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Long-term survival rate of closing wedge high tibial osteotomy with high valgus correction: a 15-year follow-up study

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Abstract

Purpose The influence of closing wedge high tibial osteotomy (CW-HTO) with high valgus correction on its survival is unclear. This study aimed to conduct a 15-year follow-up cohort study to estimate the long-term survival rate of CW-HTO. Factors related to poor outcomes were investigated.

Methods A total of 159 knees in 123 patients were followed up, and 120 knees in 96 patients were enrolled for statistical analysis. Femorotibial angles were measured by standing anterior–posterior radiographs of the knee. Clinical objective evaluation was performed by the Japanese orthopaedic association (JOA) score of the knee, and scores lower than 70 points defined the poor result (PR) group. The survival rate of OW-HTO was estimated. Logistic regression analyses were performed to determine the risk factors for PR and conversion to total knee arthroplasty (TKA).

Results A total of 16 knees in 15 patients (13.3%) underwent TKA 14.0 ± 4.8 (4-20) years after CW-HTO. The 5-year survival rate was 99.2%, 10-year was 96.7%, 15-year was 92.5%, and 86.7% at final follow-up (17.9 years). Based on the JOA score, 44 patients (35.8%) belonged to the PR group, and their risk factors were obesity ($p = 0.018$), low femorotibial angle ($p = 0.019$), low JOA score ($p = 0.040$), low knee extension angle ($p = 0.045$), and low knee flexion angle ($p = 0.046$).

Conclusions The 15-year survival rate of CW-HTO was 92.5%. While higher scores of objective outcomes were kept over long-term follow-up, the risk factors for a worsening score or TKA conversion were obesity and severity of preoperative knee symptoms.

Keywords Closed wedge high tibial osteotomy · Survival rate · 15 years · JOA scores · Total knee arthroplasty conversion

Introduction

High tibial osteotomy (HTO) is one of the established treatments for medial unicompartmental knee osteoarthritis (OA), which is transferring the mechanical axis from a medial to a slightly more lateral position to decrease the load and subsequently delay the progression of OA [16]. Realignment osteotomy had an advantage in the lower risks of restriction of range of motion (ROM), infection of prostheses, and aseptic loosening, compared with total knee

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arthroplasty (TKA) [22, 27, 30]. Although opening wedge (OW)-HTO is becoming a popular option in managing unicompartmental knee OA, its main disadvantage, which is an increase in the contact pressure and risk for OA progression on the patellofemoral (PF) joint, has not been overcome yet [15, 17].

Thus, to avoid its influence on the PF joint, closing wedge (CW)-HTO has been reconsidered. The advantages of CW-HTO compared with OW-HTO were better bone healing, larger correction, preventing enlargement of the posterior tibial slope, and smaller leg length problems [4, 25, 29]. To date, 10-year survival rates of CW-HTO were reported as 51-93.2% [1, 2, 12, 14, 24, 31]. However, long-term survival for more than 15 years has not been fully understood. This study aimed to estimate the more than 15 years of survival rate of CW-HTO and to identify predictors influencing its outcomes. The hypothesis was that a high survival rate was obtained, and correction angle and obesity will be associated with TKA conversion rate or poor clinical outcomes.

Materials and methods

Patients

A total of 206 knees of 166 patients with medial unicompartmental knee OA underwent CW-HTO from 1989 to 2002. All the patients were followed up for a minimum of 15 years after surgery. Exclusion criteria were as follows: (1) lateral knee OA with valgus deformity, (2) severe patellofemoral joint OA, (3) inflammation including rheumatoid arthritis or psoriatic arthritis, (4) dysfunction of the anterior cruciate ligament, (5) deformity at the shaft of the tibia, femur or other bone in the lower extremity. All of the patients' demographic data at the time of surgery, including age, sex, and body mass index (BMI), were picked up from medical records retrospectively. In the case of lost follow-up, the data of 59 patients with a total of 71 knees were collected by telephone interviews to investigate the presence of TKA conversion as the endpoint. All participants gave their written informed consent, and the study was conducted with the approval of the Ethics Committee of our institution.

