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ORIGINAL PAPER

Unicompartmental knee arthroplasty is superior to high tibial osteotomy in post-operative recovery and participation in recreational and sports activities

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Abstract

Purpose To compare (1) the recovery pattern of post-operative physical activity and function in the early post-operative period and (2) the difference of participation in recreational and sports activities pre- and post-operatively following unicompartmental knee arthroplasty (UKA) and high tibial osteotomy (HTO).

Methods In this prospective comparative study, 49 HTOs (49 patients) and 42 UKAs (42 patients) performed to treat medial compartmental knee osteoarthritis (OA) were included. The pain visual analog scale (VAS), Western Ontario and McMaster Universities Osteoarthritis Index score (WOMAC), Tegner activity score, Lysholm knee score, and the University of California at Los Angeles (UCLA) activity score were evaluated pre-operatively and post-operatively at three, six, 12, and 24 months. Participation in recreational and sports activities was also assessed pre-operatively and 24 months post-operatively.

Results Pre-operatively, although there were no differences in VAS, WOMAC, and Lysholm scores between the two groups, the UKA group had inferior Tegner and UCLA scores ($p < 0.05$). At post-operative three and six months, the UKA group showed superior VAS, WOMAC, and Lysholm scores ($p < 0.05$ for all). However, at 12 and 24 months post-operatively, both groups had similar outcome scores ($p > 0.05$ for all). When all the baseline scores were adjusted for the mean changes, the UKA group showed a significantly better UCLA score than the HTO group until 12 months after the operation ($p = 0.008$). The rate of return to sports activity was 94.1% in the UKA group and 75.0% in the HTO group at 24 months post-operatively ($p = 0.031$).

Conclusion These findings indicate that UKA had better short-term functional outcomes and return to recreational and sports activities than did HTO in patients with medial OA.

Keywords Unicompartmental knee arthroplasty · High tibial osteotomy · Recovery · Recreational activities · Sports activities

Level of evidence: II

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Introduction

Unicompartmental knee arthroplasty (UKA) and high tibial osteotomy (HTO) are reliable and established treatment alternatives to total knee arthroplasty (TKA) in medial unicompartmental knee osteoarthritis (OA) in younger patients [1, 2]. Even though UKA and HTO are different procedures with different concepts, they share the same indications in several cases [3, 4].

Traditionally, UKA has been indicated for patients with low levels of physical activity because of concern about early revision, and HTO is recommended for younger and active patients [3, 4]. However, advances in surgical technique, technology, and implant design have improved the clinical outcomes and survival for both UKA and HTO [5–7]. Nevertheless, the choice of UKA or HTO is still controversial for patients with various levels of age and activity [8].

Although numerous studies have reported comparable clinical results following UKA and HTO [3, 4, 9], most studies tended to use the conventional outcome scales, which are physician-assessed objective clinical outcomes [10]. These rating scores do not accurately reflect the patients' actual activity [10]. In addition, patients' expectations about participation and return to physical and sports activities after the operation are increasing rapidly [11]. Therefore, it is very important to understand the recovery of physical activity after operations and to assess the physical activity levels [12].

There are few prospective comparative studies of recovery patterns, physical activity, and participation in recreational and sports activities following UKA and HTO, especially during the early post-operative period [13, 14]. The purpose of our study was to compare (1) the recovery pattern of post-operative physical activity and function in the early post-operative period and (2) the difference between participation in recreational and sports activities pre- and post-operatively. Our hypothesis was that the recovery of the post-operative physical activity and function and participation in recreational and sports was similar in patients undergoing UKA and HTO for the treatment of medial unicompartmental knee OA during the early post-operative period.

Methods

This prospective comparative study initially included 54 HTOs (54 patients) and 49 UKAs (49 patients) performed by a single surgeon at one institution from January 2015 to March 2016. The decision to perform HTO or UKA was made by a senior surgeon based on age, OA grade, and severity of deformity. The criteria for HTO were as follows: (1) patients ≤ 65 years of age with isolated medial compartment OA and (2) absence of ligament instability [15]. The inclusion criteria for UKA were (1) OA involving isolated medial knee compartments without degenerative changes in the lateral compartment, (2) intact anterior cruciate ligament (ACL), and (3) correctable varus deformity [16].

