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Case Report

Around-knee osteotomy conversion for failed high tibial osteotomy: Re-correction high tibial osteotomy and additional distal femoral osteotomy may enable return to sporting activities

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A B S T R A C T

High tibial osteotomy (HTO) for knee osteoarthritis achieves excellent short- and long-term results. However, failure of HTO due to undercorrection or correction loss may necessitate conversion surgery. For patients with HTO failure who desire a return to sporting activities (RTS), non-prosthetic joint-preserving solutions such as conversion to around-knee osteotomies (AKO-conversion) may be more appropriate than total knee arthroplasty. The present study aimed to introduce potential non-prosthetic joint-preserving solutions for failed HTO and investigate the postoperative RTS. Among the patients who received non-prosthetic solutions for failed HTO from 2015 to 2020, this case series included those who were eager to RTS, were participating in a sporting activity with a Tegner activity scale score of $\geq$5 immediately before being affected by knee osteoarthritis, and had at least 2 years of follow-up. Deformity analysis for the preoperative planning of the AKO-conversion was based on the mechanical lateral distal femoral angle, joint line convergence angle, and mechanical medial proximal tibial angle. Four patients met the study inclusion criteria: two patients who underwent re-correction HTO and two who received additional distal femoral osteotomy (DFO). The average ages at primary HTO and AKO-conversion were 69.5 $\pm$ 11.8 years and 71.5 $\pm$ 10.9 years, respectively. The hip-knee-ankle angle was corrected from $-2.8 \pm 1.5^\circ$ before conversion surgery to $3.3 \pm 1.5^\circ$ at 2 years after AKO-conversion. All four patients finally achieved a better sporting performance after AKO-conversion than preoperatively, and the Tegner activity scale score was improved from 2.5 $\pm$ 1.0 before AKO-conversion to 5.8 $\pm$ 0.5 at the 2-year follow-up. The duration between AKO-conversion and full RTS was 11.8 $\pm$ 6.7 months. In conclusion, two patients who underwent re-correction HTO and two who underwent additional DFO for undercorrection or correction loss after primary HTO achieved highly satisfactory clinical results, including RTS. The present findings suggest that non-prosthetic joint-preserving solutions using AKO for failed HTO should be considered as options to enable RTS.

1. Introduction

High tibial osteotomy (HTO) for knee osteoarthritis has become more common since the introduction of HTO-specific locking plates,[1,2] and excellent short-to long-term results have been reported.[3,4] If the HTO fails due to undercorrection or correction loss, conversion to total knee arthroplasty (TKA-conversion) is a generally accepted procedure.[5] However, the higher infection rate after TKA-conversion than after primary TKA[6] means that this procedure should be avoided in high-risk cases, such as patients with cancer.

Furthermore, despite the increasing number of patients who desire a return to sporting activities (RTS) after failed HTO, RTS is less likely after TKA-conversion compared with primary TKA.[7] A return to high-impact sports is not recommended even after primary TKA[8]; however, one study reported that primary HTO results in satisfactory recovery of the ability to participate in both low- and

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high-impact sporting activities.[9]

Herein, we explored some non-prosthetic joint-preserving solutions for failed HTO and hypothesised that conversion to around-knee osteotomies (AKO-conversion), such as re-correction HTO[10–12] or additional distal femoral osteotomy (DFO),[13] after failed HTO enables RTS as well as primary osteotomies. Thus, the objectives of this study were: 1) to introduce potential non-prosthetic joint-preserving solutions for failed HTO and 2) to investigate the RTS after these solutions.

2. Materials and methods

2.1. Indications of non-prosthetic solutions for failed HTO

Non-prosthetic solutions for failed HTO are considered for patients who satisfy the following criteria: 1) correction loss due to delayed union with bone absorption, chronic/recurrent pain for at least 6 months after bone union with HTO undercorrection, or recurrent pain due to gradual correction loss after well-corrected HTO despite at least 6 months of conservative treatment; 2) hip-knee-ankle angle (HKA angle; the angle between the femoral and tibial mechanical axes in the anteroposterior view, with varus angles expressed as negative and valgus as positive) of <0°; 3) lateral compartment osteoarthritis that has not progressed to Kellgren-Lawrence grade[14] III or IV; 4); less than 10° of flexion contracture, and 5) high-risk patients who are unable to tolerate invasive surgeries like TKA or physically active patients for whom the risks outweigh the benefits of TKA.

