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Proximal tibiofibular division in lateral closing wedge high tibial osteotomy does not increase varus instability of the knee

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Purpose: When performing lateral closing wedge high tibial osteotomy (LCWHTO), fibular untethering can be performed with either fibular shaft osteotomy (FSO) or proximal tibiofibular division (TFD). The aim of this study was to compare the degree of varus instability between the two methods after LCWHTO and to analyze the determinants of varus instability.
Methods: This study retrospectively analyzed 108 consecutive patients with medial compartment osteoarthritis who underwent LCWHTO and had >2 years of follow-up. Patients who underwent unilateral LCWHTO without a previous history of ligament injury were included. Forty-five patients who received LCWHTO with TFD and 51 patients who received LCWHTO with FSO were finally analyzed. The mean follow-up duration was 5.3 years in LCWHTO with TFD and 4.1 years in LCWHTO with FSO. The shortest distance between the lateral tibial plateaus and the corresponding most distal subchondral bone surface of the lateral femoral condyle was measured on varus stress radiographs and compared with that on the unaffected contralateral knee. Multivariable logistic regression analyses were conducted to identify predictors of varus instability.
Results: Lateral joint space width showed no significant between-group difference. Multivariable logistic regression analysis revealed that the pre-operative hip-knee-ankle angle was positively correlated with the lateral joint space width. The type of fibular untethering procedure was not associated with postoperative varus instability.
Conclusion: The degree of pre-operative varus malalignment is associated with postoperative varus instability after LCWHTO. Proximal tibiofibular division is not a variable for postoperative varus instability after LCWHTO.
Level of evidence: Level III, Retrospective comparative study.

1. Introduction

Lateral closing wedge high tibial osteotomy (LCWHTO), compared with medial open wedge osteotomy, has the advantages of rapid bony union, quick rehabilitation, and no need for bone graft [1–4].

In LCWHTO, fibular untethering is performed during valgization [1,5]. There are several options for fibular untethering, including fibular shaft osteotomy (FSO), fibular head resection, and proximal tibiofibular division (TFD) [6–9]. Which method gives better clinical and radiologic results is still controversial. Fibular shaft osteotomy can be performed at the proximal, middle, and distal

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fibula, while a separate incision is made to resect the fibular shaft. Risk of peroneal nerve damage while performing FSO has been noted in the literature [3,10,11], and non-union of the osteotomy site has been known to cause pain at the osteotomy site [12]. Tibiofibular division is performed through the same approach as tibial osteotomy. Compared with FSO the risk of peroneal nerve injury has been reported to be lower when performing TFD [11]. Previous studies have shown that TFD may be associated with varus instability of the knee joint [13,14]. Teitge et al. stated that division of the proximal tibiofibular joint, allowing the fibula to slide proximally, may be a source of catastrophic failure because of increased varus instability [10]. Coventry originally resected the fibular head with distal advancement of the fibular collateral ligament in order to augment lateral stability [15]. However, it is believed that no studies have shown that LCWHTO with TFD actually induces varus instability.

This study aimed to compare the degree of varus instability after LCWHTO with TFD or FSO and to analyze the determinants of varus instability. It was hypothesized that the degree of varus instability would be greater in LCWHTO with TFD compared with LCWHTO with FSO, due to mobilization of the fibula in TFD.

2. Materials and methods

2.1. Study subjects

From March 2010 to October 2015, data from 108 consecutive patients who underwent LCWHTO due to medial compartment osteoarthritis of the knee with genu varum were retrospectively analyzed. Exclusion criteria for this study were: LCWHTO performed due to developmental deformity of the knee; malunion of a proximal tibial fracture; ligament injuries (posterolateral corner injury of the knee and anterior cruciate ligament (ACL) injury); and patients who underwent bilateral LCWHTO.