The exclusion criteria were patients who had a diagnosis of traumatic OA, inflammatory arthritis (rheumatoid arthritis) or osteonecrosis (ON), symptomatic OA in the lateral compartment or patellofemoral joint of the knee, a history of knee joint infection, and those who declined to participate or were unavailable for clinical outcome evaluation during the 24 months of follow-up. In the HTO group, one patient with traumatic OA, three patients who had ON, and one patient lost to follow-up were excluded. In the UKA group, six patients with ON and one patient who was lost to follow-up were excluded. Finally, 49 HTOs (49 patients) and 42 UKAs (42 patients) with a minimum follow-up time of 24 months were enrolled for prospective analysis. This study was approved by the Institutional Review Board of our hospital (KC15RISI0114).

All surgical procedures were performed in a standard fashion by a single surgeon under general anesthesia. All UKAs were performed using a Phase III Oxford mobile bearing UKA guided by the Microplasty® instrumentation system (Zimmer Biomet, Warsaw, IN, USA) and all HTOs were performed by the medial opening-wedge HTO method using TomoFix® Medial High Tibial Plate (DePuySynthes, Oberdorf, Switzerland). In the pre-operative planning for HTO, the correction angle was chosen using the Dugdale method with pre-operative anteroposterior (AP) long-leg standing weight-bearing radiographs [15]. The surgical goal of HTO was the weight-bearing line (WBL) ratio, passing through the Fujisawa point [15]. All HTO patients underwent similar rehabilitation. Beginning the day after surgery, a continuous passive motion (CPM) machine was applied for four weeks (four times daily for 30 minutes), and quadriceps-strengthening exercises were implemented by the medical team. The flexion angle of the CPM machine was 60° on the first post-operative day. The knee flexion angle was gradually increased by 10° daily until a maximum flexion angle of 130° was achieved. Patients were permitted to perform partial weight-bearing at four weeks post-operatively and full weight bearing at six weeks post-operatively [15]. In the UKA, an extramedullary cutting guide was used for the tibial cut [6]. Bone resection of the distal femur was performed using an intramedullary cutting guide. Soft-tissue release was not performed for the balance of flexion and extension gaps achieved by bone resection. Cement fixation was used for all femoral and tibial components. Similar post-operative rehabilitation programs were conducted in all UKA patients. On the first post-operative day, all patients were encouraged to do full weight-bearing walking using a walker and quadriceps isometric exercises. They started active ROM exercises and gradually increased the ROM.

Baseline OA grades were evaluated according to the Kellgren-Lawrence classification [17]. Hip-knee-ankle (HKA) angle was also recorded using AP long-leg standing weight-bearing radiographs [18]. All clinical information was evaluated using a 10-point visual analog scale (VAS) for walking, worst, and average over the past 24 hours, the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) [19], the University of California at Los Angeles (UCLA) score [20], Lysholm knee score [21], and Tegner activity scale [21] by an independent investigator who was blinded to the study. [21]. Patients were evaluated in the office according to a predesigned case form pre-operatively and at three, six, 12, and 24 months post-operatively.

The sports and recreational activity questionnaire was used to investigate patients' pre-operative and post-operative participation in 13 different sports and recreational activities. The activities were grouped into low impact (walking exercise, swimming, gymnastic riding, golf, and cycling), intermediate impact (hiking, fitness/weight training, aerobics, and

dancing), and high-impact activities (mountain climbing, jogging, tennis, and soccer) [22]. Pre-operative participation in sports and recreation was defined as that before symptom manifestation [22]. The questionnaire also surveyed the number of sports, the number of sporting sessions in a week (0–7 sessions per week), and the average session duration of sports and recreational activities (length per session) [22]. Patients were also asked about their return to sports and recreational activity, and about walking without inconvenience after the operation.

