Arthroscopic Fixation for Tibial Eminence Fractures: Comparison of Double-Row and Transosseous Anchor Knot Fixation Techniques with Suture Anchors

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Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: Tibial eminence fractures often occur during sports participation, but the optimum choice of technique for treatment is still controversial. The aim of the current work was to compare the clinical outcomes of 2 new arthroscopic anchor fixation techniques for tibial eminence fracture.

Material/Methods: We included 72 isolated tibial eminence fracture patients treated at our hospital from October 2010 to August 2015; 37 patients received the classic double-row (DR) suture anchor fixation technique and 35 received the transosseous anchor knot (TAK) fixation under arthroscopy. The clinical efficacies of the 2 techniques were assessed by radiographs, Lysholm score, and International Knee Documentation Committee (IKDC) score in follow-ups.

Results: Patients were followed for 37.6 months (range, 18–54 months). There was no significant difference of the operative time between groups (P=0.169). Postoperative radiographs of all patients showed accurate reduction and fracture healing within 3 months. Lysholm and IKDC scores improved significantly compared with preoperative scores (P<0.001). However, no significant difference in the knee range of motion or improvement of Lysholm and IKDC scores was found between groups (P>0.05).

Conclusions: The DR and TAK techniques provide precise reduction and stable fixation methods for treating tibial eminence fractures, and the clinical outcomes of the 2 arthroscopic techniques with suture anchors are satisfactory.

MeSH Keywords: Arthroscopy • Fracture Fixation • Fractures, Bone • Suture Anchors

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Background

Tibial eminence fractures are bony avulsions of the anterior cruciate ligament (ACL) from its insertion on the intercondylar eminence [1]. These injuries often occur during sports participation [2, 3], and the most frequent mechanisms are direct injury or deceleration [4]. Without stable fixation, the fractures may result in many adverse symptoms such as knee pain, instability, and limitation of the range of motion (ROM) caused by the displacement of the fracture segment [5, 6]. Surgical fixation is suitable for type III and IV tibial eminence fractures, as well as for nonreducible type II fractures and late displacement of type I fractures based on the modified Meyers-McKeever classification [7].

Compared with the more frequent postoperative complications following open surgeries [8–11], arthroscopic techniques have the advantage of minimal invasiveness and better visualization [12]. Many arthroscopic fixation techniques are widely used, such as Kirschner wires [13,14], metal screws [15,16], sutures [17,18], and suture anchors [6]. Screw and suture fixations are popular [19], but screw head impingement on the intercondylar notch can decrease terminal knee extension. Prolonged immobilization after screw fixation can increase the possibility of knee fibrosis [20] and additional surgery may be required to remove the hardware later [7]. Limitations of suture fixation include fragment tilting, and bony bridge fractures caused by cutting the sutures. The optimum choice for treating tibial eminence fracture is still controversial [21–24]. Currently, arthroscopic fixation using suture anchor is well accepted for tibial eminence fractures [6,25,26], and it can be applied to maintain the integrity of the fractures regardless of fragment size or comminution. Once seated, it can offer reliable fixation and resist strong tension. This procedure is relatively easy to perform, using a small cosmetic incision that is anatomic in its reduction. Additionally, with this technique there is no potential risk of physeal damage, as they hardly reach the growth plate [27]. Anchors can further help prevent complications that are secondary to hardware and reduce the need for a second surgery to remove the implants [28].

In the present study, we compared 2 fixation methods with suture anchors for tibial eminence fractures in a clinical setting. One was based on the classic double-row (DR) suture bridge technique used primarily for the treatment of shoulder rotator cuff tears [29,30]. The second method was the transosseous anchor knot (TAK) fixation technique, which is a combination of single-row suture anchor fixation and a concomitant transosseous suture knot. The aim of our study was to compare the efficacy of the 2 techniques for treating tibial eminence fractures.

Material and Methods

This was a nonrandomized, retrospective, case-series study. Approval was obtained from our ethics committee. The inclusion criterion was displaced tibial eminence fractures of type II, III and IV based on the modified Meyers-McKeever classification. Tibial plateau fractures and other severe injuries that can influence knee joint stability were excluded, such as meniscal tears, osteochondral lesions, and ligament injuries. The tibial eminence fractures can be confirmed by radiographs or CT scans. MRI was performed before surgery to evaluate meniscal tear, ACL, and other soft-tissue injuries.

The study included records of 127 patients with tibial eminence fractures, including 113 surgical interventions from October 2010 to August 2015 in our hospital, all performed by the senior author. Among the surgically-treated patients, a total of 41 patients (including 4 with radiographic evidence of tibial plateau fractures, 23 with evidence of meniscal tears, 11 with ACL tears, and 3 cases with ligament injuries) were excluded based on the exclusion criterion. In total, 72 patients were included, and the 37 cases that received treatment with the classic double-row fixation technique were defined as the DR group. Another 35 cases received treatment with transosseous anchor knot fixation technique and were defined as the TAK group.

