Editors' Choice

ORIGINAL PAPER

Nagoya J. Med. Sci. **86**. 91–103, 2024
doi:10.18999/nagjms.86.1.91

The relationship between preoperative foot alignment and postoperative outcomes in patients who underwent initial total knee arthroplasty

Aika Hishida[1], Hideki Hiraiwa[2], Izumi Kadono[1,3], Hidetoshi Yamaguchi[1], Takashi Okada[1,4], Chiaki Terai[1], Azusa Kayamoto[1] and Yoshihiro Nishida[1]

[1]Department of Rehabilitation, Nagoya University Hospital, Nagoya, Japan
[2]Depatment of Orthopaedic Surgery, Asahi University Hospital, Gifu, Japan
[3]Department of Rehabilitation, Aichi Development Disability Center Hospital, Kasugai, Japan
[4]Department of Rehabilitation, Zenjyokai Rehabilitation Hospital, Nagoya, Japan

ABSTRACT

We compared the relationship between foot alignments and quality of life in patients who underwent initial total knee arthroplasty (TKA). Among the patients with knee osteoarthritis (KOA) who underwent TKA from May 2015 to May 2017 at our hospital, we focused on those in whom weight-bearing foot radiographs had been evaluated preoperatively. The hallux valgus angle and Meary angle were measured by preoperative radiography, and those with hallux valgus angles of 20 degrees or more were classified into the hallux valgus (HV) group, and those with Meary angles of 4 degrees or more into the high arch (HA) group. Also knee and ankle range of motion, knee pain Visual Analog Scale, and the 36-item short-form health survey (SF-36) were measured preoperatively and at discharge, and the amount of these changes was compared in the presence/absence of HV and HA. Regarding HV, there were no significant differences in any of these items between the HV and non-HV groups. However, the SF-physical function was significantly lower in the HA group than in the normal group. In addition, ankle dorsiflexion was lower in the HA group than that in the normal group, although this difference was not statistically significant. There was little improvement of the ankle dorsiflexion, and it was associated with deterioration of the physical function items of SF-36. In total knee arthroplasty patients with HA, physical therapy of the ankles and feet, as well as of the knees, was considered to enhance the improvement of physical function.

Keywords: foot alignment, total knee arthroplasty, SF-36, high arch, physical therapy

Abbreviations:
QOL: quality of life
KOA: knee osteoarthritis
TKA: total knee arthroplasty
SF-36: the 36-item short-form health survey
HV: hallux valgus
ROM: range of motion
FTA: femoro-tibial angle
K-L classification: Kellgren-Lawrence classification
HA: high arch

Received: March 7, 2023; accepted: June 21, 2023
Corresponding Author: Hideki Hiraiwa, MD, PhD
Department of Orthopaedic Surgery, Asahi University Hospital, 3-23 Hashimoto, Gifu 500-8523, Japan
E-mail: hirahide@hosp.asahi-u.ac.jp

NA: normal arch
VAS: Visual Analog Scale

INTRODUCTION

Foot problems due to malalignment, such as hallux valgus, spread feet, flat feet, high arches, and lesser toe deformities, are common disorders, which have reached prevalence rates of 61% to 79%.[1] Foot problems may frequently be chronic conditions that first become apparent at primary care consultations, and can reduce the health-related quality of life (QOL), as well as balance and gait, and increase the risk of falls.[1] Knee osteoarthritis (KOA) is also a chronic disease, which, like foot misalignment, reduces the patient's QOL. Although total knee arthroplasty (TKA) is widely undertaken in KOA patients, postoperative pain, limited improvement in physical function, and poor QOL have been reported even after TKA.[2]

Of the QOLs, health-related QOL is defined only for items that are derived from an individual's health condition for medical evaluation. There are disease-specific scales and comprehensive scales as evaluation methods for health-related QOL, and as a representative of the latter, the 36-item short-form health survey (SF-36) questionnaire is the most commonly used tool worldwide.[3,4] SF-36 is a patient-based outcome and is an evaluation method that includes not only illness but also various other parameters such as dysfunction, disability, and psychological factors.

Some studies have been published on the relationship between KOA and foot alignment. Rao et al reported that aberrant foot structure is linked to the development of pain and OA changes at the knees and hips.[5] Roddy et al reported an association between the presence or absence of hallux valgus (HV) and KOA[6] and that the severity of HV and KOA were significantly correlated.[7] In addition, Iijima et al reported that the presence of bilateral flat feet was significantly associated with worse knee pain, [8] and Levinger et al reported that varus KOA was associated with the pronated foot type.[9] On the other hand, there are few reports on the relationship between abnormal foot alignment and QOL evaluation. There are reports on the relationship based on the Western Ontario and McMaster Universities Osteoarthritis Index[10] score for patients with KOA, [11] but not patients undergoing TKA. In the present study we compared the association between foot alignments and SF-36 in patients undergoing initial TKA.

PATIENTS AND METHODS

Participants

A retrospective case study was conducted on patients with KOA who underwent initial TKA between May 2015 and May 2017 at our hospital. The analysis was performed using the evaluation data of the rehabilitation department of this hospital. We excluded patients with a history of artificial joint replacement in the lower limb joints, those for whom weight-bearing foot radiography was not performed preoperatively, and those being treated for rheumatoid arthritis. This case-control study was approved by the Ethics Committee of Nagoya University Hospital.

