Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology 39 (2025) 1–8

Contents lists available at ScienceDirect

Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology

journal homepage: www.ap-smart.com

Original Article

Is there a difference in bony stability at three months postoperatively between opening-wedge high tibial osteotomy and opening-wedge distal tuberosity osteotomy?

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ARTICLE INFO

Keywords:
Distal tuberosity osteotomy
Flange thickness
Hinge fracture
Hinge length
High tibial osteotomy
Initial stability

ABSTRACT

Objective: To compare the initial postoperative stability of opening-wedge high tibial osteotomy (HTO) and opening-wedge distal tuberosity osteotomy (DTO) and investigate the factors that influence initial stability.

Methods: Patients with the same operative indications who underwent HTO (n = 51) and DTO (n = 55) were included. Demographic and preoperative radiographic data (weight-bearing line percentage [%WBL], femoral-tibial angle [FTA], medial proximal tibial angle [MPTA], posterior tibial slope and correction angle), and postoperative computed tomography (CT) scan data (initial postoperative stability [12 weeks postoperative], and hinge fracture [1 and 12 weeks postoperatively], and hinge length, flange thickness, flange length, axial flange osteotomy angle, sagittal flange osteotomy angle [1 week postoperatively]) were statistically analyzed. As a subgroup analysis, HTO and DTO patients were divided into Stable and Unstable groups respectively based on postoperative CT at 12 weeks; demographic and radiological data were compared.

Results: Patients with DTO was significantly younger (median [range]; 59 [22, 73] vs 64 [45, 75], P = 0.02) and had a smaller preoperative deformity (%WBL: median [range]; 28.9 [12.8, 46.0] vs 24.3 [4.9, 44.3], P < 0.01, FTA: median [range]; 179.0 [173.0, 183.0] vs 180.0 [172.5, 186.2], P < 0.01, MPTA: median [range]; 84.0 [79.0, 87.1] vs 83.0 [78.2, 86.5], P = 0.04) and smaller correction angles (median [range]; 9 [6, 12] vs 10 [7, 15], P < 0.01). Postoperative CT data showed that DTO was associated with significantly more unstable cases (stable/unstable: 31/24 vs. 39/12, P = 0.02) and hinge fractures (none/1/2/3: 24/25/3/3 vs. 36/12/1/2, P < 0.01) and shorter hinge (median [range]; 27.8 [14.7, 43.4] vs 32.6 [22.5, 44.0], P < 0.01) than HTO. The Unstable DTO group had significantly shorter hinges (median [range]; 23.2 [14.7, 33.9] vs 31.1 [15.2, 43.4], P < 0.01) and thicker flanges (median [range]: 15.2 [9.0, 24.8] vs. 11.0 [6.8, 13.8], P < 0.01) than the stable group. The other data were not significantly different between the two groups.

Conclusion: DTO resulted in less initial postoperative stability than HTO. The risk factors for initial instability in DTO were a short hinge and thick flange.

1. Introduction

Opening-wedge high tibial osteotomy (HTO) is a safe and clinically effective technique for medial femorotibial compartment osteoarthritis (OA) of the knee with varus alignment.[1] Compared to conventional techniques, the introduction of a locking plate allows for earlier weight-bearing, and improved outcomes have been reported; however, there are recent reports that HTO contributes to postoperative patellar baja and associated secondary patellofemoral (PF) OA.[2–5]

Opening wedge distal tuberosity osteotomy (DTO) is gaining attention as a solution to HTO-specific problems.[6–9] Compared to HTO, DTO does not cause patellar baja because it involves descending osteotomy of the tibial tubercles, and postoperative arthroscopy has reported less cartilage damage of the PF joint.[2–5] Furthermore, Ogawa et al. reported

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https://doi.org/10.1016/j.asmart.2024.10.001
Received 16 April 2024; Received in revised form 13 September 2024; Accepted 30 October 2024
Available online 20 November 2024

better postoperative outcomes than HTO[2]; therefore, DTO is remarkable as a new proximal tibial osteotomy technique with the potential to solve HTO problems.

On the other hand, DTO has been reported to have more complications than HTO (incidence of 9.2 vs 1.6 %), as well as DTO-specific complications, such as flange fracture (incidence of 4.5–13.5 %) and flange union failure (incidence of 11.8–20.5 %).[5,8,10–12] Although flange fracture has been reported to have no effect on clinical outcomes,[10] the impact of flange fracture and flange union failure on the stability of the osteotomy site in the early postoperative period is unknown. And there are no reports comprehensively comparing the initial stability of DTO and the conventional HTO method.

The purpose of this study was: (1) to directly compare the initial postoperative bone union/stability of HTO and DTO and (2) to investigate the factors that influence the initial stability of each technique. We hypothesized that DTO might have less initial postoperative stability and be more susceptible to bone union failure than HTO; another hypothesis was that if we could identify the factors contributing to poor postoperative stability in this study, we would be able to perform knee osteotomies with early postoperative stability.

