

# Smoking, Larger Correction, and Lateral Hinge Fracture as Risk Factors for Delayed Bone Union at 6 Months Postoperatively in Open Wedge Distal Tuberosity Tibial Osteotomy.

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## INTRODUCTION:

Open wedge distal tuberosity tibial osteotomy (owDTO) has been reported to have advantages in managing the progression of patellofemoral osteoarthritis compared to open wedge high tibial osteotomy (owHTO).<sup>1</sup> It has been suggested that owDTO might offer benefits in terms of bone union due to the increased contact area of the flange.<sup>2</sup> Risk factors such as smoking, obesity, larger correction, or unstable hinge fractures have been identified for delayed union and nonunion in owHTO.<sup>3</sup> However, there are no reports available concerning risk factors in the context of owDTO. The objective of this study is to assess the bone union rate of owDTO at 6 months postoperatively using computed tomography (CT) and to explore the risk factors associated with delayed union.

## METHODS:

A total of 117 knees from 105 patients who underwent owDTO at our institution from May 2021 to January 2023 were included in this study. The surgical procedure followed by the technique described by Akiyama et al.<sup>4</sup> Informed consent was obtained from all cases and the ethical approval for this study was obtained from the institutional review board (IRB#2301). Exclusion criteria were as follows: failure to undergo a 6-months postoperative follow-up (n=15), absence of a CT evaluation at 6 months postoperatively (n=20), simultaneous anterior cruciate ligament reconstruction (n=2), and a difficult control of deep infection (n=1). Consequently, a total of 79 knees from 77 patients were analyzed for this study. Bone union of the posterior cortex and flange was assessed using CT scans at 6 months postoperatively. The evaluation of bone union in the posterior cortex followed the method proposed by Kobayashi et al.<sup>5</sup> The osteotomy gap was divided into 5 zones on the coronal plane and numbered as zone 1 to 5 from the lateral side. Bone union of the posterior cortex was conducted on the sagittal plane. The most medial zone achieving bone union was assessed, and it was considered as bone union if it was zone 3 or beyond (Figure 1).<sup>2</sup> Flanges were divided into proximal and distal sections relative to the screw, and bone union was evaluated on the axial plane (Figure 2). The length from the screw to the proximal and distal ends of the flange were measured, respectively. Delayed union was defined as the absence of union in the posterior cortex. We examined the various factors influencing bone union, including age, sex, body mass index (BMI), smoking, lateral hinge fracture (LHF), correction width (mm), and the proximal-to-distal ratio (P/D ratio). The classification system of Takeuchi, et al.<sup>4</sup> was used to categorize LHF.

## Statistical evaluation

Fisher's exact test, Student's t-test, and Mann-Whitney U test were employed for statistical analysis, with a significance level set at 5%. A post-hoc power analysis for the Student's t-test was performed by G\*Power, comparing the groups of posterior cortex union and between groups of distal flange union. An effect size of 0.80 and  $\alpha$  error probability of 0.05 were used. The calculated power values were 0.94 and 0.81, respectively, indicating adequate sample size.<sup>6</sup>

## RESULTS:

Bone union was observed in the posterior cortex, distal flange, and proximal flange in 55 knees (69.6%), 67 knees (84.8%), and 76 knees (96.2%), respectively. LHF occurred in 20 knees overall, with 19 knees classified as Takeuchi type I and 1 knee as Takeuchi type II. Bone union rates for the posterior cortex were 77.6% in the distal flange union group and 25% in the non-union group (odds ratio: 10.0,  $p<0.01$ ). Risk factors for delayed union are summarized in Tables 2 and 3 for the posterior cortex and flange, respectively. The occurrence of LHF was significantly higher in the delayed union group than in the union group (delayed union group: 45.8%, union group: 16.4%;  $p=0.01$ ). Regarding the union of the distal flange, the percentage of smokers (delayed union group: 58.3%, union group: 22.4%;  $p=0.03$ ), and correction width (delayed union group:  $7.7 \pm 1.2$  mm, union group:  $6.8 \pm 1.5$  mm;  $p=0.03$ ) was significantly influenced delayed union.

