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Original Article

Satisfactory long-term survival, functional and radiological outcomes of open-wedge high tibial osteotomy for managing knee osteoarthritis: Minimum 10-year follow-up study



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ABSTRACT

Background: This prospective cohort study was designed to evaluate the survivorship and functional outcomes associated with long-term results of medial open-wedge high tibial osteotomy (MOWHTO) for the treatment of medial compartment knee osteoarthritis in the Chinese population. Although MOWHTO is a well-established procedure in the management of medial osteoarthritis of the knee, the long-term outcome in the Chinese population has not been reported in current literature. We hypothesised that MOWHTO would result in long-term preservation of knee function in Chinese, similar to that reported in the Caucasian population.

Methods: A cohort of 22 young adult patients (age < 55 years old) undergoing MOWHTO for the treatment of symptomatic medial compartment knee osteoarthritis between 2002 and 2008 was retrospectively surveyed with a minimum follow-up of 10 years. Kaplan–Meier survival analysis was performed, and the failure modes were investigated. The outcomes on survival (not requiring arthroplasty), clinical outcome (Knee Society Knee Score and Knee Society Function Score) and range of motion (numeric rating scale) at preoperative, 1-year post-operative follow-up and at last follow-up (>10 years) were evaluated. In addition, the mechanical tibiofemoral angle was also measured. The Wilcoxon signed-rank test was used for statistical evaluation of nonparametric data in these related samples.

Result: A total of 31 knees in these 22 cases were included. The follow-up rate was 100% at 13.4 ± 1.9 years (11–17). Mean age at time of surgery was 45.8 ± 9.5 years (18–53). At 10-year follow-up, four knees converted to require total knee arthroplasty (survival: 87.1%). Preoperative varus alignment with mechanical tibiofemoral angle of -9.26 ± 2.83 was corrected to 2.58 ± 2.46 after surgery and remained 2.01 ± 3.52 at the latest follow-up. Knee Society Knee Score increased significantly from 53.7 ± 11.1 preoperatively to 93.8 ± 6.8 at 1-year follow-up and 91.8 ± 9.7 at latest follow-up. Similarly, the functional score also increased significantly from 67.4 ± 21.0 preoperatively to 86.3 ± 14.5 at 1-year follow-up and 82.1 ± 16.6 at latest follow-up ($p < 0.01$). Whereas, the range of motion significantly decreased from 122.7 ± 6.6 preoperatively to 116.1 ± 15.5 at the latest follow-up.

Conclusion: Even in cases of severe medial osteoarthritis and varus malalignment, MOWHTO would be a good treatment option for management in active Chinese population less than 55 years. Although the long-term survival and functional outcome after MOWHTO was proven to be satisfactory in our cohort during the 10-year follow-up, a larger cohort to illustrate the long-term functional outcome is still warranted.

Translational potential: The finding in this study indicated MOWHTO is a feasible treatment option for young adult patients with osteoarthritis to achieve long-term satisfactory results.

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Introduction

Osteoarthritis (OA) is a long-term chronic disease characterised by the deterioration of cartilage in joints which results in stiffness, pain and impaired movement. OA of the knee has enormous health-care impact, which is estimated a global incidence of 3.8% of the population suffering from OA knee [1]. And in China alone, the prevalence of OA knee is as high as 8.1% [2]. Although there is a higher age-adjusted prevalence of OA knee in the elderly population (>65 years old), there is an increasing trend of young adults (18–55 years old) being presented with OA knee.

Although end-stage knee OA is commonly managed by arthroplasty, its outcome in young patients is suboptimal. Based on the latest arthroplasty registries and relevant publications, patients aged below 55 years having knee replacement will have a lifetime risk of revision ranged between 20 and 35%, and they also have high rate of dissatisfaction [3]. Alternative option other than arthroplasty is needed for these relatively young (<55 years old) and active individual with OA.

