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Therapeutic Effects of Small Incision Open Reduction and Internal Fixation and Arthroscopic High Strength Non-Absorbable Suture on Tibial Insertion Avulsion Fracture of the Anterior Cruciate Ligament

Porovnání léčebných efektů otevřené repozice a vnitřní fixace z malého přístupu vs. artroskopické vysoce pevné nevstřebatelné sutury tibiálního úponu u avulzní fraktury předního zkříženého vazu

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ABSTRACT

PURPOSE OF THE STUDY

To evaluate the therapeutic effects of small incision open reduction and internal fixation and arthroscopic high strength non-absorbable suture on tibial insertion avulsion fracture of the anterior cruciate ligament (ACL).

MATERIAL AND METHODS

In this prospectively study, 72 patients with ACL tibial insertion avulsion fracture treated from December 2017 to June 2020 were enrolled and divided into group A (treated with small incision open reduction and cannulated screw internal fixation) and group B (treated with arthroscopic high strength non-absorbable suture) using a random number table (n=36). Their general data, surgical indices and incidence of postoperative adverse reactions were compared. Knee function indices were compared before and after treatment, and evaluated by random walk model.

RESULTS

No significant differences were found in the general data, intraoperative blood loss, preoperative Lysholm score, International Knee Documentation Committee (IKDC) score, Tegner score, knee range of motion and difference of bilateral tibial forward displacement distance, and total incidence rate of postoperative adverse reactions between the two groups ($P>0.05$). Group B had significantly longer operation time, and significantly shorter hospital stay, time of first ambulation after operation and bone healing time than group A ($P<0.05$). Both groups had improved Lysholm score, IKDC score, Tegner score and knee range of motion after treatment, especially in group B ($P<0.05$). The difference of bilateral tibial forward displacement distance significantly reduced in both groups after treatment, particularly in group B ($P<0.05$). The random walk model revealed that group B had better improvement of knee function than group A.

CONCLUSIONS

Arthroscopic high strength non-absorbable suture in the treatment of ACL tibial insertion avulsion fracture can dramatically improve the knee function indices of patients, with rapid recovery and high safety, so it has a broad prospect of clinical application.

Key words: small incision open reduction and internal fixation, arthroscopic high strength non-absorbable suture, tibial insertion avulsion fracture, anterior cruciate ligament, random walk model.

INTRODUCTION

Anterior cruciate ligament (ACL) tibial insertion avulsion fracture, a type of knee ACL injury, refers to the fracture at the ACL attachment point of the intercondylar eminence of the tibial plateau, which is classified into fresh injury and old injury (14). Traffic accidents, sports and falls are all major causes of ACL tibial insertion avulsion fracture, during which knee hyperextension or tibial rotation far exceeding the load of ACL ultimately triggers tibial insertion avulsion fracture (4). After fracture, the patients are often accompanied by meniscus rupture and collateral ligament injury. If not treated timely and effectively, as the disease progresses, it may lead to bone deformity or even limited movement, seriously affecting the quality of life of patients (11). Treatments of ACL tibial insertion avulsion fracture mainly include conservative treatment and surgical treatment, both of which are effective for patients with type II fracture, but surgical treatment is often needed for patients with type III fracture (7, 16). With the increasing maturity of arthroscopic technology, arthroscopic minimally invasive surgery has become the first choice for the treatment of tibial insertion avulsion fracture, in which the bone can be accurately reduced and fixed, and the prognosis is good (18). Among them, high strength non-absorbable suture treatment will not be affected by the bone size, and can effectively avoid trauma of second operation, displaying remarkable efficacy (15). So far, there have been many studies about the surgical methods and clinical effects of the treatment of ACL tibial insertion avulsion fracture (1, 19). However, there has been no unified standard for the selection of surgical methods, and there have been few comparative studies on open surgery and arthroscopic surgery. Hence, this study aims to compare the efficacy between small incision open reduction and internal fixation and arthroscopic high strength non-absorbable suture in the treatment of ACL tibial insertion avulsion fracture, so as to provide references for clinical selection of effective treatment methods.