2.2. Surgical technique and rehabilitation

For optimum correction, the target postoperative mechanical axis was 62% (Fujisawa point), and the amount of osteotomy was determined before the operation using a standing full-limb anterior–posterior (AP) radiograph. A transverse incision was made from the tibial tubercle to the fibular neck, and the tibialis anterior muscle was dissected subperiosteally. The TFD and FSO groups varied in the method for fibular untethering before osteotomy of the tibia. In the TFD group, the tibiofibular joint between the proximal fibula and proximal tibia was removed with an osteotome and a pituitary rongeur (Figure 1A). In the FSO group, fibular shaft osteotomy was performed through a short incision 150 mm below the fibular head (Figure 1B). Under fluoroscopic guidance, two Kirschner wires for guide pins were then placed in the proximal plane of the tibial osteotomy. The area of osteotomy was marked below the proximal guide pins. Two additional Kirschner wires were inserted in the distal plane of the tibial osteotomy in the same manner. The proximal and distal osteotomies were performed using an electric saw over the two Kirschner wires to preserve the far medial cortex and periosteum. The wedge was removed and the far medial cortex was carefully decorticated using the saw or an osteotome. A valgus force was slowly applied to the extremity until the osteotomy surfaces were firmly opposing each other. A cable or alignment rod was used for intra-operative alignment measurement. The site was then rigidly fixed using a Rigid Stepped Plate (Solco Biomedical, Seoul, Korea) and cannulated screws. None of the patients underwent arthroscopic procedures. Both groups followed equal rehabilitation protocols. All patients initiated continuous passive movement exercises for 2 days postoperatively. Patients maintained partial weight-bearing with crutches for 6 weeks and were then allowed full weight-bearing.

2.3. Evaluation

Patients were evaluated at six weeks, six months, 12 months after surgery, and then annually. Clinical results were evaluated pre-operatively and every year postoperatively using the American Knee Society Knee Score and Function Score (AKSKS and KSFS) [16], Hospital for Special Surgery (HSS) score [17], Western Ontario McMaster (WOMAC) score [18], International Knee Documentation Committee (IKDC) subjective score [19], and Lysholm Knee Score (LKS) [20]. Any complications related to LCWHTO were recorded.

For radiologic assessment, pre-operative and postoperative standing full-limb AP radiographs and knee AP radiographs were performed. To assess varus instability, varus stress radiographs of both knees were taken at 30° of knee flexion using a Telos device (Metax, Hungen, Germany). All AP radiographs were taken while the device was in use with the application of a 15-Nm varus load [21] above the tibiofemoral articular space. Stress radiographs were taken two years after surgery.

Hip-knee-ankle (HKA) angle was defined as the angle formed by the intersection of the mechanical axis of the femur (the line from the femoral head center to the femoral intercondylar notch center) with the tibia (the line from ankle talus center to the center of the tibial spine tips); the knee in varus was given a negative value. The correction angle was defined as the value derived from subtraction of pre-operative and postoperative angles between the mechanical axis of the tibia and the tangent to the subchondral plate of the tibia. Lateral plateau to fibula tip distance (LPFD) was defined as the distance between the upper margin of the tibial plateau and the tip of the fibular head on knee AP radiographs (Figure 2A). Posterior tibia to fibula distance (PTFD) was defined as the distance between the posterior margin of the tibial plateau and the posterior margin of proximal fibula on lateral knee radiographs (Figure 2B). Lateral joint space width was defined as the distance between the surfaces of the femoral condyle and tibial plateau on varus stress radiographs (Figure 2C) [22]. The difference in lateral joint space width between the

Figure 1. A. Postoperative radiograph of lateral closing wedge high tibial osteotomy with proximal tibiofibular division; B. Postoperative radiograph of lateral closing wedge high tibial osteotomy with fibular shaft osteotomy.

affected knee and the unaffected contralateral knee was measured. On the basis of a previous study [22], a lateral joint space width of >8.9 mm was defined as varus instability.

2.4. Statistical analysis

Between-group differences were evaluated using the independent *t*-test and analysis of variance (ANOVA). Categorical variables were compared using the Chi-square and Fisher's exact tests. To investigate the associations of varus instability and its determinants, binary logistic regression analysis was performed. Multivariate logistic regression analysis was performed, adjusting for age and sex, and other significant covariates ($P < 0.10$) selected from the results of univariate logistic regression analysis. When positive co-linearity existed between covariates, the most objective and easily applicable variable was selected for multivariate analysis. Each odds ratio (OR) was presented with its 95% confidence interval (CI). Significance was defined as $P < 0.05$.

To determine intra-observer and inter-observer reliability of radiographic assessment, two orthopedic surgeons performed all radiographic measurements twice in 30 randomly selected knees, with a three-week interval between evaluations. The intra-observer and inter-observer reliabilities of the measurements were evaluated using intraclass correlation coefficients (ICCs). All

