



# Survivorship of high tibial osteotomy: comparison between opening and closing wedge osteotomy

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**Background:** High tibial osteotomy (HTO) is frequently used to treat varus osteoarthritis (OA) in younger patients with the goal of delaying the need for total knee arthroplasty (TKA). While it has been reported that the results of TKA following HTO are worse than those in patients without prior knee surgery, the influence of osteotomy technique (medial opening wedge versus lateral closing wedge) has not been explored. The purpose of this study was to retrospectively compare the results of closing wedge and opening wedge and assess which technique led to lower risk of failure.

**Methods:** A total of 141 knees with indication for TKA, which were previously submitted to HTO (24 opening wedge and 117 closing wedge), were included in this study. At the time of TKA, the Knee Society Score and Knee Society Score function were evaluated. Additionally, the lower limb mechanical angle and Blackburn-Peele index were retrospectively retrieved. The relative risk of failure of the two techniques was compared using the Cox proportional hazard regression model. The impact of the patient's age at HTO on the time to convert to TKA was also analyzed.

**Results:** There was no significant difference in Knee Society Score and Knee Society Score function scores based on osteotomy technique at the time of the TKA. The survival curves were significantly different between the two groups ( $P < 0.001$ ) and patients who underwent opening wedge HTO had a 3-fold higher risk of failure (relative risk = 2.91,  $P < 0.001$ ). There was a significant but weak linear correlation between higher age at HTO and lesser time until the TKA ( $r = 0.326$ ,  $P < 0.001$ ).

**Conclusions:** Opening wedge HTO was associated with a 3-fold increase in risk of conversion to TKA, when compared to the closing wedge HTO surgical technique. These results are important for HTO surgical planning and may assist the orthopaedic surgeon in the decision between opening wedge or closing wedge HTO.

**Keywords:** High tibial osteotomy (HTO); opening wedge osteotomy; closing wedge osteotomy; survivorship

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## Introduction

Varus malalignment changes the knee medial and lateral load forces distribution, medializing the mechanical axis. This, consequently, overloads the medial compartment leading to the development or progression of knee osteoarthritis (OA) (1). Within this line, high tibial osteotomy (HTO) has been considered as a reliable, efficient and biological (preserves the native joint) surgical approach for the treatment of young and active adults with knee varus deformity that have progressed into isolated medial compartment knee OA (2). The mechanical principle behind HTO is to transfer the mechanical axis to the healthier preserved lateral compartment (3). Despite the satisfactory results regarding knee pain relief and function improvement (4,5), progression of the disease often leads to the deterioration of the outcomes over time (6,7). When the progression to OA becomes symptomatic despite the osteotomy, conversion to total knee arthroplasty (TKA) is often required (6,8). The postoperative complications, loss of effectiveness over time, survival rate and increased difficulty in converting into TKA are still concerns related to HTO and put into discussion the real indications of the procedure (4,9).

The most commonly performed HTO techniques for varus deformity OA are medial opening wedge HTO (OWHTO) and lateral closing wedge HTO (CWHTO). The CWHTO has historically been used in patients with varus OA, but the OWHTO gained popularity since it avoids fibular osteotomy, allows an enhanced fixation stability and more accuracy regarding deformity correction (10). Nowadays, the development of new osteosynthesis hardware and the improvement of the surgical techniques, makes the OWHTO the technique preferred by most of orthopaedic surgeons. Nevertheless, it is often associated with several disadvantages, most of them concerning bone grafting, such as donor-site morbidity and lower osteocyte viability (long time to heal) in addition to the higher costs associated with the fixation technique (11). In severe varus or valgus deformities greater than 10°–15°, lateral hinge rupture and loss of correction may occur in both techniques (12). Another potential complication is the *patella infera* and slight tibial lengthening, which is more commonly seen after OWHTO, but also reported in CWHTO (2,13,14). These anatomical and biomechanical changes following the HTO, yield variable durability and unpredictable outcomes.

Similar clinical and imaging outcomes as well as comparable reintervention rates have been reported after

OWHTO and CWHTO (2,8). Nonetheless, OWHTO seems to provide a more accurate correction (15,16), results in a lower incidence of osteosynthesis material removal, however is more frequently related to opposite cortical fracture (2). Survival rates after HTO reported in the scientific literature fluctuate considerably (11). In this sense, CWHTO mean survival rate range from 95–96% at 5 years, 53–80% at 10 years, and 57–60% at 15 years (7,17). In turn, medial OWHTO studies show a survival rate of 89–94% at 5 years, 63–85% at 10 years and 68% at 15 years (18). Nonetheless, which osteotomy technique leads to a more longstanding survival and lower rates of conversion into TKA is still not consensual (19). Hence, the purpose of this study was to retrospectively compare the results of CWHTO and OWHTO and assess which technique lead to lower risk of failure.