Surgical procedure and rehabilitation program

All patients underwent the same surgical procedure. All implants used were Triathlon® Knee System (Stryker corp NJ, USA). The anesthesia method was general anesthesia with nerve block or epidural block.

Physical therapy was performed the day before surgery and preoperative evaluation was performed. Physical therapy resumed the day after surgery, and continued every day, except Sunday. The intervention time was 20 to 40 minutes per day, and several physiotherapists from the orthopedic team provided intervention for each patient. Full load was allowed from the day after surgery, and range of motion (ROM) training, muscle strengthening training, basic movement training, and walking training were carried out step by step. The final evaluation was performed at the time of the final physical therapy before discharge, and this was used as the evaluation at discharge.

Assessments

Demographic data including age, sex and rehabilitation period were measured. The femorotibial angle (FTA) was measured using an antero-posterior radiograph of the full-length lower extremity taken within 6 months before the operation. The severity of KOA was assessed using the Kellgren-Lawrence (K-L) classification[12] on radiographs of the knee. Also the HV angle on the side ipsilateral to the limb undergoing TKA was measured on weight-bearing antero-posterior radiographs of the foot, and the talar-first metatarsal angle (Meary angle)[13] was measured on weight-bearing lateral radiographs of the foot taken within 6 months before the operation (Figure 1).[14] From the X-ray measurement results, those with HV angles of 20 degrees or more were assigned to the HV group, and those with less than 20 degrees to the no HV group, Meary angles of 5 degrees or more to the high arch (HA) group, and those of 4 to –4 degrees to the normal arch (NA) group.[15,16] However, since there were no cases with a Mary angle of less than –4 degrees, we did not include the flatfoot group in the classification of this study.

Preoperative and discharge evaluations of the ROM of knee (flexion and extension) and ankle (dorsiflexion and plantar flexion) were performed using a goniometer, and the Visual Analog Scale (VAS) of knee pain and SF-36 were also evaluated at the same time. SF-36 consists of

A

B

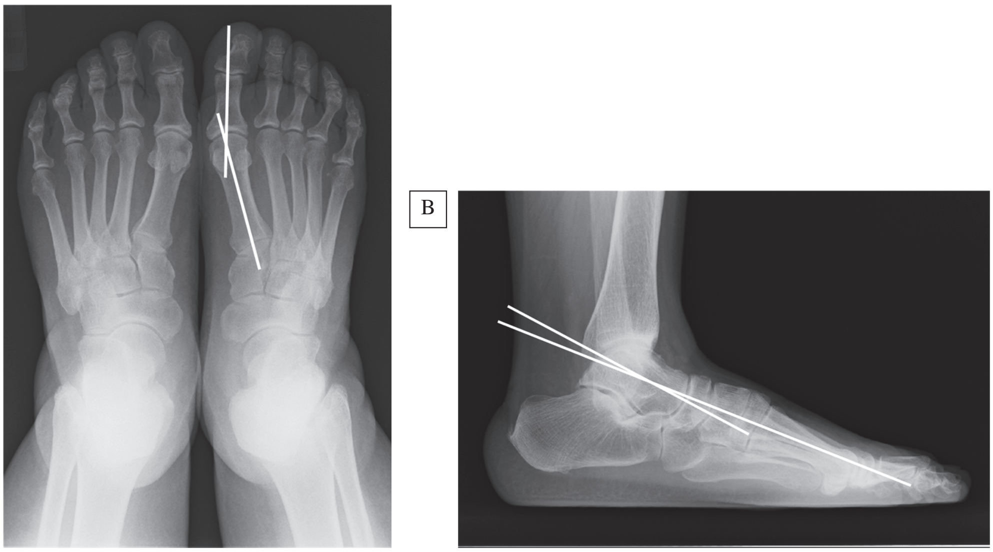

Fig. 1 The HV angle and Meary angle
The hallux valgus (HV) and Meary angles created by two white lines in each figure.
Fig. 1A: The HV angle was measured as the angle between the first proximal phalanx and first metatarsal axis.
Fig. 1B: Meary angle was measured as an angle between the first metatarsal and talar axes.

eight categories, including four categories relating to physical status (physical function [PF], role functioning physical [RP], bodily pain [BP], and general health perception [GH]) and four categories relating to mental status (vitality [VT], social functioning [SF], role functioning emotional [RE], and mental health [MH]).[3] The score for each category ranges from 0 to 100, with lower scores indicating poorer health or greater disability.[3] In this research, the Japanese version of the SF-36v2 Health Survey questionnaire[17,18] was used, and the scores for each item (SF-PF, RP, BP, GH, VT, SF, RE, MH) were also calculated.

The amounts of change in the knee ROM, the ankle ROM, knee pain VAS, and SF-36 from preoperative to discharge were compared in each foot alignment group.

