Displaced avulsion fractures of the posterior cruciate ligament: Treated by stellate steel plate fixation

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Abstract

Background: The open reduction with internal fixation is an effective approach for treatment of avulsion fracture of posterior cruciate ligament. The previously used internal fixation materials including hollow screws, absorbable screw, tension bands and sutures have great defects such as insufficient fixation strength, susceptibility to re-fracture, etc. Stellate steel plate is novel material for internal fixation which has unique gear-like structure design. We used stellate steel plate for treatment of displaced avulsion fractures of posterior cruciate ligament in this study.

Materials and Methods: 14 patients (9 men, 5 women; aged, 19–35 years; mean age, 28 years) with displaced avulsion fractures of the tibial insertion of the posterior cruciate ligament were retrospectively analyzed between June 2009 and June 2011. The mean duration from injury to the operation was 8.3 days (range 6–15 days). All the patients were treated with open reduction and internal fixation of a stellate steel plate (DePuy, Raynham, MA 02767, USA). The Lysholm-Tegner knee function score criteria were used to analyze results.

Results: The mean followup was 24.6 months (range 18–32 months). After 6 months, all the fractures healed and knee joint activity was normal, with no knee stiffness or instability. The Lysholm-Tegner scores were 97.1 ± 1.7 points at the final followup.

Conclusion: Owing to its unique gear structure, the stellate steel plate design can effectively fix an avulsion fracture block and it is a simple operation with short postoperative rehabilitation time and firm fixation.

Key words: Posterior cruciate ligament, stellate steel plate, avulsion fracture posterior cruciate ligament
MeSH terms: Knee, cruciate ligament, bone plates, fixation

Introduction

An avulsion fracture of the posterior cruciate ligament accounts for approximately 3–40% of all acute knee joint injuries of which 35% are displaced fractures.[1] Nonsurgical treatment has a high incidence rate of nonunion or malunion and can cause loss of ligament function, leading to further knee instability and traumatic arthritis.[2,3] Surgical methods include arthroscopic surgery or open reduction and internal fixation. Arthroscopic surgery is less invasive; however, because the end point of the posterior cruciate ligament is located deep on the posterior part of the tibial plateau, an arthroscopic operation would be relatively difficult and may result in avulsion of the posterior cruciate ligament, loose fracture suturing and problems in postoperative relaxation, which causes some patients to exhibit limited knee range of motion after the surgery.[4] As open reduction and internal fixation have a clear surgical field exposure, the fractures can be reduced accurately under direct vision, with reliable fixation and early rehabilitation can be performed.[5] The use of internal fixation materials such as hollow screws, absorbable screws, tension bands and sutures have many limitations; defects such as insufficient fixation strength have also been reported, leading to fractures occurring easily.[6] A stellate steel plate has a ratchet gear like design. Each ratchet was designed based on a block structure, with a fixed length of gap between the gears, which has the advantages of firm fixation. This retrospective study analyzed avulsion fracture of the posterior cruciate ligament that were treated with a stellate steel plate at our hospital.

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Materials and Methods

14 patients (9 men and 5 women) with displaced avulsion fracture of the tibial insertion of the posterior cruciate ligament treated with a stellate steel plate between June 2009 and June 2011 were included in this study. The mean age was 27 years (range 19-35 years). The left knee was

injured in five patients and the right knee was injured in nine patients. Injury factors included traffic accident injuries in six patients, fall injuries in four patients, strike injury in one patient and sports related injuries in three patients. Three patients had meniscus injuries and two patients had articular cartilage injuries; no nerve injuries were reported in any patient. The fracture fragment diameter was <5 mm in seven patients; the fracture fragment diameter was 5–10 mm in four patients and the fracture fragment diameter was >10 mm in three patients [Table 1]. All the patients were previously healthy had closed fractures, without any other injury except knee injuries and they were consecutively diagnosed and treated by the same group of surgeons. This study was conducted in accordance with the declaration of Helsinki. This study was conducted with the approval from the Ethics Committee of our Hospital. Written informed consent was obtained from all participants.

All the patients underwent open reduction and internal fixation with a stellate steel plate (DePuy, Raynham, MA 02767, USA). The mean duration from the injury to surgery was 8.3 days (range 6–15 days). The mean operation time was 53.6 min (range 36–90 min). The mean blood loss was approximately 150 ml.

Operative procedure

After combined spinal epidural anesthesia, the operation was performed under tourniquet control in the prone position. The knees were flexed to approximately 20°.

