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Higher knee survivorship in young patients with monocompartmental osteoarthritis and constitutional deformity treated by high tibial osteotomy then total knee arthroplasty compared to an early total knee arthroplasty

A COMPARATIVE STUDY AT A MINIMUM FOLLOW-UP OF TEN YEARS

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Aims

The use of high tibial osteotomy (HTO) to delay total knee arthroplasty (TKA) in young patients with osteoarthritis (OA) and constitutional deformity remains debated. The aim of this study was to compare the long-term outcomes of TKA after HTO compared to TKA without HTO, using the time from the index OA surgery as reference (HTO for the study group, TKA for the control group).

Methods

This was a case-control study of consecutive patients receiving a posterior-stabilized TKA for OA between 1996 and 2010 with previous HTO. A total of 73 TKAs after HTO with minimum ten years' follow-up were included. Cases were matched with a TKA without previous HTO for age at the time of the HTO. All revisions were recorded. Kaplan-Meier survivorship analysis was performed using revision of metal component as the endpoint. The Knee Society Score, range of motion, and patient satisfaction were assessed.

Results

Mean follow-up was 13 years (SD 3) after TKA in both groups. The 20-year Kaplan-Meier survival estimate was 98.6% in TKA post-HTO group (HTO as timing reference) and 81.4% in control group (TKA as timing reference) (p = 0.030). There was no significant difference in clinical outcomes, radiological outcomes, and complications at the last follow-up.

Conclusion

At the same delay from index surgery (HTO or TKA), a strategy of HTO followed by TKA had superior knee survivorship compared to early TKA at long term in young patients.
Level of evidence: III

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Keywords: Total knee arthroplasty, High tibial osteotomy, Survival rate, Complication, Device removal

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Introduction

The decision between a high tibial osteotomy (HTO) and total knee arthroplasty (TKA) for the young patient with monocompartmental osteoarthritis (OA) of the knee and constitutional deformity can be difficult.

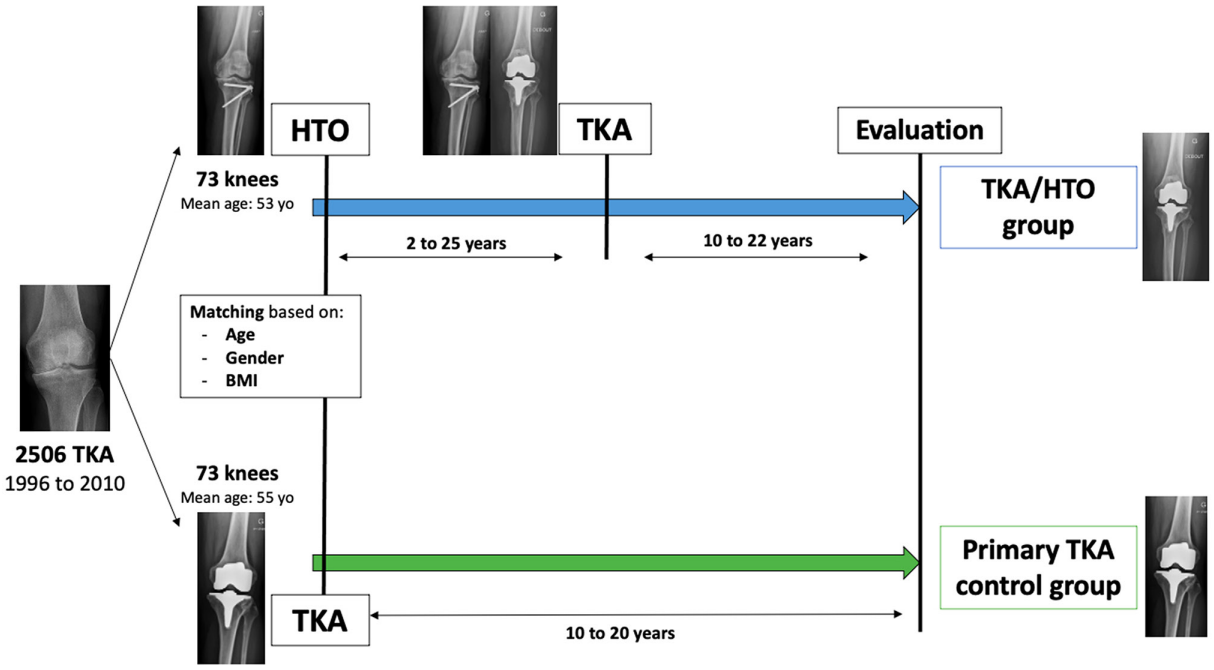

Fig. 1

Diagram of the study design. HTO, high tibial osteotomy; TKA, total knee arthroplasty.

