

# Treatment of Anterior Cruciate Ligament Tibial Insertion Avulsion Fractures with a Single Tunnel using a Double-strand Suture Anchor Under Arthroscopy

Dan Guo (✉ [ab81821689@163.com](mailto:ab81821689@163.com))

Yangzhou University Affiliated Northern Jiangsu People's Hospital: Northern Jiangsu People's Hospital  
<https://orcid.org/0000-0002-2572-713X>

Hansheng Hu

Yangzhou University Affiliated Northern Jiangsu People's Hospital: Northern Jiangsu People's Hospital

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## Research article

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

**Posted Date:** April 12th, 2021

**DOI:** <https://doi.org/10.21203/rs.3.rs-382916/v1>

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# Abstract

**Purpose** 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 single tunnel with a double-strand suture anchor in the treatment of ACL tibial insertion avulsion fractures.

**Methods** A retrospective analysis was performed on the data for 29 patients, comprising 15 males and 14 females, with Meyers-McKeeever type II or III ACL tibial insertion avulsion fractures treated with a single tunnel using a double-strand suture anchor under arthroscopy from January 2014 to June 2018. All 29 patients in this group were followed up for 12 months. The Lachman test was used to evaluate knee joint stability, the Lysholm score was used to evaluate knee joint function, and postoperative X-rays were used to evaluate healing after fracture reduction.

**Results** All 29 patients completed the follow-up. During the 12-month follow-up period, postoperative X-rays showed that all ACL tibial insertion avulsion fractures healed well and the pre-fracture function was restored. All incisions performed in patients healed well, and no surgical complications, such as infection or fracture nonunion, occurred. The anterior drawer test (ADT) and Lachman test were negative for the patients, and the knee function recovered well. The preoperative Lysholm score was  $51.14 \pm 2.34$ , and the preoperative International Knee Documentation Committee (IKDC) subjective score was  $51.24 \pm 3.16$ ; the Lysholm score at the last follow-up was  $92.52 \pm 1.35$ , and the IKDC subjective score at the last follow-up was  $92.93 \pm 2.59$  ( $P < 0.05$ ).

**Conclusion** 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, achieved good reduction, had firm fixation, ensured quick recovery, caused few complications, ensured good functional recovery, and provided satisfactory clinical results.

**Level of evidence: IV**

## Introduction

The anterior cruciate ligament (ACL) is an important ligament that maintains the stability of the knee joint. When there is injury to the knee joint, a tibial insertion avulsion fracture of the ACL may result in instability of the joint [1, 2]. According to the Meyers-McKeeever 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 nonsurgical treatment and this can result in nonunion or malunion of the fracture and ACL relaxation, which can cause knee

instability and dysfunction. Most scholars recommend accurate surgery and firm fixation. 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 address the possibility of combined injury, which affects the surgical effect. 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. 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.

## Materials And Methods

### General information

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. Each enrolled patient provided signed informed consent, and the study was approved by the Institutional Ethics Committee. A total of 29 patients, including 15 males and 14 females, age ranging from 8-66 years, with a mean age of 32.59 years, 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 was displaced ACL tibial insertion avulsion fractures in both skeletally mature and immature patients. Patients with vessel injuries, nerve injuries, tibial plateau fractures, and other significant injuries, including osteochondral lesions, or posterior cruciate ligament (PCL), ACL, and multi-ligament injuries, were excluded from the study. The number of days before surgery was 3-61 days, and the average number of days before surgery was 8.55 days. 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 Lysholm knee score was  $51.14 \pm 2.34$ , and the preoperative International Knee Documentation Committee (IKDC) subjective score was  $51.24 \pm 3.16$ . According to the

Meyers-McKeeever fracture classification, there were eight cases of type II fractures and 21 cases of type III fractures.

