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## Alignment of the hindfoot following total knee arthroplasty: A systematic review

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### Abstract

#### BACKGROUND

There appears to be a close relationship between deformities at the knee joint and at the hindfoot in patients with knee osteoarthritis (OA). Despite this intrinsic link, there is a dearth of studies investigating alterations in hindfoot alignment following total knee arthroplasty (TKA) in patients with knee OA.

#### AIM

To evaluate changes in alignment of the hindfoot following TKA, foot and ankle clinical outcomes in terms of subjective clinical scoring tools following surgical intervention, and to analyse the level of evidence (LOE) and quality of evidence (QOE) of the included studies.

#### METHODS

MEDLINE, EMBASE and Cochrane Library databases were systematically reviewed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Studies reporting changes in the postoperative alignment of the hindfoot following TKA were included. The level and QOE were recorded and assessed.

#### RESULTS

Eleven studies with a total of 1142 patients (1358 knees) met the inclusion/exclusion criteria. Six studies were of LOE II and 5 studies were of LOE III. Patients with preoperative varus knee deformity and valgus hindfoot deformity demonstrated improvement in hindfoot alignment post TKA. Patients with preoperative varus knee deformity and varus hindfoot deformity demonstrated no improvement in hindfoot alignment following TKA. Twelve different radiographic parameters were used to measure the alignment of the hindfoot across the included studies, with the tibio-calcaneal angle most frequently utilised

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(27.3%).

## CONCLUSION

This systematic review demonstrated that the hindfoot may display compensatory changes in alignment following TKA in patients with knee OA. However, the marked heterogeneity between the included studies and poor QOE limits any meaningful cross sectional comparisons between studies. Further, well designed studies are necessary to determine the changes and outcomes of hindfoot alignment following TKA.

**Key Words:** Total knee arthroplasty; Hindfoot alignment; Hindfoot; Knee osteoarthritis; Varus knee deformity; Valgus hindfoot deformity

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**Core Tip:** This current systematic review has found that correction of deformities at the knee joint following total knee arthroplasty typically resulted in improved changes in the alignment of the hindfoot. However, the poor quality of evidence together with the marked heterogeneity between the included studies, underscores the need for further higher quality studies.

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## INTRODUCTION

Osteoarthritis (OA) of the knee is one of the leading causes of pain in the older population, affecting 30% of adults over the age of 60 years old[1]. Although the etiology and pathogenesis of knee OA remains unclear, knee malalignment is a significant risk factor for knee OA. Even minor changes in knee alignment can lead to abnormal load distribution across the articular surface of the knee joint, leading to degeneration of the joint capsule and further progression of OA[2,3]. Replacement procedures, such as total knee arthroplasty (TKA), aim to restore neutral mechanical alignment of the lower extremity.

The alignment of the lower extremity is frequently evaluated by extrapolating the femoral-tibial angle (FTA) and the mechanical axis from standing, full-length, plain radiographs[4,5]. However, the FTA and mechanical axis provide an incomplete picture of the alignment of the lower limb as they exclude assessment of the hindfoot axis. There are a variety of reports demonstrating a relationship between varus or valgus deformities at the knee joint and hindfoot malalignment in patients with knee OA[6-16]. In fact, hindfoot malalignment has been shown to improve following TKA in patients with knee OA[6-10,12-16]. This suggests that knee OA leads to compensatory changes in the hindfoot or, hindfoot deformities may predispose the knee to osteoarthritic change. As a result, pre and post-operative radiological imaging of the hindfoot, *via* Cobey views or otherwise, is crucial in the management of knee OA[17].

Despite the intrinsic link between deformities at the knee joint and the hindfoot in knee OA, there appears to be scant literature extensively investigating the relationship between these 2 pathologies. There also seems to be no consensus regarding the optimal imaging method for hindfoot alignment. The purpose of this systematic review was to evaluate changes in hindfoot alignment and foot and ankle clinical outcomes in terms of subjective clinical scoring tools following TKA.