HTO aims to improve the clinical outcomes of the patient while preserving the native joint and delaying the need for TKA. The outcomes and patient satisfaction rate for HTO in this population are satisfactory at short- and mid-term follow-up.[1,2] While HTO is an established surgical treatment, clinical results might deteriorate over time, and conversion rates of HTO to TKA are high in the mid or long term (about 25% at ten years).[3-5]

The technical challenges of performing TKA in the setting of previous HTO are numerous and vary in complexity. Difficulties include management of hardware, exposure, ligament balancing, limb malalignment with malunion, altered joint line, and bone stock loss from the HTO procedure. Additional complications post-operatively such as stiffness, instability, infection, subsidence, and prosthetic loosening are associated with TKA following HTO.[6,7] It remains controversial if a previous HTO influences the outcomes and survival of TKA. Some previous studies have reported no difference between patients with and without prior HTO,[8-15] whereas others have shown poorer outcomes or survival.[7,16-18] Because of these potential difficulties and concerns of poorer outcomes, HTO to delay TKA in young patients with OA and constitutional deformity remains debated.[7,17]

Conversely, TKA in young and physically demanding patients also presents some disadvantages with a higher risk of revision being reported at medium- to long-term follow-up.[19,20] To our knowledge, no study has compared the survivorship of TKA with or without previous HTO with comparable demographic data at the time of the first surgery (HTO time in the group TKA after HTO or TKA time in the group of TKA without previous HTO) (Figure 1). Indeed, previous studies have compared the survivorship of TKA with or without previous HTO with comparable groups at the time of the TKA. Thus, the question remains in a young and active patient with an appropriate indication for HTO: should we privilege a HTO to conserve the native joint or a TKA to avoid the future challenges of a TKA after HTO?

Therefore, we aimed to compare 1) the long-term survivorship of knees with a HTO and a later TKA versus an early TKA without HTO, using the time from the first OA surgery (HTO timing for the study group versus TKA timing for the control group); 2) the clinical outcomes; and 3) the radiological outcomes and complications between both groups at minimum ten-year follow-up. We hypothesized that the survivorship was better for a strategy of HTO first with later TKA than for early TKA.

Methods

Patients. Consecutive patients undergoing TKA at a single centre between January 1996 and December 2010 were included. A total of 2,506 primary TKAs were retrospectively reviewed and a total of 144 primary posterior-stabilized (PS) TKAs for OA with a previous HTO were identified. In this series, HTO was indicated in active young patients with early stage monocompartmental OA stage 2 to 3, according to Ahlbäck classification[21] and when conservative treatment was exhausted. The exclusion criteria were inflammatory and post-traumatic OA, revision