Statistical analyses

K-L classification in each foot alignment group was assessed using the Mann-Whitney U test. Age, duration of the rehabilitation intervention, FTA, and the amount of change in each item in each foot alignment group were compared between the HV and no HV groups, and the HA and NA groups, using the non-paired *t*-test. All statistical analyses were performed using StatView-J 5.0. A value of $P < 0.05$ was considered statistically significant.

RESULTS

This study included a total of 17 cases, 3 males and 14 females, and the average rehabilitation intervention period was 24.8 days. The K-L classification was grade 4 in 13 cases, and the average FTA was 185.4 degrees. The baseline characteristics of the patients are summarized in Table 1. There were 4 cases in HV group, and 6 in HA group (Figure 2). There were no cases of flat feet or overlapping cases of HV and HA. In addition, there were no significant differences in knee pain VAS, knee ROM, ankle ROM, or SF-36 between any foot alignment group before surgery (Table 2). There were no significant differences either in age, K-L classification, or the duration of the rehabilitation period. However, FTA was significantly lower in the HA group than in the NA group ($p=0.0159$; Figure 3).

In the comparison of the amount of change of each item of each foot alignment and knee pain VAS, no significant differences between the HV and no HV groups or between the HA and NA groups were detected (Figure 4). In the knee ROM, there was no significant difference either between the HV and no HV groups or between the HA and NA groups (Figure 5). In the ankle ROM, the dorsiflexion angle was numerically lower in the HA group than in the NA group, although the difference was not statistically significant ($p=0.0729$; Figure 6).

Regarding SF-36, no significant difference was found in any of the items in the comparison between the HV and no HV group (Figure 7). However, in the comparison between the HA and NA groups, SF-PF was significantly higher in the NA group ($p=0.0224$), while SF-RP was numerically lower in the HA group but this was not statistically significant ($p=0.0907$; Figure 8).

Table 1 Baseline characteristics

	Mean	Range (min-max)	Distribution no. (%)
Age (year)	66.3	61–84	
Sex (female)			14 (82.4)
Kellgren-Lawrence classification			
1			0
2			1 (5.9)
3			3 (17.6)
4			13 (76.5)
FTA	185.4	170–197	
Rehabilitation period (day)	24.8	16–35	

FTA: femoro-tibial angle

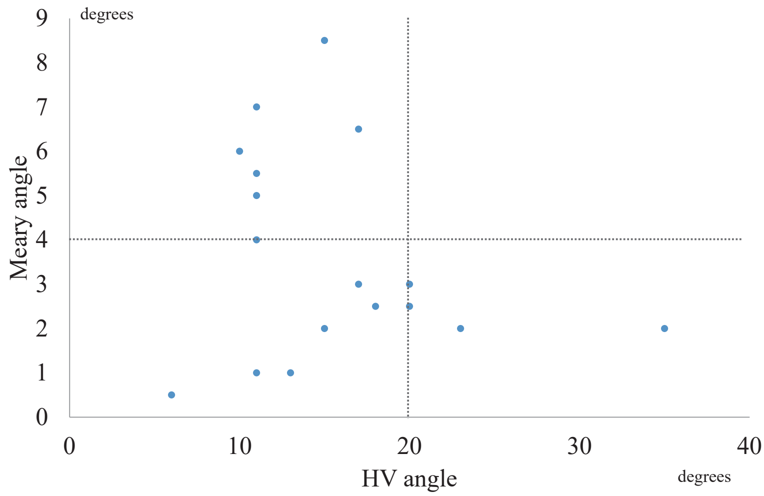

Fig. 2 Relationship between the hallux valgus (HV) and Meary angles
Patients with hallux valgus (HV) angles of 20 degrees or more were classified into the HV group and those with HV angles less than 20 degrees into the no HV group. Patients with Meary angles of 4 degrees or more were classified into the high arch (HA) group, and those with Meary angles of 4 to –4 degrees were classified into the normal arch (NA) group. The dotted lines indicate an HV angle of 20° and a Meary angle of 4°.

Table 2 The average values of knee pain VAS, knee ROM, ankle ROM, and SF-36 in each foot alignment group before surgery

