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Study of Double Button Plate Fixation for Posterior Cruciate Ligament Avulsion Fracture

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Abstract

Objective: The aim of this study was to investigate the effects of double button plate fixation in the treatment of posterior cruciate ligament avulsion fractures.

Methods: We retrospectively reviewed our database, which was collected prospectively from January 2018 to January 2019, 33 patients with posterior cruciate ligament avulsion fractures underwent surgery by a single surgeon. Patients with posterior cruciate ligament avulsion fractures were treated with double button plate fixation. The operative time, bleeding loss, fracture union time, operative complications and range of motion of the knee joint were recorded. The functional recovery of the knee joint was evaluated by the KSS and Lysholm scores. Average follow-up was 14 months (range, 12 to 16 months) after surgery.

Results: Mean operation time was 49 ± 4.3 min, and average bleeding loss were 32 ± 8.8 ml. The average preoperative scores were 42 points by KSS function scores, 40.6 by Lysholm scores. Average clinical outcome scores improved significantly at the final follow-up after surgery, 95 points by KSS function scores, 98.2 points by Lysholm scores ($P<0.05$), and all fractures were completely healed. All patients returned to work at the final follow-up. Knee active range of motion improved significantly, 88°C for range of motion. There were no cases of non-union, any infection, revision, implant removal, neural injury, and suture anchor problems.

Conclusion: In this study, double button plate fixation technology for the treatment of posterior cruciate ligament avulsion fractures has the advantages of minimal trauma, simple operation, reliable fixation and a large fracture contact area, fewer postoperative complications, and restored stability and function of knee joints. Our results suggest that this reconstruction technique is a reliable and useful alternative treatment.

Level of Evidence: Level IV, therapeutic case series.

Keywords: Posterior cruciate ligament; Avulsion fracture; Double Button Plate Fixation; Treatment

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Introduction

The posterior cruciate ligament plays an important role in maintaining the stability of the knee joint [1]. It has been reported that avulsion fracture of the tibial insertion is common in young people. The main causes of avulsion fractures are traffic accidents and falling injuries during strenuous exercise [2,3]. The damage mechanisms usually include over flexion, anteroposterior and hyperextension. PCL tibial avulsion fracture is a special type of PCL injury, accounting for approximately 10% of all PCL injuries [4]. In the past, due to insufficient understanding and limited examination instruments, misdiagnosis and missed diagnosis led to untimely treatment, poor treatment effect, a high risk of fracture displacement, delayed union and non-union, and the dysfunction of the knee joint in later stages [5].

The treatment of PCL tibial avulsion fractures includes non-operative treatment, traditional open reduction internal fixation, and arthroscopic surgery [6]. Open surgery has been widely carried out, and the main internal fixation materials include absorbable screws, cannulated screws, and anchors with threads [7]. Cannulated screw fixation has high fixation strength and stability, but all the stress is concentrated in the tail of the screw, which easily causes re-fracture and leads to internal fixation failure; at the same time, the huge tension of the PCL during knee joint movement may lead to higher risks of re-fracture and fracture block displacement, limiting early functional exercise and increasing complications [8]. Arthroscopic internal fixation can complete the exploration of the knee joint through several small incisions and monitor the operation in the process of drilling the tunnel or screw placement. It has the advantages of minimal surgical trauma and fast patient recovery but also features high technical requirements for surgeons, a long learning curve, high requirements for equipment, and requirements for expensive equipment [9]. At present, open surgery and internal fixation are still mainstream. The appearance of internal fixation materials gives surgeons more choices. They can fix the fracture block directly through the posterior small incision [10].

Internal fixation methods have many disadvantages, such as insufficient fixation strength, high tension on the cruciate ligament and long-term immobilization, which to some extent affect early postoperative rehabilitation exercise, resulting in knee joint adhesion, flexion and extension function limitations and other shortcomings [11]. An alternative is to utilize double button plate fixation methods. We adopted double button plate fixation in the management of posterior cruciate ligament avulsion fractures. To date, researchers have not reached an agreement on which type of fixation material should be used to treat PCL tibial avulsion fractures. Therefore, this study aimed to evaluate the associations of perioperative and postoperative outcomes of double button plate.

