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Long-Term Survival of High Tibial Osteotomy for Medial Compartment Osteoarthritis of the Knee

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Background: The management of degenerative arthritis of the knee in the younger, active patient presents a challenge to the orthopaedic surgeon. Surgical treatment options include high tibial osteotomy (HTO), unicompartmental knee arthroplasty, and total knee arthroplasty.

Purpose: To examine the long-term survival of closing wedge HTO in a large series of patients up to 19 years after surgery.

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

Methods: Four hundred fifty-five consecutive patients underwent lateral closing wedge HTO for medial compartment osteoarthritis between 1990 and 2001. Between 2008 and 2009, patients were contacted via telephone, and assessment included incidence of further surgery, current body mass index (BMI), Oxford Knee Score, and British Orthopaedic Association Patient Satisfaction Scale. Failure was defined as the need for revision HTO or conversion to unicompartmental knee arthroplasty or total knee arthroplasty. Survival analysis was completed using the Kaplan-Meier method.

Results: High tibial osteotomy survival was determined in 413 patients (91%). Of the 397 remaining living patients at the time of final review, 394 (99%) were contacted for follow-up via telephone interview. The probability of survival for HTO at 5, 10, and 15 years was 95%, 79%, and 56%, respectively. Multivariate regression analysis showed that age under 50 years (*P* = .001), BMI less than 25 (*P* = .006), and ACL deficiency (*P* = .03) were associated with better odds of survival. Mean Oxford Knee Score was 40 of 48 (range, 17-48). Overall, 85% of patients were enthusiastic or satisfied, and 84% would undergo HTO again at a mean 12 years of follow-up.

Conclusion: High tibial osteotomy can be effective for periods longer than 15 years; however, results do deteriorate over time. Age less than 50 years, normal BMI, and ACL deficiency were independent factors associated with improved long-term survival of HTO.

Keywords: high tibial osteotomy; knee, osteoarthritis; survival

Medial compartment osteoarthritis (MCOA) of the knee leading to varus deformity and subsequent disability is a common problem.[11,26,34] During the early stages of osteoarthritis (OA), nonsurgical treatment options include weight loss, low-impact activity, and physiotherapy.[45] As the disease progresses to end-stage MCOA, the surgical treatment options are high tibial osteotomy (HTO), unicompartmental knee arthroplasty (UKA), and total knee arthroplasty (TKA).[10,26] Arthroplasty, both UKA and TKA, is considered a good option for low-demand patients older than 60 years, with good long-term outcomes reported.[5,10,39] However, concern remains regarding the longevity of these implants in younger patients.[5,10,24]

When performed successfully, HTO is a joint-preserving procedure that does not compromise future TKA.[5,51] It is a good option for young patients with isolated MCOA and varus deformity.[6,10,24,36,42,47,53] The biomechanical principle of HTO in MCOA is to redistribute the weightbearing forces from the worn medial compartment across to the lateral compartment to relieve pain and to slow disease progression.[5,7,10,17,52,54] Biopsy and second-look arthroscopic and open procedures have shown that there is regrowth of fibrocartilage in the worn medial compartment with a predilection for the ulcerated regions of wear in the weightbearing portion of the medial femoral condyle.[8,25,32,33,41]

It has been well established that good short- and medium-term outcomes can be achieved with HTO for MCOA.[27,28] Unfortunately, these results have been shown to deteriorate over time.[1,17,29,31,46,52,55] Most recent studies report satisfactory outcomes of approximately 80% at 5 years and 60% at 10 years.[5,9,18,31,40,46,50]

The purpose of this study was to examine the long-term survival of lateral closing wedge HTO in a large series of patients up to 19 years after surgery to determine whether the results deteriorate over time, to review the complications, and to determine the factors associated with improved long-term survival of HTO.

