Clinical Effect of Day-case Arthroscopic Surgery of Tibial Eminence Fracture using the Button Plates for Treatment in Adults

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Research article

Keywords: tibial eminence fracture (TEF), day-case, arthroscopic surgery, clinical efficacy

Posted Date: November 15th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-940168/v1>

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Abstract

Background: The aim of this paper is to evaluate the early clinical efficacy and complications of arthroscopic treatment of tibial eminence fracture (TEF) with button plates.

Methods: Retrospective analysis of patients with TEF fracture treated by arthroscopic surgery was performed. Clinical subjective evaluation included the International Knee Documentation Committee (IKDC) scores, Lysholm knee score, and visual analog scale (VAS). The knee joint scores were evaluated according to the Lysholm score. Clinical objective assessment included the Lachman test, anterior drawer test (ADT), IKDC, and the range of motion. The patient's quality of life was measured using a life summary table. Assessment of fracture healing and internal fixation was performed on lateral X-rays of the knee joint. The patients' satisfaction was measured and evaluated at the last follow-up in accordance with Marsh criteria.

RESULTS: There were 22 patients (22 knees) with a mean age of 33.64 ± 8.60 years. The mean follow-up was 28.36 ± 2.79 months. The difference in Lachman test and ADT before and after the operation was statistically significant. According to the IKDC classification, there were 11 cases with type A, 9 cases with type B, and 2 cases with type C. According to the intra-articular button position classification, the rate of ideal position was 100%. The satisfaction rate was 81.8%.

CONCLUSIONS: Day surgery using double-button plates to treat TEF can achieve anatomical reduction, power and stability, and good clinical efficacy.

Background

The tibial eminence fracture (TEF) is an anterior cruciate ligament (ACL) avulsion fracture with a low incidence. Previous studies have reported that TEF commonly occurs in children and adults¹. Currently, up to 40% of these fractures occur in adults². This type of fracture was first proposed by Meyers and McKeever in 1959. TEFs are divided into four types: type 3 and 4 fractures, which require surgical treatment, nonreducible type 1 fractures, and type 2 fractures^{1,3}. The current treatment plan of displaced TEFs involves the anatomical reduction of the fracture, reconstruction of ACL, early functional exercise, restoration of the knee joint function, and improvement of life quality.

Fracture treatment options in adults include incision or arthroscopy screws, steel wires, sutures with metal, or metal-free sutures⁴. Regardless of the type of fixation, the purpose is to achieve stability, reconstruction, and early functional exercise. However, none of the above methods can achieve early functional exercise, and there are many postoperative complications. Therefore, it is important to develop a better surgical plan to facilitate patient recovery. We tried to adopt a new fracture treatment plan based on double buttons fixation to evaluate the clinical efficacy of day surgery.

Materials And Methods

This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board. The participating patients signed informed consent.

A retrospective analysis of clinical efficacy and complications of line button-steel surgical treatment in patients with TEF from April 2017 to April 2019 was conducted. All the patients were operated on by the same group of surgeons.

This study included patients with no obvious contusion of the skin of the knee joint.

The exclusion criteria were as follows: 1. closed epiphyses; 2. arteriovenous injury; 3. previous meniscus resection; 4. abnormal imaging findings; 5. lack of consent to participate in the study; 6. multiple ligament injury; 7. ACL rupture; and 8. previous knee dislocation or old TEF.

All the patients received clinical examination and radiological examination before operation, including computed examination (CT) and magnetic resonance imaging (MRI) examination.

Clinical evaluation

Postoperatively, the patients were followed up in the outpatient department after 1 week, 4 weeks, 6 weeks, 3 months, 6 months, and annually thereafter. The clinical results were evaluated using visual analog scale (VAS) score, Lysholm score, International Knee Documentation Committee (IKDC) score, range of motion (ROM), Lachman test, and anterior cruciate ligament stretch test (anterior drawer test, ADT). The Lysholm score was graded as excellent (87–100), good (77–86), general (67–76), and poor (<67)⁵. The Lachman test was graded as 0 (no difference), 1 (1–5 mm laxity), 2 (5–10 mm laxity), or 3(>10 mm laxity). The radiographs were evaluated by anteroposterior and lateral X-rays.