2.2. Variations of non-prosthetic solutions

The selection of the type of non-prosthetic solution for failed HTO depends on the deformity centre.

2.2.1. Arthroscopic osteophyte resection (Fig. 1)

When the deformity centre is located at the knee joint line (i.e., the joint line convergence angle (JLCA)[15] is > 5° due to medial tightness and/or lateral laxity), arthroscopic osteophyte resection[10,16] may be a viable option (Fig. 1). Although this procedure certainly can achieve a decompression effect of the medial compartment, it may be less effective in patients participating in high-impact sporting activities.

2.2.2. AKO-conversion

For very active patients, AKO-conversion for failed HTO is chosen according to the deformity analysis.

2.2.2.1. Re-correction HTO[10] (Figs. 2 and 3). In patients with a deformity centre on the tibial side (mechanical medial proximal tibial angle [mMPTA][15] <90°) and no deformity on the femoral side (mechanical lateral distal femoral angle [mLDFA][15] 85–90°), re-correction HTO may be a viable alternative for treating the insufficient correction (Figs. 2 and 3).[10–12]

2.2.2.2. 2-2. Additional DFO[13] (Figs. 4 and 5). When the correction loss is caused by bony deformity in the femur and the tibia is sufficiently corrected by the primary HTO (mLDFA >90° and mMPTA >90°), additional DFO may be an effective solution (Figs. 4 and 5).[13]

2.3. Inclusion criteria

Among the patients who received non-prosthetic solutions for failed HTO from 2015 to 2020, only those who met the following criteria were included in this study: 1) patients eager to RTS; 2) patients who were participating in a sporting activity with a Tegner activity scale[17] score of 5 or more immediately before being affected by knee osteoarthritis; and 3) patients who completed at least 2 years of follow-up.

2.4. AKO-conversion surgical procedure and postoperative rehabilitation

In re-correction HTO for failed primary open-wedge HTO, conversion by a hybrid closed-wedge HTO[18] was applied. When the primary HTO was performed using the closed-wedge procedure, conversion by an open-wedge HTO[10] was applied. In additional DFO, a biplanar lateral closed-wedge DFO was performed with a TomoFix MDF plate (Synthes GmbH; Solothurn, Switzerland) or with a lateral closed-wedge DFO-specific Tris-LDFO plate (Olympus Terumo Biomaterials; Tokyo, Japan).

Patients who underwent re-correction HTO were allowed to perform full weight-bearing walking exercise and range of motion exercise on the first postoperative day, and these exercises were advanced gradually as tolerated. Patients who underwent additional DFO followed the same range of motion protocol as those who underwent re-correction HTO but were not allowed to perform full weight-bearing until 6 weeks after surgery.

2.5. Assessment

The surgical procedure of the primary HTO/AKO-conversion, age at primary HTO/AKO-conversion, and reason for conversion were recorded. A full-length standing anteroposterior radiograph of the leg was taken just before AKO-conversion and at 2 years postoperatively. Deformity analysis for the preoperative planning of the AKO-conversion was based on the mLDFA, JLCA, and mMPTA. The HKA angle was assessed preoperatively and 2 years postoperatively. The Japanese Orthopaedic Association (JOA) score[19] was assessed preoperatively and 2 years after AKO-conversion. Participation in sports was examined using the Tegner activity scale preoperatively and 2 years after the conversion procedure. The duration between AKO-conversion and RTS was recorded.

For objective evaluation of the AKO-conversion results, the patients who underwent TKA-conversion from failed HTO performed during the same period were also assessed. TKA-conversion was performed with an aim to achieve painless return to usual activities of daily living, and it was indicated when recurrent disabling knee pain was present after HTO. Because the indication and/or purpose of the surgery essentially differ from each other, a statistical analysis between the AKO- and TKA-conversion groups was not performed, and the results of the latter are not listed in Table 1. A statistical analysis comparing the clinical results before and after conversion was performed only in the TKA-conversion group (paired t-test for the JOA score and the Wilcoxon signed-rank test for the Tegner activity scale score) because of the small number of patients in the AKO-conversion group.

3. Results

Between 2015 and 2020, 12 patients underwent joint-preserving surgery for failed HTO. These joint-preserving surgeries comprised three arthroscopic osteophyte resections, six re-correction HTOs, and three additional DFOs. Among these, two patients who underwent re-correction HTO and two who received additional DFO met the study inclusion criteria. No patients who underwent arthroscopic osteophyte resection met the study inclusion criteria.

