Revisiting Tension Band Fixation for Difficult Patellar Fractures

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Summary: Patella fractures with comminution, osteoporotic bone, and/or previously failed fixation are exceedingly difficult to reduce and fix. Moreover, the risk of symptomatic constructs and patients who are poorly compliant with postoperative activity restrictions can make these complex fracture patterns an even more challenging scenario. Although there is an array of techniques described for comminuted patella fractures, there lacks an accepted surgical technique for these difficult cases. In this clinical series, we describe an enhancement to the traditional tension band construct that uses additional wires and multiple tension bands to gather and fix comminuted fracture patterns in nontransverse planes, bolster osteoporotic bone, and secure fractures in patients undergoing a revision and/or have potential to be poorly compliant with postoperative activity restrictions. The clinical outcomes of 27 patients demonstrate high rates of bony union, functional range of motion, and low rates of both infection and failure. In conclusion, using the basic principles of tension band wiring remains highly versatile, useful, and economical in approaching difficult patella fractures.

Key Words: patella fracture, tension band, cerclage wire, comminuted patella fracture

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INTRODUCTION

The patella is the largest sesamoid bone in the body and the key component of the knee extensor mechanism for quadriceps leverage. Direct force to the anterior aspect of the knee, indirect force from unanticipated rapid flexion of the knee while the quadriceps is firing, or a combination of direct and indirect mechanisms are the major causes of patella injury.1–4 Fractures of the patella account for approximately 1% of all skeletal fractures and can disrupt extensor function and damage the articular surface of the patellofemoral joint.1,4 Consequently, patella fractures can lead to various amounts of long-term extensor weakness, range of motion limitations, increased incidence of osteoarthritis, and chronic pain.1,2,5–7

The goals of patellar fixation surgery for fractures with significant displacement and/or articular step-off are to restore the extensor mechanism, reduce articular incongruity, preserve patellar bone, and facilitate early knee mobilization.1,3,8 Treatment options include immobilization, open reduction with a tension band wiring construct, lag screw fixation, cerclage wiring, combinations of screw fixation and wiring, plating, and, if a patella is unsalvageable, a partial versus total patellectomy.3,9–15 Open reduction and tension band wiring using AO principles is the current standard of care and the most widely accepted method of fixation for displaced simple transverse fractures without significant comminution, the most common fracture pattern.2,4,16,17 More complex patellar fracture patterns, however, lack a standard treatment protocol. Treatments range widely including standard tension band wiring with or without supplementation of interfragmentary screws or cerclage wires, plate and screw constructs, external fixation, and partial or total patellectomy.5,7–9,17–28

Despite the array of described techniques for comminuted patella fractures, the simple tension band technique remains one of the most commonly used techniques for patella fracture fixation.7,17,29

The following is a retrospective clinical case series describing a method of fixation that uses multiple wires and tension band constructs to address varying degrees of comminution, or simpler patterns in osteoporotic bone. It is also particularly useful for revision surgery and/or for situations where there is concern a patient will be poorly compliant with postoperative activity restrictions. The technique uses established principles of fixation adapted from simple tension band fixation but modified for particularly “difficult” patella fractures. We describe the clinical outcomes of 27 patients in the first clinical case series describing this technique.

OPERATIVE TECHNIQUE

After administration of proper antibiotic prophylaxis, each procedure is performed on a standard radiolucent operating table with the patient supine. The patella is exposed via a midline incision. The bone and fracture pattern is then fully characterized to determine the degree of comminution,
orientation of principal fracture planes, and overall applicability of a multiple wire and tension band technique for fixation. Patellae that are comminuted, osteoporotic, involved revision surgery, have fracture patterns particularly concerning for fixation fragility, and/or are concerning for patient postoperative poor compliance with precautions, are primarily treated using the multiple wire and tension band construct. The technique uses 2 or more 1.6-mm Kirschner-wires (K-wires) across the principal transverse fracture plane and additional 1.6 mm K-wires across each other significant fracture plane. Multiple tension band(s) and cerclage constructs are then assembled using any of the combination of K-wires already applied as deemed necessary to secure each major fracture plane (Fig. 1). Figure-of-eight tension bands and wire cerclages are constructed using 18-gauge stainless steel wire with an attached needle for easier passing. Supplemental screw fixation, if deemed needed, is done with one or more 3.5-mm solid screw or 4.0-mm cannulated screw. Once adequate fixation is achieved, the patient’s wound is irrigated copiously, and closed with layered vicryl and staples on the skin.

