Conventional operative treatments of patella fractures are frequently associated with implant failure or displacement. Recent biomechanical studies showed that the orientation of the wire loop and the site of the wire twist can affect the fixation strength. The purpose of this study was to compare the clinical outcome of the tension band technique with loops in different orientations and different knot positions. For this retrospective study, 72 patella fractures (71 patients) were fixed with figure-of-eight configurations in combination with 2 K-wires. Patients were divided into 3 groups according to the orientation of tension band construct. A total of 40 patella fractures were placed with figure-of-eight configurations in a vertical orientation either with 1 wire twist (group 1; 16 patella fractures) or with 2 wire twists at the adjacent corners (group 2; 24 patella fractures). Thirty-two patella fractures were placed with figure-of-eight configurations in a horizontal orientation with 2 wire twists at the adjacent corners (group 3). Range of motion, complication rates, and knee scoring scales (Hospital for Special Surgery and Lysholm) were assessed during serial follow-up. Satisfactory reductions were achieved in all groups, but functional results in the early stage were different. Group 3 had better Hospital for Special Surgery and Lysholm scores at 3 months postoperatively; however, at 6 months and 1 year postoperatively, all groups had similar scores. At the 1-year follow-up, all groups achieved acceptable flexion and range of motion. The overall complication rate was lower in the horizontal group (12.5%). Placing the figure-of-eight tension band construct in a horizontal orientation can provide functional benefits in the early stage after patella fractures.
Patella fractures constitute approximately 1% of all skeletal fractures. Open reduction and internal fixation (ORIF) is indicated for fractures with displacements greater than 3 mm, articular incongruity of 2 mm or more, or a disrupted extensor mechanism. Reduction of the articular surface and restoration of the extensor mechanism are imperative for achieving an optimal outcome. The majority of patella fractures are transverse and amenable to fixation with a combination of tension band wiring and ORIF using screws or K-wires. The current gold standard for the operative fixation of transverse patella fractures uses stainless steel 1.6-mm K-wires or screws in combination with stainless steel wire in a modified AO tension band in a figure-of-eight configuration.

However, some recent reports indicate a high failure rate of the modified tension band technique despite previous good results. A review of 49 patella fractures demonstrated that 22% of fractures were displaced more than 2 mm at the fracture site with early mobilization. Complications include early displacement of fractures and soft tissue irritation due to fixation failure or migration of the wires, leading to unsatisfactory long-term results. These complications frequently require an additional surgical procedure, including additional fixation or implant removal. Several modifications have been used to increase the stabilization of the tension band technique along with other techniques.

On the basis of the AO tension band technique, several recent biomechanical studies have tested the interfragmentary compression strength of tension band wiring in a horizontally oriented figure-of-eight placement in a wooden patella model and in animal and cadaveric studies. These studies demonstrated an improvement in the interfragmentary compression in the cyclic loading test. These techniques should decrease displacement of the construct, but clinical comparisons of the orientation of the loop and knot position have not yet been performed.

The purposes of this retrospective study were to compare the clinical and radiographic results between the patients with patella fractures who underwent tension band wiring using a horizontally oriented loop and 2 wire twists at the adjacent corners and those who underwent tension band wiring with a vertically oriented loop and 1 or 2 wire twists and to assess the possibility of tension band wiring by placing the loop in a horizontal position as a modified treatment option for patella fractures.

### MATERIALS AND METHODS

#### Study Design

The institutional review board of the authors’ institution approved this study, and all patients who had been treated with the procedure were available for review. This retrospective study was performed between January 2008 and April 2012. A total of 124 consecutive patients with patella fractures were treated surgically with figure-of-eight configurations in combination with 2 K-wires. Medical records and radiographs were comprehensively reviewed to identify patient demographics, fracture type, union, further displacement, range of motion, knee score rating systems, and complications.

Inclusion criteria were the following: (1) skeletally mature patients with a transverse patella fracture, which was defined as displacement more than 3 mm or articular incongruity of 2 mm or more; (2) ORIF using a tension band technique; and (3) a minimum follow-up of at least 1 year. Exclusion criteria were the following: (1) vertical component of the fracture pattern; (2) use of other fixation device (cerclage wiring or screw fixation); (3) concomitant ipsilateral knee injury or severe osteoarthritis; and (4) previous surgery on the affected knee. All procedures were performed by 1 surgeon (L.S.K.).