Materials and Methods

We retrospectively reviewed our database, which was collected prospectively. From January 2018 to January 2019, 33 patients with posterior cruciate ligament avulsion fractures underwent surgery by a single surgeon. The patients signed an informed consent form approved by the Institutional Review Board at our hospital (Tianjin First Center Hospital). The clinical data of 33 patients with regular follow-up were obtained, with 20 males and 13 females. The inclusion criterion was a single avulsion fracture of the posterior cruciate ligament, the time of injury was less than 3 weeks, all patients had complete imaging examination of the knee joint, with a positive posterior drawer test and Lanchman test, and they were type II and type III according to the Meyers classification. The exclusion criteria included combined tibial plateau fractures, fractures around the knee joint, comminuted fracture, pathological fracture, Meyers type I, anterior and posterior cruciate ligament injuries, medial and lateral collateral ligament injuries, and combined severe vascular and nerve injuries. Traffic accidents were the major mechanism of injury, accounting for 18 (55%) of 33 cases, along with 13 cases of fall injury (39%) and 2 cases of injury involving accidental sprains (6%) (Table 1, Figure 1a, 1b).

Patient assessment

The patients provided a standard history and underwent physical examination that consisted of measurement of the knee range of motion, KSS function scores and Lysholm scores by a single surgeon before surgery; at 3, 6, and 12 months after surgery; and yearly thereafter.

Radiography and magnetic resonance imaging

We obtained preoperative and follow-up radiographs in all patients. Magnetic Resonance Imaging (MRI) was performed with a 3.0-T closed-type scanner (MRT-2000/V2, Tianjin, China). Oblique coronal, oblique sagittal and axial T2-weighted MR images were acquired for structural and qualitative assessment of the posterior cruciate ligament, and repair integrity was determined. Radiography and MRI were performed by a single surgeon before surgery; at 3, 6, and 12 months after surgery; and yearly thereafter, and this study used the final data. Average follow-up was 14 months (range, 12 to 16 months) after surgery.

Surgical technique

We performed surgery using general anesthesia with patient in the prone position, and the injury leg was bound with a tourniquet. We examined knee range of motion and positive posterior drawer test and Lanchman test with the patient under general anesthesia. An inverted L-shaped 6-cm-long incision was made on the posterior medial side of the popliteal fossa, the medial head of the gastrocnemius muscle and semi membranous muscle were separated (Figure 2c), protect the vascular and nerve bundle, and the posterior edge of the tibia was exposed. We cleared the joint cavity hematocele and soft tissue, and cleaned up with a large amount of salt solution. After reduction under approximately 30° flexion of the knee joint, a 2.0 mm guide needle and a 4.5 mm hollow drill was used to drill from the anterior medial side into the inferior area of the fracture through the locator, established a bone canal. The holes of an Endo button (Smith & Nephew) were crossed into two high-strength wires and double button plate was pressed on the surface of the PCL avulsion fracture fixation, and the ends of the high- strength wires were tightened. During the operation, the fracture was stable through passive movement. Physical examination showed that the knee joint was stable. X-ray fluoroscopy showed that the fracture was well reduced and fixed, and the position of the titanium plate was acceptable (Figure 2a, 2b). The limb was fixed with plaster at 10 degrees of extension.

Postoperative protocol

Postoperative radiographs were taken after surgery. Patients were given a plaster as protection postoperatively. In general, 0 to 90 degrees of flexion in the brace was allowed for the first 2 weeks postoperatively. Patients were given their first follow-up appointment at 2 weeks postoperatively for wound inspection, and then they were followed up every 2 to 4 weeks to monitor for functional return and clinical/radiological fracture union. The knee joint activity gradually strengthened by the fourth week after the operation, and some weight-bearing walking began at the sixth week after the operation. Passive and active-assisted exercise and strength training are allowed after eight weeks surgery, and there is no restriction on activity for 1 year after operation. Physical therapists assisted all patients.

a) CT scanning b) MRI

Figure 1: Preoperative radiograph of Posterior Cruciate Ligament (PCL) avulsion fracture.
(a) CT scanning showed the posterior cruciate ligament avulsion fracture. b) MRI confirmed the fragment size and displacement of the PCL avulsion fracture.

Table 1: Summary of patients.