2. Materials and methods

2.1. Patient selection

This retrospective study was conducted in accordance with the principles of the Declaration of Helsinki. This study was approved by the Ethics Committee of Shinshu University (March 28th, 2023/ No. 5807) Informed consent was obtained in the form of an opt-out on the hospital website. The research participants were given information about the study and were guaranteed an opportunity to refuse to participate or continue the study. This study included successive patients who underwent HTO and DTO at our hospital between August 2009 and October 2022. HTO was performed from August 2009 to September 2019, and DTO was performed from October 2019 onward. The indications for surgery were the same for HTO and DTO: OA or osteonecrosis of the medial compartment on radiography and MRI, no improvement in symptoms after at least 3 months of conservative treatment before surgery, no apparent cartilage injury in the lateral or PF compartments, and flexion contracture <15°. The exclusion criteria were concomitant anterior cruciate ligament reconstruction and loss of preoperative and postoperative radiographic data. A total of 106 knees (51 HTO patients and 55 DTO patients) were enrolled in this study (Fig. 1, Table 1).

2.2. Surgical technique

Four operators, each with more than 10 years of experience certified by the Orthopaedic Association, performed all operations. We performed preoperative long-leg weight-bearing radiography of both lower extremities, and the correction angle was calculated as the postoperative weight-bearing line percentage (%WBL) and 62.5 % for HTO and DTO.

For HTO and DTO, the patient was placed in the supine position, and arthroscopy was performed first. No injury to the ligaments or lateral compartments was observed. The medial meniscus was partially resected if injured, and repair was not performed in any case. No treatment for cartilage injury was administered. HTO and DTO were performed as described below.

2.2.1. HTO

HTO was performed as described in previous reports.[13] The pes

Table 1
Patient demographics, preoperative X-ray data, correction angle.

	HTO (n = 51)	DTO (n = 55)	P value
Follow up, month	49.0 [12.0, 154.0]	16.3 [3.0, 37.1]	<0.01
Age, y	64 [45, 75]	59 [22, 73]	0.02
Sex, male/female	16/35	22/33	0.18
Body mass index, kg/m2	24.7 [19.6, 32.4]	26.1 [17.4, 35.6]	0.18
Diagnosis, OA/necrosis	47/4	52/3	0.63
Preoperative %WBL	24.3 [4.9, 44.3]	28.9 [12.8, 46.0]	<0.01
Preoperative FTA	180.0 [172.5, 186.2]	179.0 [173.0, 183.0]	<0.01
Preoperative MPTA	83.0 [78.2, 86.5]	84.0 [79.0, 87.1]	0.04
Preoperative PTS	8.9 [3.9, 15.9]	9.1 [3.1, 16.6]	0.33
KL grade 0/1/2/3/4	0/2/20/29/0	0/5/24/26/0	0.26
Correction angle, degree	10 [7, 15]	9 [6, 12]	<0.01

Data are presented as median [range] or number. Significance level was set on P 0.05.
HTO, opening-wedge high tibial osteotomy; DTO, opening-wedge distal tuberosity osteotomy; OA. Osteoarthritis; %WBL, weight-bearing line percentage; FTA, femoral-tibial angle; MPTA, medial proximal tibial angle; PTS, posterior tibial slope; KL, Kellgren-Laurence.

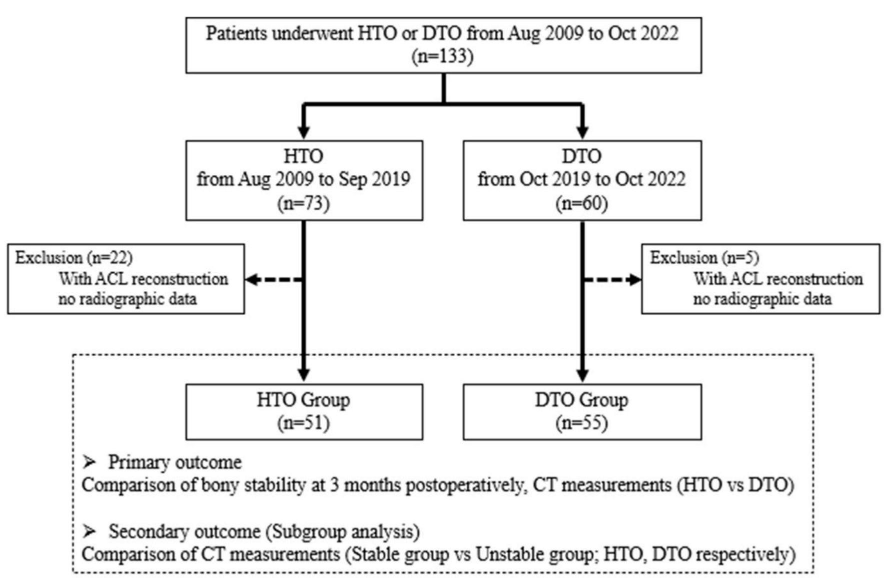

Fig. 1. Flow chart showing the criteria for patient enrolment and study design. HTO, high tibial osteotomy; DTO, distal tuberosity osteotomy; ACL, anterior cruciate ligament.