Surgical procedures

CW-HTO with Giebel® blade plate (Waldemar Link GMBH and Co., Hamburg, Germany) was performed in our institution. For preoperative planning, the correction angle was calculated based on the standing radiographs of the whole lower extremity at a target angle of 166°–168° of femorotibial angle (FTA).

Firstly, cartilage, meniscus, and ligamentous lesions were arthroscopically evaluated. Partial meniscectomy was performed when there was unstable meniscal tear at the medial femorotibial joint. In addition, exposed subchondral bones of the medial femorotibial joint were added to bone marrow stimulation. Osteotomy was performed after confirming that the lateral femorotibial joint and patellofemoral joint were intact. Resection length of the fibular shaft was calculated according to the amount of tibia resection, and the centre of the fibular shaft was resected. The lateral aspect of the tibia was approached, and proximal osteotomy was performed using an original chisel as per preoperative planning. The bony wedge was completely removed. After correction by adding valgus stress, the tibia was fixed using a Giebel plate and cortical screws. In the case of concomitant patellofemoral joint OA, tibial tubercle transfer was performed.

As postoperative rehabilitation, patients started range of motion (ROM) exercises and isometric muscle-strengthening exercises the day after surgery. After 4 weeks of non-weight bearing, patients started partial weight-bearing, and they achieved full weight-bearing within 9 weeks of surgery. After the bone union was completed in the tibia, the Giebel plate and screws were removed.

Clinical evaluations and X-ray

Weight-bearing antero-posterior radiographs of the knee were taken in all patients. Osteoarthritis and osteonecrosis were diagnosed only by these radiographs. As for the parameter of alignment of the lower extremity, the femorotibial angle (FTA) was measured before surgery, 1 year after surgery, and at the final follow-up. FTA was calculated by anatomical axis drawn at the centre of femoral and tibial shafts in weight-bearing anterior–posterior radiographs of the knee. In addition, for clinical assessment, the Japanese Orthopaedic Association (JOA) scores of the knee were recorded before surgery and at the final follow-up, which is common in Japanese clinical practice. JOA score is an observer-based scoring scale from 0 to 100 points, which consists of pain on walking, pain on ascending or descending stairs, range of motion, and joint effusion. The cut off value was defined based on the mean value and standard deviation (SD). In these cases, the (mean–1SD) of these subjects was 65 points, and the cut-off value for the worsening of knee condition was set below 70 points. Then, the patients with more than 70 points of JOA score were divided into the good result (GR) group, and those with less than 70 points were into the poor result (PR) group. In addition, the patients who underwent total knee arthroplasty were classified into the PR group.

Statistical analysis

Quantitative data were expressed as mean ± SD. The χ^2 test was used to compare differences in categorical variables, and

the Mann–Whitney U test was used to compare differences in continuous variables between followed up and drop out-patients because most of these parameters were not normally distributed by Shapiro–Wilk tests. The Kaplan–Meier curve was used to estimate the 5, 10, and 15-year survival rates, and also survival rates at final follow-up (17.9 ± 2.8 years) of the followed-up knees. To investigate the risk factors for poor outcome, logistic regression analysis was performed, with PR against GR of JOA score or conversion to TKA as dependent variables, and age, gender, body mass index, osteoarthritis/osteonecrosis, preoperative parameters including FTA, JOA score, knee extension angle, knee flexion angle, and time-lapse after surgery. Finally, to predict the estimated cut-off point for PR using JOA score at final follow-up, receiver operating characteristic (ROC) analysis was performed. The plot of false-positive fraction and true positive fraction was a curve, and the area under the curve (AUC) was calculated. The cut-off point was defined as the nearest point to the true positive. Data input and analysis were performed using SPSS version 25.0 J (SPSS Inc., Chicago, IL, USA). Every p value < 0.05 was considered statistically significant.

Results

A total of 159 knees of 123 patients, out of 206 knees of 166 patients were followed, and the follow-up rate was 74.1% for patients and 77.2% for knees. Among them, 14 patients (19 knees) died due to reasons unrelated to the procedure, and 13 patients (20 knees) with severe dementia could not meet the inclusion criteria. Finally, a total of 120 knees in 96 patients were enrolled for the statistical analysis. Their mean age at surgery was 59.5 ± 6.5 years, and they were followed up for 17.9 ± 2.8 (15–25) years. There was no difference in demographic data between followed-up patients and drop-out patients (Table 1) (Figs. 1, 2).

