Technical Note

Ankle-Angle-Adjusting Fibular Osteotomy in Closed Wedge High Tibial Osteotomy

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Abstract: Closed-wedge high tibial osteotomy (CWHTO) may be carried out to realign the knee in patients with knee osteoarthritis who do not meet the criteria for open-wedge high tibial osteotomy or total knee arthroplasty. The procedure involves both fibular and tibial osteotomy, and care is needed to prevent peroneal nerve and vessel injury during fibular osteotomy. Notably, use of a tourniquet may mask the development of hematomas or aneurysms until after surgery. We developed a 3-step ankle-angle-adjusting (triple-A) technique to relax the muscles, allowing easy retraction of the peroneal vessels. Crucially, the procedure does not require a tourniquet, thus allowing bleeding to be detected and stopped during surgery. The process involves adjusting the ankle angle by plantar-flexion and applying varus stress to highlight the tension difference between the lateral and posterior compartments; plantar-flexion of the great toe to loosen the flexor hallucis longus muscle, thus exposing the fibular posterior aspect; and valgus stress to loosen the peroneus longus muscle. The muscles can then be retracted sufficiently to allow distal and proximal osteotomies to be performed, and any bleeding can be detected and resolved before wound closure. This technique may improve the ease and safety of fibular osteotomy in patients undergoing CWHTO.

The introduction of locking plates designed specifically for the procedure has improved the clinical outcomes of open-wedge high tibial osteotomy (OWHTO).[1] However, cases with a large opening distance or patellofemoral osteoarthritis may require closed-wedge high tibial osteotomy (CWHTO).[2] Some surgeons prefer to avoid CWHTO because of the risk of peroneal nerve palsy induced by fibular osteotomy, which is an essential procedure for CWHTO. Theoretically, fibular osteotomy performed at the middle part of the fibula is extremely unlikely to cause peroneal nerve injury because the nerve runs along the posterolateral edge of the tibia (Fig 1).[3,4] However, tibial osteotomy could result in palsy[5] due to prolonged retraction of the tibialis anterior muscle (TA) in cases with a conventional large incision or crude insertion through the TA using a minimally invasive technique.

During fibular osteotomy, close attention should be paid to the peroneal artery and/or vein(s) that run along the medial crest of the fibular shaft.[3,4] However, use of a tourniquet may cause injury to the peroneal vessel(s) to be overlooked and only detected postoperatively, indicated by abnormal swelling, uncontrolled bleeding, or pain.[6] Wang et al.[7] suggested that more complete hemostasis could be achieved by identifying the potential bleeding locations during surgery using a nontourniquet technique. We therefore do not use tourniquets during fibular osteotomy or other osteotomies, or during total knee arthroplasty (TKA). Here, we present a safe and reliable nontourniquet fibular osteotomy ankle-angle-adjusting (triple-A) technique to retract the peroneal vessels.