METHODS

Ethical approval for this study was granted by The University of Sydney. The results of 455 consecutive patients undergoing lateral closing wedge HTO for MCOA between 1990 and 2001 were reviewed. Indication for surgery was MCOA that was not responsive to nonoperative treatment with grade IV changes evident clinically or radiographically. Exclusion criteria included inflammatory arthritis, symptomatic OA of the lateral compartment, previous HTO, flexion contracture greater than 10°, and flexion less than 90°.

The senior author (L.P.) performed all osteotomies. A modified Coventry[16] lateral closing wedge HTO was performed with the goal to correct the femoral-tibial alignment to 10° valgus. A posterolateral hockey-stick incision was used following the course of the common peroneal nerve. The nerve was identified and protected. The proximal tibiofibular joint was excised, leaving the styloid process and its attached structures intact. A transverse tibial osteotomy was made at the level of the superior tibiofibular joint parallel to the joint line and an angular jig was used to make the second, oblique, osteotomy to a predetermined wedge size. The medial cortex was gently fractured as the osteotomy was closed. Medial collateral ligament (MCL) laxity can lead to overcorrection of the osteotomy and more valgus than intended. Therefore, in cases of MCL laxity, 2 special considerations were made. First, MCL laxity is calculated into the wedge size by taking a smaller size wedge depending on the amount of laxity present. Second, the proximal osteotomy was intentionally completed through the medial cortex, and the distal saw cut was made with the apex of the osteotomy more lateral, such that a closing lateral osteotomy and an opening medial osteotomy were achieved, thus restoring the tension in the MCL (Figure 1). Fixation was achieved with a Krakow staple (Smith & Nephew, Memphis, Tennessee).

From 1990 to 1996, the method was for the limb to be immobilized in extension using a long-leg plaster cast. From 1997, the method was for the limb to be supported in a range of motion brace, allowing full range of motion, with pads providing 4-point pressure supporting the valgus osteotomy for 6 weeks. All patients received 1 preoperative and postoperative dose of antibiotics for infection prophylaxis and warfarin for venous thromboembolism prophylaxis for 6 weeks with a target international normalized ratio of 1.5-2.0. Patients were toe-touch weightbearing for 2 weeks,
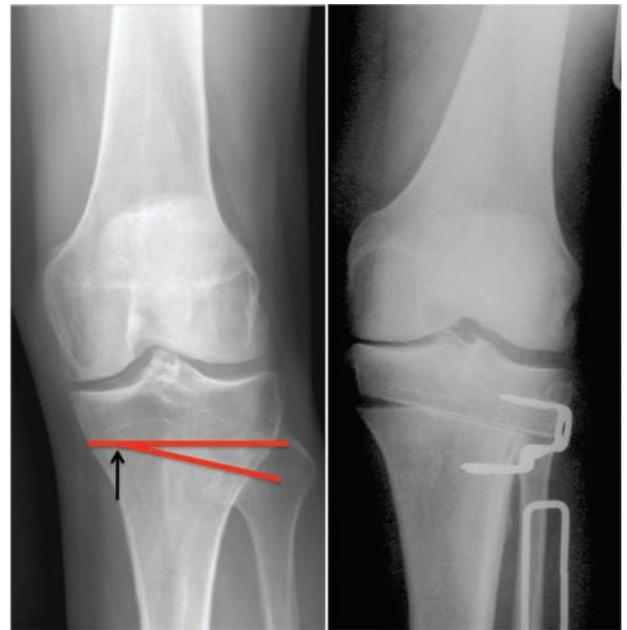

Figure 1. Preoperative planning of osteotomy cuts with lateralized apex (arrow) and final combined lateral closing and medial opening wedge osteotomy for patients with medial collateral ligament laxity.

then were partial weightbearing for 2 weeks, and then progressed to full weightbearing by 6 weeks, with commencement of an active mobilization and strengthening physiotherapy program once the brace or plaster was removed. Clinical examination was performed for union, and radiographs were obtained if needed.