anserinus was incised in a T-shape, and the superficial layer of the medial collateral ligament was completely dissected. The soft tissue posterior to the tibia was dissected, and a fluoroscopic retractor was inserted. The first guide pin was inserted (to 35–40 mm) distal to the surface of the medial proximal tibial joint towards the fibular head. A second guide pin was inserted dorsally parallel to the first guide pin with fluoroscopic confirmation, and the hinge position was set within the proximal tibiofibular joint and lateral to the medial margin of the proximal tibiofibular joint. Under fluoroscopic guidance, transverse osteotomy was performed under the two guide pins using a bone saw and chisel. Ascending osteotomy was performed at an angle of 120° from the transverse osteotomy plane. After biplane osteotomy, the transverse osteotomy gap was opened to the preoperatively planned correction angle using a spreader. β-TCP (Osferion; Olympus Terumo Biomaterials, Tokyo, Japan) was inserted into the gap. The pes anserinus is repaired to cover as much of the osteotomy gap as possible. Fixation was accomplished using a locking plate (Tomofix; DePuy Synthes, Zuchwil, Switzerland or TriS; Olympus Terumo Biomaterials, Tokyo, Japan) from the medial side of the tibia. The wound was closed after replacing the surgical drain.

2.2.2. DTO

The DTO was performed according to the procedure described by Akiyama et al.[6] Transverse osteotomy was performed as in the HTO. Under fluoroscopy, a short hinge pin was inserted in the anteroposterior direction at the hinge position. Multiple bone holes with a radius of 50 mm were created along the art-cut line using a short hinge pin. Descending osteotomy was performed carefully such that the flange thickness was not less than 10 mm, and arc osteotomy was performed to connect the created bone holes. Similar to HTO, β-TCP was inserted into the osteotomy gaps. To apply compression to the anterior osteotomy surface, a bicortical 5.5-mm cannulated cancerous screw with a washer (Meira, Nagoya, Japan) was placed in the anterior-posterior direction. The subsequent procedures were performed as previously described for HTO.

2.3. Postoperative rehabilitation

Postoperative rehabilitation was the same for the HTO and DTO groups. The patient did not undergo immobilization; range-of-motion exercises were started 1 day postoperatively. Partial weight bearing was initiated 1 week postoperatively. Weight-bearing status gradually increased, and full weight-bearing was allowed at 4 weeks postoperatively. Subsequently, the activity increased according to the bone union status.

2.4. Radiographic and CT evaluation

Radiographic evaluation was performed preoperatively and 12 weeks postoperatively. %WBL, femoral-tibial angle (FTA), and medial proximal tibial angle (MPTA) were measured by long-leg weight-bearing X-rays of both lower extremities. The posterior tibial slope (PTS) was measured by using lateral radiography. OA evaluation by Kellgren-Laurence (KL) grade was performed preoperatively and 1 year postoperatively by X-rays.

Postoperative CT was performed 1 and 12 weeks postoperatively. The following measurements were taken at 1-week postoperative CT. Hinge length (HL) was measured as the total length of the hinge in the most proximal axial slice where the hinge was visible (Fig. 2). The flange thickness (FT), which may be related to HL was measured at the base of the flange (Fig. 3). Flange length (FL) as a proxy for flange contact area was defined as the distance between the distal osteotomy level and the proximal end of the flange in HTO and the distance between the proximal osteotomy level and the distal end of the flange in DTO (Fig. 3). FT and FL measurements were performed as described by Ogawa et al.[10] The axial flange angle (AFA) was defined as the angle between the

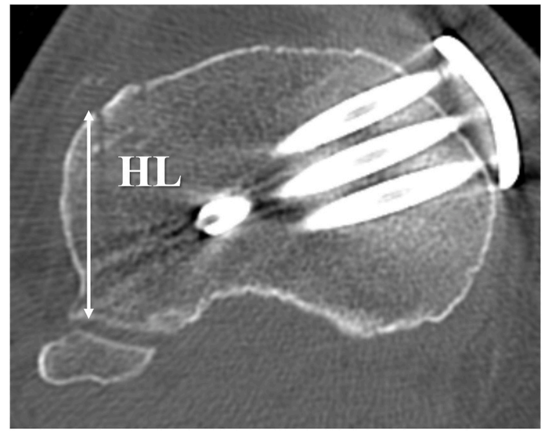

Fig. 2. Measurement of hinge length (HL) on axial CT slices
HL (white two-way allow) was measured in the most proximal axial slice, where the hinge was visible.

