Technical Note

Tibial Condylar Valgus Osteotomy Combined With Medial Open-Wedge Distal Tuberosity Tibial Osteotomy

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Abstract: Severe varus deformity in osteoarthritic knees is attributed not only to bony deformity but also to intra-articular deformity as a result of medial joint space narrowing with lateral joint space widening (increased joint line convergence angle). In such knees, correction of bony deformity by high tibial osteotomy (HTO) alone may not be capable of restoring physiological joint geometry and biomechanics. Tibial condylar valgus osteotomy (TCVO), an L-shaped osteotomy in the medial tibial condyle, has been proposed to improve articular stability and congruity by elevating the medial tibial joint line and addressing the articular component of the deformity; however, its surgical efficacy for correction of the valgus deformity is limited. Therefore a procedure combining HTO and TCVO can be a reasonable option to achieve restoration of the knee joint physiology in such situations. In our current practice, medial open-wedge distal tuberosity tibial osteotomy (MOW-DTO) has been the procedure of primary option among the HTO procedures to avoid patellofemoral overload which could be an inherent problem in medial open-wedge HTO. In this article, the surgical rationale and the combined procedure of TCVO and MOW-DTO are described.

There have been a number of studies reporting favorable outcomes after osteotomies in surgical management of osteoarthritic knees.[1-6] Knee osteoarthritis (OA) is a progressive degenerative disease characterized by a gradual loss of articular cartilage around the knee. Accordingly, severe varus deformity in the osteoarthritic knee is attributed not only to bony deformity but also to articular deformity, which exhibits an increased joint line convergence angle (JLCA) as a result of medial joint space narrowing with lateral joint space widening. In such situation, deformity correction by high tibial osteotomy (HTO) alone is not enough to restore normal joint geometry and biomechanics.[7-9] Tibial condylar valgus osteotomy (TCVO) was developed in Japan and reported by Chiba et al.[8] in 1990. This procedure is characterized by an L-shaped osteotomy in the medial tibial condyle intended to correct the articular component of the varus deformity and improve joint stability/congruity by levering up the medial tibial joint line. Although TCVO can effectively restore the articular deformity, its efficacy in correcting coronal-plane malalignment (varus deformity) is limited.[7-9]

Considering the effects and limitations that are present in HTO and TCVO procedures, a combination of HTO and TCVO is thought to be a reasonable approach to restore normal anatomy and biomechanics for severe varus osteoarthritic knees involving both bony and intra-articular deformities.[7,10] Among various HTO procedures, medial open-wedge HTO (MOW-HTO) has

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been generally performed with good clinical reports.[1-6] However, MOW-HTO has inherent shortcomings of inducing patellar infra and patellofemoral malalignment.[11,12] To avoid these patellofemoral problems, Akiyama et al.[13] introduced medial open-wedge distal tuberosity tibial osteotomy (MOW-DTO), a modified surgical technique, consisting of a triplane osteotomy. In the MOW-DTO procedure, the tibial tubercle remains attached to the proximal bony segment, and thus the increase in patellofemoral contact stress associated with wedge opening can be avoided.[13]

We describe a TCVO and MOW-DTO combination approach to treat osteoarthritic knees with severe varus malalignment associated with a large JLCA. This Technical Note describes our technique that combines a modified TCVO and MOW-DTO with the intention of restoring normal joint anatomy and biomechanics.

Surgical Technique

Indication

This combined procedure is indicated for medial compartment knee OA of Kellgren-Lawrence OA grade ≥ 3 exhibiting excessive joint convergence with JLCA $>4°$ in a weightbearing radiograph. Depression of the medial plateau like Blount disease is also one of the indications. In addition, the following criteria should be met: no lateral compartment involvement or systemic inflammatory arthritis, mechanical medial proximal tibial angle $<87°$,[14] and retained range of motion with extension loss $<10°$ and flexion $>120°$.[7]

Surgical Setting

The patient is placed in the supine position on the operating table under general anesthesia. A lateral thigh support is attached to the rail of the table to help the knee positioning during the procedure. The contralateral limb is positioned with the hip abducted to provide an easier access to the medial aspect of the operative knee. A tourniquet is not used to monitor and control intraoperative bleeding.