## Methods

Between 1996 and 2012 the TKA data was registered from the Croix-Rousse Hospital, Lyon, France to identify individuals that underwent TKA with a previously performed HTO. Patients who were submitted to HTO due to a post-traumatic lower limb malalignment were excluded. Overall, a total of 2,849 TKA were performed within this period. From these cases, 141 TKAs (5%) from 118 patients who had previously undergone HTO due to varus OA (n=24 for OWHTO and n=117 for CWHTO) were available for inclusion in this study. This patient sample was previously reported (20) with the purpose of following their clinical outcomes after the conversion to TKA.

The lower limb mechanical angle (also known as, hip-knee-ankle angle) was measured in all patients at the time of TKA. Additionally, the patellar height was measured according the Blackburn-Peele index.

For each case, the pre-TKA Knee Society Score (KSS) and the KSS function score were retrospectively collected from the hospital electronic database. KSS grading was determined as: 85–100%, excellent; 70–84%, good; 60–69%, fair; and <60%, poor. Additionally, the time from the osteotomy procedure to TKA (in months) was recorded. The association between the patient age at the time of HTO and survivorship time was calculated for all patients.

The statistical analysis was performed using the S-Plus 8.0 (SolutionMetrics, Australia). The level of significance for all hypothesis tests (P) was set at 0.05. Absolute (n) and relative (%) frequencies were computed for the categorical variables. Continuous variables were described using

**Table 1** Pre-TKA comparison of OWHTO and CWHTO groups

Variable	OWHTO (n=24)	CWHTO (n=117)	P
Age at HTO (years)	57.3±7.0	54.5±9.7	0.18
Time to TKA (years)	7.4±4.7	13.2±6.2	<0.001
Age at TKA (years)	64.3±7.6	67.8±9.8	0.10
Gender (male, %)	16 (66.7%)	60 (51.3%)	0.18
Weight (kg)	80.0±15.1	82.3±16.9	0.25
BMI (kg/m <sup>2</sup> )	27.8±5.1	29.4±5.2	0.08
Mechanical angle (degrees)	178.5±6.1	179.7±6.3	0.41
Patellar height (Blackburn-Peele index)	0.79±0.22	0.79±0.32	1.00
KSS	56.3±13.6	53.6±16.8	0.40
KSS function	59.4±15.1	60.5±18.6	0.78

KSS, Knee Society Score; OWHTO, open wedge high tibial osteotomy; CWHTO, closed wedge high tibial osteotomy; HTO, high tibial osteotomy; TKA, total knee arthroplasty; BMI, body mass index.

mean and standard deviation. The normal distribution was assessed through Kolmogorov-Smirnov test as also the skewness and kurtosis absolute values. The independent student *t*-test was performed to compare the time to surgery between the two surgical techniques. Fisher's exact test was performed to compare nominal and categorical variables. The Spearman rank correlation test was used to assess the association between time to TKA and the patient's age at osteotomy procedure. Additionally, the Cox proportional hazard regression model was used to estimate the relative risk (RR) with the 95% confidence intervals (CIs) for conversion to TKA between the two HTO techniques.

## Results

Overall, a total of 141 patients (54% male and 55% left knee) with a mean age of 55.0±9.4 years old at the time of HTO procedure were included in this study (57.3±7.0 for the OWHTO group and 54.5±9.7 for the CWHTO group). When the HTO was performed, all patients had varus malalignment. At the time of TKA, a total of 68 knees (48%) had valgus alignment and 73 knees (52%) had varus alignment (over- or under-correction; *Table 1*).

The mean time to TKA was 12.2±6.3 years (range, 1.5 to 34.4 years) and was significantly lower in the OWHTO group (7.4±4.7 *vs.* 13.2±6.2 years, *P*<0.001). The mean lower limb mechanical angle and limb alignment did not show any statistical significant differences between the two groups (*P*>0.05). The patients had a mean age of 67.2 years

old when the TKA was performed.

