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Original Article

In-hospital grouping rehabilitation of hybrid closed-wedge high tibial osteotomy results in shorter hospital stays and better clinical outcomes

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Abstract. [Purpose] This study aimed to examine the impact of physiotherapy on various patients who underwent hybrid closed-wedge high tibial osteotomy. [Participants and Methods] Eighty-four patients were divided into three groups: non-weight-bearing, enhanced recovery after surgery, and grouping exercise. The number of hospital days, distinctions in the duration of cane-walking independence, and postoperative complications were compared among the three groups. Furthermore, the Japanese Orthopaedic Association score and physical function were assessed preoperatively and at 3 and 12 months postoperatively. [Results] There were no considerable differences in postoperative complications among the three groups, and the mean hospital stay was the shortest for the grouping exercise group. At 3 months postoperatively, the grouping exercise group reported less walking pain than the enhanced recovery after surgery group. At 3 and 12 months postoperatively, the grouping exercise group showed greater mean knee extensor strength and a higher mean Japanese Orthopaedic Association score than the non-weight-bearing group. [Conclusion] Grouping exercise therapy, in addition to enhanced recovery after surgery protocol, results in shorter hospital stays, no difference in postoperative complications, and good clinical outcomes.
Key words: High tibial osteotomy, Physical therapy, Rehabilitation

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INTRODUCTION

High tibial osteotomy (HTO) for knee osteoarthritis (KOA) corrects the varus knee to the load to the lateral side of the knee joint[1)]. There are two types of HTO, medial opening wedge HTO (OWHTO) and hybrid closed wedge HTO (HCWHTO), depending on the knee joint symptoms and lower alignment. MOWHTO is chosen for early KOA, while HCWHTO is chosen for moderate to severe KOA[2)]. HCWHTO is also identified for patellofemoral joint OA, strong varus deformity,

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and knee flexion contracture[2]. Although arthroplasty was prevalently the treatment of choice for severe knee OA, HCWHTO is increasingly being chosen when recreational and sports activities are desired[3]. The stable contact surface of the lateral tibial osteotomy side enables full loading at 2–3 weeks postoperatively, and the expeditious time to the bony union has the advantage of influencing a swift return to sports[3, 4]. However, there is a risk that excessive loading may induce bone resorption and delayed union of the osteotomy[5]. Therefore, postoperative rehabilitation requires a gradual increase in exercise load while taking complications into account.

Postoperative rehabilitation after MOWHTO has been accelerated in recent years. Takeuchi[4] indicated that the Enhanced recovery after surgery pathway (ERAS pathway) for early loading for MOWHTO showed the safety of early loading after surgery and good clinical outcome. While Azuma[6] reported that, in addition to the ERAS pathway protocol, grouping exercise (GE) therapy with increased physical activity influenced further functional improvements. This GE therapy by MOWHTO indicated no difference in the postoperative incidence of hinge fracture, a shorter period of cane-walking independence, and good recovery of clinical outcome at 12 months postoperatively[6].

In general, postoperative rehabilitation for HCWHTO often requires 1–2 weeks of use of non-weight bearing[4]. The safety and effectiveness of ERAS pathway and GE therapy for HCWHTO have not been shown. In HCWHTO, the part of lateral osteotomy is fixed with a locking plate, which offers good bone-to-bone contact pressure[4]. Thus, the ERAS pathway promotes early loading in knee joint extension alignment and was deemed efficacious[6]. Furthermore, we proposed that GE therapy in addition to the ERAS pathway would promote a good clinical outcome. This study aimed to assess the effect of a physiotherapy program on clinical outcomes and complications following HCWHTO. Our hypothesis is that early loading with the ERAS pathway will reduce the day of gait independence and hospital stay. We believe that these will lead to improved clinical outcomes at 12 months postoperatively, without an increase in post-operative complications.

PARTICIPANTS AND METHODS

The study was a longitudinal observational study up to one year postoperatively. Between April 2015 and April 2020, 300 patients who had HTO for KOA or spontaneous osteonecrosis of the knee were included in the analysis. Exclusion criteria were undergoing bilateral HTO, concomitant surgery for the contralateral meniscus, anterior cruciate ligament (ACL) reconstruction and meniscus suture, distal femoral osteotomy, difficulty walking more than 10 m due to severe cardiovascular or respiratory disease, missing data in the electronic medical record, MOWHTO[7, 8]. The participants were divided into the following three groups: those who had postoperative treatment with the operative lower limb non-weight bearing until 7 days postoperatively between April 2015 and December 2016 were in the non-weight bearing group (NWB group); those who had stepwise lower limb loading from the day after surgery according to the ERAS pathway between January 2017 and September 2018 were in the ERAS pathway group (ERAS group); and those who had postoperative grouping exercise therapy in addition to the ERAS pathway from October 2018 to April 2020 were identified as the group with group exercise therapy (GE group). All study protocols were approved by the Ethics Review Board of Yawata medical center (approval numbers; 29-4). Informed consent was also obtained from all participants by obtaining their signatures in writing on admission.