## MATERIALS AND METHODS

### Search strategy

During October 2019, a systematic review of the MEDLINE, EMBASE and Cochrane Library databases was performed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Figure 1) guidelines. The following search terms were used: [(Hindfoot OR foot OR ankle) AND (alignment OR malalignment OR misalignment OR position OR kinematics OR axis OR anatomy) AND (knee replacement OR TKR OR knee arthroplasty OR TKA)]. The inclusion and exclusion criteria are shown in Table 1. Following retrieval of the data, the titles, abstracts and full text articles were screened by two independent reviewers of all searched studies by applying the aforementioned criteria. A senior author was consulted to arbitrate any disagreements that arose.

### Assessment of level of evidence and methodological quality

The level of evidence (LOE) was assessed using the criteria published by the Journal of Bone & Joint Surgery. The methodological quality of evidence (QOE) was assessed using the Modified Coleman Methodology Score (MCMS)[18]. Two independent reviewers determined the MCMS for each study. If any discrepancy existed, the senior author evaluated the available data and a consensus was reached. Excellent studies had a score between 85 to 100 points, good studies scored between 70 to 84 points, fair studies had a score between 55 to 69 points and poor studies scored less than 55 points.

### Data extraction and evaluation

Two independent reviewers independently extracted and assessed the data from each study. Patient demographic data and postoperative follow up times were gathered. Radiographic parameters used to evaluate the alignment of the hindfoot, lower extremity and ankle joint were also collected. Data on postoperative clinical outcomes in terms of subjective clinical scoring tools were evaluated.

### Statistical analysis

All other statistical analyses were performed using SAS software version 9.3 (SAS Institute, Inc., Cary, NC, United States). Descriptive statistics were calculated for all continuous and categorical variables. Continuous variables were reported as weighted mean and estimated standard deviation, whereas categorical variables were reported as frequencies with percentages. A value of  $P < 0.05$  was considered statistically significant.

## RESULTS

The search generated 2606 studies. Of these, 11 met the inclusion and exclusion criteria of this systematic review (Table 1). The studies were published between 2004 and 2019.

### Patient demographics

From the 11 studies, 1142 patients (1358 knees) with a weighted mean age of  $69.1 \pm 3.6$  years (range, 63.4-74.7), had radiographic imaging of the hindfoot following TKA. The weighted mean postoperative follow-up time was  $10.9 \pm 9.4$  mo (range, 0.75-31.3) (Table 2).

### LOE and QOE

Six studies were LOE II and 5 studies were LOE III. The mean MCMS of all included studies was  $53.5 \pm 8.5$  of 100 points. No studies were classified as excellent quality using the MCMS. There was 1 study of good quality, 3 studies of fair quality and 7 studies of poor quality. 8 studies had a large patient cohort ( $n > 60$ ).

### Radiologic assessment

The radiologic assessment data are listed in Table 3. Twelve different radiographic parameters were used to evaluate the alignment of the hindfoot. The most commonly utilised radiographic tool was the tibio-calcaneal angle (TCA) in 3 studies (27.3%)[6,7,13]. Other radiographic parameters utilised included the varus-valgus angle (VVA) in 2 studies (18.2%)[8,16], hindfoot alignment view angle (HAVA) in 1 study[10], calcaneal pitch and naviculocuboid overlap in 1 study (9.1%)[14], tibia-hindfoot angle

**Table 1 Inclusion and exclusion criteria**

Inclusion criteria	Exclusion criteria
Clinical studies related to changes in the hindfoot following TKA	Less than 10 patients
Published in a peer review journal	Case reports
Written in English	Cadaveric studies
Full text version available	Animal studies
	Review articles
	<i>In vivo</i> studies

TKA: Total knee arthroplasty.