## Outcome scores

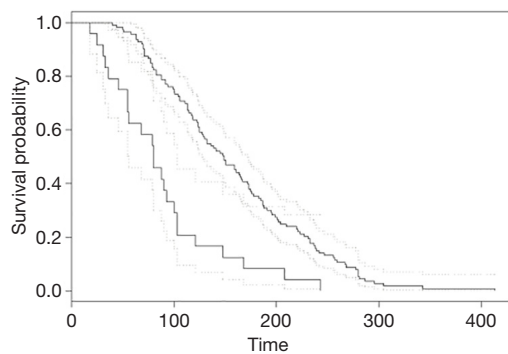
Overall, there were 81 cases of poor result (57.4%), 33 fair (23.4%), 21 good (14.9%) and 6 excellent (4.3%) regarding the KSS at pre-TKA. In the same line, the results of the KSS function were 55 (39.0%), 28 (19.9%), 32 (22.7%) and 26 (18.4%) for poor, fair, good and excellent, respectively. When considering the OWHTO and CWHTO groups (*Table 2*), no statistical significant differences were found on the KSS and KSS function scores (*P*>0.05).

## HTO survival

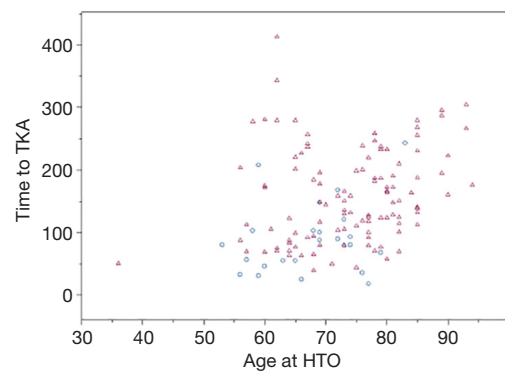
Patients who underwent OWHTO had a 3-fold higher risk of failure (RR =2.91, 95% CI: 1.85 to 4.59, *P*<0.001; *Figure 1*). The log-rank test showed that the survival curves were significantly different between the two HTO groups (*P*<0.001). Additionally, there was a significant but weak linear correlation between higher age at HTO and lesser time until the TKA (*r*=0.326, *P*<0.001; *Figure 2*).

## Discussion

The main finding of this study was that the HTO technique seems to influence the survival of the surgery. Within this line, the OWHTO technique had a 3-fold increased risk of failure. This is of utmost importance since the



**Figure 1** Survival curves for patients that underwent OWHTO (upper curve) and CWHTO (lower curve). Survival probability in percentages and time to arthroplasty in months. OWHTO, open wedge high tibial osteotomy; CWHTO, closed wedge high tibial osteotomy.



**Figure 2** Correlation between the age at HTO procedure (in years) and time elapsed until the conversion to TKA (in months) according OWHTO (blue circles) and CWHTO (red triangles). HTO, high tibial osteotomy; TKA, total knee arthroplasty; OWHTO, open wedge high tibial osteotomy; CWHTO, closed wedge high tibial osteotomy.

**Table 2** Comparison of KSS and KSS function scores between the groups

Variable	OWHTO (n=24)	CWHTO (n=117)
KSS, n (%)		
Excellent	0 (0.0)	6 (5.1)
Good	5 (20.8)	16 (13.7)
Fair	8 (33.3)	25 (21.4)
Poor	11 (45.8)	70 (59.8)
KSS function, n (%)		
Excellent	3 (12.5)	23 (19.7)
Good	6 (25.0)	26 (22.2)
Fair	1 (4.2)	27 (23.1)
Poor	14 (58.3)	41 (35.0)

KSS, Knee Society Score; OWHTO, open wedge high tibial osteotomy; CWHTO, closed wedge high tibial osteotomy.

main purpose of HTOs is to correct the mechanical axis to decrease the knee joint contact pressures and delay the progression of knee OA. In this sense, performing a CWHTO would provide higher durability and effectiveness to the procedure and further delay the development of knee OA and, subsequently, the need for TKA.

Wide survival rates have been reported in the literature regarding HTO (6). Comparison between OWHTO and CWHTO is challenging due to the difficulty in pooling results from the available studies caused by the

heterogeneity found in the patient’s characteristics and surgical techniques. In the present study, it was found a significant linear association with younger ages and longer time needed for conversion to TKA, potentially suggesting a higher durability of the HTO in younger patients. Although the association was statistically significant, it was weak. Nevertheless, patient age should be taken into account when performing index HTO as degenerative OA can also progress post-operatively and consequently lead to the need of TKA conversion. This could be explained by the higher bone and cartilage quality in younger patients.

