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Modified two-tension-band for patellar fractures

Chong Zhang, Yong Zhao and Kai Deng

Abstract

Objective: To compare a modified two-tension-band (MTTB) technique with the AO tension band in treating patellar fractures.

Methods: This retrospective study included patients treated with AO tension band (group 1) or MTTB (group 2). Data obtained during serial follow-up evaluations of time to bony union, range of motion (ROM), Hospital for Special Surgery (HSS) score and complication rates, were analysed.

Results: Fractures healed in all 51 patients included in the study (group 1, $n = 28$; group 2, $n = 23$), with no statistically significant between-group difference in time to bony union. Regarding function results, group 2 had better HSS scores at 3 and 6 months postoperatively; however, at 1 year postoperatively, both groups had similar HSS scores and achieved acceptable flexion and ROM. The overall complication rate was significantly lower in group 2, but average costs were higher in group 2 versus group 1.

Conclusion: MTTB provides secure fixation and improved knee function at 3 and 6 months postoperatively, and has a lower complication rate with early mobilization, compared with the AO tension-band technique.

Keywords

Patellar fracture, internal fixation, modified two-tension-band

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Introduction

Patellar fractures account for almost 1% of all skeletal injuries and have an incidence of about 0.013% per year. More than half of patellar fractures occur in females, and the most common type of fracture is AO type 34-C3.[1] Indications for surgery include

Department of Orthopaedic Trauma and Microsurgery, Zhongnan Hospital of Wuhan University, Wuhan, Hubei, China

Corresponding author:
Kai Deng, Department of Orthopaedic Trauma and Microsurgery, Zhongnan Hospital of Wuhan University, 169 East Lake Road, Wuchang District, Wuhan, Hubei, 430071, China.
Email: dk_1005@hotmail.com

an open fracture, an articular step of 2 mm or greater, and loss of knee extension. Historically, the AO tension-band wiring (TBW) technique has been the most commonly used, and involves two parallel axial Kirschner (K)-wires in association with a stainless steel wire placed anteriorly in a vertical figure-of-eight.[1] However, postoperative symptoms and complications related to TBW are not rare, and a review found that 22–30% of fractures treated using the TBW technique develop detrimental displacement at the fracture site.[2] Fixation with conventional K-wires has been shown to have a higher rate of implant removal caused by symptomatic irritation,[2] and technical errors, noncompliance, and unknown items are suggested to be the three main factors that lead to fixation failure.[3] K-wires at the middle layer of the patella may decrease the rates of loss of reduction.[4] In addition, following biomechanical research using a wooden model of the patella, John et al.[5] showed that placing two twists of wire at nearby corners in a horizontal figure-of-eight tension-band construct produced the greatest interfragmentary compression and had maximum stiffness to resist cyclic loads.

Due to the biomechanical merits described previously,[5] Lee et al.[6] found that the loop of the horizontally oriented tension band with two-wire twists at the adjacent corners was better regarding satisfactory bony union, improved early functional outcomes, and a lower complication rate. In another study that used the two-tension-band technique for patellar fracture revision surgery in six patients with fixation failure following TBW, it was concluded that the two-tension-band technique may avoid technical errors and provide more secure fixation.[7] Conversely, Kim et al.[8] found that using locked TBW with ring pin may avoid the shortcoming of implant migration and decrease the discomfort caused by K-wire fixation, and the braided structure of cable-ready wire has been found to provide greater resistance to fracture displacement.[9]

In order to decrease the rate of complication and fixation failure, patients at Zhongnan Hospital of Wuhan University have been treated for patellar fracture using the modified two-tension-band (MTTB) technique, which consists of two figure-zero oriented tension bands and an additional cerclage wire using ring pin (Tension Band Pin System; Acumed, Hillsboro, OR, USA) and cable-ready wire (Cable-Ready; Zimmer, Warsaw, IN, USA). The authors hypothesise that the clinical effects of MTTB are better than those of AO TBW in treating patellar fractures. Thus, the aim of the present study was to retrospectively compare the therapeutic effects of treatment with either MTTB or AO TBW in patients with patellar fractures.