Preceding Arthroscopy

Before the osteotomy, arthroscopic examination is performed to evaluate the status of the intra-articular structures such as the articular cartilage, meniscus, and synovia at all compartments. Subsequently, arthroscopic debridement, including meniscectomy or synovectomy is performed as required. In addition, osteophytes are arthroscopically harvested to be used for placement of the bone chip graft into the gap at the osteotomy site.[15]

Osteotomy Procedure

A 6-cm oblique skin incision is made at the anteromedial part of the proximal tibia, and then the periosteum of the osteotomy site is exposed. Superficial medial collateral ligament is released at the distal insertion. Posterior soft tissue is stripped from the proximal tibia and retracted to protect the neurovascular bundle and avoid injuries to those structures.

The sequence of osteotomy is initiated with TCVO. The initial osteotomy is the medial part of the L-shaped osteotomy which is made using a chisel and a bone saw under direct vision. As a guide pin for the osteotomy, a 2.0-mm K-wire is initially inserted at 4.5 cm distal from the medial tibial joint-line. The targeted location of the hinge point on the lateral side of the tibia is placed 2 mm distal to that of the subsequent transverse cut (MOW-HTO), because the osteotomy is made along the proximal side of the guide pin (Fig 1A). The apex of the L-shaped osteotomy is located at the medial border where the patellar tendon is inserted into the tibia, and where a short K-wire is inserted anteroposteriorly as a reference (Fig 1B). Then another guide pin (K-wire) for the sagittal cut is inserted from the apex toward the lateral intercondylar eminence. The sagittal osteotomy through the ridge of the lateral intercondylar eminence is implemented using a chisel following the K-wire guidance under fluoroscopic control (Fig 1C). In the lateral view, a chisel is first inserted from the anterior aspect of the tibia and extended superiorly and posteriorly while the location of the chisel tip is carefully monitored under fluoroscopy (Fig 1D). Thereafter, a transverse cut is performed along the guide pin to complete the L-shaped osteotomy in TCVO. Before the deformity correction, two 1.5 mm K-wires are inserted from the lateral tibial condyle just below the joint-line to the medial tibial condyle to prevent instability at the osteotomy site during the deformity correction. Then, the spreader is inserted into the transverse cut at the posterior cortical bone to avoid the increase in the posterior tilt of the tibia slope during the wedge opening. The spreader is opened until the coronal slope of the medial tibial plateau comes in line with that of the lateral tibial plateau (Fig 1E). Thereafter, the whole leg alignment is confirmed using an alignment rod on the fluoroscopic image. Regarding deformity correction by TCVO, the medial tibial condyle is elevated up to the level in which the lateral compartment is in contact. Once the medial and lateral compartments are in contact, further opening for alignment correction is not feasible because of separation at the osteotomy site (Fig 2). Therefore TCVO has a limited capability in correction of coronal limb alignment especially in knees with severe varus deformity.[9] If the optimal alignment is not attained, HTO should be added to the TCVO.

Our HTO procedure follows the technique reported by Akiyama et al.[13] Two 2.0-mm K-wires are inserted from the lateral tibial plateau for temporary fixation for TCVO (Fig 1F). Then, using the K-wire inserted at the beginning of the procedure as a guide, the HTO