Surgical technique

Patients received epidural anesthesia, and a bar was used to allow for 90° flexion of the knee. Diagnostic arthroscopy was performed with standard anteromedial and anterolateral portals. Standard inspection was performed to exclude or repair concomitant injuries. A motorized shaver and radiofrequency blade were used to debride the bone fracture debris and embedded synovial tissue to provide visual access to the avulsed bone fragment and fracture site. After refreshing the fracture bed, reducibility was tested with a probe.

In the DR group, for fractures of type III and IV, a 2.3-mm bioabsorbable anchor (Smith & Nephew) was placed at the posterior medial edge of the fracture site. The free ends of the suture loaded on the anchor were then punctured at the base of the ACL by a suture retriever. Another same anchor was then located at the anterior media margin, and the free ends of the suture were also punctured the ACL fibers in the same fashion, slightly in front of the previous suture. All the sutures were loaded on a 4.5-mm Footprint anchor, and then the suture bridge was created by inserting the Footprint into the hole on mid-lateral edge. Adjusting the angle of knee flexion for tensioning. The arthroscopic photographs of the DR technique are shown in Figure 1. For type II, the same procedure was performed except that a single anchor located at the medial edge of the fracture site was enough to provided stable fixation.
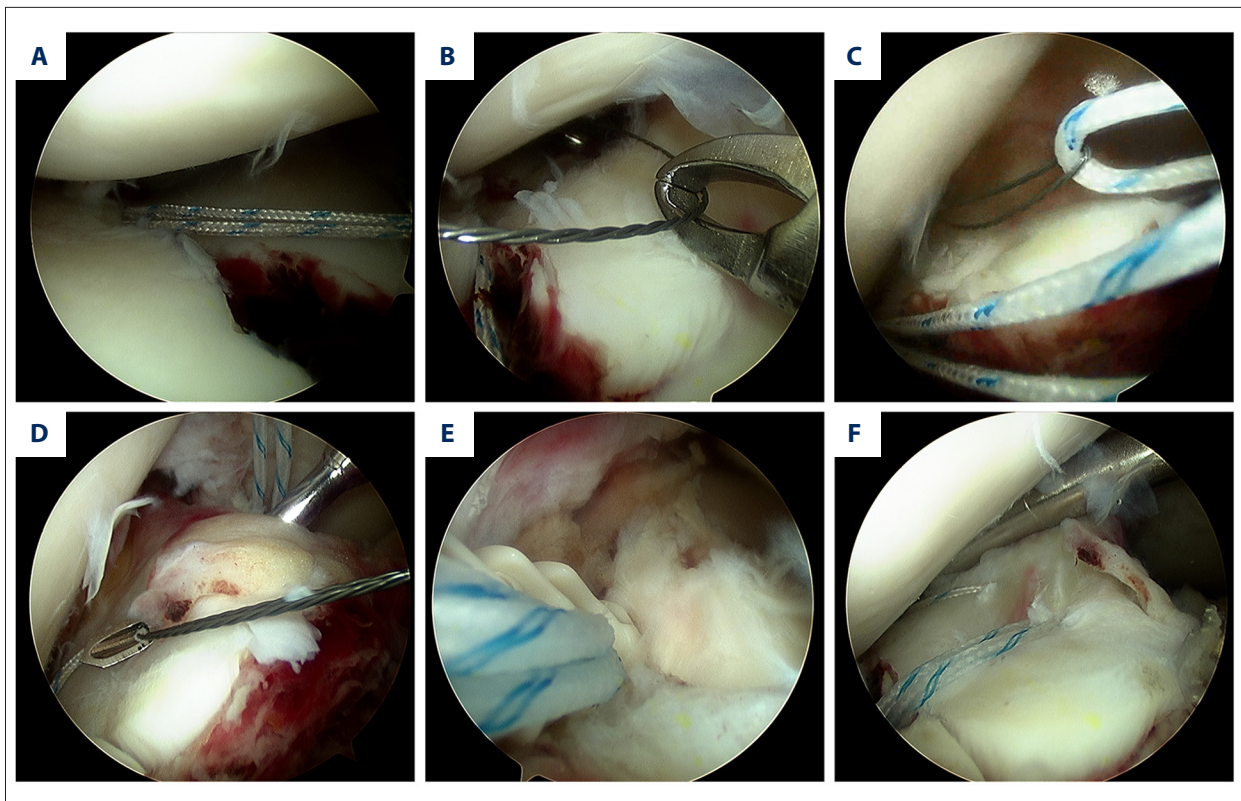
Figure 1. The DR technique was performed under arthroscopy on the left knee of a 28-year-old male patient. (**A**) A 2.3-mm bioabsorbable suture anchor loaded with 1 strand of No. 2 FiberWire was placed at the posteromedial edge of the fracture site. (**B**) A suture retriever was advanced to pierce the fibers of the ACL adjacent to the fracture fragment and pulled out of the joint by a suture grasper through the anteromedial portal. (**C**) The free end of the suture was delivered to pierce the fibers of the ACL adjacent to the fracture fragment by the suture retriever. (**D**) Another 2.3-mm bioabsorbable anchor was placed at the anteromedial margin of the fracture site and the suture retriever was advanced to pierce the fibers of the ACL slightly anterior to the previous suture to retrieve the free suture end of the second anchor. (**E**) A 4.5-mm Footprint anchor loaded with the free ends of the sutures was inserted into the mid-lateral margin of the fracture site. (**F**) The suture bridge was created to keep the fracture fragment reduced.