Patients and methods

Study population

This retrospective study included consecutive patients with patellar fracture who were treated at Zhongnan Hospital of Wuhan University between February 2012 and December 2018. Inclusion criteria were the following: (1) skeletally mature patients with a patellar fracture, defined as 3 mm of fragment diastasis with loss of knee extension or articular step of 2 mm or more;[10,11] (2) fixation technique using AO TBW or MTTB with or without accompanying K-wires; and (3) a minimum follow-up of at least 1 year. Exclusion criteria comprised: (1) open and vertical component of the fracture pattern; (2) use of alternative fixation devices (for example, screw fixation); and (3) patients with polytrauma or disease that may influence the affected knee. All of the surgical treatments were performed by the same surgeons.

Consecutive patients with patellar fractures were included and divided into two groups, according to which treatment type they had received. Group 1 comprised patients who had been treated using AO TBW, made up of oriented figure-of eight configurations with one wire twist using K-wires and stainless steel wire; and group 2 comprised patients who had been treated using MTTB, made up of two figure of-zero configurations with two-wire twists placed at the adjacent corners and a cerclage wiring using ring pin and cable-ready wire.

Medical records and radiographs of all participants were reviewed to identify patient demographic and clinical data for extraction and analyses.

The Ethics Committee of Zhongnan Hospital of Wuhan University, Wuhan, Hubei, China approved this study. Due to the retrospective study design, it was not deemed necessary to obtain informed consent from the participants.

Surgical technique

The patient, with an inflated tourniquet on the thigh, was placed in the supine position following anaesthesia and routine sterile preparation and draping. A midline longitudinal incision was used to expose the fracture focus and the fracture edges were cleaned, as described previously.[12] A temporary reduction was performed with point reduction forceps and checked under fluoroscopy. Factors that determined whether AO TBW or MTTB surgery was performed included the fracture classification and whether it was a revision surgery. Either surgery was deemed appropriate for transverse patellar fracture, and patient choice was taken into consideration in such cases. MTTB was deemed appropriate for comminuted fractures and revision surgeries.

For group 1 (AO TBW), two parallel 2.0-mm K-wires were then inserted through the fracture site from proximal to distal fragment along the long axis. In the sagittal plane, the trajectory of the pin is intended to be placed through the middle third of the patella, from the proximal pole to the distal pole.[4] A stainless steel wire was looped around the K-wire as close to the patella as possible anteriorly in the traditional vertically oriented position of the figure-of-eight configuration with one wire twist. The quadriceps and patellar tendons were left intact, and the ends of the K-wires were bent posteriorly and cut, leaving approximately 5 mm (Figure 1).

For group 2 (MTTB; Figure 2), a ring pin and cable-ready wire was used instead of traditional K-wires and stainless steel wire. A stab incision was made at each end of the ring pin to expose the surface of the bone, and then the rings were slightly punched close to the proximal end of the patella. The upper ends of the ring pin were easily bent due to its special structure, leaving approximately 2 mm; the distal ends were cut as described for group 1. For some comminuted fractures, additional K-wires were used to fix the tiny fragments (Figure 3). The wiring pattern of group 2 consisted of two figure-zero configurations with separate two-wire twists at the adjacent corners. Cerclage wiring was then performed using a cable wire whose knot was also adjacent to the proximal point.

Stability of the fixation was checked through passive full-range movement of the knee. Intraoperative fluoroscopy was used to ensure proper placement of the implant and finally, the congruity of the articular surface. The wound was irrigated and closed in layers; retinaculum defect was also repaired.

Postoperative rehabilitation comprised isometric exercises from day one postoperatively, and protected weight-bearing with the crutch on the first postoperative day. After that, active and passive range of motion (ROM) within 30°, as tolerated, was initiated gradually in the first 4–6 weeks, ROM was then increased to 90° up to 3 months postoperatively. Full ROM was allowed according to the state of