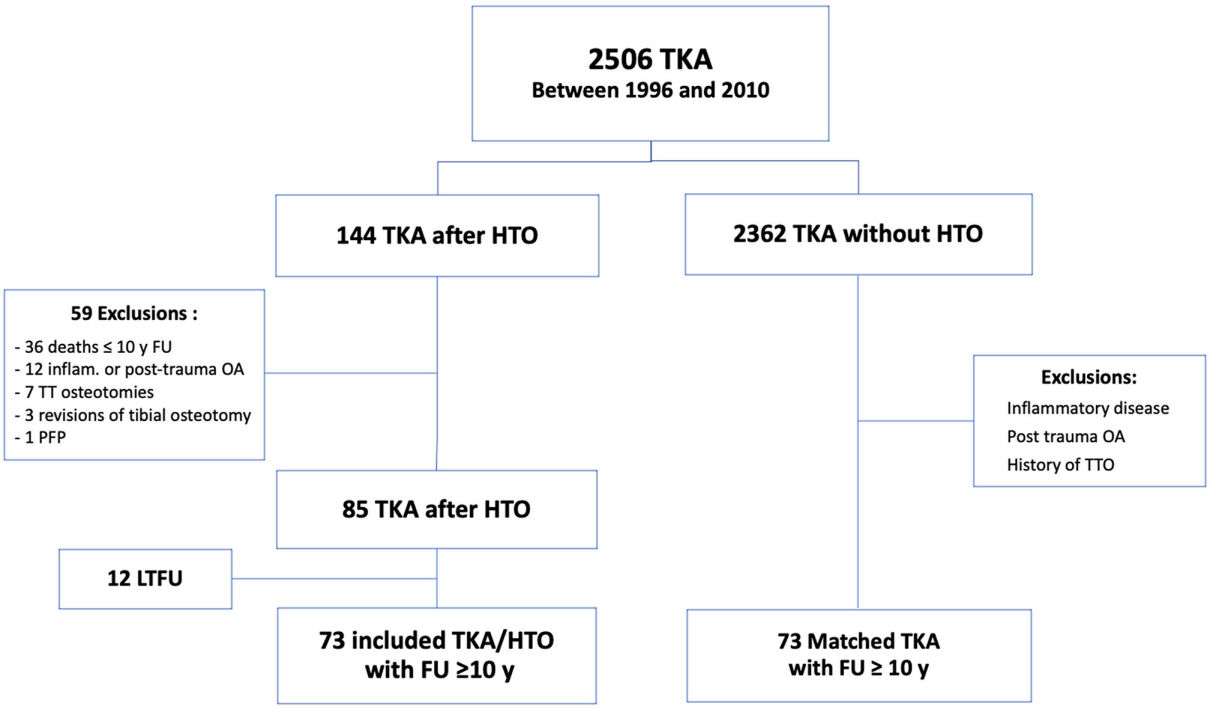

Fig. 2

Flowchart. FU, follow-up; HTO, high tibial osteotomy; LTFU, lost to follow-up; OA, osteoarthritis; PFP, patellofemoral prosthesis; TKA, total knee arthroplasty; TTO, tibial tubercle osteotomy.

of tibial osteotomy, previous tibial tubercle osteotomy (TTO) procedure, and death before ten-year follow-up after TKA without revision (Figure 2). The follow-up was a minimum of ten years after TKA or until revision with implant removal. Of the 144 TKAs after HTO, 59 patients were excluded (36 deaths before ten-year follow-up, 12 cases of inflammatory or post-traumatic OA, seven previous TTOs, three revisions of tibial osteotomy, and one patellofemoral prosthesis), and 12 (8%) were lost to follow-up. A total of 73 TKAs after HTO were included in the study group.

Each case was matched (1:1) with a primary TKA without previous HTO based on BMI (subgroups: < 18.5; 18.5 to 25; 25 to 30; 30 to 35; > 35), sex, and age (five-year periods) at the time of HTO in the study group and at the time of TKA in the control group (Figure 1). All control patients had a primary PS TKA for OA. The exclusion criteria in the control groups were inflammatory and post-traumatic OA, previous tibial or femoral osteotomy, follow-up less than ten years after TKA, and stage 4 OA according to the Ahlbäck classification. Clinical and radiological data were recorded preoperatively. There was no significant difference concerning demographic data and clinical data preoperatively between both groups (Tables I and II).

TKA surgery. All surgery was performed by three senior surgeons (SL, ES, PN). A cemented PS TKA was performed using manual instrumentation (Tornier-Corin, France) for all patients in both groups. The design of this implant has been previously described.[22] The TKA surgical approach was a medial parapatellar or lateral parapatellar approach according to Keblish.[23] The objective of limb alignment after TKA was to achieve mechanical alignment (HKA angle = 180°). Hardware (staples or plates) were removed only when it was necessary. TTO was performed at the surgeon's discretion to facilitate exposure. A total of 12 knees (16.4%) underwent TTO in TKA after HTO group versus one (1.4%) in the control group ($p < 0.001$ (Fisher's exact test)). A tibial stem could be used if necessary. There was no significant difference in the use of tibial stem between groups. The patella was resurfaced in all cases in both groups.

Clinical and radiological assessment. A standardized postoperative clinical and radiological follow-up was performed at two and 12 months after TKA surgery, then every two years. All reoperations and revisions with implant removal were recorded, and the reason for the reoperation or the revision was documented. The Knee Society Score (KSS),[24] range of motion (ROM) (measured with a goniometer by the surgeon) and a satisfaction score were collected at the last follow-up. The radiological assessment included: anteroposterior view, lateral view, patellar axial view, and long leg standing radiograph. On each long leg standing radiograph, coronal alignment was determined by measuring the hip knee ankle (HKA) angle, the medial proximal tibial axis (MPTA), and the

Table I. Demographic characteristics for total knee arthroplasty with and without prior high tibial osteotomy.