High tibial osteotomy (HTO), historically by closing wedge, is an established surgical procedure for managing medial compartmental osteoarthritis of the knee but later overshadowed by the success of arthroplasty [4]. HTO works by overcorrecting the mechanical axis of the lower limb to unload the medial compartment and load the non-diseased lateral compartment [5]. In recent years, medial opening-wedge HTO (MOWHTO) has gained popularity because it does not require a fibular osteotomy, common peroneal nerve dissection, disruption of proximal tibiofibular joint and bone stock loss as opposed to closing wedge HTO. The advantages of MOWHTO can allow multi-planar correction and easier subsequent total knee replacement. Although this surgical technique has been widely used for treating active, young and middle-aged individuals with an isolated medial compartment knee OA, current literatures on its findings are mainly based on the Western population [6,7]. Beside our previous report, there is no recent report toward the outcome on MOWHTO in the Chinese population, especially on long-term follow-up [8]. As MOWHTO works by altering the anatomy of tibia, the long-term MOWHTO findings from these Caucasian studies may not truly reflect the outcome for translating to the Chinese population owing to the anatomical difference [9]. Such that, previous literatures have shown that Chinese have higher tibial shaft offset, higher bowing and more valgus anatomical axis when compared with the Caucasian population [10,11]. In addition, peak bone mass and bone mineral density have also been reported to be lower in Chinese than Caucasians [12,13]. These difference in tibial bone geometry and bone density may have an unknown effect on the proximal tibial bone remodelling and hence survival of MOWHTO given the paucity of long-term MOWHTO results in Chinese. And with the global burden of knee OA [as measured by years lived with disability (YLD)] is highest among Chinese with those younger than 60 years old [14], which contributed to over 40% of the total YLDs, it would be of interest to know whether MOWHTO can sustain an effective joint preservation in Chinese in the long run.

Therefore, the aim of this current study was to determine the survivorship and long-term functional results following MOWHTO in Chinese patients aged younger than 55 years with medial OA. The hypothesis was that patients would demonstrate preservation of alignment, along with significant clinical, functional and survival outcomes that can postpone arthroplasty, similar to that reported in the Caucasian population.

Materials and methods

Ethical statement

This study complied with the Declaration of Helsinki after obtaining approval from the Institutional Review Board of the local institution's Research Ethical Committee (CREC 2018.524).

Patient selection

Using a prospectively collected arthroplasty database, we identified 22 patients who underwent MOWHTO between 2002 and 2008 at the Prince of Wales Hospital and Alice Ho Miu Ling Nethersole Hospital. MOWHTO was indicated if conservative treatment failed in a symptomatic patient with medial compartment knee OA grade 3 or milder according to Kellgren–Lawrence classification [15]. The exclusion criteria were lateral or patellofemoral symptomatic OA or Kellgren–Lawrence grade >3, rheumatoid arthritis, inflammatory arthritis, flexion range less than 100 or flexion contracture >10, ligamentous instability, obviously obese, severe osteoporosis or inability to communicate in Chinese or English language. Patient characteristics are displayed in Table 1.

Clinical assessment

The clinical results were assessed preoperatively, 1-year postoperatively and at last follow-up in all patients. The knee and function score of Knee Society [Knee Score (KS) and Function Score (FS)] were evaluated using a 100-point scale [16]. The range of motion (ROM) was measured using a manual goniometer.

Radiological assessment

Anteroposterior (AP) knee radiographs and long cassette standing radiographs, showing the hip, knee and ankle, were taken preoperatively, 1-year postoperatively and the last follow-up to assess mechanical tibiofemoral angle (mTFA). All radiographs were taken with the patient in the standing position with the knee extended, and their body weight distributed evenly across both lower extremities. Lateral knee and patella skyline views were also taken for assessing the tibial slope and patellofemoral joint condition, respectively. The mTFA was calculated using AP standing full lower limb radiographs. A line was drawn from the centre of the femoral head to centre of the knee and from the centre of the knee to the centre of the ankle joint. The medial angle between the intersections of these two lines was recorded as the mTFA. Negative angles denote varus deviation from neutral alignment.