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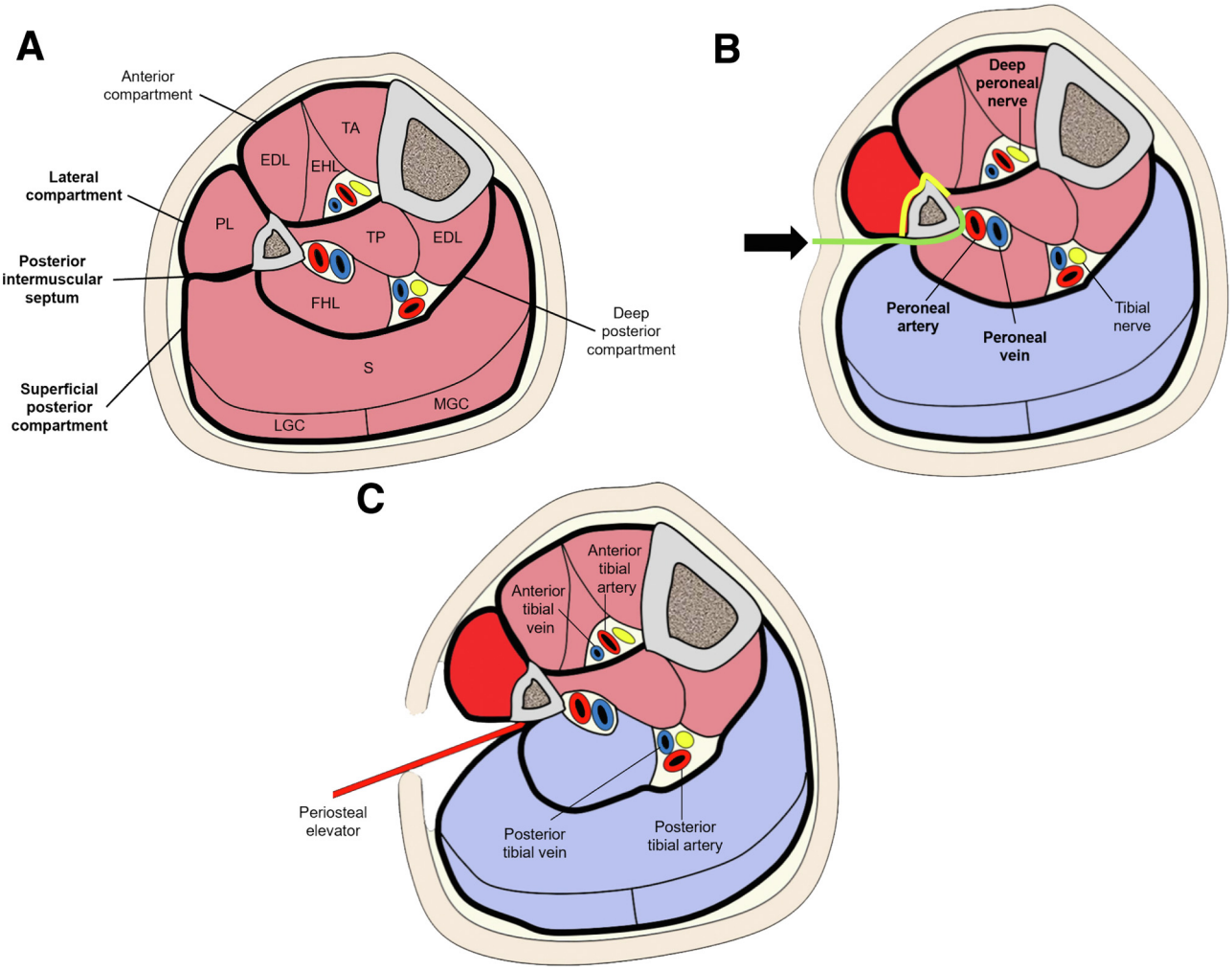

Fig 1. Schema showing midsection of the lower leg in ankle-angle-adjusting (triple-A) fibular osteotomy. During triple-A fibular osteotomy, tension of the muscles around the fibula is controlled to allow the safe and easy retraction of the attached muscles. Red and light blue indicate tensed and relaxed muscles, respectively. (A) The border between the lateral and superficial posterior compartments cannot be detected on the skin surface in the neutral ankle position. (B) Varus stress with plantar-flexion tenses and relaxes the lateral and posterior compartments, respectively, enhancing the intercompartmental tension difference. The concave skin produced by the tension difference can be palpated easily (black arrow). Green and yellow lines indicate posterior and anterior approach routes, respectively. (C) Plantar-flexion of the great toe reduces the tension of the FHL, which facilitates detachment of the FHL muscle from the posterior aspect of the fibula. (D) The peroneal vessels just medial to the medial crest of the fibula are gently detached and the posterior retractor is hooked over the crest. (E) Valgus stress of the ankle relaxes the PL muscle. (F) The relaxed PL muscle can be easily detached from the lateral aspect of the fibula. (G) The anterior retractor is hooked over the anterior margin of the fibula. The muscle belly of the TP, which attaches to the medial aspect of the fibula, becomes the only unretracted tissue during fibular osteotomy; however, it can be safely detached from the fibula after completing the distal and proximal fibular osteotomies by flipping the osteotomized part. (EDL, extensor digitorum longus; EHL, extensor hallucis longus; FDL, flexor digitorum longus; FHL, flexor hallucis longus; LGC, lateral head of the gastrocnemius; MGC, medial head of the gastrocnemius; PL, peroneus longus; S, soleus; TA, tibialis anterior; TP, tibialis posterior.)

