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Original Article

Deadman tension band for patella fractures: a clinical study

Ming Yang[1*], Shuhua Li[2], Shu Zhang[3], Wei Huang[1*], Baoguo Jiang[1], Peixun Zhang[1]

[1]*Department of Trauma and Orthopedics, Peking University People's Hospital, Beijing, China;* [2]*Pharmacy Intravenous Admixture Service, Weifang People's Hospital, Weifang City, Shandong Province, China;* [3]*The NO.1 Hospital of Dali City, Yunnan Province, China.* [*]*Equal contributors.*

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Abstract: Purpose: We compared the new deadman tension band (DTB) technique with the conventional modified anterior tension band (MATB) technique for patellar fractures. Methods: This retrospective study included 53 patients with displaced transverse patellar fracture. Twenty-eight patients underwent the conventional MATB technique and 25 patients underwent the DTB technique. Patients were followed up at postoperative intervals of 4, 8, and 12 weeks, and 1 year. Knee function was assessed by the Hospital with Special Surgery (HSS) score. We also evaluated the data including operation time, distance from the tension band to the bone surface of the proximal patella (DTBB), and complications. Results: The DTB group had a significantly shorter operation time (P=0.025) and significantly lower DTBB compared with the MATB group (P=0.039). The DTB group had a significantly better 3-month postoperative HSS score (P=0.032) and range of flexion (P=0.017) and extension (P=0.041) than the MATB group; however, these differences were not significant at 12 months postoperatively. Compared with the MATB group, the DTB group had significantly fewer complications (P=0.017), and less DTB patients underwent a second operation to remove hardware (P=0.031). Conclusion: The DTB technique allowed the tension band to be placed closer to the bone surface, and was superior to the conventional MATB technique in terms of shorter operation time, better early function, and less complications.

Keywords: Patellar fracture, deadman tension band, K-wire, cannulated screws

Introduction

Patellar fractures account for 0.5-1.5% of all bone fractures [1, 2]. Surgical treatment becomes necessary when the fracture displacement exceeds 3 mm or the articular incongruity exceeds 2 mm [3]. The AO/ASIF recommends treatment of patellar fractures with two vertical Kirschner wires (K-wires) and a longitudinal anterior figure-of-eight tension band and steel wire technique, which has become the accepted standard fixation method for displaced patellar fractures [4, 5]. This modified anterior tension band (MATB) technique can convert the tension forces acting on the anterior surface into compression forces at the articular surface, and can substantially improve results because of its reliable fixation and allowance of early joint motion [6, 7]. However, the MATB still has some complications, such as loosening and migration of the K-wires [8, 9], and the potential for skin irritation [5, 10, 11]. Hence, many other patellar fracture fixation methods have been tried [12-18]. Whichever method is chosen, biomechanical testing has revealed that the tension band should closely contact the bone; in particular, the soft-tissue interference should be reduced on the distal and proximal end of the patella [19, 20].

Using the MATB technique, we often found it difficult to place the upper transverse limb of the tension band completely in contact with the bone surface at the proximal end of the patella, and there was often some distance between these structures on the lateral radiographic view. To make the tension band contact the bone more closely, we devised a new deadman tension band (DTB) technique to treat patellar fracture (**Figure 1**). We performed this retrospective clinical study to compare the DTB technique with the MATB technique. Our hypotheses were that the DTB technique would: (1) enable the tension band to be placed closer to

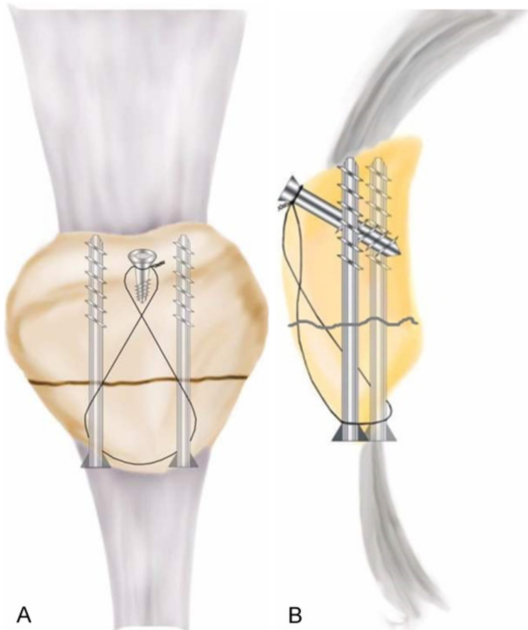

Figure 1. Illustration of the deadman tension band technique. A: Anterior posterior view, B: Lateral view.

the bone at the proximal end of the patella; (2) shorten the operation time and fracture healing time, and decrease complications such as loosening of implants; and (3) achieve better knee function.