Knee	Sex	Age (year)	Job	Meyers classification	Injury	Operation time (min)	Bleeding Loss (ml)
1	M	55	Manual worker	Type II	Traffic accident	45	25
2	F	59	Housewife	Type II	Traffic accident	46	20
3	M	61	Manual worker	Type II	Fall	48	30
4	M	58	Housewife	Type II	Traffic accident	50	25
5	M	59	Farmer	Type III	Fall	48	30
6	F	64	Housewife	Type III	Traffic accident	42	25
7	F	61	Housewife	Type III	Fall	45	25
8	M	56	Manual worker	Type II	Fall	49	40
9	M	59	Farmer	Type II	Traffic accident	55	45
10	M	58	Farmer	Type III	Accidental sprains	46	35
11	F	59	Housewife	Type II	Traffic accident	56	25
12	M	55	Desk work	Type II	Traffic accident	44	15
13	F	59	Farmer	Type II	Fall	43	35
14	M	61	None	Type II	Traffic accident	52	45
15	M	54	Farmer	Type II	Fall	54	40
16	F	58	None	Type II	Traffic accident	48	35
17	F	52	Desk work	Type II	Fall	49	35
18	M	59	Farmer	Type II	Traffic accident	45	30
19	F	58	None	Type II	Fall	50	40
20	M	56	Farmer	Type II	Traffic accident	51	40
21	M	57	Manual worker	Type II	Fall	52	35
22	M	54	Desk work	Type II	Traffic accident	53	25
23	F	53	Desk work	Type II	Fall	55	40
24	M	58	Manual worker	Type III	Traffic accident	45	35
25	M	58	Farmer	Type III	Traffic accident	46	25
26	F	57	None	Type III	Traffic accident	49	20
27	M	63	Manual worker	Type III	Fall	41	15
28	F	57	Housewife	Type III	Traffic accident	49	25
29	M	58	Manual worker	Type III	Fall	45	40
30	F	51	Desk work	Type III	Traffic accident	54	45
31	M	59	Farmer	Type II	Traffic accident	58	45
32	M	60	Manual worker	Type III	Fall	53	35
33	M	59	Manual worker	Type II	Accidental sprains	52	40
Average	N/A	57	N/A	N/A	N/A	49	32
SD	N/A	2.9	N/A	N/A	N/A	4.3	8.8

Abbreviations: M: Male; F: Female

Statistical analysis

Data were analyzed using SPSS 13.0 software (SPSS, Chicago, IL, USA). All data were reported as the mean ± Standard Deviation (SD). One-way ANOVA was employed for all statistical analyses, followed by Student-Newman-Keul's test. Values were compared using multiple comparisons, where p-values of 0.05 or less were considered significant.

Results

Mean operation time was 49 ± 4.3 min, and average bleeding loss were 32 ± 8.8 ml (Table 1). At 2 weeks after the operation, the plaster was removed. All patients had normal flexion and extension of the knee joint at 6 to 8 weeks. Functional outcomes were assessed by means of walking status, range of motion, and KSS function and Lysholm scores upon final follow-up (Table 2).

The average preoperative scores were 42 points by KSS function scores, 40.6 by Lysholm scores. Average clinical outcome scores improved significantly at the final follow-up (mean, 14 months, range, 12 to 16 months) after surgery, 95 points by KSS function scores, 98.2 points by Lysholm scores ($P<0.05$) (Table 2). All patients returned to work at the final follow-up. Knee active range of motion improved significantly, 88° for range of motion. There were no cases of non-union, any infection, revision, implant removal, neural injury, and suture anchor problems.

At the final follow-up, all fractures were completely healed. The

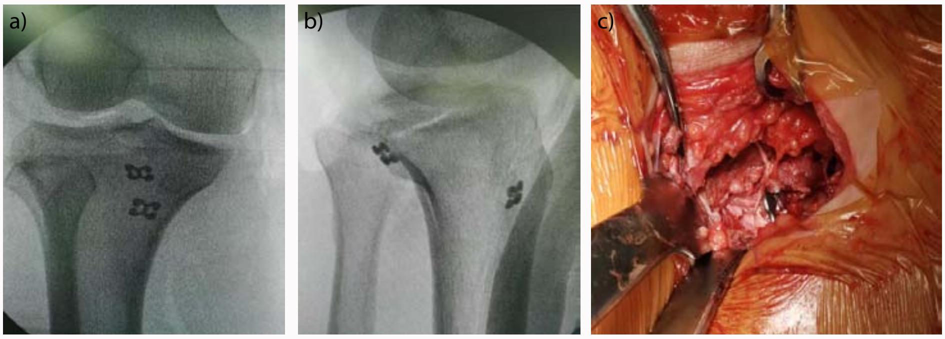

Figure 2: Intraoperative radiograph of double button plate fixation.
a, b) intraoperative X-ray showed that the fracture was well reduced and fixed, C) showed the titanium plate passed bone canal and position was acceptable.

