

# An Acute Oblique Osteotomy and Suture Ligation Procedure to Shorten the Fibula in Lateral Closing-Wedge High Tibial Osteotomy



Kazunori Yasuda, M.D., Ph.D., Eiji Kondo, M.D., Ph.D., Daisuke Ueda, M.D., Jun Onodera, M.D., Ph.D., Koji Yabuuchi, M.D., Yoshie Tanabe, Ph.D., R.P.T., Norimasa Iwasaki, M.D., Ph.D., and Tomonori Yagi, M.D., Ph.D.

**Abstract:** The purpose of this description is to report an “acute oblique osteotomy and ligation” (AOOL) procedure to shorten the fibula in high tibial osteotomy (HTO). A 4-cm longitudinal skin incision is made at the lateral aspect of the leg. After the central portion of the fibula is circumferentially isolated from all the periosteal tissues, a simple osteotomy is performed at the mid-portion of the fibular diaphysis in the quasi-frontal plane, which is inclined by 25 to 30° to the long axis of the fibula. Two thin holes are created beside the osteotomy line on the lateral surface of the fibula. A polyester thread is passed through the 2 holes. After the HTO is completed, the surgeon easily reduces the displaced fibular ends using this thread. This thread is securely tied to keep the contact between the 2 osteotomized surfaces. The AOOL procedure is technically easy and safely performed. We believe that the AOOL procedure is clinically useful to shorten the fibular shaft in HTO.

Lateral closing-wedge (LCW) high tibial osteotomy (HTO) procedures are widely performed for medial osteoarthritic (OA) knees with severe varus deformity. In these procedures, fibular osteotomy is needed to shorten the fibula. Previously, a procedure in which an approximately 1-cm long fibular shaft was transversely resected at the proximal one third portion of the fibula was commonly performed. However, it had a high instance of peroneal nerve palsy.<sup>1-3</sup> Currently, a 1-cm long resection of the fibular shaft at the central portion has been recommended to shorten the fibula in the

LCW-HTO. Nevertheless, it has still been reported that serious intraoperative complications, including fibular nerve palsy and bleeding from the fibular artery or vein, occasionally occur.<sup>3-6</sup> For example, Ramanoudjame et al.<sup>7</sup> and Kurosaka et al.<sup>8</sup> reported that the incidence of the peroneal nerve palsy was 2.8% and 13.7%, respectively, in their clinical experience. In addition, pseudoarthrosis frequently occurs at the osteotomy site in this procedure. For instance, the rate of non-union has been reported to range from 14% to 68%.<sup>7-9</sup> Importantly, Kurosaka et al.<sup>8</sup> pointed out that 13.7% of the patients with the fibular non-union complained of pain or tenderness at the fibular osteotomy site. Thus, the necessity of a fibular osteotomy is regarded as a significant disadvantage in LCW-HTO procedures, and it becomes one of the reasons why medial opening-wedge HTO, in which the fibular osteotomy is not needed, has been more frequently carried out in the world. However, it has recently been reported that the medial opening-wedge HTO has several disadvantages.<sup>10,11</sup> Therefore, it is important to conduct clinical studies to improve the fibular osteotomy procedure associated with LCW-HTO, not only to diminish the intra- and postoperative complications but also to make it technically easier.

Nevertheless, few studies have been conducted to improve the fibular osteotomy since Kurosaka et al.<sup>8</sup> reported an improved procedure reported in 2000. In

From Knee Research Center, Yagi Orthopaedic Hospital, Sapporo (K. Yasuda, D.U., J.O., K. Yabuuchi, T.Y.); Center for Sports Medicine, Hokkaido University Hospital, Sapporo (E.K., N.I.); and Department of Physical Therapy, Hokkaido Bunkyo University, Eniwa, (Y.T.) Japan.

The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

Received December 17, 2019; accepted May 15, 2020.

Address correspondence to Kazunori Yasuda, M.D., Ph.D., Knee Research Center, Yagi Orthopaedic Hospital, 3-Jo 5-Chome, Nishino, Nishi-ku, Sapporo 063-0033, Japan. E-mail: [yasukaz@med.hokudai.ac.jp](mailto:yasukaz@med.hokudai.ac.jp)

© 2020 by the Arthroscopy Association of North America. Published by Elsevier. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

2212-6287/191559

<https://doi.org/10.1016/j.eats.2020.05.008>

**Table 1.** Indications and Contraindications of the AOOL Procedure

Indications	The intact fibula, which is surrounded by normal soft tissues, in the medial osteoarthritic knee that will undergo LCW-HTO with various procedures.
Relative contraindications	Mild deformation of the fibula due to trauma. Mild contracture of the muscles in the anterior, lateral, and deep posterior compartments of the leg. Incomplete palsy of the peroneal nerve. Mild vascular diseases (thrombophlebitis, arteriosclerosis obliterans, etc.).
Absolute contraindications	Various infectious status of the fibula or the soft tissue surrounding the fibula. Remarkable deformation of the fibula due to previous trauma. Extensive contracture of the muscles in the anterior, lateral, and deep posterior compartments of the leg.

AOOL, acute oblique osteotomy and ligation; LCW-HTO, lateral closing-wedge high tibial osteotomy.

their procedure, the fibular head was crushed by circumferentially resecting the cortical bone of the fibular head. However, they described that peroneal nerve palsy occurred in 4.4% of their 45 patients. In addition, this procedure may be technically difficult to perform, particularly in men, whose fibular head is too hard to be easily crushed. Subsequently, this procedure has not

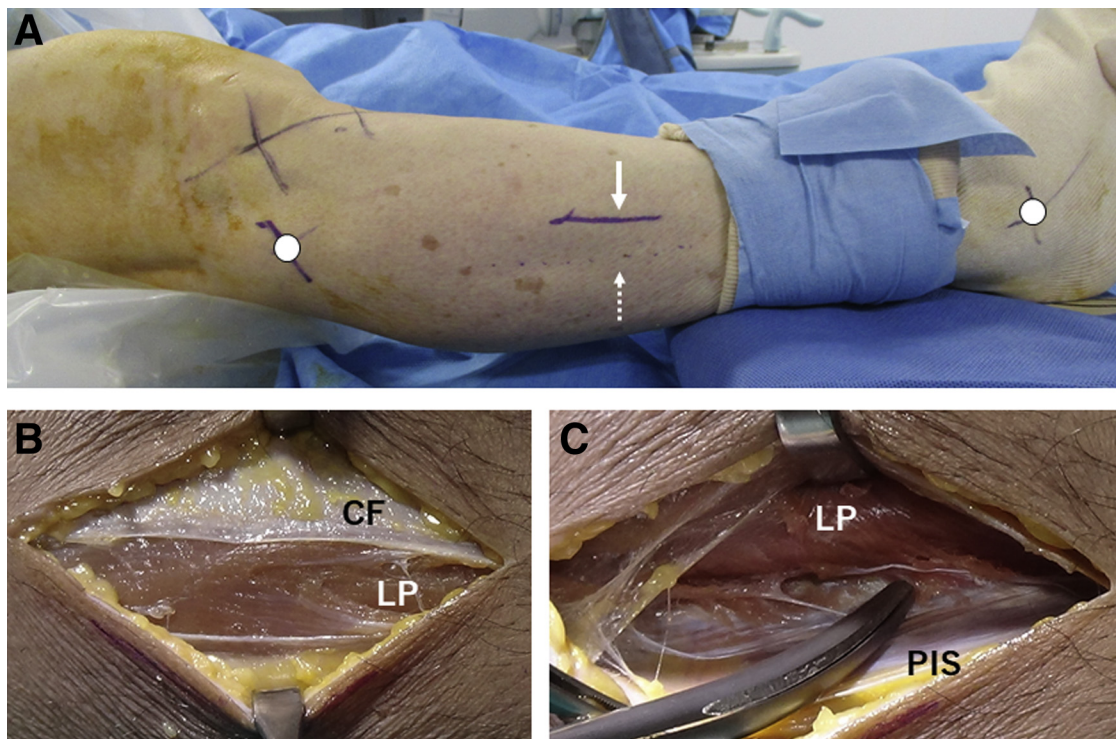
been commonly performed. A safer and easier procedure for fibular osteotomy needs to be developed.

