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The Effectiveness of Tripod Index in Defining Hallux Valgus Deformity: A Retrospective Study

Kadir İlker YILDIZ [1], Mehmet ARICAN [2]

ABSTRACT

Aim: The aim of this study is to investigate the effectiveness and reliability of the Tripod Index (TI) in defining hallux valgus (HV) deformity and accompanying deformities and evaluating the treatment outcome.

Material and Methods: Fifty and fifty two patients were included to the study who underwent Chevron (group 1) and proximal dome (group 2) osteotomy, respectively. Preoperative and postoperative hallux valgus angle (HVA), intermetatarsal angle (IMA), Meary angle (MA), talar declination angle (TDA), calcaneal inclination angle (CIA), talar head uncover (THU) and TI were measured. Then, the relationship between TI and other angular variables was evaluated.

Results: There was no significant difference between the mean age, body mass index (BMI), side and gender of the patients in both groups. The mean values of HVA and IMA differed between two groups both pre- and postoperatively. The preoperative TDA, THU and MA values were significantly higher in group 2. The preoperative mean CIA was significantly higher in group 1. The preoperative value of the TI was significantly higher in group 2. There was a significant decrease in all angular parameters in group 2 postoperatively. There was a significant decrease in mean HVA, IMA and TI postoperatively in group 1. There was strong correlation between TI and IMA, THU, CIA, TDA and MA, and moderate correlation with HVA in both groups.

Conclusion: TI can provide partial data on the transverse and sagittal plane deformity of the first metatarsal deformity in HV with a single radiograph. Additionally, it can be a guiding measurement in evaluating the need for calcaneal shift osteotomy in pes planovalgus deformities accompanying HV. However, it is insufficient to define complex HV deformity alone.

Keywords: Hallux valgus; osteotomy; metatarsal deformity.

Halluks Valgus Deformitesinin Tanımlanmasında Tripod İndeksin Etkinliği: Retrospektif Bir Çalışma

ÖZ

Amaç: Bu çalışmada, Tripod Index'in (TI) halluks valgus (HV) deformitesini tanımlamada ve tedavi sonucunu değerlendirmede etkinliğini ve güvenilirliğini araştırmayı amaçladık.

Gereç ve Yöntemler: Bu çalışma, sırasıyla Chevron (grup 1) ve proksimal kubbe (grup 2) osteotomisi yapılan 50 ve 52 hastayı içermektedir. Halluks valgus açısı (HVA), intermetatarsal açı (İMA), Meary açısı (MA), talar eğim açısı (TEA), kalkaneal eğim açısı (KEA), talar baş örtünme (TBÖ) ve TI değerleri ameliyat öncesi ve sonrası ölçüldü. TI ile diğer açısal değişkenler arasındaki ilişki değerlendirildi.

Bulgular: Her iki gruptaki hastaların ortalama yaş, vücut kitle endeksi, taraf ve cinsiyet dağılımları arasında anlamlı bir fark yoktu. Ortalama HVA ve İMA değerleri iki grup arasında ameliyat öncesi ve sonrası farklılık saptandı. TEA, TBÖ ve MA değerleri incelendiğinde grup 2'nin preoperatif ortalama değeri anlamlı olarak yüksekti. Preoperatif ortalama KEA grup 1'de anlamlı olarak daha yüksekti. Preoperatif ortalama TI değerleri grup 2'de anlamlı derecede yüksekti. Grup 2'de postoperatif tüm açısal parametrelerde anlamlı azalma oldu. Grup 1'de ortalama HVA, İMA ve TI'de postoperatif olarak anlamlı düşüş vardı. Her iki grupta da TI ile İMA, TBÖ, KEA, TEA ve MA arasında güçlü, HVA ile orta derecede korelasyon vardı.

1 Istanbul Metın Sabancı Baltalimanı Bone Dıseases Training and Research Hospital, Istanbul, Turkey
2 Department of Orthopedic and Traumatology, Duzce University School of Medicine, Duzce, Turkey

Sorumlu Yazar / Corresponding Author: Kadir İlker YILDIZ, e-mail: kadirilkeryildiz@yahoo.com
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Sonuç: TI, HV deformitesinde birinci metatarsın transvers ve sagital düzlemdeki deformitesi hakkında tek bir radyografi ile kısmi veri sağlayabilir. Ayrıca, HV'ye eşlik eden pes planovalgus deformitelerinde kalkaneal kaydırma osteotomisi ihtiyacının değerlendirilmesinde yol gösterici bir ölçüm olabilir. Ancak kompleks HV deformitesini tek başına tanımlamakta yetersizdir.