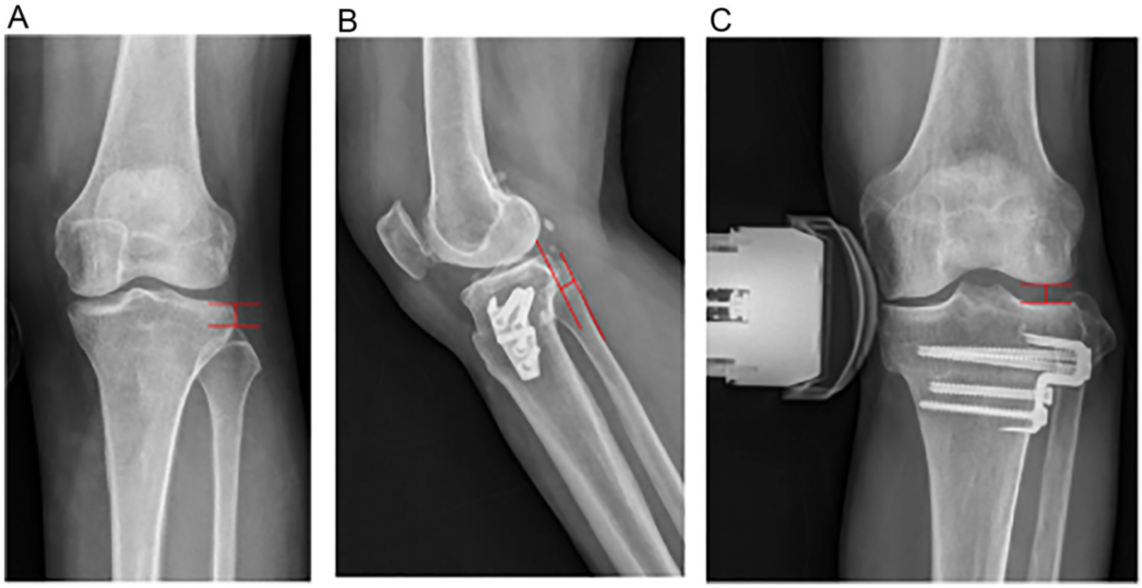

Figure 2. A. Lateral plateau to fibula tip distance was defined as the distance between the upper margin of the tibial plateau and the tip of the fibular head on knee AP radiograph; B. Posterior tibia to fibula distance was defined as the distance between the posterior margin of the tibial plateau and the posterior margin of proximal fibula on lateral knee radiograph; C. Lateral joint space width was defined as the distance between the surfaces of the femoral condyle and tibial plateau on varus stress radiograph. All distances are marked in red on the figures.

ICCs of intra-observer and inter-observer reliabilities of alignment measurements were satisfactory, ICC > 0.89 (range 0.89–0.99); thus, measurements taken by one investigator were used in the analyses. SPSS for Windows (version 20.0; SPSS Inc., Chicago, IL) was used for statistical analysis.

3. Results

Of the 108 cases of LCWHTO, 47 were performed with tibiofibular division and 61 were performed with fibular shaft osteotomy. Eight cases were excluded because LCWHTO was performed on bilateral knees, and four cases were excluded because they had concomitant ACL injury. Forty-five patients who underwent LCWHTO with TFD and 51 patients who underwent LCWHTO with FSO were analyzed.

Baseline characteristics including age, sex, body mass index (BMI), surgical site (right/left), pre-operative HKA angle, and follow-up period of the two groups showed no significant differences (Table 1). Mean pre-operative HKA angles were 8.3° and 8.9° varus in the TFD and FSO groups, respectively.

Lateral joint space width of the two groups showed no significant difference. When the patients were classified as varus stable and unstable according to the degree of lateral joint space width, the ratio of patients with stability to those with instability showed no significant difference. Lateral joint space width of the contralateral knee also showed some degree of varus instability in both groups without any significant difference. The lateral joint space width difference between the affected knee and the unaffected contralateral knee also showed no significant between-group difference. The amount of correction angle of the two groups showed no significant difference (Table 2).

Table 1
Baseline characteristics of the study groups.

	TFD group (n = 45)[a]	FSO group (n = 51)	*P*
Age (years)	52.8 ± 8.7	51.8 ± 6.6	n.s
Male/female	19/26	19/32	n.s
BMI (kg/m^2)	25.2 ± 2.6	25.8 ± 2.8	n.s
Right/left knee	27/18	30/21	n.s
Pre-operative HKA angle (°)	8.3 ± 3.0[b]	8.9 ± 3.1	n.s
Follow-up period (years)	5.3 (2.0–7.8)	4.1 (2.0–8.1)	n.s

TFD, tibiofibular division; FSO, fibular shaft osteotomy; BMI, body mass index; HKA, hip knee ankle; n.s, not significant.
[a] Values are expressed as mean ± standard deviation.
[b] Positive HKA angle values were given for varus angle and negative HKA values were given for valgus angle.

Table 2
Baseline lateral joint space width, correction angle, LPFD difference, and PTFD difference of the study groups.