To minimise any observation bias, two independent investigators performed all radiographic measurements. The intraobserver and interobserver reliability of the measurements was assessed using intraclass correlation coefficients. The intraclass correlation coefficients for intraobserver and interobserver reliability were 0.832 (95% confidence interval, 0.647–0.920) and 0.808 (95% confidence interval, 0.597–0.909), respectively, indicating good reliability.

Surgical techniques and rehabilitation procedure

A medial opening-wedge osteotomy in a biplanar fashion was performed as described previously [8,17]. Preoperative planning was performed on lower limb standing AP radiographs. In the year of the study, the mechanical axis was planned to cross the knee at the Fujisawa point (a point at 62.5% of the cross-sectional diameter of the tibial plateau), providing slight overcorrection when weight bearing [18]. After sufficient exposure, an osteotomy was created proximal to tibial tuberosity and was internally fixed with either an AO T-plate, AO L-buttress plate or Tomofix locking plate (Synthes, Oberdorf, Switzerland), with use of bone graft or synthetic bone substitutes. Towards the rehabilitation process, patients were allowed nonweight bearing walking for 6 weeks followed by partial weight bearing with crutches for another 6 weeks. After that, no walking aids were mandatory. Moreover, complications, such as lateral hinge fracture, loss of reduction, compartment syndrome, delayed union, infection, malunion or nonunion, were also monitored.

Table 1
Preoperative demographic data of the patients with MOWHTO.

Patients characteristics (n = 22)	
Age (years)	45.8 ± 9.5 (18–53)
Sex	
Male	13 (59.1%)
Female	9 (40.9%)
Side	
Left	13 (41.9%)
Right	18 (58.1%)
Duration of follow-up (years)	13.4 ± 1.9 (11–17)
Standing mechanical tibiofemoral angle (°)	170.7 ± 2.8 (varus: –9.3)
Range of motion (°)	122.7 ± 6.6 (110–140)
Knee flexion contracture (°)	1.8 ± 3.0 (0–10)
Knee Society Knee Scores in Point	53.7 ± 11.1 (32–80)
Knee Society Functional Scores in Point (Range)	67.4 ± 21.0 (35–100)

MOWHTO = medial open-wedge high tibial osteotomy.

Data presented as mean ± standard deviation (and range) or number (percentage)

Survival analysis

The survival analysis was conducted using Kaplan–Meier methods. Success was defined as a preserved MOWHTO procedure throughout the study period. Failure was defined as revision to total knee arthroplasty (TKA) because of symptomatic osteoarthritis progression. The length of the follow-up period was determined by the date of revision or last follow-up visit. The follow-up interval was 1 year.

Statistical analysis

Data obtained preoperatively, 1 year after surgery and at the most recent follow-up visit were subjected to statistical evaluation. All statistical analyses were performed using SPSS statistical software version 22 (IBM corporation, Armonk, NY, USA). The normality of distributions was evaluated using the one-sample Kolmogorov–Smirnov test. Continuous variables were compared using the paired *t* test. For statistical evaluation of nonparametric data in related samples the Wilcoxon signed-rank test was used. The log-rank test was used for comparing Kaplan–Meier survival curves between the different types of fixators. All reported *p* values are two-tailed, with an alpha level <0.05 considered as significant. Unless otherwise stated, descriptive results are demonstrated as mean ± standard deviation (and range).

A *post hoc* power analysis was performed with G. Power (Version 3.1., Kiel, Germany) exemplary for the obtained Knee Society scores preoperatively and at final follow-up. A 10-point difference on the Knee Society scores was considered significant. With a given alpha of 0.05 and the calculated effect size, a statistical power of 99.9% was found.

Result

Demographics

Between January 2002 and December 2008, 31 knees (left: 18, right: 13) from 22 cases (13 males, 9 females) were included in the study. Mean age at surgery was 45.8 ± 9.5 years (range 18–53 years). No patient dropped off the study. The median time to follow-up was 13.4 ± 1.9 years (range 11–17 years). The follow-up rate was 100% (22 of 22) after 13.4 ± 1.9 years (11.0–17.0). The demographic and baseline parameters of the 22 patients are shown in Table 1.

