Long-Term Survivorship of Closed-Wedge High Tibial Osteotomy for Severe Knee Osteoarthritis

Outcomes After 10 to 37 Years

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Background: High tibial osteotomy (HTO) was developed as a joint-preserving procedure to treat relatively young patients with isolated medial compartmental knee osteoarthritis (OA). Long-term survivorship after HTO is important to determine whether patients will need additional surgery.

Purpose: To determine the long-term (>35-year) survivorship and prognostic factors for closed-wedge HTO (CWHTO) for severe medial OA.

Study Design: Case series; Level of evidence, 4.

Methods: We retrospectively evaluated patients who underwent CWHTO for severe medial knee OA between 1983 and 2009 at our institution, Nagoya University Graduate School of Medicine (Nagoya, Japan). Patient demographics, follow-up period, and pre- and postoperative femoral-tibial angle (FTA) were reviewed. The patients or the relatives of the patients were interviewed by telephone to record postoperative status, including conversion to total knee arthroplasty (TKA).

Results: Of the 74 CWHTO procedures performed, we evaluated 56 procedures in 45 patients (mean age at time of surgery, 56.8 years). The mean follow-up period was 17.1 years. Nine knees (16.1%) underwent conversion to TKA. The mean time to TKA conversion was 15.6 years. Kaplan-Meier analysis revealed a 10-year survival rate of 90.1%, a 15-year rate of 83.8%, a 20-year rate of 75.9%, and a 35-year rate of 75.9%. Log-rank test showed that age $\geq$55 years ($P = .044$), body mass index (BMI) $\geq$25 kg/m^2 ($P = .0016$), and preoperative FTA $<185^\circ$ ($P = .0034$) were risk factors associated with TKA conversion. Multivariate analyses adjusted for age and sex identified BMI $\geq$25 kg/m^2 (hazard ratio [HR], 13.4; 95% CI, 1.7-106.9; $P = .014$) and preoperative FTA $<185^\circ$ (HR, 4.2; 95% CI, 1.1-16.6; $P = .04$) as risk factors associated with TKA conversion.

Conclusion: The survival rate of CWHTO for severe medial knee OA was 90.1% at 10 years, 83.8% at 15 years, and 75.9% at 20 years and 35 years. Furthermore, a BMI $\geq$25 kg/m^2 and FTA $<185^\circ$ were the independent risk factors associated with TKA conversion after CWHTO.

Keywords: arthroplasty; high tibial osteotomy; osteoarthritis; survival rate

The management of knee osteoarthritis (OA) remains challenging in young, active patients, for whom joint-preserving treatment is preferred. High tibial osteotomy (HTO) was developed as a joint-preserving surgical procedure to treat relatively young patients with isolated medial compartmental knee OA,[3,8-10,26,35,38] whereas knee arthroplasty tends to be performed for older patients with low activity.[1,5,11,31] The indications for HTO and unicompartmental knee arthroplasty (UKA) are overlapping, and clinical outcomes and survival rates are reported to be similar, especially in terms of short- to midterm results.[7,13,19,28,29]

To determine whether patients need additional surgery in their lifetime after undergoing HTO, long-term survivorship, especially >20-year longevity, is important. Previous long-term follow-up studies have reported a 30% to 90.4% HTO survival rate after 15 to 20 years (Table 1).[2,4,14,21,23,27,30,32,33] Few studies have evaluated survival rates of more than 30 years for HTO.[4,22,32,33] Furthermore, some studies have reported that the survival rate following HTO declines abruptly after 10 to 15 years,[6,18,21,30]

The Orthopaedic Journal of Sports Medicine, 9(10), 23259671211046964
DOI: 10.1177/23259671211046964
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TABLE 1
Previously Reported Long-Term HTO Survivorship[a]

Study	Type of HTO	Knees, n	Mean Age, y	Mean Follow-up, y	Survivorship, %
Naudie et al (1999)[27]	CW	106	55	20	30
Sprenger and Doerzbacher (2003)[33]	CW	76	69	20	46
Koshino et al (2004)[23]	CW	241	59.6	15	86.9
Akizuki et al (2008)[2]	CW	159	62.9	15	90.4
Gstottner et al (2008)[14]	CW	134	54.5	18	54.1
Schallberger et al (2011)[30]	OW or CW	71	40	15	71
Keenan et al (2019)[21]	OW	111	45	15	55
Song et al (2019)[32]	CW	60	59.7	20	48.3
Berruto et al (2020)[4]	CW	94	53	20	80

[a]CW, closed wedge; HTO, high tibial osteotomy; OW, open wedge.

whereas a few studies have reported a survival rate at 15 years of more than 85%.[2,22,23]

For appropriate patient selection, it is useful for surgeons to understand which factors influence the survival rate, especially in the long term. The purpose of this study was to determine long-term (>35-year) survivorship of closed-wedged HTO (CWHTO) for severe medial knee OA and to identify factors associated with improved survival rates.