	HV(n=4)		no HV(n=13)		HA(n=6)		NA(n=11)	
	preOP (SD)	AOC (SD)	preOP (SD)	AOC (SD)	preOP (SD)	AOC (SD)	preOP (SD)	AOC (SD)
Knee pain VAS	33.3 (34.7)	–5.1 (24.6)	41.5 (18.7)	–13.7 (30.8)	38.8 (17.2)	–13.7 (16.5)	40.0 (25.5)	–10.7 (34.6)
Flexion	118.8 (11.1)	–31.2 (14.4)	113.1 (20.3)	–25.0 (19.0)	106.7 (20.7)	–19.2 (16.0)	118.6 (16.4)	–30.5 (18.2)
Extension	–12.5 (8.7)	8.8 (8.5)	–10.0 (7.1)	5.0 (6.1)	–6.7 (6.8)	4.2 (3.8)	–12.7 (6.8)	6.8 (7.8)
Dorsiflexion	10.0 (4.1)	1.3 (2.5)	10.0 (9.4)	–2.3 (8.3)	9.2 (12.4)	–5.8 (8.0)	10.4 (5.7)	0.9 (6.3)
Plantar flexion	40.0 (10.8)	0 (7.1)	46.2 (8.5)	2.3 (8.1)	43.3 (7.5)	3.3 (7.5)	45.5 (10.1)	0.9 (8.0)
SF-PF	37.5 (13.2)	5.0 (7.1)	44.6 (22.8)	4.1 (18.5)	45.0 (23.9)	–7.5 (5.2)	41.8 (20.0)	10.7 (16.9)
SF-RP	29.8 (35.2)	28.1 (45.8)	54.8 (33.2)	4.3 (33.4)	55.2 (40.8)	–10.4 (36.8)	45.5 (31.9)	21.0 (32.9)
SF-BP	31.23 (26.5)	–2.8 (9.8)	39.4 (18.5)	–2.8 (13.8)	36.5 (18.6)	–2.0 (19.7)	38.0 (21.7)	–3.2 (7.9)
SF-GH	47.3 (23.2)	12.8 (19.6)	58.9 (15.5)	4.2 (16.7)	56.0 (16.2)	3.7 (14.3)	56.3 (19.0)	7.4 (19.3)
SF-VT	46.9 (24.2)	4.7 (24.1)	63.5 (10.8)	–9.6 (22.0)	60.4 (9.4)	–10.4 (19.6)	59.1 (18.8)	–4.0 (24.7)
SF-SF	43.8 (36.1)	25.0 (33.9)	72.1 (24.6)	–2.9 (28.0)	58.3 (28.2)	10.5 (29.0)	69.3 (30.3)	0 (32.6)
SF-RE	31.3 (21.9)	29.2 (47.9)	58.3 (37.9)	4.4 (40.1)	58.3 (42.8)	–4.3 (33.0)	48.5 (33.7)	18.2 (45.5)
SF-MH	57.5 (24.7)	–1.3 (24.6)	68.4 (16.3)	–8.1 (21.6)	62.5 (15.7)	–5.8 (15.7)	67.7 (20.0)	–6.8 (25.3)

There were no significant differences in any of the parameters between the foot alignment groups before surgery.
AOC: amount of change
HV: hallux valgus
SD: standard deviation
HA: high arch
NA: normal arch
preOP: pre-operation
VAS: Visual Analog Scale
SF-36: 36-item short-form health survey
PF: physical function
RP: role functioning physical
BP: bodily pain
GH: general health perception
VT: vitality
SF: social functioning
RE role functioning
MH: mental health

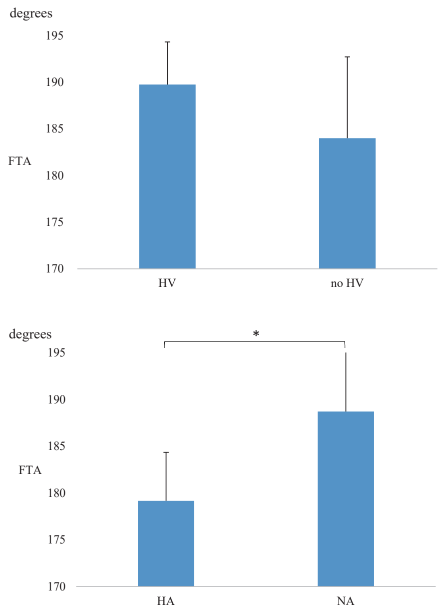

Fig. 3 Femoro-tibial angle (FTA) before surgery
FTA was significantly lower in the high arch (HA) group than in the normal arch (NA) group (lower graph). Each vertical bar indicates a standard deviation.
* p=0.0159 (the non-paired *t*-test).
HV: hallux valgus

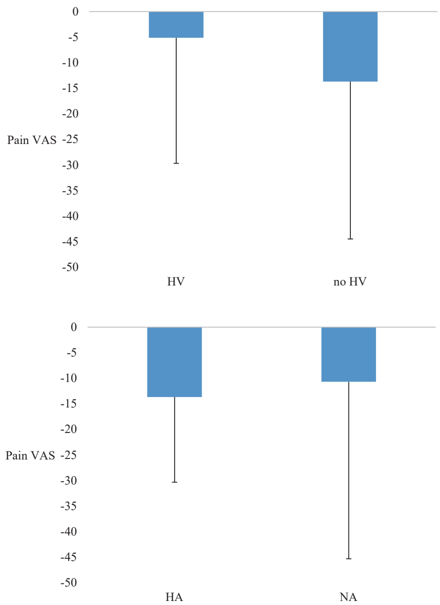

Fig. 4 Knee pain: visual analogue scale (pain VAS) changes from pre- to post-operation
There was no significant difference between the hallux valgus (HV) and no HV groups and between the high arch (HA) and normal arch (NA) groups. Each vertical bar indicates a standard deviation.