Statistical analysis

The sample size based on a two-tailed test was estimated using the Tegner and Lysholm knee score as the main outcome parameter. The minimal clinically important difference (MCID) was approximately 0.85 point in the Tegner score and 9.9 points in the Lysholm knee score [23]. A standard deviation of 1.6 in the HTO group and 0.7 in the UKA group was estimated in the Tegner score from a previous study. The mean differences in the Lysholm knee score at different times were normally distributed, with a standard deviation of approximately 19.0 in the HTO group and 11.0 in the UKA group [23]. The sample size was calculated using an Internet-based computer software (G*Power3.1.0, Duesseldorf, Germany) for a two-group Wilcoxon-Mann-Whitney test. A sample size of 40 patients per group was sufficient to obtain a significant difference in the Tegner and Lysholm knee score between the groups by a power of 0.80 at a level of $p < 0.05$. Results were presented as means and standard deviations. Continuous variables were analyzed using the Mann-Whitney *U* test and categorical data were analyzed using a chi-squared test (or Fisher's exact test where appropriate) for two independent samples. All statistical analyses were performed using SPSS ver. 21.0 program (SPSS, Inc., Chicago, IL). A p value < 0.05 was taken to indicate statistical significance.

Results

The baseline characteristics are shown in Table 1. Preoperatively, there were no significant differences in clinical scores except for the Tegner and UCLA scores ($p = 0.008$ and $p < 0.001$, respectively) (Figs 1 and 2). At post-operative three and six months, the UKA group showed significantly superior results in terms of VAS walking ($p < 0.05$), WOMAC ($p < 0.05$), and Lysholm knee scores ($p < 0.05$). There were no significant differences in any of the evaluated scores between the two groups at 12 and 24 months post-operatively ($p > 0.05$ for all) (Figs 1 and 2). When all baseline scores were adjusted to compare mean change, the UKA group showed significantly better improvements than did the HTO group in all scores evaluated at post-operative three months, in VAS working, average, WOMAC, Lysholm knee, and UCLA scores at post-operative six months, and in UCLA score at 12 months ($p < 0.05$ for all) (Table 2).

The average time to walk without inconvenience and to participate in sports activity after operation was 6.2 months and 8.4 months in the HTO group and 3.7 months and 3.8 months in the UKA group ($p = 0.001$ and $p < 0.001$, respectively). In the HTO group, 40 out of 49 patients (81.6%) participated in sports and recreational activities before the operation, and 30 out of 49 patients (61.2%) participated in activities 24 months after the operation ($p = 0.001$). In the UKA group, 34 out of 42 patients (81.0%) participated in sports and recreational activities before the operation, and 32 out of the 42 patients (76.2%) participated in activities after the operation ($p = 0.493$). Overall, a significantly greater rate of patients returned to sports and recreation in the UKA group (94.1%) than in the HTO group (75.0%) ($p = 0.031$). At post-operative 24 months, the UKA group was involved in longer session lengths than was the HTO group ($p = 0.046$) (Table 3 and Fig. 3).

In the HTO group, both high-impact activities, such as mountain climbing and tennis, and low-impact activities,

Table 1 Pre-operative demographics for the two groups

	HTO ($n = 49$)	UKA ($n = 42$)	p value
Gender (female: male)	43: 6	35: 7	0.548
Age	56.1 ± 6.2 (31–65)	63.6 ± 5.5 (54–79)	< 0.001
BMI	26.6 ± 9.2 (19.4–32.8)	25.3 ± 2.4 (20.7–30.8)	0.534
ASA grade	1.9 ± 0.4	1.9 ± 0.3	0.814
Operation side (right: left)	25: 24	17: 25	0.400
Kellgren-Lawrence grade			0.005
2	9 (18.4%)	0 (0%)	
3	28 (57.1%)	23 (54.8%)	
4	12 (24.5%)	19 (45.2%)	
Hip-knee-ankle angle	Varus 7.8 ± 2.8 (varus 2.7–13.5)	Varus 4.5 ± 2.3 (varus 0–8.9)	< 0.001