A total of 16 knees of 15 patients (13.3%) underwent TKA 14.0 ± 4.8 (4-20) years after CW-HTO (Figs. 1, 2). The 5-year survival rate was 99.2%, the 10-year survival rate was 96.7%, 15-year rate was 92.5%, and the survival rate at final follow-up (17.9 years) was 86.7% (Fig. 3). Logistic regression analysis showed that the time-lapse after surgery was the only significant risk factor for TKA conversion in this series (Table 2).

Knee extension angle increased and flexion angle decreased from immediate preoperative condition to final follow-up ($p < 0.001$, respectively) (Table 3). In addition, the postoperative JOA score was significantly higher than the preoperative one ($p < 0.001$). Among them, a total of 44 patients (35.8%) were of the poor results group. The postoperative FTA of the PR group at final follow-up was significantly higher than that of the GR group ($p < 0.001$), even though there was no significant difference between them at immediately after surgery (Fig. 4). Furthermore, logistic regression analysis showed that preoperative predictive factors for PR were obesity ($p = 0.018$, Odds ratio: 1.26), lower femorotibial angle ($p = 0.019$, Odds ratio: 0.69), lower JOA score ($p = 0.040$, Odds ratio: 0.95), lower knee extension angle ($p = 0.045$, Odds ratio: 0.89), and lower knee flexion angle ($p = 0.046$, Odds ratio: 0.95) (Table 2). Furthermore, ROC analysis showed the cut-off values of JOA score as 60 ($p < 0.001$, AUC: 0.716 [95% CI 0.617–0.815]) (Fig. 5).

Discussion

The most important findings of this study were that CW-HTO had excellent long-term survival rates as against conversion rates to TKA or rates of poor clinical outcomes in objective scales. From previous studies, CW-HTO was considered as a time-saving procedure, because the conversion rate to TKA was not low in their long-term follow-up. However, our results suggested that CW-HTO promisingly provides more than 15 years of therapeutic effects.

Table 1 Demographic data of the enrolled patients and drop out patients

	Follow-up	Drop out	p-value
Sample numbers	120	86	
Age, years	59.5 ± 6.5	63.9 ± 5.9	< 0.001
Females, n, %	110 (91.7%)	72 (83.7%)	0.150
Body mass index, kg/m^2	25.7 ± 3.5	26.4 ± 3.6	0.379
Preoperative JOA score	64.4 ± 14.2	65.2 ± 13.3	0.698
Loss of knee extension angle, degree	4.0 ± 5.0	2.6 ± 4.1	0.023
Knee flexion angle, degree	135.9 ± 13.7	138.4 ± 12.8	0.146
Femorotibial angle, degrees	179.7 ± 2.9	179.8 ± 2.9	0.871

Values are expressed as mean ± standard deviation of the pre-operative demographic data. Values in parentheses indicate percentage in each group. Demographic background data between followed up patients and drop out patients were compared using Mann–Whitney U test or Chi square test. P values < 0.05 were considered statistically significant. JOA: Japanese Orthopaedic surgery association