posterior condyle axis of the proximal tibia and the flange osteotomy surface (external rotation, +) (Fig. 4). The sagittal flange angle (SFA) was defined as the angle between the distal (HTO) or proximal (DTO) and flange osteotomy planes in a sagittal slice (Fig. 5).[12] Hinge fractures were evaluated by radiography and CT (1 week and 12 weeks postoperatively) based on the report by Takeuchi et al.[14]

The initial postoperative stability of the osteotomy site was evaluated based on the following three criteria on CT images at 12 weeks postoperatively: (1) bony integrity at the lateral hinge (includes hinge fractures with bone union), (2) bony union of the anterior flange, and (3) no loosening or breakage of the medial plate and screw. Bone union of the anterior flange was determined on a slice in the middle of the tibial tubercle showing bone continuity for at least 50 % of the total length of the flange (modified measurement method by Ogawa et al.[10]). When all three requirements were deemed met by the three examiners, initial stability was deemed to have been attained. Based on these criteria, the HTO and DTO groups were subdivided into stable and unstable groups, respectively.

2.5. Statistical analyses

Demographic and radiological data were compared between the HTO and DTO groups and between each subgroup. For statistical comparisons between the two groups, Fisher's exact test was used for binary variables if any of the items were five or fewer, Pearson's chi-square test was used for all other variables, and the Mann–Whitney *U* test was used for continuous and ordinal variables. At this time, if confounding of demographic factors was observed in the inter-procedural comparison of outcomes, a stratified analysis was performed with the confounding factors as stratification factors. If the confounding factor was a continuous scale, it was binaries at the median. The Cochran–Mantel–Haenszel test was used for the nominal scale, and the stratified Wilcoxon-Mann-Whitney (van Elteren) test for the ordinal and continuous scales. Wilcoxon signed-rank sum test was used for paired data. No previous reports have investigated the association between hinge length and flange thickness. Therefore, the Spearman correlation test was used to evaluate the association between hinge length and flange thickness for HTO and DTO.

Two orthopedic surgeons evaluated the hinge length and flange thickness ($n = 30$ each) without patient information and calculated the inter-examiner ICC. Each examinee was reassessed 2 weeks later, and the intra-examiner ICC was calculated. The inter-examiner and intra-examiner ICCs for hinge length were 0.99 and 0.95, respectively, and the inter-examiner and intra-examiner ICCs for flange thickness were 0.97 and 0.95, respectively. A power analysis indicated that a sample

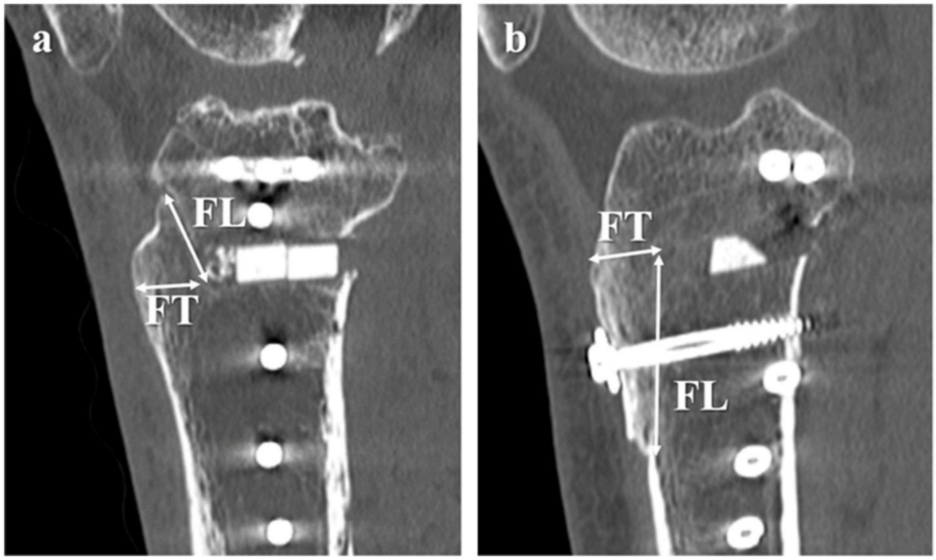

Fig. 3. Measurement of flange thickness (FT) and flange length (FL) on sagittal CT slice in (a) high tibial osteotomy (HTO) and (b) distal tuberosity osteotomy (DTO) The slices were at the centre of the flange. FT was measured at the base of the flange. FL was measured as the distance between the distal osteotomy level and the proximal end of the flange in HTO and the distance between the proximal osteotomy level and the distal end of the flange in DTO.