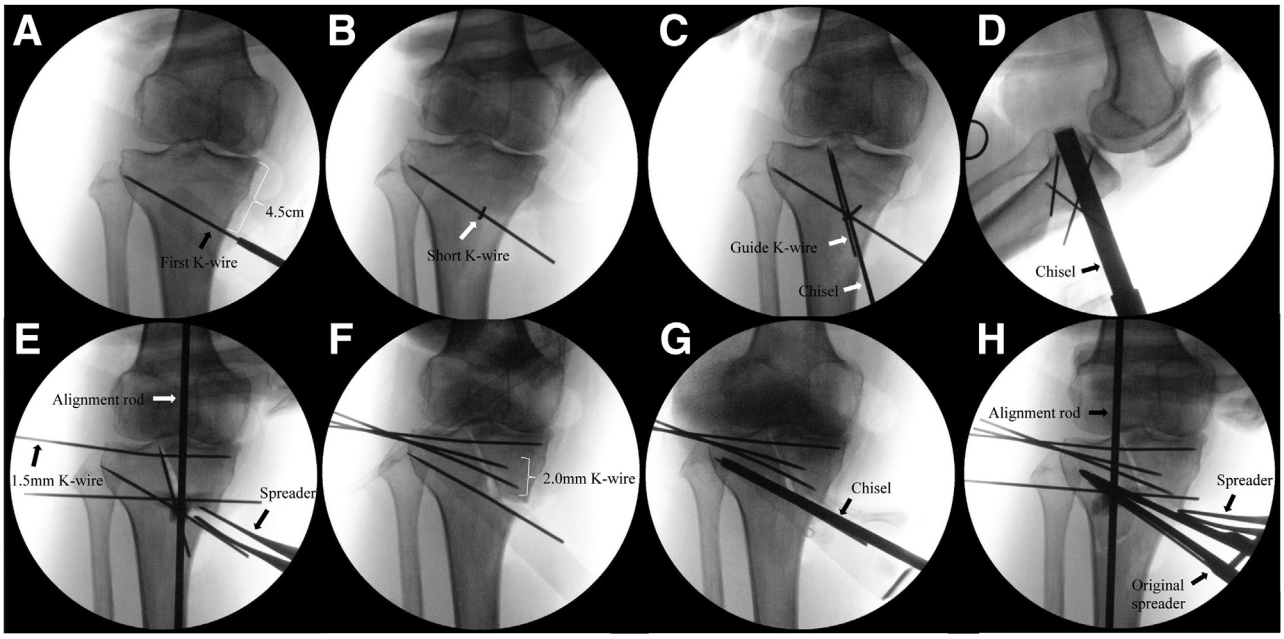

Fig 1. Surgical sequence of the combined TCVO and OWDTO procedure. (A) The first K-wire (black arrow) is inserted at 4.5 cm from the medial tibial joint line. (B.) A short K-wire (white arrow) is inserted at the apex of the L-shaped osteotomy as a reference. (C) The sagittal osteotomy is made using a chisel following the K-wire guidance (white arrows). (D) The chisel (black arrow) is advanced while location of its tip is carefully monitored on a lateral fluoroscopic image. (E) After completing the L-shaped osteotomy, a spreader is inserted into the transverse cut of the TCVO for wedge opening. (F) Two 2.0-mm K-wire are inserted from the lateral side for temporary fixation of the TCVO. (G) The transverse cut for HTO is made with a chisel (black arrow) along the proximal side of the initially inserted guide wire. (H) Two bone spreaders (black arrows) are simultaneously used for wedge opening while the location of the alignment rod at the tibial plateau is checked on a fluoroscopic image. TCVO, tibial condylar valgus osteotomy; MOW-DTO, medial open-wedge distal tuberosity tibial osteotomy; HTO, high tibial osteotomy.

transverse cut is performed along the proximal side of the K-wire. Then, the MOW-DTO triplane cut was accomplished with the following sequential steps.[13] After the transverse cut is made, a short hinge pin was inserted into the hinge position of the MOW-DTO in the anteroposterior direction under fluoroscopic control while maintaining a neutral position of the knee joint. This pin serves as an axis for arc osteotomy, which

