsion fractures of the ACL and were treated with arthroscopic reduction using a single tunnel with double-strand nonabsorbable suture anchors from January 2014 to June 2018. All enrolled patients provided signed informed consent from all adult participants or their parents/legal guardian**s** of under 18 years old, the study and relevant details which were approved by the Institutional Ethics Committee of North Jiangsu People's Hospital had been performed in accordance with the Declaration of Helsinki. All protocols were performed in accordance with the relevant guidelines and regulations. A total of 29 patients, including 15 males and 14 females, age ranging from 8–66 years old, with a mean age of 32.59 years old, visited the emergency department for ACL tibial insertion avulsion fractures; none of the patients had cruciate ligament injuries or any other fractures. The inclusion criterion : patients with displaced ACL tibial insertion avulsion fractures. The exclusion criterion :patients with vessel injuries, nerve injuries, tibial plateau fractures, osteochondral lesions, posterior cruciate ligament (PCL) injuries, ACL injuries and multi-ligament injuries. The patients had varying degrees of knee pain and instability after injury, accompanied by swelling and pain in the knee joint after exercise. Before the operation, all physical tests were performed by the same doctor; the anterior drawer test (ADT) and the Lachman test were positive, which indicated anterior instability exceeding 5 mm. All patients underwent X-ray, computed tomography (CT), and MRI before surgery (Fig. 1). Among these patients, five had meniscal injuries and two had collateral ligament injuries. The preoperative International Knee Documentation Committee (IKDC) subjective score was 51.24 ± 3.16. According to the Meyers-McKeever fracture classification, there were 8 cases of type II fractures,12 cases of type IIIA fractures and 9 cases of type IIIB fractures.

Surgical techniques

Patients were placed in the supine position, spinal or general anesthesia was applied, a tourniquet was placed to prevent bleeding. The knee was bent at 90°. Through the front lateral approach and front medial approach, arthroscopy was performed to check the ACL, PCL, and meniscus for better understanding of the damage and treatment needed for the combined injury. Blood clots and the soft tissue between the fracture blocks were cleared.We used the probe to press the fracture block and tried to restore the fracture block, make sure the fracture block can be restored optimally. Through the front medial approach, PDS-II (ETHICON, LLC, USA) was placed through the posterior 1/3 or middle of the ACL tibial base. An high-strength suture from A Ti 5.0 mm suture anchor was tied to one end of the PDS-II line. Pull the other end of PDS-II so that the high-strength suture can cross the ACL. The ACL tunnel locator(Smith & Nephew, USA) was placed through the front medial approach,and located in the front of the fracture block. Under the guidance of the ACL tunnel locator, a 6 mm longitudinal incision was made near the tibial tuberosity, then a 2 mm Kirschner wire was drilled along the ACL tunnel locator, after that,the ACL tibial tunnel locator was removed. In adult, a 4.5 mm drill was used to enlarge the bone tunnel along the Kirschner wire. Pliers were placed through the bone tunnel, and pull out the high-strength suture through the bone tunnel.In adolescent, we removed the Kirschner wire and used a 18# epidural needle place through Kirschner wire bone tunnel. With the help of the 18# epidural needle ,Another PDS-II was placed through Kirschner wire bone tunnel and tied to the two end of the high-strength suture, when we pulled out the PDS-II, the high-strength suture can be pulled out through the Kirschner wire bone tunnel.A Ti 5.0 mm suture anchor with a double-strand #2 preloaded ULTRABRAID suture (Smith & Nephew Inc, Andover, MA 01810, USA) was placed beside the outside end of bone tunnel. The high-strength suture through the bone tunnel was knotted with the suture from suture anchor tightly. At last, the joint cavity was checked under arthroscopy, and make sure the fracture block was fixed effectively(Fig. 2).

Postoperatively, the wound in each patient was covered with compression dressing for 3 days, and a brace was fixed for 6 weeks. Under the protection of the brace, patients were encouraged to undergo long-term contraction and straight leg raise training for the quadriceps. Static knee training was started one week after the operation, and the knee joint activity was gradually increased to 90° in the fourth week. In the sixth week, the knee joint activity was required to be > 120°. At this time point, the brace could be removed for functional exercises, and the patients could resume normal activity after 3 months.

Follow-up

All 29 patients were followed up for 12 months. X-ray were taken intermittently to determine fracture reduction and healing. During the follow-up period, CT and MRI were performed to evaluate reduction and healing (Fig. 3). The Lachman test and ADT were performed by the same doctor to determine knee joint stability. The IKDC subjective score were used to evaluate postoperative knee function recovery.