## DISCUSSION:

The most important findings of this study are that smoking, larger correction, and LHF are risk factors for delayed union in owDTO. Smoking and larger correction were risk factors for delayed union, similar to previous studies on owHTO. In previous studies, unstable LHF (Takeuchi type II or III) was a risk factor for delayed union in owHTO.<sup>3</sup> However, in this study, even Takeuchi type I was also identified as a risk factor. This difference might be attributed to the distinct osteotomy surfaces in owHTO and owDTO. In owHTO, the tension of the quadriceps muscle acts as a compression force on the flange, whereas in owDTO it exerts a force to separate the flange. This divergence could have impacted the stability between the proximal and distal fragments, even in cases of stable LHFs, potentially leading to delayed union. The results of this study underscore the need for surgeons to be attentive to the occurrence of LHF. Notably, the rehabilitation protocol remained unchanged upon recognizing LHF in this study, resulting in successful bone union without supplementary treatment for all patients during the final follow-up. Surgeons should contemplate interventions upon identifying LHF.

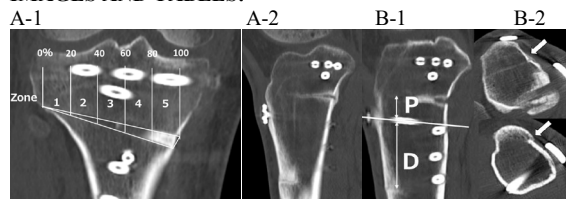
## SIGNIFICANCE / CLINICAL RELEVANCE:

In owDTO, smoking, larger correction, and LHF were risk factors for delayed union.

## REFERENCES:

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## IMAGES AND TABLES:



**Figure 1:** This figure shows the point of evaluation for union. The osteotomy site was divided into 5 zones by coronal plane (A-1), and bone union of the posterior cortex was evaluated in each of the five zone by sagittal plane (A-2). Flanges were divided proximal (P) and distal (D) (B-1) to the screw, and bone union was evaluated for each by axial plane (B-2). The lengths of P and D were measured and the P/D ratio was calculated.

	Union(n=55)	Nonunion(n=24)	p
age(mean, SD, range), years	53.3, 10.6, 24-78	57.3, 8.86, 40-74	0.115
Sex (male:female 43:36)	32:23	11:13	0.336
BMI(mean, SD, range), kg/m2	24.9, 3.58, 17.85-34.01	25.3, 4.46, 18.85-34.85	0.671
Smoking +(22)	14	8	0.586
LHF +(19:type1,1: type2)	9	11	0.0102
correction (mean, SD, range), mm	6.79, 1.45, 4.0-10	7.31, 1.56, 4.5-11	0.298
P/D(mean, SD, range)	0.59, 0.38, 0.232-2.16	0.74, 0.39, 0.11-1.71	0.114

**Table 1:** Risk factors for delayed union (posterior cortex union)

	Union(n=67)	Nonunion(n=12)	p
Age(mean, SD, range), years	54.5, 10.0, 24-78	54.6, 11.6, 37-74	0.946
Sex (male:female 43:36)	35:32	8:4	0.531
BMI(mean, SD, range), kg/m2	24.8, 3.62, 17.9-34.9	26.1, 4.9, 18.9-34.6	0.298
Smoking +(22)	15	7	0.0305
LHF +(20:type1=11,2=1)	14	6	0.0648
correction(mean, SD, range), mm	6.82, 1.50, 4-11	7.7, 1.23, 6-10	0.0437
P/D(mean, SD, range)	0.623, 0.375, 0.11-2.16	0.711, 0.445, 0.17-1.71	0.508

**Table 2:** Risk factors for delayed union (distal flange union)