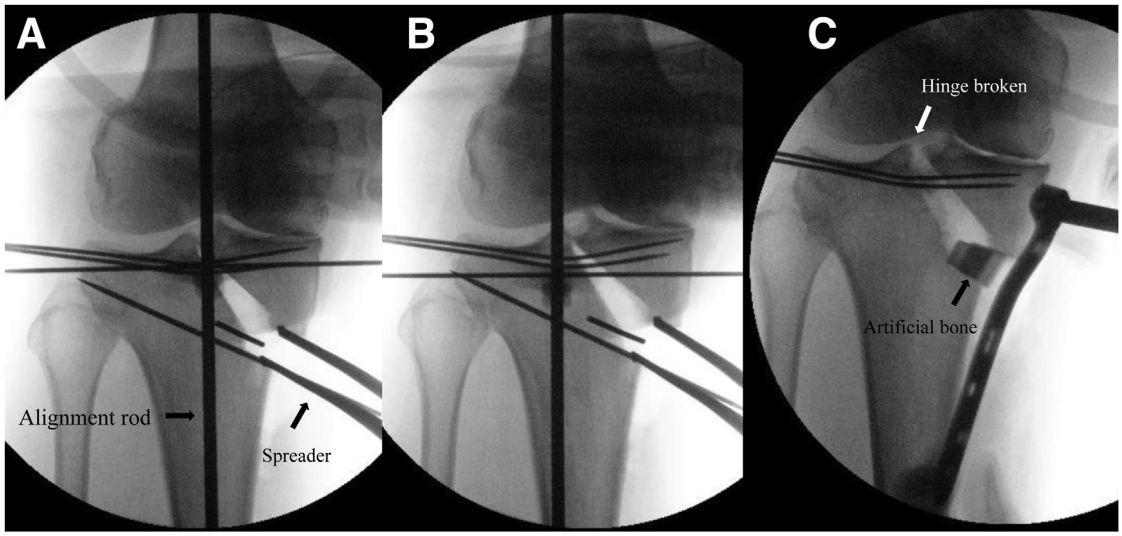

Fig 2. Breakage of the osteotomy hinge caused by excessive wedge opening in TCVO. (A) The osteotomy site is opened by a spreader (black arrow). (B) The wedge is further opened in an attempt to correct the deformity. (C) Excessive wedge opening results in breakage of the hinge associated with separation at the osteotomy site. TCVO, tibial condylar valgus osteotomy.

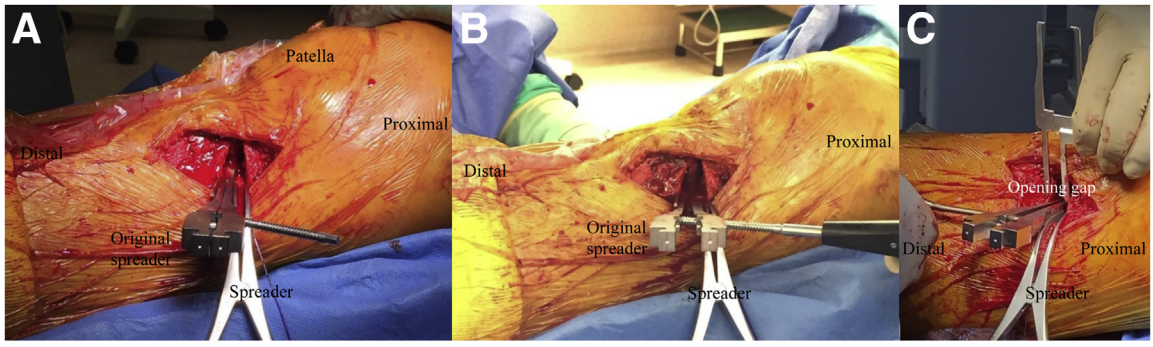

Fig 3. Intraoperative photographs showing wedge opening with two spreaders. (A) Insertion of two spreaders. (B) Wedge opening of MOW-DTO transverse osteotomy. (C) Wedge opening of TCVO transverse osteotomy. TCVO, tibial condylar valgus osteotomy; MOW-DTO, medial open-wedge distal tuberosity tibial osteotomy.

is at the center of the arc with a radius of approximately 55 mm for female or 60 mm for male. The arc osteotomy line is marked with an electric cautery on the anterior aspect of the tibia followed by multiple 2-mm holes drilled on the arc line. The arc osteotomy is performed using a small bone saw along the line connecting the drill holes. During the osteotomy, it is crucial to cut the lateral portion of the ascending osteotomy line. The end of the arc cut was connected with the descending cut. The descending cut is initiated at 15 mm posterior from the tibial tubercle and continued distally on the coronal plane to the level of the arc osteotomy using a small sagittal bone saw.