Indication and Surgical Procedure of CWHTO

High tibial osteotomy, including OWHTO or CWHTO, is indicated for knee osteoarthritis when the patient satisfies the following criteria: medial compartment osteoarthritis, location of the deformity centered on the proximal tibia, and flexion contracture <10°. OWHTO is the preferred choice when the patient meets the following additional criteria: preoperatively calculated opening distance <12 mm, nonsmoker, absence of severe osteoporosis, and flexion contracture <5°, while CWHTO is indicated in patients who do not meet these additional criteria. There are several types of CWHTO, and we performed hybrid CWHTO,[8] which can

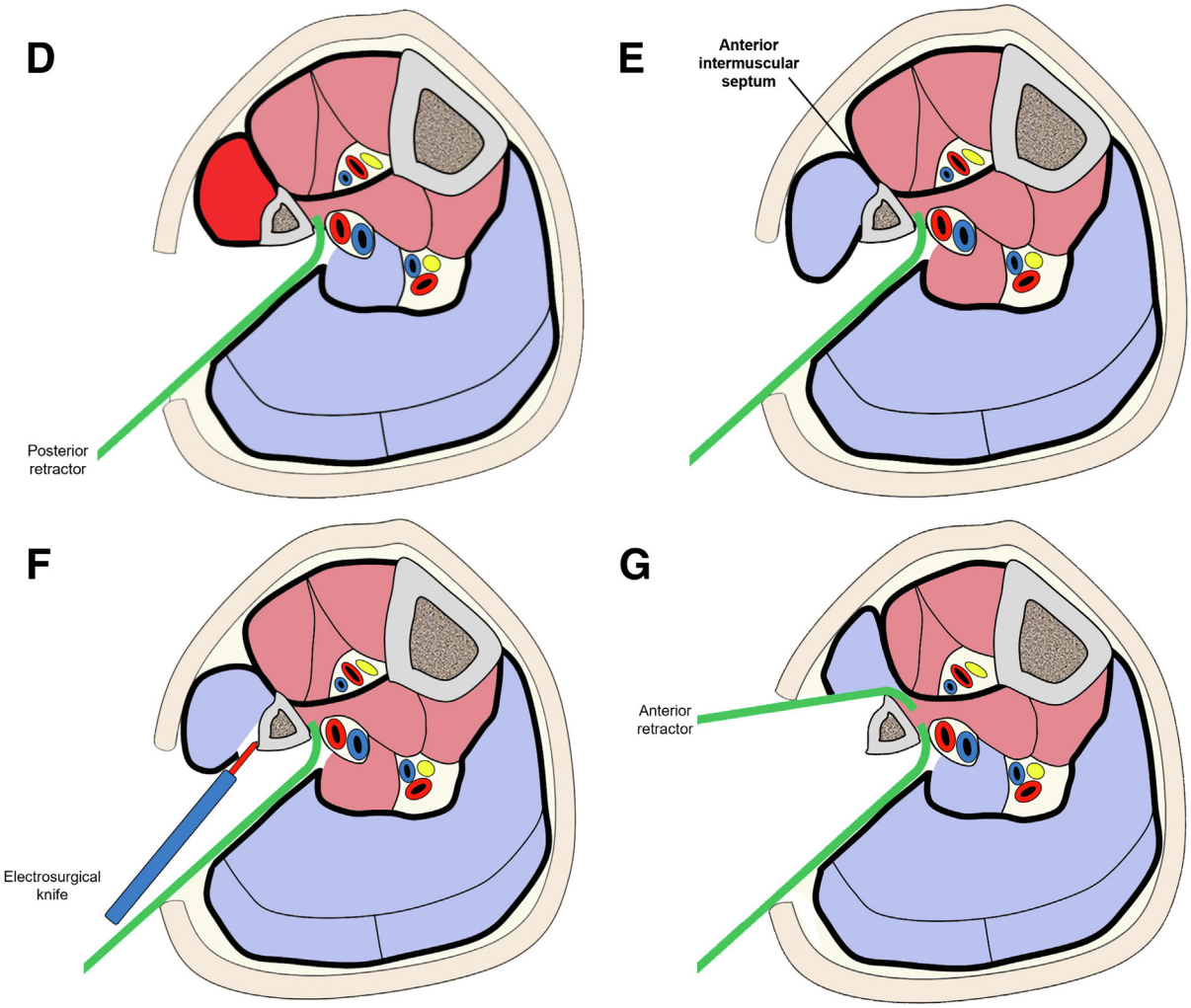

Fig 1. (*continued*).

control the posterior tibial slope and patellofemoral alignment.