In the TAK group, a 2.3-mm anchor loaded with suture was located at the posterior medial edge of the fracture site. Another 2.3-mm anchor was then located at the anterolateral edge. The fragment was reduced and maintained using an ACL tibial guide. The tip of the guide was positioned at the center of the fracture segment, and a 2.4-mm drill-tip guide wire was used to create a tunnel from the medial tibia into the fracture segment in a retrograde manner. The tip was positioned on the tibial guide at the mid-medial margins of fracture, and a parallel tunnel that was 2.4-mm in diameter was created. One of the free ends of the suture loaded on each anchor was shuttled to puncture the base fibers of the ACL, and then was retracted from the center tibial tunnels. The other 2 free ends of sutures from the posterolateral and anterolateral anchors were placed behind and in front of the base of the ACL, respectively. Then, they were retracted from the medial tibial tunnels in the same way. At last, the sutures were tightened over the bony bridge under constant tension at approximately 30° of knee flexion. A probe was used to evaluated the fixation

stability and tension of the ACL. Arthroscopic photographs of this technique are shown in Figure 2. The schematic drawings of the 2 fixation techniques are shown in Figure 3.

Postoperative protocol and follow-up

For the first 3 weeks after surgery, a hinged brace was used to fully extend the knee joint, and weight-bearing was forbidden. Over the next 4–6 weeks, the brace was adjusted to allow the involved knee to have a 0–90° ROM and a touchdown weight-bearing with crutches. At approximately 6 weeks after surgery, full weight-bearing and full ROM were allowed. However, the brace should not be removed until the bony union is confirmed on radiograph at 3 months. During the whole immobilization period, isometric quadriceps exercises were suggested to prevent disuse atrophy. Some light sports activities could be performed at 6 months after surgery.
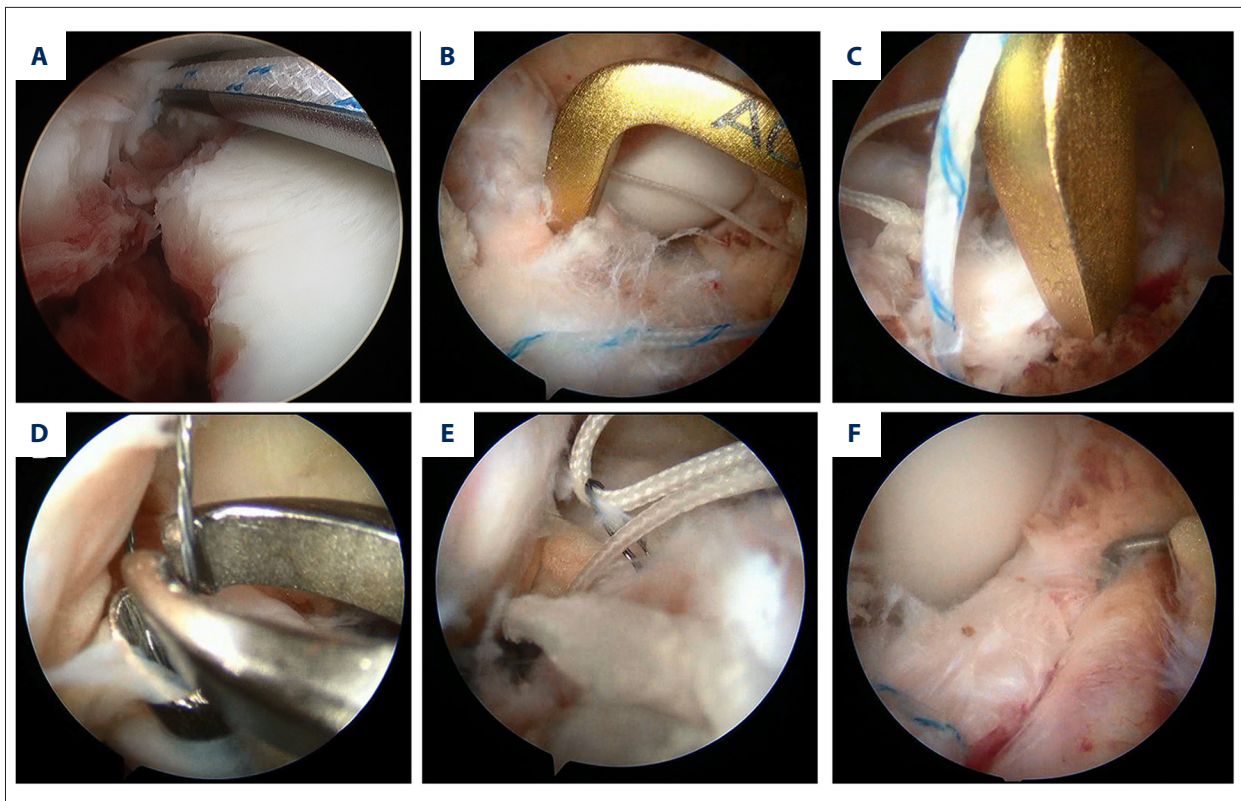
Figure 2. The TAK technique was performed under arthroscopy on the left knee of a 22-year-old female patient. (**A**) Two 2.3-mm bioabsorbable suture anchors loaded with 1 strand of No. 2 FiberWire were placed at the posteromedial and anterolateral edge of the fracture site respectively. (**B**) Positioning the tip of the Acufex ACL tibial guide at the center of the fragment; a tunnel was created using a 2.4-mm drill-tip guide wire. (**C**) Positioning the tip of the tibial guide at the mid-medial margins of the fracture site, and another 2.4-mm diameter parallel tunnel was created in the same fashion. (**D, E**) The 2 free ends of each suture were retracted out of the center and medial tibial tunnels by use of a suture retriever introduced through the tunnels. (**F**) The sutures were tightened over the bony bridge to keep the fracture fragment reduced, and fixation stability was evaluated with a probe under arthroscopy.