The clinical and functional outcomes (KSS and KSS function) after OWHTO or CWHTO were not significantly different. This data is important to report as it shows that the two groups were similar at the time of the TKA. The presence of good and excellent results in KSS and KSS Function scores when TKA were performed is explained by the presence of untreatable pain which was the main surgical indication. In this sense, some patients can have considerable good final scores, but still with a formal indication for TKA when pain is considered. When considering the postoperative outcomes following HTO, there is a lack of clinical and functional superiority between the two surgical approaches (21,22). In this sense, Brouwer *et al.* (21) followed 92 patients for a 1-year period after HTO procedure (OWHTO, n=45; CWHTO, n=47) controlled by a Puddu plate. They found no statistical significant differences in the clinical and functional

outcomes (visual analogue scale and hospital for special surgery score) at 1-year follow-up. Nevertheless, this is still a controversial topic as conflicting results have been reported (21,22).

There is no consensus about the optimal mechanical axis obtained after a HTO surgery. For varus deformity, a slight valgus position is desirable with the objective of shifting axial load to the opposite compartment and relieve pain. However, over- and under-correction of the deformities may lead to surgical failure (23). Moreover, mechanical axis can change over the time and with the development of OA. In our series, at the time of TKA, a total of 68 knees (48%) had valgus alignment and 73 knees (52%) had varus alignment (under-correction or loss of correction). This reflects the evolution of the disease with the progression of the cartilage and bone deterioration reflected in a knee joint varus angulation recurrence.

The mechanical angle did not show any statistical significant differences between the two HTO groups at pre-TKA. Similarly, Gaasbeek *et al.* (24) did not find any statistically significant differences in the mechanical angle between OWHTO and CWHTO. On the opposite, Brouwer *et al.* (21), found significantly different mechanical angles between OWHTO and CWHTO at 1-year follow-up. Within the same line, the patellar height did not show any significant differences in this study. However, it has been shown that OWHTO increases the incidence of *patella infera* (13). In addition to these radiological results, it has also been reported conflicting evidence regarding the technique accuracy in correcting the mechanical axis (16,21). In this sense, the risk of failure is increased if the alignment is not overcorrected to at least 8 degrees of valgus angulation and if the patient is substantially overweight (25). Additionally, good post-operative muscle strength and male gender are correlated with better outcomes [1].

It has been suggested that after TKA conversion in patients with previous HTO, the clinical and radiological outcomes are poorer, than when the TKA is performed as a primary procedure (26-28). This is caused by an increased difficulty in performing the TKA following a previous HTO (27,29). Still, these results show conflicting evidence in the literature, as there are also many reports of similarity of the results (20,30). In addition, CWHTO has been associated with several disadvantages, including fibular osteotomy or proximal tibiofibular joint disruption, lateral muscle detachment, peroneal nerve dissection and bone stock loss. Nonetheless, OWHTO requires bone grafting and has the risk of collapse or loss of correction (30). Despite the

advantages in performing OWHTO, there are no significant differences between the two surgical approaches (8). Thus, patient's age, associated procedures and technical difficulties should be taken into account when performing a primary HTO. Moreover, the choice of whether to perform an OWHTO or a CWHTO may be based on preoperative patellar height and surgeon's preferences (24).

Limitations of this study must be highlighted. The retrospective design of the study precluded the randomization of the patients between OWHTO and CWHTO, and indications other than OA for the HTO procedures may have varied between the groups. Additionally, even though all the TKA procedures have been performed at a single hospital, the index HTO procedures were performed by different orthopaedic surgeons at different hospitals, which may have influenced the results. Nevertheless, our results reflect the real-life daily practice application of HTO procedure. Although the groups seem homogenous at the baseline, the lack of the HTO surgical data and other related unquantified differences between the groups may have existed and therefore biased the results. The significant different sample sizes between the groups may be related to the evolution of the HTO technique over time, which may have yielded significant influence in the time to TKA conversion. Taking into account all these limitation, despite the observed higher risk of failure in CWHTO, it cannot be assumed a superiority to the OWHTO technique. Thus, it is required further research to answer this question and future studies should randomize their age-matched patients equally into the two surgical approaches and follow them prospectively to compare the effectiveness and durability of both techniques.

## Conclusions

The OWHTO was associated with a 3-fold increased risk conversion to TKA, when compared to CWHTO surgical technique. These results are important when planning a HTO procedure and assist orthopaedic surgeon decide between OWHTO and CWHTO.

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## Footnote

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at <http://dx.doi.org/10.21037/aoj.2018.05.05>). The authors have no conflicts of interest to declare.

*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This was a retrospective study and an ethical approval was not required. Informed consent was waived.

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