METHODS

This study was approved by the institutional review board of our hospital, Nagoya University Graduate School of Medicine (Nagoya, Japan) and was in compliance with the Helsinki Declaration. Each patient provided written consent for participation in the study prior to enrollment. We retrospectively evaluated patients aged over 16 years who underwent CWHTO between January 1983 and December 2009 at our institution. The inclusion criteria for CWHTO were symptomatic primary knee OA (Kellgren-Lawrence grade 3 or 4) with varus malalignment needing to be corrected. A total of 74 CWHTO procedures performed on 60 patients were identified. One knee in which CWHTO was performed for valgus deformity and 2 knees with posttraumatic OA were excluded. A further 15 cases with incomplete demographic and follow-up data were excluded. Of the 74 procedures, 56 procedures in 45 patients (mean age, 56.8 years) were included in this study (Figure 1). The range of follow-up for these patients was 3.0 to 37.3 years.

Patient records, including age, sex, side of operation, height and weight, body mass index (BMI) at the time of surgery, follow-up period, and pre- and postoperative femoral-tibial angle (FTA), were reviewed. FTA is the lateral angle between the distal femoral and proximal tibial axes (ie, <180° and >180° correspond to valgus alignment and varus, respectively). We then contacted the patients (or relatives of patients who had died) by telephone to record postoperative status, including conversion to total knee arthroplasty (TKA) at the time of final follow-up. If a patient underwent multiple revisions, only the time to initial arthroplasty was included

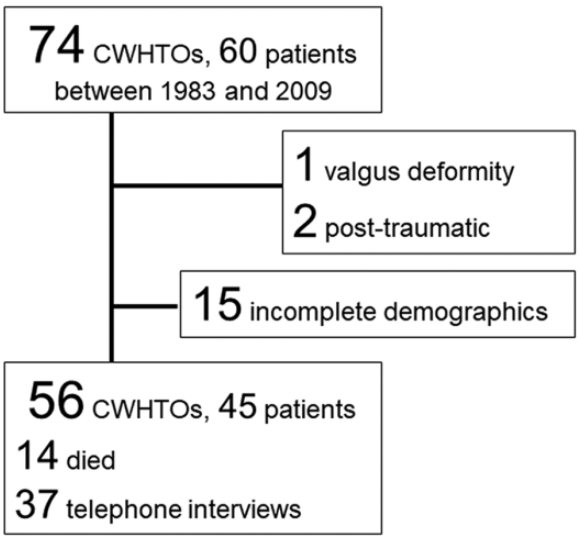

Figure 1. Flowchart of the study design. CWHTO, closed-wedge high tibial osteotomy.

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Final revision submitted May 12, 2021; accepted June 29, 2021.
The authors declared that there are no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval for this study was obtained from Nagoya University Hospital.

TABLE 2
Patient Demographics (N = 45 Patients; 56 Knees/Procedures)[a]

Characteristic	Mean (Range) or No.
Age, y	56.8 (18-67)
BMI, kg/m^2	25.4 (18.3-33.8)
Follow-up period, y	17.1 (3.0-37.3)
Sex, male/female	11/45
Side, left/right	30/26
Preoperative FTA	186.0° (178°-204°)
Postoperative FTA	170.3° (168°-180°)
Total knee arthroplasty	9

[a]BMI, body mass index; FTA, femoral-tibial angle.

in the analysis. Patients who died from causes unrelated to CWHTO or who were lost to follow-up were censored from further analysis. The follow-up period was defined as the period from the date of surgery to the last follow-up visit, telephone interview, or death.

Surgical Procedure

Valgus osteotomy was performed above the tibial tuberosity, with removal of a lateral wedged bone in all cases. After releasing the extensor muscles at the level of the middle to proximal fibula, the midshaft of the fibula was osteotomized and removed. The transverse tibial osteotomy was made 18 to 20 mm below the joint line. The desirable postoperative angle was 168° to 170° in all cases. A second cut was made, creating a wedge of a precalculated size. After cutting the wedge, the medial cortex was broken gently with valgus compression stress, and then the osteotomy was fixed with a few staples, conventional compression plate, or Geabel plate.