Recently, we have developed a fibular osteotomy procedure for LCW-HTO that is easier and safer with a high union rate of the osteotomized site. In this procedure, briefly, a simple osteotomy is performed at the mid-portion of the fibular diaphysis in an acutely inclined frontal plane of the lower limb. The fibular ends are displaced due to the tibial alignment change after the HTO is completed. Then, the fibular ends are reduced and simply ligated with a polyester thread. The purpose of this surgical technique description is to report this procedure, which is named the “acute oblique osteotomy and ligation” (AOOL) procedure, to enable the reproducible results of this procedure.

## Surgical Technique

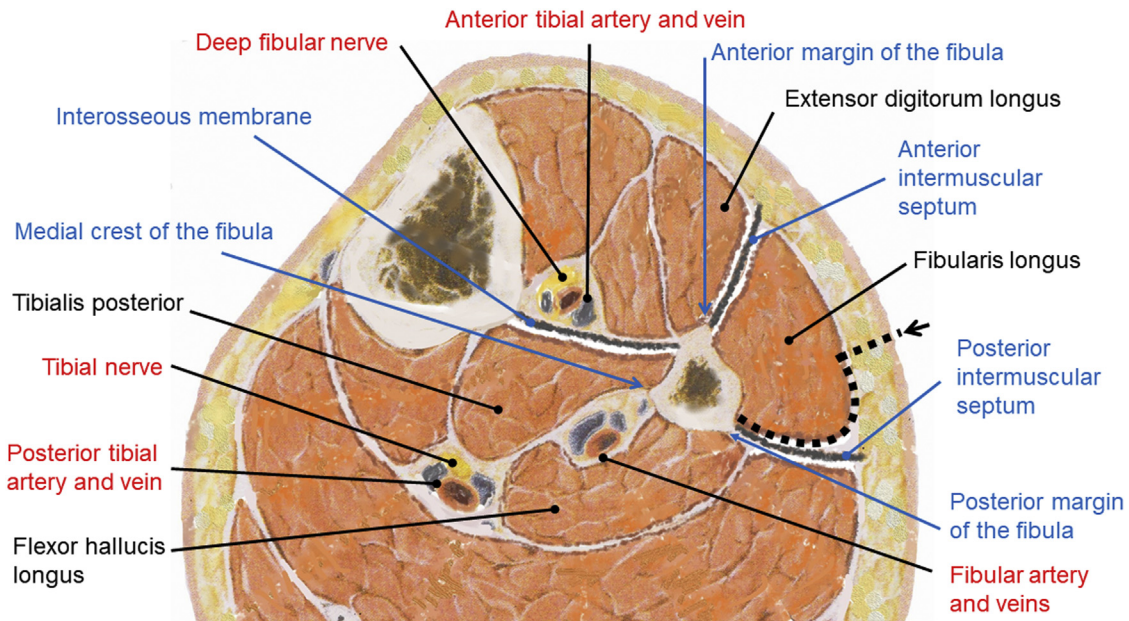
### Indications and Contraindications

This procedure has been authorized by the Ethical Review Board in our hospital. An essential indication of the AOOL procedure is the intact fibula, which is surrounded by normal soft tissue, in the medial OA knee that will undergo LCW-HTO with various procedures (Table 1). In our clinical experience, the AOOL procedure was indicated for almost all knees that underwent LCW-HTO. Relative contraindications are



**Fig 1.** (A) The solid arrow shows a skin incision line and the dotted arrow indicates the location of the posterior intermuscular septum. White circles show the fibular head and the lateral malleolus. (B-C) The CF is resected. The LP released from the PIS is retracted anteriorly. The attachment fibers of this muscle are split along a longitudinal line 3 mm away from the posterior margin of the fibula. (CF, crural fascia; LP, long peroneal muscle; PIS, posterior intermuscular septum.)