The patient characteristics, values of the deformity analyses for the selection of the AKO-conversion procedure, and outcome measures are listed in Table 1. The average ages at primary HTO and

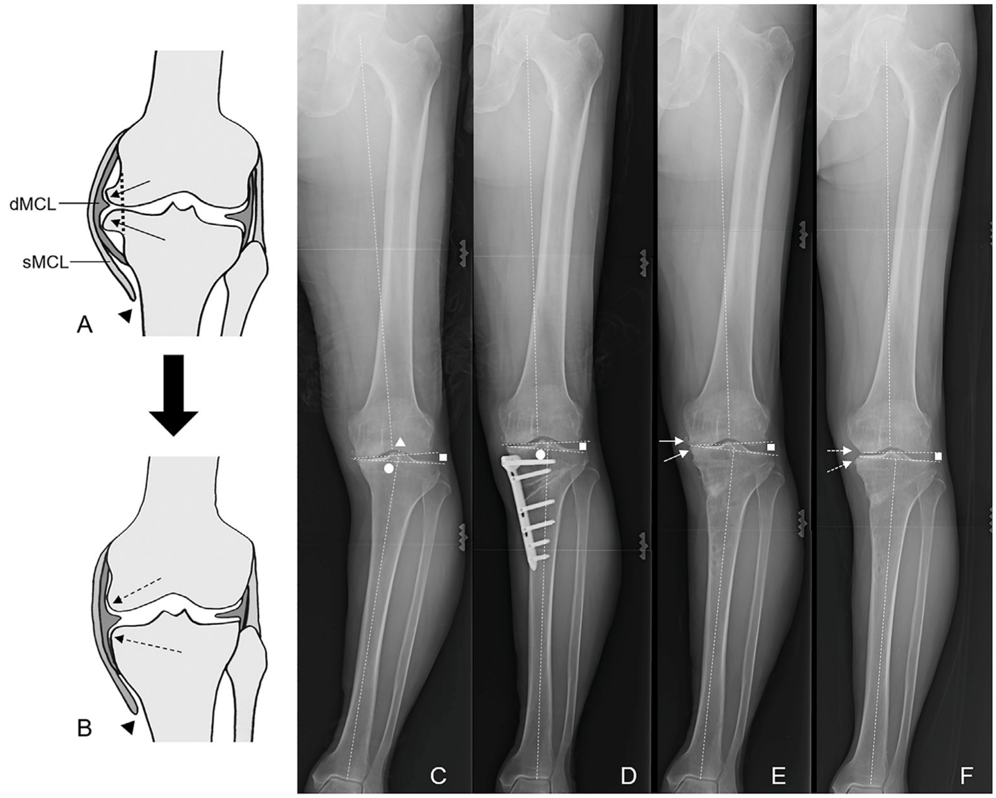

Fig. 1. Images of a patient who underwent arthroscopic resection of osteophytes because invasive surgery was inappropriate due to the detection of systemic adrenal cancer metastases after plate removal
A. The excluded dMCL by large medial osteophytes (black arrows) results in medial tightness even after complete release of the sMCL (black triangle), which is fundamental to prevent medial overload in open-wedge HTO. B. The medial compartment can be completely decompressed only after dMCL release by osteophyte resection (dashed arrows). C. Full-length anteroposterior view radiograph shows varus deformity before primary HTO (HKA angle of −12° [angle between the two vertical dashed lines]) caused by the proximal tibial medial inclination and medial joint closure (mLDFA of 88° [white triangle], JLCA of 8° [white square], and mMPTA of 83° [white circle]). D. After the primary open-wedge HTO, despite the sufficiently corrected mMPTA (91° [white circle]), the alignment is still varus with an HKA angle of −1° due to the uncorrected JLCA (7° [white square]). E. Further exacerbation of the varus deformity (HKA angle of −8°) due to the increased JLCA (10° [white square]) is seen 3 years after HTO when the patient developed difficulty walking. We decided to perform arthroscopic resection of large osteophytes on the medial side (white arrows). F. After the arthroscopic osteophyte resection (dashed white arrows), the medial joint space is opened (JLCA of 5° [white square]) despite insufficient correction of the varus deformity. dMCL, deep medial collateral ligament; sMCL, superficial medial collateral ligament; HTO, high tibial osteotomy; HKA angle, hip-knee-ankle angle; mLDFA, mechanical lateral distal femoral angle; JLCA, joint line convergence angle; mMPTA, mechanical medial proximal tibial angle.