Table 2: Summary of patients' knee functional scores.

Knee	KSS function (scores)	Postoperative	Lysholm (scores)	Postoperative	ROM (degree)	Postoperative
	Preoperative		Preoperative		Preoperative	
1	40	95	40.5	100	0-40	0-130
2	45	98	41.5	95	0-45	0-130
3	35	90	38.5	100	0-35	0-125
4	50	100	41.5	100	0-40	0-135
5	55	100	42.5	100	0-45	0-130
6	45	98	40.5	96.5	0-40	0-135
7	40	100	40.5	100	0-45	0-130
8	35 92	100	36.5 89.5	100	0-40 0-120	0-130 0-120
9	40	95	40.5	100	0-45	0-135
10	45	98	42.5	95	0-40	0-135
11	40	90	40.5	100	0-45	0-125
12	40	91	40.5	95	0-40	0-130
13	45	95	41.5	95	0-45	0-125
14	35	92	38.5	100	0-35	0-135
15	50	100	41.5	100	0-40	0-130
16	55	100	42.5	100	0-45	0-130
17	45	95	40.5	100	0-40	0-125
18	40	90	40.5	95	0-45	0-130
19	35	92	36.5	100	0-40	0-125
20	40	90	40.5	100	0-45	0-130
21	45	90	42.5	95	0-40	0-130
22	40	90	40.5	95	0-45	0-130
23	40	90	40.5	95	0-40	0-135
24	45	95	41.5	100	0-45	0-135
25	35	92	38.5	100	0-35	0-130
26	50	100	41.5	100	0-40	0-130
27	55	100	42.5	100	0-45	0-130
28	45	95	40.5	95	0-40	0-130
29	40	95	40.5	92.5	0-45	0-120
30	35	92	36.5	100	0-40	0-120
31	40	90	40.5	100	0-45	0-135
32	45	90	42.5	95	0-40	0-130
33	40	92	40.5	100	0-45	0-135
Average	42	95	40.6	98.2	0-42	0-130
SD	5.9	4	1.5	2.5	3.3	4.1
P	<0.05		<0.05		<0.05	

Abbreviations: ROM: Range of motion; KSS: Knee Society Score

Table 3: Summary of patients' complication.

Knee	FWB (weeks)	Non-union	Any infection	Revision	Implant removal
1	10	N0	N0	N0	N0
2	11	N0	N0	N0	N0
3	11	N0	N0	N0	N0
4	12	N0	N0	N0	N0
5	10.5	N0	N0	N0	N0
6	11	N0	N0	N0	N0
7	11.5	N0	N0	N0	N0
8	12	N0	N0	N0	N0
9	11	N0	N0	N0	N0
10	12	N0	N0	N0	N0
11	11.5	N0	N0	N0	N0
12	11	N0	N0	N0	N0
13	12	N0	N0	N0	N0
14	11	N0	N0	N0	N0
15	12	N0	N0	N0	N0
16	10.5	N0	N0	N0	N0
17	11	N0	N0	N0	N0
18	11.5	N0	N0	N0	N0
19	12	N0	N0	N0	N0
20	11	N0	N0	N0	N0
21	12	N0	N0	N0	N0
22	11.5	N0	N0	N0	N0
23	11	N0	N0	N0	N0
24	12	N0	N0	N0	N0
24	11	N0	N0	N0	N0
26	13	N0	N0	N0	N0
27	10.5	N0	N0	N0	N0
28	11	N0	N0	N0	N0
29	11.5	N0	N0	N0	N0
30	12	N0	N0	N0	N0
31	11	N0	N0	N0	N0
32	12	N0	N0	N0	N0
33	11.5	N0	N0	N0	N0
Average	11.4	N/A	N/A	N/A	N/A
SD	0.6	N/A	N/A	N/A	N/A

Abbreviations: FWB: Full Weight Bearing

fractures were not displaced. Follow-up X-rays showed that the avulsion fracture fragments of the tibial attachment point of the PCL healed well, and there was no displacement or implant breakage of the fracture fragments (Figure 3, Table 3).