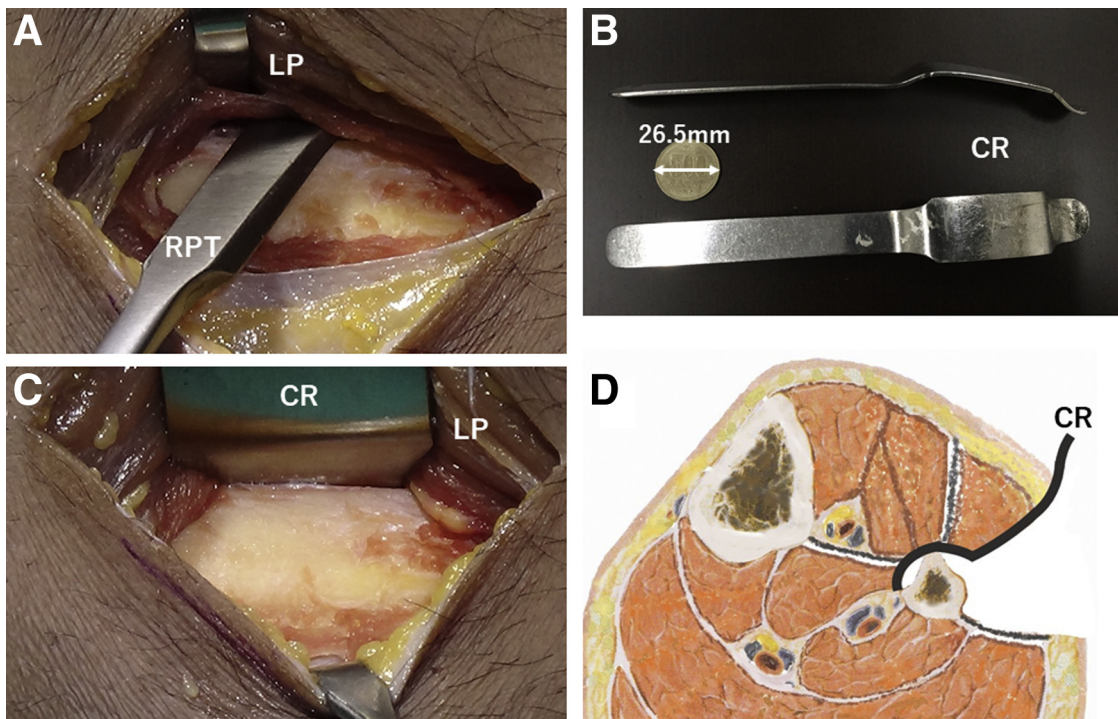




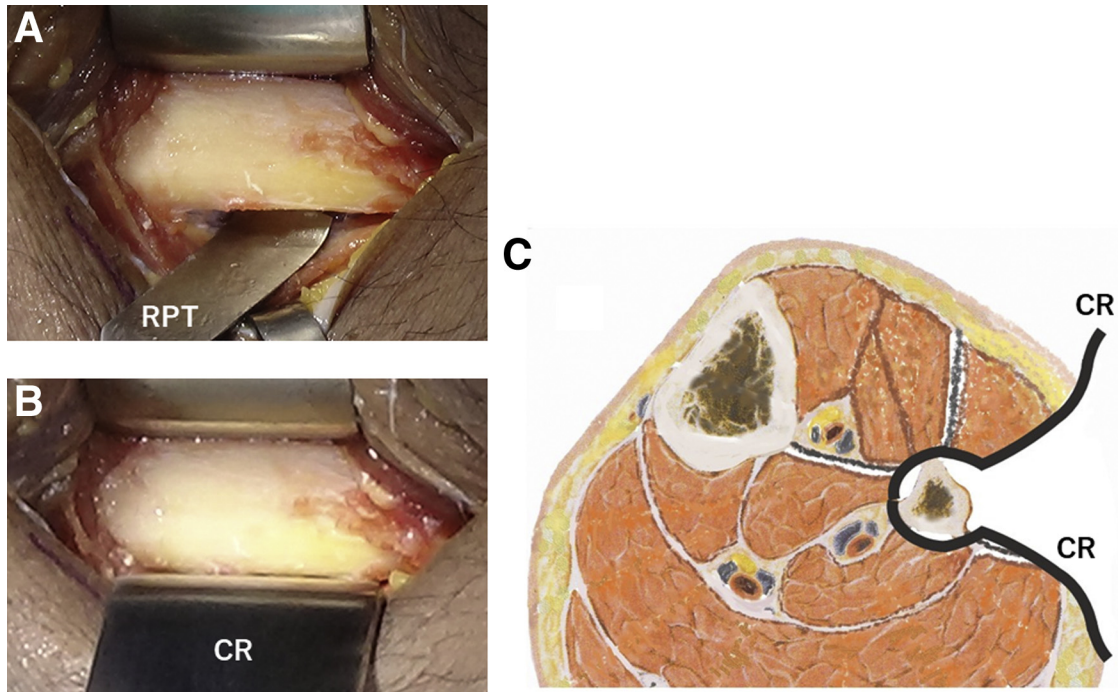
**Fig 2.** Cross-sectional anatomy around the fibula. The dotted line shows an approach from the skin incision (an arrow) to the posterior margin of the fibula along with the posterior intermuscular septum. It is noted that the fibular artery and veins are located near the medial crest of the fibula.

- (1) mild deformation of the fibula due to trauma;
- (2) mild contracture of the muscles in the anterior, lateral, and deep posterior compartments of the leg;
- (3) incomplete palsy of the peroneal nerve; and
- (4) mild vascular diseases including thrombophlebitis,

arteriosclerosis obliterans, and so on (Table 1). In each pathologic status concerning the relative contraindications, a careful examination is needed to determine whether this procedure can be used for the HTO to be performed for an OA knee. Absolute contraindications



**Fig 3.** (A) The periosteal tissues are scraped using a curved RPT from the anterior margin of the fibula, retracting the LP. (B) A CR having a 3-centimeter width. (C-D) The CR is inserted between the scraped periosteal tissues and the medial surface of the fibula. (CR, curved retractor; LP, long peroneal muscle; RPT, raspatorium.)



**Fig 4.** (A) The periosteal tissues are scraped using a curved RPT from the posterior margin of the fibula. (B) Another CR is inserted between the scraped periosteal tissues and the posterior surface of the fibula. (C) The tip of the CR should be placed beyond the medial crest of the fibula. The central portion of the fibula is circumferentially isolated from all the periosteal tissues. (CR, curved retractor; LP, long peroneal muscle; RPT, raspatrium.)

include (1) various infectious status of the fibula or the soft tissue surrounding the fibula, (2) remarkable deformation of the fibula due to previous trauma, and (3) extensive contracture of the muscles in the anterior, lateral, and deep posterior compartments of the leg, which is caused by previous trauma, infection, or neurovascular diseases (Table 1).

### Preoperative Examinations

Preoperative examinations are carried out to detect contraindications and relative contraindications for this procedure. Careful inspection and palpation of the skin and subcutaneous tissues as well as physical examinations of the knee, ankle, and toe motion are made to find out any pathologic changes or muscle dysfunction in the leg. Fibular deformity with ectopic new bone formation can be diagnosed using radiograms and computed tomograms of the leg.

### Patient Positioning

The patient is placed supine on a radiolucent operating table, which is needed for the following HTO surgery to allow for fluoroscopic evaluation from the hip to the ankle, under general anesthesia. For the operative leg, a pneumatic tourniquet is placed high on the thigh. After the whole lower limb is sterilized with iodine solution, the body and the opposite lower limb are draped with sterilized waterproof sheets. A sterilized