Materials and methods

Patients

This retrospective study included 53 patients aged 19-79 years who underwent surgery between January 2008 and June 2014. From January 2008 to December 2011, patients were treated with the MATB technique. From January 2012 to June 2014, we performed the DTB technique in some patients; patient selection for each technique was made according to the surgeon's preference. The injury mechanism included slip and fall accidents (45 patients) and car accidents (eight patients). The mean time from fracture to operation was 3.27 days (range 1-8 days). The inclusion criteria were: (1) AO/OTA34-C1 fractures (patellar fractures with a primarily transverse fracture line); and (2) AO/OTA 34-C2 fractures (transverse fractures with a single additional fragment created by a longitudinal fracture line) [21]. The exclusion criteria were: (1) AO/OTA 34-C3 fractures (comminuted fractures); (2) open fractures; (3) proximal end fractures; and (4) old fractures. Patients were divided into either the MATB group or the DTB group, according to the technique used during their operation.

Surgical technique

We applied a tourniquet cuff before making a longitudinal incision. After exposure of the fracture site, the fracture was reduced and provisional fixation was undertaken with reduction forceps. In fractures of the distal end of the patella with a longitudinal fracture line, we reconstructed the distal segments using provisional fixation with transverse or oblique K-wires, or definitive fixation with screw stabilization.

In the MATB group [4-7], two longitudinal K-wires (2.0-mm diameter, with a 1-cm separation and 5-10 mm distance from the articular surface) were then driven across the fracture site from distal to proximal. Both K-wires were placed parallel and did not penetrate the articular surface. A longitudinal figure-of-eight wire was then placed; the transverse limbs of the figure-of-eight wire were placed as close as possible to the pole of the patella. The surgeon simultaneously made one twist and another compression ring in the vertical limb of the figure-of-eight wire to prevent asymmetric tightening. The upper end of both longitudinal K-wires was then bent 180° as close as possible to their entry points into the proximal patella. The excess wire was cut, leaving a 2- to 4-mm hook. The bend in each wire was then turned so that the hook was directed posteriorly. The quadriceps tendon was split for several millimeters, and, with the tendon retracted, the bent wire was advanced distally with a punch. We ensured that as little tendon as possible was captured by the bend in the wire, and engaged the bone with the bend to reduce the risk of wire blackout [14].

In most cases in the DTB group, we performed reduction and provisional fixation with forceps, and then placed two guide wires similar to the K-wire placement in the MATB group. We then performed fluoroscopic examination and measured the depth (**Figure 2A**). We drilled along the guide wire with a cannulated drill, and placed two 4.0-mm titanium cannulated compression screws (Synthes Inc., West Chester,