Clinical outcomes

Both average KS and FS showed statistically significant improvement between preoperative and 1-year postoperative evaluation (*p* < 0.001) and between preoperative and final postoperative evaluation (*p* < 0.001), whereas there were no significant changes between the 1-

Table 2
Clinical score preoperatively and within follow-up.

Parameter	Numerical Values	<i>p</i> value ^c
Knee score ^a		
Preoperative	53.7 ± 11.1 (32–80)	
1 year follow-up	93.8 ± 6.8 (73–100)	<0.001
Last follow-up	91.8 ± 9.7 (69–100)	<0.001
Function score ^b		
Preoperative	67.4 ± 21.0 (35–100)	
1 year follow-up	86.3 ± 14.5 (45–100)	<0.001
Last follow-up	82.1 ± 16.6 (45–100)	<0.001
ROM (°)		
Preoperative	122.7 ± 6.6 (110–140)	
1 year follow-up	118.8 ± 11.6 (90–150)	0.106
Last follow-up	116.1 ± 15.5 (70–150)	0.019

The results in the table were presented as mean ± standard deviation (range). MOWHTO = medial open-wedge high tibial osteotomy; ROM = range of motion.

^a Knee Society Knee score.

^b Knee Society function score.

^c Wilcoxon signed-rank test, when compared with preoperative.

year and latest postoperative evaluation (KS *p* = 0.075; FS *p* = 0.100) (Table 2). Although there was no difference in ROMs between preoperative and 1-year postoperatively (*p* = 0.106), the ROMs declined after more than 10-years postoperatively (*p* = 0.019) (Table 2). In addition, there were no significant changes between ROM at 1-year and latest postoperative evaluation (*p* = 0.345).

Radiological findings

Preoperative varus deformity decreased in all knees after operations. The mTFA was corrected to slight valgus, from –9.26 ± 2.83 preoperatively to 2.58 ± 2.46 1-yr postoperatively (*p* < 0.001) (Table 3). Although overcorrection was aimed and achieved intraoperatively, there were three MOWHTO only achieved mTFA = 0, whereas two MOWHTO were in slight varus alignment (–2 and –4) at postoperative weight bearing radiograph (Table 3). Four out of these five cases developed progression of medial knee osteoarthritis and required correction to total knee arthroplasty later on subsequent follow-up. Whereas one of these cases was able to maintain its neutral alignment at latest follow-up without further replacement or other revisions. Overall, the corrections have minor deterioration at the final follow-up after a mean of 13.4 years (mTFA = 2.01 ± 3.52) (Figure 1).

Survivorship

Of the 31 MOWHTO performed between 2002 and 2008, four patients had converted or requiring total knee arthroplasty. The survival after 5 years of follow-up for the total group was 96.8% (Figure 2); after 10 years of follow-up, it was 87.1% (Fig. 2). During the entire follow-up period, the rate of HTO failure is 1.29%/person-year, and the 1- and 10-year cumulative risks of HTO failure were 0% and 9.7% (Fig. 2). For the group using L-buttress plate, survival after 5 years was 100%; after 10 years, it was 88.2%. For the group using T-plate, survival at 5 years was 100.0% and was 90.0% at 10 years (Figure 3). While for the group using Tomofix, the survival at 5 years and 10 years was 100.0% (Figure 3).

Table 3
Radiographic result preoperatively and within follow-up.

Variable	Mechanical tibiofemoral angle (°)	<i>p</i> value ^a
Preoperative	–9.26 ± 2.83	
1 year follow-up	2.58 ± 2.46	<0.001
Last follow-up	2.01 ± 3.52	<0.001

MOWHTO = medial open-wedge high tibial osteotomy.