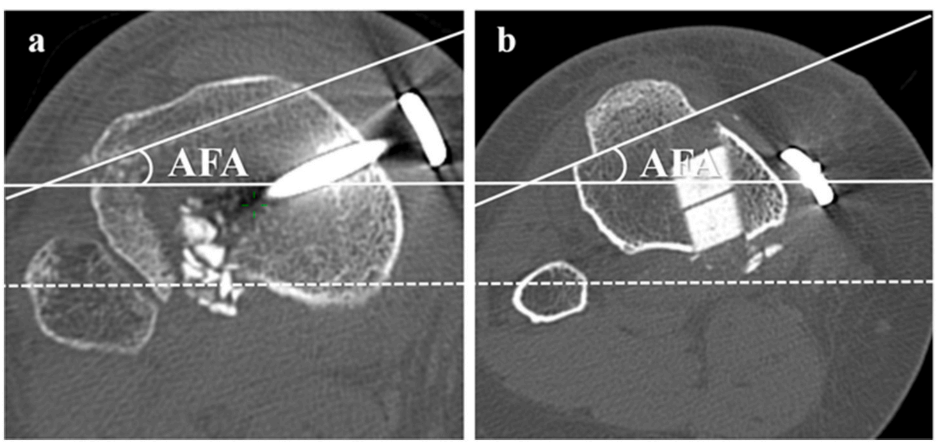

Fig. 4. Measurement of axial flange angle (AFA) on axial CT slice in (a) high tibial osteotomy and (b) distal tuberosity osteotomy
AFA was measured as the angle between the posterior condyle axis of the proximal tibia (the dotted line) and the flange osteotomy surface.

size of at least 44 persons in each group was necessary to detect group differences with an alpha of 0.05 and a power of 80 %. EZR 2.7–0 was used for all statistical analyses.[15]

3. Results

3.1. Comparison of HTO and DTO

For preoperative demographic data, the DTO group was significantly younger (59 vs 64) and had a smaller preoperative deformity (%WBL, 28.9 vs 24.3; FTA, 179.0 vs 180.0; MPTA, 84.0 vs 83.0) and correction angles (9 vs 10) than the HTO group (Table 1).

Because there were significant differences in age among the procedures, a stratified analysis was performed with age as the stratification factor for outcome (Table 2). A postoperative comparison of the CT data at 12 weeks showed that the DTO group had significantly fewer stable cases and more hinge fractures than the HTO group (Table 2). A postoperative comparison of CT data at 1 week showed that DTO had a significantly shorter hinge length than HTO; there were no flange fractures in HTO and DTO.

KL grade (0/1/2/3/4) at 1 year postoperatively were not significantly different from preoperatively in both HTO and DTO (HTO; 0/2/20/29/0, $P > 0.99$, DTO; 0/4/24/27/0, $P = 0.62$), and no significant difference was found between the two groups ($P = 0.33$).

3.2. Subgroup analysis (comparison of stable and unstable)

The Unstable HTO group had a significantly smaller preoperative MPTA and larger correction angle than the stable HTO group (Table 3). The other data were not significantly different between the two groups; all HTO cases showed bone union. The Unstable DTO group had a significantly shorter hinge length and thicker flange thickness than the stable DTO group (Table 4). The other data were not significantly different between the two groups. All patients in the stable DTO group showed bone union; however, two cases of flange pseudarthrosis were observed in the unstable DTO group (Fig. 6).

3.3. Correlation test

Although there was no significant correlation between hinge length and flange thickness in HTO, a significantly strong negative correlation was found for DTO (correlation coefficient: -0.74, $P < 0.01$) (Fig. 7).