## Surgical methods

Patients were placed in the supine position, spinal or general anesthesia was applied, a tourniquet was placed to prevent bleeding, and 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, and the fracture block was reset. The optimal bone tunnel was determined in front of the ACL and it was also determined whether the ACL was fixed. The knee was bent at 90°, and the ACL tunnel locator was placed through the anteromedial approach. The point was located at the inner end of the tunnel for optimal fracture reduction. Under the guidance of the positioner, a longitudinal incision of approximately 0.6 cm was made at the positioning point of the tibial tuberosity inside the tibial tuberosity, and a 2 mm Kirschner wire was drilled along the positioner. The ACL tibia tunnel locator was removed, and a 4.5 mm drill was used to enlarge the bone tunnel along the Kirschner wire. Through the anteromedial approach, a shoulder rotator cuff suture was placed through the posterior 1/3 or middle of the ACL base, and the ACL was sewn through the rotator cuff suture with PDS-II (ETHICON, LLC, USA). Pliers were placed through the bone tunnel, and the PDS-II was pulled out through the ligament of the anterior ligament. The two ends of the PDS-II were removed from the joint cavity. One of the high-strength lines from the Ti 5.0 mm with a double-strand #2 preloaded ULTRABRAID suture anchor (Smith & Nephew Inc, Andover, MA 01810, USA) was tied to one end of the PDS-II line. The PDS-II was extended and one end of the high-strength line was pulled out from the joint through the tunnel, while the other end of the high-strength line was pulled out of the joint through the bone tunnel using pliers. The 5.0 mm suture anchor had been removed from one of the high-strength lines before it was placed beside the tunnel mouth. The high-strength line through the tunnel was knotted first with one side of the other high-strength line under the knot, and then the other high-strength line was knotted tightly. Finally, the joint cavity was checked under arthroscopy, and the fracture block was fixed using staples (Fig. 2).

## Postoperative treatment

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 at 3 months. Follow-up and evaluation indicators: All 29 patients were followed up for 12 months. X-ray films were taken at a monthly interval 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 Lysholm score and IKDC subjective score were used to evaluate postoperative knee function recovery.

## Statistical methods

Statistical analysis was performed using the SPSS23.0 (IBM Corp). Data were expressed as the mean  $\pm$  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 at 12 months after surgery. The Lysholm score was  $92.52 \pm 1.35$  at 12 months after surgery (**Table 1**). Compared to the preoperation score, the difference was statistically significant ( $P = 0.00$ ). The IKDC subjective score was  $92.93 \pm 2.59$  at 12 months after surgery. Compared to the preoperation score, the difference was statistically significant ( $P = 0.00$ ) (**Table 2**).

**Table 1**

Demographic data

| NO | Gender | Age | Preoperation time | Lysholm score |               | IKDC subjective score |               |
|----|--------|-----|-------------------|---------------|---------------|-----------------------|---------------|
|    |        |     |                   | Preoperation  | Postoperation | Preoperation          | Postoperation |
| 1  | Female | 27  | 3                 | 48            | 93            | 46                    | 94            |
| 2  | Male   | 26  | 11                | 54            | 92            | 52                    | 92            |
| 3  | Male   | 35  | 4                 | 50            | 90            | 52                    | 89            |
| 4  | Female | 12  | 3                 | 49            | 94            | 55                    | 96            |
| 5  | Female | 35  | 4                 | 50            | 93            | 46                    | 90            |
| 6  | Female | 8   | 61                | 50            | 92            | 48                    | 90            |
| 7  | Female | 39  | 11                | 53            | 94            | 52                    | 95            |
| 8  | Male   | 15  | 6                 | 50            | 92            | 50                    | 94            |
| 9  | Female | 53  | 5                 | 55            | 94            | 54                    | 95            |
| 10 | Male   | 16  | 7                 | 51            | 93            | 53                    | 96            |
| 11 | Male   | 32  | 8                 | 52            | 91            | 52                    | 90            |
| 12 | Female | 13  | 7                 | 49            | 94            | 48                    | 96            |
| 13 | Female | 33  | 3                 | 52            | 93            | 50                    | 92            |
| 14 | Male   | 61  | 7                 | 54            | 91            | 56                    | 92            |
| 15 | Male   | 40  | 5                 | 55            | 90            | 58                    | 90            |
| 16 | Male   | 46  | 6                 | 50            | 91            | 48                    | 93            |
| 17 | Male   | 34  | 11                | 49            | 94            | 49                    | 96            |
| 18 | Female | 21  | 4                 | 50            | 92            | 51                    | 94            |
| 19 | Female | 46  | 4                 | 52            | 92            | 52                    | 92            |
| 20 | Female | 12  | 9                 | 48            | 94            | 48                    | 95            |
| 21 | Female | 7   | 9                 | 49            | 95            | 50                    | 98            |
| 22 | Male   | 53  | 6                 | 54            | 92            | 56                    | 90            |
| 23 | Female | 36  | 8                 | 55            | 91            | 54                    | 89            |
| 24 | Male   | 51  | 3                 | 52            | 93            | 52                    | 93            |
| 25 | Female | 66  | 7                 | 50            | 92            | 48                    | 92            |
| 26 | Male   | 48  | 21                | 48            | 91            | 48                    | 89            |
| 27 | Male   | 12  | 5                 | 49            | 94            | 52                    | 96            |
| 28 | Male   | 52  | 6                 | 55            | 92            | 56                    | 92            |