AKO-conversion were 69.5 ± 11.8 years and 71.5 ± 10.9 years, respectively. The HKA angle was corrected from −2.8 ± 1.5° to 3.3 ± 1.5°. The types of sporting activity that the four patients participated in were tennis, skiing, aerobics, and mountain climbing. All patients recovered to achieve better performance than preoperatively, and the Tegner score was improved from 2.5 ± 1.0 before AKO-conversion to 5.8 ± 0.5 at the 2-year follow-up, which was the same as before they were affected by knee osteoarthritis. The duration between AKO-conversion and full RTS was 11.8 ± 6.7 months. All four cases of re-correction HTO and additional DFO are depicted in Figs. 2–5.

There were 16 cases of TKA-conversion during the same period as AKO-conversion, and the breakdown of the cruciate-retaining, posterior-stabilised, and constrained type was 4, 6, and 6, respectively. However, no patient participated in a sporting activity with a Tegner activity scale score of ≥5. In the TKA-conversion group, the mean age at primary HTO and TKA-conversion was 63.7 ± 6.3 and 70.6 ± 6.6 years, respectively. Because the reason for the conversion was osteoarthritis progression with correction loss in all cases, most patients had varus deformity immediately before the TKA-conversion (HKA angle, −2.7 ± 3.5°). The TKA-conversion resulted in significant improvement of the JOA score and the Tegner score from 59.1 ± 9.7 to 78.8 ± 10.2 ($p < 0.001$) and from 1.4 ± 1.2 to 2.1 ± 1.2 ($p < 0.005$), respectively.

3.1. Case details

3.1.1. Case 1 (Fig. 2)

An 85-year-old man was referred to our hospital due to persistent right knee pain for 3 months after hybrid closed-wedge HTO. The full-length standing anteroposterior radiograph revealed correction loss due to delayed union with bone absorption (Fig. 2A). Micro-motion caused by insufficient angular stability and an inappropriate fibular osteotomy were considered the possible causes of the failure.[10] As the patient had played tennis every day before he developed knee osteoarthritis and the main purpose of the primary HTO was to enable a return to tennis, a re-correction HTO with osteophyte grafting[10] was planned according to the deformity analysis (Fig. 2B, Table 1). After removing the proximal screws of the lateral plate, an opening procedure from the medial side was performed. Re-osteotomy was necessary because the osteotomised site was fused with fibrous tissue. The medial side was fixed with a TomoFix small plate (Synthes GmbH), and new proximal screws were inserted into the lateral plate. Despite a large amount of bone absorption around the initial osteotomised site (Fig. 2C), complete bone union was obtained at 6 months after re-correction HTO (Fig. 2D) and he fully returned to daily tennis.

Table 1
Case details.

Case	Sex	Primary HTO procedure	Age at primary HTO (years)	AKO-conversion procedure	Age at AKO-conversion (years)	Reason for conversion	Deformity analysis values before AKO-conversion (°)			Hip-knee-ankle angle (°)		Japanese Orthopaedic Association score		Sports	Tegner activity level score			Time to RTS (months)
							mLDFA	JLCA	mMPTA	Pre-conversion	Two years after AKO-conversion	Pre-conversion	Two years after AKO-conversion		Before affected by knee osteoarthritis	Pre-conversion	Two years after AKO-conversion	
1	M	HCWHTO	85	re-correction OWHTO	85	Correction loss with delayed union	87	2	84	−4	2	60	85	tennis	6	2	6	6
2	M	OWHTO	57	re-correction HCWHTO	60	Under-correction	87	1	85	−4	5	75	80	skiing	5	2	5	17
3	F	HCWHTO	65	additional DFO	66	Under-correction	92	0	92	−2	2	80	100	aerobics	6	4	6	6
4	F	OWHTO	71	additional DFO	75	Correction loss	91	4	93	−1	4	60	95	mountain climbing	6	2	6	18
Mean			69.5		71.5					−2.8	3.3	68.8	90.0		5.8	2.5	5.8	11.8
SD			11.8		10.9					1.5	1.5	10.3	9.1		0.5	1.0	0.5	6.7

SD, standard deviation; HTO, high tibial osteotomy; HCWHTO, hybrid closed-wedge HTO; OWHTO, open-wedge HTO; AKO, around-knee osteotomy; DFO, distal femoral osteotomy; mLDFA, mechanical lateral distal femoral angle; JLCA, joint line convergence angle; mMPTA, mechanical medial proximal tibial angle; RTS, return to sporting activity.