**POSTOPERATIVE PROTOCOL**

Patients who are admitted postoperatively received 24 hours of antimicrobial prophylaxis, whereas those discharged the same-day of surgery do not receive additional antibiotic doses. Postoperative activity and physical therapy protocol involve the operative leg being locked in extension in a Bledsoe brace with weightbearing as tolerated for 6 weeks. In addition to bracing, therapy includes both quadriceps isometric exercises and neuromuscular electrical stimulation to help maintain quadriceps muscle bulk. At 6 weeks after surgery, the Bledsoe brace is progressively opened by 10–15 degrees increases of flexion each subsequent week until the brace is discontinued at 12 weeks. As motion is advanced within the brace, the patient has no restrictions and is allowed to continue to weightbear fully and use the limb as able within the range of motion allowed. Physical therapy continues twice a week for 12–16 weeks.

**CLINICAL SERIES**

The present study is a retrospective clinical case series performed on consecutive patients with patella fractures and more than 12 months follow-up who underwent reduction and fixation using a multiple wire and tension band technique at our institution from April 20, 2005 to September 25, 2014. Institutional review board approval was obtained to assess all patella fractures presenting during that period and managed by 2 fellowship trained orthopaedic traumatologists. Exclusion criteria comprised skeletally immature patients, patients who underwent patella fracture reduction and fixation with a technique other than the use of multiple wires and tension bands, and patients with less than 12 months of follow-up. Indications for operative intervention using the technique included fracture diastasis >3 mm and/or articular step-off >2 mm in the setting of one of the following: fracture comminution, osteoporotic bone, revision surgery, and patients at risk for noncompliance with postoperative activity restrictions.

Records reviewed for each patient included preoperative notes, anesthesia notes, and operative reports. A total of 27 patients met inclusion criteria, which constitutes 25% of all the surgically treated patella fractures during the designated time period (107 patients in total). Patient demographic information gathered included age, body mass index, comorbidities (hypertension, diabetes, obesity, and neuromuscular disorders), smoking status, and American Society of Anesthesiologists (ASA) class. The mean age was 50 years (median, 54) with 9 male patients (33.3%) and 18 female patients (66.7%) (Table 1). Comorbidities included 5 patients (18.5%) having diabetes and 8 patients (29.6%) were obese.

**FIGURE 1.** Open reduction internal fixation of a comminuted patella fracture using the multiple wire and tension band technique: AP and lateral preoperative x-rays of a comminuted patella fracture (A), intraoperative x-rays demonstrating the use of K-wires to fix the significant fracture planes and additional tension band and cerclage wire to secure the construct (B).
TABLE 1. Demographic Characteristics for Patients With Multiple Wire and Tension Band Constructs

<table>
<thead>
<tr>
<th>No. Patients</th>
<th>27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)*</td>
<td>50, 54 (33, 65)</td>
</tr>
<tr>
<td>Sex (%)</td>
<td>Male 9 (33.3)</td>
</tr>
<tr>
<td></td>
<td>Female 18 (66.7)</td>
</tr>
<tr>
<td>BMI (kg/m²)*</td>
<td>27.3, 25.6 (23.6, 31.1)</td>
</tr>
<tr>
<td>ASA class (%)</td>
<td>I 6 (22.2)</td>
</tr>
<tr>
<td></td>
<td>II 14 (51.9)</td>
</tr>
<tr>
<td></td>
<td>III 7 (25.9)</td>
</tr>
<tr>
<td></td>
<td>≥ IV 0 (0.0)</td>
</tr>
<tr>
<td>Smoking status (%)</td>
<td>Never 12 (44.4)</td>
</tr>
<tr>
<td></td>
<td>Current 3 (11.1)</td>
</tr>
<tr>
<td></td>
<td>Former 8 (29.6)</td>
</tr>
<tr>
<td></td>
<td>Unknown 4 (14.8)</td>
</tr>
<tr>
<td>Diabetes mellitus (%)</td>
<td>Yes 5 (18.5)</td>
</tr>
<tr>
<td></td>
<td>No 22 (81.5)</td>
</tr>
<tr>
<td>Follow-up (d)*</td>
<td>679, 567 (492, 774)</td>
</tr>
</tbody>
</table>