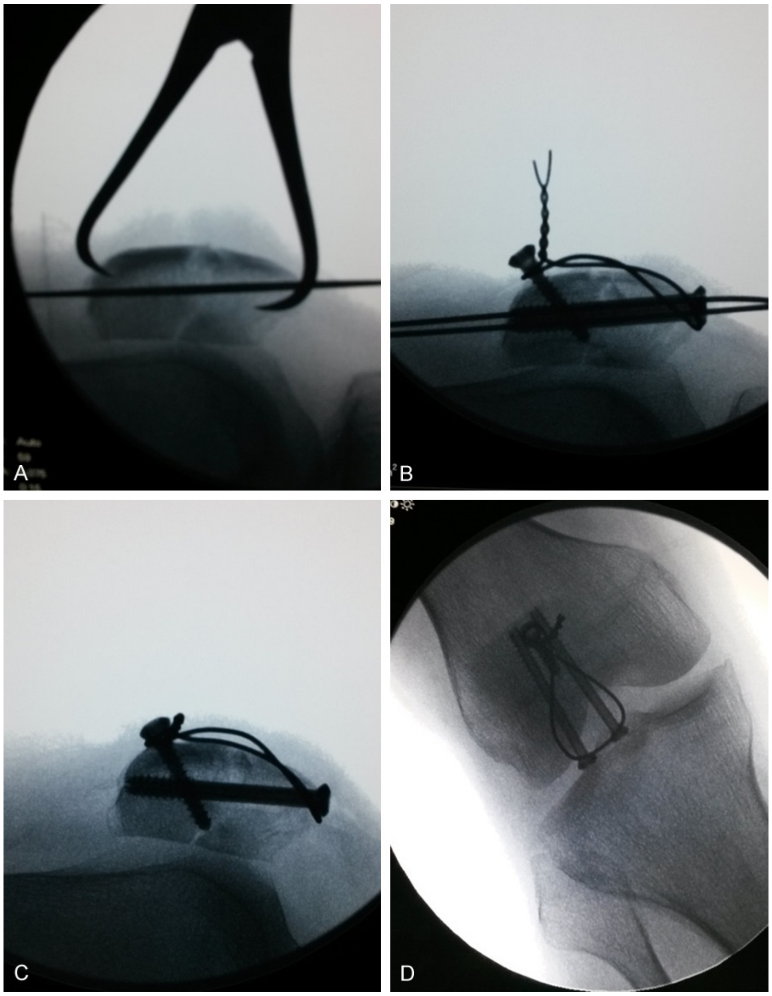

Figure 2. Schematic showing patellar fracture fixation using the deadman tension band technique. A: Fracture reduction and placement of the guide wire; B: Placement of the cannulated screw, deadman screw, and tension band with steel wire; C: Final positions of all implants; D: The final position on fluoroscopy on an anteroposterior view.

PA, USA). At first we did not completely advance the screws to their final positions, but kept the screw tails 5 mm from the cortex of the distal patellar end. Next, we placed the third 4-mm total-spiralcancellous screw into the proximal fragment as deadman, which was placed in the anterior area of the quadriceps tendon insertion and directed obliquely toward the distal end at an angle of 30-45° with the longitudinal axis of the patella. The deadman screw was also initially not completely placed into the bone, with a 5-mm tail retained outside the bone. We then made a longitudinal figure-of-eight tension band around the three screw tails using steel wire. Only one twist was tightened in the tension band (**Figure 2B**) before we completely placed the three screws into their definitive positions. We made sure the deadman screw did not penetrate the articular surface (**Figure 2C**). The final position was verified by passive motion and radiography (**Figure 2D**). The associated retinacular tear was repaired. In our initial two DTB cases, we used K-wires rather than cannulated screws (**Figure 3**). In our most recent three cases, we substituted No. 5 fiber wire suture and a Nice knot [22] for steel wire, and substituted semi-spiral screws for total-spiral screws to avoid suture cut (**Figure 4**).

Rehabilitation

As recommended in the literature [15], passive range of motion exercises, isometric quadriceps muscle exercises, passive motion, and protected weight bearing with crutches were started as soon as possible. Active range of motion exercises were started at 3 weeks postoperatively. Full weight-bearing without crutches was allowed 8 weeks postoperatively.

Patient follow-up and assessment

We took anteroposterior (AP) and lateral radiographs on postoperative day 2. All patients were followed up monthly until fracture healing, and at 4, 8, and 12 weeks postoperatively. The function of the knee was assessed by the Hospital for Special Surgery (HSS) score 3 and 12 months postoperatively [23]. Fracture healing was assessed by radiography and physical examination. The distance from the upper transverse limb of the tension band to the bone surface of the proximal patella (DTBB, the distance from tension band to bone) was measured on the lateral radiographic view as an index to determine how close the tension band was to the bone (**Figure 5**). The DTBBs of three patients in the DTB group with suture were measured directly intraoperatively, but not on a

Figure 3. Lateral radiographic view of our first case of patellar fracture fixation via the deadman tension band (DTB) technique. The Kirschner wire and DTB technique was used, but the Kirschner wire tail caused skin irritation.

lateral radiographic view. The complication incidence, range of flexion and extension, and HSS score were recorded during follow-up. The tension band wire was removed only in patients with significant hardware-related symptoms, and in some patients according to their preference.

Statistical analysis

Statistical analyses were performed using SPSS version 20.0 software (IBM Corporation, Armonk, NY, USA). Data were presented as mean ± standard deviation for continuous variables and number (percentage) for categorical variables. The distribution differences of variables between groups were analyzed by Chi-square test or by Student's t test or nonparametric test based on the characteristics of the data. *P* values of less than 0.05 were considered statistically significant.

