Received: 2016.05.26
Accepted: 2016.07.14
Published: 2016.08.03

Two-Tension-Band Technique in Revision Surgery for Fixation Failure of Patellar Fractures

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ABCDEF **Zichao Xue**
BCDE **Hui Qin**
BCD **Haoliang Ding**
BC **Haitao Xu**
A **Zhiquan An**

Department of Orthopedic Surgery, Shanghai Jiao Tong University Affiliated Sixth People's Hospital, Shanghai, P.R. China

Corresponding Author: Zhiquan An, e-mail: zhiquan_an@163.com
Source of support: Departmental sources

Background: Failed patellar fracture fixation is rare, and is usually attributed to technical errors. There are no specific details available on how to address this problem. We present our two-tension-band technique for fixing patellar fractures.

Material/Methods: Between March 2010 and March 2013, 4 men and 2 women with failed fixation patellar fractures were treated in our department. Their average age was 34 years (range 23–49 years). The initial fracture type was C1 in 3, C2 in 1, and C3 in 2, according to the AO classification. The initial fracture patterns included 3 transverse and 3 comminuted fractures. There were no open fractures. All patients underwent internal fixation with a modified anterior tension band (MATB) supplemented with cerclage wiring. All failures were caused by tension bands sliding past the tip of the Kirschner wires. The mean time between the primary and revision operations was 16.2 months (range 2–63 months). We revised the fractures by two-separate-tension-band technique.

Results: The mean follow-up was 52 months (range 31–67 months). All patients healed radiographically without complications at an average of 14.7 weeks (range 8–20 weeks). The Bostman knee score was excellent in 3 and good in 3. All patients regained full extension and the mean range of flexion was 147.5° (135–155°).

Conclusions: Use of this two-tension-band technique can avoid technical errors and provide more secure fixation. We recommend it for both primary and revision surgery of patellar fractures.

MeSH Keywords: **Fracture Fixation • Patella • Reoperation**

Full-text PDF: <http://www.medscimonit.com/abstract/index/idArt/899753>

1770 3 2 18

Background

Patellar fractures account for approximately 1% of all fractures [1,2]. The tension band principle has become a widely accepted method for treating this problem [3–5]. It provides rigid fixation and allows early mobilization [2,6,7], ensuring that fixation failure of patellar fractures is rare [5,8]. However, when this complication does arise, advanced fixation methods are often needed for successful management. To the best of our knowledge, only a few investigators have reported fixation failures, and no one has specifically addressed the details of treating a fixation failure.

We present our experience with, and good results of, patellar fracture revision using 2 tension bands in each of 6 patients who sustained fixation failure of a repaired patellar fracture.

The study protocol was approved by the Ethics Committee of Shanghai Sixth People's Hospital affiliated to Shanghai Jiao Tong University.

Material and Methods

Between March 2010 and March 2013, 4 men and 2 women with failed fixation patellar fractures were treated in our department. Their average age was 34 years (range 23–49 years). None had a co-morbidity. The mechanism of the primary injury was a fall in 5 cases and a motor vehicle accident in 1. The left knee was involved in 5 cases and the right in 1. One patient suffered multiple fractures at the time of the primary injury. According to the AO classification, there were 3 C1 type fractures, 1 C2 type fracture, and 2 C3 type fractures. The initial fracture patterns included 3 transverse and 3 comminuted fractures. There were no open fractures (Table 1).

The mean interval between injury and the primary operation was 4 days (range 2–8 days). Each patient underwent internal fixation with a modified anterior tension band (MATB) supplemented with cerclage wiring. Except for 1 referred patient, the average time to fixation failure was 11.8 weeks (range 6–19 weeks) postoperatively. All failures were caused by tensioned cable sliding past the tip of the Kirschner wires (K-wires) (Figure 1). The mean time between the primary and revision operations was 16.2 months (range 2–63 months) (Table 2).

The surgical procedure was explained to the patients, and written informed consents were obtained before the surgery.

Surgical technique

After anesthesia was administered, the patient was placed in the supine position. The lower extremity was prepped and draped in the usual sterile manner. The tourniquet was inflated.