The results in the table were presented as mean ± standard deviation

^a Wilcoxon signed-rank test, when compared with preoperative

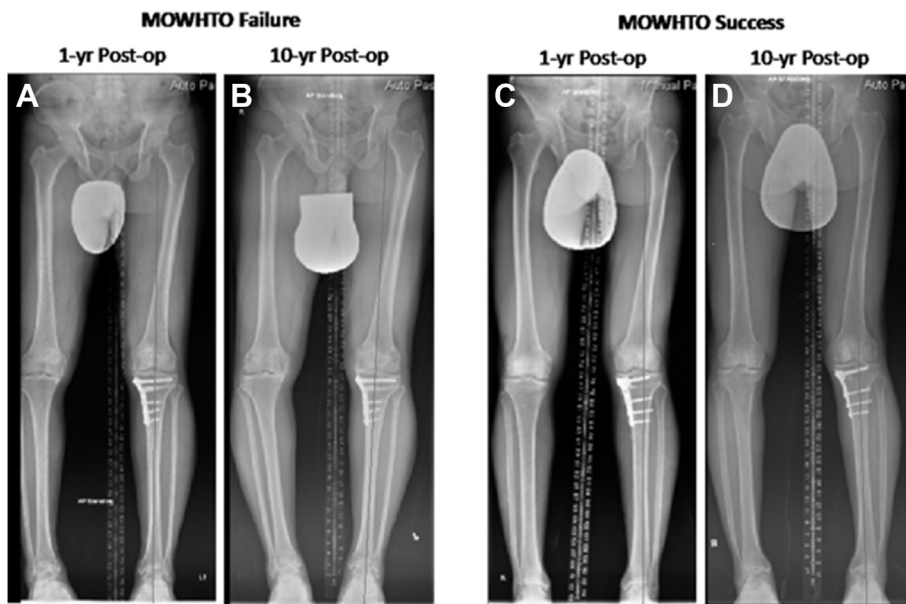


Figure 1. Long leg standing anteroposterior (AP) radiographs at 1-year and 10-years after MOWHTO. (A) MOWHTO failure correlated with neutral alignment at 1-year postop radiograph. (B) MOWHTO failure at 10-year postop showing progressive varus deformity and medial compartmental osteoarthritic changes. (C) MOWHTO success significantly correlated with valgus alignment at 1-year postop. (D) MOWHTO success at 10-year postop showing preservation of alignment, medial and lateral compartmental joint spaces. MOWHTO = medial open-wedge high tibial osteotomy.

Although Tomofix and T-plate showed better survival than L-buttress, statistical significance was not reached given the limited sample size.

Complications

In this series, we did not observe any intraoperative complication such as fracture of the lateral cortex or of the proximal fragment of the tibia. One case of early wound infection was treated with immediate wound debridement and patient was well thereafter. Two cases of suboptimal posterior slope were revised immediately after it was found in postoperative radiographs. These were not found to affect the long-term clinical and radiological outcome of MOWHTO in our series. No

other postoperative complication, such as lateral hinge fracture, compartment syndrome, peroneal nerve palsy, delayed union of the opening gap, deep venous thrombosis and complex pain regional syndrome, were observed.

Discussion

The major findings of this study show that a good long-term result of MOWHTO could be achieved in relatively young (under 55 years old) Chinese with severe medial osteoarthritis and varus malalignment. Based on our result, it showed a survival rate of 87.1% with a minimal 10 years follow-up and significant improvement on knee function