MATERIAL AND METHODS

In this prospective study, 72 patients with ACL tibial insertion avulsion fracture treated in our hospital from December 2017 to June 2020 were enrolled, and divided into group A (treated with small incision open reduction and cannulated screw internal fixation, n=36) and group B (treated with arthroscopic high strength non-absorbable suture fixation, n=36) using a random number table. Group A included 21 males and 15 females, aged 10–50 years old, with an average of (34.62±7.85) years old, while group B included 25 males and 11 females, aged 11–52 years, with a mean of (35.68±8.13) years old.

The inclusion criteria involved:

1) patients diagnosed as ACL tibial insertion avulsion fracture by X-ray computed tomography, with tibial intercondylar eminence fracture could be seen, local swelling, pain and functional limitation of the affected knee, and positive for Lachman test (12),

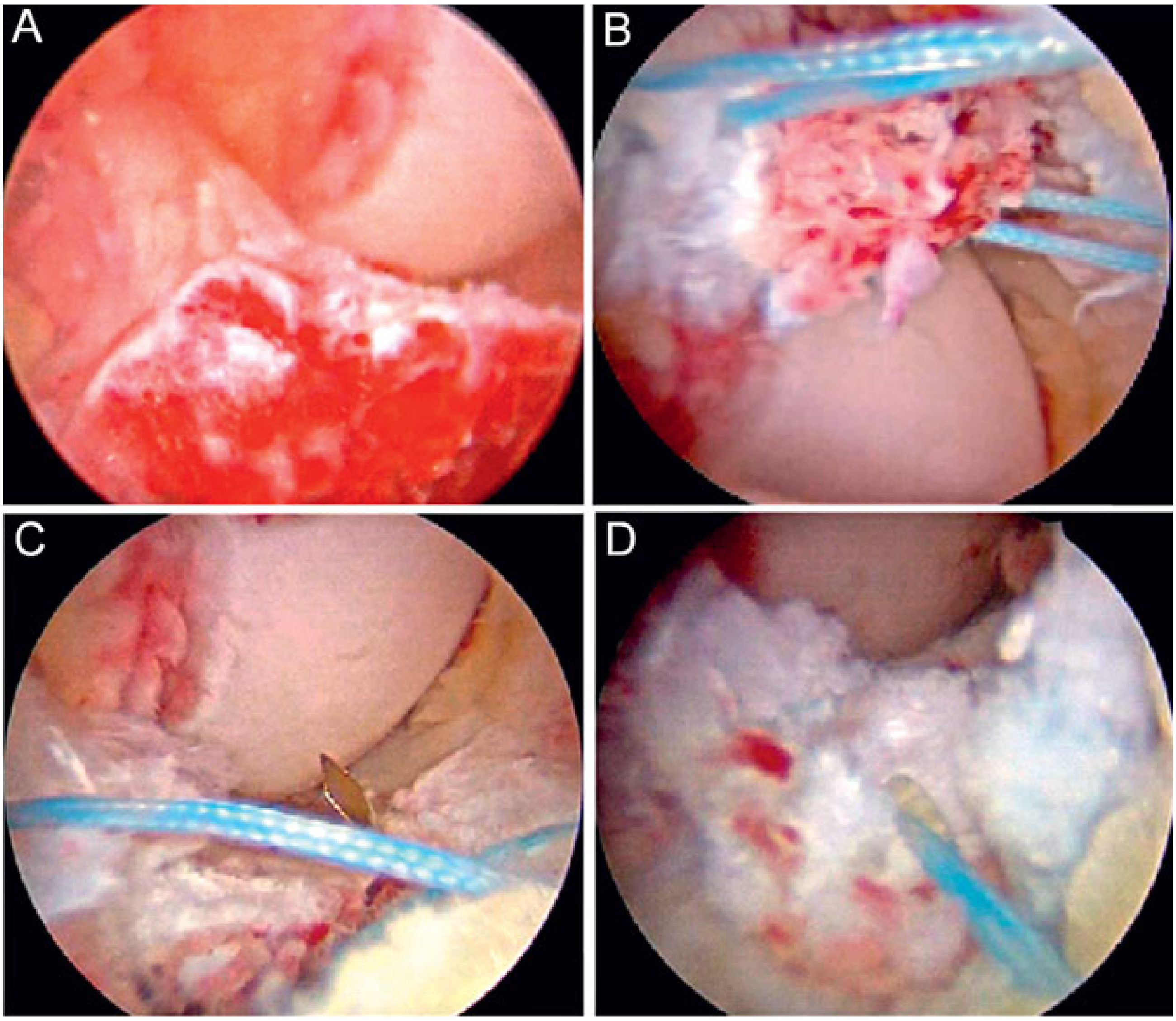

Fig. 1. Procedure of arthroscopic high strength non-absorbable suture.
A – arthroscopy showed ACL tibial insertion fracture and displacement of fractured ends, B – non-absorbable suture, C – establishment of tibial tunnel, D – reduction and fixation of fracture.

2) those with Meyers-McKeever type II or III fractures,
3) those with complete clinical data, and
4) those who and whose families signed the informed consent.

The exclusion criteria were as follows:
1) patients complicated with tibial plateau fracture or posterior cruciate ligament injury,
2) those with severe hepatic or renal insufficiency,
3) those with bilateral knee injury, or
4) those with old ALC tibial insertion avulsion fracture.

The general data of patients were collected through electronic medical records, including age, sex, cause of injury, time from injury to operation and site of injury. In addition, Meyers-McKeever type was recorded: type II was defined as fracture with partial displacement or less displacement, while type III was defined as complete displacement avulsion fracture.