Rehabilitation

The patients were allowed to walk with a long knee brace or hard knee brace via 2 crutches without bearing weight for 4 weeks. Weightbearing of 10 kg was allowed at 4 weeks and this increased by 10 to 20 kg every 1 or 2 weeks. Full weightbearing was allowed 8 to 12 weeks postoperatively, and strengthening exercises were initiated. Hardware removal was usually recommended after bone union at 1 to 2 years.

Statistical Analysis

Kaplan-Meier survivorship curves with log-rank tests were constructed to estimate 10- to 37-year survivorship. Multivariate Cox proportional hazards model analyses were used to verify the relationship between survivorship and each possible prognostic factor. All variables were expressed as means with ranges. All differences were defined as significant at $P < .05$. All data were analyzed using SPSS Version 26 (IBM SPSS Statistics 19.0).

TABLE 3
Cumulative Number of CWHTO Procedures (N = 56)[a]

Follow-up Period, y	Procedures Evaluated, No. (%)
5	51 (91.1)
10	46 (82.1)
15	28 (50.0)
20	14 (25.0)
25	9 (16.1)
30	3 (5.4)
35	1 (1.8)

[a]CWHTO, closed-wedged high tibial osteotomy.

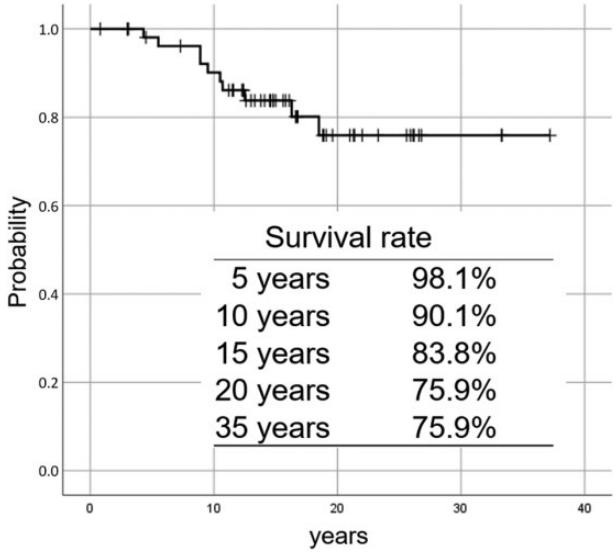

Figure 2. Kaplan-Meier survivorship curves of closed-wedge high tibial osteotomy with conversion to total knee arthroplasty.

RESULTS

Patient demographics are summarized in Table 2. The mean follow-up of the study cohort was 17.1 years (range, 3.0-37.3 years). During this time, 14 patients (31.1%) died, and 9 knees (9 patients; 16.1%) underwent conversion to TKA. The average time to TKA conversion was 15.6 years (range, 7.6-22.4 years). Pre- and postoperative FTAs were 186.0° (range 178°-204°) and 170.3° (range 168°-180°), respectively. The cumulative number of CWHTO procedures is summarized in Table 3. Kaplan-Meier analysis revealed that the survival rate was 90.1% at 10 years, 83.8% at 15 years, and 75.9% at both 20 and 35 years (Figure 2). Log-rank test showed that an age ≥55 years at time of surgery ($P = .044$), BMI ≥25 kg/m^2 ($P = .0016$) at time of surgery, and preoperative FTA <185° ($P = .0034$) were the risk factors associated with TKA conversion (Figure 3).

Analysis of the potential risk factors for TKA conversion using a log-rank test showed that BMI ≥25 kg/m^2 ($P = .0016$) and preoperative FTA <185° (0.034) were risk factors associated with TKA conversion (Figure 3).