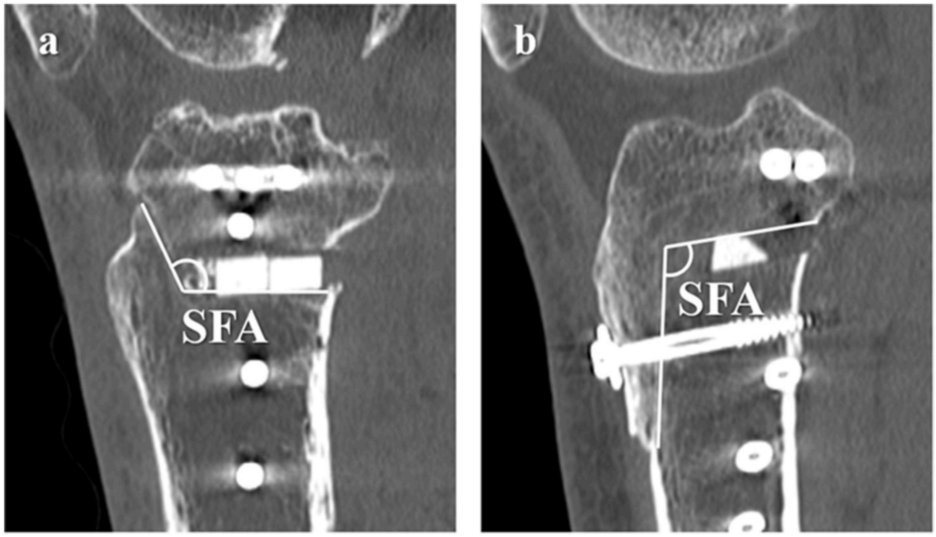

Fig. 5. Measurement of sagittal flange angle (SFA) on sagittal CT slice in (a) high tibial osteotomy (HTO), and (b) distal tuberosity osteotomy (DTO) SFA was measured as the angle between the distal (HTO) or proximal (DTO) osteotomy plane and the flange osteotomy plane.

Table 2
Postoperative CT data stratified by age.

	Age group	HTO (n = 51)	DTO (n = 55)	P value
Stable/unstable[A]	Overall	39/12	31/24	0.02 (a)
	Age < median (62y)	15/3	20/12	–
	Age ≥ median	24/9	11/12	–
Hinge fracture, none/1/2/3[A],[B]	Overall	36/12/1/2	24/25/3/3	<0.01 (b)
	Age < median	14/4/0/0	17/12/1/2	–
	Age ≥ median	22/8/1/2	7/13/2/1	–
Hinge length, mm[B]	Overall	32.6 [22.5, 44.0]	27.8 [14.7, 43.4]	<0.01 (b)
	Age < median	34.1 [22.5, 44.0]	28.2 [14.7, 43.0]	–
	Age ≥ median	32.1 [23.0, 43.7]	26.8 [19.4, 43.4]	–
Flange thickness, mm[B]		10.6 [6.8, 19.8]	12.2 [6.8, 24.8]	
Flange length, mm[B]		17.6 [8.1, 27.2]	43.6 [30.7, 57.5]	
Axial flange osteotomy angle, degree[B]		24.7 [6.8, 43.9]	21.3 [0.3, 42.9]	
Sagittal flange osteotomy angle, degree[B]		116.6 [100.2, 153.7]	93.1 [74.0, 114.0]	

Data are presented as median [range] or number. Significance level was set on P 0.05.
P value: a) The Cochran–Mantel–Haenszel test, b) The stratified Wilcoxon-Mann-Whitney (van Elteren) test.
CT, computed tomography; HTO, opening-wedge high tibial osteotomy; DTO, opening-wedge distal tuberosity osteotomy.
[A] measured at 12 weeks.
[B] measured at 1 week.

Table 3
Subgroup analysis; HTO.

	Stable (n = 39)	Unstable (n = 12)	P value
Age, y	64 [45, 75]	65 [52, 72]	0.55
Sex, male/female	11/28	5/7	0.59
Body mass index, kg/m2	24.1 [19.6, 30.5]	25.1 [20.3, 32.4]	0.41
Diagnosis, OA/necrosis	37/2	10/2	0.59
Preoperative %WBL	24.5 [5.4, 44.3]	20.0 [4.9, 31.5]	0.17
Preoperative FTA	179.7 [172.5, 184.0]	180.6 [177.6, 186.2]	0.27
Preoperative MPTA	85.1 [82.2, 88.2]	82.9 [80.1, 86.5]	0.01
Preoperative PTS	8.9 [3.9, 15.9]	9.2 [5.0, 15.2]	0.89
Correction angle, degree	10 [7, 15]	13 [8, 15]	0.03
Hinge fracture, none/1/2/3	35/4/0/0	1/8/1/2	<0.01
Hinge length, mm	32.6 [22.5, 43.7]	32.7 [27.0, 44.0]	0.94
Flange thickness, mm	10.8 [6.8, 19.8]	10.4 [7.0, 14.7]	0.41
Flange length, mm	17.6 [8.1, 24.8]	16.9 [8.8, 27.2]	0.72
Axial flange osteotomy angle, degree	25.1 [6.8, 43.9]	22.2 [11.7, 35.4]	0.32
Sagittal flange osteotomy angle, degree	118.2 [100.2, 153.7]	112.5 [103.6, 129.6]	0.30

Data are presented as median [range] or number. Significance level was set on P 0.05.
HTO, opening-wedge high tibial osteotomy; OA. Osteoarthritis; %WBL, weight-bearing line percentage; FTA, femoral-tibial angle; MPTA, medial proximal tibial angle; PTS, posterior tibial slope.

4. Discussion

The most crucial finding of this study was that DTO had less initial stability than HTO, with the Unstable group characterized by a short hinge and thick flange compared with the stable group in DTO. This is the first study to directly compare HTO and DTO in terms of bone union, and the results provide important insights into surgical procedures for DTO.