Patients in group A were treated with small incision open reduction and cannulated screw internal fixation. Specifically, after general anesthesia combined with nerve block anesthesia, the patient bent the knee for 90° of the affected limb in a supine position, and an air bag was placed at the groin to stop bleeding and fixed with a baffle. The tourniquet pressure was set at 37–40 kPa, and the arthroscope was placed on the anterolateral side of the knee. After the fracture area was rinsed with normal saline, an incision (2.5–3.0 cm) was made at the inner edge of the patellar ligament in front of the affected limb, and the joint capsule was cut open. After the insertion avulsion fracture block and joint cavity of cruciate ligament were fully exposed, the wound was cleaned, and the ACL tibial insertion avulsion fracture was reduced under direct vision and fixed temporarily with 1.5-mm Kirschner wire. After satisfactory reduction was confirmed by the fluoroscopy using the C-arm X-ray machine, 1–2 pieces of 4.0-mm cannulated screws were screwed along the direction of the Kirschner wire and fixed under pressure. Later, the Kirschner wire was removed, and the incision was sutured layer by layer.

Patients in group B were treated with arthroscopic high strength non-absorbable suture. Specifically, after lumbar anesthesia, the air bag tourniquet was tied to the middle and upper thigh of the affected limb in a supine position. Then 3,000 mL of normal saline was used for lavage at 1.5–2.0 m above the surgical site. Arthroscope (Stryker, USA, diameter: 4.0 mm, angle: 30°) and related surgical instruments were inserted into the bilateral knee-eye approach. After the tibial tunnel was established with 2.0-mm Kirschner wire, 2 non-absorbable sutures (Johnson, USA) were used to bypass the back of ACL tibial insertion, and the ACL tibial insertion was ligated in a style of "8". After the tail line was led to the tibial tunnel, the keen was bent at 30°. Then the two ends of the non-absorbable sutures were tightened and fixed to the tibia. The procedure of arthroscopic high strength non-absorbable suture is exhibited in Figure 1.