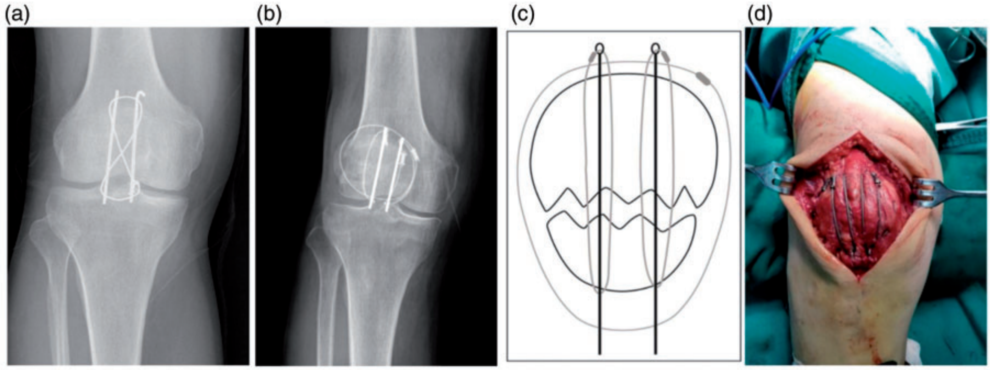

Figure 1. Representative images of patellar fracture treatment showing: (a) anteroposterior radiograph of AO tension-band wiring (TBW) technique; (b) anteroposterior radiograph of modified two-tension-band (MTTB) technique; (c) schematic diagram of MTTB; and (d) intraopertative view following fixation using MTTB.

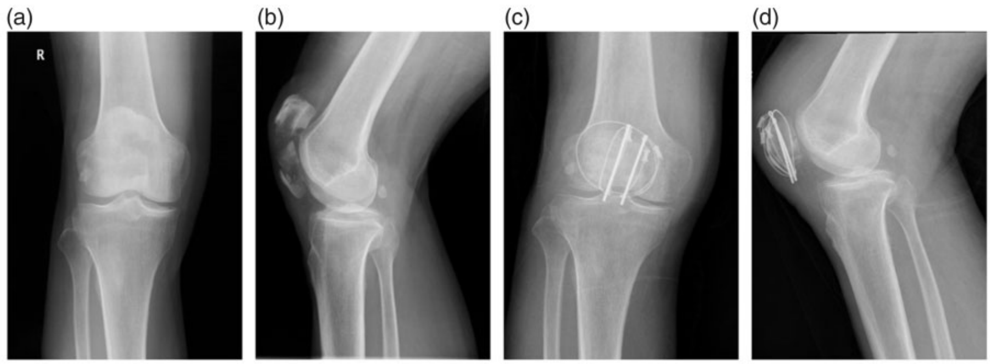

Figure 2. Representative images from the case of a 67-year-old male patient who underwent patellar fracture fixation surgery using the modified two-tension-band (MTTB) technique, showing: (a) anteroposterior and (b) lateral radiographs prior to surgery; and (c) anteroposterior and (d) lateral radiographs at 2 months following surgery.

fracture healing. Patients with complicated fractures were permitted to remain immobilized for 2–4 weeks following surgery.

Patient assessment

All patients were followed up on a general monthly basis during the first 6 months after surgery. After this time, patients with any problem were followed up typically every 2 months. Patients without any problem were permitted to be followed every 6 months. Follow-up radiography was performed at each visit. The cost of hospitalization, time to bone union, complication rates, ROM, and Hospital for Special Surgery (HSS) score[13,14] were recorded during the clinical follow-up. Bone union was defined as the presence of bony trabeculae bridging between patellar fragments on follow-up radiography. HSS scores were measured by an independent

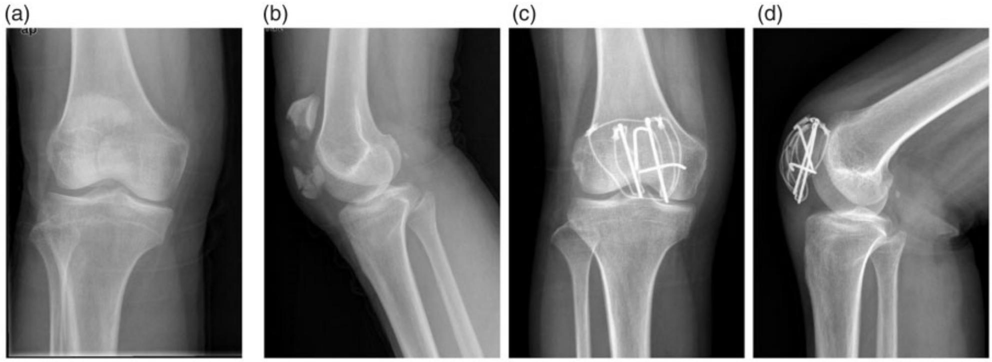

Figure 3. Representative images from the case of a 48-year-old male patient who underwent patellar fracture fixation surgery using the modified two-tension-band (MTTB) technique with an extra two K-wires to fix two tiny fracture parts, showing: (a) anteroposterior and (b) lateral radiographs prior to surgery; and (c) anteroposterior and (d) lateral radiographs at 2 months following surgery.

observer, and ranged from 0 to 100, where a score of 100 indicated no disability.