*Values shown are mean, median, 25th and 75th percentiles in parentheses. BMI, body mass index.

Based on body mass index >30. Current smokers at the time of injury included 3 patients (11.1%). ASA class included mostly patients with ASA class II distributed as indicated in Table 1. Mean follow-up was 679 days (median, 567 days). The fractures were all classified using the standard OTA system as determined using preoperative and intraoperative radiographs as well as radiological and operative report. The most common fracture pattern was a comminuted (OTA 34-C3) patellar fracture comprising 51.9% of cases treated with multiple wire and tension band technique (Table 2). The next most common fracture patterns included stellate (OTA 34-C2) (37%) followed by transverse (OTA 34-C1) (7.4%). Associated injuries included 3 patients (11.1%) with a concomitant quadriceps or patella tendon injury and 2 patients (7.4%) with an open fracture (Table 2).

Multiple wire and tension band constructs were divided into 4 types based on the number of K-wires, tension bands, cerclage wires, and/or screws (Fig. 2). Type I included constructs with 2 K-wires, 2 tension bands, and no cerclage wire (9 constructs, 33.3%). Type II included constructs with more than 2 K-wires, 2 or more tension bands, no cerclage (3 constructs, 11.1%). Type III included constructs with 2 or more K-wires, 1 or more tension bands, and cerclage wire (12 constructs, 44.4%). Type IV included constructs with 1 or more screws with combination K-wires, tension bands, and/or cerclage wire (3 constructs, 11.1%) (Table 2).

The outcome measures recorded included postoperative follow-up, failures of fixation needing revision, postoperative infections needing irrigation and debridement (I&D), removal of implant procedures, need for postoperative reoperation for other patella-related issues (not including loss of fixation, postoperative infection, removal of implant), and both the maximal postoperative range of motion and the time postoperatively it took to get to that point.

**Primary Outcome: Fixation Failure**

Three patients (11.1%) sustained a failure of patellar fixation (Table 3). The median time to failure of fixation and need for revision was 40 days. One patient did not follow postoperative range of motion restrictions and was not wearing a knee immobilizer as had been ordered, 1 patient had a mechanical fall onto the knee with subsequent refracture and loss of fixation, and 1 patient’s construct failed before fracture union.

**Secondary Outcomes: Removal of Implants, Infection, Patella-Related Reoperations**

Nineteen patients (70.4%) required postoperative removal of implants (Table 3). The median time to removal was 260 days. None of the patients had a postoperative infection requiring an I&D. Five patients (18.5%) underwent a patella-related postoperative reoperation (Table 3). Median time to reoperation was 232 days. One patient underwent knee arthroscopy for continued postoperative anterior knee pain with noted intraoperative findings of chondral degeneration, synovitis, and adhesions. Two patients required manipulations for loss of range of motion. One patient needed manipulation along with heterotopic ossification excision and quadricepsplasty for difficulty with range of motion. One patient required a patella tendon repair after their initial surgery and during their removal of implant procedure.