The operation time, intraoperative blood loss, hospital stay, time of first ambulation after operation, and bone healing time (bone healing examined by X-ray) were recorded. Besides, the knee function of the patients before and after treatment was evaluated by Lysholm knee scoring scale, including limp (5 points), using cane or crutches (5 points), squatting (5 points), swelling (10 points), climbing stairs (10 points), locking sensation in the knee (15 points), pain (25 points), joint instability (25 points), with a total score of 100 points. The lower the score, the poorer the knee function. Besides, the International Knee Documentation Committee (IKDC) Subjective Knee Form was adopted to evaluate the knee function of patients before and after treatment, including locking sensation in the knee (4 points), activity (4 points), joint instability (4 points), swelling (8 points), self-evaluation (20 points), pain (24 points), function (36 points), with a total score of 100 points. The lower the score, the poorer the knee function. Moreover, the Tegner activity scale was employed to evaluate the knee motor function of the patients before and after treatment, with a total score of 0–10 points. The lower the score, the poorer the knee motor function. Knee range of motion: 0–130°: range of normal knee flexion, external rotation: 0–40°, internal rotation: 0–30°. The difference of bilateral tibia forward displacement distance was used to evaluate the knee stability of patients. X-ray film was utilized to measure the forward displacement distance of bilateral tibia before and after treatment, and the bilateral differences before and after treatment were calculated. Moreover, the incidence of postoperative adverse reactions were recorded, including wound infection and hematoma.

The patients were followed up for 6 months until December 2020 by telephone or outpatient clinic, and the follow-up data were collected. Besides, the Lysholm score, IKDC score, Tegner score, knee range of motion, difference of bilateral tibial forward displacement distance and incidence of adverse reactions were recorded during the last follow-up.

Statistical analysis

SPSS19.0 software was utilized for statistical analysis, and GraphPad Prism 5.0 software was used for plotting. The numerical data were expressed as percentage, and chi-square test was performed for intergroup comparison. The measurement data were expressed as mean ± standard deviation, independent *t*-test was conducted for intergroup comparison, and paired *t*-test was performed for intragroup comparison. Oracle 10g was employed to evaluate the knee function indices of patients through random walk model. $P<0.05$ suggested that difference was statistically significant.

RESULTS

No significant differences were found in the age, sex, cause of injury, time from injury to operation, injury site and Meyers-McKeever type between the two groups ($P>0.05$) (Table 1).

Surgical indices

No significant difference was observed in the intraoperative blood loss between the two groups ($P>0.05$).

Table 1. General data

Group	Group A (n=36)	Group B (n=36)	t/χ^2	P
Age (Y)	34.62±7.85	35.68±8.13	0.563	0.575
Male/Female (n)	21/15	25/11		
Cause of injury (n(%))			0.910	0.635
Traffic accident injury	24 (66.67)	27 (75.00)	-	-
Sports injury	8 (22.22)	7 (19.44)	-	-
Fall injury	4 (11.11)	2 (5.56)	-	-
Time from injury to operation (d)	5.84±2.31	6.06±2.44	0.393	0.696
Injured site [n(%)]			0.510	0.475
Left knee	22 (61.11)	19 (52.78)	-	-
Right knee	14 (38.89)	17 (47.22)	-	-
Meyers-McKeever type [n(%)]			0.900	0.343
II	18 (50.00)	14 (38.89)	-	-
III	18 (50.00)	22 (61.11)	-	-

Table 2. Surgical indices

Group	Group A (n=36)	Group B (n=36)	*t*	P
Operation time (min)	55.37±8.62	68.41±7.65	4.382	0.000
Intraoperative blood loss (mL)	20.37±4.05	19.42±3.85	0.774	0.443
Hospital stay (d)	8.62±1.31	7.55±1.22	3.586	0.001
Time of first ambulation after operation (d)	8.16±2.08	6.37±1.85	3.858	0.000
Bone healing time (week)	15.28±3.78	12.74±3.53	2.947	0.004

However, group B had significantly longer operation time and significantly shorter hospital stay, time of first ambulation after operation and bone healing time than group A (P<0.05) (Table 2).