Statistical analyses

Statistical analyses were performed using SPSS software, version 20.0 (IBM Corporation, Armonk, NY, USA). Continuous and categorical variables are presented as mean $\pm$ SD or number (%), respectively. Pre- and postoperative radiographic and functional assessments were compared using a two-sample *t*-test or χ^2-test, as appropriate. A P value < 0.05 was considered statistically significant.

Results

A total of 51 consecutive patients with patellar fractures were included: 28 patients in group 1 (treated with AO TBW), and 23 patients in group 2 (treated with MTTB). A summary of demographic and clinical data is shown in Table 1. For patients with comminuted fractures, seven patients in group 1 and six patients in group 2 were classified as having 34-C1 fractures; and 11 patients in group 1 and eight patients in group 2 were classified as having 34-C2 fractures. Two patients in group 2 were treated with revision surgery (Figure 4). Four patients in group 1 and five in group 2 were treated using additional K-wires (Figure 3). No statistically significant between-group differences in demographic and clinical characteristics were found, including time between injury and surgery, operation time and BMI (Table 1).

A satisfactory reduction was achieved in all cases, and all patellar fractures healed with anatomical reduction. There was no between-group difference in the time to bone union. Compared with group 1, patients in group 2 attained higher HSS scores at 3 and 6 months postoperatively, and hospitalization costs were higher. However, HSS scores were similar between the two groups at 12 months postoperatively, and patients in both groups achieved identical acceptable ROM (Table 2).

During the follow-up period (Table 2), overall frequency of complications was higher in group 1 (AO TBW; 13 complications [46.4%]) versus group 2 (MTTB; four complications [17.4%]; $P = 0.015$). Amongst patients with complications, six out of 13 patients in group 1 showed further

Table 1. Demographic and clinical data from 51 patients treated for patellar fracture using either AO tension-band wiring (group 1) or modified two-tension-band technique (group 2).

Demographic	Group 1 ($n = 28$)	Group 2 ($n = 23$)
Sex		
Female	16	13
Male	12	10
Age, years	55.0 ± 10.3	54.7 ± 8.1
Body mass index	22.1 ± 3.5	22.1 ± 3.6
Fracture pattern		
Transverse	10	9
Comminuted	18	14
Fracture side		
Left	9	8
Right	19	15
Follow-up duration, months	16.0 ± 3.5	16.8 ± 3.4
Time between injury and surgery, days	2.8 ± 1.2	3.1 ± 1.2
Operating time, min	75.3 ± 12.5	75.3 ± 12.3

Data presented as *n* prevalence or mean ± SD.
No statistically significant between-group differences.

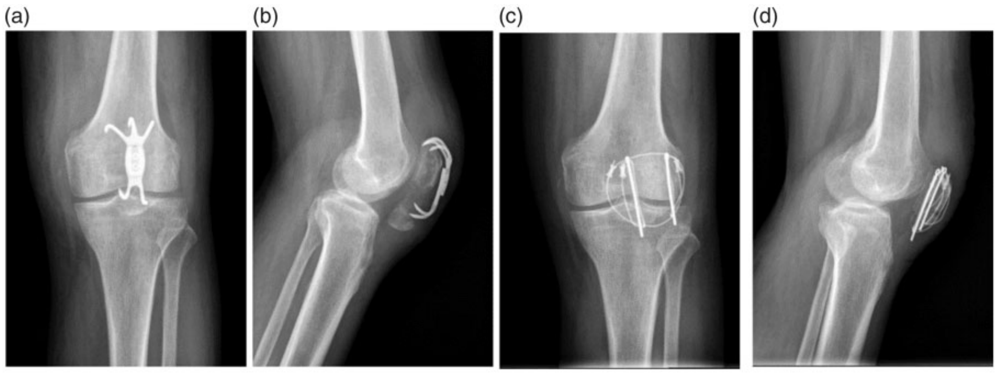

Figure 4. Representative images from the case of a 54-year-old male patient who underwent revision patellar fracture fixation surgery using the modified two-tension-band (MTTB) technique, showing: (a) anteroposterior and (b) lateral radiographs prior to revision surgery; and (c) anteroposterior and (d) lateral radiographs at 2 months following revision surgery.