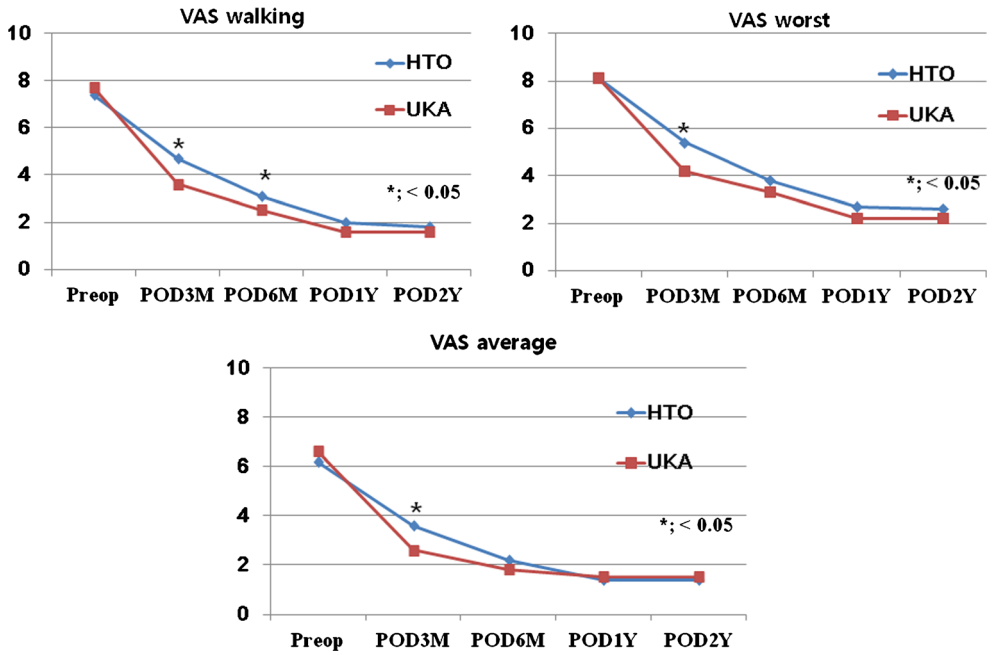

Fig. 1 Mean values visual analog scale (VAS) walking, worst, and average. *Significant ($p < 0.05$)

such as walking, were significantly decreased at post-operative 24 months (Fig. 4). On the other hand, there was a decrease in high-impact activities, such as mountain climbing, but no definitive decrease in participation was found in low-impact activities, such as walking and hiking, in the UKA group (Fig. 5). After surgery, swimming and gymnastic riding were increased in both groups (Figs 4 and 5).

Discussion

The most important finding of this study was that patients undergoing UKA recovered faster to previous activity levels post-operatively than did those undergoing HTO until 12 months. In addition, the frequency of return to sports and recreation was significantly higher and quicker in the UKA group than in HTO group at 24 months.

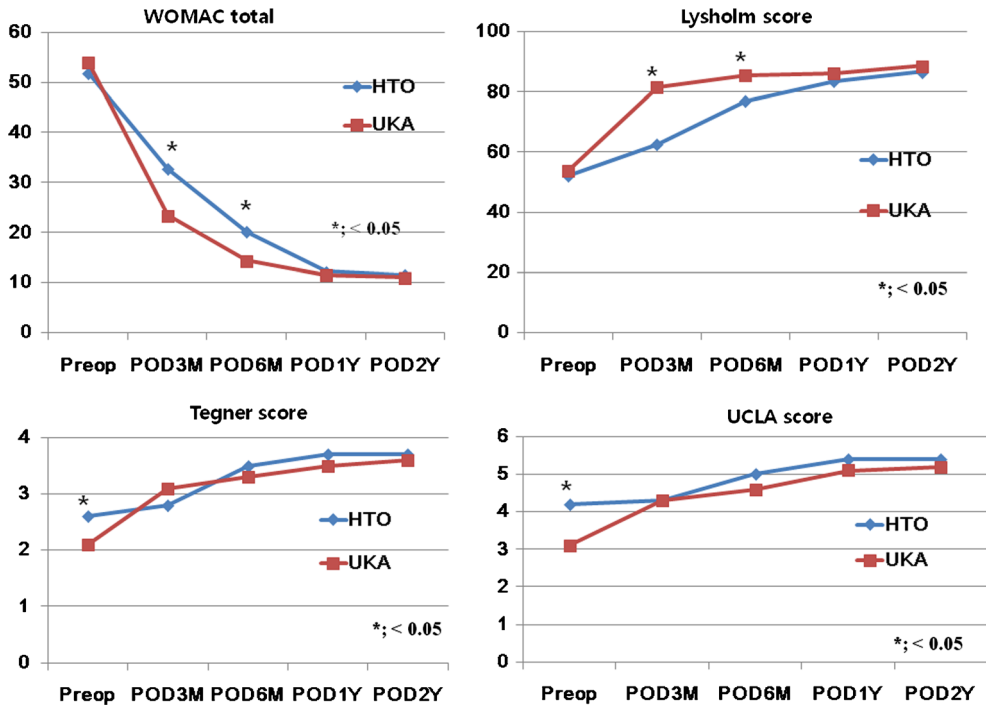

Fig. 2 Mean values Western Ontario McMasters Osteoarthritis Index (WOMAC), Lysholm score, Tegner Activity Scale, and University of California at Los Angeles (ULCA) score. *Significant ($p < 0.05$)