Basic medical data were gender, age, height, weight, body mass index (BMI), KOA severity classification (Kellgren & Lawrence grade: KL grade)[9], mechanical axis (%MA)[10], presence of bone resorption at 3 months postoperatively, and delayed union[5] at 12 months postoperatively. Bone resorption was defined as instability (bone resorption image) at the oblique osteotomy of the HCWHTO. KL grade and %MA were acquired by anteroposterior radiographs in the bipedal standing position. The presence of bone resorption and delayed union were evaluated by the CT outcomes. Physical function data were knee joint extensor strength, knee joint range of motion (knee ROM), the pain of knee during gait (visual analog scale, VAS), and 10-meters (10-m) walking time, which was determined preoperatively, 3 months postoperatively, and 12 months postoperatively. Knee joint extensor strength was determined using a Mobile manual muscle tester (Sakai Medical Co., Ltd., Tokyo, Japan), with the bed and machine fixed with a special belt, and the optimum value of the maximum isometric muscle force (N) divided by the body weight (kg) for 3 s was measured twice[11]. Knee ROM was measured by the maximum values of knee flexion and extension ROM in automatic exercise using a goniometer following the Japanese Orthopedic Association measurement method. 10-m walking time was measured with a stopwatch. The total score of the Japanese Orthopaedic Association score (JOA score) was employed as the clinical outcome[12]. The number of days until patients could walk with a cane was determined as the number of days until they could walk independently on the ward using a T-cane, with the day after surgery being the first day. The number of days in the hospital was also evaluated using the day after surgery as the first day until the day of discharge. The continuation of outpatient rehabilitation after discharge was collected from the electronic medical record.

Physiotherapy of the NWB group was started after removing drains on the first postoperative day. During the period of unloading up to 7 days postoperatively, quadriceps muscle contractile exercises such as knee range of motion exercises on the bed and isometric knee joint extension exercises utilizing a towel, including stretching and resistance exercises for the hip and ankle joints were conducted. From 8 to 21 days postoperatively, patients underwent lower limb loading exercises utilizing a half-weight on parallel bars, advancing to crutch walking exercises, or using a walker. Concurrently, aerobic exercise utilizing a bicycle ergometer and seated upper and lower limb exercise equipment (NUSTEP, Sakai Medical, Tokyo, Japan) was started. On the 22nd postoperative day, full weight bearing was implemented and cane walking and independent walking exercises were performed as allowed. The individual physiotherapy regimen comprised two sets of 40 minutes per day for 7 days a week. Patients were discharged when they were able to live independently in the hospital with or without a cane.

Physiotherapy of the ERAS group was implemented upon removing the drain on the same day as the operation. The patient was allowed to bear the full load on the first postoperative day, with the load applied incrementally as allowed. Loading exercises were implemented with bilateral loading on the parallel floor, advancing to walking on parallel bars, crutches or a walker, cane, and independent walking. Knee joint extension loading prevented increased pain with a VAS of 40 mm or more. Dynamic lower limb alignment should be attended to the knee joint extension in the standing position, and if the extension is hard to maintain, use a brace. If the pain prevented them from doing the loading exercises in the standing position, they conducted knee joint extension exercises and half-sitting exercises on the bed. Resistance exercises were mostly conducted in the standing position including ankle joint plantar flexion exercises and one-leg standing, and squatting exercises (up to 45° knee joint flexion) were also conducted as allowed. The individual physiotherapy regimen and discharge criteria were consistent with the NWB group.

In the GE therapy group, full weight bearing was started from the day after surgery according to pain with a protocol equivalent to that in the ERAS path group. In addition to individual physiotherapy, GE therapy was conducted upon transfer from the general ward to the community comprehensive care ward. Community care wards had no upper limit on physiotherapy time, which enabled longer exercise therapy in a group setting. Individual physiotherapy sessions of 15 min each were performed for 1–2 sets per day, and GE therapy sessions of 60 min each were performed for 2 sets per day, with two physiotherapists supervising. The program was classified into the following two phases: the basic phase for those unable to walk independently and the active phase for those who could walk independently. Resistance and aerobic exercises, patient education, and stretching and resistance exercises were conducted, with the intensity and duration varying between phases.