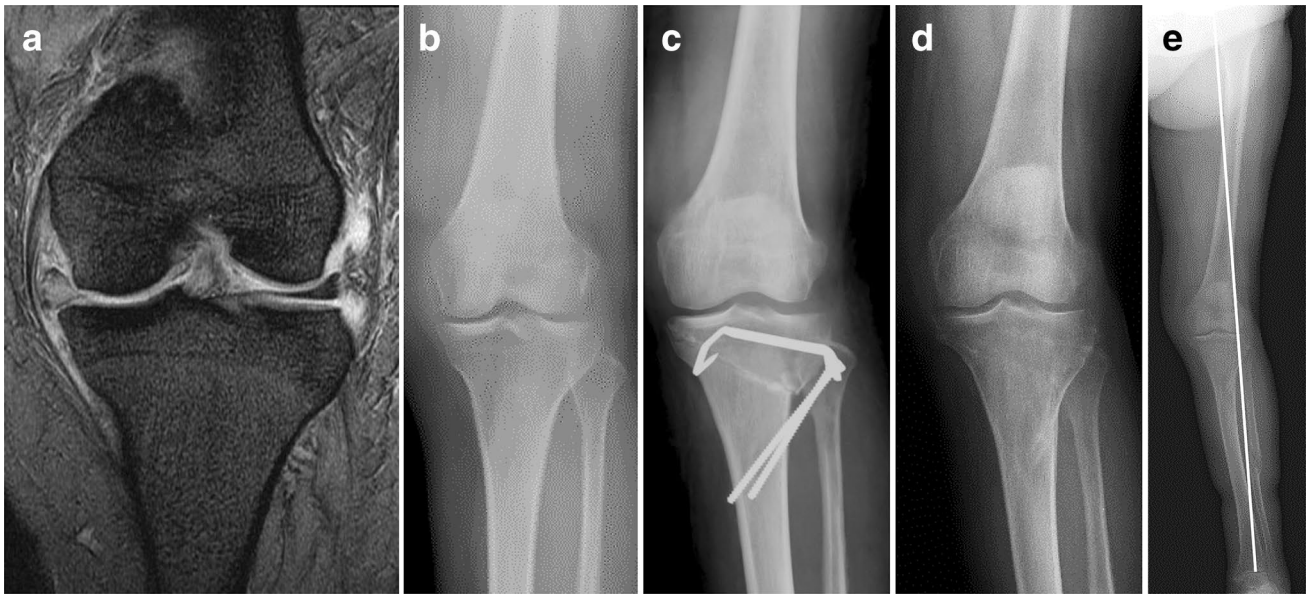

Fig. 1 A representative case of good outcome. Patient was a 62-year-old female who underwent CW-HTO. Preoperative MRI coronal plane (**a**) showed the medial meniscal extrusion and cartilage wear. Radiographs at preoperative (**b**), postoperative (**c**), and at final follow up (**d**, **e**) were shown