Table 2 Mean change from baseline visual analog scale (VAS) walking, worst, average, Western Ontario McMasters Osteoarthritis Index (WOMAC), Lysholm score, Tegner Activity Scale, and University of California at Los Angeles (ULCA) score

	HTO ($n = 49$)	UKA ($n = 42$)	p value
VAS walking			
Post-operative 3 M	2.7	4.1	0.007
Post-operative 6 M	4.3	5.1	0.034
Post-operative 12 M	5.4	6.1	0.073
Post-operative 24 M	5.7	6.2	0.157
VAS worst			
Post-operative 3 M	2.7	3.9	0.040
Post-operative 6 M	4.2	4.8	0.217
Post-operative 12 M	5.3	5.9	0.172
Post-operative 24 M	5.7	6.0	0.305
VAS average			
Post-operative 3 M	2.6	4.1	0.001
Post-operative 6 M	4.0	4.8	0.042
Post-operative 12 M	4.7	5.1	0.342
Post-operative 24 M	4.7	5.2	0.180
WOMAC Total			
Post-operative 3 M	19.1	30.8	0.013
Post-operative 6 M	31.6	39.7	0.029
Post-operative 12 M	39.6	42.7	0.376
Post-operative 24 M	40.8	44.4	0.304
Lysholm			
Post-operative 3 M	10.3	27.8	< 0.001
Post-operative 6 M	24.8	31.8	0.045
Post-operative 12 M	31.0	32.5	0.640
Post-operative 24 M	38.8	33.9	0.075
Tegner			
Post-operative 3 M	0.3	1.0	0.002
Post-operative 6 M	0.9	1.2	0.176
Post-operative 12 M	1.2	1.3	0.483
Post-operative 24 M	1.2	1.4	0.417
UCLA			
Post-operative 3 M	0.1	1.2	0.001
Post-operative 6 M	0.8	1.4	0.009
Post-operative 12 M	1.2	1.9	0.008
Post-operative 24 M	1.5	2.1	0.061

Table 3 The number of sports, average session number, and average session length

†	HTO ($n = 49$)	UKA ($n = 42$)	p value
The number of sports			
Pre-operative (number)	2.1 ± 0.9	2.1 ± 0.9	0.946
Post-operative 24 M	2.2 ± 0.9	2.2 ± 0.8	0.802
	0.574	0.839	
Average number of sessions of sports in a week			
Pre-operative (number)	3.4 ± 2.3	2.9 ± 1.1	0.270
Post-operative 24 M	2.7 ± 1.7	3.0 ± 1.3	0.388
	0.285	0.469	
Average session length of sports			
Pre-operative (hour)	1.1 ± 0.8	0.9 ± 0.5	0.116
Post-operative 24 M	1.0 ± 0.5	1.3 ± 0.7	0.046
	0.114	0.004	

†Pre-operative participants of activities: HTO ($n = 40$), UKA ($n = 34$)
Post-operative participants of activities: HTO ($n = 30$), UKA ($n = 32$)

The time course of clinical outcomes was important in patients, especially during the early post-operative period, because they were interested in the recovery pattern and return to daily life and sports activity [24]. The UKA group showed a significantly higher activity level during the early post-operative period than did the HTO group, and this continued until mid-term follow-up after five years post-operatively by Krych et al [23]. However, this was a retrospective study and there was much follow-up loss in both groups and no comparison of activity level at post-operative *six* months. In addition, medial opening and lateral closing wedge HTOs were mixed in their HTO group. Yoon et al. [25] demonstrated that the UKA group showed significantly better clinical outcomes at post-operative six months than did the HTO group using KOOS and IKDC scores, but there was no difference at one and two years after the operation. However, this was also a retrospective study without any comparison of clinical outcomes in the early post-operative period at three months. In addition, the sample size of 47 patients (26 HTOs and 21 UKAs) was too small to show a clear statistical difference of outcomes. In this study, significantly superior and faster recovery was seen in the UKA group than in the HTO group at one year after surgery with a sufficient sample size.