Patients were followed up at 6, 12, and 24 weeks, and every 6 months thereafter. To better evaluate the fracture healing and the recovery of knee function, radiographs, ROM, physical examinations (e.g., anterior drawer test), Lachman test, and scoring systems (including Lysholm score and International Knee Documentation Committee (IKDC) scores) were used in follow-up. Radiographs were obtained immediately after surgery and at every follow-up to evaluate the fixation and healing of the fracture. CT and MRI scans were not used as a regular examination during postoperative followup due to the relatively higher cost. All the preoperative and postoperative radiographic and clinical evaluations were evaluated and recorded by an observer independent from the treatment team.

Statistical analyses

All statistical analyses were performed using SPSS software. Comparison of the functional scores before and after surgery was performed by paired t test. Comparison of the improvement

of the functional scores between groups were performed by independent-samples t test and chi-square test. Statistical significance was set at $P<0.05$.

Results

Complete follow-up was achieved for all patients in both groups. These patients received complete serial radiological examinations and functional evaluations. Both groups were well matched with regard to the basic data (Table 1). Postoperative follow-up was similar between the 2 groups ($P>0.05$). The ADT and Lachman tests of all patients were positive in the preoperative examination performed under anesthesia. All 72 patients had successful operations. There were no serious intraoperative complications or early postoperative complications such as infection, thrombosis, joint fibrosis or adhesions, or implant failure. Three cases in the DR group and 2 in the TAK group had open physis; no physeal arrests or bars were
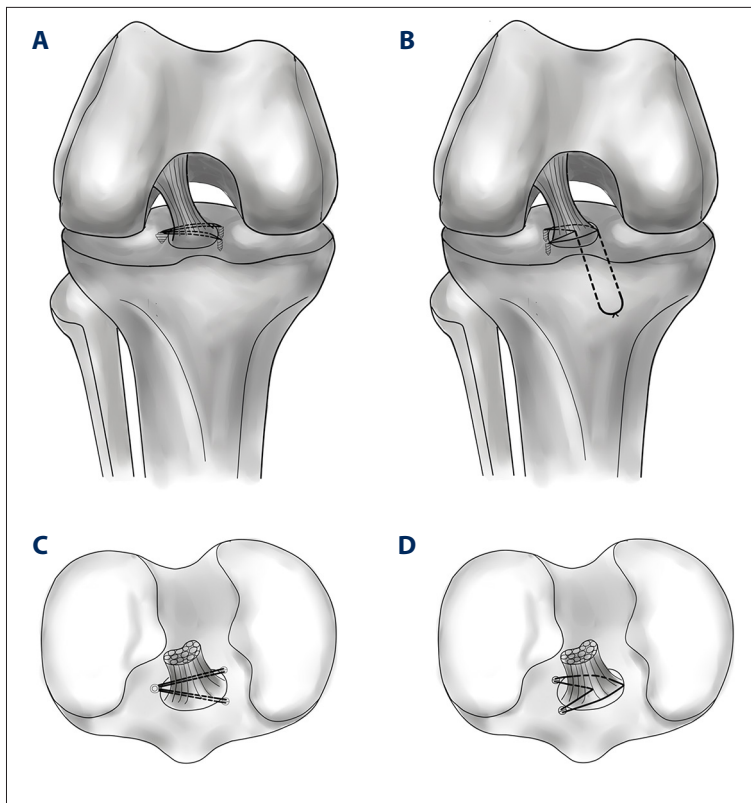
Figure 3. Schema showing the procedures of the 2 fixation techniques: (**A, C**) DR fixation and (**B, D**) TAK fixation.