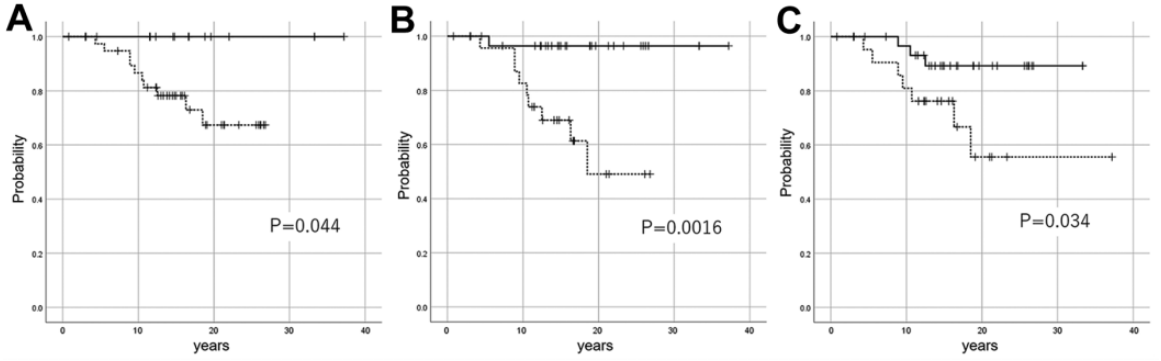

Figure 3. Survival curves for CWHTO according to each of the 3 risk factors: (A) age (solid line, age <55 y; dotted line, age ≥55 y), (B) BMI (solid line, BMI <25; dotted line, BMI ≥25), and (C) FTA (solid line, FTA ≥185°; dotted line, FTA <185°). BMI, body mass index; CWHTO, closed-wedge high tibial osteotomy; FTA, femoral-tibial angle.

TABLE 4
HRs for Conversion to Arthroplasty After CWHTO[a]

	Unadjusted Model		Adjusted Model[b]	
	HR (95% CI)	*P*	HR (95% CI)	*P*
BMI ≥25	13.2 (1.6-105.2)	.015	13.4 (1.7-106.9)	0.014
Preoperative FTA <185°	3.9 (1.0-15.4)	.049	4.2 (1.1-16.6)	0.014

[a]BMI, body mass index; CWHTO, closed-wedge high tibial osteotomy; FTA, femoral-tibial angle; HR, hazard ratio.
[b]Adjusted for age and sex.

Factors that were significant ($P < .05$) on the log-rank test were entered into multivariate Cox proportional hazards model analyses. Multivariate analyses adjusted for age and sex showed that a BMI ≥25 kg/m^2 (hazard ratio [HR], 13.4; 95% CI, 1.7-106.9; $P = .014$) and preoperative FTA <185° (HR, 4.2; 95% CI, 1.1-16.6; $P = .04$) were risk factors associated with TKA conversion (Table 4).

DISCUSSION

This study showed that the survival rate of CWHTO for severe medial knee OA was 90.1% at 10 years, 83.8% at 15 years, and 75.9% at both 20 and 35 years and that there were 2 independent predictors of TKA conversion: BMI ≥25 kg/m^2 and FTA <185°.

Previous studies have reported that long-term 10- to 15-year survival rates after CWHTO range from 30% to 90.4%.[2,16,27,33] However, because of improvements in implant stability, better patient selection, and established surgical techniques, clinical outcomes after HTO have improved and survivorship has been extended in the past decade. In a recent study, Kuwashima et al[24] reported that the survival rate of HTO was 94.4% at 10 years and 84.6% at 15 years. A recent meta-analysis by Jeon et al[19] comparing open-HTO versus CWHTO showed an 85.4% survival rate of CWHTO at 10 years. Our 10- and 15-year survival rates, 90.1% and 83.8%, respectively, were similar to the results of these recent studies. Previously, only a few studies had reported survival rates beyond 20 years after CWHTO; in fact, the rates were less than 50% at 20 years. Sprenger and Doerzbacher[33] performed 76 CWHTO procedures for medial compartment OA and reported a 20-year survival rate of 46%. A 2019 study by Song et al[32] reported 5, 10, 15, and 20-year survival rates of CWHTO of 100%, 91.0%, 63.4%, and 48.3%, respectively.

This is the first study to our knowledge to report survival rates at >30 years after CWHTO, with a rate of 75.9% for both 20- and 35-year survival; these rates were better than the previous 2 studies and also comparable with survival rates for UKA. At 20 years, 14 patients who underwent CWHTO (mean age, 85.4 years) survived and none of these 14 cases were converted to arthroplasty at the end point.

