

## RESEARCH ARTICLE

# The Effect of Total Knee Arthroplasty on Hindfoot Alignment in Patients with Severe Genu Varum and Genu Valgum

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## Abstract

**Background:** The maintenance of deformity in the ankle and hindfoot after correction of knee deformity following knee arthroplasty may cause abnormal tension in the knee and patient dissatisfaction. The aim of this study was to determine the effect of knee arthroplasty on the hindfoot alignment in patients with severe genu varum and valgum.

**Methods:** A total of 84 patients with primary osteoarthritis, were enrolled in the study. The knee deformity was measured using a long leg film before surgery. The long axial radiographic view of hindfoot was taken in the standing position for all patients, before and six months after surgery. Comparisons were made on changes in the hindfoot angles measured before and after surgery.

**Results:** A total of 84 patients with mean age of  $62.28 \pm 7.77$  years, 77 (92%) and seven patients (eight percent) had knee varus and valgus deformity, respectively. In the knee varus group, the mean preoperative hindfoot angle was  $+ 5.32 \pm 6.12^\circ$  (valgus) which was changed to  $- 0.25 \pm 4.91^\circ$  (varus) in the postoperative phase. In the knee valgus group, the mean pre and postoperative hindfoot angles were  $- 7.71 \pm 7.06^\circ$  (varus) and  $- 2.14 \pm 5.92^\circ$  (varus), respectively. The mean preoperative hindfoot angle in severe and very severe varus knee groups were  $+ 5.45 \pm 3.30$  and  $+ 5.28 \pm 6.86^\circ$ , respectively. These angles were changed to  $+ 0.21 \pm 5.17$  and  $- 1.60 \pm 3.89^\circ$  six months after surgery, respectively. The mean preoperative hindfoot angle in severe and very severe valgus knee deformity groups were  $- 7.00 \pm 4.69$  and  $- 8.66 \pm 10.69^\circ$ , respectively. These angles were changed to  $- 2.00 \pm 5.71$  and  $- 2.33 \pm 7.50^\circ$  after surgery, respectively. There was no significant difference between patients with severe and very severe deformity in terms of pre and post-operative hindfoot angle.

**Conclusion:** The hindfoot alignment is significantly corrected after knee arthroplasty. The severity of knee deformity does not correlate with the severity of the hindfoot deformity before and after surgery.

**Level of evidence:** I

**Keywords:** Genu valgum, Genu varum, Hindfoot alignment, Knee arthroplasty

## Introduction

The mechanical axis of lower limb or weight bearing line (WBL) passes just medial to the center of the knee by a line extended from the center of the

femur head to the ankle center (1). In a limb with normal alignment, the medial compartment will tolerate 60-70% of the weight bearing force (2).

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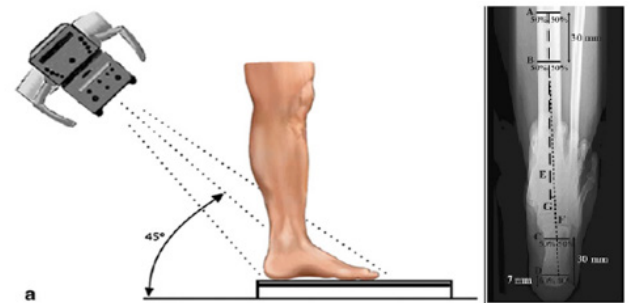
The mechanical axis deviation seen in the lower limb during genu varum and genu valgum deformities can lead to deviation of the ground reaction force (GRF) and challenge the strategy of postural control in the standing position (3). Foot supination or pronation can lead to poor posture control in the unipedal standing (4). These changes can lead to mechanical axis deviation (MAD) in the frontal plane as well as displacement of the center of pressure on the sole plate (5). Considering the effect of genu valgum and genu varum on knee MAD and the effect of supination and pronation on the ankle MAD, the results of these studies indicate that this deviation can have a significant impact on the lack of balance (6).

The hindfoot alignment of about five degrees (valgus) provides an appropriate stability in the ankle and normally passes a weight bearing line from the medial calcaneus. This causes a small amount of forefoot pronation, which in turn causes proper weight distribution toward the plantar. The slight hindfoot valgus also allows the forefoot to be flexible (7).