Surgical Procedure

Preparation (Video 1)

The patient is placed in a supine position under general anesthesia, and an initial arthroscopy is performed before the fibular osteotomy. No tourniquet is used throughout the whole arthroscopy, fibular osteotomy, and tibial osteotomy procedure. In this report, we focus on the procedure of triple-A fibular osteotomy.

Skin Incision (Video 1)

The first crucial step in fibular osteotomy is the accurate detection of the intercompartmental plane between the lateral and superficial posterior compartments (Fig 1A). The patient's heel is placed on a high pillow to make the posterior muscles droop under gravity, and the ankle is plantar-flexed for further posterior muscular relaxation (Fig 2A). Varus stress is applied to tense the lateral muscles (Fig 2A). The tension difference between the peroneus longus muscle and the soleus muscle can easily be felt by palpating the skin at the midpoint of the fibula (Figs 1B, 2B). A straight 4-cm longitudinal incision is then made just at the interface (Fig 2B).

Posterior Exposure (Video 1)

The crural fascia is dissected using a knife, directly at the interface between the peroneus and soleus muscles, which can be detected by the intercompartmental fat tissue (Fig 2C) and by the tension difference. The interface is gently separated with blunt scissors and a finger (Fig 2D). The great toe is plantar-flexed to reduce the tension of the flexor hallucis longus muscle (FHL)