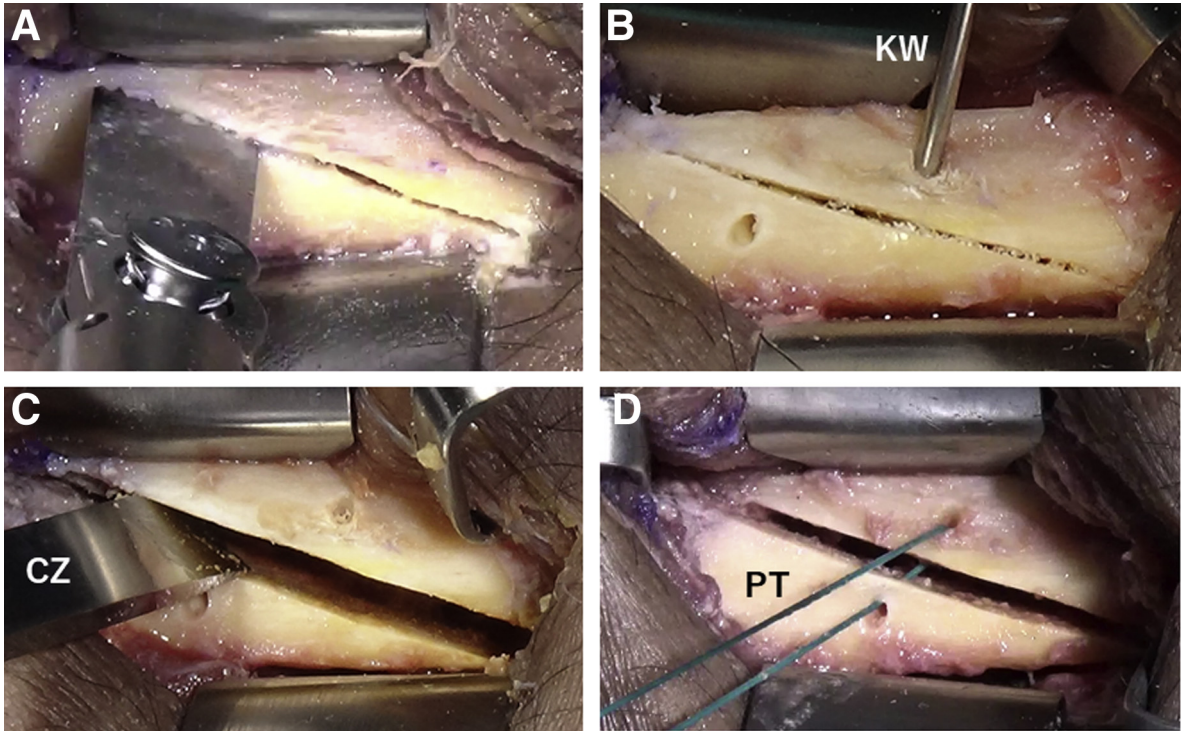
stockinet is used to wrap the foot and the distal part of the leg.

### Fibular Osteotomy (With Video Illustration)

A 4-cm longitudinal incision is made on the skin at the lateral aspect of the leg (Video 1), which is at the central portion between the fibular head and the lateral malleolus (Fig 1A). The crural fascia is exposed by undermining the subcutaneous fat tissue. A longitudinal incision is made on the central portion of the crural fascia (Fig 1B). The posterior part of the long peroneal muscle is easily released from the crural fascia and then released from the posterior intermuscular septum of the leg (Fig 1C). By retracting this muscle anteriorly, the posterior margin of the fibula, to which the posterolateral intermuscular septum is attached, can be identified by palpation, but the lateral surface of the fibula cannot be directly seen because the long peroneal muscle is attached to this surface (Fig 2).

To expose the lateral surface of the fibula, the attachment fibers of the long peroneal muscle are split along a longitudinal line 3 mm away from the posterior margin of the fibula (Fig 1C), and the muscle attachment fibers are scraped from the lateral surface of the fibula (Video 1). The peroneal muscle is retracted anteriorly so that the lateral surface of the fibula is exposed. Then, the surgeon identifies the anterior margin of the fibula at the anterior edge of the lateral aspect (Fig 3A) and scrapes





**Fig 5.** (A) Fibular osteotomy is made on the quasi-frontal plane, which is inclined by 25 to 30° to the long axis of the fibula, using a thin oscillating saw. (B) Immediately before the osteotomy is completed, 2 thin holes are created with a 2-mm thick KW. (C) After the osteotomy is completed with the oscillating saw and a chisel, mobility of the fibular osteotomy site is confirmed by spreading the osteotomized space with the inserted CZ. (D) A PT is passed through the 2 holes. A suture-passage technique is shown in [Figure 9](#). (CZ, chisel; KW, Kirshner wire; PT, polyester thread.)

the periosteal tissues, including the anterior intermuscular septum, the interosseous membrane, and attachment fibers of the extensor digitorum longus muscle ([Fig 2](#)), from the medial surface of the fibula using a curved raspatrium. Then, a curved retractor ([Fig 3B](#)), which has a 3-cm width, is inserted between the scraped periosteal tissues and the medial surface of the fibula ([Fig 3 C and D](#)).

The surgeon identifies the posterior margin of the fibula at the posterior edge of the lateral aspect ([Fig 4A](#)) and scrapes the periosteal tissues, involving the posterior intermuscular septum and attachment fibers of the flexor hallucis longus muscle, from the posterior surface and the medial crest of the fibula using a curved raspatrium ([Fig 2](#)). Special care should be taken in scraping the periosteal tissues from the medial crest to avoid injury of the peroneal artery and vein. Then another curved retractor is inserted between the scraped periosteal tissues and the medial surface of the fibula ([Fig 4B](#)). The tip of the retractor should be placed beyond the medial crest of the fibula. Thus, the central portion of the fibula is circumferentially isolated from all the periosteal tissues ([Fig 4C](#)).

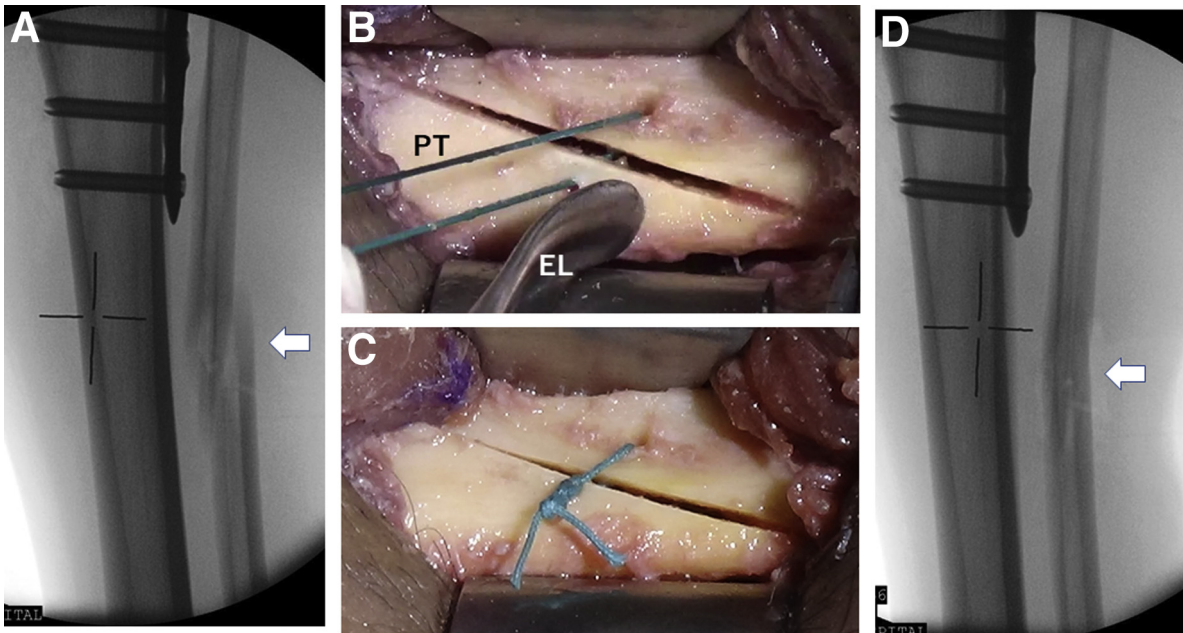
Fibular osteotomy is made using a 10 mm-wide thin oscillating saw ([Fig 5A](#)). The osteotomy line should be on the quasi-frontal plane, which is inclined by 25 to 30° to the long axis of the fibula ([Video 1](#)). Immediately

before this osteotomy is completed, 2 thin holes are created with a 2-mm thick Kirshner wire on the lateral surface of the fibula ([Fig 5B](#)). One hole is in the proximal surface to the osteotomy line, and the other is in the distal part. Each hole is located at a point 3 mm away from the fibular osteotomy line.