**Table 2**

Statistical analysis of the Lysholm scores and IKDC subjective scores

|                       | Preoperation | Postoperation | P value |
|-----------------------|--------------|---------------|---------|
| Lysholm score         | 51.14 ± 2.34 | 92.52 ± 1.35  | 0.00    |
| IKDC subjective score | 51.24 ± 3.16 | 92.93 ± 2.59  | 0.00    |

## 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]. Arthroscopic surgery causes minimal trauma and rapid postoperative recovery. The arthroscopic technique is the first choice for treating ACL tibial insertion fractures [5-7]. The early application of fixed materials, such as Kirschner wire, steel wire, and screws [7-11] cannot be used for early rehabilitation training due to unreliable fixation, the potential to cut the bone, and difficulty with fixation. These materials have been used to a lesser extent with the development of biological materials, 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 [12-14]. In this group, one of the high-strength sutures with a double-strand suture anchor was used. The high-strength suture was passed through the ACL under arthroscopy, pulled out through a single tunnel, and finally knotted and fixed inside the tibial tuberosity.

In the past, ACL tibial insertion avulsion fractures were treated with arthroscopic double-tunnel suture fixation. However, the double-tunnel method requires a tunnel that is not very wide, which inevitably results in limited operation space. 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. The advantages of this technique are as follows: (1) only one tunnel needs to be drilled, which simplifies the operation and reduces joint trauma. Moreover, the issues of tunnel position and the distance between tunnels when drilling double tunnels do not need to be considered. (2) The inner end of the single tunnel is in the middle of the ACL and the PCL, and the two ends of the high-strength suture are pulled out through the outer opening of the single tunnel. The mechanical direction required for traction and resetting is nearly uniform, thus avoiding the need for a double tunnel. The dispersion of the mechanics allows for firm fixation, concentration of the fixed force, large fixation strength, early rehabilitation, and effective prevention of the rotation and upturn of the fracture block. Especially when the ACL becomes loose, the deep bone bed can be selected and the reduction can be over-reset to restore tension in the ligaments. When tension is applied, a single tunnel is more conducive to excessive reduction to restore ACL tension. (3) Single tunnel high-strength suture fixation is simple and convenient, thus reducing the number of crossings and related

instruments entering the joint cavity and decreasing the joint cartilage damage. (4) In adolescents, as the tunnel needs to pass through the skeleton, a single tunnel avoids multiple points of damage to the epiphysis and minimizes the impact on the growth of the epiphysis. (5) Sutures can be removed in the outpatient operating room under local anesthesia. The operation is simple, and no arthroscopic operation is required.

The precautions for surgical treatment in this group of patients include the following: (1) recognizing the surgical indications, providing early surgical treatment, avoiding the impact of old fractures, and avoiding secondary damage to the articular cartilage due to malunion or joint instability; (2) knowing 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, using a planer to trim the ACL tibia to stop the bone bed surface and refresh the bone bed surface promotes the fracture block into the bed, which is conducive to bone healing; (3) selecting the suture point of the threader in a biased manner to prevent the bone from tilting backwards; suturing the bone-ligament joint in the most successful manner since repeated punctures will cause ligament cutting and even avulsion of the bone from the ligament; (4) using arthroscopy to restore the fracture block under direct vision and adjusting the tension in the suture at the same time; increasing the depth of the tibial bone bed and restoring the tension in 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 reset, attention should be paid to the tension in the ACL and the intercondylar fossa; (5) biasing the inner mouth of the tibial tunnel to avoid difficulties during the operation; and (6) care while fixing the fracture block, tightening the suture at the same time, flexing the knee joint, and adjusting the position of the line and the fracture block. After reduction, the bone block is always fixed under tension.