Results

There were 28 patients in the MATB group (11 males and 17 females) with a mean age of 46.21±13.27 years (range, 24-71 years), and 25 patients in the DTB group (12 males and 13 females) with a mean age of 47.56±15.69 years (range, 19-79 years). There were no statistically significant demographic differences between the two groups in age, injured side, sex, and fracture classification (**Table 1**).

The average operation time was 44.37±7.74 min in the DTB group, which was significantly shorter than that in the MATB group (51.42±10.21 min, P=0.025; **Table 2**). The DTBB was 1.13±0.61 mm in the DTB group, which was significantly shorter than that in the MATB group (2.45±1.24 mm, P=0.039; **Table 2**). The average time to union was 2.23±0.57 months postoperatively in the DTB group, which was significantly shorter than that in the MATB group (2.87±1.10 months, P=0.041; **Table 2**).

At 3 months postoperatively, the DTB group had significantly better HSS scores (P=0.032), and range of flexion (P=0.017) and extension (P=0.041) compared with the MATB group. However, at 1-year postoperatively, the total range of motion and the HSS scores were similar in the two groups (**Table 2**). The DTB group had a significantly lower rate of hardware removal resulting from any reason (P=0.031; **Table 2**).

All complications observed during follow-up are listed in **Table 3**. During scheduled follow-up radiography, one patient in the MATB group showed early implant fail; there was further fracture displacement, and a second operation was conducted. Hardware loosening (K-wire or guide wire) occurred in two patients in the MATB group and in no patients in the DTB group. All patients eventually acquired bone union. Three patients in the MATB group and one patient in the DTB group had hardware irritation symptoms. Delayed union occurred in one patient in the MATB group. The total complication rate in the MATB group was significantly higher than that in the DTB group (P=0.017).

Discussion

The current results showed that the DTB technique resulted in shorter operation time and

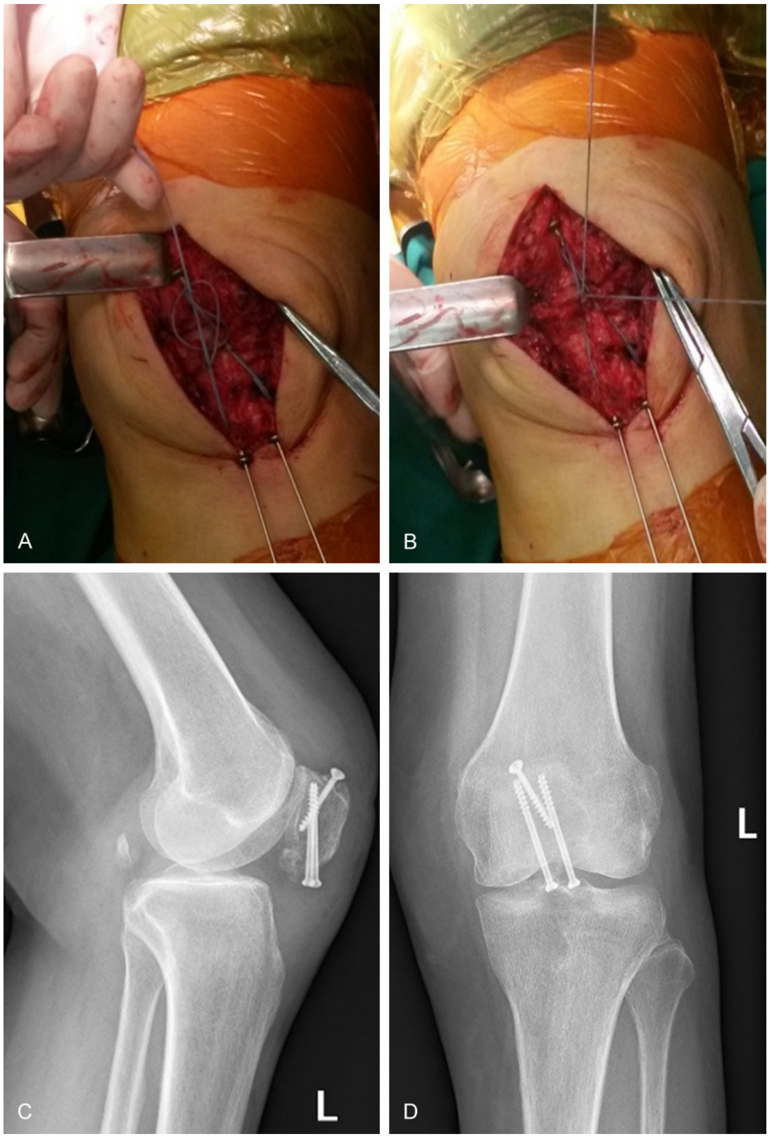

Figure 4. Nice knot and deadman tension band technique. A and B: Intraoperative photographs of the Nice knot; C: Postoperative radiograph anteroposterior view; D: Postoperative radiograph lateral view.