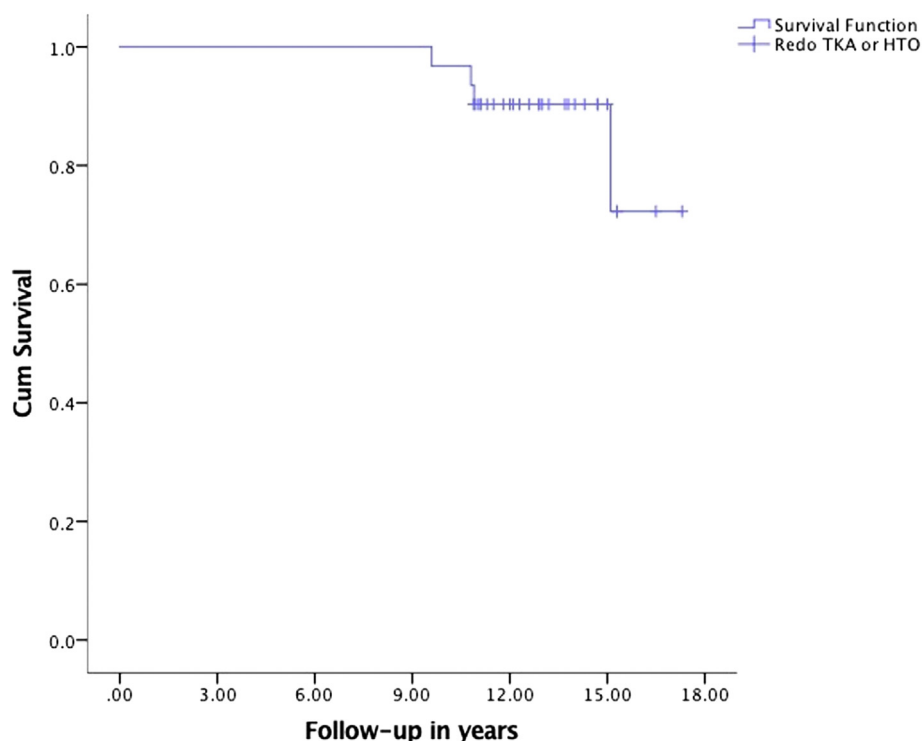


Figure 2. Kaplan–Meier curve illustrates the survival of the MOWHTO. Ten-year survival rate was 87.1%. MOWHTO = medial open-wedge high tibial osteotomy

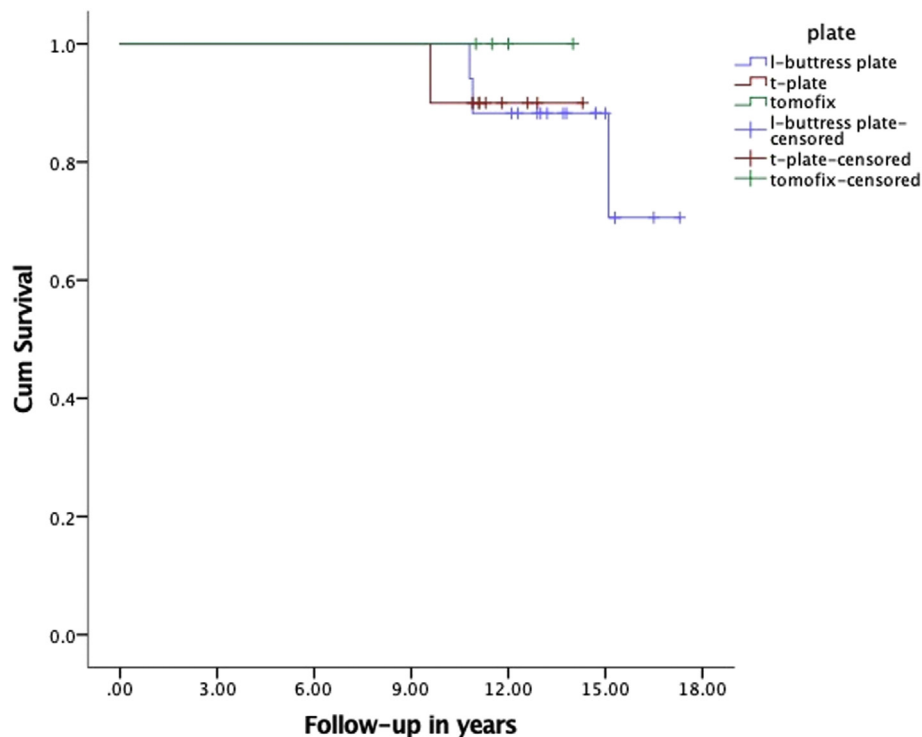


Figure 3. Kaplan–Meier survival curve on the types of plates used (L-buttress plate, T-plate, Tomofix). Five-year survival rate for L-buttress plate, T-plate and tomofix plate were $94.1\% \pm 5.7\%$, $90.0\% \pm 9.5\%$ and 100% , respectively. MOWHTO = medial open-wedge high tibial osteotomy