Then, fibular osteotomy is completed using the oscillating saw and a chisel ([Video 1](#)). After mobility of the fibula at the osteotomy site is confirmed by spreading the osteotomy plane with the inserted chisel ([Fig 5C](#)), a no. 2 polyester thread (ETHIBOND Excel Suture, Johnson & Johnson Medical N.V., Belgium) is passed through the 2 holes ([Fig 5D](#)). This thread will be used for reduction and fixation of the displaced fibular ends after HTO surgery. The 2 ends of the thread are loosely tied once, and a sheet of gauze is temporarily packed into the space between the long peroneal muscle and the posterior intermuscular membrane. Then, the HTO is started.

### HTO Procedure

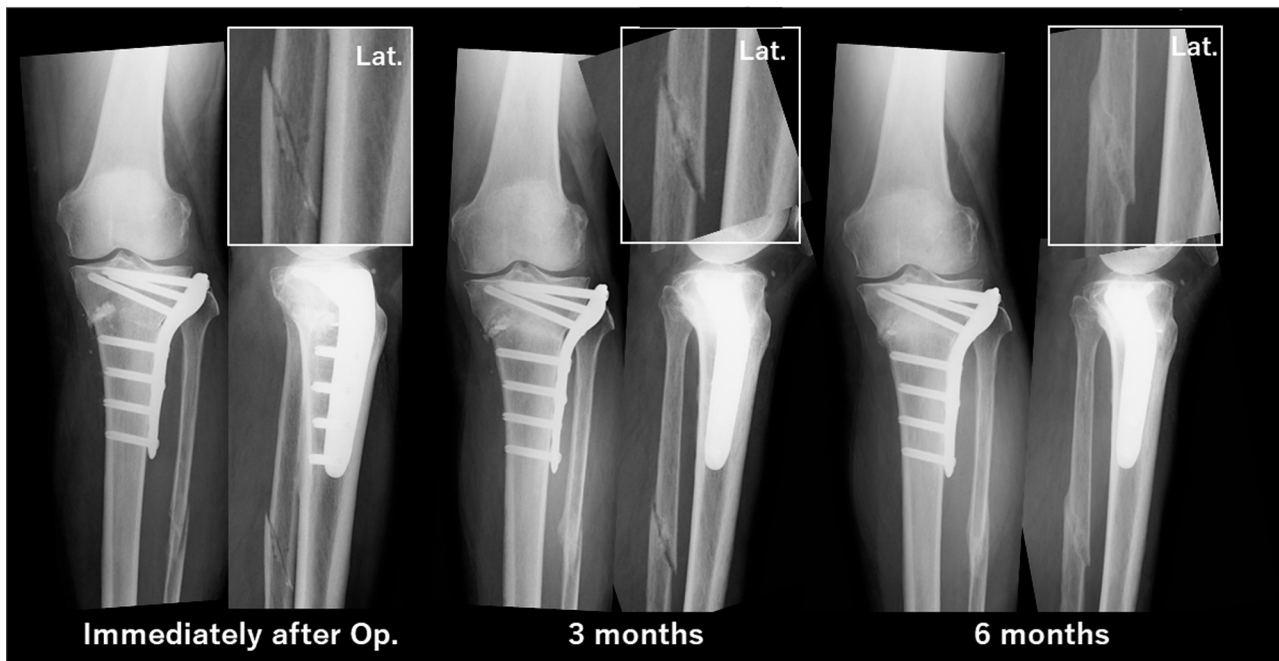
We have commonly performed the inverted V-shaped (iV) HTO,<sup>12,13</sup> a lateral hemi-closing wedge, and medial hemi-opening wedge osteotomy with a local bone graft, which was developed to solve some serious disadvantages of the LCW-HTO procedures. In the iV-HTO procedure, the center of tibial correction osteotomy is



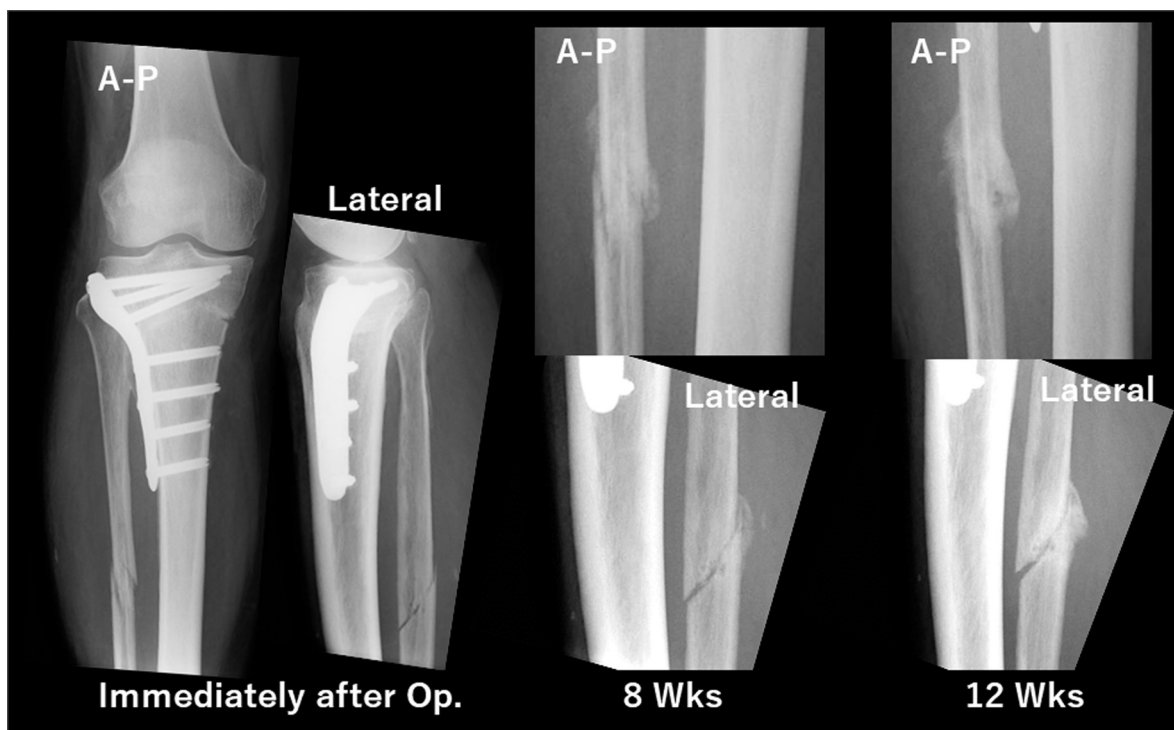
**Fig 6.** (A) The osteotomized fibular ends (white arrow) are displaced after HTO is completed. (B) To reduce the displaced fibular ends, a light tension is applied to the PT, pushing the distal end of the fibula medially with an EL. (C) The thread is securely tied 5 times to keep the contact between the 2 osteotomized surfaces. (D) The displaced fibular ends are almost reduced, leaving some degree of displacement, angulation, and shortening (white arrow). (EL, elevatorium; HTO, high tibial osteotomy; PT, polyester thread.)