We used the same incision as that performed for the primary surgery. Invalid hardware was removed after being identified. Fibrous tissue at the fracture site was cleared until we could see fresh cancellous bone. An iliac bone graft was inserted and packed into the fracture site when a significant bony defect was encountered. The fracture was reduced and temporarily fixed using point reduction forceps. Intraoperative fluoroscopic images revealed excellent reduction and congruency of the articular surface.

We then inserted 2 2.5-mm Kirschner (K)-wires distally from the proximal pole of the patella through the fracture site and the cortex of the distal fragment. A stab incision was made at each end of the K-wires to expose the surface of the bone. Two stainless steel wires ($\phi 0.8 \times 465$ mm) were looped around the K-wires separately in a figure-eight manner. We tightened the

Table 1. Demographic and fracture details of the patients.

Case No.	Age	Gender	Comorbidities	Mechanism	Side	Associated injuries	AO classification	Fracture pattern	Open fracture
1	23	M	None	Fall	L	None	C1	Transvers	No
2	33	F	None	MVA	L	None	C1	Transvers	No
3	32	M	None	Fall	L	Left radial head and olecranon fractures	C3	Comminuted	No
4	40	M	None	Fall	L	None	C2	Comminuted	No
5	27	M	None	Fall	R	None	C3	Comminuted	No
6	49	F	None	Fall	L	None	C1	Transvers	No

MVA – motor vehicle accident.

Figure 1. A representative case of fixation failure. A 32-year-old man suffered a type C3 patellar fracture after falling (A). It was initially fixed by tension band and cerclage wiring (B). The tension loop slipped out of the K-wires, and fixation failed after 8 weeks (C).

loops to make them cling to the anterior surface of the patella and twisted the steel wires at the insertions in the K-wires. Cerclage wiring was then performed using a cable or a stainless steel wire. The knee was flexed and extended to check the stability of the fixation and to determine if there was any abnormal movement. Intraoperative fluoroscopy was used to ensure that the hardware was properly placed and the articular surface was not displaced. The proximal ends of the K-wires were bent posteriorly and cut, leaving a 6-mm length. We then drew the other ends of the K-wires so the proximal ends

attached to the upper surface. The distal ends were then cut, leaving 5 mm. The wound was irrigated and closed in layers.

Postoperatively, patients were allowed to perform active and passive range of motion (ROM) within 30 degrees in the first 6 weeks. ROM was increased to 90 degrees till 3 months postoperatively. After that, full ROM was allowed according to the situation of fracture healing. In the setting of a tenuous fixation or an osteoporotic patient, immobilization in a cast was prescribed for 4 weeks after the surgery.

Table 2. Treatment details of the patients.

Case No.	Time between injury and primary operation (days)	Primary fixation	Time to failure (weeks)	Time between primary and revision operations (months)
1	3	MATB + Cerclage wiring	14	63
2	3	MATB + Cerclage wiring	13	8
3	6	MATB + Cerclage wiring	7	8
4	8	MATB + Cerclage wiring	Unknown	12
5	2	MATB + Cerclage wiring	6	2
6	2	MATB + Cerclage wiring	19	4

MATB – modified anterior tension band.

Results

All patients were followed up for an average of 52 months (range 31–67 months) after the revision. The mean time to radiographic union was 14.7 weeks (range 8–20 weeks). The Bostman knee score was introduced to evaluate knee function. It takes into consideration factors such as ROM, pain, ability to return to work, muscle atrophy, use of aids, effusion, instability of the knee, and ability to climb stairs. Of a maximum score of 30 points, an excellent outcome is 28–30 points, good 20–27 points, and poor <20 points. At the last follow-up of our patients, the Bostman knee scores were 28 points in 3 patients and 27 points in the other 3. All patients regained full extension. The mean range of flexion was 147.5° (135–155°). No complications (e.g., infection) were detected (Table 3; Figure 2).

Discussion

The tension band technique has been the most commonly used method for treating patellar fractures, including comminuted ones. Numerous studies have proved that it can provide adequate biomechanical stability [7,9–14]. Although the incidence of fixation failure is low [6,8,15], it is still a major postoperative complication. Smith et al. reported a higher rate of re-displacement, with 22% of fractures becoming displaced by ≥2 mm [5].