Osteoarthritis is a common cause of varus and valgus deformity of the knee. Knee varus and valgus are effective on the hindfoot alignment and affect the coronal hip-knee-ankle alignment (8). This disturbance in coronal plane causes the subtalar joint to compensate for this deformity. The subtalar valgus and varus are caused by osteoarthritis of the knee varus and knee valgus, respectively (7). Bihave et al. stated that six percent of the functional problems after total knee arthroplasty (TKA) are due to the inappropriate hindfoot alignment of the same side (2). Accordingly, considering the effects of knee varus or valgus on the hindfoot alignment, we decided to study the relationship between the severity of knee and hindfoot deformity and to investigate the correction of hindfoot deformity after total knee arthroplasty in patients with severe genu varum and genu valgum deformity.

### Materials and Methods

A total of 84 patients (84 knees) with primary osteoarthritis of the knee who were candidates of total knee arthroplasty were enrolled in the study. The knee deformity was measured using a long leg film before surgery. Coronal knee deformities with angles more than  $10^\circ$  between mechanical axes of femur and tibia were considered as severe deformity and enrolled. Coronal malalignment of more than  $15^\circ$  was considered as very severe deformity. In order to investigate the severity of hindfoot deformity, long axial radiographic view was taken in the standing position before and six months after surgery [Figure 1]. Hindfoot valgus of two degrees was considered as neutral alignment (17). Therefore, angles greater than two degrees of valgus were considered as the valgus deviation more than the standard and are recorded by positive numbers. Angles less than two degree of valgus and hindfoot varus were defined as deviations below the standard and recorded by a negative numbers. Comparisons were made on changes in the hindfoot angles measured before and after surgery. Measurement method for the long axial view defined in this way: the mid-diaphyseal axis of the tibia by bisecting the tibia



B)

**Figure 1. Long axial view of ankle, A. measurement method of hindfoot alignment, B. patient positioning.**

into two mid-diaphyseal points with 30 mm distance and extending the line distally. The mid-diaphyseal axis of the calcaneus was defined by a line through the two points in the calcaneus. At a distance of 7 mm from the most distal part of the calcaneus, a horizontal line was drawn. This horizontal line was divided into 40%:60% ratio, where the length of the 40% line is measured from the lateral side. A second line was drawn horizontally, 30 mm from the most distal part of the calcaneus. The calcaneus axis was drawn by connecting the 40% mark at the first and the second line (that bisected (50%:50% ratio)). The hindfoot angle was the angle between this line of calcaneus and the line drawn on midtibia [as in Figure 1] (17).

The exclusion criteria were: underlying neuromuscular disease, knee or ankle degeneration due to trauma or underlying diseases other than knee osteoarthritis, and previous fracture in the thigh, leg or ankle leading to the deformity of the limb as well as systemic arthritis. Data analysis was carried out using SPSS ver. 20. Mean ( $\pm$ SD) and frequency plus frequency percentage were recorded for quantitative and qualitative variables, respectively. Paired t-test was used to investigate and compare the hindfoot alignment before and after the knee arthroplasty and its relationship with knee alignment was compared using the Pearson's regression test.

### Results

In this self-controlled clinical trial, 84 patients were examined in terms of hindfoot alignment

**Table 1. Hindfoot alignment before and after knee arthroplasty in all patients and those with knee valgus and varus deformities (Mean ± SD)**

Variable	Hindfoot before surgery	Hindfoot after surgery	P value
All patient	+4.23±7.14	-0.416±4.99	0.0001
Valgus knee	-7.71±7.06	-2.14±5.92	0.025
Varus knee	+5.32±6.12	-0.25±4.91	0.0001
P value (Comparing groups with knee varus and valgus deformity)	0.0001	0.343	

**Table 2. The mean hindfoot alignment before and after surgery based on the severity of deformity**

group	Hindfoot alignment before surgery	Hindfoot alignment after surgery	P value before surgery	P value after surgery
Very severe varus knee deformity	+5.28±6.86	+0.21±5.17	0.061	0.113
Severe varus knee deformity	+5.45±3.3	-1.6±3.891		
Very severe valgus knee deformity	-8.66±10.69	-2.33±7.5	0.08	0.71
Severe valgus knee deformity	-7.0±4.697	-2.0±5.712		

in preoperative phase and six months after knee arthroplasty. The mean age of the patients was  $69.28 \pm 7.77$  years. Sixty five patients (77.4%) were women and 19 patients (22.6%) were men. Among 84 patients, 77 patients (92%) and seven patients (eight percent) had knee varus and valgus deformities, respectively. The mean preoperative hindfoot angle was  $+4.23 \pm 7.14$  degree of valgus in all patients, which was changed to  $-0.416 \pm 4.99$ ° varus after the surgery. This change was statistically significant ( $P=0.0001$ ) [Table 1]. In patients with knee varus deformity, the mean preoperative hindfoot alignment was  $+5.32 \pm 6.12$ ° valgus, which was changed to  $-0.25 \pm 4.91$ ° varus after surgery. Also, the mean preoperative hindfoot alignment was  $-7.71 \pm 7.06$ ° valgus in patients with valgus knee deformity which was changed to  $-2.14 \pm 5.92$ ° varus. Fifty five percent improvement was seen in the hindfoot alignment of valgus knee group and 174 percent improvement in varus knee group.