For wedge opening, the original bone spreader (Olympus Terumo Biomaterials, Tokyo, Japan) is inserted to the MOW-DTO transverse osteotomy line, then another spreader for TCVO is inserted between the original spreader and the proximal/medial tibial bony segment (Fig 3A). First, the spreader for TCVO is opened until contact between the medial and lateral

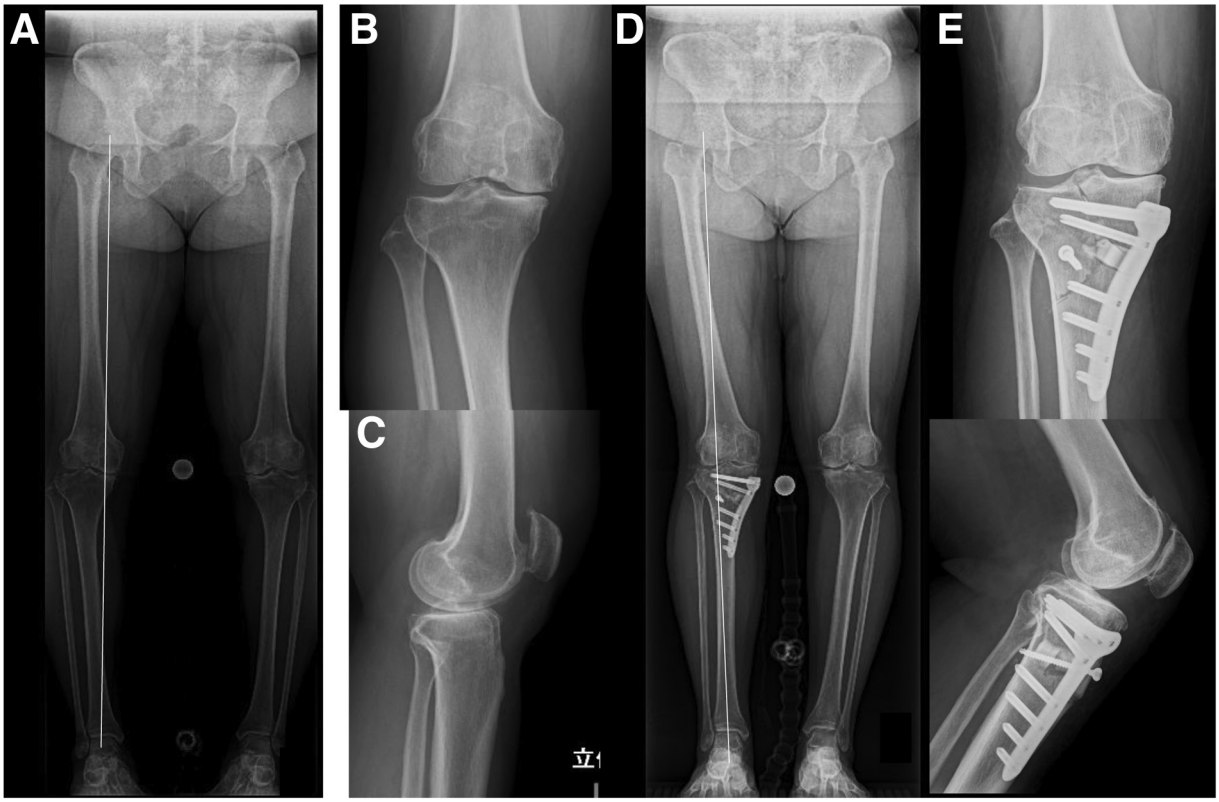

Fig 4. Preoperative and postoperative plane radiographs (right knee). (A) Preoperative whole leg standing view. (B) Preoperative standing anteroposterior view. (C) Preoperative standing lateral view. (D) Postoperative whole leg standing view. (E) Postoperative anteroposterior view. (F) Postoperative lateral view.