## Limitations

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.

## Conclusion

In conclusion, under arthroscopy with a single tunnel, the application of a double-strand suture anchor and a high-strength line to treat ACL tibial insertion avulsion fracture resulted in minimal injury to the knee joint, a greatly simplified operation, a short operation time, a low cost, simple method to reset fractures, a wide application range, fast function recovery, and good clinical efficacy. Thus, this method is worthy of promotion.

## 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 author would like to acknowledge the patient on whom this article is based.

## **Conflicting of interest**

The authors declare that there is no conflict of interest.

## **Ethics approval and Consent to participate**

The study was approved by the Institutional Ethics Committee of Northern Jiangsu People's Hospital (NJPH).

## **Consent for publication**

The study was consented for publication by adult patients, parents of children or legal guardians .

## **Availability of data and materials**

All data generated or analysed during this study are included in this published article.

## **Funding**

Not applicable

## **Competing interests**

Not applicable

## Authors' contributions

| -                                  | Contributor 1 | Contributor 2 |
|------------------------------------|---------------|---------------|
| Concepts                           | √             |               |
| Design                             | √             |               |
| Definition of intellectual content | √             |               |
| Literature search                  | √             |               |
| Clinical studies                   | √             | √             |
| Experimental studies               | √             | √             |
| Data acquisition                   | √             | √             |
| Data analysis                      | √             | √             |
| Statistical analysis               | √             | √             |
| Manuscript preparation             | √             |               |
| Manuscript editing                 | √             |               |
| Manuscript review                  | √             |               |
| Guarantor                          | √             |               |

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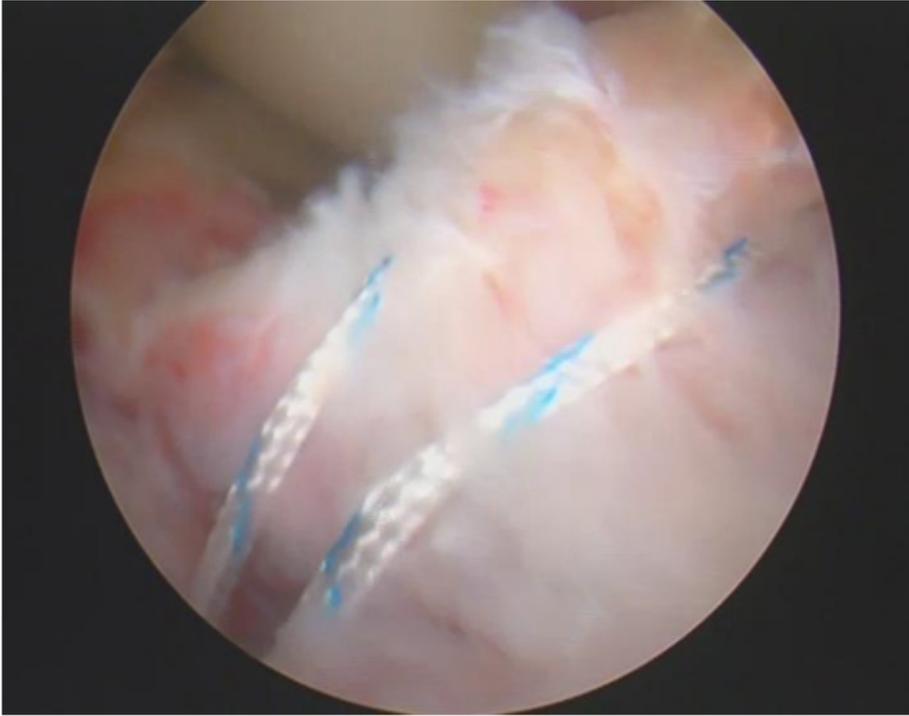
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## Figures



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.