The goal of surgical treatment of patella fractures is to reestablish the extensor mechanism and restore articular congruence.\textsuperscript{1-3)} Various materials and methods have been applied for the fixation of patella fractures with high rates of treatment success. Proper selection of a construct to fix patella fractures is important because of its subcutaneous location and high level of force transmission during knee movement. Tension band wiring (TBW) has been commonly used for surgery of displaced patella fractures.\textsuperscript{2)} However, hardware irritation and the need for implant removal are often encountered after TBW. There are several issues to consider in association with the selection of the optimal fixation device: low-profile constructs to avoid soft-tissue irritation and biomechanical strength of a material to maintain patella fractures in position after treatment. Furthermore, improved fixation techniques could potentially reduce postoperative complications such as implant migration, loss of reduction, and painful hardware.

We introduce a vertical interfragmentary suture technique using the Nice knot designed to achieve stable fixation of displaced patella fractures and reduce the need for implant removal. The Institutional Review Board of Gumi CHA Medical Center (IRB No. 2019136) reviewed and approved this study.

**TECHNIQUE**

A patient with a patella fracture (Fig. 1A) was positioned on a radiolucent table and a pneumatic tourniquet was used. A sharp dissection was carried down to the fracture site and medial and lateral full-thickness flaps were made to expose the extensor mechanism and the fracture site. The fracture plane and geometry were assessed through the traumatic tears in the medial and lateral retinaculum. The fractured surface was slightly inverted, and 3 or 4 drill holes were made using a 1.8-mm Kirschner wire, which was aimed from the fracture plane to the outer cortical border of the patella. Then, the polydioxanone (PDS) suture was passed in the bone tunnels through a 16-g spinal needle to facilitate shuttle relay of the suture material (e.g., FiberWire; Arthrex, Naples, FL, USA) (Fig. 1B and C). After doubled-over sutures were passed, the displaced fragments were anatomically reduced and held in posi-
tion with a reduction clamp. We usually placed 3 or more sutures at an appropriate distance apart, depending on the fracture geometry (Fig. 1D). Temporary tightening of ties can be adjusted and fracture reduction can be corrected as needed before the knots are finally tightened and secured. In order to further compress the fracture site, we sequentially repeatedly slid and tightened the knots. Finally, to secure the knot, 3 alternating simple knots were made using the 2 separated free limbs. We placed knots at the superior margin of the patella to reduce soft-tissue irritation (Fig. 1E).

As in the Nice knot technique, the suture material was folded in half to get 2 free limbs at one end and a loop on the other. (B) The simple square knot was thrown using the loop on one hand and the 2 free limbs on the other. (C) The loop was opened and both free limbs were passed through it. (D) The knot was then dressed by making the loop smaller. (E) The knot was slid down by pulling the 2 free limbs apart. (F) To secure the knot, 3 alternating half hitches or surgeon’s knots were performed using the 2 separated free limbs.

Lee et al. Sequential Tightening with Nice Knot Tie for Displaced Patella Fracture
Clinics in Orthopedic Surgery • Vol. 12, No. 3, 2020 • www.ecios.org
process can be halted and resumed at any step, as the loop security of the knot prevents slippage. Finally, to secure the knot, 3 alternating simple knots were made using the 2 separated free limbs (Fig. 2F).

Joint congruity was verified with fluoroscopy and the final fixation stability was checked through a full range of knee movement. For the postoperative care, a long leg splint was applied for 2 or 3 weeks and full weight-bearing was allowed (Fig. 3). Then, we applied a hinged brace and allowed progressive knee flexion for the following 4 weeks. Unlike the fracture stabilization mechanism of TBW, fracture stabilization solely depends on the primary compression power of tightening tie, so early rehabilitation was avoided.

DISCUSSION

TBW using AO (Arbeitsgemeinschaft für Osteosynthesefragen) principles is the most widely accepted standard method of fixation for displaced transverse fractures. Beside TBW, there are various methods that can be used to fix patella fractures, including lag screw fixation, wiring through cannulated screws, vertical wiring, and their combinations. Each of these methods has its own advantages and disadvantages. Most of these constructs are placed over the anterior aspect of the patella and make fracture more stable when the knee joint is flexed, but soft-tissue and skin irritation due to implants are reported as postoperative complications. Due to the thin subcutaneous tissue over the anterior aspect of the knee, the implant can cause pain during joint movement and may restrict the knee movement range. Hardware irritation resulting in the need for removal is a frequent complication after treatment, with an incidence of 23% to 52%. Therefore, strong, low-profile constructs are necessary to diminish implant migration, loss of reduction, and painful implant.

Recognition of these complications and limitations led to the search of alternative fixation materials to reduce reoperation rates. Wright et al. reported that FiberWire showed a higher failure strength than the stainless steel wire in the maintenance of a tension band under force. Recently, Bryant et al. reported there was no difference in biomechanical properties in fracture displacement and load to failure between FiberWire and stainless steel wire.