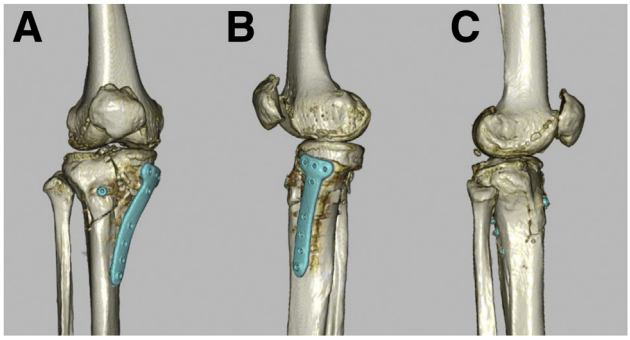

Fig 5. Postoperative 3dimensional computed tomography scan (right knee). (A) Anteroposterior view. (B) Medial view. (C) Lateral view.

compartments are made, then, the transverse osteotomy site is opened to achieve optimal coronal alignment as planned while checking the location of the alignment rod at the tibial plateau on fluoroscopic image (Figs 1H, 3B). During the opening of the osteotomy sites, the bony cut interfaces at the arc osteotomy site continued to be in contact with each other, and those at the descending osteotomy site were also kept attached to each other. The total opening width of osteotomy (TCVO + MOW-DTO) was estimated before surgery (Fig 3C).

When the optimal alignment was confirmed, plate fixation is performed. Fixation is accomplished using a plate and 8 screws using a TriS plate (Olympus, Tokyo, Japan) that is inserted into a subcutaneous tunnel formed on the medial aspect of the tibia using the minimum invasive plate osteosynthesis technique.[2-4] The resultant gap between the bony cut surfaces is filled with a wedge-shaped bone substitute (Osferion 60; Olympus Terumo Biomaterials) and autogenous bone chips prepared from preharvested osteophytes. After the plate fixation, the 2 spreaders are removed, and the pes anserinus is sutured and secured to each other under the plate, over the osteotomy gap. Finally, bi-cortical screw (Synthes, Paoli, PA) fixation from the tuberosity to the posterior tibia is performed under fluoroscopic control in the lateral view (Video 1). The wound is closed after placement of a surgical drain. Preoperative and postoperative radiographs and 3-dimensional computed tomography scans are shown in Figures 4 and 5.

Postoperative Rehabilitation

The operated knee is not immobilized after surgery, and range of motion exercise is initiated as tolerated on the following day. Weightbearing is not allowed for 2 weeks after surgery. Partial weight-bearing using crutches with 20-kg axial load is initiated at 2 weeks after surgery with progression to full weightbearing at 6 weeks after surgery.

Table 1. Pearls and Pitfalls

Pearls	Pitfalls
Make an oblique skin incision in approaching the surgical area.	During the sagittal osteotomy in TCVO, the location of the chisel tip must be carefully monitored on lateral fluoroscopic image to avoid inadvertent neurovascular injuries.
Start the osteotomy at 45 mm distal from the medial tibial joint line.	Bony cut in the posterolateral direction during the descending osteotomy may result in undesirable obliquity of the osteotomy plane.
Insert a short hinge pin at the apex of the L-shaped osteotomy as a reference.	Excessive opening in TCVO may lead to hinge breakage associated with separation at the osteotomy site.
If the optimal alignment is not attained by an isolated TCVO, MOW-DTO is added as a combined procedure.	Failure to accomplish all the triplane cuts with the intact hinge in MOW-DTO may lead to iatrogenic hinge fracture
Insert a short hinge pin at the hinge position of the MOW-DTO transverse cut which serves as an axis for the arc osteotomy.	Descending cut of MOW-DTO too deep from the anterior tibial surface may result in insufficient thickness of the remaining tibia posterior to the bony cut, posing a risk of inadvertent tibial shaft fracture.
The radii of the arc are approximately 55 mm for female and 60 mm for male.	During bicortical screw insertion from the tuberosity to the posterior tibia, careful fluoroscopic control is required to avoid the risk for popliteal neurovascular bundle injury.
Start the descending cut of MOW-DTO at 15 mm from the tibial tuberosity providing enough thickness for the anterior flange.	
Supplement with bicortical screw insertion from the tibial tuberosity after the plate and screw fixation to ensure secure fixation of the osteotomy site.	