Analyzed cohort	TKA/HTO group (n = 73)	Control group (n = 73)	p-value
Mean age at TKA, yrs (SD; range)	64.9 (9.1; 31 to 83)	55.0 (9.7; 27 to 70)	< 0.001*
Mean age at HTO, yrs (SD; range)	53.7 (9.5; 27 to 69)	N/A	
Mean comparison age at HTO in study group and at TKA in control group, yrs (SD; range)	53.7 (9.5; 27 to 69)	55.0 (9.7; 27 to 70)	0.399*
Mean BMI, kg/m^2 (SD; range)	29.1 (5.5; 20 to 50.2)	29.2 (4.5; 19.5 to 42.9)	0.889*
Female sex, n (%)	38 (52)	39 (53.4)	0.868†
Mean follow-up after TKA, yrs (SD; range)	13.3 (3.3; 10 to 22)	13.1 (3.0; 10 to 20)	0.787*
Mean delay between HTO and TKA, yrs (SD; range)	11.1 (5.2; 2 to 25)	N/A	
Mean total FU since HTO, yrs (SD; range)	24.4 (6.9; 12 to 41)	N/A	
HTO procedure, n (%)			
Opening HTO	17 (23.3)	N/A	
Closing HTO	56 (76.7)	N/A	
Mean number of surgeries prior to TKA (SD; range)	2.9 (1; 1 to 7)	1.4 (0.8; 1 to 5)	< 0.001†
TKA procedure, n (%)			
Medial approach	43 (58.9)	73 (100)	< 0.001†
Lateral approach	30 (41.1)	0	
TT osteotomy	12 (16.4)	1 (1.4)	0.001†
Extended stem	10 (13.7)	4 (5.5)	0.158†

*Independent-samples *t*-test.
†Fisher's exact test.
FU, follow-up; HTO, high tibial osteotomy; N/A, not available; NS, non-significant; SD, standard deviation; TKA, total knee arthroplasty; TT, tibial tubercle.

Table II. Preoperative clinical and radiological data in both groups (total knee arthroplasty with and without prior high tibial osteotomy).

Analyzed cohort	TKA/HTO group (n = 73)	Control group (n = 73)	p-value*
Mean preoperative knee KSS (SD; range)	57.3 (14.6; 19 to 87)	55.2 (12.6; 22 to 88)	0.363
Mean preoperative function KSS (SD; range)	62.2 (17.0; 0 to 90)	63.8 (16.7; 20 to 100)	0.562
Mean preoperative global KSS score (SD; range)	119.5 (23.7; 63 to 164)	119.1 (20.9; 70 to 160)	0.912
Mean preoperative flexion, ° (SD; range)	118 (16; 75 to 140)	121 (16; 80 to 140)	0.246
Mean preoperative HKA angle, ° (SD; range)	180 (6.4; 162 to 197)	174.7 (3.7; 167 to 180)	< 0.001
Mean preoperative MDFA, ° (SD; range)	90.9 (2.4; 84 to 98)	90.7 (2.5; 85 to 97)	0.522
Mean preoperative MPTA, ° (SD; range)	90.7 (4.3; 81 to 102)	86.6 (2.9; 76 to 97)	< 0.001
Mean preoperative Blackburne-Peel ratio (SD; range)	0.75 (0.20; 0.27 to 1.25)	0.80 (0.23; 0.32 to 1.81)	0.180

*Independent-samples *t*-test.
HKA, hip knee ankle; HTO, high tibial osteotomy; KSS, Knee Society Score; MDFA, medial distal femoral axis; MPTA, medial proximal tibial axis; NS, non-significant; SD, standard deviation; TKA, total knee arthroplasty.

medial distal femoral axis (MDFA). Axial views were performed using the Merchant method.[25] Patellar height was calculated using the Blackburne-Peel ratio.[26] Patella baja was defined as Blackburn-Peel ratio < 0.54.[26] Radiolucent lines were analyzed on each anteroposterior and lateral view and collected. Radiological loosening was defined as a progressive radiolucent line greater than 2 mm. All radiographs were performed in the same hospital radiology department using a standardized protocol.

Statistical analysis. The statistical analysis was performed with the online software EasyMedStat (France). Continuous variables were described using means, standard deviation (SD), and ranges. Categorical variables were described using counts (percentage). Statistical analysis was performed using Fisher's exact test or Mann-Whitney U test. Categorical variables were compared using Fisher's exact test. Kaplan-Meier survivorship analysis (with a 95% confidence interval (CI)) was performed with knee revision as the endpoint, defined as a revision with metal component removal, and the comparison of knee survivorship was estimated with log-rank. The time reference was the time from the first OA surgery (HTO timing for the study group vs TKA timing for the control group). The preoperative data, postoperative clinical outcomes, and radiological measurements were compared between groups using an independent-samples *t*-test for the continuous variables and Fisher's exact test for the categorical variables. A p-value < 0.05 was considered statistically significant for all analyses.

Results

Survival analysis. The mean follow-up after TKA was 13.3 years (SD 3.3, 10 to 22) in the TKA after HTO group and 13.1 years (SD 3.0, 10 to 20) in the control group (p = 0.787 (independent-samples *t*-test)). The rate of TKA revision with implant removal at 13 years of follow-up after

Table III. Revision and reoperation in both groups (total knee arthroplasty with and without prior high tibial osteotomy).