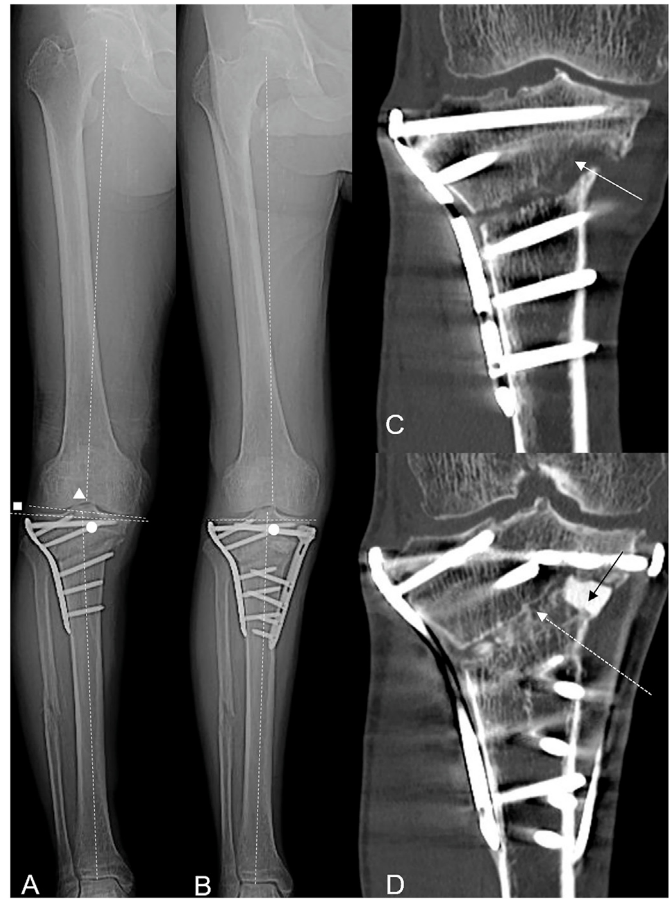

Fig. 2. Re-correction HTO (Case 1 in Table 1).
A. Full-length anteroposterior radiograph reveals persistent varus deformity after closed-wedge HTO because of correction loss due to delayed union (HKA angle of −4° [angle between the two vertical dashed lines], mLDFA of 87° [white triangle], JLCA of 2° [white square], and mMPTA of 84° [white circle]). B. The alignment is appropriately corrected by re-correction open-wedge HTO (HKA angle of 2° and mMPTA of 92° [white circle]). C. Coronal multiplanar reconstruction computed tomography image demonstrates severe bone absorption around the osteotomised site (white arrow) immediately before re-correction HTO (3 months after primary closed-wedge HTO). D. Coronal multiplanar reconstruction computed tomography image shows bone union at 6 months after re-correction HTO. White dashed arrow: grafted osteophytes; black arrow: bone-substitute block. HTO, high tibial osteotomy; HKA angle, hip-knee-ankle angle; mLDFA, mechanical lateral distal femoral angle; JLCA, joint line convergence angle; mMPTA, mechanical medial proximal tibial angle.

3.1.2. *Case 2 (Fig. 3)*

A 60-year-old man who underwent open-wedge HTO of the left knee at 57 years of age presented with a chief complaint of intractable pain that had not been relieved after the primary HTO. Full-length radiography showed 4° varus with a remaining medial tilt of the tibial plateau (Fig. 3A, Table 1). The radiological data immediately after the primary HTO at the previous hospital indicated a similar mMPTA, and undercorrection rather than a correction loss over time was presumed to be the cause of the failure. As he was eager to ski again, conversion to a hybrid closed-wedge HTO was chosen according to the deformity analysis (Fig. 3B, Table 1). Although 3 years had passed since the primary HTO, the plate had not been removed. After removing the proximal screws of the medial plate, a closed-wedge procedure from the lateral side was performed. The lateral side was fixed with a TomoFix Proximal Lateral Tibial plate (TomoFix PLT; Synthes GmbH), and new proximal screws were inserted into the medial plate (Fig. 3B). The varus was corrected to 5° of valgus (Fig. 3B, Table 1), and he returned to