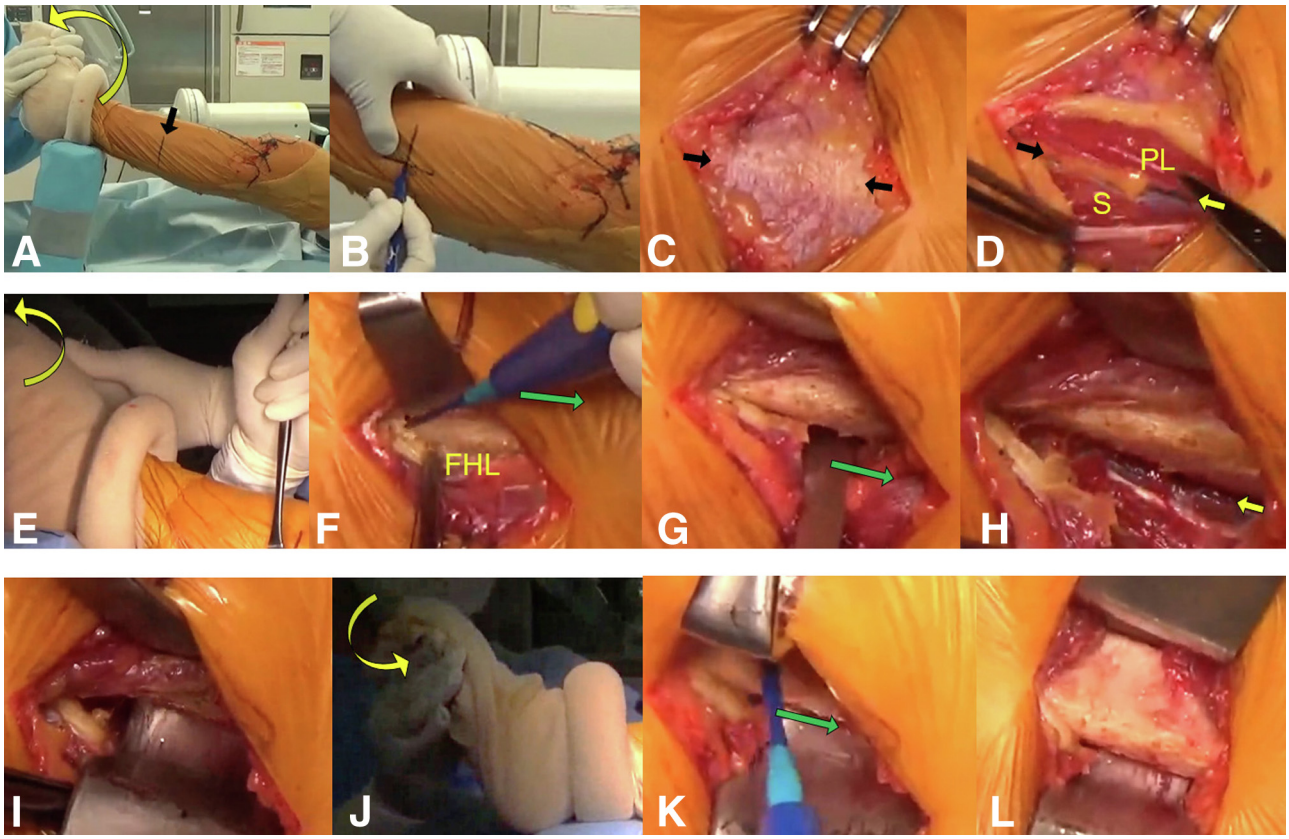

Fig 2. Surgical exposure of the left fibula. (A) The patient's heel is placed on a pillow to make the posterior muscles droop. Plantar-flexion and varus stress are applied (yellow arrow) to allow further posterior muscle relaxation and tensioning of the lateral muscles, respectively. Black arrow indicates center of the fibula. (B) A skin incision is drawn on the intercompartmental plane between the lateral and superficial posterior compartments. (C) The fat tissue between the peroneus longus and soleus muscles can be seen through the crural fascia (between black arrows), which is a useful indicator of fascial incision. (D) The interface between the peroneus longus and soleus muscles (between black and yellow arrows) is bluntly dissected. (E) The great toe is plantar-flexed (yellow arrow) to reduce the tension of the flexor hallucis longus muscle. (F) The flexor hallucis longus muscle is detached distally to proximally (green arrow) using an electrosurgical knife and a blunt periosteal elevator. (G) The tibialis posterior muscle is detached from the medial aspect (i.e., the backside of the fibula) using a blunt periosteal elevator, distally to proximally (green arrow). (H) The peroneal vein (yellow arrow) can be seen after releasing the backside. (I) A curved retractor is hooked on the scraped medial crest of the fibula to retract the posterior muscles. (J) Valgus stress is applied to relax the lateral compartment to facilitate lateral exposure. (K) The peroneus muscle is detached using an electrosurgical knife distally to proximally (green arrow). (L) An additional curved retractor is hooked on the scraped anterior margin of the fibula. (FHL, flexor hallucis longus; PL, peroneus longus; S, soleus.)

(Fig 2E). The FHL is then gently detached distally to proximally using an electrosurgical knife (Fig 2F) and a small blunt periosteal elevator, until the medial crest of the fibula can be palpated by the tip of the elevator (Figs 1C, 2G). The intermuscular septum between the tibialis posterior muscle (TP) and the FHL, which contains the peroneal vessels, is separated carefully from the medial crest. Peroneal veins can be detected in some cases after this separation (Fig 2H). A curved retractor is inserted beyond the crest for posterior retraction, which enables complete retraction of the peroneal artery and vein(s) (Figs 1D, 2I).

Anterior Exposure (Video 1)

After applying valgus stress to the ankle for further relaxation of the lateral compartment (Figs 1E, 2J), the peroneus muscle is detached using an electrosurgical knife (Figs 1F, 2k). The anterior intermuscular septum, which divides the extensor digitorum longus and the peroneus longus (PL) muscles (Fig 1E), is then separated from the anterior margin of the fibula using an electrosurgical knife and a periosteal elevator. A curved retractor for anterior retraction is then hooked on the anterior margin of the fibula (Figs 1G, 2L).