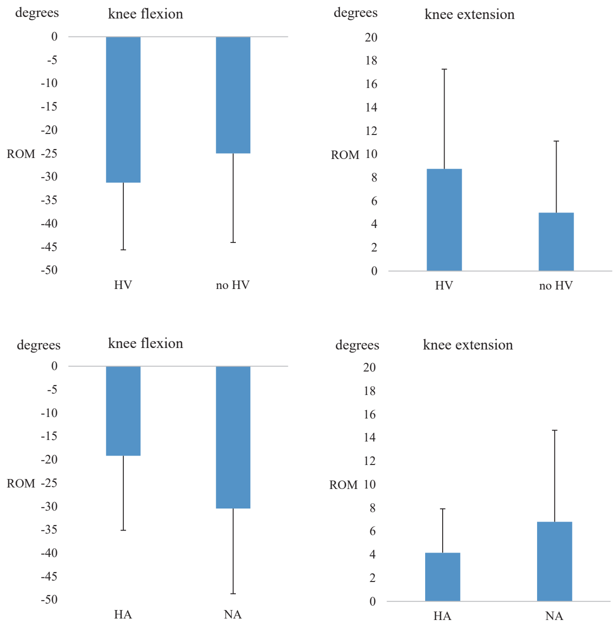

Fig. 5 Changes in range of motion (ROM) of knee joint from pre- to post-operation
There was no significant difference between the hallux valgus (HV) and no HV groups, or between the high arch (HA) and normal arch (NA) groups. Each vertical bar indicates a standard deviation.

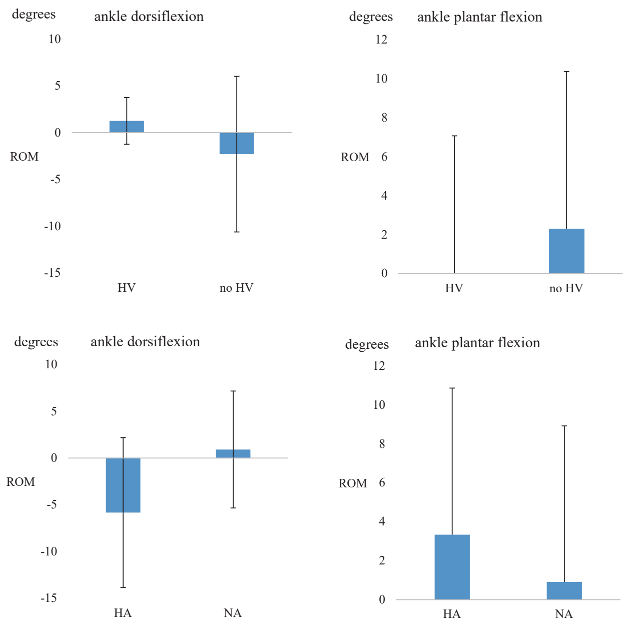

Fig. 6 Changes in range of motion (ROM) of ankle joint from pre- to post-operation
There was no significant difference between the hallux valgus (HV) and no HV groups, or between the high arch (HA) and normal arch (NA) groups. Each vertical bar indicates a standard deviation.

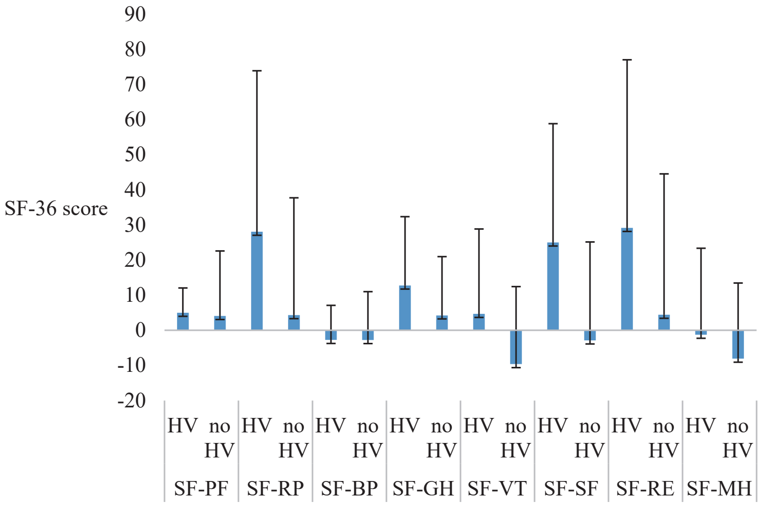

Fig. 7 Comparisons of score changes of SF-36 from pre- to post-operation between the hallux valgus (HV) and the no-HV groups

There was no significant difference. Each vertical bar indicates a standard deviation.

SF-36: the 36-item short-form health survey
PF: physical function
RP: role functioning physical
BP: bodily pain
GH: general health perception
VT: vitality
SF: social functioning
RE: role functioning emotional
MH: mental health