Nice knot tying is a secure suture fixation technique introduced by Boileau et al. It is an easy-to-perform, self-secured, adjustable, solid technique, which combines a double suture with a sliding knot. It can be applied to fix torn tendons, ligaments, and fractured bones in both open and arthroscopic surgery. This technique has several

Table 1. Patient Demographics

| Case | Age (yr)/sex | Type of injury | Fracture location | No. of Nice knot ties | Follow-up (mo) | Union time (wk) | ROM at final FU | F-VAS | Removal of ties | Complication |
|------|-------------|----------------|-------------------|-----------------------|---------------|-----------------|----------------|-------|----------------|--------------|
| 1    | 62/F        | Slip down      | Inferior pole     | 3                     | 12            | 11              | 0–130          | 0     | No             | -            |
| 2    | 45/M        | TA             | Transverse body   | 3                     | 16            | 14              | 5–130          | 1     | No             | Superficial infection |
| 3    | 58/M        | TA             | Transverse body   | 4                     | 13            | 13              | 0–140          | 0     | No             | -            |
| 4    | 67/F        | Slip down      | Transverse body   | 3                     | 12            | 15              | 10–130         | 2     | No             | Preexisting PF arthritis |
| 5    | 72/F        | Slip down      | Transverse body   | 3                     | 14            | 12              | 10–110         | 2     | No             | Delayed union  |
| 6    | 65/F        | Fall down      | Inferior pole     | 3                     | 15            | 12              | 0–130          | 0     | No             | -            |

ROM: range of motion, FU: follow-up, F-VAS: final visual analog scale, TA: traffic accident, PF: patella-femoral.
advantages. First, the doubled-over suture doubles the suture strength. As the tension in each strand is halved, the risk of failure is decreased as well. Using a double-folded, braided material increases internal suture friction, which translates into excellent loop and knot security. Second, knot tying can be easily performed by pulling the free limbs apart, and the process can be adjusted at any step as the internal suture friction prevents slippage. This allows accurate, adjustable tensioning of the suture. Therefore, temporary tying and adjusting for fracture reduction can be performed as required before the final knot securing. Third, the Nice knot remains low profile compared to the metallic hard device and causes less irritation to surrounding tissues. It provides sufficient holding security without excessive complexity and bulkiness.  

We performed a vertical interfragmentary suture with Nice knot tying using a nonabsorbable suture instead of classical TBW in 6 cases of displaced transverse patella fractures as a pilot study (Table 1). There were 4 transverse body fractures and 2 inferior pole fractures. The fractures were relatively easy to reduce and fix due to the lack of comminution or multiple fragmentation. In this technique, postoperative stability depends on the compression force of the ties and the configuration of the fracture plane. If a fracture has comminuted fragments or is crushed, it will be difficult to obtain sufficient strength to withstand the tensile force after the procedure. Hence, our procedure is amenable for simple transverse fractures than severely comminuted patella fractures.

In our pilot study, we achieved solid bony union without soft-tissue irritation, and there was no need for a further operation to remove the securing materials. The Nice knot tying can be an easy-to-perform, alternative technique for the treatment of patella fractures, particularly for displaced simple transverse patella fractures.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

REFERENCES

1. Melvin JS, Mehta S. Patellar fractures in adults. J Am Acad Orthop Surg. 2011;19(4):198-207.
2. Bucholz RW, Heckman JD, Court-Brown CM, et al. Rockwood and Green’s fractures in adults. Philadelphia: Lippincott Williams & Wilkins; 2010. 1761-5.
3. Levack B, Flannagan JP, Hobbs S. Results of surgical treatment of patellar fractures. J Bone Joint Surg Br. 1985; 67(3):416-9.
4. Boileau P, Alami G, Rumian A, Schwartz DG, Trojani C, Seidl AJ. The doubled-suture nice knot. Orthopedics. 2017; 40(2):e382-6.
5. Bryant TL, Anderson CL, Stevens CG, Conrad BR, Vincent HK, Sadasivan KK. Comparison of cannulated screws with FiberWire or stainless steel wire for patella fracture fixation: a pilot study. J Orthop. 2014;12(2):92-6.
6. Song HK, Yoo JH, Byun YS, Yang KH. Separate vertical wiring for the fixation of comminuted fractures of the inferior pole of the patella. Yonsei Med J. 2014;55(3):785-91.
7. 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(7):653-9.
8. Bostrom A. Fracture of the patella: a study of 422 patellar fractures. Acta Orthop Scand Suppl. 1972;143:1-80.
9. LeBrun CT, Langford JR, Sagi HC. Functional outcomes after operatively treated patella fractures. J Orthop Trauma. 2012;26(7):422-6.
10. Lee BJ, Chon J, Yoon JY, Jung D. Modified Tension band wiring using FiberWire for patellar fractures. Clin Orthop Surg. 2019;11(2):244-8.
11. Wright PB, Kosmopoulos V, Cote RE, Tayag TJ, Nana AD. FiberWire is superior in strength to stainless steel wire for tension band fixation of transverse patellar fractures. Injury. 2009;40(11):1200-3.