Some factors are correlated with the fixation failure. Among demographics, only a high body mass index is significantly associated with fixation failure. Neither the fracture type nor the presence of an open fracture affects the final results [8]. During fracture management, technical errors, noncompliance, and unknown items are the 3 main factors that lead to fixation failure [5,8]. Some authors advocate using less prominent material, such as cannulated screws, non-absorbable polyester and second generation non-absorbable suture, to reduce

the risk of re-operation [15–17]. An additional cerclage wire for a tension band was not correlated with fixation failure [8]. In a multivariate regression analysis, Kadar et al. found that a history of diabetes significantly increased the risk of a second operation, including hardware removal, debridement, and revision surgery [15].

Technical errors have been attributed to improper placement of the hardware, to which surgeons should pay attention during fixation [5,6,8]. In our series, all 6 patients exhibited improper placement of the tension band. The tension bands were all passed posterior to the K-wires but did not cling to the insertions, capturing only soft tissue. This allowed the loops to sling around the tips of the K-wires during early mobilization. They therefore did not create an effective tension band construct. The soft tissue between the insertion and the wire weakened the efficiency of the tension band, converting tension into compression (Figure 1B). This led to a prolonged union process during which the wire kept moving around the K-wires. After the loops slipping out of the K-wires, the tension band failed. Once this happened, the other hardware could not provide enough stability [8], and fracture re-displacement was inevitable (Figure 1C). To make it worse, the migration of loops may result in more soft-tissue irritation which would lead to metallic hypersensitivity. That would increase the risk and cost of medical care [8,18].

To the best of our knowledge, little research on treatment recommendation or data has specifically addressed the fixation failure of patellar fractures. In this series, we revised re-displaced fractures by a two-tension-band technique. Because of the quadriceps and the patellar tendon, it is difficult to ensure that the tension wire clings to the insertions of all the ends of the K-wires. We think this is why the primary fixation failed in our 6 patients. Using our technique, 2 wires are looped separately around a single K-wire through stab incisions. This ensures that the wires cling to the K-wires and

Table 3. Results of the revision surgeries.

Case No.	Time of follow-ups (months)	Time to union (weeks)	Bostman Knee Score	Range of motion (extension/flexion)	Complications
1	61	19	27	0/130	No
2	31	13	27	0/155	No
3	51	20	27	0/150	No
4	53	8	28	0/150	No
5	67	15	28	0/150	No
6	48	13	28	0/150	No

Figure 2. A representative case of revision with 2 tension bands. A 33-year-old woman had fixation failure 8 weeks after primary surgery for a patellar fracture. She underwent revision surgery, with the fracture being fixed using 2 tension bands (A). The fracture displayed radiographic union after 3 months (B).

bone at the insertions of the K-wires. In the previous single-tension-band construct, once the slipping happened in any of the K-wire tips, the whole construct failed. Instead of 1 tension band, we used 2 tension bands. Thus, in case one loosens, the other still provides compression.

All of our 6 patients healed without complications. The outcome was excellent in 3 patients and good in the other 3. All patients returned to their normal daily activities with full extension and an average range of flexion of 147.5° (135–155°).

Previous biomechanical studies of various tension bands were invariably done on cadavers with a simple transverse osteotomy, which does not simulate the reality of clinical practice. Also, all of the studies were performed in a load-to-failure condition and ignored cyclic loading, which is more practical.

Therefore, those studies reported wide variations to the extent that they have drawn opposite conclusions [7,9–14]. To resolve these limitations and obtain accurate measurements of interfragmentary compression, John et al. performed a study on wooden models. They found that incorporating a horizontal figure-eight pattern with 4 strands crossing the fracture site, and tensioning the wire with 2 twists at the corner of the tension band, improved interfragmentary compression by 63% compared with the vertical MABT with a single twist. This construct also significantly increased the resistance to cyclic loading. The improvement was achieved by increased number of wire strands passing across the fracture site, and had nothing to do with the materials used [12].