The results showed a significant difference between the valgus and varus knee deformity groups before surgery in terms of the hindfoot alignment ( $P < 0.0001$ ). However, there was no significant difference between the above groups in terms of the postoperative hindfoot alignment ( $P > 0.05$ ) [Table 1]. Also, there was a significant difference among patients with knee varus deformity ( $P = 0.0001$ ) as well as those with knee valgus deformity ( $P = 0.0205$ ) in terms of pre and post-operative hindfoot angles [Table 1]. There was no significant difference in valgus and varus knee deformity groups in terms of gender and age ( $P > 0.05$ ).

In order to evaluate the effect of knee deformity severity on the hindfoot alignment and its postoperative correction rate, patients were divided into two groups based on the angle between the mechanical axes of femur and tibia. Patients with  $10 - 15$ ° of deformity were placed

in severe deformity group and those with more than  $15$ ° were placed in very severe deformity group. In the varus knee group, 57 (74%) and 20 patients (26%) had very severe and severe deformity, respectively. In the valgus knee group, three (42.9%) and four patients (57.1%) had very severe and severe deformity, respectively. The mean preoperative hindfoot alignment was  $+5.28 \pm 6.86$ ° and  $+5.45 \pm 3.30$ ° valgus in the group with very severe and severe varus knee deformity, respectively. Also, the mean preoperative hindfoot alignment was  $-8.66 \pm 10.69$  and  $-7.00 \pm 4.69$ ° varus in the groups with very severe and severe valgus deformity, respectively. There was no correlation between the severity of preoperative knee deformity and preoperative hindfoot deformity in both genu varum and genu valgum groups ( $P = 0.061$  and  $P = 0.08$ , respectively) [Table 2]. The mean postoperative hindfoot alignment in the groups with very severe and severe varus knee deformity was  $+0.21 \pm 5.17$  and  $-1.60 \pm 3.89$ °, respectively. The mean postoperative hindfoot alignment in groups with the very severe and severe valgus deformity was  $-2.33 \pm 7.50$  and  $-2.00 \pm 5.71$ °, respectively. There was also no correlation between the severity of preoperative knee deformity and postoperative hindfoot alignment in both genu varum and genu valgum groups ( $P = 0.113$ ,  $P = 0.710$ , respectively) [Table 2].

A significant difference was seen between the patients with varus and valgus knee deformities with regard to hindfoot deformity preoperatively ( $P = 0.0001$ ). Before surgery, 63 patients had hindfoot valgus and varus knee deformity and 14 patients had hindfoot varus and varus knee deformity and seven patients had hindfoot varus and valgus knee deformity. However, no significant difference was observed after the surgery. In fact, before the surgery, most patients with knee varus had their hindfoot in the valgus alignment and

**Table 3. Frequency of knee and hindfoot deformity before and after surgery**

variable	group	Varus knee number(percent)	Valgus knee number(percent)	P value
Before surgery	valgus hindfoot	63 (81/81)	0(0)	0/0001
	varus hindfoot	14 (18/18)	7(100)	
After surgery	valgus hindfoot	24 (31/16)	2 (28/57)	0/628
	varus hindfoot	53 (68/83)	5 (71/42)5	

patients with knee valgus had their hindfoot in the varus alignment [Table 3].

### Discussion

In a varus deformity, the load bearing axis (LBA) passes medially to the knee and increases the force applied to the medial compartment (9). In a valgus deformity, the LBA passes laterally to the knee midline and increases the force applied to the lateral compartment (10). In a valgus deformity, more force is likely to be applied to the ankle medially (11). An excessive asymmetrical load to the knee prosthesis component due to inappropriate alignment of the limb or a ligament imbalance can result in bone collapse and component failure (12, 13). The postoperative limb alignment also plays a very important role in long term outcomes of total knee prostheses (9).