healing time, satisfactory bony union rate, better early functional outcomes, and a lower complication rate compared with the MATB technique, although the eventual function was similar. Our study found that the main shortcomings of the MATB technique were loosening and migration of the K-wires [8, 9], and skin irritation [5, 10, 11].

Recently, new fixation methods based on the principle of the tension band have made some improvements in the treatment of patellar fracture [12-18]. One such technique uses metal cannulated screws as substitutes for K-wire and combines a steel wire or cable tension band through the screws [2, 12, 24]; this is a more rigid fixation method that has become increasingly popular. We also preferred to use cannulated screws in the DTB group. However, we performed a deadman technique without passing the wire through the cannulated screw, to avoid having to split the quadriceps tendon as required when using the other technique. Another technique used cable as a substitute for steel wire [12, 13]; although the results were satisfactory, the cost was obviously much higher. Elastic suture fixation has been used as a substitute for steel wire to avoid skin irritation or a second operation to remove the implant [16-18]; we tried this technique in three cases and acquired satisfactory results. Finally, some authors have used a horizontal figure-of-eight rather than a vertical figure-of-eight [15], but this needs further investigation.

We believe that this is the first study to introduce the deadman technique combined with a longitudinal tension band in patellar fracture fixation. The DTB technique had some advantages. First, it can increase the contact of the tension band with the bone, especially in the proximal patella, which results in less soft-tissue interference. We used the DTBB on the lateral view as an index to demonstrate this point. Second, the deadman screw is placed on the anterior area of the quadriceps tendon insertion, and thus it is not necessary to split or involve the quadriceps tendon. Third, this technique shortened the longitudinal distance of the tension band, which potentially increases the effect of the tension band. Fourth, as the tension band is only one point of inflection in the proximal end of patella (like using a cancellous screw plus tension band in the treat-

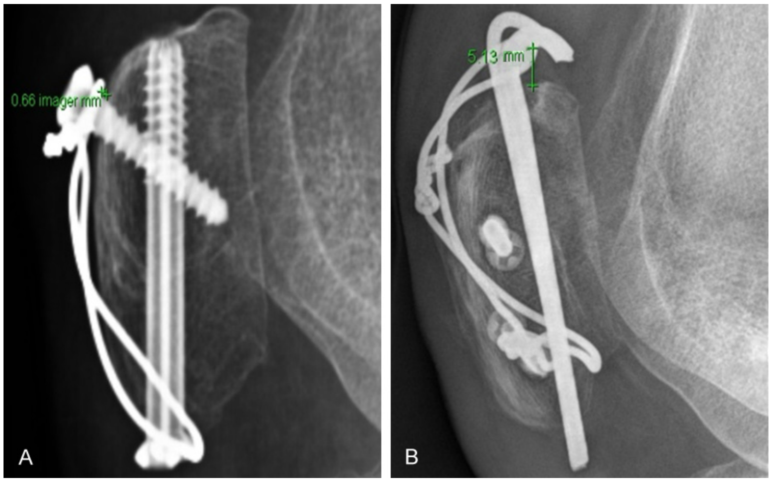

Figure 5. The measurement of the distance from the tension band to the bone surface of the proximal patella (DTBB). A: DTBB of the deadman tension band (DTB) case was 0.66 mm (green word); B: DTBB of another case treated with the conventional MATB technique was 5.13 mm (green word).

Table 1. Basic characteristics of the two groups

Variables	MATB (N=28)	DTB (N=25)	*P* Value
Age (years)	46.21±13.27	47.56±15.69	0.737
Side			
Left	12	10	0.833
Right	16	15	
Gender			
Male	11	12	0.523
Female	17	13	
AO classification			
34-C1	18	14	0.538
34-C2	10	11	

MATB: modified anterior tension band; DTB: deadman tension band.