Our technique is similar to that of John et al. It is composed of 2 figure-eight oriented tension bands and has 4 strands

passing through the fracture site. This construct distributes the loads onto 4 strands and makes it more rigid. Placing the twists at the insertions of K-wires decreases losses due to friction and plastic deformation caused by the wire sliding around the K-wires [12]. We believe that our technique provides more secure fixation than does that designed by John et al.

Our study is limited by its small size. However, our aim was to report our experience and present a new alternative treatment technique in management of fixation failure of patellar fracture.

References:

1. Bostrom A: Fracture of the patella. A study of 422 patellar fractures. *Acta Orthop Scand Suppl*, 1972; 143: 1–80
2. Bostman O, Kiviluoto O, Santavirta S et al: Fractures of the patella treated by operation. *Arch Orthop Trauma Surg*, 1983; 102: 78–81
3. Bostman O, Kiviluoto O, Nirhamo J: Comminuted displaced fractures of the patella. *Injury*, 1981; 13: 196–202
4. Levack B, Flannagan JP, Hobbs S: Results of surgical treatment of patellar fractures. *J Bone Joint Surg Br*, 1985; 67: 416–19
5. Smith ST, Cramer KE, Karges DE et al: Early complications in the operative treatment of patella fractures. *J Orthop Trauma*, 1997; 11: 183–87
6. Hung LK, Chan KM, Chow YN, Leung PC: Fractured patella: Operative treatment using the tension band principle. *Injury*, 1985; 16: 343–47
7. Weber MJ, Janecki CJ, McLeod P et al: Efficacy of various forms of fixation of transverse fractures of the patella. *J Bone Joint Surg Am*, 1980; 62: 215–20
8. Hoshino CM, Tran W, Tiberi JV et al: Complications following tension-band fixation of patellar fractures with cannulated screws compared with Kirschner wires. *J Bone Joint Surg Am*, 2013; 95: 653–59
9. Lotke PA, Ecker ML: Transverse fractures of the patella. *Clin Orthop Relat Res*, 1981; (158): 180–84
10. Fortis AP, Milis Z, Kostopoulos V et al: Experimental investigation of the tension band in fractures of the patella. *Injury*, 2002; 33: 489–93
11. Benjamin J, Bried J, Dohm M, McMurtry M: Biomechanical evaluation of various forms of fixation of transverse patellar fractures. *J Orthop Trauma*, 1987; 1: 219–22
12. John J, Wagner WW, Kuiper JH: Tension-band wiring of transverse fractures of patella. The effect of site of wire twists and orientation of stainless steel wire loop: A biomechanical investigation. *Int Orthop*, 2007; 31: 703–7
13. Burvant JG, Thomas KA, Alexander R, Harris MB: Evaluation of methods of internal fixation of transverse patella fractures: A biomechanical study. *J Orthop Trauma*, 1994; 8: 147–53
14. Carpenter JE, Kasman RA, Patel N et al: Biomechanical evaluation of current patella fracture fixation techniques. *J Orthop Trauma*, 1997; 11: 351–56
15. Kadar A, Sherman H, Glazer Y et al: Predictors for nonunion, reoperation and infection after surgical fixation of patellar fracture. *J Orthop Sci*, 2015; 20: 168–73
16. Kumar G, Mereddy PK, Hakkalamani S, Donnachie NJ: Implant removal following surgical stabilization of patella fracture. *Orthopedics*, 2010; 33
17. Camarda L, La Gattuta A, Butera M et al: FiberWire tension band for patellar fractures. *J Orthop Traumatol*, 2016; 17: 75–80
18. Gupta R, Phan D, Schwarzkopf R: Total knee arthroplasty failure induced by metal hypersensitivity. *Am J Case Rep*, 2015; 16: 542–47

Conclusions

The fixation failure of patellar fracture has been attributed to technical errors, most commonly involving improper placement or insufficient band wire tension. The two- tension-band technique can resolve these problems, and it provides secure fixation. The postoperative outcomes were excellent. We recommend this technique for both primary and revision surgery of patellar fractures.

Conflict of interest

There is no conflict of interest in relation to this article.