**Table 2 Study characteristics and patient demographics**

Ref.	LOE	Patients, n (%)	Knees, n (%)	Age (yr)	Sex (M/F)	Follow-up (mo)	MCMS
Chandler and Moskal[6], 2004	2	86	86	N/R	N/R	3	48
Cho <i>et al</i> [7], 2017	2	117	195	69.1	8/187	24	66
Hara <i>et al</i> [8], 2015	3	100	100	74.3	14/86	0.75	48
Jeong <i>et al</i> [9], 2018	2	331	375	68.3	23/308	6	60
Kim <i>et al</i> [10], 2018	3	55	65	69.3	N/R	31.3	71
Levinger <i>et al</i> [11], 2012	2	19	26	67.5	13/6	12	46
Mansur <i>et al</i> [12], 2019	2	72	72	N/R	23/49	3	44
Mullaji and Shetty[13], 2011	2	125	165	66.1	24/101	12	51
Okamoto <i>et al</i> [14], 2017	3	75	80	72.5	8/67	24	48
Palanisami <i>et al</i> [15], 2020	3	91	121	63.4	29/62	12	58
Takenaka <i>et al</i> [16], 2016	3	71	73	74.7	17/56	12	48

LOE: Level of evidence; M/F: Male/female; MCMS: Modified Coleman methodological score.

and varus-valgus index (VVI) in 1 study (9.1%)[15], foot posture index in 1 study (9.1%)[11], the hindfoot alignment angle (HA), hindfoot alignment ratio (HR) and hindfoot alignment distance (HD) in 1 study (9.1%)[9], and the intersection of the load axis of the leg and the calcaneus axis in 1 study (9.1%)[12].

Six radiographic parameters were used to measure the alignment of the lower extremity, the most common of which was the FTA in 4 studies (36.4%)[6,8,11,12]. Other radiographic tools used included mechanical axis in 2 studies (18.2%)[9,14], mechanical axis deviation angle in 1 study (9.1%)[10], mechanical alignment angle in 1 study (9.1%)[7], conventional mechanical axis deviation in 1 study (9.1%)[13], femorotibial mechanical angle in 1 study (9.1%)[15].

Only 3 studies (27.3%) recorded the alignment of the ankle joint, with the talar tilt (TT) utilised in 3 studies (27.3%)[9,10,14], the tibial anterior surface angle (TAS) used in 2 studies (18.2%)[9,10], the ground talar dome angle of foot (GD) and lateral surface angle of distal tibia used in 1 study each (9.1%)[9], the TAS, distal medial clear space (DMCS), and medial tibiotalar joint space (MTTJS) and frontal tibial ground angle (FTGA) were utilised in 1 study each (9.1%)[10].

### **Changes in hindfoot alignment following TKA**

Ten studies evaluated changes in hindfoot alignment following TKA for patients with varus deformity of the knee joint[7-16]. Nine of these studies demonstrated improvement of hindfoot valgus alignment following TKA[7-10,12-16]. Chandler and Moskal[6], Cho *et al*[7] and Mullaji and Shetty[13] showed a mean postoperative improvement in TCA of 3.1°, 3.1° and 2.0° respectively. Hara *et al*[8] and Takenaka *et al* [16] highlighted a mean postoperative improvement in VVA of 3.1° and 3.4° respectively. Jeong *et al*[9] demonstrated a mean postoperative improvement in HA,