#### Patients

Based on the inclusion and exclusion criteria, 71 patients with 72 patella fractures were enrolled in the study. Patients were divided into 3 groups based on the orientation of the loop and knot position in the cyclic loading test. These groups were compared in terms of displacement, range of motion, knee score rating systems, and complications.

### Table 1

**Demographic Data**

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Group 1 (n=16)</th>
<th>Group 2 (n=24)</th>
<th>Group 3 (n=31)</th>
<th>MD or OR</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender, No.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>7 (44%)</td>
<td>10 (42%)</td>
<td>15 (48%)</td>
<td>1.52</td>
<td>.59</td>
</tr>
<tr>
<td>Male</td>
<td>9 (56%)</td>
<td>14 (58%)</td>
<td>16 (52%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean±SD age, y</td>
<td>53.5±12.7</td>
<td>60.1±13.5</td>
<td>59.1±15.3</td>
<td>-1.59</td>
<td>.39</td>
</tr>
<tr>
<td>Side, No.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>6 (38%)</td>
<td>11 (46%)</td>
<td>18 (58%)</td>
<td>1.33</td>
<td>.80</td>
</tr>
<tr>
<td>Right</td>
<td>10 (62%)</td>
<td>13 (54%)</td>
<td>14 (42%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean±SD fracture displacement, mm</td>
<td>18±6.7</td>
<td>17.9±10.2</td>
<td>18.5±10.7</td>
<td>0.7</td>
<td>.74</td>
</tr>
<tr>
<td>Mean±SD follow-up, mo</td>
<td>12.0±4.7</td>
<td>17.3±6.5</td>
<td>17.1±10.5</td>
<td>-1.79</td>
<td>.79</td>
</tr>
</tbody>
</table>

**Abbreviations:** MD, mean difference; OR, odds ratio.

*(Vertically oriented position of the loop with 1 wire twist.)*

*(Vertically oriented position of the loop with 2 wire twists at the adjacent corners.)*

*(Horizontally oriented position of the loop with 2 wire twists at the adjacent corners; includes 1 patient who had 2 fractures.)*

*(OR for categorical variable.)*

*(MD for continuous variable.)*
Patients’ demographic and general medical information are provided in Table 1. Forty patella fractures were treated with traditional vertically oriented figure-of-eight configurations with either 1 wire twist (group 1, 16 patella fractures) or 2 wire twists placed at the adjacent corners (group 2, 24 patella fractures). Thirty-one patients with 32 patella fractures were treated with horizontally oriented figure-of-eight configurations with 2 wire twists placed at the adjacent corners (group 3).

**Surgical Technique**

The operation was performed using the standard procedure for ORIF on the basis of the AO modified tension band technique. First, 2 parallel 1.6-mm K-wires were driven across the fracture site, 5 mm from the articular surface approximately one third the width of the patella from the medial and lateral border. An 18-gauge wire was secured around the K-wire anteriorly in different patterns for each group. The quadriceps and patellar tendons were left intact, and the wire was secured as close to the patella as possible.

The wiring pattern of group 1 used the traditional vertically oriented position of the figure-of-eight configuration with 1 wire twist (Figure 1). The wiring pattern of group 2 used the same as that in group 1 but 2 wire twists were placed at adjacent corners (Figure 2). The wiring pattern of group 3 used a horizontally oriented figure-of-eight configuration with 2 wire twists at the adjacent corners (Figure 3).

Anatomic reduction and secure fixation were confirmed by visual inspection and fluoroscopic imaging. Then, the extensor retinaculum was repaired and the wound was closed in layers.

**Rehabilitation**

For postoperative rehabilitation, passive range of motion exercises were started as tolerated. Protected weight bearing with 2 crutches was allowed on the first postoperative day. Patients were discharged between 3 to 5 days postoperatively. Isometric quadriceps muscle exercise was started the first postoperative day. Active range of motion exercises were started at 3 weeks postoperatively. Full weight bearing without crutches was allowed after 8 weeks postoperatively.