Statistical analysis

Statistical analysis was performed using the SPSS23.0 (IBM Corp). Data were expressed as the mean ± standard deviation, and paired t-tests were used for comparison between groups; test level $\alpha = 0.05$. P values < 0.05 were considered statistically significant.

Results

The incisions in this group of patients healed well, and no complications, such as wound infection and thrombosis of the lower limbs, occurred. All 29 patients in this group were followed up for 12 months. The X-ray, CT scans, and MRI examinations showed good reduction, and all fractures achieved bone healing. Compared to the preoperation levels, all patients had normal flexion and extension of the knee joint and no subjective knee instability.

Postoperatively, the Lachman test and ADT showed anterior instability below 5 mm, while the same tests showed anterior instability exceeding 5 mm before the operation. The test scores were negative after surgery. The IKDC subjective score was 92.93 ± 2.59 at 12 months after surgery(Table 1). Compared to the preoperation score, the difference was statistically significant ($P < 0.05$).

Discussion

The purpose of surgical treatment is to restore the function of the ACL and maintain stability in the knee joint so that early functional exercises can prevent joint stiffness and joint instability[2]. The risk of postoperative stiffness can be reduced by early and effective rehabilitation.Arthroscopic surgery causes minimal trauma and rapid postoperative recovery. The arthroscopic technique is the first choice for treating ACL tibial insertion fractures [6,9]. The early application of fixed materials, such as Kirschner wire, steel wire, and screws [10–13] cannot be used for early rehabilitation training due to unreliable fixation, the potential to cut the bone, and difficulty with fixation. With the development of biological materials, new sutures are widely used ,some of which have special suture strengths similar to that of steel wire and flexibility much better than that of the latter. The principle of fixation is to reverse the displacement of the fracture block, which is more in line with the mechanical principle of fracture fixation and is suitable for various types of fractures[7,14–15]. So the suture fixation has been shown to be effective both biomechanically and clinically.In this group, we simplify surgery and further reduce trauma, a double-strand suture anchor with two high-strength sutures was used. The high-strength suture was passed through the ACL under arthroscopy, pulled out through a single tunnel, and finally knotted and fixed beside the tibial tuberosity.

Table 1
clinical information and outcomes

NO	Gender	Age	Type	IKDC subjective score	
				Preoperation	Postoperation
1	Female	27	IIIB	46	94
2	Male	26	II	52	92
3	Male	35	IIIB	52	89
4	Female	12	IIIA	55	96
5	Female	35	II	46	90
6	Female	8	IIIA	48	90
7	Female	39	II	52	95
8	Male	15	IIIA	50	94
9	Female	53	IIIB	54	95
10	Male	16	IIIB	53	96
11	Male	32	II	52	90
12	Female	13	IIIB	48	96
13	Female	33	II	50	92
14	Male	61	IIIA	56	92
15	Male	40	IIIA	58	90
16	Male	46	IIIA	48	93
17	Male	34	IIIB	49	96
18	Female	21	II	51	94
19	Female	46	IIIA	52	92
20	Female	12	IIIA	48	95
21	Female	7	II	50	98
22	Male	53	II	56	90
23	Female	36	IIIB	54	89
24	Male	51	IIIB	52	93
25	Female	66	IIIA	48	92
26	Male	48	IIIA	48	89

NO	Gender	Age	Type	IKDC subjective score	
				Preoperation	Postoperation
27	Male	12	IIIA	52	96
28	Male	52	IIIB	56	92
29	Male	16	IIIA	50	95

ACL tibial insertion avulsion fractures were also treated with double-tunnel suture fixation under arthroscopy. However, with limited operation space ,the tunnel of double-tunnel method is not very wide. Additionally, compared with the fixed traction line, drawing out the suture line is more difficult. Therefore, for this group of patients, the single-tunnel suture technology was adopted. This method needs only one bone tunnel to be drilled, which simplifies the operation and reduces surgical trauma,so that we can avoid many complications such as bleeding, iatrogenic damage and so on. The inner end of the single tunnel is in the front of the fracture block,before drilling,we should try to restore the fracture block under arthroscopy ,so that we could decide the pinpoint of the ACL tibial tunnel locator. The mechanical traction is nearly in line with restoration traction, thus avoiding dispersion of the mechanics traction with a double tunnel,and concentrating the fixation force, strengthening fixation strength. Because single tunnel with high-strength suture fixation is simple and convenient, thus shortening the time of operation, reducing the number of crossings and related instruments entering the joint cavity and decreasing the joint cartilage damage.