Table 1. Comparison of patients' data of the two groups.

Item	Group		Statistic	P value
	DR (n=37)	TAK (n=35)		
Gender (Male/Female)	21/16	18/17	χ^2=0.158	NS (0.691)
Age	11.9–39.1	13.6–42.5	t=−0.990	NS (0.327)
Injury mechanism (traffic accident/sport/fall)	16/12/9	15/12/8	χ^2=0.359	NS (0.836)
Fracture Classification (II/III/IV)	12/17/8	10/18/7	χ^2=0.355	NS (0.837)
Interval from injury to surgery (days)	6.4–9.2	5.9–8.3	t=0.723	NS (0.473)
Follow-up period (months)	35.7–42.5	33.6–40.6	t=0.841	NS (0.404)

Data are presented as n or 95% confidence intervals. t and χ^2 are the corresponding statistics in independent-samples t-test and χ^2-square test, respectively. NS – no significant difference; DR – double-row technique; TAK – transosseous anchor knot technique.

noted for these patients in the both group in the entire follow-up period. There was no significant difference in operative time between groups (P=0.169).

Patients were followed up for 37.6 months on average (range, 18–54 months). Postoperative radiographs or MRI in all patients showed that anatomic reductions were gained immediately after surgery, and the bone unions were achieved within 3 months (Figures 4, 5). All patients had limited ROM preoperatively, but the range was restored to normal at the final follow-up; a range deficit of less than 10° was also accepted. However, asymptomatic grade II laxity was found in 2 patients