Knee function scores before and after treatment

No significant differences were found in Lysholm score, IKDC score and Tegner score between the two groups before treatment (P>0.05). After treatment, both groups had significantly increased Lysholm score, IKDC score and Tegner score compared with those before treatment, and group B had more obvious increases than group A (P<0.05) (Table 3).

Knee range of motion and difference of bilateral tibial forward displacement distance before and after treatment

No significant differences were observed in the knee range of motion and difference of bilateral tibial forward displacement distance between the two groups before treatment (P>0.05). Compared with those before treatment, the knee range of motion was significantly improved, and the difference of bilateral tibial forward displacement distance was significantly reduced in both groups (P<0.05). Moreover, group B had significantly improved knee range of motion and significantly smaller difference of bilateral tibial forward displacement distance than group A (P<0.05) (Table 4).

Random walk model evaluation results

The knee function indices of the two groups of patients were evaluated by random walk model. There were 182 and 178, 155 and 150, 128 and 126, 98 and 96, and 172 and 170 comprehensive evaluation records of Lysholm score, IKDC score, Tegner score, knee range of motion and difference of bilateral tibial forward dis-

Table 3. Knee function scores before and after treatment

Group	Group A (n=36)		Group B (n=36)	
	Before treatment	After treatment	Before treatment	After treatment
Lysholm score (point)	27.42±2.18	79.73±4.69*	26.85±2.24	85.27±5.28*#
IKDC score (point)	42.83±1.64	80.37±1.59*	43.06±2.08	85.43±1.74*#
Tegner score (point)	2.24±0.95	5.72±1.31*	2.18±1.05	6.65±1.41*#

*P<0.05 vs. before treatment, #P<0.05 vs. group A after treatment.

Table 4. Knee range of motion and difference of bilateral tibial forward displacement distance before and after treatment

Group	Knee range of motion (°)		Difference of bilateral tibial forward displacement distance (mm)	
	Before treatment	After treatment	Before treatment	After treatment
Group A (n=36)	43.85±2.68	97.58±5.42*	8.16±1.12	2.24±0.72*
Group B (n=36)	44.32±2.71	108.45±5.79*	7.95±1.03	1.12±0.65*
t	0.740	8.223	0.828	6.928
P	0.462	0.000	0.410	0.000

#P<0.05 vs. before treatment.

Table 5. Random walk model evaluation results of knee function indices

Index	Group	Maximum stochastic volatility	Walking steps	Positive growth rate of walking	Power law value of stochastic fluctuation	Growth rate	Number of index records	Ratio
Lysholm score	A	19	182	0.1047	0.5283	0.1047	182	9.55
	B	31	178	0.1742	0.5564	0.1742	178	5.71
IKDC score	A	22	155	0.1389	0.5125	0.1389	155	7.20
	B	28	150	0.1871	0.5146	0.1871	150	5.34
Tegner score	A	63	128	0.4923	0.5128	0.4923	128	2.03
	B	66	126	0.5264	0.5374	0.5264	126	1.90
Knee range of motion	A	34	98	0.3565	0.5018	0.3565	98	2.81
	B	36	96	0.3758	0.5283	0.3758	96	2.66
Difference of bilateral tibial forward displacement distance	A	77	172	0.4489	0.5312	0.4489	172	2.23
	B	83	170	0.4912	0.5564	0.4912	170	2.04

Table 6. Incidence of adverse reactions (n(%))

Group	Group A (n=36)	Group B (n=36)	χ^2	P
Wound infection	1 (2.78)	1 (2.78)	0.000	1.000
Hematoma	3 (8.33)	0 (0.00)	3.130	0.077
Total complication rate	4 (11.11)	1 (2.78)	1.934	0.164

placement distance for group A and group B, respectively, and the improvement coefficients were 0.1047 and 0.1742, 0.1389 and 0.1871, 0.4923 and 0.5264, 0.3565 and 0.3758, and 0.4489 and 0.4912, respectively. For every one point of improvement, the patients needed to walk 9.55 and 5.71, 7.20 and 5.34, 2.03 and 1.90, 2.81 and 2.66, and 2.23 and 2.04 steps, respectively (Table 5 and Fig. 2).