Table 3 Summary of outcomes

Ref.	Patients, n (%)	Knees, n (%)	Knee deformity	Radiographic Assessment		AOFAS			
				Hindfoot	Ankle	Lower limb alignment	Pre-op	Post-op	Postoperative outcomes
Chandler and Moskal [6], 2004	86	86	Both valgus and varus	TCA: Pre-op = 0.4°; Post-op = -0.1°		FTA: Pre-op = 3.6°; Post-op = 6.6°			Both valgus and varus hindfoot alignment improved post TKA  Valgus hindfoot alignment remained in valgus alignment post TKA  Varus hindfoot alignment remained in varus alignment post TKA
Cho <i>et al</i> [7], 2017	117	195	Varus only	TCA: Pre-op = 5.2° valgus; Post-op = 2.1° valgus		Mechanical alignment angle: Pre-op = 10.8° varus; Post-op = 1.8° varus			Valgus hindfoot alignment improved post TKA  Severe varus knee deformities had best improvement in hindfoot alignment post TKA
Hara <i>et al</i> [8], 2015	100	100	Varus only	VVA: Pre-op = 78.8°; Post-op = 76.7°		FTA: Pre-op = 186.7°; Post-op = 174.4°			Varus hindfoot alignment with varus knee deformity remained in varus alignment post TKA  Valgus hindfoot alignment with varus knee deformity improved post TKA
Jeong <i>et al</i> [9], 2018	331	375	Varus only	HA: Pre-op = 13.5°; Post-op = 5.8°. HR: Pre-op = 0.2°; Post-op = 0.3°. HD: Pre-op = 11.0°; Post-op = 5.2°	TT: Pre-op = 0.4°; Post-op = 0.1°. GD: Pre-op = 6.5°; Post-op = 0.2°. TAS: Pre-op = 92.0°; Post-op = 92.0°. TLS: Pre-op = 81.8°; Post-op = 81.3°	Mechanical axis: Pre-op = 11.1° varus; Post-op = 0.3° varus			Valgus hindfoot alignment improved post TKA  Subtalar joint became more varus post TKA
Kim <i>et al</i> [10], 2018	55	65	Varus only	HAVA: Pre-op = 6.1°; Post-op = 5.7°	TT: Pre-op = 1.9°; Post-op = 1.7°. TAS: Pre-op = 85.9°; Post-op = 84.9°. MCS: Pre-op = 2.4 mm; Post-op = 2.6 mm. MITJS: Pre-op = 2.8°; Post-op = 2.3°. FIGA: Pre-op = 85.6°; Post-op = 86.5°	Mechanical axis deviation angle: Pre-op = 10.0°; Post-op = 1.9°	95.2	91.5	Valgus hindfoot alignment slightly improved post TKA  Newly developed ankle pain post TKA was associated with larger degrees of residual varus knee deformity
Levinger <i>et al</i> [11], 2012	19	26	Varus only	FPI: Pre-op = 2.9°; Post-op = 2.7°		FTA: Pre-op = -1.2°; Post-op = 4.9°			Increased range of motion of the rearfoot in the frontal plane post TKA  No change in static foot pressure post TKA
Mansur <i>et al</i> [12], 2019	72	72	Both varus and valgus	Intersection of the load axis of the leg and the calcaneus axis: Pre-op = -3.8°; Post-op = -4.4°		FTA: Pre-op = ?	74.3	89.4	Varus hindfoot alignment with varus knee deformity remained in varus alignment post TKA  Varus hindfoot alignment with valgus knee deformity, valgus hindfoot alignment with valgus knee deformity and valgus hindfoot alignment with varus knee deformity all improved post TKA
Mullaji and Shetty [13],	125	165	Both varus and valgus	TCA: Pre-op = 188°; Post-op = 185.5°		CMAD: Pre-op = 34.3 mm;			Valgus hindfoot alignment with varus knee deformity