In adolescents, surgical intervention for tibial insertion avulsion fracture of the ACL is considered to have potential risk of growth disturbance.As the tunnel needs to pass through the epiphysis, many doctors fear growth disturbance caused by the tunnel,in their opinion ,the iatrogenic epiphyseal injuries should be avoided as much as possible. Sinha [16] used hollow nails and sutures to pass through the bone tunnel through the bone tunnel to fix the tibial anchor avulsion fracture of the anterior cruciate ligament in children, and there is no obvious growth disorder in the follow-up.also, McConkey and Shea [17, 18] found that drills with diameters of 6, 7, 8 and 9mm to make bone tunnels on the tibia will remove about 1.6%, 2.2%, 2.9% and 3.8% of the epiphyseal plate. The scholars [16–19] suggest that less than 5% of the epiphyseal plate damage is unlikely to occur growth arrest or limb deformity, but the epiphyseal plate damage reaches 7%-9%, the growth arrest occurs or the possibility of limb deformity is very high. In this paper, a 2.0mm Kirschner wire is used to make a single-bone tunnel, The epiphyseal plate damage caused by a 2.0mm Kirschner wire is much less than 1.6% of the epiphyseal plate damage caused by a 6mm drill, which is much less than 5% of the epiphyseal plate damage. Therefore, a single tiny tunnel avoids multiple points of damage to the epiphysis and minimizes the impact on the growth of the epiphysis.

The precautions for surgical treatment in this group of patients should be brought to the forefront.We should recognize the surgical indications, provide early surgical treatment, avoid the impact of old fractures, and avoid secondary damage to the articular cartilage due to malunion or joint instability. When the operation is carried out,we also should know that soft tissue in the fracture is often embedded in the fracture block, which hinders reduction of the fracture and leads to nonunion of the fracture; instead, clear the soft tissue between the fracture blocks and refresh the bone bed surface promotes the fracture block into the bed, which is conducive to bone healing.We should suture ACL at the bone-ligament junction in the most successful manner since repeated punctures will cause ligament cutting and even avulse the bone from the ligament. When we restore the fracture block under direct vision ,we should adjust the tension at the same time, we can increase the depth of the tibial bone bed and restore the tension of the ACL. ACL retraction can lead to ligament relaxation and ectopic elevation of the fracture block; thus the possibility of impact injury to the intercondylar fossa exists. Therefore, when the bone is initially restored, attention should be paid to the tension in the ACL and the intercondylar fossa.

There are some limitations of this study that need to be described. First, this study was a nonrandomized retrospective study, the follow-up period was short, and the sample size was small. A randomized controlled trial with a larger sample size and longer follow-up period should be performed. Second, clinical physical examinations, such as the ADT and Lachman test, are dependent on the examiner and may be inaccurate; thus, some of the results may not be reliable. These examinations should be performed using the KT-2000. Third, the rotation and upturn of the fracture block could not be effectively prevented; therefore, improvement is needed in this area.

Conclusions

The application of a double-strand suture anchor with its high-strength suture to treat ACL tibial insertion avulsion fracture under arthroscopy with a single tunnel resulted in minimal injury to the knee joint.It greatly simplified operation.The procedure caused minimal trauma,had firm fixation, ensured quick recovery and provided satisfactory clinical results.

Abbreviations

ACL=Anterior cruciate ligament, IKDC=Pediatric International Knee Documentation Committee, CT=Computed tomography, MRI=Magnetic resonance imaging, ADT=Anterior drawer test, PCL=Posterior cruciate ligament.

Declarations

Acknowledgements

The authors are grateful to the study participants

Author contributions

Dan Guo made substantial contributions to conception, study design , prepared all figures write the manuscript, analysis and interpretation of data. Dan Guo and Hansheng hu analyzed and collected the patient data.All authors reviewed the final manuscript.

Funding

No funding

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The research was in compliance with the Declaration of Helsinki. This study was approved by the Ethical Committee of North Jiangsu People's Hospital. All enrolled patients provided signed informed consent from all adult participants or their parents/legal guardians of under 18 years old.

Consent for publication

Not applicable.

Competing interests

The authors confirm that they have no competing interests.

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Figures

Figure 1

A 38-year-old man with a type IIIA ACL tibial insertion avulsion fracture due to trauma: anteroposterior X-ray film (a) and lateral X-ray film (b) showed apparent displacement; CT (c, d, and e) and MRI (f, g, and h) scans confirmed the fracture and displacement.