Variable, n (%)	TKA/HTO group (n = 73)	Primary TKA group (n = 73)	p-value*
Revision TKA	6 (8.2)	4 (5.5)	0.745
Deep infection	1 (1.4)	2 (2.7)	
Aseptic loosening	1 (1.4)	0	
Fracture	1 (1.4)	0	
Coronal instability	2 (2.7)	0	
Unexplained pain	1 (1.4)	2 (2.7)	
Reintervention	8 (11.0)	15 (20.5)	0.172
Stiffness	2 (2.7)	4 (5.5)	
Deep infection	1 (1.4)	2 (2.7)	
Aseptic loosening	1 (1.4)	0	
Fracture	1 (1.4)	1 (1.4)	
Clunk syndrome	0	1 (1.4)	
Coronal instability	2 (2.7)	0	
Patellar complications	0	4 (5.5)	
Unexplained pain	1 (1.4)	2 (2.7)	
Dislocation	0	1 (1.4)	

*Fisher's exact test.
HTO, high tibial osteotomy; NS, non-significant; TKA, total knee arthroplasty.

TKA was 8.2% in the TKA after HTO group and 5.5% in the control group (p = 0.745, Fisher's exact test)). The causes of revision are detailed in Table III. The ten- and 20-year Kaplan-Meier survival estimate was 98.6% (95% CI 90.4% to 99.8%) in the TKA after HTO group (HTO time as reference) and 81.4% (95% CI 45.1% to 94.8%) in the control group (TKA time as reference) (p = 0.030) (Figures 3 and 4).

Clinical outcomes and satisfaction. Global KSS, knee KSS, and function KSS scores were improved in both groups following TKA without significant difference. There was no significant difference in postoperative global KSS, knee KSS, function KSS scores, ROM, or satisfaction score between both groups (Table IV).

Radiological results and complications. No significant difference was found in the rates of radiolucent lines between TKA after HTO and the control group (Table V). There was no statistical difference in postoperative HKA angle, MPTA, MDFA, or Blackburne-Peel ratio between both groups (Table V).

There was no significant difference in reoperation rate between both groups at the last follow-up. Details of these complications are reported in Table III.

Discussion

The main finding of this study was that a strategy of HTO first with later TKA had superior survivorship at 20 years, compared to a primary TKA without HTO in young patients. Moreover, there was no further TKA revision 13 years after TKA with a previous HTO than after primary TKA, with similar functional outcomes. Thus, HTO remains essential in OA treatment, allowing many years free from TKA and TKA revision with equal functions.

This study found a 20-year estimated survival rate free from any revision of 98.6% in the HTO with a delayed TKA, with the HTO as time zero. Implant survival was significantly different from a matched control primary TKA group (20 years survival rate = 81.4%, p = 0.030, Kaplan-Meier analysis). Revision rates were equivalent at a mean follow-up of 13 years between TKA post-HTO and primary TKA. HTO delayed TKA for a mean of 11 years (SD 5.3) with no detrimental effects on survivorship of the subsequent TKA. Studies to date have assessed TKA survivorship with or without HTO, but have not assessed knee survivorship since the beginning of symptomatic OA (Table VI). A recent retrospective study on 231 TKAs with prior HTO found 90% of survivorship free from any revision at ten years.[27] Another study on uncemented TKA after HTO found no significant difference in survival rate at a mean follow-up of eight years, with 97.6% in the group TKA after HTO versus 100% in the control group.[8] Studies on the national registers showed conflicting results. A study from the Norwegian registry compared the survival of TKA after HTO versus primary TKA.[11] They found a ten-year estimated survival of 92.6% in the TKA post-HTO group and 93.8% in the primary TKA group, which was not statistically significant. In contrast, a study from the Danish registry reported inferior survival in TKA after HTO patients with a ten-year estimated survival of 91% compared to 94% for de novo TKA.[7] It should be noted that the mean age in the TKA after HTO group was significantly younger than the primary TKA group (62 vs 70 years old, p < 0.001). A study from the Finnish registry found similar results,[4] with 91.8% at ten years and 88.4% at 15 years in the TKA after HTO group, versus 94.5% at ten years and 90.5% at 15 years in the

Fig. 3

a) Radiographs of a left knee (male, 52 years old) showing monocompartmental osteoarthritis (OA) before high tibial osteotomy (HTO), at eight years after HTO followed by total knee arthroplasty (TKA) at 18 years of follow-up, with good clinical outcomes. b) Radiographs of a right knee showing TKA with symptomatic tibial and femoral aseptic loosening at 12 years of follow-up in a young patient (male, 56 years old at the time of TKA implantation).

primary TKA group, which was significantly different. The pathway of performing a HTO first, then later a TKA, appears to increase the implant survivorship compared to performing the TKA as the index procedure at the beginning of symptomatic knee OA.