**Range of Motion**

Postoperative range of motion was documented in 26 patients (96.2%) (see Table, Supplemental Digital Content).
Median flexion was 130 degrees. One patient (3.7%) had a reported flexion contracture of 20 degrees and was one of the patients with a failure of fixation due to noncompliance with postoperative activity restrictions. All other patients had full extension without a notable flexion contracture or extensor lag. Median time to maximal range of motion was 461 days after surgery. Two patients in particular had significant postoperative limitations in flexion. One patient had significant preoperative lack of flexion in the setting of a history of ipsilateral thigh carcinosarcoma needing chemoradiation and resection; their postoperative flexion was 30 degrees. The other patient’s patella fracture was in the setting of a motor vehicle accident and sustained an ipsilateral femur fracture needing an intramedullary nail. At last follow-up, the patient had full extension but flexion limited to 45 degrees.

Radiographic Analysis

Postoperative radiographs were sequentially reviewed to determine time from surgery to union and to determine unions, nonunions, and delayed healing (see Table, Supplemental Digital Content 1, http://links.lww.com/BOT/A781). Nonunion was defined as a fracture that is at least 9 months old and has not shown any signs of healing for 3 consecutive months.22 Twenty-two patients (81.5%) demonstrated bony union of their fracture on follow-up radiographic analysis. Median time to union was 168 days. One patient had noted union 560 days after surgery in the setting of preoperative history of ipsilateral thigh carcinosarcoma that underwent chemoradiation and resection. Two patients (7.4%) were determined to have bony nonunion at postoperative follow-up visits; however, both patients did not require revision surgery for the nonunion and maintained acceptable range of motion with full extension and greater than 110 degrees of flexion. Three patients (11.1%) had complicated postoperative courses that made radiographic outcomes from primary fixation unavailable. Two of those patients needed revision surgeries; the first patient sustained a fall and refractured their patella before union, and the second patient had a failed fixation in the early postoperative setting. Both patients went onto bony union after revision surgery. The third patient was noncompliant with postoperative activity restrictions, had loss of fixation in the early postoperative period, and then was lost to follow-up.

<table>
<thead>
<tr>
<th>TABLE 3. Primary and Secondary Outcomes for Patients With Multiple Wire and Tension Band Constructs</th>
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<tbody>
<tr>
<td>No. Patients</td>
</tr>
<tr>
<td>Primary outcome</td>
</tr>
<tr>
<td>No failure</td>
</tr>
<tr>
<td>Failure</td>
</tr>
<tr>
<td>Secondary outcome</td>
</tr>
<tr>
<td>No implant removal</td>
</tr>
<tr>
<td>Implant removal</td>
</tr>
<tr>
<td>Secondary outcome</td>
</tr>
<tr>
<td>No infection</td>
</tr>
<tr>
<td>Infection</td>
</tr>
<tr>
<td>Secondary outcome</td>
</tr>
<tr>
<td>No additional surgery (excluding fixation failure, I&amp;D, implant removal)</td>
</tr>
<tr>
<td>Additional surgery (excluding fixation failure, I&amp;D, implant removal)</td>
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</table>

Values are given as n (%).
DISCUSSION

The objective of the clinical case series was to describe a specific technique that can be adapted to patients presenting with “difficult” patellar fractures, including patella fractures with comminution and/or osteoporotic bone, patient’s present- for revision surgery, situations concerning for fixation fragility using standard methods, and when there is concern for patient noncompliance with a postoperative activity protocol. Our study’s major primary and secondary outcomes paralleled recent large patellar fracture comparative studies, which included 1 major primary outcome of fixation failure needing reoperation and 3 major secondary outcomes: need for removal of implants, postoperative infection needing I&D, need for postoperative reoperation for other patella-related issues.17 Our results demonstrate low rates of fixation failure, no postoperative infections, and a frequent need for symptomatic implant removal.