**Patient Assessment**

All patients were followed up in the same manner (generally, biweekly in the first month, monthly until 6 months postoperatively, and every 6 months thereafter). Follow-up radiography was performed at each visit. Bony union and the presence of complications were assessed by anteroposterior (coronal plane), lateral (sagittal plane), and oblique radiographs. The incidences of complications, range of motion, and knee scores 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. The Hospital for Special Surgery (HSS) score evaluates pain, function, range of motion, flexion deformity, and instability of the involved knee as measured by an independent observer. A maximum HSS score of 100 indicates no disability. The Lysholm knee scoring scale was also used to evaluate knee function. Individual scores for locking, instability, pain, swelling, limping, use of walking aids, or decreased ability to climb stairs and to squat were summed. The highest obtainable score is 100, which it indicates no disability.

To reduce measurement errors, radiological measurements were obtained twice by each author and the average values were calculated. Intraobserver reliability was recorded using the criteria of Winer (degree of bias and mean squared error). Reliability was classified according to the intraclass correlation coefficient as absent to poor (0 to 0.24), low (0.25 to 0.49), fair to moderate (0.50 to 0.69), good (0.70 to 0.89), or excellent (0.90 to 1.0). An intraobserver reliability of 0.94 was achieved.

Statistical Analysis
Statistical analyses were performed using SPSS version 20.0 software (IBM Corporation, Armonk, New York). Data were presented as mean±SD for continuous variables and number (percentage) for categorical variables. A one-way analysis of variance followed by the Tukey post hoc test was used to compare the pre- and postoperative radiographic and functional assessments. The level of significance was set at a P value less than .05.

RESULTS
No statistically significant demographic differences were found between groups, including preoperative displacement of fractures (Table 1). Mean follow-up period was 16.3 months (range, 7-27 months). Satisfactory reduction was achieved in all patella fractures. All of the patella fractures healed, with union achieved at an average of 12.5 weeks (range, 9-18 weeks) postoperatively. No difference was found in the time to union between groups. At 3 months postoperatively, group 3 had better HSS and Lysholm scores; however, at 6 months and 1 year postoperatively, the HSS and Lysholm scores were similar in all groups (Table 2). At 1-year follow-up, patients in all 3 groups achieved similar acceptable flexion and total range of motion (Table 3).

All complications during the follow-up period are noted in Table 4.
Comparison of Range of Motion at 1 Year Postoperatively

<table>
<thead>
<tr>
<th>Movement</th>
<th>Group 1 (n=16)*</th>
<th>Group 2 (n=24)b</th>
<th>Group 3 (n=32)c</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extension, deg</td>
<td>-1.2±3.7</td>
<td>-0.9±3.9</td>
<td>-0.8±3.8</td>
<td>.625</td>
</tr>
<tr>
<td>Flexion, deg</td>
<td>137.1±8.5</td>
<td>139.5±7.7</td>
<td>140.1±6.1</td>
<td>.351</td>
</tr>
<tr>
<td>ROM, deg</td>
<td>136.0±10.2</td>
<td>138.8±8.5</td>
<td>139.1±8.2</td>
<td>.298</td>
</tr>
</tbody>
</table>

Abbreviations: deg, degrees; ROM, range of motion.
*Vertically oriented position of the loop with 1 wire twist.
*bVertically oriented position of the loop with 2 wire twists at the adjacent corners.
*cHorizontally oriented position of the loop with 2 wire twists at the adjacent corners; includes 1 patient who had 2 fractures.

Comparison of Complications

<table>
<thead>
<tr>
<th>Complications</th>
<th>Group 1 (n=16)*</th>
<th>Group 2 (n=24)b</th>
<th>Group 3 (n=32)c</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement</td>
<td>6 (37.5%)</td>
<td>7 (29.2%)</td>
<td>3 (9.4%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Delayed union</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Broken wires</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Recalcitrant keloid</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>9 (56.3%)</td>
<td>13 (54.2%)</td>
<td>4 (12.5%)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*aVertically oriented position of the loop with 1 wire twist.
*bVertically oriented position of the loop with 2 wire twists at the adjacent corners.
*cHorizontally oriented position of the loop with 2 wire twists at the adjacent corners; includes 1 patient who had 2 fractures.