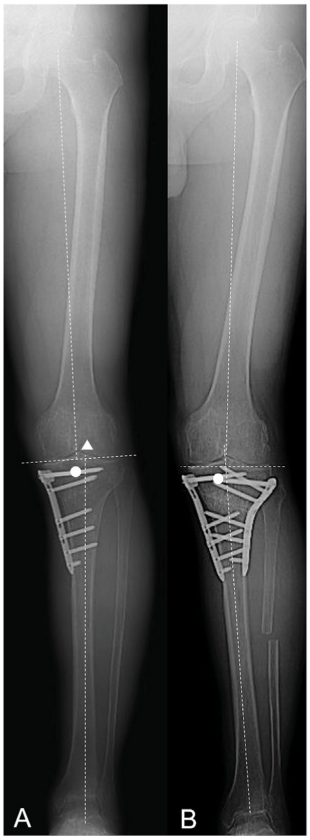

Fig. 3. Re-correction HTO (Case 2 in Table 1).
A. Full-length anteroposterior radiograph 3 years after the primary HTO indicates undercorrection (HKA angle of −4° [angle between the two vertical dashed lines]) due to the remaining medial tibial tilt (mMPTA of 85° [white circle]) without femoral deformity (mLDFA of 87° [white triangle]). B. Full-length anteroposterior radiograph after closed-wedge HTO conversion shows the sufficiently corrected limb alignment (HKA angle of 5° and mMPTA of 93° [white circle]). HTO, high tibial osteotomy; HKA angle, hip-knee-ankle angle; mMPTA, mechanical medial proximal tibial angle; mLDFA, mechanical lateral distal femoral angle.

skiing 17 months after the conversion.

3.1.3. *Case 3 (Fig. 4)*

A 65-year-old woman with severe varus knees (Fig. 4A) who participated in aerobics every day developed subchondral insufficiency fracture of the medial femoral condyle (Fig. 4B). The deformity analysis showed that she required overcorrection by a double-level osteotomy (i.e., DFO combined with HTO). However, we intentionally chose a hybrid closed-wedge HTO with an anatomical alignment of 2° varus (Fig. 4C, Table 1) because intraoperative arthroscopy confirmed that the cartilage surface at the affected area was intact. Once she fully returned to aerobics, the involved area gradually collapsed because of the insufficient correction (Fig. 4D and E), and she began to have limitations in her usual activities of daily living. We then performed an additional DFO (Fig. 4F), and she finally returned to aerobics again 6 months later.

3.1.4. *Case 4 (Fig. 5)*

A 71-year-old woman underwent left open-wedge HTO to enable a return to mountain climbing and was able to climb mountains as high as 3,000 m at 1 year after surgery. Although the correction was appropriately performed, she started to experience difficulties in mountain climbing at 75 years of age due to recurrent varus induced by the gradual progression of femoral bowing