in the DR group and 1 in the TAK group from the results of physical examinations. Table 2 shows there were no significant differences in pain, ADT, Lachman test, knee ROM, and activity level between the 2 groups. Compared with preoperatively, the Lysholm score was significantly improved in the DR group (t=−68.14, P<0.001) and the TAK group (t=−54.23, P<0.001) at the last follow-up, and the IKDC score was also significantly improved in the DR group (t=−45.129, P< 0.001) and the TAK group (t=−46.852, P<0.001) at the last follow-up. However, improvement of functional scores was not significantly different between groups.
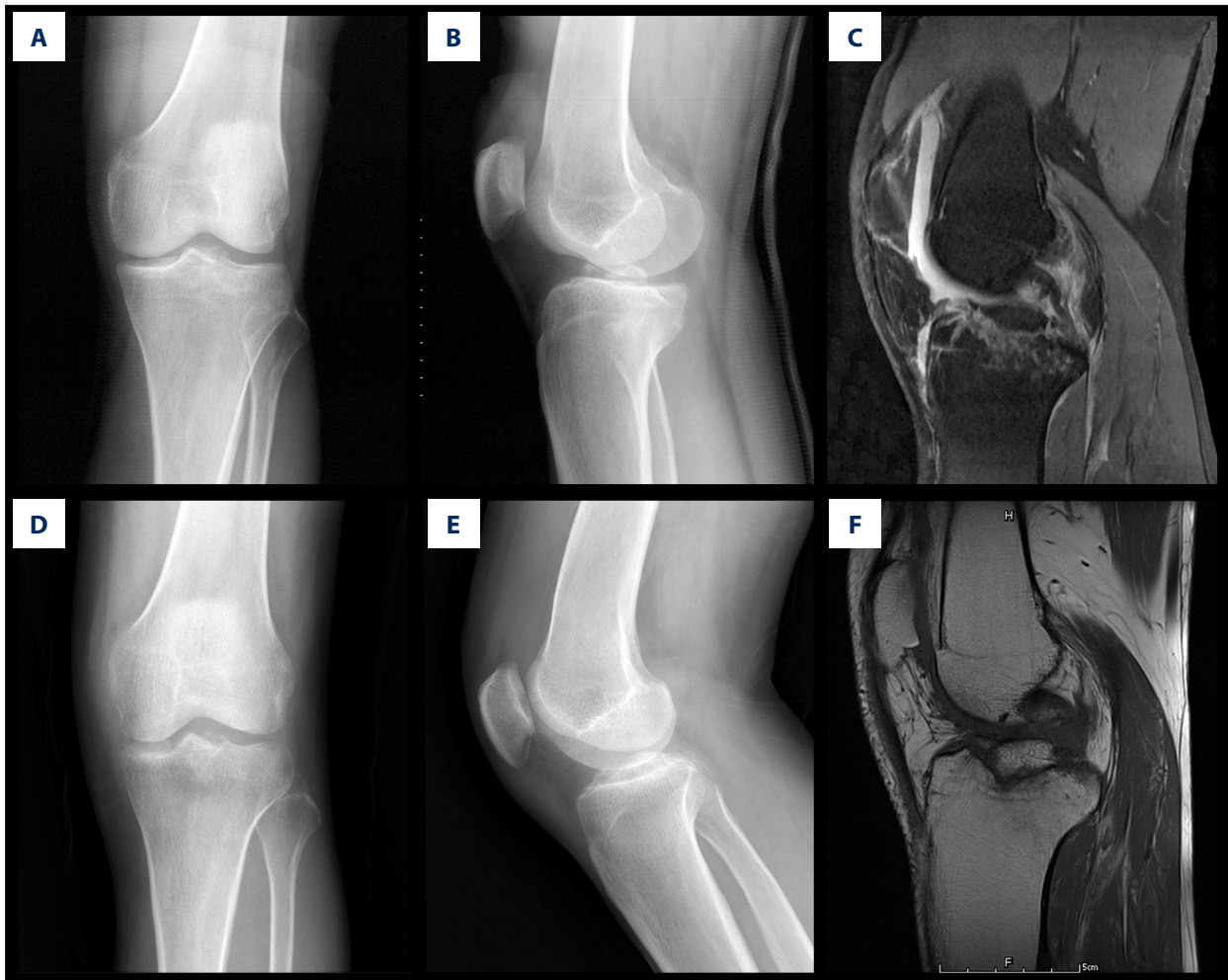
Figure 4. The preoperative and postoperative imaging of a 42-year-old male patient from the DR group. (**A, B**) Preoperative radiographs and (**C**) preoperative MRI showed a tibial eminence fracture in the right knee. (**D, E**) Radiographs at 6 months postoperatively and (**F**) MRI at 3 months postoperatively showed bony union in the patient fixed by suture technique at 3 months postoperatively.

Discussion

The suture anchor fixation method has been used for treating tibial eminence fractures due to its satisfactory outcomes in repairing rotator cuff tears [29]. Sawyer reported that the suture bridge technique with suture anchors constructed for tibial eminence fractures had a higher ultimate failure load than with traditional screw and suture fixations [21]. Hapa indicated that suture anchor fixation results in less displacement than with suture for tibial eminence fractures [24]. In et al. and Lu et al. reported satisfactory clinical results after more than 1 year of postoperative follow-up of bioabsorbable suture anchors fixation for tibial eminence fractures. The healing times and functional scores of suture anchors are also comparable with those of other treatment techniques [26,31].