The concept of more rigid fixation in patellar fracture is controversial. However, high complication rates are observed with the tension band technique and more rigid fixation facilitates early rehabilitation. Several researchers have tried to overcome the drawbacks of tension band wiring. Some authors treated patellar fracture with other fixation devices; staples, locking plates, and other devices have been used in combination with tension band wiring and many of them have shown better results. However, additional supporting research has not yet been documented. Currently, modified tension band wiring is considered the gold standard for the treatment of transverse patella fractures.

Several recent biomechanical studies assessed the interfragmentary compression strength of tension band wiring with horizontal placement in a figure-of-eight. Baran et al used bovine patella and John et al used a wooden model of the patella; both studies showed improvements in the interfragmentary compression strength in the cyclic loading test. These results are comparable with those of the current study. Improved compression strength results in uniform force distribution, better functional results in the early stage, and decreased complication rates.

The forces that act at the fracture site after fixation are either a distraction 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, in which the tension band converts tensile force into compression force. Greater interfragmentary compression not only helps in bone healing, but it is also a measure of resistance to displacement at the fracture site secondary to distraction forces generated by the quadriceps in extension. John et al reported that the compression force increased by 63% with a horizontally oriented loop with 2 twists at the adjacent corners. In the current study,
the patients in whom the horizontally oriented loops were placed (group 3) had better outcomes in the early stage.

John et al.18 divided vertical oriented tension band construct into 3 groups for use in a wooden model of the patella: 1 twist placed at a random point, 2 twists placed at random points, and 2 twists placed at adjacent corners. The compression force increased by 12% with 2 twists placed at random points and by 18% with 2 twists placed in the adjacent corners.18 Despite this biomechanical study showing better compression force according to the twist number and position, the current study did not show a remarkably different clinical result between groups 1 and 2. The reason is unclear, but the in vitro and in vivo environments are different, so in vivo stress loads may reduce the effect of twists.

The compression strength of wires in a horizontally oriented figure-of-eight is increased due to the increase in the wire segments. A vertically oriented figure-of-eight has 2 wire segments in line with the interfragmentary forces, whereas a horizontal construct has 4 wire segments in line with the interfragmentary forces. Although the horizontally oriented figure-of-eight fixation has been used by Lotke and Ecker,23 it has been used without K-wires. Weber et al.24 showed that the use of K-wires is necessary for the tension band technique to prevent further displacement of the fracture site. To the authors’ knowledge, the current study is the first clinical report on the use of a horizontally oriented loop for tension band wiring for the fixation of patella fractures.

There are some limitations to this study. First, the authors did not assess the results of a horizontally oriented loop with 1 or 2 twists in another position. Hence, the effect of twists could not be determined. Second, the authors did not evaluate the change in residual displacement. The incidence of macroscopic displacement was low in all 3 groups; therefore, other radiological methods may be needed for an accurate comparison of displacement. Third, the study included displaced patellar fractures but not comminuted patellar fractures with multiple displaced and stepped fragments. Further research is needed to assess the efficacy of horizontally oriented figure-of-eight configurations in comminuted patella fractures.

Despite these limitations, this study has several strengths. First, the study had a high follow-up rate for functional evaluation and integrity using various scoring scales and plain radiography postoperatively. Second, compared with other studies, the number of participants in the current study was high, and all of the operations were performed by a single surgeon (L.S.K.) at 1 hospital. Hence, the statistical strength of the study is relatively higher.

These results suggest that the orientation of the loop of figure-of-eight tension band construct affects the functional outcome in the early stage. Compared with a vertical orientation, placing the wire in a figure-of-eight in a horizontal orientation increases the interfragmentary compression force. Hence, better functional outcomes in the early stage and lower complication rates were achieved with the horizontally oriented construct. However, no significant difference was found in the functional results between groups at the 6-month and 1-year follow-up.

REFERENCES