The indications for HTO and UKA are overlapping. Interestingly, one of the factors that influences indications for HTO and UKA is patient age. Previous studies on UKA have reported that a younger age increases the risk of failure after UKA.[15,34] Jeschke et al[20] reported that the 5-year survival rate for UKA in patients aged <55 years was 79.9%, whereas it was 87.8% overall. In contrast, some studies have reported that a younger age improved clinical results, including the survival rates after HTO.[6,18,21] Howells et al[17] reported that the 10-year survival rates in patients aged <55 and ≥55 years who underwent HTO were 87% and 63%, respectively. Therefore, when deciding the surgical procedure to be performed for isolated medial compartmental knee OA, most surgeons believe that HTO would be better for younger patients and UKA would be better for older patients. Thus, our results of 30-year longevity after CWHTO could be helpful in decision-making when considering HTO for younger patients. The log-rank test showed that age ≥55 years was a prognostic factor associated with TKA conversion. Numerous studies have reported the positive association between older age and TKA conversion after HTO.[6,18,21] Gstottner et al[14] reported that the probability of conversion to TKA increases approximately 5% every year with the patient's age at HTO. Most studies have a cutoff age of between 50 and 60 years when comparing the survival rates in young and old patients.

Keenan et al[21] showed that an age of 47 years or older was a risk factor for conversion to TKA after HTO. They determined the cutoff age by preliminary receiver operating characteristic analysis, however, and we defined 55 years as the cutoff age because this has been used in several previous studies.[25,39]

Multivariate analyses identified BMI $\geq$25 kg/m^2 and FTA <185° as independent risk factors associated with TKA conversion after CWHTO. With regard to BMI, Hui et al[18] retrospectively analyzed 394 patients who underwent CWHTO and found that a BMI <25 was associated with a better outcome following HTO, and Howells et al[17] reported that a BMI <30 was a predictor of improved survival. Although several studies have shown a positive correlation between obesity and conversion after HTO,[18] other studies have reported no association between BMI and survivorship.[12,37] van Raaij et al[36] retrospectively examined 100 patients who underwent CWHTO and concluded that there was no association between BMI and survival rates. However, they evaluated prognostic factors at 10 years after surgery. In our study, subanalysis showed that there was no significant difference in survivorship between low and high BMI groups at 10 years (BMI <25, 97.7%; $\geq$25, 84.6%; $P = .235$). Therefore, a higher BMI does not influence short- or midterm outcomes but does influence long-term survivorship.

Previous studies have reported that proper correction or overcorrection of valgus knee alignment is necessary to avoid postoperative return to varus alignment and subsequent failure.[2,33] In our study, a postoperative FTA of 168° to 170° was the goal in all cases. Indeed, postoperative FTA was 170.3° and the standard deviation was 2.2°. Hence, it was not suitable for further analysis because of the small dispersion of the angle in each case. On the other hand, there have been no studies that show preoperative FTA is a predisposing factor for HTO survivorship. An FTA less than 185° represents neutral to mild varus of lower limb alignment. In the present study, the indication for CWHTO was severe medial knee OA, while the existence of lateral compartment OA changes was not excluded. It is possible that because of the lateralization of the lower limb mechanical axis in severe varus knee, the condition of lateral compartment might be worse in mild varus knee than in severe varus knee. However, because of incomplete medical records and imaging, accurate evaluation of lateral OA changes was impossible in this study. To confirm these results, further research is required.

Several limitations in this study must be considered. First, the small number of patients weakened our analysis. This study included only 3 types of fixation devices, and therefore, small heterogeneity was unavoidable. Because all the patients were Asian, the results may not be generalizable to other populations.

Clinical examination was not performed for all patients, because most medical interviews were performed by telephone. Owing to incomplete data, a clinical outcome could not be obtained in this study. Because we could not evaluate the clinical outcome, the reason why patients were offered TKA conversion was unclear; the willingness of the patient or surgeon to undergo TKA conversion may have been influenced by the patient's age rather than poor clinical outcomes of the original CWHTO. Age was identified as one of the independent risk factors of TKA conversion. Patient death also should be considered as a competing risk.

Conversely, age was also related to death, especially on long-term survival analysis. In this study, 14 patients died prior to follow-up examinations. It is possible that death might have led to an underestimation of the number of TKA conversions after CWHTO. Finally, the grade of lateral compartmental OA was not recorded preoperatively in all cases, and, therefore, discussion about the preoperative FTA as an independent risk factor of TKA conversion was limited.

CONCLUSION

To the best of our knowledge, this is the first study to report >30-year survivorship after CWHTO. The rate of 76% at 30 years was satisfactory compared with that of UKA. CWHTO offers excellent longevity and may be a good option as a temporary, time-saving, joint-preserving surgical procedure before total knee replacement and as a final surgery, even for relatively young patients with severe medial knee OA. We identified 2 independent predictors of TKA conversion: BMI $\geq$25 and FTA <185°. These results could be useful for selecting patients who are suitable for CWHTO so that they may have no need for further such procedures in their lifetime.

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