Anahtar Kelimeler: Halluks valgus; osteotomi; metatarsal deformite.

INTRODUCTION

In hallux valgus deformity, medialization is observed in the first tarsometatarsal (TMT) joint, and lateralization in the first metatarsophalangeal joint of the hallux (1). Various radiological findings are used to assess the severity of HV. HV is regarded as transverse plan deformity in many previous studies, and the HVA formed by the first metatarsal and proximal phalanx axes is considered as diagnostic radiological parameter (2,3). In contrast, some recent research has revealed that the hallux valgus is a three-dimensional deformity that affects the frontal plane, leading to the rotation and pronation of the first metatarsal, along with the transverse and sagittal plane (4-8). HV is sometimes observed as a complex deformity, which is a combination of deformations such as thumb pronation, sesamoid lateralization, arch collapse or flat foot (8). Therefore, standard radiological measurements can sometimes be insufficient to describe the complexity of HV deformity (6-8).

TI was defined by Arunakul et al. (9) as a valid and reliable radiographic parameter to evaluate complex foot deformities such as pes planus and cavovarus foot, with a single measurement. It has been created with the need to explain complex deformities in different parts of the foot and compensatory changes for these deformities with a single measurement. This index uses the medial and lateral borders of the forefoot, the center of the heel and the head of the talus as reference points, interprets the deformity over the relationship between them (10). The aim of this study was to investigate the effectivity and reliability of TI for determining the HV deformity and also to compare the effect of different osteotomies on hindfoot, midfoot and forefoot by this index. Our hypothesis is that the first metatarsal deformity and accompanying midfoot and hindfoot deformities in HV can be defined by TI, similar to predefined axial and sagittal plane radiological parameters.

MATERIAL AND METHODS

After the approval of the Noninvasive-Clinical Ethics Committee of the Düzce University School of Medicine (2020 (2020/247)), 145 patients who applied to our orthopedic clinic with the diagnosis of hallux valgus and underwent corrective osteotomy between 2015-2018 were retrospectively reviewed. 137 patients without foot deformity, polyneuropathy and a history of foot surgery were detected. Of these, 58 had been treated by chevron osteotomy and 59 had been treated by proximal dome osteotomy. Different corrective osteotomies had been performed to the remaining 20 patients. 50 patients who underwent Chevron osteotomy (group 1) and 52 who underwent proximal dome osteotomy (group 2) were included in the study. None of these patients had complications of delayed wound healing, non-union or reflex sympathetic dystrophy.

Preoperative and postoperative standard weight-bearing anteroposterior (AP) and lateral foot radiographs were used for the radiographic evaluation. For determination of the heel center, a hemispheric marker was used during perform radiographs (Figure 1).

Figure 1: Clinical photograph demonstrating placement of foot for AP radiograph with hemispherical markers around the heel

HVA, IMA, MA, TDA, CIA, THU and TI (Figure 2) measurements were performed by two observers using INFINITT PACS digital measurement system (Infinite Healthcare Co., Seoul, South Korea) tools on x-ray radiographs. These measurements were repeated at fourth week of postoperation.

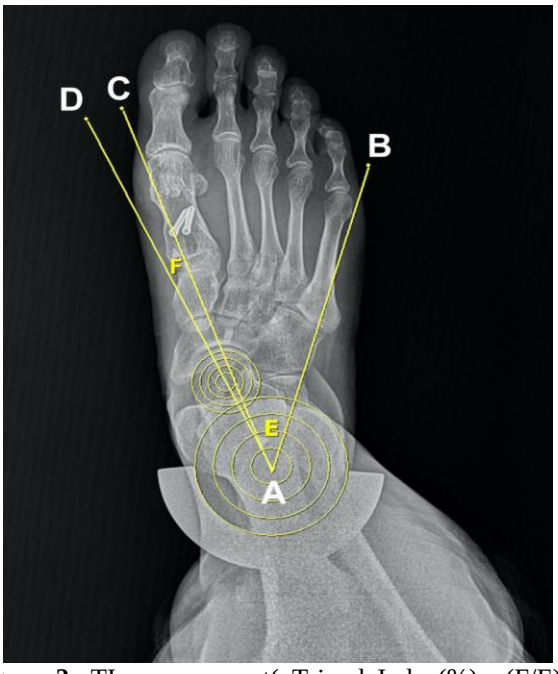

Figure 2: TI measurement(Tripod Index(%)= (F/E) x 100) on AP weight-bearing radiograph with hemispherical markers around the heel (E: Angle between AB and AC lines, F: Angle between AC and AD lines