Incidence of adverse reactions

The adverse reactions in group A included wound infection and hematoma, with a total incidence rate of 11.11%, which was higher than that in group B (2.78%). However, there was no significant difference between the two groups (P>0.05) (Table 6).

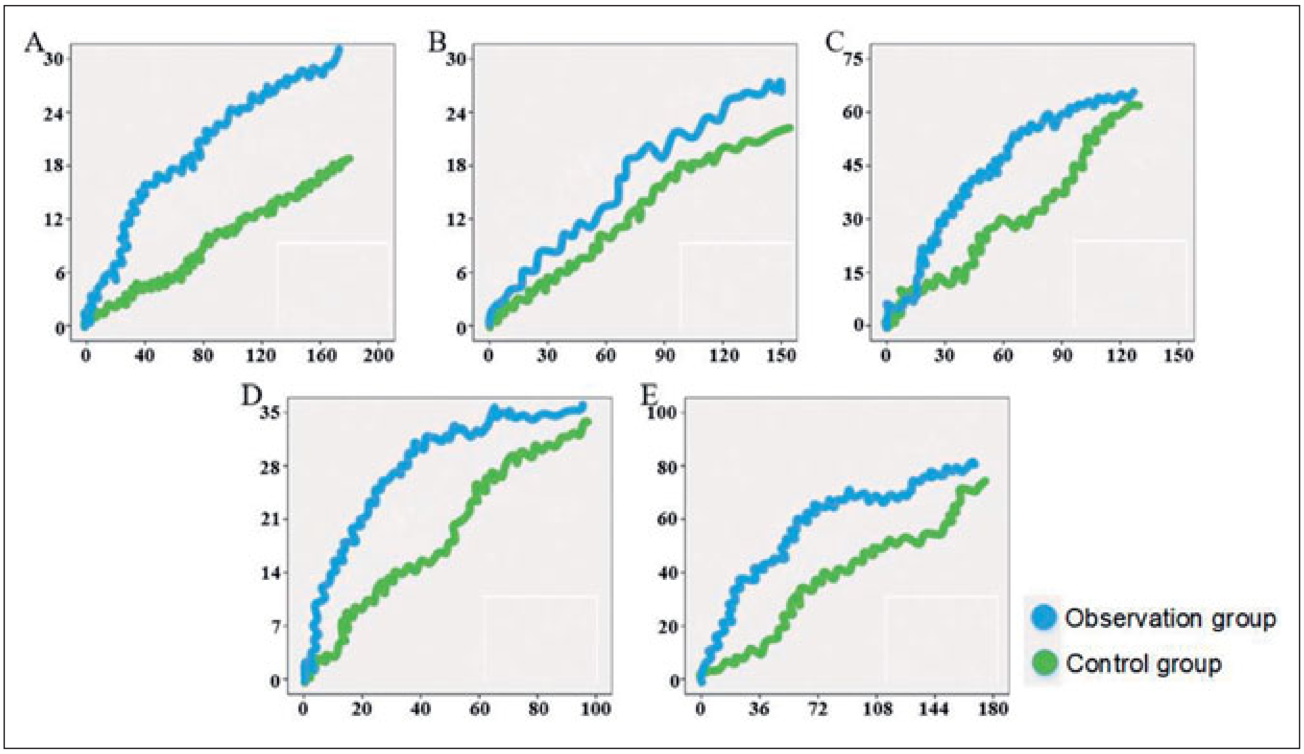

Fig. 2. Random walk model evaluation results of knee function indices.
A – Lysholm score, B – IKDC score, C – Tegner score, D – knee range of motion, E – difference of bilateral tibial forward displacement distance.