These outcome measures were regarded to be essential for evaluating the fracture healing and knee function of patients with TEF. The disappearance of the fracture line indicated healing.

Quality of life:

The patients' health status was evaluated using short form 12 (SF-12) profiles, including a physical component summary (MCS) and a mental component summary (PCS).

Satisfaction:

Patients' satisfaction was based on Marsh's⁶ classification to evaluate the patients at the last follow-up. It included six levels: extremely satisfied, satisfied, partially satisfied, neither satisfied nor dissatisfied, somewhat dissatisfied, and very dissatisfied.

Surgical technique

Depending on the patient condition, the arthroscopic procedure was performed under general anesthesia or epidural anesthesia. The patients were placed in the supine position, and the lower extremity tourniquet was used.

The first step was to use the arthroscopic anterolateral, anteromedial, and patellar approaches to explore the joint cavity. The arthroscopy was continued to flush the joint cavity. The electric scalpel and radiofrequency electrocautery were used to clean up the blood clots and clean the synovium of the fractured end. First, the fracture was cleaned, and then if it was a type 4 fracture, it was tied with a non-absorbable thread to modify it to a type 3 fracture. The second step was to carefully explore the surroundings and use the rear drawer test to facilitate reduction. After resetting the bone block, a 1.0-mm Kirschner wire was used for temporary fixation (Fig. 1).

A C-type (point-to-point) guide positioner was placed on the tibial intercondylar eminence to maintain the reset simultaneously into the guide pin. (For the location, we suggest that the intra-articular plate be placed in the first 1/2 to the first 1/3 of the free bone to prevent “seesawing”). In the third step, a 2.4-mm threaded needle was introduced through the guide crossing the tibial cortex and the tibial eminence and terminating at the ACL insertion. A 4.5-mm tunnel was drilled along this threaded needle, which allowed the operator to insert the oblong button down through the osseous tunnels. A guidewire was successively passed through the cannulated drill, which was used to prepare passage for an intra-articular button (Figs. 2–4).

Intra-articular button was turned and placed over tibial eminence under the supervision of arthroscopy. Then, we tightened the traction suture. The traction sutures were tied on the round extra-articular metal button, which was created to keep the fracture fragment reduced (Figs. 5 and 6).

Postoperative treatment plan

The knee joints were treated postoperatively with the same rehabilitation programs. After wearing the knee brace adjustable knee flexion and extension, full weight-bearing exercise was set from 0° to 30° for the second day, 0°–50° for the second week, 0°–60° for the third week, 0°–75° for the fourth week, and 0°–90° for the sixth week. Six weeks after the surgery, the brace was removed and the knee flexion and extension were strengthened in an unrestricted state functional exercise.

Statistical analysis

All data were analyzed using SPSS 18.0 statistical software. Mean and standard deviation (SD) was calculated for the IKDC subjective scores, VAS scores, SF-12 scores, and Lysholm score. Ratios were calculated for categorical variables (Lachman grade, ADT, and overall IKDC grade) and compared using

the χ^2 test. A paired t -test was used to compare the Constant score before the operation and that at the last follow-up. The level of significance was defined as $P < 0.05$.

Results

We included a total of 32 patients (32 knees) with TEF types 2–4 according to the Meyers and McKeever classification. Ten patients (10 knees) were lost to follow-up; a total of 22 patients (22 knees) with displaced TEF, who had undergone arthroscopic treatment between April 2017 and April 2019, completed the follow-up study at the last follow-up.

The average follow-up duration was 28.36 ± 2.79 months (range, 25–36 months). This study included 12 men and 10 women, with a mean age of 33.64 ± 8.60 years. The mean time interval between injury and surgery was 6.59 ± 2.22 hours. There were 20 patients (90.91%) with Meyers and McKeever type 3 avulsion fracture and 2 patients (9.1%) with type 4 fracture. Twenty out of 22 patients had concomitant injury of meniscus and cartilage⁷, and seven had simple fractures. Two patients had 5° and 10° loss of normal knee joint function compared with the contralateral normal knee joint at the last follow-up.