Our study found that patients walked without inconvenience and returned to sport more quickly following UKA than after HTO. Consequently, the improvement of post-operative activity level was faster in the UKA group than in the HTO group during the early post-operative period, which was explained in two ways. First, the slower recovery of activity level might be explained by higher walking VAS at post-operative three and six months, suggesting incomplete pain relief in the HTO group. HTO is a joint-preserving surgery; the pain source in the medial compartment still persisted, and the low level of pain remained following increased activity [26]. In contrast, the elimination of nociceptive input of the entire medial compartment was replaced by a resurfacing implant in UKA. Resurfacing arthroplasty was used to resolve pain and symptoms [26]. The patients tended to show less activity in order to decrease pain and symptoms efficiently [23]. Second, the gait was altered after UKA and HTO. Increase in the maximal gait velocity and duration of single-leg support was observed in the UKA group with pre- and post-operative gait analysis [27]. However, there was no

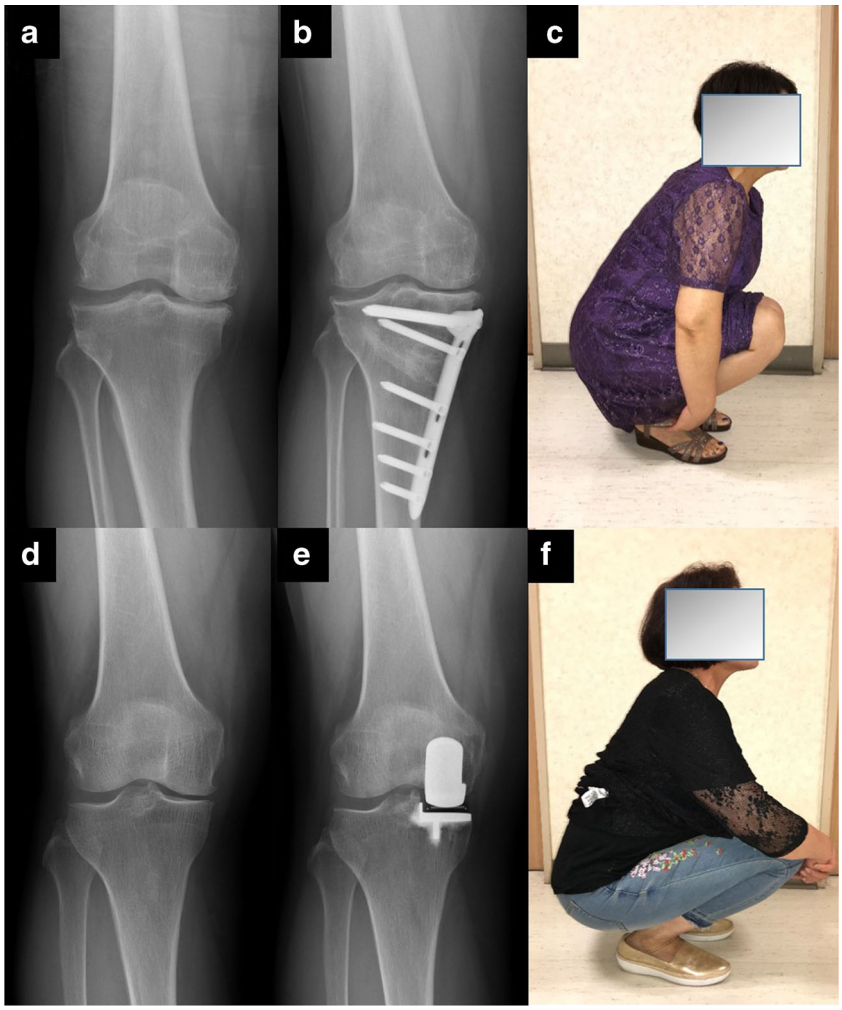

Fig. 3 A 59-year-old female underwent medial opening-wedge high tibial osteotomy (HTO). Pre-operative standing radiograph of the right knee joint (**a**). Post-operative standing radiograph of the right knee joint at 3 years after surgery (**b**). Although she could not work out at the gym before surgery, she could be able to resume working out in her local health centre and safely perform squatting after HTO (**c**). A 64-year-old female underwent medial unicompartmental knee arthroplasty (UKA). Preoperative standing radiograph of the right knee joint (**d**). Post-operative standing radiograph of the right knee joint at 3 years after surgery (**e**). Even though she could not be able to exercise before surgery, it was possible to jog and squat following UKA (**f**)