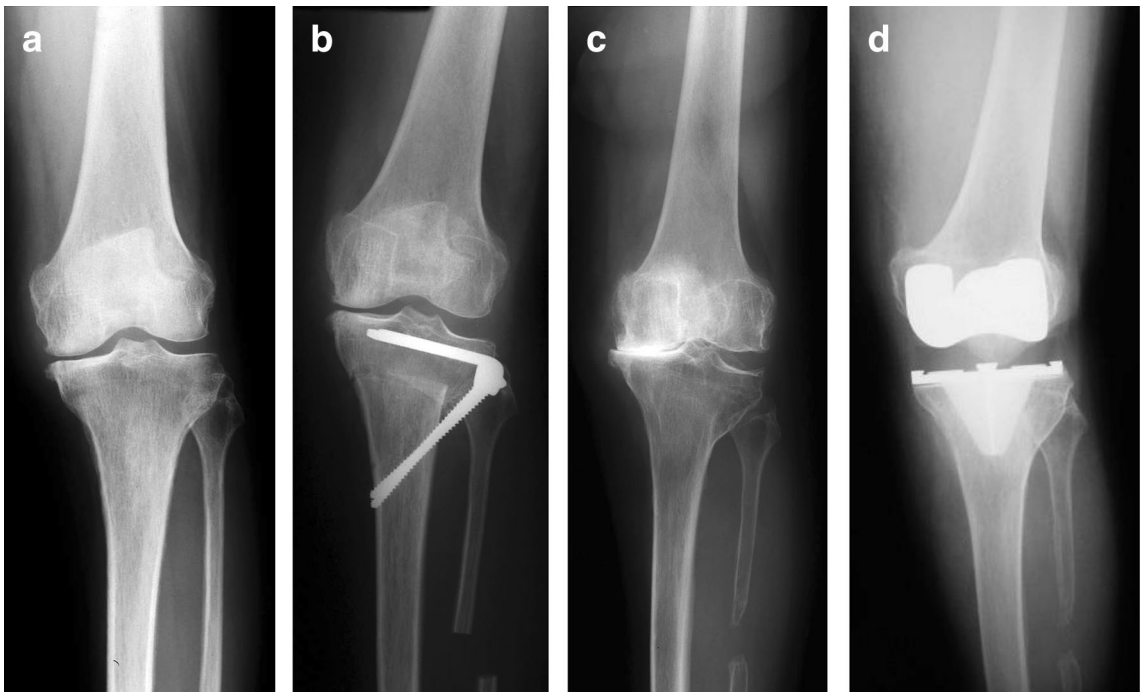

Fig. 2 A representative case of conversion to total knee arthroplasty. The patient was a 45-year-old female. Preoperative femorotibial angle (FTA) was 182°, and the JOA score was 60 points (**a**). Postoperative FTA decreased to 167° (**b**). After 16 years from primary CW-HTO, joint space of medial femorotibial joint disappeared and FTA increased up to 178° (**c**). This patient underwent total knee arthroplasty conversion (**d**)

Recently, concerning the comparison between OW-HTO and CW-HTO, there were no differences in clinical evaluation, radiographic evaluation, and conversion rate to TKA [7, 29, 32]. On the other hand, higher numbers of complications, including non-union or recurrent varus alignment, were identified as disadvantages of OW-HTO [8]. While

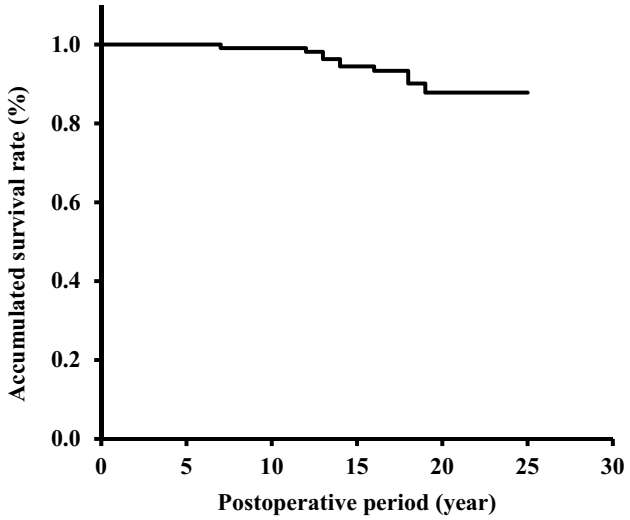

Fig. 3 Kaplan–Meier curve of CW-HTO

there were several disadvantages of CW-HTO, including compartment syndrome due to the fibular resection, peroneal nerve palsy, lower patellar height, or inaccurate correction including knocked knee [29, 33], 15 years survival rate was extremely high in this study. One systematic review showed that the TKA conversion rate from CW-HTO was 2% to 49% at 10 years after surgery [2]. Previously, the probability of survival of HTO was 75% at 10 years with knee replacement as the endpoint [31]. In addition, Naudie et al. reported that only 73% of patients at 5 years, 51% of patients at 10 years, 39% at 15 years, and 30% at 20 years after high tibial osteotomy had not required conversion of the high tibial osteotomy to a total knee arthroplasty [24]. However, in the recent surgical procedure, Akizuki showed an excellent long-term result of CW-HTO that the 15-year survival rate of CW-HTO was 90.4% [1]. Furthermore, from a recent systematic review, Kim revealed that the 10-year survival rate of CW-HTO was 85.4% when the endpoint was set to TKA [19]. In this study, the long-term survival rate of CW-HTO was 93.1% in the 15-year observation. These long-term results would be reflected by a better indication and appropriate correction angle from our result of regression analysis.