Conclusions about functional outcomes are not consistent in the literature. Some studies have observed poorer clinical outcomes in patients receiving TKA after HTO group,[16-18,28,29] while others have found equivalent clinical results compared to the primary TKA group.[8,9,12,14,30-32] Differences may be due to the mean age at the time of TKA being older in several early studies (between 69 and 78 years old)[16,17,28] than in some later studies mentioned (between 54 and 70 years old).[8,9,14,30-32] In the present study, the mean age at TKA in the control group was low (55 years old) because matching was based on the HTO time. The comparison of the clinical outcomes between TKA post-HTO and primary TKA in our study showed no significant difference at the mean follow-up of 13 years. Our postoperative data showed an important improvement in KSS knee and function scores, and flexion, compared to the preoperative scores. Both groups had satisfactory clinical results at the last follow-up. A recent study comparing outcomes in patients with bilateral TKAs following unilateral HTO demonstrated excellent long-term clinical function of TKA following HTO, with patients demonstrating comparable subjective outcomes and equivalent knee preference compared with the contralateral TKA-only knees.[33] A prior study found similar clinical outcome scores comparing TKA post-HTO and primary TKA groups, but reported significantly reduced knee flexion in the TKA post-HTO group (91° vs 106°).[16] Another study found similar results, with 14° greater ROM in the control group.[34] The current study found similar good knee flexion in both groups at the last follow-up (117°).

It is generally accepted that TKA after HTO is technically more challenging than a primary TKA.[35] The findings

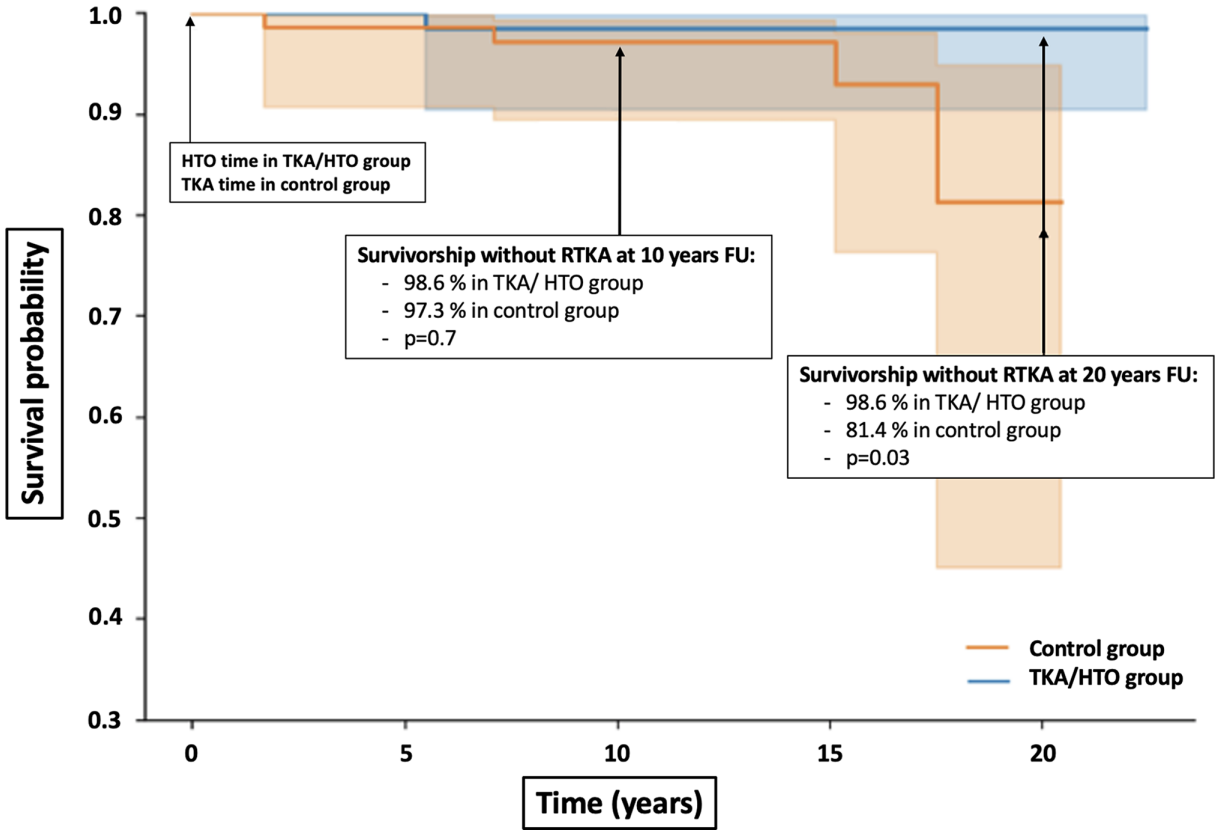

Fig. 4

The 20-year Kaplan-Meier survival estimate in the total knee arthroplasty (TKA) after high tibial osteotomy (HTO) group (HTO time as reference) and in the control group (TKA time as reference). FU, follow-up; RTKA: revision total knee arthroplasty.