DISCUSSION

Traditional open surgery for the treatment of ACL tibial insertion avulsion fracture is traumatic, resulting in slow postoperative recovery, prolonged hospital stay, and it easily leads severe complications such as knee joint adhesion and stiffness, affecting the prognosis of patients (2, 6). Currently, small incision open reduction and internal fixation and arthroscopic internal fixation are the major surgical methods for the treatment of ACL tibial insertion avulsion fracture (9, 13). Small incision open reduction and internal fixation has the advantages of simple operation, less trauma and better exposure of the attachment point of ACL tibia. However, it fails to deal with cartilage, meniscus and other injuries during the operation. Arthroscopic surgery has the advantage of detecting and dealing with combined injuries at the same time, and the risk of vascular and nerve injury is reduced due to less surgical trauma. However, so far, the selection of surgical methods for the treatment of ACL tibial insertion avulsion fracture is still controversial, and there have been few comparative studies on small incision open reduction and internal fixation and arthroscopic high strength non-absorbable suture for the treatment of ACL tibial insertion avulsion fracture. Therefore, the purpose of this study is to explore the efficacy of the two surgical methods in the treatment of ACL tibial insertion avulsion fracture, so as to provide references for clinical selection of effective treatment methods.

In this study, group B had obviously shorter hospital stay, time of first ambulation after operation and bone healing time than group A, indicating that arthroscopic high strength non-absorbable suture is beneficial to the postoperative recovery of patients. Consitently, Huang et al. reported that after arthroscopic non-absorbable suture fixation, the knee joint function of 94% patients was recovered to normal, without inducing complications such as nonunion of fractures and intra-articular fibrosis (8).

However, group B had dramatically longer operation time than group A, and the prolonged operation time led to an increased risk of postoperative infection. Nevertheless, there was no evident difference in the incidence rate of postoperative wound infection between the two groups. The reason may be that arthroscopic surgery brings less trauma, which reduces the risk of postoperative wound infection.

Long-term postoperative limitation is a risk factor for the loss of knee motor function. The function and stability of knee are co-determined by the dynamic muscle, meniscus, articular cartilage and static ligament (5). In clinical practice, the treatment efficacy of ACL tibial insertion avulsion fracture is not satisfactory, and the extension of knee is limited or the stability of the anterior part of the knee is poor, mainly because improper reduction of ACL tension and poor fixation effect during operation. The Lysholm score, IKDC score, Tegner score, knee range of motion and difference of bilateral tibial forward displacement distance are all important indices to evaluate the knee function of patients with ACL tibial insertion avulsion fracture before operation and after operation. According to a study, arthroscopic 8-style suture fixation for the treatment of ACL tibial insertion avulsion fracture can dramatically improve the Lysholm score and IKDC score, and ameliorate the knee function and stability (10). A related literature report showed that arthroscopic high strength suture technique for the treatment of ACL tibial insertion avulsion fracture can remarkably improve the Lysholm score, IKDC score, Tegner score and knee range of motion (20). Another study revealed that arthroscopic suture bridge technique for the treatment of fresh ACL tibial fracture in children can remarkably reduce the difference of bilateral tibial forward displacement distance (3). In this study, the Lysholm score, IKDC score and Tegner score of the two groups of patients were increased dramatically after treatment, and group B had obviously better improvement of knee function scores than group A. The reason may be that the combined injury of cartilage and meniscus cannot be treated by small incision open reduction and internal fixation, while arthroscopic surgery has the advantage of detecting and dealing with the combined injury simultaneously. Since articular cartilage and meniscus are important components to maintain the knee stability (17), arthroscopic high strength non-absorbable suture can obviously better improve the knee function and stability of patients than small incision open reduction and internal fixation.

CONCLUSIONS

In summary, arthroscopic high strength non-absorbable suture in the treatment of ACL tibial insertion avulsion fracture can dramatically improve the knee function indices of patients with tibial insertion avulsion fracture, with rapid recovery and high safety, so it has a broad prospect of clinical application.

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