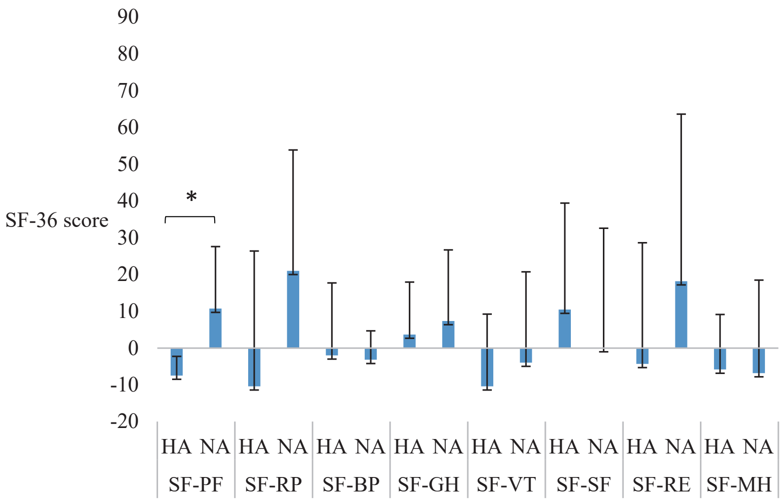

Fig. 8 Comparisons of score changes of SF-36 from pre- to post-operation between the high arch (HA) and normal arch (NA) groups

SF-PF was significantly higher in the normal arch (NA) group than in the high arch (HA) group. Each vertical bar indicates a standard deviation.

* $p=0.0224$ (the non-paired *t*-test).

SF-36: the 36-item short-form health survey
PF: physical function
RP: role functioning physical
BP: bodily pain
GH: general health perception
VT: vitality
SF: social functioning
RE: role functioning emotional
MH: mental health

DISCUSSION

A previous study showed that HV and flat feet are examples of foot misalignments associated with KOA patients.[6,7,9] In this study, HV and HA were observed. Bi O Jeong et al described that following the correction of varus deformity of the knee by TKA, significant compensatory reactions occurred in the ankle and the subtalar joints.[19] However, there were no reports of changes in foot alignment, and none of them reported the effects of foot alignment on postoperative physical function and QOL. In this study, there was no significant difference in any item regarding the presence/absence of HV. In contrast, in the HA group, the improvement in SF-PF scores was significantly poor. Moreover, in the HA group, the improvement in ankle dorsiflexion was numerically lower, although this did not reach statistical significance, which may have affected the decrease in the SF-PF.

There were no significant differences in age, K-L classification, or rehabilitation period between any foot alignments, but preoperative FTA was significantly lower in the HA group. In this group, surgery may have been selected before the knee varus worsened. Factors that determine receiving TKA include KOA severity, degree of knee pain, limited knee ROM, and decreased ADL and QOL. There was no significant difference between any of the foot alignment groups in preoperative K-L classification or knee pain VAS. Further, we could not find any significant difference in QOL due to any foot alignment in any items of SF-36. There was no significant difference in the knee ROM, but flexion in the HA group (107 degrees) was more restrictive than that in the NA group (119 degrees). We did not investigate ADL disorders, but difficulty in standing up due to flexion restriction has been reported as an ADL disorder in KOA patients.[20] Therefore, early restriction of knee flexion in KOA patients with HA causes ADL disorders, and TKA may be selected before knee varus deformity progresses.

HA can be caused by neuromuscular diseases such as Charcot-Marie-Tooth disease and hereditary factors, but it often occurs as a result of various functional deteriorations in the foot and ankle joints.[21] Factors involved in the HA are considered to be (1) the effect of the kinematic chain that causes the inversion movement of the foot due to the external rotation of the lower leg, and (2) decreased extensibility of the triceps surae muscle and excessive traction.

Regarding the former factor, Hamai et al demonstrated that knees in KOA are always in external tibial rotation compared to healthy knees.[22] Farrokhi et al analyzed knee kinematics during downhill walking with two-way X-ray fluoroscopic images, and reported that the varus KOA was always in the external rotation of the lower leg, and the mobility of the internal rotation was smaller than that of a healthy knee.[23] Due to KOA the ROM of the internal rotation of the lower leg was limited, and when the external rotation of the lower leg is performed for a long period of time, the subtalar joint is in the supination position due to the movement chain, which promotes the inversion movement of the foot and may cause HA. There is no report on the correlation between HA and the severity of KOA, but Nakao et al reported that in an HA group, intrinsic muscle strength and the 2-step test were significantly decreased compared to low arch and NA, which affected the decrease in mobility function.[24] Therefore the presence of HA may be implicated in diminished physical function. However, the research period of this study is short, and it is unclear how the foot alignment changes after TKA. We believe that longer-term follow-up evaluation will be necessary for future research.

Regarding the latter factor, plantar fascia is partly continuous with the triceps surae muscle and tendon tissue, and tension increases due to decreased extensibility of the triceps surae muscle.[25] In this way shortening of the triceps surae promotes elevation of the medial longitudinal arch.[26] Also triceps surae tightness is a cause of ankle dorsiflexion disorders,[27] and when dorsiflexion limitation of the ankle joint is recognized, the peroneus longus muscle works more predominantly than the tibialis anterior muscle, and the first metatarsal bone is pulled strongly in the plantar flexion direction, so that the medial longitudinal arch tends to rise.[28] In KOA, the knee flexion and extension, and ankle dorsiflexion are reduced compared to healthy knees[29] and gastrocnemius contracture has been reported to be the cause of flexion contracture of the hip and knee joints.[30] Therefore in TKA patients with preoperative knee flexion contracture, the gastrocnemius muscle tightness may limit the ankle dorsiflexion and promote HA. However, in this study, although preoperative knee flexion restriction was particularly marked in the HA group, no significant difference was observed, and further investigation to address this issue will be necessary in the future.