Postoperative patella baja is a common problem of HTO, results increasing PF joint pressure and PF OA.[2,3,16–21] In the DTO technique, the tibial tuberosity is attached to the proximal tibial fragment; therefore, the patellar height does not change after the surgery.[2,3,7,11,12,22–25] Two biomechanical cadaveric studies showed that DTO had no significant effect on PF contact pressures and maintained normal PF joint biomechanics.[18,19] Furthermore, clinical studies have shown that DTO does not exacerbate cartilage injury compared to HTO on second-look arthroscopy[2,3]; therefore, the advantages of DTO over HTO for PF joints were demonstrated.

In contrast, DTO has unique complications around the tibial tubercle that is not associated with HTO. One complication is flange fracture, with a reported incidence of 4.5–13.5 %[8,10–12,26]; a thin flange is the most common risk factor for flange fracture.[6,8,11] Another characteristic

Table 4
Subgroup analysis; DTO.

	Stable (n = 31)	Unstable (n = 24)	P value
Age, y	59 [22, 73]	60 [39, 72]	0.97
Sex, male/female	11/20	11/13	0.58
Body mass index, kg/m2	25.0 [17.4, 31.4]	26.2 [21.3, 35.6]	0.55
Diagnosis, OA/necrosis	29/2	23/1	0.63
Preoperative %WBL	29.9 [14.9, 44.2]	27.7 [12.8, 46.0]	0.38
Preoperative FTA	178.0 [175.5, 183.0]	179.0 [173.2, 183.1]	0.43
Preoperative MPTA	84.0 [79.0, 87.1]	84.1 [80.8, 86.0]	0.71
Preoperative PTS	9.2 [3.1, 16.6]	8.9 [3.7, 11.2]	0.66
Correction angle, degree	9 [6, 12]	9 [6, 12]	0.15
Hinge fracture, none/1/2/3	21/8/2/0	3/17/1/3	<0.01
Hinge length, mm	31.1 [15.2, 43.4]	23.2 [14.7, 33.9]	<0.01
Flange thickness, mm	11.0 [6.8, 13.8]	15.2 [9.0, 24.8]	<0.01
Flange length, mm	40.6 [30.7, 54.8]	44.4 [32.4, 57.5]	0.07
Axial flange osteotomy angle, degree	21.7 [0.3, 42.9]	20.1 [6.3, 35.6]	0.68
Sagittal flange osteotomy angle, degree	92.4 [74.0, 103.6]	93.7 [78.3, 114.0]	0.24

Data are presented as median [range] or number. Significance level was set on P 0.05.
DTO, opening wedge distal tuberosity osteotomy; OA. Osteoarthritis; %WBL, weight bearing line percentage; FTA, femoral-tibial angle; MPTA, medial proximal tibial angle; PTS, posterior tibial slope.

complication is flange union failure, with a reported incidence of 11.8–20.5 %.[8,12] The absence of flange fixation screws was the only risk factor for flange union failure.[12,26] Notably, a systematic review reported a significantly higher total complication rate with DTO than with HTO, which is not only around the tibial tubercle.[5]

The initial postoperative stability is important because it significantly affects early rehabilitation and social reintegration. However, to our knowledge, no reports have compared DTO and HTO concerning initial postoperative stability. Nejima et al. reported that DTO had a significantly larger osteotomy area and flange contact area than HTO in a bone model, which may favor bone union.[27] In contrast, this study showed that DTO had a significantly lower initial stability than HTO; this is a significant finding of this study. The initial stability of opening wedge osteotomy is thought to be achieved by the acquisition of the following three columns: (1) medial (plate fixation), (2) lateral (hinge integrity), and (3) anterior (flange bone union). However, the DTO in this study had more hinge fractures than the HTO, which was thought to result from the thicker flange obviating flange fractures, resulting in a shorter hinge length. This might have affected the initial stability and complete union of the osteotomy site.

There is a trade-off relationship between the flange thickness and hinge length, and the results of this study suggest that it is crucial to maintain a longer hinge length by making the flange thinner to achieve initial stability in the DTO. Ogawa et al. reported that thinner flanges are more stable in mechanical experiments using a bone model.[28] However, there are concerns regarding the risk of flange fracture with thinner flanges. Although several authors recommend a thicker flange in DTO to avoid flange fractures,[6,8,11] the patellar tendon attaches to a wide range of soft tissues distal to and around the tibial tubercle[29,30]; the stability of the flange can be improved using a fixation screw.[12,26] Considering the report by Ogawa et al. that flange fractures do not affect clinical outcomes,[10] we recommend DTO with a thin flange in favor of initial