outcomes. Along with the clinical and the radiological outcomes remaining stable with a mean of 13.4 years, the overall survival rate also was comparable to the other non-Chinese population studies with patients undergoing MOWHTO being follow-up for over 10 years [7, 19]. In addition, the correction of the mechanical axis (mTFA) was kept almost constant after 10 years, which indicated the prevention on the progression of arthritis on the medial compartment of the knee joint. Overall, MOWHTO was found to minimise the need of arthroplasty in our Chinese cohort. Thus, we recommend that this procedure to be recommended as an alternative to arthroplasty for young Chinese adult patients with knee osteoarthritis.

In this study, there were only four failures (87.1% survival), with no patients awaiting a revision or knee arthroplasty before 9.5 years. This actually performed better than those reported in the Caucasian populations with 10 years follow-up [19–21]. As shown in Darees et al.'s study, it reported a revision of TKA of 12.1% in 48 patients using Tomofix fixation followed up for a minimum of 10 years [20].

Even though HTO has a long history of development in the Japanese and Korean population, however, a majority of these long-term results mainly focused on closing-wedge rather than medial open-wedge [22, 23]. Additionally, such studies focusing on the long-term survival of MOWHTO were mainly composed of Caucasians descents or conducted in Europe [6,21] (Table 3). There is no such study in the Asian population. Although Han Chinese, Japanese and Korean are consisted of the three major ethnicities in East Asia, they each have distinct genetic makeup which may differentiate the outcomes [9]. Such that, studies have shown a lower prevalence of osteoporosis being found in the Chinese population than their Japanese counterparts [24,25]. Individual studies have also described the difference in morphologies of knee and proximal tibia between the Japanese and Korean population [26,27]. However, a study on the direct comparison among these Asian ethnicities remains to be further elucidated.

On the other hand, the knee alignment differences between Chinese and Caucasian patients have been well evaluated by a study using large population-based cohorts from Framingham Osteoarthritis Study (FOA)

and the Beijing Osteoarthritis Study (BOA) [11]. The study reported more valgus anatomic axis angle and condylar angle in the distal femur in Chinese than Caucasian, with similar plateau angle between the two races. Whereas, some other studies have also showed other anatomical differences between Chinese and Caucasian. These included a higher tibial shaft offset and bowing and lowered peak bone mass and bone mineral density in Chinese than Caucasian [10–13]. Despite these differences, our study showed MOWHTO can provide satisfactory long-term survival and improved self-reported outcomes in Chinese patients, similarly to those previously reported using the Caucasian population.

Based on other literatures, MOWHTO with Tomofix plate have shown to have the best satisfactory outcomes in the long-term (Table 4). The survival ranges from 87.9 to 100% at 10 years follow-up. These studies included mainly patients with European descendants [6,20,28]. And from our finding, the survival rate is 100% in young Chinese adults. We believe that this good result can be translatable for further recommendation to people with knee arthritis.

The strength of the present study is that it adds some useful insights in a difficult problem on young Chinese patients with symptomatic medial knee arthritis. The global burden of knee OA among Chinese is huge. In recent publications, the estimated total YLD from knee OA in China (4,149,628–4,351,059) was much larger than that in the highly developed regions such as North America (~1,117,424) and Western Europe (~1,200,593) [2,14]. The prevalence of developing symptomatic knee OA in young Chinese is 9.6% and 19.3% in their 40s and 50s, respectively [29]. This huge burden is accompanied by the surge on the use of knee arthroplasty, as shown in previous publications [30,31]. Comparatively, there are limited publications discuss the use of HTO in Chinese. Given the young age and huge burden of knee OA in Chinese, HTO as a knee preserving surgery is a feasible alternative to arthroplasty as demonstrated in this study, and further education and promotion are warranted. And based on our unique case series, it only included young active Chinese patients that was treated with MOWHTO and being evaluated in a long-term follow-up. Importantly, our findings showed the satisfactory clinical and radiological results of MOWHTO without any major

Table 4

Over 5-years follow-up studies on survival rates and functional outcome of MOWHTO procedures.