displacement of the fracture fragment versus two out of four patients in group 2; one patient in group 1 had infection, and also showed delayed fracture union, and was treated conservatively with the use of crutches for an additional postoperative period; five patients in group 1 had implant symptoms (two with accompanying simple implant migration, one with simple broken wire and one with both implant migration and broken wire); and one patient had broken wire without any other simultaneous complications. All patients with broken wire and migrated implants showed progress of patellar fracture union once the breakage of the figure-of-eight

Table 2. Surgical results in 51 patients treated for patellar fracture using either AO tension-band wiring (group 1) or modified two-tension-band technique (group 2).

Characteristic	Group 1 ($n=28$)	Group 2 ($n=23$)	Statistical significance
Time to bone union, weeks	12.5 ± 2.3	12.6 ± 2.1	NS
ROM, degree	114.8 ± 13.5	118.3 ± 14.7	NS
HSS score			
3-month	79.1 ± 7.9	83.5 ± 6.7	$P=0.041$
6-month	86.7 ± 5.8	90.2 ± 5.4	$P=0.031$
12-month	93.2 ± 3.7	94.4 ± 3.4	NS
Complications	13 (46.4)	4 (17.4)	$P=0.015$
Loss of reduction	6	2	
Broken wires	3[a]	0	
Implant symptom	5	2	
Migrated implant	3[b]	0	
Infection (delayed union)	1	0	
Cost of hospitalization, CNY	22001.5 ± 2162.2	31314.6 ± 2151.9	$P<0.001$

Data presented as mean ± SD or *n* (%) prevalence.
ROM, range of motion; HSS, Hospital for Special Surgery.
[a]Two were accompanied by implant symptom; [b]All were accompanied by implant symptom.
NS, no statistically significant between-group difference.

wire was detected. No other complications were observed.

Discussion

The results of the present study showed that MTTB provided satisfactory bony union, better functional outcomes at an early stage and a lower complication rate compared with the AO TBW technique.

Due to its height, the patella increases the moment arm of the quadriceps.[15] Therefore, the principles of therapy to patellar fracture include rebuilding the extensor mechanism and anatomical reduction of the articular surface, which can decrease the occurrence of traumatic arthritis and provide stable internal fixation for early mobilization.[10] Surgery is the preferred treatment for displaced patellar fractures and many surgical procedures with different fixation devices have been used, such as staples, locking plates, and other devices used in combination with tension-band wiring, however, current evidence is limited for guiding the management of patellar fracture.[16] Tension-band wiring is the most widely used technique, and has produced satisfactory outcomes.[3] Forces acting at the fracture site following fixation include either a tensile force, due to the action of the quadriceps in extension, or 3-point bending that occurs during knee flexion. The 3-point bending is essential for the tension-band principle, which neutralizes tension forces anteriorly produced by the extensor mechanism at knee flexion and converts them into stabilizing compressive forces at the articular surface.[5] Only during knee flexion is it possible to obtain sufficient compression at the fracture site, as compression is insufficient when the knee extends fully. Insufficient compression provided by the tension-band devices may lead to fracture displacement, so tension-band devices providing greater compression are needed to prevent fracture displacement.[17]

At the same time, postoperative symptoms and complications related to tension-band wiring are not rare. In a study based on Sawbone® models of transverse patellar fractures, that compared fixed-angle plate with tension-band wiring using K-wires or cannulated screws, Thelen et al.[18] found that the modified tension-band technique showed significant displacement of the fracture gap during cyclic loading. In addition, 22–30% of patients treated with tension-band wiring had a displacement of more than 2 mm.[2,14,19] Compared with screws, fixation with conventional K-wires have shown a higher rate of implant removal caused by symptomatic irritation, and technical errors, noncompliance, and unknown items are the three main factors that lead to fixation failure.[3] Among demographic factors, diabetes has been shown to significantly lead to fixation failure and increase the risk of a second operation.[20] In the present research, there was no significant difference in BMI between the two groups. Regarding technical errors, incorrect implant placement or insufficient band-wire tension are most commonly involved.[3] Hsu et al.[4] found that K-wires at the middle layer of the patella may decrease rates in the loss of reduction. As the trend in patellar fracture incidence shows an increase with increasing age and patellar fracture is gradually treated as fragility fractures,[1] greater wire tension is needed to provide more stable fixation and to decrease the rate of fixation failure through avoidance of technical errors.