Statistical analyses included a one-way analysis of variance and Tukey's test for differences in the number of days in the hospital and the period of cane-walking independence in the three groups, and a χ^2 test for the presence or absence of continued outpatient rehabilitation after discharge, bone resorption at 3 months postoperatively, and delayed bone fusion at 12 months postoperatively. A two-way analysis of variance was employed to evaluate changes in JOA score and physical function information preoperatively, 3 months postoperatively, and 12 months postoperatively. These were determined to be significant at the 5% level. All statistical analyses were performed using EZR version 1.52 (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R version 4.02 (The R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

In each group, 74 patients (26 NWB group, 22 in the ERAS group, and 26 in the GE group) who did not reach the exclusion criteria (Bilateral HTO and concomitant surgery for the contralateral meniscus: n=80, distal femoral osteotomy: n=10, ACL reconstruction and meniscus suture: n=20, difficulty walking more than 10 m due to severe cardiovascular or respiratory disease: n=5, missing data in the electronic medical record: n=4, MOWHTO: n=107) were included from the 300 patients in whom HTO was conducted. All study participants had an exercise program within the ERAS pathway and GE therapy. In preoperative basic medical data, only %MA was more varus in the GE group, while postoperative %MA, the prevalence of bone resorption, and bone union failure were not significant in the three groups (Table 1). The duration of cane-walking independence was shorter in the GE group than in the NWB group and ERAS groups ($p<0.01$) (Table 1). There was no interaction between the major effects of time and group on joint range of motion (Table 2). Knee extensor strength showed a main effect (time) and interaction between time and group and was higher in the GE group than in the NWB group at 3 and 12 months postoperatively ($p<0.01$) (Table 2). The JOA score also demonstrated a main effect (time) and interaction between time and group and was higher in the GE group than in the NWB group at 12 months postoperatively ($p<0.01$) (Table 2). Knee joint extensor strength indicated a significant decrease in the NWB group at 3 months postoperatively when compared to preoperatively, and no significant difference from preoperatively at 12 months postoperatively ($p<0.01$) (Table 2). In the GE group, there was a considerable increase at 3 and 12 months postoperatively than preoperatively ($p<0.01$) (Table 2). The JOA score indicated a significant increase in the NWB and ERAS groups at 12 months postoperatively when compared to preoperatively, and a significant increase in the GE group at 3 and 12 months postoperatively than preoperatively ($p<0.01$) (Table 2).

DISCUSSION

This study suggests that GE therapy for HCWHTO has no impact on the prevalence of postoperative complications compared to the NWB and ERAS groups, but has a good impact on the duration of cane walking independence and hospital stay. In the postoperative period, the GE group showed higher knee extensor strength and JOA scores than the NWB group. Furthermore, at 3 months postoperatively, the GE group was found to have lower walking pain than the ERAS group.

A comparison of the ERAS group with the NWB group discovered that the ERAS group was a shorter time to T-cane walking independence and shorter hospital stays. Furthermore, there were no distinctions in the incidence of complications, such as bone resorption and delayed bone fusion. The effects of unloading, such as disuse muscle weakness and reduced

Table 1. Participants characteristics and complication rate

	NWB group	ERAS group	GE group
	(n=26)	(n=22)	(n=26)
Age (years)	67.5 ± 9.4	65.5 ± 11.9	66.9 ± 8.3
Height (cm)	158.7 ± 8.5	157.2 ± 9.8	159.9 ± 10.2
Weight (kg)	65.7 ± 8.5	62.6 ± 13.9	66.4 ± 10.6
BMI (kg/m^2)	25.9 ± 4.1	25.1 ± 4.0	25.8 ± 2.5
Gender (female/male)	9/17	7/15	16/10
KL grade	I: 2 II: 1	I: 4 II: 2	I: 1 II: 4
	III: 11 IV: 12	III: 9 IV: 7	III: 13 IV: 7
Pre % MA (%)	18.1 ± 17.3	22.1 ± 15.2	10.2 ± 12.3¶
3M % MA (%)	56.6 ± 11.3	59.7 ± 14.7	59.1 ± 11.9
12M % MA (%)	55.3 ± 12.5	59.8 ± 14.7	59.6 ± 12.8
Bone resorption [n (%)]	3 (8)	0 (0)	3 (8)
Delayed union [n (%)]	3 (11.5)	0 (0)	1 (3.8)
Days spent in hospital (days)	56.0 ± 16.7	51.8 ± 11.8§	41.1 ± 9.7$^{\|\|\P\P}$
Days of cane walking independence (days)	40.2 ± 13.9	32.4 ± 12.6§	21.8 ± 9.4$^{\|\|\P\P}$
Outpatient rehabilitation continuation rates (%)	80.8	86.4	96.2