In many previous studies, coronal deformity of more than 10° caused by knee osteoarthritis was considered as severe and more than 15° as very severe deformity (14-16). The hindfoot alignment cannot be measured by usual lateral and Anteroposterior radiography. In most studies, hindfoot alignment view and long axial view radiographs are used to evaluate the hindfoot alignment. It has been shown that the long axial view has been more reliable in measuring the hindfoot alignment than the hindfoot alignment view and was recommended to use for evaluation of hindfoot alignment (17). The mean angles obtained for the hindfoot alignment vary according to how radiographs are measured. If long axial view radiographs are used in bipedal and unipedal standing positions, the mean of 2.2 and 3.2 degree valgus will be obtained, respectively. If the hindfoot alignment view is used in bipedal and unipedal standing positions, the mean of 3.3 and 4.3 degree valgus will be obtained, respectively (17).

In a normal knee, the mechanical axis of the limb is closely linked to the hindfoot alignment. If the mechanical axis of the limb is changed to the varus or valgus, the hindfoot alignment will shift to the varus or valgus accordingly. For every degree increase in the valgus mechanical axis angle, the hindfoot shifts into varus by -0.43°, and for every degree increase in the varus mechanical axis angle, the hindfoot shifts into valgus by -0.49° (18). There is a controversy in the literature regarding that how much deformity of hindfoot should be corrected. Kenan et al. suggested that any hindfoot deformity should be corrected before TKA to minimize stress on the implant

(19). Most of the recent studies have suggested that TKA should be initially performed, and the correction of the lower limb alignment after TKA leads to changes in the ankle alignment (20-23).

This self-controlled clinical trial was carried out on 84 patients for the hindfoot alignment in preoperative phases and six months after knee arthroplasty. Among 84 patients, 77 patients (92%) had varus deformity and seven (eight percent) of them had valgus deformity. The mean preoperative hindfoot angle was  $+4.23 \pm 7.14^\circ$  valgus, which was changed to  $-0.416 \pm 4.99^\circ$  varus in the postoperative phase ( $P=0.0001$ ). In the varus deformity group, the mean preoperative hindfoot angle was  $+5.32 \pm 6.12^\circ$  valgus and was changed to  $-0.25 \pm 4.91^\circ$  varus in the postoperative phase. In the valgus deformity group, the mean pre and postoperative hindfoot angle were  $-7.71 \pm 7.06^\circ$  varus and  $-2.14 \pm 5.92^\circ$  varus, respectively. Fifty five percent improvement was seen in the hindfoot alignment of valgus knee group and 174% improvement in varus knee group. The results showed a significant difference between the valgus and varus deformity groups before surgery in terms of the hindfoot alignment ( $P<0.0001$ ). However, there was no significant difference between the two groups in terms of the hindfoot alignment after the surgery ( $P>0.05$ ). Significant correction of hindfoot deformity was obtained in both patients with knee varus ( $P=0.0001$ ) valgus ( $P=0.0205$ ) deformities after surgery.

There was no correlation between severity of preoperative knee deformity and preoperative hindfoot deformity in both genu varum and genu valgum groups ( $P=0.061$  and  $P=0.08$ , respectively). There was also no correlation between the severity of preoperative knee deformity and postoperative hindfoot alignment in both genu varum and genu valgum groups ( $P=0.113$  and  $P=0.710$ , respectively) [Table 2].

The hindfoot in patients with varus knee deformity before the surgery was in valgus and varus in 63 and 14 patients, respectively; while, it was in varus in all patients with valgus deformity before surgery. However, no significant difference was observed after the surgery. In fact, before surgery, most patients with knee varus had their hindfoot in the valgus and patients with knee valgus had their hindfoot in the varus.

Jeong et al. conducted a study to investigate the changes in the ankle and hindfoot alignment in 375 knees with varus deformity following arthroplasty. The mean knee deformity angle was changed from  $10.6 \pm 5.1^\circ$  varus

before surgery to  $0.1 \pm 3.2^\circ$  varus. They used radiographic view to determine the hindfoot alignment. The heel angle was changed from  $11.4 \pm 7.0^\circ$  before surgery to  $5.0 \pm 7.4^\circ$  postoperatively. The hindfoot alignment was significantly changed to the varus ( $P < 0.001$ ). They concluded that the knee varus deformity was more associated with ankle and hindfoot valgus deformity. Therefore, ankle and hindfoot alignment should be investigated before the surgery (24). Their results were consistent with the results of the present study.

Gao et al. in their study of 149 patients including 24 valgus knees, 82 unilateral and 43 patients (86 knees) bilateral varus knees, the talus-articular angle (TAA) was used to measure hindfoot alignment. This angle was obtained as the angle between the horizontal line and a line that passes through the talus dome. There was a significant difference between the ankle-knee alignment before and after the surgery ( $P < 0.05$ ). The preoperative TAA angle in patients with knee varus was  $3.6 \pm 6.8^\circ$ , which was changed to  $-1.4 \pm 5.0^\circ$  after the surgery. The preoperative and postoperative TAA angle in patients with knee valgus was  $-6.9^\circ$  and  $-1.1^\circ$ , respectively. The ankle alignment was corrected after surgery (25). Their results were consistent with the results of our study.