The recent 2015 Cochrane Review on interventions for treating fractures of the patella in adults concluded that there was limited evidence from randomized controlled trials on both the relative effects of different surgical interventions for treating patella fractures in adults or the relative effects of surgical versus conservative treatments for patella fractures in adults.33 Until further randomized trials and conclusive evidence becomes available, their recommendations are to choose treatment options on an individual patient basis with careful consideration of the relative risks and benefits of each intervention and patient preferences.33

Unlike simple transverse patella fractures, complex patterns lack a standard accepted treatment protocol, and treatment strategies range widely including standard tension band wiring with or without supplementation of interfragmentary screws or cerclage wires, plate and screw constructs, external fixation, and partial or total patellectomy.5,7–9,17–28 Despite the array of described techniques for comminuted patella fractures, the predominant surgical technique described in literature remains the simple tension band technique.7,17,29 Bostman et al reported 86% good to excellent results in their series of patients with comminuted patella fractures treated with tension band wiring with a follow-up study further suggesting improved results when the tension band technique was compared with circumferential wiring, screw fixation, or lower patellar pole excision.7,34 Outcomes results using a simple tension band for comminuted fractures are at times inconsistently reported in the literature, but reported rates of fixation failure mostly remain low at less than 5%.1,7,8,17,34,35 Despite the low fixation failure, authors specifically report the increased difficulty of reducing and fixing comminuted fractures with tension band wiring. Levack et al16 described how increased comminution correlated closely with worse patient results when using simple tension band wiring for comminuted fracture patterns compared with more simple fracture patterns.

Less common techniques have been described in the literature for more comminuted fractures that are technically difficult to reduce and fix. Alternative techniques to standard tension band wiring have been described but usually in the form of small case reports, case series, and surgical technique papers. These include tension band fixation with transversely drilled holes, partial patellectomies with patellar tendon advancement, circular external fixator with arthroscopic reduction, cannulated screw fixation, circumferential cables, patella ring fixation device, basket plates, separate vertical wiring oriented in the sagittal plane, double anterior tension bands, and supplementation with screws, ring pins, and/or circumferential cerclage wires.1–4,7,17,18,21–23,26,36

Despite the lack of conclusive evidence on the use of specific interventions for complex patella fractures, there is agreement on the primary goals of patella fixation—to restore the joint surface, to maintain the continuity of the extensor mechanism, and to provide a stable construct for early joint motion.1,3,16,22,37 Building a stable construct has been the main objective behind many of the described techniques in the literature.3,9–15 Many of the constructs, including the classic tension band technique, were built on the knowledge gained from analyzing and comparing the biomechanics of different constructs.38–41

The literature suggests the ideal fixation for transverse fractures is with the tension band construct.12,16,17,34 Specifically, the modified anterior tension band technique, involving longitudinal K-wires and anterior figure-of-eight looped stainless steel wire, is the widely accepted method for most transverse and comminuted patella fractures.3 Benjamĩn et al40 suggested using the modified tension band fixation, a tension band with longitudinal K-wires, in patients with osteopenia and/or comminuted patellar fractures based on results of biomechanical studies comparing the load to failure for different tension band technique and screw fixation. Their study described concern for fractures at the screw heads using screw fixation in weaker bone that was not observed with tension band fixation.39 Moreover, the modified tension band technique was found to be the most consistent in withstanding greater than 30 kg of tension.39 Furthermore, biomechanical studies also support the addition of cerclage wires for strength; Fortis et al described the addition of a circular cerclage to a tension band construct can significantly increase compressive strains on the posterior patellar surface throughout the entire range of knee movement.38 Their analysis demonstrated that during the initial degrees of knee flexion for patella fractures, a well-tensioned figure-of-eight wire construct produces little compressive strains on the posterior surface and the fracture line tends to separate.38 The compressive forces on the articular surface from the tension band alone will only commence once the knee is in deeper flexion. The cerclage wire is used in our multiple wire and tension band construct when the fracture is highly comminuted to provide compressive circumferential forces while the patella is healing in extension and as postoperative rehabilitation range of motion is slowly increased. In addition, the literature suggests increasing the number of tensioning wire strands crossing the fracture improves compression significantly. John et al42 found that by incorporating a horizontal figure-of-eight pattern with 4 strands crossing the fracture site and tensioning the wire at 2 ends improved interfragmentary compression by 63%. Therefore, these studies taken together suggest that the combination of cerclage and multiple tension bands theoretically creates a sturdier construct optimizing...
compressive forces across the patella fracture lines at all ranges of motion.