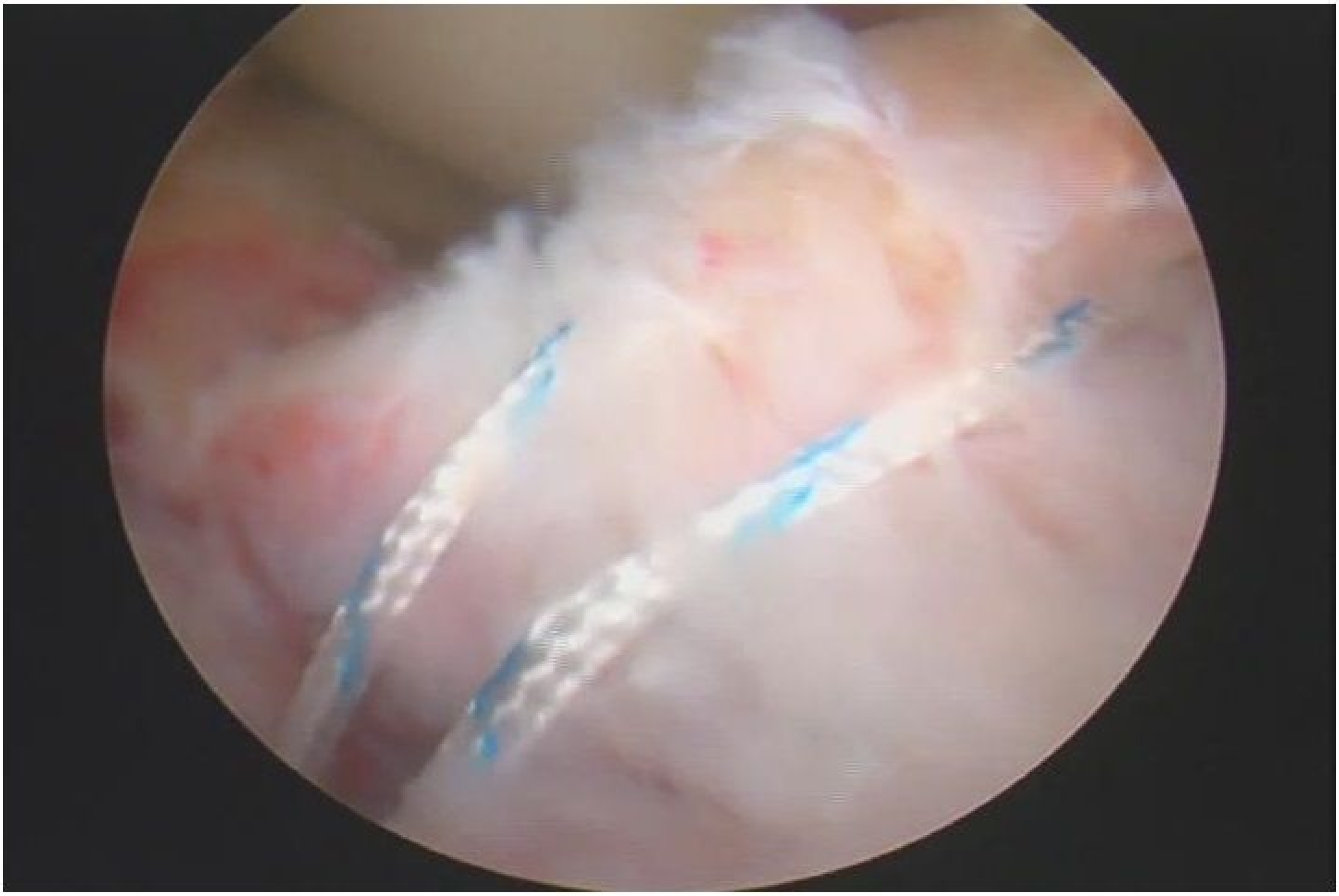

Figure 2

Arthroscopy film (a) of the patient in Figure 1 shows the suture and fixation of the fracture.

Figure 3

Anteroposterior X-ray film (a) and lateral X-ray film (b) taken one day post-operation for the patient in Figure 1 show reduction of the fracture. For the same patient, a CT scan (c, d) performed one day post-operation shows reduction of the fracture and tunnel. MRI (e, f) performed 5 months post-operation and X-ray (g, h) taken 12 months post-operation show fracture healing.