All the patients restored the ROM of the involved knee to a completely normal range or a range with an acceptable deficit of less than 10° when compared with that of the normal contralateral knee. One patient had sporadic abnormal sound in the knee, but the function was not affected.

Subjective function assessment

VAS Score: The VAS score significantly declined from 7.00 ± 1.07 preoperatively to 1.55 ± 1.22 at the last follow-up ($t=20.90$, $p<0.001$) (Table 1).

IKDC Subjective: The mean IKDC score improved from 37.36 ± 4.75 perioperatively to 90.09 ± 2.27 postoperatively ($t=47.02$, $p<0.001$) (Table 1).

Table 1

Scores differences between Perioperatively and Postoperatively.

	VAS	IKDC Subjective	Lysholm Score	SF-12 PCS	SF-12 MCS
Perioperatively	7.00±1.07	37.36±4.75	6.41±4.32	32.47±5.96	43.69±4.89
Postoperatively	1.55±1.22	90.09±2.27	96.41±0.59	41.61±7.73	54.60±7.04
t	20.90	47.02	96.86	3.92	9.14
p	***	***	***	***	***

Values are reported as Means ±SD. ***means $P \leq 0.001$

Lysholm Knee Score. The Lysholm score increased from 6.41±4.32 to 96.41±0.59 points before surgery ($p < 0.05$), and the difference between the two was statistically significant ($t = 96.86$, $p < 0.001$). According to the Lysholm knee score, the knee joint score had excellent rate of 100%.

Quality of Life and Satisfaction

The mean PCS score increased from 32.47±5.96 before surgery to 41.61± 7.73 at the last follow-up ($t = 3.92$, $p < 0.001$); the mean MCS increased from 43.69±4.89 before surgery to 54.60±7.04 at the last follow-up ($t = 9.14$, $p < 0.001$) (Table 1).

The satisfaction of patients was measured as suggested by Marsh⁶: 6 (27.3%) patients felt extremely satisfied, 12 (54.5%) patients felt very satisfied, 3 (13.64%) patients felt somewhat satisfied, and 1 patient felt neither satisfied nor dissatisfied. The satisfaction rate was 81.8%.

Objective Function Assessment

Anterior Drawer Test (ADT)

Perioperatively, among 20 patients (20 knees) with positive ADT, only three knees showed positive ADT at the last follow-up (difference between before and after: $\chi^2 = 26.33$, $p < 0.0001$) (Table 2).

Table 2

Patients with Objective Results of differences between Perioperatively and Postoperatively.

(ADT and Lachman test)

	ADT		Lachman test	
	⊕+⊕	⊕-⊕	⊕+⊕	⊕-⊕
Perioperatively	20	3	18	1
Postoperatively	2	19	4	21
χ ²	26.33		26.77	
P	⊕0.0001		⊕0.0001	
Values are reported as the number of patients (%).				

Lachman test

Among 18 patients (18 knees) with preoperative positive Lachman test, only one knee showed a positive Lachman test at the last follow-up, and the difference between before and after was statistically significant ($\chi^2 = 26.77$, $p < 0.0001$) (Table 2).

Range of Movement (ROM)

The ROM of the patients with knee extension/flexion serious functional limitation was increased from $4.00^\circ \pm 4.69^\circ$ to $130.47^\circ \pm 9.55^\circ$, and none of the patients needed arthroscopic release therapy. The knee movements returned to an acceptable normal range in 20 patients. One patient had a deformity of approximately 10° at the last follow-up.

Overall IKDC

According to IKDC classification, 11 patients (11 knees) were normal (A), 9 patients (9 knees) were nearly normal (B), and 2 patients (2 knees) were abnormal (C) at the final follow-up.

Radiographic Results

According to the evaluation of the lateral X-ray of the knee joint, all the patients achieved an anatomical reduction of the bone block, and the fracture block healed within 3 months after the operation.

Intra-articular button Position

According to the lateral X-ray of the knee joint, the relationship between the long axis of the rectangular button loop in the joint and the sagittal plane of the human body was divided into three states: ideal, close to ideal, and not ideal.

The ideal position (A) means parallel, which is between the long axis of the steel plate and the sagittal plane of the human body (Fig. 7).