difference in maximal gait velocity and duration of single-leg support in the HTO group [27]. In addition, Ivarsson et al. also reported that muscle strength was higher in the UKA group than in the HTO group at six months after the operation, whereas comparable results were seen in the two groups at one year after the operation [27]. This finding was explained

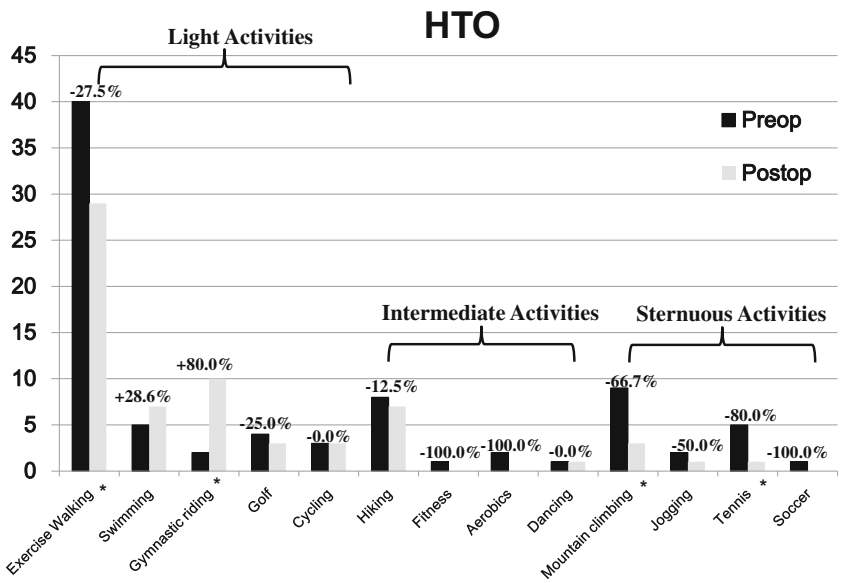

Fig. 4 Participation in sports activities before and after high tibial osteotomy. The number of patients who participate regularly in the category's activity is shown. The difference between pre- and post-operative participation in activities is also shown. *Significant ($p < 0.05$)

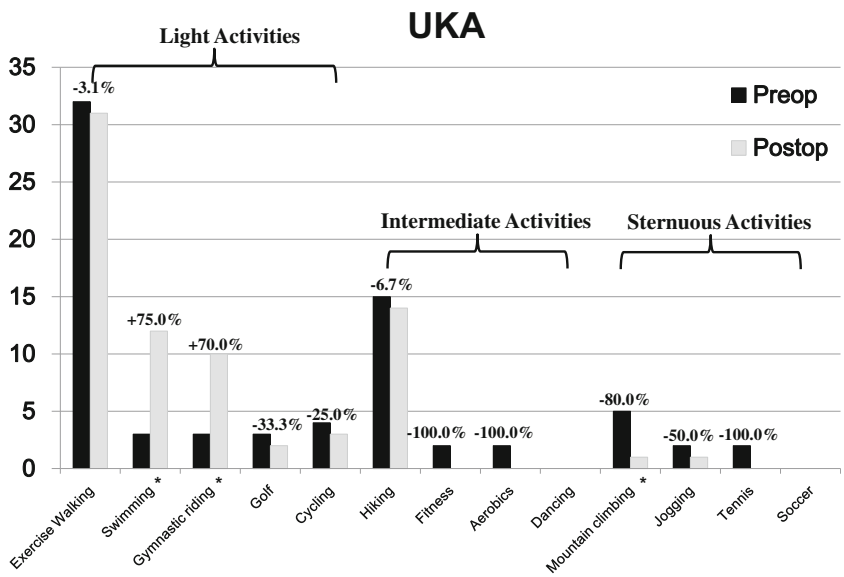

Fig. 5 Participation in sports activities before and after unicompartmental knee arthroplasty. The graph shows the number of patients who participated regularly in the category's activity, as well as the difference between pre- and post-operative participation in activities. *Significant ($p < 0.05$)