placed at a point close to the CORA (center of rotation of angulation). Therefore, this HTO procedure has several absolute advantages, including no limitation on

the degree of valgus correction, no changes in the leg length or the patellar height, minimal deformation of the proximal tibia occurs, no changes of bone stock in



**Fig 7.** A representative case (61-year old woman) of the AOOL procedure for fibular osteotomy associated with HTO. The osteotomized fibular ends were almost reduced immediately after surgery, leaving some degrees of displacement, angulation, and shortening. At 3 months postoperatively, new bone formation was observed at the fibular osteotomy site. At 6 months, bone union was completed. (AOOL, acute oblique osteotomy and ligation; HTO, high tibial osteotomy.)



**Fig 8.** A representative case (62-year old woman) concerning early bone union after the fibular osteotomy with the AOOL procedure. At 2 months postoperatively, new bone formation was observed around the osteotomy site. At 3 months, bone union was completed. (AOOL, acute oblique osteotomy and ligation; A-P, anteroposterior.)

the tibia, no vacant space in the tibia, and less damage to the medial collateral ligament.<sup>13</sup> The details of this procedure have been reported in the literature.<sup>13</sup>

To summarize, through a 7-cm anterolateral curved skin incision, the tibialis anterior muscle attachment is detached subperiosteally from the tibial cortex. Using a C-arm fluoroscope, the surgeon inserts a K-wire at the apex point of the *iV* osteotomy, which is located at the center of the tibial condyle width and approximately 3 cm distal to the joint surface line. The protractor-installed Wedge Cutting Guide (Olympus Terumo Biomaterials Corp, Tokyo Japan) is attached to the apex K-wire, and 2 pairs of other K-wires are inserted into the tibia through the parallel sleeves, so that each inserted K-wire precisely reaches the apex wire. For the biplanar osteotomy, an ascending osteotomy is carried out made in the frontal plane, leaving the tibial tubercle intact with a width of 10 mm. Then, a lateral hemi-wedge bone resection is made along the 2 pairs of previously inserted guidewires, using a thin oscillating saw and a thin chisel. The resected bone wedge is kept moist on the preparation table to be grafted into the medial opening space after the tibial alignment correction. Then, the anteromedial periosteum and a part of the superficial medial collateral ligament is scraped from the tibia just along the medial osteotomy line. The medial side osteotomy is performed with a thin chisel along the thin parallel holes, which have been drilled

using a Parallel Drill Guide (Olympus Terumo Biomaterials). Here, the valgus tibial correction is made by making an incomplete fracture at the apex portion of the V-shaped osteotomy. After the surgeon confirms that the mechanical axis of the corrected knee passes through the Fujisawa point (65%) on the tibial plateau, temporal fixation is carried out with 2 K-wires. Tibial fixation is made using a locking compression lateral plate under observation of the fluoroscopic image. Finally, the bone block resected from the lateral tibia is implanted in the medial opening space created after plate fixation.

After irrigation with normal saline solution, the proximal part of the anterior tibial muscle is tethered with absorbable sutures (no. 0 VICRYL) to fibrous tissue at the lateral edge of the tibial tubercle, leaving a suction tube posteriorly to the installed plate. The subcutaneous tissue and the skin are sutured with absorbable sutures in layers.

#### **Ligation Procedure of the Osteotomized Fibular Ends With a Suture**

The final phase of the fibular osteotomy is resumed (Video 1). The surgeon observes the osteotomized fibular ends, which are displaced due to the alignment correction of the tibia (Fig 6A). Commonly, the proximal fibular end is displaced medially. The surgeon reduces the displaced fibular ends using the following



**Table 2.** Advantages and Limitations of the AOOL Procedure**Advantages**

Technically so easy that the whole fibular osteotomy and ligation procedure can be completed within 10 minutes or less.

Intraoperative and postoperative complications can be almost completely avoided.

Bone union at the fibular osteotomy site can be obtained within 4 months in nearly 100% of the patients.

Does not need any additional cost for special fixation devices, except a thread for ligation.

**Disadvantages**

A 4-cm longitudinal skin incision is needed at the mid-lateral side of the leg.

Some technical experience is needed to quickly pass a thread into the 2 thin holes created on the lateral surface of the fibula.

**Limitations**

It is unknown whether this fibular osteotomy procedure has any limitation concerning the tibial correction angle in HTO.

It is unknown whether there are any clinical symptoms around the fibular osteotomy site at 1 year or more after surgery.

AOOL, acute oblique osteotomy and ligation; HTO, high tibial osteotomy.

maneuver. To reduce the displaced fibular ends, the surgeon applies light tension to the polyester thread that was previously passed through the 2 holes created at both sides of the osteotomy line, pushing the distal end of the fibula medially (Fig 6B). The relatively reduced position is maintained by applying a tension to the thread after this maneuver, because the thread applies reductive and compressive forces to the osteotomized ends. By repeating this maneuver a few times, the displaced fibular ends can be reduced, leaving some degree of displacement, angulation, and shortening (Fig 6 C and D). This thread is securely tied 5 times to keep the contact between the 2 osteotomized surfaces. The complete reduction of the osteotomized fibular ends is not needed, because the fibular ends will be healed with new bone formation within 6 months after surgery in almost all patients. A representative clinical case is shown in Figure 7.

**Wound Closure and Dressing**

The wounds for the fibular and tibial osteotomies are irrigated with normal saline solution. Then, the air tourniquet is released, and bleeding from the fibular osteotomy site is checked. Commonly, it is not necessary to leave a suction tube at the fibular osteotomy site, because the bleeding is very little. Closure of the resected crural fascia is not performed so as to prevent lateral compartment syndrome. Then, the subcutaneous tissue and the skin are sutured with absorbable sutures in layers. A soft dressing is applied to the whole leg without any knee brace.

**Postoperative Rehabilitation**

Postoperative rehabilitation is performed using the protocol for the HTO.<sup>13</sup> For the fibular osteotomy, no specific rehabilitation is needed postoperatively. To

summarize, quadriceps exercise with quadriceps-setting and straight leg raising begins on the next day after surgery. During the first 2 weeks, passive knee motion is encouraged in a range between 0 and 90° of knee flexion. Half weight bearing is allowed at 2 weeks and full weight bearing is permitted at 4 weeks, based on clinical and radiographic evidence of bone healing.