The nearly ideal position (B) means the existence of an angle, which is between the long axis of the steel plate and the sagittal plane of the human body (Fig. 8).

The nonideal position (C) means vertical, which is between the long axis of the steel plate and the sagittal plane of the human body.

According to position classification, 6 patients (6 knees) showed ideal position (A), 16 patients (16 knees) showed nearly ideal position (B), and none of the patients had nonideal position (C).

Complications

Two patients showed a loss of 5° and 10° knee joint motion compared with the contralateral normal knee joint at the last follow-up. One patient (1 knee) had twisting pronunciation or abnormal sound, without alterations of the knee function. There was no infection in any of the 22 patients.

Discussion

Most adult TEFs have a history of trauma, especially high-energy trauma of a car accident, falls, and other injuries^{2,8}; the fractures are often accompanied by ligament and/or meniscus damage. The treatment plan in these patients is to provide elastic quality, tough stitching, and rigid hard metal fork-fixed avulsion bone and ligament reconstruction treatment. All treatment regimens attempt to rebuild the ACL tension and ligament proprioceptive function.

The tensile force of the native ACL^{9,10} during normal human activities is 500 N. The mean force of TEF is about 2500 N^{10,11}. According to the biomechanical properties of two mental buttons (Tightrope@ model), the mean vertical force in static load leading to failure measured 982 N and the mean anterior force in static load leading to the failure was 627 N¹². The ultimate tensile force of this button system is strong enough to fix the fracture and restore ACL^{13,14}. It also illustrates the biomechanical property, that is, the feasibility, of the button plates, which can be used to treat TEF.

The treatment plan includes conservative management for type 1 nondisplaced TEFs; surgical treatment is required for type 2 TEFs if the reduction is not anatomical^{7,15}, and for type 3 and type 4 fractures^{16,17}. Successful arthroscopic reduction and fixation have been described in recent literature¹⁴.

With the use of arthroscopy in treatment, early activity and rapid recovery can be achieved, and the number of hospitalization days can be reduced. The treatment options reported so far include purse nails, cancellous bone screws, Kirschner wires, U-shaped nails, threaded rivets, sutures, and wire fixation. However, previous literature has reported that using suture fixation technology can help achieve good results.

Suture and rivet technology can achieve fixation of tibial intercondylar ridge fractures and reconstruction of anterior fork ligament tension^{7, 18, 19}. It has been reported in the literature that suture and screw fixation techniques are very effective in fixing fractures and reconstructing anterior fork ligaments^{7, 18, 19}. However, fixing the strength of these tools is not sufficient to favor the healing of fractures; most of them require a fixed full knee extension position and non-weight-bearing exercise for a long time, which leads to the knee joint adhesion and low activity. After treatment with these technologies, patients have a low quality of life and poor satisfaction.

We performed day-case, arthroscopic, double-button fixation technique treatment regimen; good function and relatively excellent knee joint scores were achieved, and this technique yielded the same or better results than other approaches^{5, 13, 20, 21}. There have been reports of this treatment plan in the literature, but there are few evaluation indicators included^{9, 22}. In this day-surgery study, the patients were treated with a double-button plate, which has both rigid and elastic characteristics. In this study, we adopted early function exercises and full weight-bearing after 2 days postoperatively. In contrast to the available literature, arthrofibrosis can be effectively avoided by continuously increasing the range of activities²⁰, and we suggest this aggressive regimen to secure the fixation (Fig. 9). At the last follow-up, the average knee mobility was about 130.45° (118–145°), which is comparable or better than previously reported^{13, 20, 21}. We believe that early day-case arthroscopic surgery of TEFs achieves a better immediate surgical effect with more favorable cost-effectiveness.

At the same time, the SF-12 score (PCS, MCS) of the patients increased significantly. By this treatment, patients can perform knee joint functional rehabilitation exercises early, which can effectively reduce postoperative adhesion and stiffness caused by braking and increase the confidence of postoperative knee joint rehabilitation.

We believe that patients with TEF often have ACL injuries, such as traction, which may affect the stability of the knee joint after surgery². In the previous literature, for TEF carina fractures, ACL injury was caused by traction during the fracture, resulting in more than 50% of the ACL injury, but this injury will not cause ligament rupture^{2, 3}, and no injury will lead to knee instability.