The multiple wire and tension band technique combines biomechanical principles with multiple fixation techniques described in literature, including the use of tension bands, multiple K-wires, and cerclage wires and/or rings, to build a strong and stable construct. The guiding principles of the technique being, first, to convert highly comminuted fracture patterns into simple patterns and then, second, to use standard tension bands with or without cerclage wire to maximize compression across fracture planes.

The primary and secondary results of our study are comparable with those studies found in the literature that include all types of patella fractures from simple transverse to highly complex. Unfortunately, there are few studies that solely investigate the treatment of “difficult” patella fractures, such as comminuted fracture patterns, osteoporotic bone, revisions, concern for fragility, and/or situations where there is concern for patient compliance with postoperative activity restrictions. With regard to our primary outcome of failure of fixation, overall this has been shown to be infrequent in the literature and occurred in 11.1% of our treated patella fractures. Failure of fixation has been reported to be 8% by Smith et al and 9.2% by Scott et al in cases using a modified anterior tension band technique, and further reported by Hoshino et al with an incidence of 7.5% and 3.5% with tension band constructs using cannulated screw and K-wires, respectively.17,42,43

The need for implant removal was higher in our case series as compared with the common modified tension band techniques given the additional wires and tension bands used in our technique. A symptomatic implant is the most common reason for removal, and the additional wires placed in our technique hypothetically increase the likelihood of having symptoms postoperatively. Of the treated patella fractures in our study, 70.4% needed implants removed. The modified tension band technique using cannulated screws or K-wires described in the Hoshino et al17 retrospective cohort study reported implant removal in 22.6% and 36.8% of fractures, respectively. However, for studies treating comminuted patella fractures, the reported need for removal is inconsistent; those reported range from 33.3% to 100% depending on the technique and type of fixation construct.26,36,44

Further postoperative outcomes remained similar to those found in the literature. Deep infection requiring I&D is rare and did not occur in our clinical case series; the reported incidence of infection for the common tension band methods in literature is 1.5%-4.4%.17 Nonunion is also uncommon with most series, including those specifically assessing comminuted fractures, reporting rates of less than 1%.26,36,44 In our study, there was a 7.4% incidence of nonunion. Given the fragility of the “difficult” fractures described in our study, the postoperative protocol delayed active range of motion until 6 weeks after surgery. However, despite the delay in postoperative activity, the reported range of motion at last postoperative visit was overall comparable with those seen in reports analyzing motion after the fixation of comminuted patella fractures.7,10,25,36,44 It is also noted that the 3 patients needing postoperative manipulations for limitations in range of motion is a known postoperative complication in other series.1,7

The limitation of the case series includes the small patient cohort, short follow-up period, missing data from patients lost to follow-up, the lack of a control group for comparison, and the absence of biomechanical analysis to confirm the hypothetical increase in structural strength and stability of the described technique. Future studies would ideally include a randomized controlled trial as well as a comparative biomechanical analysis with the aim of describing the advantages of the multiple wire and tension band technique specifically for “difficult” patella fractures.

In conclusion, this case series uniquely describes a highly versatile and economical enhancement to the traditional tension band construct. It is a technique best used in scenarios where there are multiple comminuted fracture planes, concern for future failure of fixation, and/or the need for increased construct strength. Despite the difficult nature of the fractures, the rate of fixation failure and postoperative infection using multiple wire and tension band constructs was low and comparable with many retrospective studies describing single tension band or cannulated screw fixation techniques. However, a symptomatic fixation construct was the most common complication observed with this technique and more frequent than rates found in literature using other standard techniques. The multiple wire and tension band construct may be a technique to consider for particularly difficult patella fractures including those with severe comminution, osteoporotic bone, needing a revisions, and/or situations where there is concern for fixation fragility or patient postoperative noncompliance.

REFERENCES