Between 2008 and 2009, patients were contacted via telephone for long-term follow-up assessment. This included incidence of further surgery, current body mass index (BMI; weight [kg]/height [m]^2), Oxford Knee Score,[19] and British Orthopaedic Association Patient Satisfaction Scale.[4] For those patients who had proceeded to surgery, the medical records were reviewed for BMI at time of failure. Failure was defined as the need for revision HTO or conversion to UKA or TKA.

The probability of failure was estimated as a function of time using the Kaplan-Meier survival method with a 95% confidence interval. Comparisons of survival curves were made with log-rank tests. Univariate and multivariate Cox proportional hazards analyses were used to verify the relationship between survival and each possible associated factor. These included cause of OA, previous surgery, status of the ACL, age, BMI at review or failure, gender, and MCL laxity. Estimation of the hazard ratio was used to evaluate the association between the risk of failure and contributing factors. $P < .05$ was considered statistically significant.

RESULTS

From 1990 to 2001, 460 patients underwent lateral closing wedge HTO for MCOA. Five patients (1%) declined
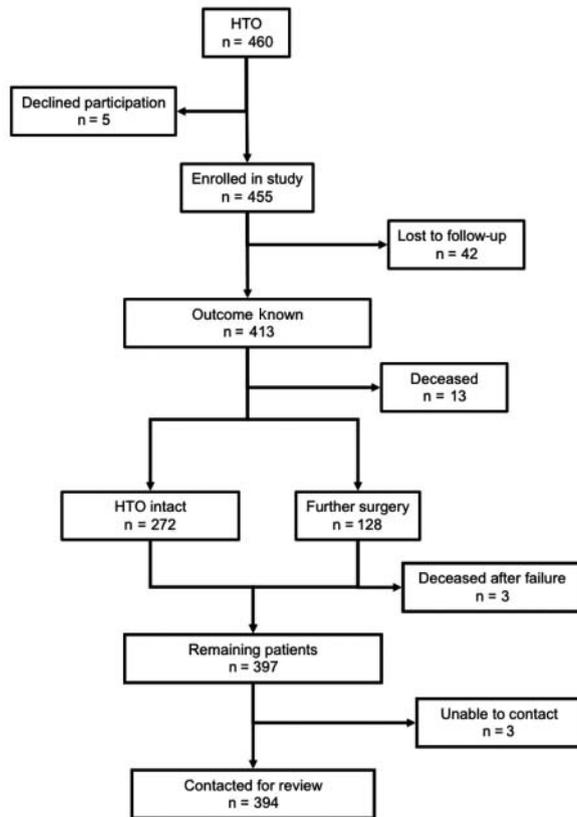
Figure 2. Participant flow.

participation in the study and were excluded, leaving 455 patients enrolled in the study. Forty-two patients (9%) were lost to follow-up. High tibial osteotomy survival was determined in 413 patients (91%). Thirteen patients (3%) had died of unrelated causes with intact osteotomies, 128 patients (31%) required further knee surgery (104 TKAs, 22 UKAs, and 2 revision HTOs), and 272 patients (66%) had surviving osteotomies. By 2008 to 2009, 3 patients were deceased after HTO failure, leaving 397 living patients remaining. Three hundred ninety-four (99%) of these patients were contacted for telephone interview. Three patients that were known to have undergone TKA were unable to be contacted for subjective review (Figure 2).

There were 326 (79%) men and 87 (21%) women in the final HTO study. The mean age at the time of osteotomy was 50 years (range, 24-70 years). There were 208 (50%) left and 205 (50%) right knees. The mean time to follow-up was 12 years (range, 1-19 years).

The mean initial femoral-tibial alignment was 0° (standard deviation [SD], 3.8). Immediately postoperatively, all limbs were in valgus alignment with a mean femoral-tibial alignment of 10.3° (SD, 1.9). The mean BMI at the time of final review or HTO failure was 28.3 (SD, 3.8). The BMI was categorized according to the definitions of the World Health Organization for analysis (Table 1).