MOW-DTO, medial open-wedge distal tuberosity tibial osteotomy; TCVO, tibial condylar valgus osteotomy.

Discussion

HTO is a popular surgical option for varus osteoarthritic knees, and satisfactory outcomes have been reported in literatures[1-6]; however, expected surgical benefits cannot be achieved in some cases. Postoperative malalignment is a primary reason for an unsatisfactory outcome. Varus knee deformity is composed of bony and articular components.[14] Deformity correction by HTO alone can only address the bony component of the deformity. Especially in cases with severe varus deformity with a large JLCA, which represents instability and incongruity at the articular level, changes in JLCA after HTO is unpredictable leading to misalignment (mostly overcorrection).[7-9,16]

TCVO, which is an L-shaped osteotomy in the medial tibial condyle, can correct the alignment by levering up

Table 2. Advantages and Disadvantages

Advantages	Disadvantages
Correction of both intra- and extra-articular deformities	Technically demanding surgery
Capability to correct large JLCA	Prolonged surgical time
Attainment of joint congruity and stability by TCVO	Increase in number of the osteotomies (Addition of 2 osteotomies in TCVO to 3 osteotomies in MOW-DTO)
Prevention of patella infra by MOW-DTO	Intraoperative use of the alignment rod for several times to confirm alignment
Enhancement of fixation stability by the anterior cortical continuity on the tibial crest in MOW-DTO	Requirement of the additional bicortical screw fixation for MOW-DTO
Wide cancellous bone contact at the descending osteotomy site promoting bone healing in MOW-DTO	Limitation in aggressive early postoperative rehabilitation in terms of weight bearing, motion, and muscle exercise
Improvement of knee range of motion is shortened after MOW-DTO.	Potential for increased postoperative hemorrhage and swelling requiring use of a surgical drain

JLCA, joint line convergence angle; MOW-DTO, medial open-wedge distal tuberosity tibial osteotomy; TCVO, tibial condylar valgus osteotomy.

the medial tibial joint line. Kuwashima et al.[9] reported that the primary advantages of TCVO are improvements in joint congruity and joint stability, whereas the disadvantage of TCVO is the limitation in the amount of valgus correction. If a further valgus correction was needed, MOW-HTO should be considered alongside TCVO to address deformities in both the bony and articular components.[10] In consideration of osteotomy techniques in HTO, MOW-HTO is most widely performed at our current clinical practice. However, a potential inherent shortcoming of the MOW-HTO is patellofemoral overload by lowering the level of the tibial tubercle.[11,12] On the other hand, MOW-DTO can eliminate the risk of developing patellofemoral problems.[13] Therefore we feel that the combination of TCVO and MOW-DTO introduced in this article can be a reasonable surgical approach to treat varus osteoarthritic knees with both bony and intra-articular deformities. There are some additional risks and pitfalls associated with application of this technique. First, postoperative limb swelling can be more evident than isolated HTO because of the increased area of the bony-cut surface (2 additional osteotomies in TCVO). To avoid postoperative complications such as hematoma and compartment syndrome, a surgical drain is routinely used in our practice. Moreover, if the descending cut of MOW-DTO is made too deep from the anterior tibial surface, the thickness of the remaining tibia posterior to the bony cut is reduced posing a risk of inadvertent tibial shaft fracture by a minor trauma (Table 1, Table 2).

Conclusions

TCVO combined with MOW-DTO can achieve optimal alignment for varus knee deformity with a large JLCA by addressing both bony and articular deformities. This surgical option can reasonably improve articular stability and congruity while avoiding the risk of developing patellofemoral problems.

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