Mean ± deviation.
§NWB group vs. ERAS group, $^{\|}$NWB group vs. GE group, ¶ERAS group vs. GE group: single symbol p<0.05, two symbol p<0.01.
Age, Height, Weight, BMI, %MA, Days spent in hospital, Days of cane walking independence: ANOVA (one-way analysis of variance).
KL Grade: Kruscal Wallis test.
Bone resorption, Days spent in hospital: χ^2 test.
BMI: body mass index; KL grade: Kellgren & Lawrence grade; %MA: % mechanical axis; NWB: non-weight bearing; ERAS: enhanced recovery after surgery; GE: group exercise therapy.

Table 2. Longitudinal changes in physical function and clinical outcomes

		NWB group	ERAS group	GE group	Main effect		Interraction
		(n=26)	(n=22)	(n=26)	Time	Group	Time × Group
Knee extension ROM (°)	Pre	−6.7 ± 3.4	−6.4 ± 4.4	−6.5 ± 4.2	0.01<	0.20	0.28
	3M	−5.0 ± 4.5	−3.9 ± 4.6	−2.7 ± 2.9*			
	12M	−4.4 ± 4.3	−4.3 ± 4.1	−2.3 ± 2.5†			
Knee flexion ROM (°)	Pre	129.2 ± 13.2	135.0 ± 12.6	128.3 ± 10.8	0.01<	0.47	0.14
	3M	133.6 ± 9.8	135.2 ± 4.7	135.7 ± 7.8*			
	12M	133.3 ± 8.9	133.8 ± 10.1	133.8 ± 9.2†			
Knee extension strength (N/kg)	Pre	3.9 ± 1.8	3.2 ± 1.7	3.5 ± 1.3	0.01<	0.21	0.01<
	3M	2.8 ± 1.0*	3.5 ± 1.3§	3.7 ± 1.4$^{\|}$			
	12M	3.7 ± 1.2‡	4.1 ± 1.6	4.8 ± 1.3$^{\dagger\ddagger\|}$			
Pain of knee during gait (mm)	Pre	31.8 ± 19.4	30.5 ± 27.1	29.4 ± 20.4	0.01<	0.01<	0.05<
	3M	27.1 ± 16.1	15.8 ± 13.8§	8.5 ± 10.1$^{\|\P*}$			
	12M	7.4 ± 11.1†‡	3.2 ± 5.7†‡	1.2 ± 3.3$^{\dagger\|}$			
10m gait time (sec)	Pre	7.6 ± 1.8	8.9 ± 3.6	7.1 ± 1.7	0.01<	0.07	0.11
	3M	7.9 ± 2.0	7.7 ± 2.9	7.3 ± 1.7			
	12M	6.9 ± 1.5	7.4 ± 2.1	6.1 ± 1.1‡¶			
JOA score (points)	Pre	75.4 ± 12.8	75.5 ± 11.2	71.2 ± 11.9	0.01<	0.11	0.01<
	3M	72.9 ± 13.4	80.1 ± 8.7	81.0 ± 9.0*$^{\|}$			
	12M	83.7 ± 12.1†	88.4 ± 8.5†‡	91.4 ± 6.1$^{\ddagger\dagger\|}$			

Mean ± deviation.
*Pre vs. 3M, †Pre vs. 12M, ‡3 M vs. 12 M.
§NWB group vs. ERAS group, $^{\|}$NWB group vs. GE group, ¶ERAS group vs. GE group.
Knee extension ROM, flexion ROM, Knee extension strength, Pain of knee in gait, 10 m gait time, JOA score: two-way ANOVA (time, group).
Post hoc test: Multiple comparison tests for the three groups at various pre/post-operative times (Tukey test).
ROM: range of motion; JOA score: Japanese Orthopaedic Association score; Pre: preoperative; 3M: postoperative three month; 12M: postoperative twelve month; NWB: non-weight bearing; ERAS: enhanced recovery after surgery; GE: group exercise therapy.

lower limb muscle contraction during gait due, were inhibited by the ERAS program[6]. In the ERAS pathway, progressive loading exercises were conducted in cases of low pain, while loading exercises in the sitting position were conducted in cases of high pain. Quadriceps contraction in HCWHTO good influences bony union by applying compressive forces to the osteotomy via the patellar tendon[4]. The ERAS pathway also highlights loading in the knee joint extension position, which may inhibit bone resorption and delayed union by avoiding rotational stress on the knee joint[6]. From this, it can be deduced that the prevention of postoperative muscle weakness was successful, and no difference in complication and resulting in a reduction in the number of days of cane-walking independence. Because there were no substantial differences in gender (male), which are risk factors for these complications in both groups, we presume that the ERAS path is safe and effective.