As risk factors for conversion to TKA, advanced age [10], obesity [1], pre-operative OA grade [9, 10], and pre-operative WOMAC functional score [15] were previously reported. These factors are generally considered as contraindications for osteotomy. Furthermore, from the nation-wide study, patients with HTO had an increased risk of TKA conversion in cases of recipients of Medical Aid programme benefits, the presence of hyperlipidemia, the presence of diabetes, and the presence of osteoporosis, besides advanced age or female sex [35]. In addition, Akizuki suggested risk factors predicting early failure as a pre-operative body mass

Table 3 Comparison of range of motion and clinical objective scores between preoperative condition and final follow up

	Pre-op	Final follow up	*p*-value
Loss of knee extension angle, degree	3.9 ± 5.1	8.0 ± 5.6	< 0.001
Knee flexion angle, degree	135.6 ± 13.5	114.7 ± 20.4	< 0.001
JOA score	64.3 ± 13.9	77.8 ± 15.1	< 0.001

Values are expressed as means ± standard deviations of knee extension and flexion angle, and JOA scores. Differences between preoperative condition and final follow up were compared by Wilcoxon signed-rank test. *p* values < 0.05 were considered statistically significant. JOA: Japanese orthopaedic association

Table 2 Preoperative predictive factors for the worsening JOA score or total knee arthroplasty conversion

	Risk for poor results in JOA			Risk for TKA conversion		
	B	*p*-value	Odds	B	*p*-value	Odds
Age	0.06	0.227	–	−0.01	0.857	–
Gender	21.05	0.999	–	19.39	0.999	–
Body mass index	0.23	0.018	1.26	0.14	0.386	–
Osteoarthritis/osteonecrosis	−1.44	0.214	–	−2.28	0.094	–
Preoperative femorotibial angle	−0.38	0.019	0.69	−0.21	0.404	–
Preoperative JOA score	−0.05	0.040	0.95	0.04	0.290	–
Preoperative loss of knee extension angle	−0.12	0.045	0.89	−0.01	0.932	–
Preoperative knee flexion angle	−0.05	0.046	0.95	−0.03	0.571	–
Period after surgery	−0.23	0.074	–	−0.58	0.012	0.56

Logistic regression analysis was performed to determine preoperative predictive factors for worsening JOA scores and total knee arthroplasty conversion. Dependent variables were: poor result against good result of JOA score, or conversion to total knee arthroplasty; and independent variables were age, Gender, body mass index, osteoarthritis/osteonecrosis, and preoperative parameters. *JOA* Japanese orthopaedic association

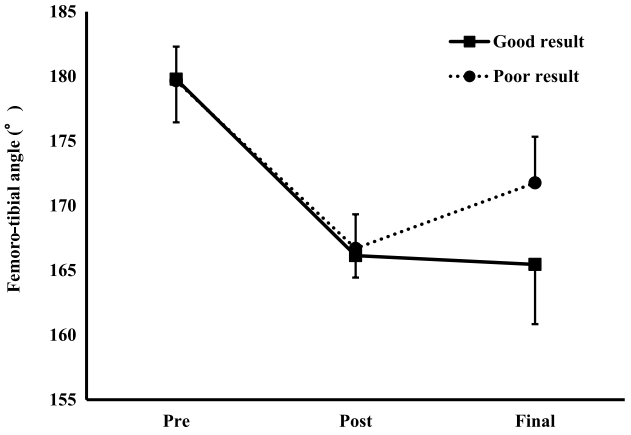

Fig. 4 Change of femorotibial angle of the good result and poor result groups. Time course of the femorotibial angle at preoperative, postoperative (6 to 12 month after surgery), and final follow-up, in good result and poor result groups.

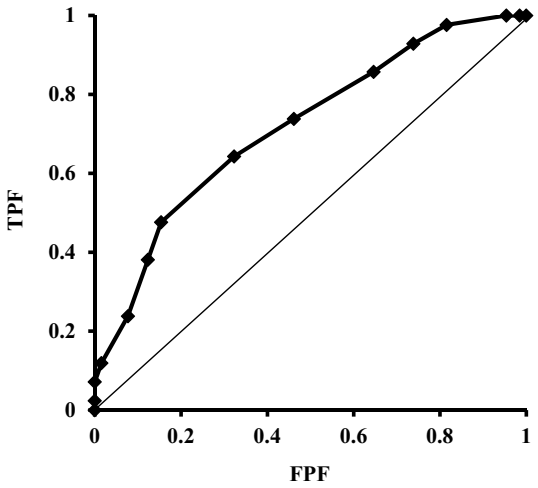

Fig. 5 ROC curve. The cut-off value of JOA score for poor result of JOA score or total knee arthroplasty conversion

index above 27.5 kg/m^2 and range of movement below 100° [1]. In this study, similar risk factors were identified for poor outcomes of functional scores, which were obesity, preoperative varus deformity, lower functional scores, and restricted range of motion.