However, previous studies reported that 44% of patients with screw and wire fixation had physical instability and knee instability, and re-reconstruction of the ACL after this type of fracture was needed. It has been reported that the re-reconstruction rate of the ACL in adults is from 7% (5 years after surgery) to 12% (15 years after surgery)^{5, 6, 8}. None of the patients needed ACL reconstruction in our study. The injury composition was different than that from the previous report, which may have influenced the result at the

last follow-up. Before performing the fixation, the joint was thoroughly inspected to exclude ligament rupture by arthroscopy. The satisfaction rate was 81.8%, which was measured as suggested by Marsh⁶.

The knee flexion and extension activities of all patients were severely restricted before the operation. The imaging examination of all patients after 3 months showed that the anatomical reduction of the bone block and fracture healing were achieved. At the last follow-up, ADT was positive in three patients (3 knees, 13.63%), and Lachman test was positive in one patient (1 knee, 4.54%); the overall result was better than the previous examination of screw or suture fixation⁴. We considered that the reason for the positive ADT and Lachman test was the possibility of postoperative anterior fork ligament relaxation, and in 10 of 22 patients, there was also meniscus ligament compression and cartilage injury. The meniscus injury rate in our study is consistent with that reported in the literature, and the patients in this study were less involved in the vigorous knee joint sports, such as football or basketball and long-distance running. During the follow-up, none of the patients had obvious discomfort, and none of them underwent secondary knee arthroscopy.

It is well known that no matter whether incision or arthroscopic surgery is performed for tibial intercondylar ridge fractures, there are complications such as adhesion, fracture nonunion, dysfunction, loss, and relaxation^{3, 13, 15, 20}. Early rehabilitation exercises after fracture surgery can effectively restore knee function, but may also increase the risk of re-fracture, non-union fracture displacement, increased bleeding, increased inflammatory response, and repeated knee swelling^{13, 20}. The recovery process of postoperative patients is different from previous similar reports^{9, 22}. In this study, we included more evaluation indicators, and we asked patients to be fully weight-bearing on the second day after the operation. The functional exercise was within the adjustment range of the brace. We believe that early functional exercise is conducive to knee rehabilitation and improves knee mobility (ROM). Button steel plate fixation has the characteristics of elastic fixation and promotes fracture healing^{10, 11}. Postoperative complications after treatment with this treatment protocol are significantly less common than previously reported in similar literature^{7, 12-16}. In this study, there were two patients with knee joint extension loss at the last follow-up, which is similar to the previous literature; there was no joint release or joint ROM release under anesthesia. After being discharged from the hospital, the patient was urged to do strengthening functional exercise of the knee joint at home in a timely manner, and the restricted movement of the knee joint could be significantly improved. The proportion of patients with car accident trauma in this study is high, and there were often soft tissue injuries around the knee joint. These injuries led to easy adhesion, causing knee joint dysfunction. Patients undergoing day-case arthroscopic surgery do not need to wait long before operation, and these patients can exercise earlier.

The direction of the tunnel and the placement of intra-articular buttons may affect fracture healing and knee functional rehabilitation. The button plate requires anatomical reduction and fixation of the bone block and the combined force direction of the ACL for the nail path during treatment, which can achieve the maximum mechanical fixation direction. For the location, we suggest that the intra-articular plate be placed in the first 1/2 to the first 1/3 of the free bone to prevent “seesawing”; If the intra-articular plate is