Table IV. Postoperative clinical outcomes in both groups (total knee arthroplasty with and without prior high tibial osteotomy).

Analyzed cohort	TKA/HTO group (n = 67)	Control group (n = 69)	p-value
Mean postoperative knee KSS (SD; range)	88.8 (11.9; 49 to 100)	89.8 (10.0; 58 to 100)	0.358*
Mean postoperative function KSS (SD; range)	73.9 (24.8; 0 to 100)	78.6 (22.8; 0 to 100)	0.174*
Mean postoperative global KSS (SD; range)	162.7 (29.1; 90 to 200)	168.4 (28.7; 69 to 200)	0.139*
Mean improvement knee KSS (SD; range)	30.3 (17.4; -16 to 68)	34.4 (14.5; 6 to 69)	0.162*
Mean improvement function KSS (SD; range)	10.8 (28.4; -80 to 60)	14.9 (30.1; -80 to 80)	0.441*
Mean improvement global KSS (SD; range)	41.1 (35.0; -70 to 107)	49.2 (35.7; -60 to 120)	0.208*
Satisfaction score, n (%)			0.212†
Very satisfied	45 (67.2)	38 (55.1)	
Satisfied	17 (25.4)	25 (36.2)	
Disappointed	5 (7.5)	5 (7.2)	
Dissatisfied	0	1 (1.4)	
Mean postoperative flexion, ° (SD; range)	117.6 (11.6; 70 to 140)	117.3 (12.0; 90 to 140)	0.497*

*Independent-samples *t*-test.
†Fisher's exact test.
HTO, high tibial osteotomy; KSS, Knee Society Score; NS, non-significant; SD, standard deviation; TKA, total knee arthroplasty.

of the current study support this conclusion, with 16.4% of patients in the TKA after HTO group requiring a TTO during the surgery compared to 1 (1.4%) in the control group and 41.1% requiring a lateral parapatellar approach to facilitate the exposure compared to none in the control group. A previous study in a large cohort of primary TKA reported that IKS scores, ROM, and number of revisions were not different when TTO was required.[36] However, local complications such as skin necrosis and fracture of the tibial tubercle were significantly higher in the TTO group. It has also previously been shown that lateral parapatellar approach is a safe and effective technique

Table V. Postoperative radiological results in both groups (total knee arthroplasty with and without prior high tibial osteotomy).

Analyzed cohort	TKA/HTO group (n = 67)	Control group (n = 69)	p-value
Mean postoperative HKA angle, ° (SD; range)	179.2 (2.9; 171 to 186)	178.9 (2.9; 171 to 188)	0.276*
Mean postoperative MDFA, ° (SD; range)	89.7 (2.3; 83 to 95)	89.7 (2.0; 82 to 95)	0.834*
Mean postoperative MPTA, ° (SD; range)	89.9 (1.7; 86 to 95)	89.4 (1.3; 86 to 92)	0.069*
Mean postoperative Blackburne-Peel ratio (SD; range)	0.69 (0.2; 0.3 to 1.25)	0.65 (0.2; 0.3 to 1.2)	0.308*
Patella baja, n (%)	12 (17.9)	14 (20.3)	0.830†
Radiolucent lines, n (%)	11 (16.4)	14 (20.8)	0.663†

*Independent-samples *t*-test.
†Fisher's exact test.
HKA, hip knee ankle; HTO, high tibial osteotomy; MDFA, medial distal femoral axis; MPTA, medial proximal tibial axis; NS, non-significant; SD, standard deviation; TKA, total knee arthroplasty.

Table VI. Literature on total knee arthroplasty after high tibial osteotomy survey.