2011						Post-op = 0.0 mm. GMAD: Pre-op = 31.0 mm; Post-op = -6.0 mm	improved post TKA
Okamoto <i>et al</i> [14], 2017	75	80	Varus only	Calcaneal pitch: Pre-op = 14.9°. Naviculocuboid overlap: Pre-op = 84.7°; Post-op = 65.7°	TT: Pre-op = 13.1°; Post-op = 4.4°. TI: Pre-op = 9.9°; Post-op = 0.8°	Mechanical axis: 46.6 60.2 Pre-op = 5.0°; Post-op = 0.7°	87% of patients had persistent valgus hindfoot alignment post TKA  Valgus hindfoot alignment with severe varus knee deformity did not improve post TKA  Valgus hindfoot alignment with moderate varus knee deformity improved post TKA
Palanisami <i>et al</i> [15], 2020	91	121	Varus only	TH: Pre-op = 9.9°; Post-op = 4.7°. VVI: Pre-op = -0.29; Post-op = -0.04		FTMA: Pre-op = 162.0°; Post-op = 178.8°	Valgus hindfoot alignment with varus knee deformity improved post TKA  TKA restores foot loading pattern medially
Takenaka <i>et al</i> [16], 2016	71	73	Varus only	VVA: Preop = 78.2; Post-op = 76.0		FTA: Pre-op = 184.8; Post-op = 173.9	Valgus hindfoot alignment with varus knee deformity improved post TKA  Varus hindfoot alignment with varus knee deformity did not improve post TKA

TKA: Total knee arthroplasty; FTA: Femoral-tibial angle; VVA: Varus valgus angle; TH: Tibial hindfoot; VVI: Varus-valgus index; FTMA: Femorotibial mechanical angle; AOFAS: American Orthopaedic Foot and Ankle Society; TCA: Tibio-calcaneal angle; FPI: Foot posture index; MTTJS: Medial tibiotalar joint space; FTGA: Frontal tibial ground angle; HA: Hindfoot alignment; CMAD: Conventional mechanical axis deviation.

HR and HD of 7.7°, 0.1° and 5.8° respectively. Kim *et al*[10] illustrated a mean postoperative improvement in HAVA of 1.4°. Mansur *et al*[12] demonstrated a mean postoperative improvement of hindfoot alignment of 3.6. Okamoto *et al*[14] illustrated a mean postoperative improvement in naviculocuboid overlap of 19.0°. Palanisami *et al*[15] highlighted a mean postoperative improvement in VVI of 0.25.

Okamoto *et al*[14] noted that a cohort of patients with severe varus knee deformity did not show correction of hindfoot malalignment following TKA[14]. Conversely, Cho *et al*[7] showed that patients with severe varus knee deformity had the greatest overall improvement in hindfoot alignment. Patients with a severe varus knee deformity displayed a mean change in HA of 4.0° ± 3.0° in contrast to patients with a less severe varus knee deformity who displayed a mean change in HA of 1.8° ± 2.5°[7].

Three studies highlighted that patients with preoperative hindfoot varus malalignment with varus deformity at the knee joint retained varus hindfoot alignment post TKA[8,12,16].