Complications included 5 pulmonary emboli and 8 deep vein thromboses that were treated with therapeutic levels of anticoagulation, 1 nonunion requiring bone grafting, and 1 postoperative subarachnoid hemorrhage related to a pre-existing aneurysm that was subsequently clipped. One patient had a transient peroneal nerve palsy that was explored and found to be due to a hematoma, which was evacuated. There were no infections.

Using the Kaplan-Meier survivorship estimate of failure, the overall probability of survival of HTO was 95% at 5 years, 79% at 10 years, and 56% at 15 years (Figure 3).

Univariate Analysis

Analysis of the potential risk factors for failure of HTO using univariate Cox regression analysis showed that post-traumatic OA ($P = .001$), any previous surgery ($P = .04$), ACL deficiency ($P = .001$), age less than 50 years ($P < .001$), and BMI less than 25 ($P = .04$) (Figure 4) were factors associated with longer HTO survival. Univariate analysis failed to show a significant association between early failure and gender and MCL laxity (Table 1).

Multivariate Analysis

Factors that were significant ($P < .05$) on univariate analysis were entered into a multivariate Cox regression analysis. Factors were then eliminated one at a time in a step-wise fashion, until only the independent significant factors remained (Table 2). Analysis of the potential risk factors for failure of HTO using multivariate Cox regression analysis showed that age less than 50 years ($P = .001$), BMI at review less than 25 ($P = .006$), and ACL deficiency ($P = .03$) (Table 2, Figure 4) were factors associated with longer HTO survival.

Subjective Outcomes

The results of patients who were enthusiastic or satisfied according to the British Orthopaedic Association Patient Satisfaction Scale and whether the patient would undergo surgery again are presented in Table 3. Patients who did not require further surgery were asked to complete the Oxford Knee Score regarding their HTO (n = 272). The mean Oxford Knee Score was 40 of 48 (range, 17-48). There was no difference in Oxford Knee Score between patients less than 50 and more than 50 years of age ($P = .15$).

DISCUSSION

To our knowledge, we report the long-term follow-up of lateral closing wedge HTO in the largest group of patients in the literature. We found that age less than 50 years, BMI less than 25, and ACL-deficient knees were independent factors associated with improved long-term survival of the osteotomy. Consistent with previous studies, we found that the results of HTO do deteriorate over time but that HTO can be effective for longer than 15 years.[17,29,31,46,52,55]

TABLE 1
Univariate Cox Regression of Potential Risk Factors[a]

Factor and Category	No. of Patients	Survival, y			Hazard Ratio	95% CI	*P* Value
		5	10	15			
Cause of OA							
Posttraumatic	227	97	84	67	2.0	1.4-2.8	.001
Idiopathic	186	92	74	46			
Previous surgery							
Any	299	95	79	60	1.5	1.0-2.1	.04
Nil	114	94	80	46			
Status of ACL							
Deficient	90	99	90	74	2.6	1.5-4.4	.001
Intact	323	94	76	51			
Age, y							
<50	198	99	94	72	3.7	2.5-5.5	.00
≥50	215	90	65	41			
Gender							
M	326	95	80	57	1.2	0.8-1.8	.48
F	87	95	78	53			
BMI at review or failure, kg/m²							
<25	63	90	82	76	1.9	1.0-3.4	.04
≥25	331	96	79	52			
<30	272	96	80	58	0.9	0.62-1.32	.60
≥30	122	93	79	54			
MCL laxity, mm							
0-3	279	95	81	57	0.7	0.5-1.1	.17
3-10	134	94	75	55			