Discussion

The tension of the PCL is highest in the flexion position of the knee joint, and tibial avulsion fracture mainly occurs in knee flexion [12,13]. In the flexion position, the lateral condyle of the femur moves backward, and the femur rotates outwards. The force from front to back causes the posterior tibia to be impacted by the femoral condyle, and the tension of the PCL increases sharply, which eventually leads to avulsion fracture of the PCL tibial insertion point [14]. Because the contact area between the posteromedial tibia and the medial femoral condyle is larger than that between the posterolateral tibia and the lateral femoral condyle, PCL tibial avulsion fracture fragments are increasingly larger [15]. If not intervened, they can seriously affect the stability of the posterior part of the knee joint, and the fracture block protrudes behind the tibial intercondylar ridge, which may induce impingement syndrome [16]. In the late stage, quadriceps atrophy, joint effusion, articular cartilage degeneration and secondary meniscus injury can become aggravated, which will seriously affect the quality of life of patients. Therefore, the current view is that PCL tibial avulsion fractures should be firmly fixed to avoid postoperative displacement or poor healing, resulting in the instability of the knee joint [17].

Figure 3: Postoperative radiograph of double button plate fixation (12 months) Cannulated screw fixation.
Follow-up X-rays showed that the avulsion fracture fragments of the tibial attachment point of the PCL healed well, and there was no displacement or implant breakage of the fracture fragments.

There are many kinds of surgical methods for PCL tibial avulsion fracture, including arthroscopic and open surgical approaches [18,19]. Arthroscopic surgery has the advantages of minimal trauma, a small amount of soft tissue damage and fast recovery [20,21]. However, in most total arthroscopic surgeries, a bone tunnel must be drilled on the tibia. The tunnel introduces an internal fixator through the tunnel, which has the characteristics of complex operation, high equipment requirements and a long learning time, limiting its development [21,22]. Open surgery for PCL a tibial avulsion fracture has been widely carried out. The internal fixation materials mainly include steel wires, absorbable screws, hollow screws, Kirschner wires, and wire anchors [23,23]. Steel wire fixation is convenient and economical, but it easily causes further fracture of the fracture block in the process of the operation, causing secondary damage to the blood supply of the fracture block and affecting fracture healing [24]. Moreover, to avoid the fracture of the steel wire after the operation, long-term braking is necessary, resulting in limited joint function and joint stiffness [25]. The absorbable screw material can be absorbed after the operation, and it is unnecessary to remove the internal fixator, avoiding a secondary operation and trauma [26]. However, the external fixation time of absorbable screws, such as plasters or braces, is long, and 4~6 weeks of fixation is advocated [27]. At the same time, absorbable screws have low strength and are characterized by weak fixation and easy displacement. Simple cannulated screw fixation has high fixation strength and stability, but all the stress is concentrated in the screw tail, which easily leads to stress concentration, refracture and internal fixation failure [28].

Due to comminuted fracture, small bone fragments are often difficult to fix, but early rehabilitation exercise requires relatively stable fixation. For the treatment of this kind of fracture, in addition to conventional surgical methods such as tension band steel wire fixation, purse suture fixation and special plate fixation are also currently commonly used [29]. For patients with posterior cruciate ligament avulsion fracture and repair difficulties, a more classic treatment method is to insert two button plates into the broken end of the fracture [29]. The sutures are sewn out along the aponeurosis, and then the two circuits are sewn and knotted with each other. With a button plate, the fracture block is fixed reliably, the fracture surface is in good contact, and the PCL is connected by a non-absorbable tension suture. This method can reduce any large movement of the fracture block during knee joint functional exercise, disperse the concentrated stress around the button plate during knee joint flexion, reduce the risk of refracture, promote fracture healing and avoid joint adhesion complications.

The use of double button plate fixation technology has the following advantages: less trauma, shorter operation time, convenient use of instruments and fixtures, and it does not need to be taken out again, thus avoiding secondary trauma. Moreover, the strength of the suture is large, and the tension of the posterior cruciate ligament can be fully reduced by tying the suture band. Double button plate fixation under direct vision is safe and reliable without the need for additional equipment. Even comminuted fractures can also be effectively fixed by knotting.

Limitations

There are also shortcomings in this study, such as small sample size, which may lead to deviations in the evaluation of curative effect. Further expansion of sample size and long-term follow-up are needed to confirm this.

Conclusion

In this study, double button plate fixation technology for the treatment of posterior cruciate ligament avulsion fractures has the advantages of minimal trauma, simple operation, reliable fixation and a large fracture contact area, fewer postoperative complications, and restored stability and function of knee joints. Our results suggest that this reconstruction technique is a reliable and useful alternative treatment.

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