**Discussion**

In the previous literature, Ramanoudjame et al.<sup>7</sup> reported that, in 108 patients who underwent various fibular shaft osteotomy, there were 15 knees with non-union (13.9%) and 3 knees (2.8%) with nerve injury. Kurosaka et al.<sup>8</sup> compared the clinical results of 2 fibular osteotomy procedures. One is a segmental resection procedure at the mid-third of the fibular shaft. The other is an enucleation and morselization procedure at the fibular head. Concerning the former procedure (80 knees), there were 52 knees (65.0%) with non-union at the fibular osteotomy site and 11 knees (13.8%) with peroneal nerve palsy. Regarding the latter procedure (45 knees), there were no knees with non-union at the fibular osteotomy site but 2 knees (4.4%) with peroneal nerve palsy. Bicer et al.<sup>9</sup> pointed out that not only the union rate but the risk of the peroneal nerve palsy was greater after the segmental shaft resection at the proximal third than that at the mid-third. Thus, no previous study reported a procedure which shows the union rate of 100% without any serious complications including peroneal nerve palsy. In our experience (31 knees) with the AOOL procedure,<sup>14</sup> bone union was obtained at 3 months (Fig 8) in 84.0% of the knees, and at 6 months in 100%.<sup>14</sup> Postoperatively, we did not experience any complications, including intraoperative bleeding, peroneal nerve palsy, infection, and so on. In addition, previous literature did not report any data concerning the operation time used for each fibular osteotomy procedure, which showed the technical ease of each procedure. Concerning the AOOL procedure, the operation time ranged between 6.5 and 8.3 minutes.<sup>14</sup>

**Table 3.** Pearls and Pitfalls of the AOOL Procedure**Pearls**

When scraping the posterior periosteal tissues, carefully move a tip of the curved elevator to avoid bleeding from the fibular veins.

The 2 holes should be created with a K-wire on the fibular lateral surface before the fibular osteotomy has been completed.

A special needle in which a looped nylon suture has been passed is useful to quickly pass a polyester thread through each hole.

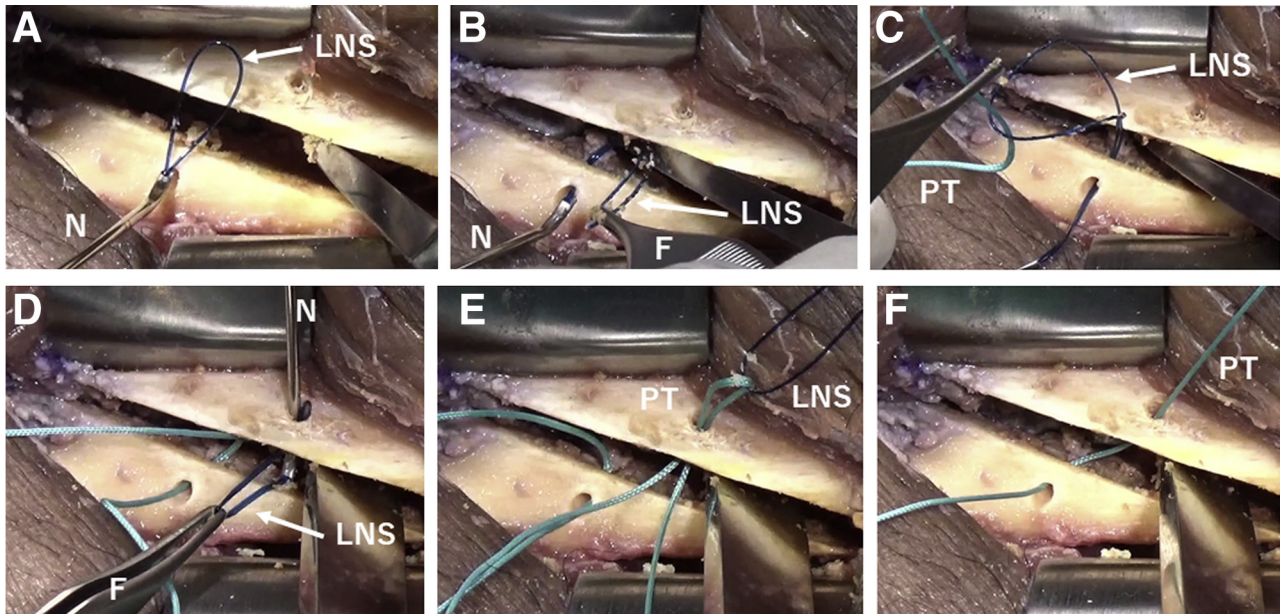
**Pitfalls**

If the degree of inclination of the fibular osteotomy is insufficient, a contact area becomes insufficient, resulting in delayed bone union.

Even if a part of the osteotomized space appeared to be spread 2 or 3 mm, the fibular may not be completely resected.

AOOL, acute oblique osteotomy and ligation.





**Fig 9.** A technique to quickly pass a polyester thread through each hole created on the fibular lateral surface. (A) A special needle (N) having a flexed tip, in which an LNS has been passed. (B) The tip of the needle is inserted into the hole from the lateral surface, and a tip of the suture loop is pulled out from the osteotomized space by grasping it with thin forceps (F). (C) A tip of a no. 2 PT is passed through the nylon loop. (D) The technique B is repeated for the other hole. (E) By pulling out the nylon loop from the hole, the no. 2 PT is passed through the hole. (F) The no. 2 PT is easily passed through the 2 holes. (LNS, looped nylon suture; PT, polyester thread.)

Thus, the AOOL procedure has 4 advantages (Table 2): First, this procedure is technically easy. Second, intra-operative and postoperative complications can be almost completely avoided. Third, bone union at the fibular osteotomy site can be obtained within 6 months in 100% of the patients. Finally, this procedure does not need any cost for fixation devices, except only a thread for ligation. Although we used a polyester suture, we believe that any nonabsorbable thread may be available for the ligation. Therefore, this is an economical advantage. We considered the reasons why the early bone union at the fibular osteotomy site occurs in the AOOL procedure. First, the contact area between the osteotomized surfaces of the fibula in the acute oblique osteotomy obviously increases than that in the conventional segmental resection osteotomy. Second, the suture ligation technique can let the contact between the osteotomized surfaces continue postoperatively. Bicer et al.<sup>9</sup> pointed out that the postoperative presence of diastasis of the osteotomized ends of the fibula significantly delayed bony union. Third, it is considered that the combined forces, which are applied to the whole fibular shaft not only from the ligated thread but also from the preserved interosseous membrane may sufficiently stabilize the osteotomized fibular ends. We consider that, due to a combination of these reasons, the early bone union at the fibular osteotomy site occurs in this procedure.