	TFD group (n = 45)	FSO group (n = 51)	*P*
Lateral joint space width of affected knee (mm)	9.5 ± 2.6	9.2 ± 2.0	n.s
Lateral joint space width of contralateral knee (mm)	9.1 ± 2.1	9.0 ± 1.9	n.s
Lateral joint space width of affected knee (stable/unstable)	19/26	21/30	n.s
Lateral joint space width of contralateral knee (stable/unstable)	22/23	26/25	n.s
Lateral joint space width difference to contralateral knee (mm)	0.5 ± 1.7	0.3 ± 1.2	n.s
Postoperative hip-knee-ankle angle (°)[a]	−1.2 ± 2.6	−1.1 ± 3.9	n.s
Correction angle (°)[b]	9.2 ± 2.6	10.2 ± 2.8	n.s
LPFD difference[c]	8.4 ± 3.4	1.9 ± 2.8	<0.001
PTFD distance[d]	2.6 ± 1.1	−0.3 ± 0.5	<0.001

Values are expressed as mean ± standard deviation.
TFD, tibiofibular division; FSO, fibular shaft osteotomy; LPFD, lateral plateau to fibula tip distance; PTFD, Posterior tibia to fibula distance; n.s, not significant.
[a] Postoperative hip-knee-ankle angle was measured at postoperative 2 years.
[b] Correction angle was defined as the value derived from subtraction of pre-operative medial proximal tibial angle from postoperative medial proximal tibial angle.
[c] Lateral plateau to fibula tip distance difference was defined as the pre-operative and postoperative difference of the distance between the upper margin of the tibial plateau and the tip of the fibular head on knee anteroposterior radiograph.
[d] Posterior tibia to fibula distance difference was defined as the pre-operative and postoperative difference of the distance between the posterior margin of the tibial plateau and the posterior margin of proximal fibular on lateral knee radiograph.

The mean difference (± standard deviation) between the pre-operative and postoperative LPFD showed a statistically significant difference ($P < 0.001$). The mean difference (± standard deviation) in the pre-operative and postoperative PTFD was statistically significant ($P < 0.001$) (Table 2).

Based on the univariate logistic regression analysis, only the pre-operative HKA angle was significantly associated with varus instability after LCWHTO (OR 1.47; 95% CI 1.14–1.90; $P = 0.003$; Table 3). According to the age-adjusted and sex-adjusted multivariate analysis, the pre-operative HKA angle (OR 1.66; 95% CI 1.22–2.27; $P = 0.001$) was the independent variable for postoperative varus instability.

All clinical scores – including AKSKS, KSFS, HSS, IKDC, WOMAC, and LKS – significantly improved after surgery, but there were no statistically significant between-group differences (Table 4). Postoperative complications, including peroneal nerve dysfunction, were not noted in any patient.

4. Discussion

The most important finding in this study was that pre-operative HKA angle is an independent variable of postoperative varus instability after LCWHTO. The method of fibular untethering was not a variable for postoperative varus instability.

The hypothesis was based on anatomical background suggesting that proximal TFD would increase the incidence of varus instability of the knee joint because of superior migration of the fibular head when the site of osteotomy is closed. Thus, the fibular collateral ligament, which is a primary stabilizer to varus stress, would be loose compared with that in an intact knee [23]. However, there is a lack of evidence in the literature to show that TFD would result in varus instability. In the present study, LCWHTO with TFD showed superior migration of the fibular head compared with LCWHTO with FSO. However, results of stress radiographs showed no significant between-group difference in the amount of varus instability. These results may be explained by posterior translation of the fibular head in TFD or the effect of other stabilizers to varus stress in the knee joint. Further imaging studies are warranted.

In the study by Laprade et al., 10-nonpaired fresh-frozen cadavers were used to investigate the effects of posterolateral corner structure sectioning and lateral compartment opening [22]. This study stated that, in an intact knee, lateral joint space width was 8.87 mm and, with fibular collateral ligament excision, lateral joint space width was 10.99 mm. In the current study, lateral joint space width in the intact knees of patients in both the TFD and FSO groups was >8.87 mm. Cartilage loss or bony deformities that result in loss of joint space in the medial tibiofemoral compartment cause varus malalignment [8,24]. Lateral soft tissue laxity has been associated with varus deformities, especially dynamic varus deformities [24,25]. Lateral laxity may be caused by

Table 3
Univariable and multivariable logistic regression analyses for factors influencing postoperative lateral joint space width.