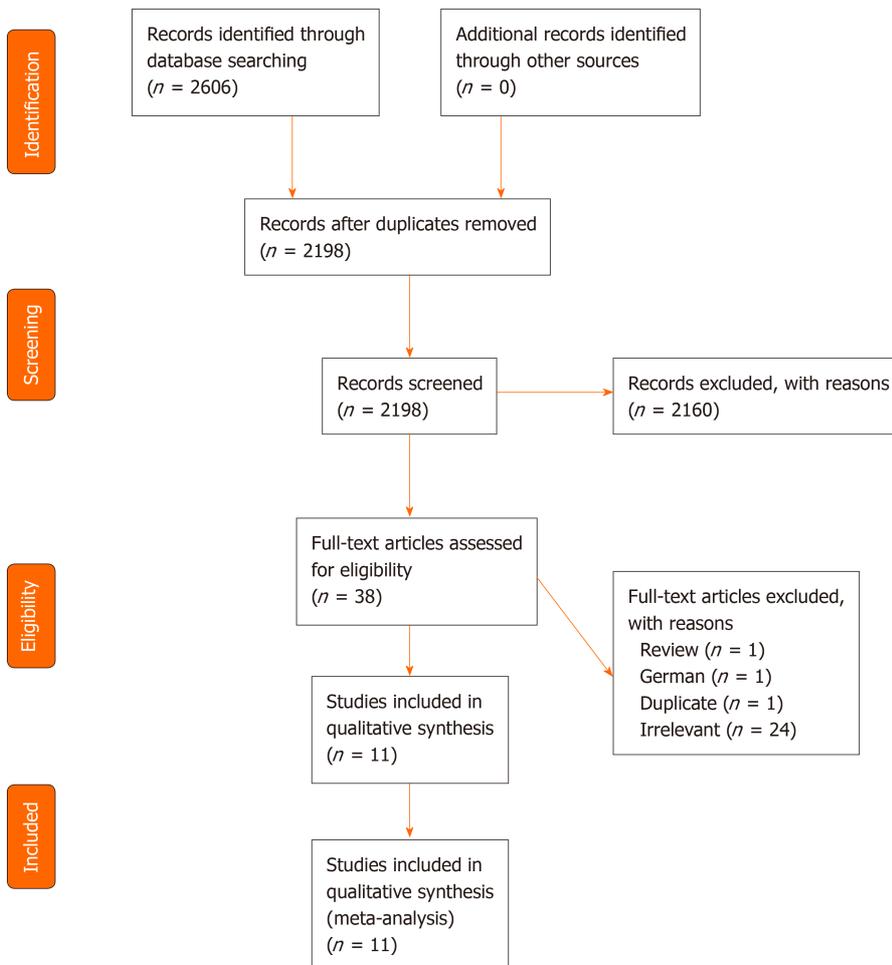
Two studies investigated alterations in hindfoot alignment following TKA in patients with valgus deformity at the knee joint[12,13]. Both studies recorded improvements in postoperative hindfoot varus alignment. Mansur *et al*[12] reported an increase in mean hindfoot alignment axis of 7.5, while Mullaji and Shetty[13] recorded a mean decrease in TCA of 1.5°. Also, Mullaji and Shetty[13] reported an improvement in postoperative hindfoot valgus alignment, as evident by a decrease in mean hindfoot alignment axis of 3.3.

### Changes in ankle joint alignment following TKA

Three studies reported changes in ankle joint alignment following TKA for knee OA[9,10,14]. There was a decrease in the TT postoperatively in 2 studies, indicating a varus shift in the TT[9,14], with no significant change reported in 1 study[14]. The GD shifted towards a valgus alignment in 1 study[9]. The TLS changed significantly in 1 study[9]. The TAS, DMCS, MTTJS and FTGA showed no statistically significant change following TKA.

### Subjective clinical outcomes

Clinical outcomes were evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) score in 4 studies[10,12,14,15]. The weighted mean preoperative AOFAS score improved from 66.1 ± 18.1 to 82.0 ± 12.9 postoperatively at a mean of 17.6 mo of follow-up. One study reported that patients with newly developed ankle



**Figure 1** A systematic review of the MEDLINE, EMBASE and Cochrane Library databases was performed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

pain or who experienced an aggravation of existing pain after TKA had significantly larger degrees of residual varus knee than patients without ankle pain before and after TKA or those with ankle pain before surgery that did not change during the follow-up period[10]. One study demonstrated that patients with severe preoperative varus deformity at the knee had no statistically significant improvement in AOFAS score following TKA

## DISCUSSION

This current systematic review has found that correction of deformities at the knee joint following TKA typically resulted in improved changes in the alignment of the hindfoot. However, the poor QOE together with the marked heterogeneity between the included studies, underscores the need for further higher quality studies.