There are a few disadvantages in the AOOL procedure (Table 2). First, it is a cosmetic disadvantage that a 4-cm longitudinal skin incision is needed at the mid-lateral

side of the leg, although almost all fibular osteotomy procedures have the same disadvantage. The second disadvantage is that some technical experience is needed to quickly pass a thread into the 2 thin holes created on the lateral surface of the fibula. In addition, there are a few limitations of this procedure at the present time. First, it is still unknown about the maximum displacement length of the osteotomized fibular ends, which can be reduced by this procedure. Second, we have not yet carried out a follow-up study to evaluate whether there are any clinical symptoms around the fibular osteotomy site at 1 year or more after surgery, although it is commonly considered that the symptoms disappear after complete bone union. Currently, we are conducting a follow-up study to evaluate the clinical symptoms around the fibular osteotomy site at 2 years or more after surgery.

Pearls of the AOOL procedure are listed in Table 3. First, when the surgeon scrapes the periosteal tissues covering the posterior margin and the posterior surface of the fibula, the surgeon should carefully move a tip of the curved elevator, while letting it come in contact with the surface of the cortical bone surface, to avoid bleeding from the fibular veins, which are located very close to the posterior margin of the fibula. Second, the 2 holes should be created with a K-wire on the fibular lateral surface before the fibular osteotomy has been completed, because the osteotomized ends of the fibula become unstable after the osteotomy is completed. This unstable status of the fibula makes the creation of the 2 holes on the surface difficult. Third, to quickly pass a

polyester thread through each hole created on the fibular lateral surface (Video 1), we use a special needle having a flexed tip in which a looped nylon suture has been passed (Fig 9A). We insert the tip of the needle into the hole from the lateral surface, and we push out the looped nylon suture from the needle to the osteotomized space, which has been spread with a narrow chisel (Fig 9B). Then, we grasp a tip of the suture loop with thin forceps in the osteotomized space, and we pull out the loop from the space (Fig 9B). A tip of the no. 2 polyester thread is passed through the loop (Fig 9C). By pulling out both the needle and the nylon suture from the hole, the no. 2 polyester thread is easily passed through the hole. By repeating this procedure again for the other hole, the no. 2 polyester thread is easily passed through the 2 holes (Fig 9 D, E, and F).

Pitfalls of the AOOL procedure also are listed in Table 3. First, if the degree of inclination of the fibular osteotomy is insufficient, a contact area between the osteotomized surfaces becomes insufficient, resulting in delayed bone union. Second, even if the edges of the osteotomized fibula can be spread 2 or 3 mm by inserting a chisel, the fibular may not be completely resected. To confirm completion of the fibular resection, the surgeon should make sure that both the proximal and distal ends of the osteotomy space can be spread out 3 mm or more by turning the chisel inserted into the osteotomized space.

In conclusion, we believe that the AOOL procedure is clinically useful to shorten the fibular shaft in LCW-HTO. It is commonly considered that an ideal procedure for the fibular osteotomy associated with HTO must have the following features: First, it is technically easy. Second, it is so safe that complications can be completely avoided. Third, complete bone union of the osteotomy site can be obtained in several months after surgery. We consider that the AOOL procedure is close to an ideal fibular osteotomy procedure. However, further long-term follow-up studies are needed to assess the subjective and objective patient outcomes. We encourage further studies by other groups to evaluate this surgical technique.

### Acknowledgments

The AOOL procedure was developed in Yagi Orthopaedic Hospital, Sapporo, Japan. The authors appreciate the staff of the Department of Operation for their specialized assistance to devise the operation techniques. The authors also thank Olympus Terumo Biomaterials Corp., Tokyo, Japan, for supporting the cadaver experiments to develop this osteotomy procedure.

### References

- Jokio PJ, Ragni P, Lindholm TS. Management of the fibula in high tibial osteotomy for arthritis of the knee. Union times and complications. *Ital J Orthop Traumatol* 1986;12: 41-52.
- Rupp RE, Podeszwa D, Ebraheim NA. Danger zones associated with fibular osteotomy. *J Orthop Trauma* 1994;8:54-58.
- Wildner M, Peters A, Hellich J, Reichelt A. Complications of high tibial osteotomy and internal fixation with staples. *Arch Orthop Trauma Surg* 1992;111:210-212.
- Cameron HU, Welsh RP, Jung YB, Noftall F. Repair of nonunion of tibial osteotomy. *Clin Orthop* 1993;287: 167-169.
- Georgoulis AD, Makris CA, Papageorgiou CD, Moebius UG, Xenakis T, Soucacos PN. Nerve and vessel injuries during high tibial osteotomy combined with distal fibular osteotomy: A clinically relevant anatomic study. *Knee Surg Sports Traumatol Arthrosc* 1999;7:15-19.
- Kirgis A, Albrecht S. Palsy of the deep peroneal nerve after proximal tibial osteotomy. An anatomical study. *J Bone Joint Surg Am* 1993;74:1180-1185.
- Ramanoudjame M, Vandenbussche E, Baring T, Solignac N, Augereau B, Gregory T. Fibular nonunion after closed-wedge high tibial osteotomy. *Orthop Traumatol Surg Res* 2012;98:863-867.
- Kurosaka M, Tsumura N, Yoshiya S, Matsui N, Mizuno K. A new fibular osteotomy in association with high tibial osteotomy (a comparative study with conventional mid-third fibular osteotomy). *Int Orthop* 2000;24:227-230.
- Bicer EK, Basa CD, Gunay H, Aydogdu S, Sur H. The fate of fibular osteotomies performed during high tibial osteotomy. *Arch Orthop Trauma Surg* 2016;136:1085-1090.
- Marti CB, Gautier E, Wachtl SW, Jakob RP. Accuracy of frontal and sagittal plane correction in open-wedge high tibial osteotomy. *Arthroscopy* 2004;20:366-372.
- Brouwer RW, Bierma-Zeinstra SM, van Koeveeringe AJ, Verhaar JA. Patellar height and the inclination of the tibial plateau after high tibial osteotomy. The open versus the closed-wedge technique. *J Bone Joint Surg Br* 2005;87: 1227-1232.
- Aoki Y, Yasuda K, Mikami M, Omoto H, Majima T, Minami A. Inverted V-shaped high tibial osteotomy compared with closing-wedge high tibial osteotomy for osteoarthritis of the knee. Ten-year follow-up result. *J Bone Joint Surg Br* 2006;88:1336-1340.
- Kondo E, Yasuda K, Yabuuchi K, Aoki Y, Inoue M, Iwasaki N, Yagi T. Inverted V-shaped high tibial osteotomy for medial osteoarthritic knees with severe varus deformity. *Arthrosc Tech* 2018;7:e999-e1012.
- Ueda D, Yasuda K, Yabuuchi K, Onodera J, Onodera S, Yagi T, Kondo E. Acute oblique osteotomy and ligation procedure with inverted V-shaped high tibial osteotomy. Complications around the surgery and the bone union rate [in Japanese]. *J Jpn Soc Joint Dis* [in press].