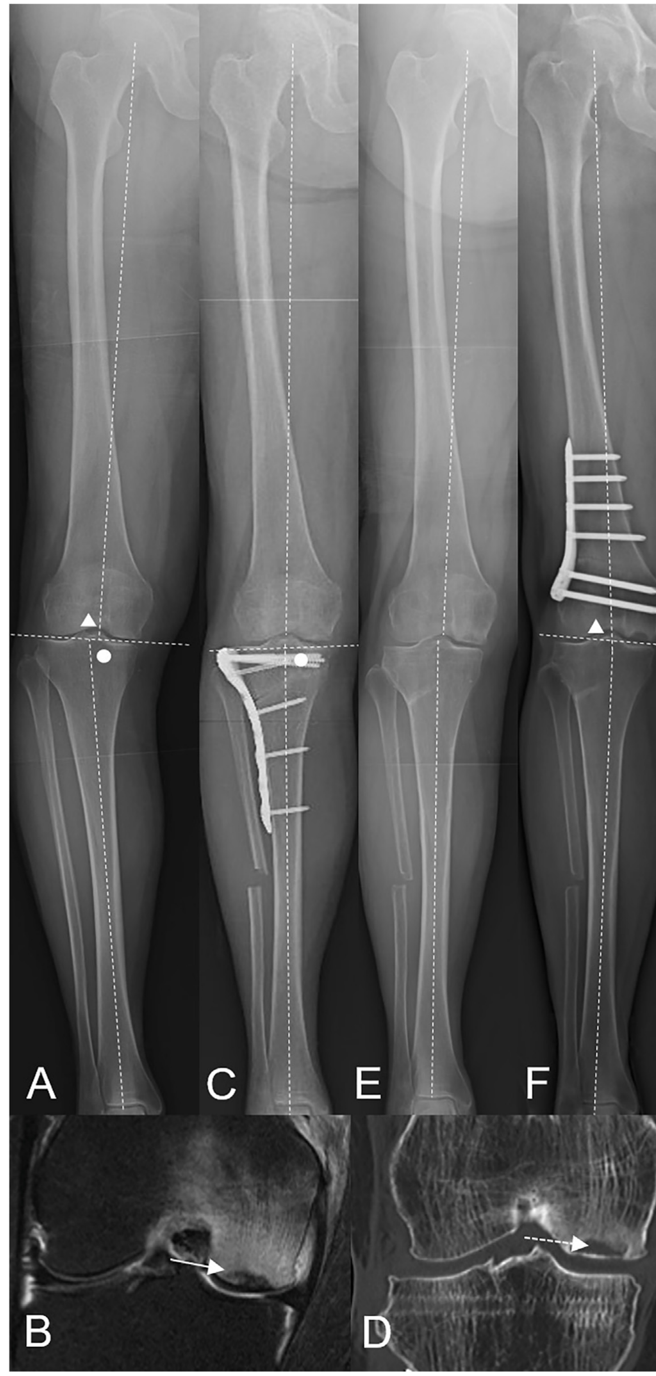

Fig. 4. Additional DFO (Case 3 in Table 1).
A. Full-length anteroposterior radiograph reveals the varus deformity before primary HTO caused by both the femur (mLDFA of 92° [white triangle]) and the tibia (mMPTA of 82° [white circle]). B. A subchondral insufficiency fracture in the medial femoral condyle (white arrow) is detected on a coronal T2-weighted fat saturation magnetic resonance image with no cartilage defects. C. Leaving a slight varus deformity, the leg alignment is anatomically corrected by closed-wedge HTO (HKA angle of −2° [angle between the two vertical dashed lines] and mMPTA of 92° [white circle]). D. The coronal slice of the multiplanar reconstruction computed tomography image at 6 months reveals collapsed osteonecrosis (white dashed arrow) induced by the subchondral fracture. E. Despite the lack of correction loss (HKA angle of −2°), the necrosis is not improved at 1 year after primary HTO. F. Appropriate alignment is achieved after the additional DFO (HKA angle of 2° and mLDFA of 86° [white triangle]). HTO; high tibial osteotomy; mLDFA, mechanical lateral distal femoral angle; mMPTA, mechanical medial proximal tibial angle; HKA angle, hip-knee-ankle angle; DFO, distal femoral osteotomy.