All studies reported that preoperative varus or valgus knee deformity was associated with malalignment of the hindfoot. Typically varus knee OA was accompanied by a valgus hindfoot deformity. Furthermore, the findings of this current review highlights that patients who undergo TKA for a varus osteoarthritic knee with pre-existing valgus hindfoot deformity may display improvements in hindfoot alignment postoperatively. This suggests that these patients may have a residual capacity to compensate for the corrected lower limb malalignment. Interestingly, Cho *et al*[7] reported improvement in hindfoot alignment at 6 wk post TKA but little to no improvement at 2 years postoperatively, suggesting that compensatory changes in hindfoot alignment predominantly occur during the early postoperative period. This lack of improvement in hindfoot alignment at the 2 year follow up point may indicate that following the early postoperative period, there may be no further hindfoot alignment compensation as the knee joint alignment has now been corrected following

TKA. However, Takenaka *et al*[16] recorded improvement in hindfoot alignment at 3 wk post TKA with further improvement noted 1 year post TKA. The discrepancy between these 2 studies highlights that further research is warranted to understand the complex lower limb biomechanical alterations that occur in sequential postoperative time points following TKA.

This current study demonstrated that patients with co-existing varus knee deformities and varus hindfoot malalignment showed no improvement in hindfoot alignment post TKA[8,12,16]. There are several reasons that could explain this resistance to change in varus hindfoot deformity. Firstly, varus feet cause nonparallel alignment of the midtarsal axes, which in turn leads to the foot displaying rigid stability so as to support the body's weight[8]. This may reduce the ability of the preoperative varus hindfoot to change alignment following TKA of a varus osteoarthritic knee. Varus hindfoot is often associated with a rigid or non-correctible hindfoot alignment, either from increase calcaneal pitch or mechanical changes from neuromuscular changes that are not reversible. Charcot Marie Tooth is commonly associated with a varus hindfoot but this is typically not compensated for by knee realignment. In contrast, many valgus hindfoot alignments are correctible and flexible adapting to better alignment in the femoral tibia joint by re-establishing improved hindfoot alignment.

The ability to achieve a neutral alignment is essential if knee re-alignment is to have any measurable impact on hindfoot alignment. Tarsal coalition in valgus hindfeet and CMT and other neurological conditions associated with varus hindfeet will prevent re-establishing normal hindfoot alignment. In addition, advanced post-traumatic osteoarthritis (PTOA) of the ankle or subtalar joint will also prevent neutral alignment of the hindfoot[9]. The ability to change alignment of the hindfoot is critical in survivorship of the knee implant as persistent varus hindfoot deformity post TKA may lead to asymmetric wear, osteolysis and failure of the implant[19].

There were conflicting reports regarding the severity of knee joint deformity and postoperative outcomes. Okamoto *et al*[14] demonstrated that patients with severe varus knee deformity presented with postoperative hindfoot pain and valgus alignment[14]. This may in part be explained by the advanced stage of PTOA in the hindfoot and the advanced stage of knee varus malalignment from delayed operative intervention. Restriction in motion preventing restoration of neutral hindfoot alignment would be expected in the advanced stages of PTOA where peri articular osteophytes and soft tissue cicatrization would prevent choparts and ankle joint motion. In contrast, Cho *et al*[7] showed that patients who underwent surgical intervention for severe varus knee deformity had the best postoperative outcomes but his cohort was younger and had less advanced ankle arthritic change[7]. Further studies are required to determine the correlation between severity of knee deformity and post TKA outcomes, but it does seem that earlier intervention in knee OA is helpful in addressing knee pain but also has downstream effects on hindfoot biomechanical alignment and consequent health of the ankle joint.

This current systematic review has demonstrated that there is marked heterogeneity in the assessment of the alignment of the hindfoot. Twelve different radiographic parameters were utilised across the 11 studies, with the TCA being the most commonly utilised metric in 3 studies[6,7,13]. The lack of consensus regarding what radiographic parameter to utilise to evaluate the alignment of the hindfoot underpins the need for a standardised imaging protocol of the limb following knee arthroplasty. In addition, only 2 studies reported radiographic data at 2 or more sequential operative time points[7,16]. Assessing the alignment of the hindfoot at regular intervals postoperatively may be necessary to determine the time at which correction of hindfoot malalignment occurs and could possibly predict the time at which a surgical realignment of the hindfoot is required to protect the longevity of the knee implant (Table 4).