Author	Year	No. cases	Ethnicity	Follow-up (years)	Implant	Survival % (years)	Functional outcomes
Altay MA [33]	2016	34 (35 knees)	Turkish	6.2	Anthony-K plate	97.2% (5)	Significantly improved VAS, WOMAC and Lysholm scores
Bode G [28]	2013	51	German	5.0	Tomofix plate	96% (5)	Significantly improved IKDC and Lysholm scores
Bonasia DE [34]	2014	99	Italian	7.5	Puddu plate	98.7% (5)	Significantly improved KSS and WOMAC scores
Darees M [20]	2018	48	French	10	Tomofix plate	87.9% (10)	KSS similar to preop at 10 years
Duivenvoorden T [35]	2014	36	Dutch	7.3	Puddu plate	91.6% (6)	Improved VAS, HSS scores
Hantes ME [6]	2018	20	Greek	12.3	Tomofix plate	95% (12)	Significant improved IKDC, KOOS, OKS and SF-12
Hernigou P [36]	2001	87	French	10	Buttress plates	94% (5) 85% (10) 68% (15) 72% (10)	
Hernigou P [21]	1987	93	French	11.5	—	72% (10)	
Saragaglia D [19]	2011	110 (124 knees)	French	10.4	T plate	88.6% (5) 74% (10)	Lysholm 88, KOOS 86
Schallberger A [37]	2011	16	Swiss	16.5	Plate	70% (15)	VAS 0, KOOS 71, WOMAC 84
Schuster P [38]	2019	21 (21 knees)	German	12.0	Tomofix plate	100% (12)	Significant improved IKDC, OKS and reduced pain level
Schuster P [39]	2018	73 (79 knees)	German	10.0	Angular-stable plate	96.1% (5) 81.7% (10)	Significant improved IKDC
van Egmond N [40]	2016	25	Dutch	7.9	Angular-stable plate	91.7% (5) 81.3% (8)	KSS 155.5, VAS 4.1, WOMAC 36.2

MOWHTO = medial open-wedge high tibial osteotomy; VAS = visual analog scale. IKDC = international knee documentation committee score; WOMAC = Western Ontario and McMaster Universities osteoarthritis index score. KSS = knee society score. HSS = hospital for special surgery score. KOOS = knee injury and osteoarthritis outcome score. OKS = oxford knee society score. SF-12 = the 12-item short form health survey.

complications after a mean of 13.4 years, which shows it is a safe and effective treatment.

Limitations of the study include the small number of patients, its retrospective nature and the lack of a control. This may preclude the statistical analysis on defining the risk factors involved. In addition, the MOWHTO were performed in a supine nonweight bearing position. This may result in deviation of mechanical axis in postoperative weight-bearing radiograph, as reported previously [32]. And based on our study, overcorrection is a must for the long-term success of MOWHTO in Chinese. Even though overcorrections were aimed and achieved intraoperatively, neutral or varus alignments was still resulted possibly because of this limitation. Moreover, the functional outcome is only based on the self-reported satisfaction scores by the patients. Definitely, the employment of an objective functional assessment (such as gait analysis) should be warranted.

Conclusion

This study confirms that MOWHTO is an effective joint preservation method to treat medial compartment knee osteoarthritis in our active adult cohort of less than 55 years of age. The clinical and radiological results were satisfactory with an overall survival rate of 87.1% after 10 years of surgery. Functional outcome and pain levels were found to be satisfactory postoperatively.

Conflicts of Interest

The authors have no conflicts of interest to disclose in relation to this article.

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