placed too far forward, such as 1/3 of the free bone, there will be “excessive reduction” in the front of the block and tilt in the back, resulting in poor reduction. Moreover, the internal and external diameters of the free bone fragments will be larger when the intra-articular plate is placed backward, which is more advantageous to prevent the bone fragments from breaking when drilling. In addition, the rotation of the intra-articular plate can be prevented by placing it in the anterior cruciate ligament. The design of the nail path of our patients’ bone block followed the force direction (Fig. 10). Femoral intercondylar presence is different in men and women, and the differences in the femoral intercondylar width were previously reported in the literature with the femoral intercondylar terminus average width of 14.5 mm–24 mm^{17, 20}. However, the width of the intercondylar fossa in patients with osteoarthritis is narrower. The length of the long axis of the intra-articular loop plate is about 10 mm. We recommend that the long axis of the intra-articular loop plate should be parallel to the sagittal plane of the knee joint. This can effectively avoid the impact of the button plate on the narrower intercondylar fossa and reduce damage. We routinely sutured and reinforced the intra-articular button into the anterior ligament. However, during the postoperative follow-up, we found that the intra-articular button had rotated. This resulted in the risk of collision between the button plate and the intercondylar fossa. However, 16 patient follow-ups were found in the continuous presence of loop rotation button, intra-articular rectangular loop into a fixed position B type. One patient developed C-type and had no knee discomfort during follow-up. During the follow-up process, one patient had postoperative bouncing weakness and abnormal noise when the knee joint moved, but the knee flexion and extension function was good.

Button plates are used to treat TEF. We do not recommend secondary surgery to remove the internal fixation device because it is covered by soft tissue and ligament fibers after fracture healing. It is difficult to find and remove it under arthroscopy. Secondary surgery increases the costs and pain; however, if the intra-articular button body becomes loose in the knee, it must be removed.

Conclusion

Double-button plate for TEF in day surgery can significantly reduce the hospital stay and preoperative waiting time; it can also accelerate the rehabilitation of the knee joint function, reduce the rehabilitation time, and significantly improve the early postoperative exercise ability of the patients.

Limitations Of The Study

First, this was a retrospective study. Second, the sample size was small. Third, the follow-up period was short. We will continue this study using a larger sample size and longer follow-up time in order to make our study more meaningful.

Abbreviations

The tibial eminence fracture (TEF) ♂ anterior cruciate ligament (ACL) ♂ computed examination (CT) ♂ magnetic resonance imaging (MRI) ♂ visual analog scale (VAS) ♂ International Knee Documentation

Committee (IKDC) range of motion (ROM) anterior drawer test ADT short form 12 (SF-12) physical component summary (MCS) mental component summary (PCS) Mean and standard deviation (SD)

Declarations

Competing interests

No conflicts of interest were declared by the authors.

Ethics approval and consent to participate

Every patient has to give his/her written consent before participation in the clinical trial.

The content of the consent information is documented on the patient information/informed consent form. The patient will be notified, if essential findings appear during the study. All authors have completed and submitted the ICMJE Form for Disclosures of Potential Conflicts of Interest and none were reported. All procedures were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Authors' contributions

XX participated in the design of the study and drafted the manuscript. FG participated in the design of the study and coordination and helped drafted the manuscript. HW and FC participated in the radiological evaluation and performed the statistical analysis. All authors approved the final manuscript.

Funding

This study had no financial support.

Acknowledgments

We thank LetPub (www.letpub.com) for its linguistic assistance during the preparation of this manuscript.

Availability of data and materials

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

Consent for publication

For any individual person's data in any form (including any individual details, images or videos), consent for publication must be obtained from that person.

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Figures

Figure 1

Arthroscopic view: Type 3 fracture with ligament being obstacle to reduction.

Figure 2

Arthroscopic view: Reduction of fracture block with reducer.

Figure 3

Arthroscopic view: The guide holes the reduction and determines the pin placement. The pin was inserted through the proximal tibia and the fragment.

Figure 4

Arthroscopic view: A 4.5-mm hole is then drilled along the pin using a cannulated drill.

Figure 5

The assistant pulls the white cord in order to pull the button plate out through the hole.

Figure 6

Arthroscopic view: Pull and flip button plate.

Figure 7

Postoperative anterior–posterior and lateral view radiographs. The ideal position (A).

Figure 8

Postoperative anterior–posterior and lateral view radiographs. The nearly ideal position (B).

Figure 9

Changes in range of motion of the knee joint after operation for TEF.

Figure 10

1. The direction of the force line represents the tension direction of the anterior bifurcate ligament. 2. The direction of the force line represents the pressure direction of the fracture block. 3. The direction of the button was fixed at the combined force direction, which was between the bone mass and the ACL.