	Univariate analysis			Multivariate analysis		
	OR	95% CI	*P*	OR	95% CI	*P*
Age (years)	0.92	0.93–1.07	0.918	0.92	0.83–1.02	0.101
Sex	0.03	0.25–2.10	0.838	0.98	0.26–3.67	0.971
BMI (kg/m^2)	0.98	0.81–1.19	0.849			
Surgical technique	1.17	0.41–3.32	0.773			
Pre-operative HKA angle (°)	1.47	1.14–1.90	0.003	1.66	1.22–2.27	0.001
Correction angle (°)[a]	1.15	0.93–1.42	0.199			

OR, odds ratio; 95% CI, 95% confidential interval; BMI, body mass index; HKA, hip knee ankle
[a] Correction angle was defined as the value derived from subtraction of pre-operative medial proximal tibial angle from postoperative medial proximal tibial angle.

Table 4
Comparison of pre-operative and postoperative clinical score between FSO group versus TFD group.

Outcome		FSO group		TFD group		
		Score	P^a	Score	P^a	P^b
AKSKS	Pre-operative	56.6 ± 13.2	<0.001	56.5 ± 9.8	<0.001	n.s
	Postoperative	92.0 ± 10.8		90.6 ± 14.1		n.s
KSFS	Pre-operative	63.5 ± 14.4	0.002	50.1 ± 20.1	0.003	n.s
	Postoperative	79.9 ± 17.3		84.4 ± 21.2		n.s
HSS	Pre-operative	75.0 ± 5.9	<0.001	73.0 ± 10.1	0.005	n.s
	Postoperative	90.6 ± 10.1		88.5 ± 11.9		n.s
IKDC	Pre-operative	40.1 ± 13.6	0.016	31.5 ± 16.6	<0.001	n.s
	Postoperative	58.1 ± 17.2		51.7 ± 19.2		n.s
WOMAC	Pre-operative	32.4 ± 5.1	0.002	37.2 ± 13.5	0.016	n.s
	Postoperative	10.1 ± 9.8		16.5 ± 10.1		n.s
LKS	Pre-operative	59.0 ± 19.1	<0.001	56.6 ± 19.3	0.042	n.s
	Postoperative	84.6 ± 11.2		71.4 ± 13.3		n.s

Values are expressed as mean.
FSO, fibular shaft osteotomy; TFD, tibiofibular division; AKSKS, American Knee Society Knee score; KSFS, Knee Society Function score; HSS, Hospital for Special Surgery Knee Score; IKDC, International Knee Documentation Committee subjective score; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; LKS, Lysholm Knee Score; n.s, not significant.
[a] Comparison of pre-operative and postoperative outcomes.
[b] Comparison of clinical scores after FSO vs. TFD.

overstretching of the fibular collateral ligament following bony malalignment and stretching of the lateral capsule. The influence of lateral laxity is also shown in the logistic regression analysis for factors influencing postoperative lateral joint space width. The current results showed that pre-operative varus malalignment, but not the method of fibula untethering, affected postoperative varus instability. More severe pre-operative varus alignment could be associated with lateral soft tissue laxity, which could result in postoperative varus instability. Some studies have recommended that lateral laxity be corrected when performing LCWHTO [24,26], whereas others have shown that lateral soft tissue structures undergo spontaneous contraction when correction of the malalignment is achieved after HTO [27].

Due to the risk of iatrogenic peroneal nerve injury, LCWHTO with FSO is generally performed at the diaphyseal level [5,7]. However, previous studies have reported complications in up to 16% of patients after fibular shaft osteotomy [12]. The most common complication was fibular non-union, which caused some patients to undergo secondary surgery due to pain. While the risk of complications such as fibular non-union and peroneal nerve palsy are low in LCWHTO with TFD, varus instability and proximal tibiofibular joint pain were noted as possible complications [3]. Several studies, including the present study, have demonstrated that division of the tibiofibular joint does not induce varus instability [28].

This study had several limitations. First, the fibular collateral ligament was evaluated on plain radiograph in relation to the movement of the fibular head. A more accurate assessment of the fibular collateral ligament would have been possible if pre-operative and postoperative magnetic resonance evaluation was performed. Second, this study was a retrospective cohort study and the patients were not randomized. Therefore, there may have been selection bias between the groups. However, the surgical indications for LCWHTO with FSO or TFD were not different, and the demographic data between the groups did not significantly differ.

In conclusion, the degree of pre-operative varus malalignment is associated with postoperative varus instability after LCWHTO. Tibiofibular division is not a variable for postoperative varus instability after LCWHTO.

Declaration of competing interest

The authors certify that they have no commercial association that might pose a conflict of interest in connection with this article.

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