Using the modified Burks-Shaffer approach,[7] a 2 cm curved incision was made from the transverse skin crease of the popliteal fossa inwardly exploring along the inner edge of the medial head of the gastrocnemius muscle 7–9 cm away and bluntly dissecting between the medial head of the gastrocnemius muscle and semimembranosus to arrive at the posterior joint capsule. The medial head of the gastrocnemius muscle and the popliteal vascular nerve were pulled to one side to expose the semimembranosus muscle insertion, popliteal muscle and posterior joint capsule. The joint capsule was split longitudinally along the joint space and complete removal of the hematoma and soft tissue was performed to reveal the posterior cruciate ligament and bone fragments in order to clean up the broken ends of the fracture and to achieve reduction of the fracture. During the operation, the type of avulsed bone block was determined. If the fracture block was >5 mm, the patient underwent temporary Kirschner wire fixation after reduction. The steel plate was sheathed in the Kirschner wire and it was hammered to make the sharp steel teeth embed into the bone. The Kirschner wire was then removed and fixed with a hollow compression screw. If the fracture block was <5 mm or crushed bones were observed, a simple fixation was first performed by using a nonabsorbable suture (Ethibond Number 0), and the steel teeth were then embedded at the binding site of the bone and ligament that underwent screw fixation. The incision was sutured and a drainage tube was placed.

Forty eight hours after the operation, the drainage tubes were removed. Patients were encouraged to perform quadriceps contraction exercises in bed on the second postoperative day, knee flexion and extension 3 weeks later, walking was allowed with crutches after one month and walking without crutches after 2 months.

Patients were followed up at 2 weeks, 4 weeks, 3 months, 6 months, 9 months, 12 months, 18 months, 24 months and 32 months after the operation. All the followups were carried out by the same group of surgeons. The followup included radiographic examination, analysis of the patient's knee joint activity, evaluation of pain and questions concerning subjective patient feelings.

Table 1: Clinical details of patients

Cases	Gender	Age (years)	Mode of trauma	Injury to surgery duration	Diameter of fracture fragment	Lysholm-Tegner score
1	Male	19	Traffic injury	10 days	1.5 mm	52
2	Male	23	Sports injury	7 days	5.7 mm	66
3	Female	34	Traffic injury	6 days	2.0 mm	59
4	Male	28	Fall damage	9 days	10.8 mm	73
5	Female	30	Traffic injury	14 days	3.2 mm	63
6	Male	25	Strike injury	8 days	2.7 mm	61
7	Male	35	Traffic injury	15 days	4.0 mm	65
8	Male	20	Sports injury	13 days	20 mm	72
9	Male	26	Traffic injury	6 days	Crush	68
10	Female	33	Fall damage	7 days	6.5 mm	70
11	Male	29	Sports injury	11 days	11.0 mm	74
12	Female	31	Traffic injury	10 days	Crush	70
13	Male	30	Fall damage	9 days	5.5 mm	63
14	Male	29	Fall damage	6 days	6.8 mm	71

Efficacy was evaluated according to the Lysholm-Tegner[8] knee joint function score criteria. The score consists of eight factors including limp, joint locking, pain, stair climbing ability, usage of a walking aid, edema, squatting ability and stability. The maximum score is 100 points, in which a score of 95–100 points is excellent, a score of 84–94 points is good, a score of 65–83 points score is medium, and a score of <65 points is poor.

Results

The mean followup was 24.6 months (range 18-32 months). Two and half months after the operation, bone fracture healing was observed in 10 patients who had a negative posterior drawer test. Six months after the operation, a radiographic image showed healed fractures and 12 patients achieved anatomic reduction of the fracture [Figure 1]. Two patients with crushing fractures did not show anatomical alignment.

Knee joint activity returned to normal in all, (range of motion of 0°–130°), with no knee joint stiffness or knee instability. At the final followup, the mean Lysholm-Tegner knee function score was 97.1 ± 3.7. Twelve patients had satisfactory scores [Table 2].

Discussion

The posterior cruciate ligament is divided into the following two bundles: The anterolateral bundle and the posteromedial bundle.[9-11] The anterolateral bundle and the posteromedial bundle play a role in knee flexion and extension activities, respectively and they have a synergistic effect.[12] A biomechanical experiment showed that the *in vitro* tensile strength of the posterior cruciate ligament is twice that of the anterior cruciate ligament.[13]

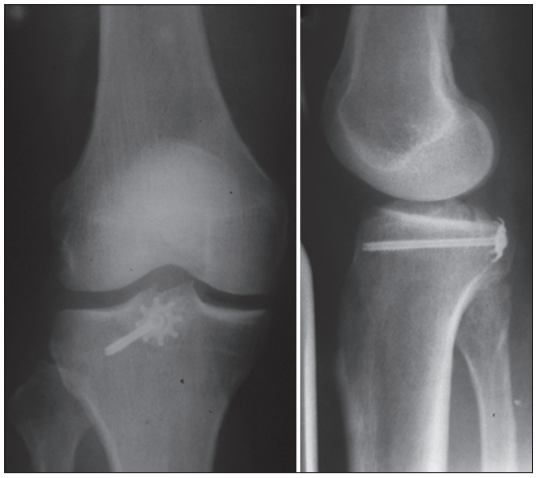

Figure 1: Anteroposterior and lateral x-rays of knee joint showing avulsion fracture of posterior cruciate ligament fixed with stellate steel plate

The posterior cruciate ligament is one of the most important structures for knee joint stability and its main role is to prevent tibial posterior displacement as well as external rotation and varus of the tibia.[14] Avulsion fracture of the posterior cruciate ligament is more common in sports related injuries which account for approximately 40% of these injuries.[15] The mechanism of injury is mainly caused by direct impact of the tibial tuberosity and posterior tibial displacement, during which the posterior cruciate ligament is tensed. If anatomical reduction of the displaced fracture is not achieved, proper fracture union will not occur and the posterior cruciate ligament can loss function due to its misshapen form, leading to knee instability and traumatic arthritis as well as other problems,[16] and this may seriously influence patient prognosis. Therefore, many researchers such as Nicandri *et al*.,[17] believe that, regardless of the size of the displacement, an operation is necessary for the treatment of avulsion fractures of the posterior cruciate ligament.