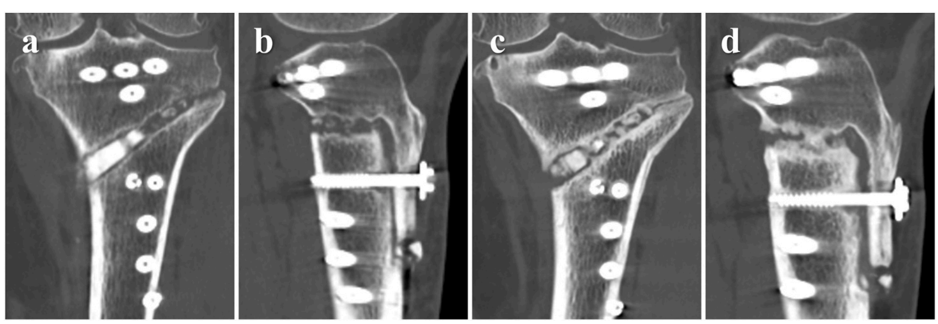

Fig. 6. A case of 56-year-old woman underwent distal tuberosity osteotomy, 12 weeks postoperative coronal (a) and sagittal (b), 24 weeks postoperative coronal (c) and sagittal (d) CT images
Lateral hinge fracture and delayed union at the opening gap and anterior flange occurred.

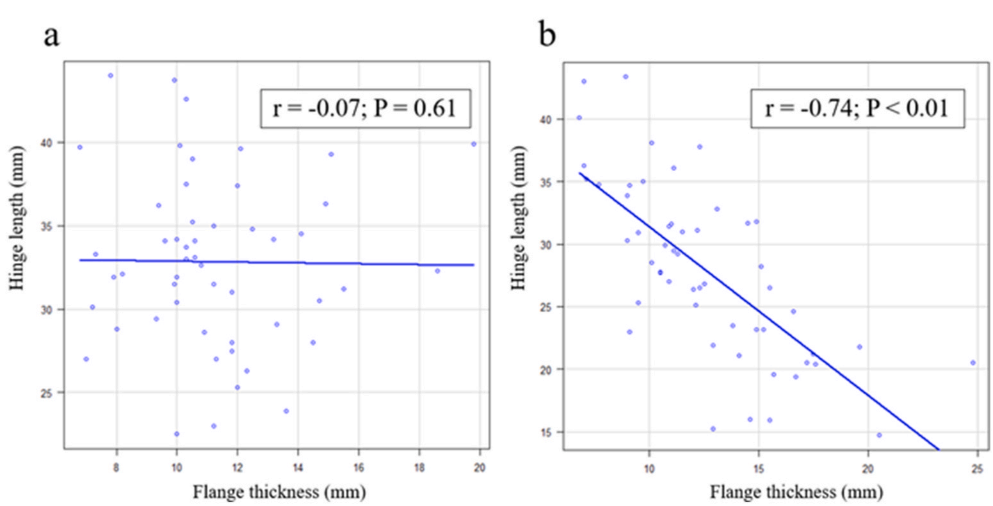

Fig. 7. Spearman correlation coefficient between hinge length and flange thickness in (a) high tibial osteotomy and (b) distal tuberosity osteotomy.

stability. However, because no flange fractures occurred in this study, the association between flange fractures and initial stability was unclear. We believe that the further study with a larger number of cases is needed to determine the ideal flange thickness that achieves initial stability and no flange fracture.

This study had several limitations: first, it is a comparative study of HTO and DTO over a short period separated by time series; in the future, a randomized controlled trial with a long-term follow-up would be desirable. Second, the relationship between initial stability and clinical outcomes was unclear because this study did not evaluate patient-reported outcomes. Third, the patient backgrounds of the HTO and DTO groups were not unified; the DTO group was younger, had fewer preoperative deformities, and required corrective angles than the HTO group. However, these background factors may have had a significant advantage in achieving stability, and it is unlikely that they influenced the results of the present study. Fourth, the ideal flange thickness remains unknown. Based on the results of this study, a thin flange is recommended; however, a thinner flange is associated with an increased risk of flange fracture. We believe a study with more patients is required to determine the appropriate flange thickness that does not increase the risk of flange fracture or adversely affect the bone union.

5. Conclusions

In this study, DTO was less likely to achieve early postoperative bone union and initial stability than HTO. The risk factors for initial instability in DTO were short hinges and thick flange.

Informed consent

Informed consent was obtained in the form of an opt-out on the hospital website. The research participants were given information on the study and guaranteed an opportunity to refuse to participate or to continue the study.

Ethical approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Shinshu University (March 28th, 2023/ No. 5807)

Funding

This work was supported by Johnson & Johnson Medical Research Grant [grant numbers AS2024A000134467].

Acknowledgements

We would like to thank Editage (www.editage.com) for English language editing.

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