On the other hand, regarding HV, Nishimura et al reported that moderate to severe HV was associated with decreased physical function such as decreased grip strength and decreased maximum walking speed, but was not related to the presence of KOA.[31] The development of HV involves intrinsic muscles such as the flexor hallucis brevis, abductor hallucis brevis, and abductor hallucis valgus stiffness and lateral deviation of the plantar fascia,[32] and it is considered that dysfunction and deterioration of QOL due to HV are not directly related to KOA because the gastrocnemius is not involved. In this study as well, there were no significant differences in the knee and ankle ROM, knee pain VAS, or SF-36 according to the presence/absence of HV.

Thus, for patients with HA who underwent TKA, the preoperative knee flexion limitation and impaired ADL may be prominent, and the postoperative recovery and QOL in terms of physical function may be poor. Therefore physical therapy from the lower leg to the ankle joint and foot in addition to the knee joint, such as internal rotation of the lower leg, stretching of the triceps surae muscle, ROM training of the ankle joint, mobilization of the foot, and muscle strength training of the toe flexor muscle may be effective in improving physical function and QOL at discharge.

This study has some limitations. First, the number of cases was small, and we did not find any cases with flat feet in this study, but the distribution of foot misalignment might change. Second, this was a short-term evaluation during hospitalization at our hospital, and the long-term results were not explored. In this study, 15 of 17 patients were discharged to their homes, and the SF-36 score might change within six months or one year of discharge. Third, postoperative foot alignment could not be evaluated. This study evaluated the foot radiographs before surgery, and TKA might change the foot alignment after surgery. Finally, few physical therapy was given to the ankle or foot. Physical therapy for the ankle and foot might have improved the SF-36 scores at discharge.

CONCLUSION

Postoperative SF-PF was significantly reduced in patients with initial TKA who presented with HA. Physical therapy from the lower leg to the ankle joint and foot should also be considered when performing TKA in patients with HA.

ACKNOWLEDGMENTS

We gratefully acknowledge the work of past and present members of our department.

CONFLICT OF INTEREST

All authors declare that they have no conflict of interest.

REFERENCES

1 Palomo-López P, López-López D, Becerro-de-Bengoa-Vallejo R, et al. Concurrent Validity of the Foot Health Status Questionnaire and Study Short Form 36 for Measuring the Health-Related Quality of Life in Patients with Foot Problems. *Medicina (Kaunas).* 2019;55(11):750. doi:10.3390/medicina55110750.

2 Siviero P, Marseglia A, Biz C, et al. Quality of life outcomes in patients undergoing knee replacement surgery: longitudinal findings from Qpro-Gin study. *BMC Musculoskelet Disord.* 2020;21(1):436. doi:10.1186/s12891-020-03456-2.

3 Fujimoto A, Suzuki R, Orihara K, et al. Health-related quality of life in peripheral blood stem cell donors and bone marrow donors: a prospective study in Japan. *Int J Hematol.* 2020;111(6):840–850. doi:10.1007/s12185-020-02852-7.

4 Ware JE Jr, Sherbourne, CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care*. 1992;30(6):473–483. doi:10.1097/00005650-199206000-00002.

5 Rao S, Riskowski JL, Hannan MT. Musculoskeletal conditions of the foot and ankle: assessments and treatment options. *Best Pract Res Clin Rheumatol.* 2012;26(3):345–368. doi:10.1016/j.berh.2012.05.009.

6 Roddy E, Zhang W, Doherty M. Prevalence and associations of hallux valgus in a primary care population. *Arthritis Rheum.* 2008;59(6):857–862. doi:10.1002/art.23709.

7 Nishimura A, Fukuda A, Nakazora S, et al. Prevalence of hallux valgus and risk factors among Japanese community dwellers. *J Orthop Sci.* 2014;19(2):257–262. doi:10.1007/s00776-013-0513-z.

8 Iijima H, Ohi H, Isho T, et al. Association of bilateral flat feet with knee pain and disability in patients with knee osteoarthritis: A cross-sectional study. *J Orthop Res.* 2017;35(11):2490–2498. doi:10.1002/jor.23565.

9 Levinger P, Menz HB, Fotoohabadi MR, Feller JA, Bartlett JR, Bergman NR. Foot posture in people with medial compartment knee osteoarthritis. *J Foot Ankle Res.* 2010;3:29. doi:10.1186/1757-1146-3-29.

10 Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient-relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. *J Rheumatol*. 1988;15(12):1833–1840.

11 Guler H, Karazincir S, Turhanoglu AD, Sahin G, Balci A, Ozer C. Effect of coexisting foot deformity on disability in women with knee osteoarthritis. *J Am Podiatr Med Assoc.* 2009;99(1):23–27. doi:10.7547/0980023.

12 Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. *Ann Rheum Dis*. 1957;16(4):494–502. doi:10.1136/ard.16.4.494.