[a]Posttraumatic, history of ACL injury (with and without reconstruction), meniscectomy performed >5 years prior to high tibial osteotomy, osteochondritis dissecans, previous lower limb fracture; idiopathic, no history of trauma or arthroscopic surgery performed within 5 years of high tibial osteotomy. CI, confidence interval; OA, osteoarthritis; BMI, body mass index; MCL, medial collateral ligament.
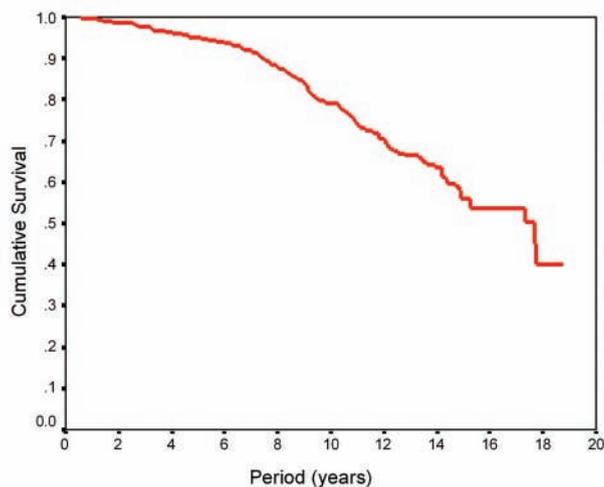

Figure 3. Kaplan-Meier survivorship analysis for all high tibial osteotomy participants.

In our study, the overall Kaplan-Meier probability of survival of HTO was 95% at 5 years, 79% at 10 years, and 56% at 15 years, which is consistent with previously published results in the literature. Previous studies have reported 73% to 99% survival at 5 years and 55% to 75% survival at 10 years.[3,9,18,24,34,40,50,53] Recently, Akizuki et al[3] reported survivorship of HTO to be 99% at 5 years, 98% at 10 years, and 90% at 15 years. The Japanese authors acknowledged that their results were significantly better than those of other countries, but were consistent with another Japanese study that reported survivorship to be 98% at 5 years, 96% at 10 years, and 93% at 15 years.[34] Whether these improved results compared with studies from Western countries are aberrant, or possibly related to Japanese body habitus, culture, and lifestyle requires further study.

Flecher et al,[24] Holden et al,[28] and Odenbring et al[42] found age less than 50 years to be the only factor associated with long-term HTO survival. The long rehabilitation after HTO has been well documented. Younger patients are able to recover more quickly and more fully from the rigorous rehabilitation.[30] These patients also have the greatest chance for satisfactory long-term function when compared with those patients who have the operation done at an older age.

Overweight is defined by the World Health Organization as BMI greater than 25, and obese is defined as BMI greater than 30. We report the BMI of the patients at the time of HTO failure or final review. There was incomplete data on BMI at the time of surgery, so it was not reported. We found that a normal BMI was an independent factor associated with improved long-term survival of HTO. This is consistent with several other studies in the literature.[3,18,24,37] In our study, BMI greater than
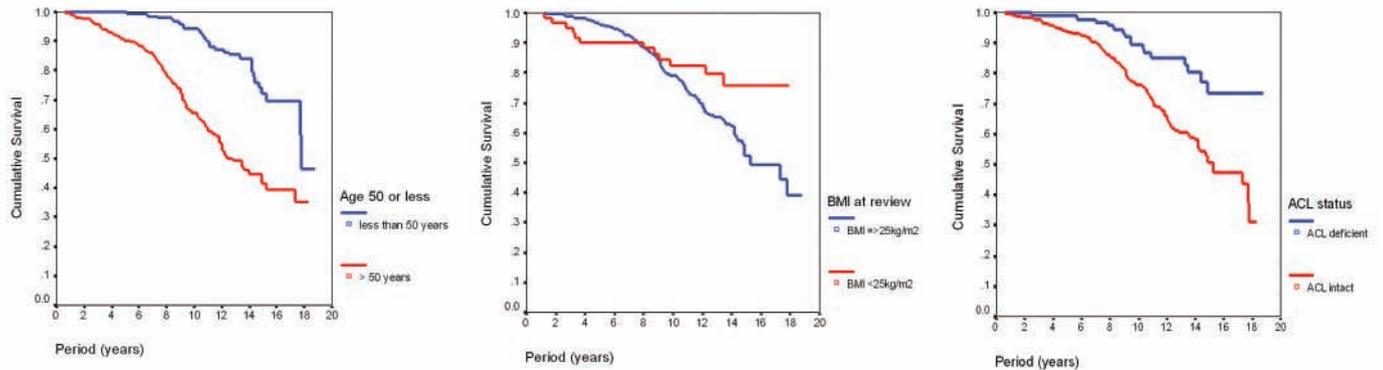
Figure 4. Kaplan-Meier survivorship analysis for all high tibial osteotomy participants.