The target angle for realignment by osteotomy has been controversial until now. Previously, Koshino et al. reported that 170° of FTA leads to better outcomes [20]. In addition, Sasaki et al. reported that 169° of FTA yield good results over 7 years [26]. On the other hand, recent reports suggested that higher valgus correction was necessary for better long-term clinical outcomes. Yasuda et al. reported that good results over 10 years required FTA to be changed from 164° to 168° [34]. Further, Majima reported that adequate valgus correction contributed significantly to preventing the progression of medial osteoarthritis with varus deformity without facilitating the progression of OA in the lateral compartment [21]. Akizuki demonstrated that excellent long-term survival rates could be obtained with CW-HTO, as a 15-year survival rate of 90.4% was achieved when the FTA was increased from 164° to 173° [1]. In this study, the postoperative FTA was 167°, and good survival rates were obtained. However, in the case of PR group with poor functional outcomes, FTA at the final follow-up became 171.8°, although the FTA immediately after surgery was 166.7°. While the detailed mechanism of this correction loss, progression of varus deformity, and joint space narrowing were not revealed in this analysis, intra articular conditions would affect these results. While it is reported that cartilage regeneration would contribute to keep valgus alignment and make their survival longer [18, 28], second lock arthroscopy or postoperative MRI evaluation could not be conducted.

There were several limitations besides the retrospective study design. First, evaluation of clinical outcome was performed only by the JOA score for objective scales and commonly used global clinical scores or patient-reported outcome scales were not investigated. In addition, the JOA score lacks its cut-off value or minimal clinically significant difference; hence, in this study, the cut-off values based on the mean and SD values were defined. Furthermore, the JOA score of patients immediately before TKA was not recorded in our institute; therefore, it could not be evaluated. Second, the follow-up rate was not so high in this study. Although we could evaluate the patients without any difference in demographic data but with drop-out patients, it would be important to know the reasons why they dropped out. In addition, it is necessary to take care of the potential bias to the survival rate due to this drop-out. Third, the FTA was measured only by standing anterior–posterior radiographs of the knee in this study. However, it would be better to be measured by standing long-leg radiographs for a more precise evaluation of mechanical and anatomical axes. Fourth, the indication for TKA was not clearly defined. Although TKA was performed in cases with severe knee pain and disabilities, there were no definitive criteria, including the degree of deformity, patient-reported outcome scales, or objective scores. Because this point would influence the survival rate, objective score was also focused on the poor outcomes using the JOA score to avoid overestimating its survival. Indeed, 33.3% of patients with correction loss of more than 170° of FTA went into TKA, and 41.7% were classified into the PR group in this study. Fifth, the underlying causes and its therapeutic strategy for severe knee OA had to be researched more. It is well known that 10-year survival rates were greater than 90% in both TKA [3, 11] and unicompartmental knee arthroplasty [5, 23]. Furthermore, the 10-year survival rate of TKA converted from HTO was 97% [6]. However, surgeons should take care that there are

more surgical technical concerns in TKA from CW-HTO than from OW-HTO [13]. Despite these limitations, the excellent long-term survival rate of CW-HTO is shown. In this case series study, the target FTA was 167°, and the 15-year survival rate was 92.5%. This result suggested that adequate valgus correction would contribute to better clinical outcomes, thereby avoiding TKA. However, in some patients, FTA 1 year after surgery increased at final follow-up, and their clinical objective scale decreased with correction loss. Further studies to investigate the mechanisms of this correction loss are needed.

Conclusions

The 15-year survival rate of CW-HTO was 92.5%. While higher scores of objective outcomes were kept over long-term follow-up, the risk factors for worsening scores were obesity and preoperative severity of knee symptoms.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Ethics approval The study was conducted with the approval of the Ethics Committee of our institution.

Consent to participate All participants gave their written informed consent.

Consent for publication All of the co-authors agreed with publishing this manuscript.

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