Table 2. Comparison of postoperative results in the two groups

Variable	MATB (N=28)	DTB (N=25)	*P* Value
Operation time (minutes)	51.42±10.21	44.37±7.74	0.025*
DTBB (mm)	2.45±1.24	1.13±0.61	0.039*
Time to bone union (months)	2.87±1.10	2.23±0.57	0.041*
HSS score			
3 months	78.54±9.26	84.07±8.94	0.032*
12 months	95.32±7.17	96.39±6.84	0.474
Flexion (°)			
3 months	79.29±14.30	87.76±11.74	0.017*
12 months	132.02±10.11	134.61±9.84	0.313
Extension (°)			
3 months	-3.76±1.36	-1.81±0.64	0.041*
12 months	-1.09±0.33	-0.89±0.45	0.371
Remove of hardware	9 (32.14%)	2 (8%)	0.031*

MATB: modified anterior tension band; DTB: deadman tension band; DTBB: the distance from tension band to bone; HSS: Hospital for Special Surgery. *$P<0.05$.

ment of olecranon fracture [25]), it is not necessary to make a compression ring or twist in another longitudinal limb of the tension band. In addition, having only one inflection may reduce the friction between the tension band and the post, and then enhance the compression of the fracture site. The above-mentioned advantages may be the reasons that the DTB technique resulted in shorter operation time, earlier post-operative movement, shorter healing time, and better early function compared with the MATB technique.

To the best of our knowledge, this is the first introduction of the DTBB index as a measure of the distance between the tension band and the bone. Although many authors believe that closer contact between the tension band and patellar bone could acquire more stable fixation, there was previously no reported method to objectively measure the degree of contact [19, 20]. In our study, we found that the DTBB was an accurate index.

The DTB technique also has some potential disadvantages. First, it requires the proximal screw to be enhanced as deadman, thus the cost is slightly increased. Second, the deadman screw carries a risk of being pulled out, and therefore the DTB technique is contraindicated in comminuted proximal patellar fractures and cases of severe osteoporosis. Third, the screw can penetrate the articular surface, thus we must pay attention to the angle and the length of the deadman screw

Table 3. Comparison of complications in the two groups

Complications	MATB (N=28)	DTB (N=25)	*P* Value
Lose of reduction	1	0	
Hardware loosen	2	0	
Hardware Irritation	3	1	
Delayed union	1	0	
Total	7	1	0.017*

MATB: modified anterior tension band; DTB: deadman tension band. *P<0.05.

intraoperatively. In general, the angle is 30-60° with the longitudinal axis of the patella. The head of the screw should not penetrate the articular surface on the lateral view.

Our study had some limitations. First, although we used the deadman technique in 25 cases, in the initial two cases we used K-wires rather than cannulated screws. One of these patients complained of discomfort when she knelt on the bed. We think that the end of the K-wires irritated the skin, and thus we used cannulated screws as a substitute for the K-wire in all subsequent cases. Second, the most recent three cases used the suture tension band and Nice knot to substitute for the steel wire and twist. Previous biomechanical test results [19, 26] and the current results indicate that the effect of the suture tension band is encouraging. Therefore, in the future we will use suture tension band combined with cannulated screws in more cases to avoid a second operation to remove the steel wire. We must use a semi-spiral screw rather than a total-spiral screw as deadman to avoid suture cut in these cases. Third, our sample size was small and follow-up time was short; longer term follow-up of larger sample sizes is warranted. Fourth, although all surgeries in the DTB group were performed by one surgeon (the first author), a different surgeon performed the MATB operations. Fifth, there were so many variables in the DTB group that we could not investigate the correlation between the DTBB and the outcome.

Compared with the MATB, the DTB technique can place the tension band closer to the patellar and does not involve the quadriceps tendon; hence, the DTB resulted in a shorter operation time, satisfactory early function, and decreased complications (especially implant loosening and second operation). The DTB technique should be considered as an alternative method for the treatment of transverse patellar fractures.

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Disclosure of conflict of interest

None.

Address correspondence to: Drs. Baoguo Jiang and Peixun Zhang, Department of Trauma and Orthopedics, Peking University People's Hospital, Beijing 100044, China. Tel: 0086-10-8832-6550; Fax: 86-10-88324570; E-mail: jiangbaoguo@vip.sina.com (BGJ); zhangpeixun@bjmu.edu.cn (PXZ)

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