The GE group resulted in shorter cane-walking independence and hospital stay than the ERAS group. However, no significant differences were found in the presence or absence of postoperative complications. Preoperative patient characteristics of the two groups demonstrated significant differences only in %MA. In general, severe preoperative KOA and poor preoperative JOA score lead to poor JOA score at 12 months postoperatively. Although the GE group had a varus knee alignment, the effect on the postoperative JOA score was believed to be small, as no significant differences in JOA score or KOA grade were found. One feasible explanation for the shorter time to cane-walking independence and hospital stay in the GE group when compared to the ERAS group, was the provision of more exercise than in individual physiotherapy sessions[6]. The GE therapy included aerobic and resistance exercise programs aimed at decreasing the pain of the knee in gait, with 60 min of exercise in the morning and afternoon. This enabled more exercise time than individual physiotherapy and was deemed one of the elements that boost the effectiveness of decreasing the pain of the knee in gait. In addition, exercise using a bicycle ergometer for a total of 40 min at 10N, which is conducted in GE therapy, is said to induce muscle activity equal to walking 10,000 steps in the quadriceps muscle[13]. Furthermore, aerobic exercise has been shown to provide exercise-induced pain reduction[14]. According to Tan et al.[14], 40 minutes of aerobic exercise for about two weeks can result in exercise induced hypoalgesia. We speculate that these resistance training and aerobic exercises resulted in improved gait stability and pain reduction due to increased muscle activity during walking.

Postoperatively, the GE group showed higher knee extension muscle strength and JOA scores than the NWB group. This result supports the report of Azuma et al. in OWHTO[6], who found a large difference in hospital stay of 15 days and 21 days to walking independence in the participants in this study, which suggests that prevention of disuse muscle weakness was achieved. However, there were no significant differences in knee extensor strength and JOA scores between the GE group and ERAS group, suggesting that many moderate and severe KOA eligible for HCWHTO have metabolic syndrome-related factors, which may influence their continued exercise habits and comorbidities after discharge[7]. No significant differences regarding knee joint ROM also supports the OWHTO report[6], indicating a small effect of physiotherapy programs on postoperative ROM.

Our GE group participants' characteristics were age (66.9 ± 8.3 years), KL grade (severe OA rate: 75%), complication rate (bone resorption: 8.0%, Delayed union 3.8%), JOA score (preoperatively: 71.2 ± 11.9 to post 12 months: 91.4 ± 6.1), VAS (preoperatively: 29.4 ± 20.4 to post 12 months 1.2 ± 3.3). Previous study[3, 5, 15–17], reported that age (56.7–69.2 years), KL grade (severe OA rate: 52–100%), and JOA score (preoperatively: 61.0–72.2 to post 12 months: 86.4–92.0), VAS (preoperatively: 46.0 ± 19.0 to post 12 months: 10.0 ± 0.9), complication (Delayed union 4.0%–8.5%). Compared to these previous studies, the present study resulted in less pain, fewer post-operative complications, and higher JOA scores. This indicates that the addition of GE treatment and individual treatment in the ERAS pathway may influence good clinical outcomes with no difference in postoperative complications.

Limitations of the study include the lack of comprehensive management of voluntary physical activity and steps taken during hospitalization and insufficient evaluation of the continuation of exercise habits after discharge. Another limitation of the study is the lack of sample size for some of the study results. After testing the sample size by post-test (power 80%, significance level 5%), the required sample size was 22 cases in each group (days spent in hospital, days of cane walking independence), 26 cases in each group (JOA score, knee extension strength, and 40 cases in each group (pain of knee during gait). The sample size was considered adequate for results other than knee pain in gait. Although no significant differences in gender in the participants of the present study were obtained, there was a trend towards more females in the GE group who showed good clinical outcomes. Clinical outcomes 6 years after HTO surgery have been reported to be lower in women than in men, and few previous studies have shown good clinical outcomes in women[18]. We believe that further analysis by gender is needed in the future.

Funding and Conflict of interest

All authors declare that they have no known competing financial interests or personal relationships that could influence the work reported in this paper.

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