In this clinical study, all of the patients achieved bony union with anatomic reductions in 3 months. Additionally, all of the patients achieved preinjured ROM of the knee, with no arthrofibrosis. Postoperative functional score improved significantly compared with preoperative functional scores. According to the results of the ADT and Lachman test, there were only 3 patients who showed asymptomatic grade II laxity, which may be due to our conservative rehabilitation program. We advise use of this program, which locked the knee in full extension for the first 3 weeks after surgery, to secure the stability of fixation. This recommendation contrasts with the regimen of moving the knee immediately after surgery to avoid joint fibrosis, which has been used in other studies [32]. All 3 patients with asymptomatic grade II laxity in our study were satisfied with their clinical results [5,7]. Furthermore, no significant difference in the functional scores or the improvement of them was found between the 2 groups.
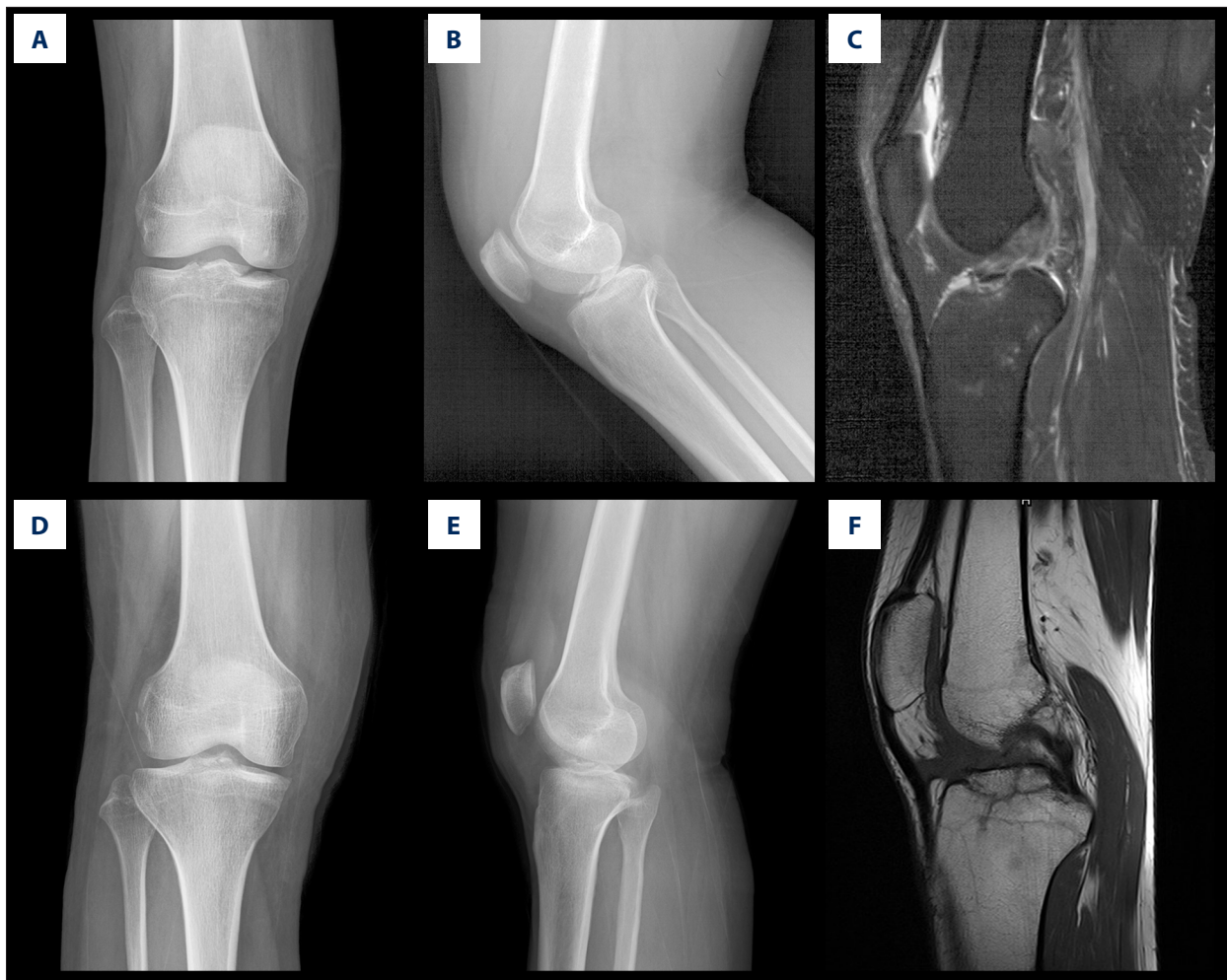
Figure 5. The preoperative and postoperative imaging of a 26-year-old female patient from the DR group. (**A, B**) Preoperative radiographs and (**C**) preoperative MRI showed a tibial eminence fracture in the left knee. (**D, E**) Radiographs at 12 months postoperatively and (**F**) MRI at 3 months postoperatively showed bony union in the patient fixed by suture technique.

For the DR technique, the anchors placed around the fracture fragment provided stable fixation from multiple points. The number of anchors can be changed based on the type of fracture. A single suture anchor was enough to fix the type II fractures, while a comminuted fracture had to be fixed with 2 suture anchors as described in our study. Suture anchors may be indicated for both adult and pediatric patients, as they are less invasive and growth plate was spared without drilling tibial tunnels [33,34]. However, the blood supply of the ACL may be damaged by being pierced. Additionally, the insertion of the 4.5-mm Footprint anchor could expand the lateral fracture line and injure the cartilage of the medial tibial plateau.