13 Younger AS, Sawatzky B, Dryden P. Radiographic assessment of adult flatfoot. *Foot Ankle Int*. 2005;26(10):820–825. doi:10.1177/107110070502601006.

14 Kido M, Ikoma K, Sotozono Y, et al. The influence of hallux valgus and flatfoot deformity on metatarsus primus elevates: A radiographic study. *J Orthop Sci.* 2020;25(2):291–296. doi:10.1016/j.jos.2019.03.020.

15 Gould N. Graphing the adult foot and ankle. *Foot Ankle*. 1982;2(4):213–219. doi:10.1177/107110078200200407.

16 Seaman TJ, Ball TA. *Pes Cavus.* In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023.

17 Fukuhara S, Bito S, Green J, Hsiao A, Kurokawa K. Translation, adaptation, and validation of the SF-36 Health Survey for use in Japan. *J Clin Epidemiol.* 1998;51(11):1037–1044. doi:10.1016/s0895-4356(98)00095-x.

18 Fukuhara S, Ware JE Jr, Kosinski M, Wada S, Gandek B. Psychometric and clinical tests of validity of the Japanese SF-36 Health Survey. *J Clin Epidemiol.* 1998;51(11):1045–1053. doi:10.1016/s0895-4356(98)00096-1.

19 Jeong BO, Kim TY, Baek JH, Jung H, Song SH. Following the correction of varus deformity of the knee through total knee arthroplasty, significant compensatory changes occur not only at the ankle and subtalar joint, but also at the foot. *Knee Surg Sports Traumatol Arthrosc.* 2018;26(11):3230–3237. doi:10.1007/s00167-018-4840-7.

20 Hoogeboom TJ, van Meeteren NL, Kim RH, Stevens-Lapsley JE. Linear and curvilinear relationship between knee range of motion and physical functioning in people with knee osteoarthritis: a cross-sectional study. *PLoS One.* 2013;8(9):e76173. doi:10.1371/journal.pone.0076173.

21 DiGiovanni CW, Greisberg J, eds. *Foot & Ankle: Core knowledge in orthopedics.* 1st ed. Philadelphia: Elsevier; 2007.

22 Hamai S, Moro-oka TA, Miura H, et al. Knee kinematics in medial osteoarthritis during in vivo weight-

bearing activities. *J Orthop Res.* 2009;27(12):1555–1561. doi:10.1002/jor.20928.

23 Farrokhi S, Meholic B, Chuang WN, Gustafson JA, Fitzgerald GK, Tashman S. Altered frontal and transverse plane tibiofemoral kinematics and patellofemoral malalignments during downhill gait in patients with mixed knee osteoarthritis. *J Biomech.* 2015;48(10):1707–1712. doi:10.1016/j.jbiomech.2015.05.015.

24 Nakao H, Imaoka M, Hida M, et al. Correlation of medial longitudinal arch morphology with body characteristics and locomotive function in community-dwelling older women: A cross-sectional study. *J Orthop Surg (Hong Kong).* 2021;29(2):23094990211015504. doi:10.1177/23094990211015504.

25 Huerta JP. The effect of the gastrocnemius on the plantar fascia. *Foot Ankle Clin.* 2014;19(4):701–718. doi:10.1016/j.fcl.2014.08.011.

26 DiGiovanni CW, Kuo R, Tejwani N, et al. Isolated gastrocnemius tightness. *J Bone Joint Surg Am.* 2002;84(6):962–970. doi:10.2106/00004623-200206000-00010.

27 Baumbach SF, Braunstein M, Seeliger F, Borgmann L, Böcker W, Polzer H. Ankle dorsiflexion: what in normal? Development of a decision pathway for diagnosing impaired ankle dorsiflexion and M. gastrocnemius tightness. *Arch Orthop Trauma Surg.* 2016;136(9):1203–1211. doi:10.1007/s00402-016-2513-x.

28 Manoli A 2nd, Graham B. The subtle cavus foot, "the underpronator". *Foot Ankle Int.* 2005;26(3):256–263. doi:10.1177/107110070502600313.

29 Matsumura M, Usa H, Ogawa D, Ichikawa K, Hata M, Takei H. Pelvis/lower extremity alignment and range of motion in knee osteoarthritis: A case-control study in elderly Japanese women. *J Back Musculoskelet Rehabil.* 2020;33(3):515–521. doi:10.3233/BMR-171038.

30 You JY, Lee HM, Luo HJ, Leu CC, Cheng PG, Wu SK. Gastrocnemius tightness on joint angle and work of lower extremity during gait. *Clin Biomech (Bristol, Avon).* 2009;24(9):744–750. doi:10.1016/j.clinbiomech.2009.07.002.

31 Nishimura A, Ito N, Nakazora S, Kato K, Ogura T, Sudo A. Does hallux valgus impair physical function? *BMC Musculoskelet Disord.* 2018;19(1):174. doi:10.1186/s12891-018-2100-0.

32 Taş S, Çetin A. Mechanical properties and morphologic features of intrinsic foot muscles and plantar fascia in individuals with hallux valgus. *Acta Orthop Traumatol Turc.* 2019;53(4):282–286. doi:10.1016/j.aott.2019.03.009.