Greater interfragmentary compression produced by greater wire tension helps in bone healing and can be used as a measure of resistance to displacement at the fracture site. Although many previous biomechanical studies of various tension bands have been performed on cadavers, opposite conclusions have been drawn versus the clinic, due to differences in properties of the cadaveric patella.[7] To avoid these drawbacks, research using a wooden model of the patella found that placing two twists of wire at nearby corners in a horizontal tension-band construct increases interfragmentary compression by 63%, and increases resistance to cyclic loading compared with the vertical figure-of-eight tension band with a single twist.[5] The authors suggested that further increase of interfragmentary compression can be explained by the following: (1) there is a decrease in losses from friction and plastic deformation with the two twists at nearby corners; and (2) there are four strands crossing the fracture site in a horizontally oriented figure-of-eight.[5] The merits of the biomechanism for excellent postoperative outcomes are also supported by clinical research.[6,7]

The present technique is similar to that used previously;[7] with four strands crossing the fracture site and two twists at the adjacent corner, this type of tension band technique complies with the biomechanical principles described by John et al.[5] At the same time, research has shown that an additional cerclage wire increases the compressive strain.[17] All of these factors suggest that MTTB may be more effective than the AO TBW technique.

Apart from the merits mentioned above, the present study used the ring pin, which has wires threaded through the hole that can prevent them from slipping out of the superior end, instead of traditional K-wire. A previous study reported that the locked TBW using ring pin can avoid the shortcoming of implant migration and perfectly decrease the prominence caused by K-wire fixation.[8] In addition, to avoid fixation failure, wires should be positioned closer to the bone surface at the proximal and superior ends. First, a stab incision is made deep into the surface of the bone to remove as much soft tissue as possible from around the ends of the ring pins. Then, once the wires have been threaded through the hole of the proximal ends, the ring pin is hammered in to make the hole, and thus the wires, closer to the bone surface. Failure to do this may result in failure of the fixation after shifting or necrosis of the soft tissue between the bone-to-implant interfaces.[8,12,21] Due to the ring pin, the ends of the pin are almost 2 and 5 mm left, respectively. The placement of the ring pin is all at the middle layer of the patella, satisfying the construction requirements suggested by Hsu et al.[4] Furthermore, as there are two tension bands, even if one loosens, the other still works.

Instead of stainless steel, cable was used as the tension-band wires and cerclage wire in the present study. Compared with traditional stainless steel, the tensile strength of braided titanium cable is 3- to 6-fold higher, and the fatigue resistance is 9 to 48 times higher,[9] so this braided structure provided greater resistance to fracture displacement. Moreover, the excellent pliability meant that the cables conformed to the bone surface better after tensioning, providing more reliable stability and decreasing the known complications associated with stainless steel wire.[22,23] Thus, in the present study, patients treated with MTTB had better knee function at 3 and 6 months postoperatively, and a lower complication rate, even in the two patients who received revision surgery due of fixation failure. The present authors believe that this technique can be used for patellar fractures, including patellar revision surgery. Regarding more complicated patellar fractures, MTTB combined with additional K-wires for a few tiny fracture parts also attained acceptable outcomes.

The present results may be limited by several factors. First, MTTB is not suitable for all kinds of comminuted patellar fractures, particularly AO classification 34C3-3, as the patella is divided into >4 parts and in the authors' own experience, is sometimes impossible to fix with MTTB. Secondly, the average cost of hospitalization for patients treated with MTTB was higher than that of patients treated with AO TBW, but the cost of hospitalization did not include rehabilitation costs, or losses due to unemployment, etc, so further investigation is required to understand the total costs associated with patellar fracture treatment. Finally, the study was retrospective and the sample size was relatively small, thus, it is unclear whether there was bias in any of the statistical analyses. Further research should involve a large sample, randomized controlled trial.

In conclusion, MTTB using ring pin and cable-ready wire for patellar fracture may provide secure fixation with excellent postoperative results, even for revision surgery. Compared with the AO TBW technique, MTTB provides improved knee function at 3 and 6 months following surgery, and a lower complication rate.

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Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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ORCID iD

Chong Zhang https://orcid.org/0000-0003-4335-8021

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