Norton et al. in 518 cases of knee arthroplasty showed that hindfoot deformity is more likely to occur in cases with simultaneous knee and ankle pathology. They showed that each one degree of valgus and varus deviation in limb mechanical axis, causes  $0.43^\circ$  varus and  $0.49^\circ$  valgus deviation in the hindfoot, respectively (18). In contrast to Norton et al.'s study, the present study showed no relationship between the severity of knee deformity and the hindfoot deformity. This difference may be due to the larger sample size in Norton et al.'s studies. However, in other studies such as a Mullaji's study, as in the present study, the severity of knee deformity was not related to the severity of the hindfoot deformity. This difference could also be attributed to the fact that they investigated patients with an abnormality or pathology in their ankles.

Nakada et al. performed a study on 110 patients with rheumatoid arthritis (RA) undergoing knee arthroplasty in Japan and observed that there was a significant correlation between the knee and hindfoot deformities. The greater the knee deformity, the more severe the hindfoot deformity. A stronger relationship was observed in the group with damaged subtalar joints with a Larsen grade of less than three ( $P = 0.004$ ). These results emphasize the importance of examining the foot and ankle in patients with RA before arthroplasty (26). The present study is not consistent with their study. This difference with our study may be attributed to the fact that their study focused on patients with RA, who were not included in the present study.

Duggal et al. conducted a computer-aided study of the effect of hindfoot alignment on mechanical axis deviation of the lower limbs. This study showed a significant relationship between the knee varus or valgus deformities and hindfoot deformity. The minimum and maximum conventional mechanical axis deviation

(MADC) and ground mechanical axis deviation (MADG) in the bipedal standing was  $-63.08^\circ$ ,  $+63.08^\circ$ ,  $-107.63^\circ$ , and  $+113.14^\circ$ , respectively. The minimum and maximum difference between MADG and MADC was 44.55 and 50.06, respectively. They highlighted the importance of using MADG to include the effect of the hindfoot deformity along with lower extremities in this study (27).

Mullaji et al. examined the mechanical axis that included the hindfoot and the tibioalcanal angle in 125 subjects. There was a marked improvement in the hindfoot valgus after surgery. In their study, the hindfoot alignment was evaluated using weight-bearing modified Cobey's view. They used two mechanical axes in their study. One was the same conventional mechanical axis (CMA) and the ground mechanical axis (GMA). GMA measures the mechanical axis instead of a line that runs from the center of the femur head to the center of the ankle using the ground reaction point. The hindfoot valgus decreased regardless of the severity of the hip-knee-ankle (HKA) deformity. There was a relationship between the knee varus deformity and hindfoot valgus. Finally, they concluded that the exact recovery of the limb alignment after the TKA may depend on hindfoot valgus and ground MAD, which passes through the lateral to center of the knee, and this can affect the lifespan of the implant (28). Similar to our study, they showed no correlation between the severity of the limb deformity and the degree of hindfoot correction.

Desai et al. observed that there is a significant relationship between the knee varus angle and the degree of the hindfoot correction after arthroplasty (12). In an interventional study, Hara used new hindfoot radiographic view to measure the hindfoot angle. Hindfoot was corrected after the arthroplasty in the valgus hindfoot group ( $P < 0.001$ ), while this correction was not observed in the varus group (29). In the present study also, the valgus hindfoot group was corrected more than the varus hindfoot group.

Chandler et al. also showed that the hindfoot alignment was corrected significantly after knee arthroplasty and was significantly correlated with the severity of knee deformity. In general, the valgus and varus deformities remain in valgus and varus, respectively; although their angles were reduced by half after TKA. As in the present study, the severity of knee deformity was not related to the severity of the hindfoot deformity ( $P = 0.22$ ) (20).

Significant corrections were observed in all patients in terms of the mean pre and postoperative hindfoot angles. Fifty five percent improvement was seen in the hindfoot alignment of valgus knee group and 174% improvement in varus knee group. The results showed a significant difference between the knee valgus and varus deformity groups before surgery in terms of the hindfoot alignment, but, no significant difference after surgery. There was also no correlation between the severity of preoperative knee deformity and preoperative and postoperative hindfoot alignment in both genu varum and genu valgum groups. Before the surgery, most patients with knee varus had their hindfoot in the valgus and patients with knee valgus had their hindfoot in the varus.

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