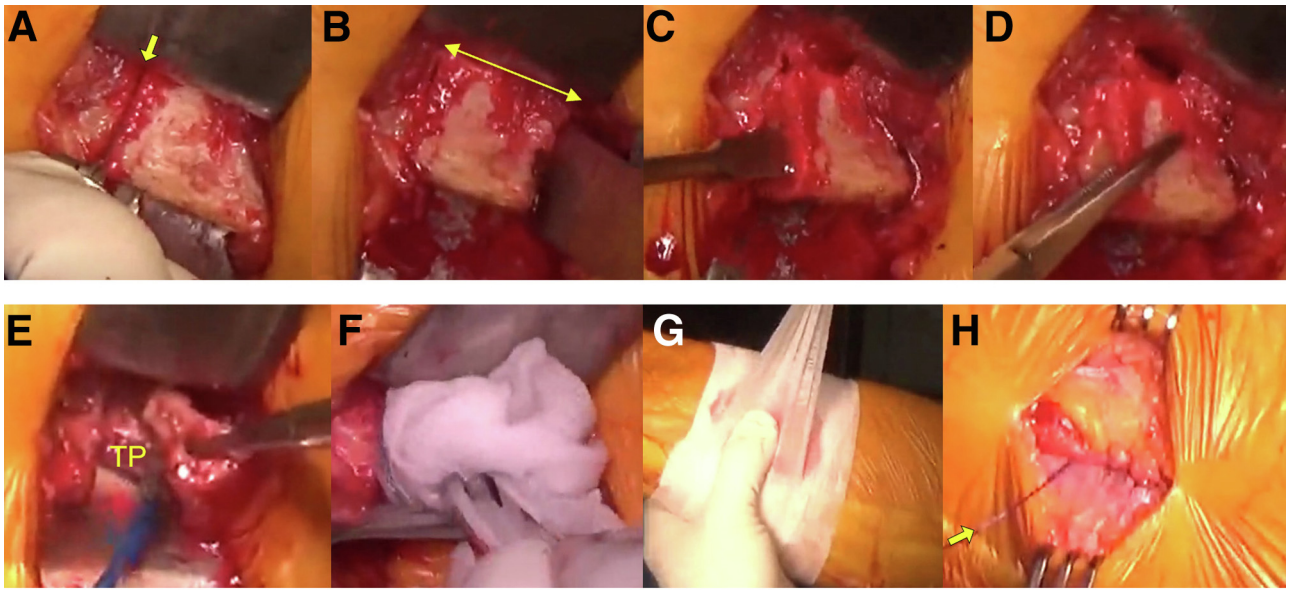

Fig 3. Osteotomy of the left fibula. (A) Distal osteotomy is performed using a micro-oscillating saw and a chisel (yellow arrow). (B) Proximal osteotomy is started approximately 15 mm from the distal osteotomy line (yellow double-headed arrow). (C) The tip of the blunt periosteal elevator is inserted from the distal medullary cavity and the resected part is elevated. (D) The elevator is replaced with a straight clamp. (E) The remaining tibialis posterior muscle is detached distally to proximally using an electrosurgical knife. (F) A gauze impregnated with epinephrine-containing saline is packed in the resected portion. (G) A compression bandage is applied for complete hemostasis, and the wound is closed after finishing high tibial osteotomy. (H) The crural fascia is sutured tightly with a STRATAFIX (Ethicon) (yellow arrow) to prevent muscle herniation. (TP, tibialis posterior.)

Osteotomy (Video 1)

Distal osteotomy is first performed under sufficient retraction using an oscillating saw and a chisel (Fig 3A). A lightweight cordless micro-oscillating saw (Hall MicroFree Cordless Small Bone Power System; CONMED) is recommended for safe and secure osteotomy. Proximal osteotomy is performed in the same manner, 15 mm proximal to the distal osteotomy line (Fig 3B). After completing both osteotomies, the tip of the blunt periosteal elevator is inserted into the distal medullary cavity and the resected part is elevated (Fig 3C). The elevator is replaced by a straight clamp (Fig 3D), and the remaining TP is detached distally to proximally using an electrosurgical knife (Fig 3E). It is essential to check carefully for bleeding from the peroneal vessels to prevent the development of postoperative hematoma or aneurysm. Finally, a wet gauze impregnated with epinephrine-containing saline is packed into the resected portion (Fig 3F), and the wound is wrapped to further secure hemostasis (Fig 3G). Tibial osteotomy is then performed and the wound is closed after CWHTO using TomoFix Lateral High Tibia (Johnson & Johnson). Before skin closure, the crural fascia is tightly repaired with a knotless continuous suture (STRATAFIX Spiral PDS PLUS 3-0; Ethicon) to prevent muscle herniation (Fig 3H).

Table 1. Pearls and Pitfalls

Pearls
Safe and easy exposure by adjusting the ankle angle (expressed as: surgical step [applied stress and purpose])
Identification of the interface between the lateral and the superficial posterior compartments
[Plantar-flexion to relax the superficial posterior compartment]
[Varus stress to tense the lateral compartment]
Deep posterior exposure
[Plantar-flexion of the first toe to reduce tension of the flexor hallucis longus muscle]
Anterior exposure
[Valgus stress to reduce tension of the peroneus longus muscle]
Pitfalls
Strict control of blood pressure at <100 mm Hg is desired.
A skin incision of 4 cm may be insufficient in obese patients.
If the simultaneous anterior/posterior retraction is tight, cut the posterior side of the fibula with posterior retraction and then cut the anterior side with anterior retraction, in sequential order.