For the TAK fixation technique, the anchors were placed at the anterolateral and posterolateral edges. The tunnel was through the center of the fracture fragment, which was also the center of the ACL attachment, thus the fixation force direction was consistent with the ACL. This fixation method could better balance

out with the tug from the ACL during activities, especially the anteromedial bundle [35]. Generally, the second drill hole was located at the medial margins. However, if the transverse diameter of the fragment was larger than 3 cm, we drilled on the fracture fragment, and if the fragment was smaller than 1.5 cm, the second drill hole was located at the medial tibial plateau. The number of sutures and drill holes can also be adjusted. Additionally, Matthias reported that accompanying meniscal injuries in patients with tibial eminence fractures must be expected in almost 40% of patients, and one of the most common tear patterns was root detachment of the lateral meniscus [36]. In the clinic, in patients with tibial eminence fracture accompanied by root detachment of the lateral meniscus, we can locate the anchor loaded with 2 strands sutures at the root of the lateral meniscus, and fix the root detachment using one suture before the fixation of the fracture. However, this technique requires transphyseal drilling, which may lead to growth disturbances in skeletally immature patients [37,38].

Table 2. Comparison of clinical assessments between the two groups.

Item	Group		Statistic	P value
	DR	TAK		
Operative time (min)	81.06–89.03	84.89–92.87	t=−1.395	NS (0.169)
Postoperative pain (−/+)	37/0	34/1	χ^2=2.080	NS (0.149)
Postoperative ADT (0/I/II/III/IV)	30/5/2/0/0	28/6/1/0/0	χ^2=0.453	NS (0.797)
Postoperative Lachman test (0/I/II/III/IV)	31/4/2/0/0	29/5/1/0/0	χ^2=0.468	NS (0.791)
Postoperative ROM (°)	131.5–133.9	130.6–132.2	t=1.882	NS (0.066)
Postoperative activity level (normal/lower)	34/3	33/2	χ^2=0.145	NS (0.704)
Preoperative Lysholm score	49.63–55.01	48.98–54.22	t=0.393	NS (0.696)
Postoperative Lysholm score	90.79–94.01	90.64–93.59	t=0.270	NS (0.788)
Improvement of Lysholm score	38.87–41.29	38.97–42.06	t=−0.457	NS (0.650)
Preoperative IKDC subjective score	55.64–59.30	57.79–61.07	t=−1.632	NS (0.109)
Postoperative IKDC subjective score	90.40–93.10	90.34–94.03	t=−0.488	NS (0.627)
Improvement of IKDC subjective score	32.62–35.73	31.31–34.20	t=1.370	NS (0.177)

Data are presented as n or 95% confidence intervals. t and χ^2 are the corresponding statistics in independent-samples t-test and chi-square test, respectively. ADT and Lachman test were both graded according to the anterior tibial translation value: grade 0, no laxity; grade I, 0 to 5 mm; grade II, 5 to 10 mm; grade III, 10 to 15 mm; and grade IV, >15 mm. DR – double-row technique; TAK – transosseous anchor knot technique.

A literature review showed that passing through a transphyseal tunnel of sutures in pediatric lead to few complications [38]. In animals study, 9% or less of the physeal surface is injured, the transphyseal drilling technique is considered with no risk [39]. A 2.4-mm diameter in a teenager represents 0.9–1.2% of the physeal surface [39]. Thus, the risk of epiphysiodesis should not limit this technique [24]. In addition, there are some other limitations in this technique, such as the potential of fragment tilt during suture tying caused by incorrect tunnel orientation or unbalanced stressing, bony bridge fracture and tunnel connection due to suture cutting of cortical bone, or inappropriate location for the external exits of tibial tunnels.

Both the DR and TAK fixation techniques achieved satisfactory clinical outcomes, and they can be used to treat all types of fractures, and neither technique requires the implant removal with a second intervention. We chose the more suitable technique to have the greatest benefit for each patient and according to the indications. In the case of the fracture accompanied by lateral meniscal root detachment, we would choose the TAK technique because it can repair the meniscal injuries directly at the time of the fracture fixation. For the adolescent patients with immature skeletons, the DR technique for preservation of the proximal tibial physis may be more suitable. The fracture classification did not bias our choice of fixation, as both techniques are applicable in fractures with different degrees of displacement and comminution. Therefore, we could guarantee both the clinical efficacy of each patient's treatment and the comparability of both study groups.

Limitations

First, this was a nonrandomized retrospective study, the follow-up period was short, and the sample size was small, which may increase the risk of type II error. A randomized controlled trial with a larger sample size and longer follow-up period should be performed. Second, the clinical physical examinations, such as the ADT and Lachman tests, were dependent on the examiner and may be inaccurate; no inter- or intra-observer reliability/variability was reported in this study; thus, some of the results may not be as reliable with respect to differences between the 2 groups.

Conclusions

DR and TAK techniques both provide precise reduction and stable fixation for treating tibial eminence fractures, and the clinical outcomes of the 2 arthroscopic techniques with suture anchors are satisfactory.

Acknowledgments

Conflict of interest

None.

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