		TKA, n		Mean FU since TKA, yrs			Survivor rate, %		
Author	Study design	TKA/HTO	TKA	TKA/ HTO	TKA	Minimum FU, yrs	TKA/HTO	TKA	p-value
Batailler et al[8]	III	41	82	7.8	7.3	5	97.6 (7.8 yrs)	100 (7.3 yrs)	NS
Chalmers et al[27]	IV	231	N/A	8	N/A	2	90 (10 yrs)	N/A	N/A
El-Galaly et al[7]	IV (registry)	1,044	63,763	8.55	6.58	N/A	91 (10 yrs)	94 (10 yrs)	< 0.001
Badawy et al[11]	IV (registry)	1,399	31,077	N/A	N/A	N/A	92.6 (10 yrs)	93.8 (10 yrs)	NS
Niinimäki et al[4]	IV (registry)	1,036	4,143	6.7	6.2	0	91.8 (10 yrs)	94.5 (10 yrs)	0.010
							88.4 (15 yrs)	90.5 (15 yrs)	
Our study	III	73	73	13.3	13.1	10	98.6 (10 yrs from HTO)	97.3 (10 yrs from TKA)	NS
							98.6 (20 yrs from HTO)	81.4 (20 yrs from TKA)	0.030

FU, follow-up; HTO, high tibial osteotomy; N/A, not available; NS, non-significant; TKA, total knee arthroplasty.

compared to medial approach with no difference in clinical outcomes and complications rates.[37] In the current study, despite the significant differences in exposure, it did not translate into poorer long-term outcomes, with survivorship and clinical scores in our study showing no difference between both groups. Furthermore, most patients were satisfied or very satisfied at the last follow-up. HTO allows for many years to be arthroplasty-free, and despite the challenges faced when converting a HTO to TKA, outcomes do not appear to be compromised when compared to patients receiving a primary TKA as their initial surgery.

Although TKA after HTO is a challenging, this study did not find a significant difference between groups in complications requiring reoperation. In our TKA post-HTO group, stiffness requiring manipulation under anaesthesia and coronal instability were the main complications, although rare (2.7% for each). In a recent retrospective study of 231 TKAs after HTO,[27] the most common complication was also stiffness requiring manipulation under anaesthesia (4%). A study comparing TKA after opening versus closing wedge osteotomy reported a rate 3% of joint stiffness without differences between groups.[6] The authors reported a 5.5% rate of aseptic loosening and a 3.6% rate of deep infection requiring revision. In the current study, there was a 1.4% rate of deep infection and aseptic loosening in TKA after HTO group, which are slightly superior. This may be due to the inclusion of PS TKA exclusively, excluding complex TKA after HTO needing a condylar constrained knee (CCK) TKA. Further, all prostheses were cemented, and a majority were closing lateral wedge osteotomy. Thus, there were fewer cases with bone loss in this series related to opening osteotomy and bone graft integration. Lateral closing wedge HTO may lead to tibial malunion, complexifying the subsequent TKA implantation. Despite this concern, some studies have reported no difference in functional outcomes, complications, or survivorship between the two techniques,[38,39] as in this study.

Patella baja increases the difficulty of a TKA, but the impact on outcomes is less clear. Patella baja post-HTO is more common, with a previous study on 34 TKAs after medial opening wedge HTO reporting patella baja in 27% of cases.[29] In our study, there were similar rates of patella baja in both groups (17.9% vs 20.3% (p = 0.5)) but both lateral closing and medial opening wedge osteotomy were included in this series. In this study, the presence of patella baja was not associated with poorer outcomes. These results are consistent with those observed in a study on a large cohort of patients undergoing TKA using the same implant.[22]

This study has several limitations. First, it was a retrospective study, subject to confounders associated with research of this nature; however, information entered

into our institutional database is completed prospectively. Second, although this is one of the largest populations of TKA after HTO with a long-term follow-up, the series is still relatively small because TKA after HTO is less common. Moreover, 12 patients (8%) were lost to follow-up due to the long-term design. Furthermore, CCK and rotating hinged implants were not included in this study. Nevertheless, this study aimed to compare the same implants in order to have a relevant comparison. Despite these limitations, to our knowledge, it is the first study that compares knee survivorship after a symptomatic monocompartmental OA treated by a HTO first followed by a later TKA, or by an early TKA.

In conclusion, at the same delay from the index surgery (HTO or TKA), a strategy of HTO followed by later TKA had superior knee survivorship compared to primary TKA without HTO at long-term follow-up in young patients with monocompartmental OA and constitutional deformity. HTO delays TKA on average of 11 years, with no consequence on clinical and radiological outcomes at 13 years of follow-up after TKA. Therefore, HTO should continue to be part of the OA treatment strategy in this active and young population.

Take home message

- At the same delay from the index surgery (high tibial osteotomy (HTO) or total knee arthroplasty (TKA)), a strategy of HTO followed by TKA had superior knee survivorship compared to primary TKA without HTO at long-term follow-up in young patients with monocompartmental osteoarthritis (OA) and constitutional deformity.
- HTO should continue to be part of the OA treatment strategy in this active and young population.

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