Chen *et al*.[4] believes that the arthroscopic surgery technique has improved quickly over the past 20 years, has little trauma and can effectively suture and fix posterior cruciate ligament avulsion fractures. However, some patients still have limited postoperative knee joint range of motion, which is related to postoperative posterior cruciate ligament relaxation and operation scarring. In addition, because the posterior cruciate ligament is located lateral to the tibial plateau and the location is deep, arthroscopic surgery is relatively difficult. Owing to the fact that open reduction is a simple operation, with clear exposure, leading to open fracture reduction, reliable fixation and accurate and early exercise of joint function, it has become the first choice of most physicians.[5,6,18]

Table 2: Results

Case	Followup (months)	Knee joint activity (ROM)	Posterior drawer test	Lysholm-Tegner score	Patient's satisfaction
1	32	0-120	Negative	92	Satisfactory
2	18	0-135	Negative	95	Satisfactory
3	24	0-127	Negative	93	Satisfactory
4	24	0-137	Negative	98	Satisfactory
5	24	0-130	Negative	96	Satisfactory
6	32	0-136	Negative	94	Satisfactory
7	32	0-128	Negative	95	Satisfactory
8	24	0-137	Negative	96	Satisfactory
9	18	0-129	Negative	89	Somewhat satisfactory
10	18	0-130	Negative	96	Satisfactory
11	24	0-135	Negative	97	Satisfactory
12	24	0-127	Negative	90	Somewhat satisfactory
13	32	0-137	Negative	96	Satisfactory
14	18	0-135	Negative	97	Satisfactory

ROM=Range of motion activities

Commonly used internal fixations include hollow screws, absorbable screws, wires, suture, among others.[19] The application of hollow screws and joint gaskets to cancellous bone screws achieved better fixation and could obtain better postoperative knee range of motion in acute injuries that had bigger fracture fragments, but it was not suitable for smaller fragment damages. A screw might result in small or crushed bone blocks and there are other problems such as not being firmly fixed, easy rotation, easily getting loosened and extracted and the possibility of entering into the joint cavity, which means that patients cannot do functional exercises early. The strength of a wire suture fix during recovery of a fracture is poor, as the fracture is easily displaced again and the postoperative breaking time is longer, leading to limited knee range of motion. The absorbable screw has weak antirotation ability and it should be placed next to a screw with a larger diameter to meet the need of fixed strength; it is not suitable for fixation of small or crushed fractures. Nicandri *et al*.[17] used an atlanto-odontoid dentoid plastic washer and screw fixation for avulsion fractures, with satisfactory results, but the fixed strength needs to be strengthened, and which was lack of long term followup. Wajsfisz *et al*.[20] introduced a type of button suspension fixation technique. The curative effect is relatively satisfactory, but the operation is complex and auxiliary arthroscopy is needed. A stellate steel plate for the treatment of avulsion fracture of the posterior cruciate ligament has the advantages listed below. First, it will change the single screw force bearing point to a wide force bearing area, to avoid the bone block splitting again, which is suitable for fixation of different diameter bone blocks or crushed fractures. Second, the surrounding spines unique gear type design can be embedded in the bone and fixed with hollow compression screws, leading to stronger fixation. Mechanical experiments show that, compared with other types of implants, a stellate steel plate has significantly enhanced pulling resistance.[21] Third, each ratchet structure is designed with a barrier structure, and the gap between the gears can avoid compression of soft tissue, causing less vesicular damage as well as promoting fracture healing. All the fractures in the current study healed and a literature review revealed that the healing rate was significantly higher than that of other fixation methods.[1,2] Fourth, this technique has the advantages of being a simple operation, leading to effective shortening of the operation time as well as reducing the risk of infection and bleeding. Fifth, because of firm fixation, early functional exercise of patients and shortened recovery time, the recovery of knee joint function was better. Compared to patients treated with other implants reported in the literature,[6,17] the functional scores and patient satisfaction of this group were significantly high, which supports our use of the treatment method.

Limitations of the current study include the small number of patients, the relatively short followup time, and the lack of a corresponding control group. Therefore, further research is needed for a more objective evaluation.

Conclusion

The stellate steel plate can be used effectively to fix different types of avulsion fracture blocks, as it has the advantages of being a simple operation with short rehabilitation time and firm fixation.

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