This current systematic review found that only 4 studies reported pre and postoperative clinical scoring systems, with the AOFAS score utilised in all 4 studies [10,12,14,15]. AOFAS scores tended to increase post TKA, suggesting that correction of lower limb malalignment resulted in improved functional and pain outcomes in the foot and ankle. Interestingly, 1 study demonstrated that patients presenting with new or aggravated pre-existing foot and ankle pain following TKA had a residual varus deformity at the knee joint[10]. Furthermore, Okamoto *et al*[14] reported that patients with severe varus deformity at the knee joint had no statistically significant improvement in AOFAS score, possibly due to loss of residual capacity for compensation in the hindfoot[14]. However, these outcomes should be assessed with caution due to a lack of a validated scoring tool for the foot and ankle following TKA.

Table 4 Hindfoot radiographic parameters

Hindfoot radiographic parameters	Studies, n (%)
TCA	3 (27.3)
VVA	2 (18.2)
HAVA	1 (9.1)
Intersection of the load axis of the leg and the calcaneus axis	1 (9.1)
TH	1 (9.1)
Calcaneal pitch	1 (9.1)
Naviculocuboid overlap	1 (9.1)
FPI	1 (9.1)
HA	1 (9.1)
HR	1 (9.1)
HD	1 (9.1)

TCA: Tibiocalcaneal angle; VVA: Varus valgus angle; HAVA: Hindfoot alignment view angle; TH: Tibial hindfoot angle; FPI: Foot posture index; HA: Hindfoot alignment angle; HR: Hindfoot alignment ratio; HD: Hindfoot alignment diameter.

This systematic review has several inherent limitations and/or potential biases. The criterion was limited to MEDLINE, EMBASE and Cochrane Library Database articles published exclusively in English. A further limitation was the marked heterogeneity between studies, in terms of both patient selection and pre and post-operative radiographic assessment. As a result, cross-sectional comparison amongst studies could not be analysed. Another limitation with this review is the poor QOE of the included studies. Lastly, the data was not extracted blindly, but was extracted by two independent reviewers and later confirmed by the lead author.

## CONCLUSION

In conclusion, this systematic review demonstrated that the hindfoot typically displays compensatory changes in alignment following TKA in patients with knee osteoarthritis. However, the marked heterogeneity between the included studies and poor QOE limits any meaningful cross sectional comparisons between studies. Further, well designed studies, are necessary to determine the changes and outcomes of hindfoot alignment following TKA.

## ARTICLE HIGHLIGHTS

### **Research background**

There are a variety of reports demonstrating a relationship between deformities at the knee joint and hindfoot malalignment in patients with knee osteoarthritis (OA).

### **Research motivation**

The relationship between knee joint deformities and alterations in hindfoot alignment following total knee arthroplasty (TKA) has not been fully investigated to date.

### **Research objectives**

To evaluate changes in alignment of the hindfoot following TKA and foot and ankle clinical outcomes in terms of subjective clinical scoring tools following surgical intervention.

### **Research methods**

MEDLINE, EMBASE and Cochrane Library databases were systematically reviewed. Studies reporting changes in the postoperative alignment of the hindfoot following

TKA were included.

### Research results

Eleven studies with a total of 1142 patients (1358 knees) were included. Patients with preoperative varus knee deformity and valgus hindfoot deformity demonstrated improvement in hindfoot alignment post TKA. Patients with preoperative varus knee deformity and varus hindfoot deformity demonstrated no improvement in hindfoot alignment following TKA. Twelve different radiographic parameters were used to measure the alignment of the hindfoot, with the tibio-calcaneal angle most frequently utilised (27.3%).

### Research conclusions

The hindfoot may display compensatory changes in alignment following TKA in patients with knee OA. However, the marked heterogeneity between the included studies and poor quality of evidence confounds the generation of robust conclusions from this review.

### Research perspectives

Further, higher quality studies are required to determine the changes and outcomes of hindfoot alignment following TKA.

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