Discussion

All knee surgeons adjust the knee-flexion angle during total knee arthroplasty, taking care not to injure the popliteal artery. During distal femoral osteotomy, relaxation of the hamstring muscles makes it easier to retract the posterior structures, including neurovascular structures.[9] However, the muscle relaxation position during fibular osteotomy has been largely ignored.

Our triple-A fibular osteotomy technique includes 3 steps (Table 1): (1) accurate detection of the intercompartmental interface, (2) safe posterior retraction without vascular injury, and (3) nonresistant anterior

Table 2. Advantages and Disadvantages

Advantages
Gravitational drooping of the posterior muscles achieved by putting the heel on a high pillow aids identification of the intercompartmental interface between the lateral and superficial compartments.
Nontourniquet technique enables detection of possible vascular injury during surgery.
Bleeding from the peroneal vessels can be observed from the window of the segmental resection.
A gauze wetted with epinephrine-containing saline is packed in the osteotomized site during tibial osteotomy, ensuring hemostasis.
No drain is required because all bleeding can be stopped during surgery.
Postoperative swelling is minimized because all bleeding can be stopped during surgery.
Use of a micro-oscillating saw improves the safety margin.
Disadvantages
Two osteotomies are needed for the segmental resection, compared with only 1 for oblique fibular osteotomy.
Removal of the fibula may cause postoperative pain due to pseudoarthrosis or delayed union.

retraction. For the first step, the ankle angle is adjusted by plantar-flexion with varus stress to accentuate the tension difference between the lateral and posterior compartments. In addition to adjusting the angle, gravitational drooping of the posterior muscles by putting the heel on a high pillow aids identification of the intercompartmental interface (Table 2). The assistant should take care not to drop the heel from the pillow, potentially resulting in severe vascular injury (Table 3). In the second step, plantar-flexion of the great toe is added to loosen the FHL to expose the fibular posterior aspect, which is critical for protecting the peroneal vessels. Finally, valgus stress is applied to loosen the PL muscle. These steps of muscle-tension control enable safe and secure fibula exposure, without difficulties (Table 1). However, it is difficult to adjust the ankle angle in patients with severe ankle osteoarthritis with contracture, and detection of the peroneal vessels may be difficult if the muscles around the calf are thick (Table 3). Use of a micro-oscillating saw may improve the safety of the procedure (Table 2).

Regarding bleeding control, appropriate exposure using the triple-A technique implements the nontourniquet procedure, which enables possible vascular injuries to be detected during surgery. Strict blood pressure control (<100 mm Hg) is desired to detect bleeding (Table 1). In addition, bleeding from the peroneal vessels can be observed via the segmental resection window even after osteotomy (Table 2), compared with oblique osteotomy without removal, thus enhancing the safety. A gauze wetted with epinephrine-containing saline packed in the osteotomized site during tibial osteotomy further ensures complete hemostasis (Table 2). These strict bleeding-control procedures help to minimize postoperative swelling due to hemorrhage, without an indwelling drain (Table 2). As for OWHTO[10] or TKA,[11] the safe nontourniquet procedure may decrease the intraoperative/perioperative risks of complications such as bleeding, hematoma, or infection and may enhance postoperative recovery.

Table 3. Risks and Limitations

Risks
The assistant should take care not to drop the heel from the pillow, potentially resulting in severe vascular injury.
If the peroneal artery is severely injured, it may be difficult to identify the origin of the bleed in the event of gushing bleeding.
Limitations
The ankle-angle-adjusting technique cannot be applied in patients with severe ankle osteoarthritis with contracture.
Detection of the peroneal vessels may be difficult in cases with thick muscles.
There is no consensus on whether segmental resection or osteosynthesis is better in fibular osteotomy.

Fibular osteotomy in CWHTO is broadly divided into segmental resection[6,8] and bone cut without removal.[4] The disadvantages of the former include (Table 2) the need for 2 osteotomies for segmental resection, compared with only 1 for oblique fibular osteotomy, and removal of the fibula may cause postoperative pain due to pseudoarthrosis or delayed union. Although there is no consensus on the preferred technique for fibular osteotomy (Table 3), we use the former because of the safety issues noted above. In patients who may require fibular osteosynthesis, such as young patients or top-level athletes, arthroscopically removed osteophytes are grafted[12] to the removed portion and ligation is performed using strong sutures.[4]

In conclusion, this nontourniquet triple-A technique can enhance the safety of fibular osteotomy in CWHTO.

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