by the differences in rehabilitation between the two procedures [27]. The patients started full weight-bearing walking post-operatively on day one in UKA, whereas full weight bearing was permitted in patients undergoing HTO only after six weeks post-operatively. In addition, the change in post-operative alignment was greater in the HTO patients than in the UKA ones; so additional time was required for adjustment [28].

Although there was no difference in the average minimum session length of sports between the two groups pre-operatively, the UKA patients participated in longer sporting sessions than did the HTO patients post-operatively in the present study. However, the number of participants in sports and the average number of weekly sports sessions were similar for the two groups. Naal et al. [22] reported that the average sessions of patients' participation per week and the minimum session length were decreased from pre-operative to post-operative levels with no significant differences after UKA, which was a slightly different result than that of our study. Faschingbauer et al. [29] reported a shorter duration of activities in patients undergoing HTO after the operation, which was contrary to our findings. On the other hand, Salzmann et al. [30] demonstrated that there was no decline in frequency and length of sports activities after HTO, which was comparable to this study.

In this study, sports participation shifted to low-impact activities after the operation in both groups, despite reduced knee pain and improved activity level after the operation. Salzman et al. [30] reported no change in sports participation in terms of low-impact activities without a decline in the frequency and duration of sports activity after HTO. However, the average age was 41 years, which was very much younger than that of this study. On the other hand, Faschingbauer et al. [29] showed that patient participation in high-impact activities declined significantly after HTO, with less decline in low-impact activities, even though the average age was younger (42 years) than in this study, showing similar results. Naal et al. [22] demonstrated a shift away from high-impact activities after UKA. The average age was 65 years, similar to that of our study. Pietschmann et al. [31] also reported a shift from high-impact sports towards low-impact sports after UKA. The patients undergoing UKA and HTO might be concerned about the type, amount, and intensity of sports and recreational activities, because the activities increase the risk of sports-related injuries, which might result in unpredictable disease progression in HTO or conversion to TKA in UKA [2, 32]. Sports participation was changed to less-impact activities after the operation because of patients' concern about disease progression after activities and activity-related trauma [29, 30]. Reasons for the shift to low-impact activities were advice against participation in high-impact sports activity [29, 30]. Most orthopaedic surgeons recommend that contact sports should be stopped after the operation [20, 22, 29]. In contrast, sports such as swimming, cycling, and walking are recommended after knee operations [22]. These recommendations are consistent with our protocol of rehabilitation after HTO and UKA, providing a rationale for shifting from high-impact to low-impact sports after both procedures. In addition, physical deterioration in the overall health condition of aging patients caused the shift towards low-impact sports [31].

This study had several limitations. First, most of the patients were females undergoing UKA and HTO. The demographic characteristics of our study population were considered before extrapolating the findings to other populations, because all the patients were of Asian ethnicity in this study [1]. Thus, our findings might not be generalizable. Second, the follow-up period of patients in this study was short term, although both procedures scored similar results in all the

systems used in this study at 24 months; hence, it remains unclear whether the activity level and sports participation are valid at longer-term follow-up. The results should be tested in a longer-term study. Third, the UKA patients may be older and have more advanced OA than HTO patients, because it affects their whole knee and sports activities, favoring HTO patients, who participated in increased sports activity more than did the UKA patients. Nevertheless, the results of our study showed a better recovery by the UKA group than by the HTO group. Finally, most patients followed our recommendations to avoid high-impact sports activities after the operation. Our exercise recommendations might have influenced and limited the choice of sports activities by patients after surgery.

Conclusion

In conclusion, UKA had superior recovery and functional outcomes compared to HTO for 12 months post-operatively. Patients in the UKA group returned to recreational and sports activity more rapidly and for a longer time than did the patients in the HTO group. These findings may help surgeons optimize treatment options for individual patients with medial OA.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

Disclaimer None.

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