TABLE 2
Multivariate Cox Regression of
Significant Risk Factors[a]

Risk Factor	Category	Hazard Ratio	95% CI	P Value
Age, y	<50	3.4	2.2-5.1	.001
	≥50			
BMI at review or failure, kg/m²	<25	2.3	1.3-4.2	.006
	≥25			
Status of ACL	Deficient	2.0	1.1-3.6	.03
	Intact			

[a]CI, confidence interval; BMI, body mass index.

TABLE 3
Patient Satisfaction[a]

	Overall	Surviving HTO	Further Surgery
BOA Patient Satisfaction Scale	85% (335/394)	93% (252/272)	68% (83/122)
Surgery again	84% (332/394)	91% (247/272)	70% (85/122)

[a]HTO, high tibial osteotomy; BOA, British Orthopaedic Association.

25 seemed to be a critical number when looking at the effect of BMI on survival of HTO. The strong association between OA and being overweight or obese has been well established.[14,21,22] Early failure of the osteotomy may be related to the extra weight and larger force per unit area through the knee.

The improved results observed in ACL-deficient knees may be related to the osteotomy improving not only the pain related to MCOA, but also to the HTO improving the stability of the knee. All HTOs have been shown to alter the slope of the tibia. Lateral closing wedge osteotomies tend to decrease posterior tibial slope and medial opening wedge osteotomies increase posterior tibial slope.[5,10,20] Biomechanical studies have shown a linear relationship between tibial slope and anterior tibial translation with weightbearing (ie, the greater the tibial slope, the greater the anterior tibial translation).[2,20] Therefore, closing wedge osteotomies improve instability secondary to ACL incompetency.[5,10,20] Furthermore, patients with chronic ACL deficiency have a tendency for posteromedial tibial wear.[38] Decreasing the tibial slope decreases the tibiofemoral contact area and pressure and offloads the worn posterior tibial plateau.[2] We have shown that the lateral closing wedge HTO is an effective way to address symptoms related to both MCOA and anterolateral instability, if present, in patients with varus alignment and chronic ACL deficiency.

There was no statistically significant difference in survival between male and female patients in our study. However, we acknowledge that there was a selection bias present as the senior author preferred not to perform HTO in obese patients, particularly obese female patients, because of known inferior outcomes in this subset of patients.[11,13,15,16,18,40]

Multiple studies have looked at risk factors for early failure of HTO. These have included age, gender, BMI, grade of OA, prior surgery, MCL laxity, varus thrust, walking aids, range of motion, preoperative alignment, and amount of overcorrection.[1,3,5,10,24,40,48,54] The results from these studies have been inconsistent, often contradicting each other. These inconsistent results reflect the fact that the origin of OA is multifactorial, with a natural history of disease progression over time.[23] The goal of HTO is to attempt to alter the natural history of the disease both biomechanically by altering the weightbearing axis[5,7,10,17,54] and biologically by inciting the repair of the worn articular cartilage with fibrocartilage.[8,25,32,33,41] What we can draw from these previous studies is that the ideal patient for HTO is one who is under age 50 years with isolated MCOA and who wishes to continue participating in high-level activity.[6,10,24,36,47] For patients older than 60 years, TKA is a good, long-lasting treatment for OA.[5,10,39] In patients between 50 and 60 years, careful discussion with the patient to determine their activity level and goals is needed to determine whether they are better suited for HTO or arthroplasty.[10,12,29]