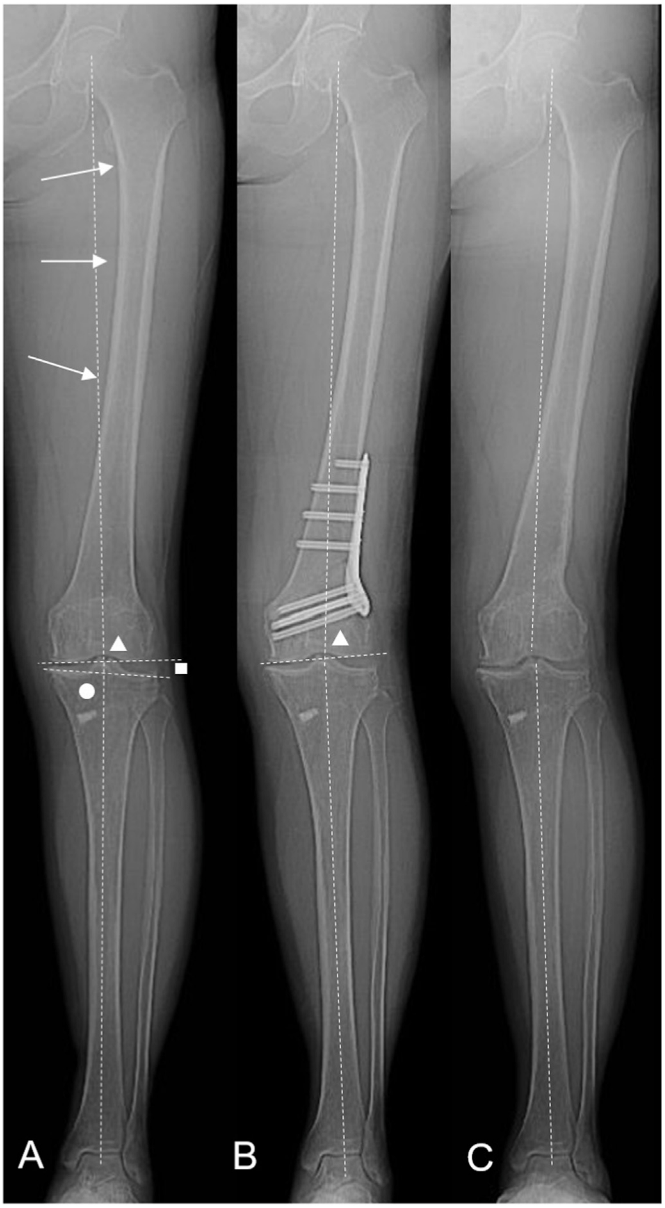

Fig. 5. Additional DFO (Case 4 in Table 1).
A. Full-length anteroposterior radiograph 4 years after the primary HTO reveals varus deformity caused by femoral bowing (white arrows, HKA angle of −1° [angle between the two vertical dashed lines] and mLDFA of 91° [white triangle]), although the appropriate tibial correction is preserved (mMPTA of 93° [white circle]). The closed medial joint space is contributing to the varus deformity as well (JLCA of 4° [white square]). B. The HKA angle and the mLDFA are corrected to 4° and 86° (white triangle), respectively, by the additional DFO. C. Two years after the additional DFO, no further femoral bowing is seen and the medial joint space is opened because of the sufficient valgus correction. HTO, high tibial osteotomy; HKA angle, hip-knee-ankle angle; mLDFA, mechanical lateral distal femoral angle; mMPTA, mechanical medial proximal tibial angle; JLCA, joint line convergence angle; DFO, distal femoral osteotomy.

(Fig. 5A). As she desired a return to mountain climbing again, additional DFO was performed based on the deformity analysis (Fig. 5B, Table 1). At 1.5 years after surgery, she successfully returned to mountain climbing at the same level as before being affected by knee osteoarthritis. Further progression of the femoral bowing was not seen for 2 years after the additional DFO (Fig. 5C).

4. Discussion

Even though the most common solution for failed HTO is TKA-conversion, it is not always easy to obtain an appropriate soft tissue balance, and so a constrained prosthesis may be required.[20] In the present series of TKA-conversion, despite the significant improvement in the JOA score, 6 of 16 cases (37.5%) actually required constrained type prosthesis because of the medial excessive laxity. A conversion to unicompartmental knee arthroplasty is an option, but high failure rates have been reported[21] because of technical problems associated with ligamentous instability or lateral wear and subsequent failure.

In contrast to the prosthetic solutions, the advantage of non-prosthetic AKO-conversion is that there is no need to adjust the ligamentous soft tissue balance because of the extra-articular procedure. In re-correction HTO, however, osteotomy on the same side as the primary HTO may cause difficulty in cutting the bone and/or delayed union due to the sclerotic bone around the osteotomised site. The findings of the present case series suggest that these problems may be eliminated by performing a lateral closing procedure after medial opening primary HTO or a medial opening procedure after lateral closed primary HTO. Although additional DFO is a reoperation, this procedure is the first osteotomy of the femur, as the initial osteotomy was performed on the tibia. Thus, there are no adhesions at the femoral osteotomy site and no unmanageable postoperative sclerotic bones.[13]

Although the Tegner activity scale score was significantly improved in the TKA-conversion group, no patients participated in a high-level sporting activity. In contrast, all four patients in the AKO-conversion group returned to their desired sports at the desired level. These results support our hypothesis that AKO-conversion for failed HTO enabled a RTS that was comparable to that achieved by primary osteotomy. Despite some reports of a decrease in participation in high-impact activities after HTO,[22,23] AKO enables patients to return to basically unrestricted high- or low-impact sporting activities due to the lack of any intraarticular prostheses. In comparison with non-prosthetic solutions, high-impact sporting activities are not recommended after TKA because of the presence of intraarticular prostheses.[8] Furthermore, the risk of periprosthetic fracture should be considered, especially when older adult patients return to sports after TKA. As we routinely remove the plates after bone union, the risk of implant-related complications such as fracture around the plate is eliminated. Therefore, non-prosthetic AKO-conversion for failed HTO may have substantial benefits that enable a safe RTS.

5. Conclusion

Two patients with re-correction HTO and two with additional DFO for undercorrection or correction loss after HTO achieved highly satisfactory clinical results, including RTS. Non-prosthetic joint-preserving solutions using AKO for failed HTO should be considered as options that enable RTS.

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Ethics statement

Approvals were obtained (2018-11 and 2022-4) from Yawata Medical Center and Harue Hospital ethics committees, respectively.

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