Tang and Henderson[50] reported patient satisfaction of 76%, with 90% of patients stating they would choose the operation again at an average of 6.5 years after HTO. We found that 85% of our patients were enthusiastic or satisfied with the HTO, and 84% of patients would have the same surgery again when asked at a mean of 12 years after surgery. Many patients perceive HTO as a useful and worthwhile procedure to alleviate pain and improve quality of life.

We have shown that HTO is a successful surgical treatment option for carefully selected patients with severe MCOA of the knee. Medial UKA is another surgical treatment option often considered in this group of patients. Previous outcome studies of UKA have shown much higher survival rates than with HTO.[44,49] However, these studies have been in much older patients than those in our study group (mean age, 50 years) and any comparison would not be meaningful. Parratte et al[43] recently published a retrospective review of 31 patients (35 knees) with a mean age of 46 years and a mean BMI of 26. These patients all underwent medial UKA using a cemented metal-backed prosthesis and had a mean follow-up of 9.7 years. Patients were allowed unrestricted activity. Survival was 81% at 12 years and 70% at 16 years. These results are similar to our survival rates in patients undergoing HTO with age less than 50 years at the 15-year time point (72%); however, survival of HTO appears to be markedly better at the 10-year mark (95%) than UKA. The concern regarding UKA in younger patients remains polyethylene wear. Parratte et al[43] found that 19% of their patients required revision, two thirds of these because of polyethylene wear and aseptic loosening. Kuster[35] has previously shown that running and jumping produce surface loads that exceed the limits of polyethylene resistance. The benefit of HTO is that the patient is afforded unrestricted activity without the concerns of polyethylene wear and the need for further revision surgery.

The greatest strength of this study is the long-term follow-up of a large group of patients with minimal loss to follow-up. Further, all osteotomies were performed by a single surgeon using the same technique. Also, subjective outcomes were measured using validated outcome scores and were gathered prospectively via telephone interview.

Limitations of this study are related to its retrospective nature, especially with incomplete data. However, the main purpose of our study was to determine the survivorship of lateral closing wedge HTO. The missing data are of secondary outcomes. To exclude such a large number of patients when the primary outcome is known (ie, survivorship) but a secondary outcome is unknown has the potential to introduce selection bias into the study.

The primary outcome in this study is the long-term survival of lateral closing wedge HTO. We made no attempt to look at clinical or radiographic outcomes. Although we recognize that the study would be improved with the addition of the postoperative angle of overcorrection, we do not have these data. Furthermore, the angle of correction and postoperative angle of overcorrection have been studied in previous studies in the literature, with inconsistent results on what the exact angles should be. Insall et al[29] and Holden et al[28] have also shown that good clinical outcomes may not be related to the exact amount of correction. What we can draw from previous studies is that the limb should be in valgus alignment postoperatively without too much overcorrection that would lead to overload and more rapid deterioration of the lateral compartment.[27] In our study, immediate postoperative alignment was in valgus in all patients. So as to minimize radiation to patients, 3-foot to 4-foot standing alignment films were not performed routinely postoperatively. It was the practice of the senior author to assess limb alignment clinically at each subsequent follow-up visit. If there was any concern, a long-leg alignment film was then obtained. To avoid too much overcorrection, we carefully assessed MCL laxity preoperatively and took this into consideration when determining the wedge size.

The management of early degenerative arthritis of the knee in the young adult presents a challenge to the orthopaedic surgeon. Improved long-term survival of HTO is associated with age less than 50 years, BMI less than 25 kg/m^2, and ACL deficiency. We have shown that in appropriately selected patients and circumstances, HTO gives high patient satisfaction and affords patients unrestricted activity for many years.

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