Statistical analysis

All statistical analyses were performed by using Statistical Package for the Social Sciences (SPSS) version 20 (SPSS Inc., Chicago, IL, USA). The normal distribution of the data was determined by Kolmogorov-Smirnov test. The variables were presented as mean and standard deviation or median and range depending on the normality of the distribution. Student t test, Paired t test and Chi-square test were used to compare continuous and categorical variables, respectively. For all measured radiographic parameters, inter-observer and intra-observer reliability were evaluated with intra-class correlation coefficient (ICC). The relationship between TI and other angular variables were evaluated by Pearson correlation coefficient (PCC). A p-value of less than 0.05 was defined as statistically significant. The sample size was estimated by using the free-software G*Power 3.1.9.2 (Franz Faul, University of Kiel, Kiel, Germany). With a power of %80, the sample size for each group was calculated as 35.

RESULTS

In the Group 1 (n = 50), there were 43 female and 7 male patients. The mean age of this group was 46.96 ± 14.71 (19-73). The Group 2 included 46 female and 6 male. The mean age of this group was 43.90 ± 14.67 (20-67). In terms of laterality; 30 patients' right feet and 20 patients' left feet in Group 1; 28 patients' right feet and 24 patients' left feet in Group 2 were operated. Mean body mass index (BMI) of group 1 was 23.63 ± 2.82 (18.21-28.67), while in Group 2 this value was 24.65 ± 2.96 (18.04-32.05). As shown in Table 1, no significant difference was observed between the two groups in terms of age, body mass index, surgical side and gender distribution.

Table 1. Comparison of demographic data between groups

	Distal Chevron Osteotomy Group 1 (n=50)	**Proximal Dome Osteotomy Group 2 (n=52)**	**p**
Age	46.96 ±14.71 (19-73)	43.90 ±14.67 (20-67)	0.128
Gender			
Female	43	46	0.709
Male	7	6	
Surgical Side			
Right	30	28	0.530
Left	20	24	
Height (cm)	165.42 ±5.86 (152-179)	166.15 ±5.92 (151-182)	0.531
Weight (kg)	67.22 ±6.74 (54-89)	65.19 ±8.11 (51-84)	0.174
BMI (kg/m^2)	23.63 ±2.82 (18.21-28.67)	24.65 ±2.96 (18.04-32.05)	0.080

Table 2. Intraobserver and interobserver intraclass correlation coefficients for radiographic measurements.

Radiographic Parameters	**Intraobserver**	**Interobserver**
	Preop / Postop	**Preop / Postop**
HVA	0.89/0.92	0.86/0.85
IMA	0.92/0.88	0.87/0.83
TDA	0.82/0.85	0.84/0.88
CIA	0.94/0.91	0.89/0.87
MA	0.91/0.88	0.85/0.84
THU	0.92/0.91	0.86/0.85
TI	0.93/0.91	0.84/0.87

HVA: Hallux valgus angle , IMA: Intermetetarsal angle, TDA: Talar declination angle, CIA: Calcaneal inclination angle, MA: Meary's angle, THU: Talar head uncover, TI: Tripod index

The intra and inter-observer reliability for all radiographic parameters were good to excellent (Table 2). HVA and IMA values significantly decreased postoperatively in both groups (Table 3). Both preoperative and postoperative values were higher in Group 2. Preoperative TDA, THU and MA values were significantly higher in Group 2, but there was no significant difference between the groups in terms of these parameters postoperatively (Table 3). The preoperative CIA was found to be higher in group 1, but the postoperative value was not different between the groups. Preoperative TI values were significantly higher in Group 2, but postoperative TI values did not differ between the groups. While there was a significant decrease in all postoperative angular parameters in Group 2, there was no significant difference between the preoperative and postoperative TDA, CIA, THU and MA values in Group 1. In group 1, there was a significant decrease in the postoperative HVA, IMA and TI (Table 3). There was strong correlation between TI and IMA, THU, MA, CIA and TDA and moderate correlation with HVA regarding preoperative and postoperative measurements in both groups (Table 4).

Table 3. Comparison of mean values of HVA, IMA, CIA, talar-1st metatarsal angle, THU and TI within and between groups

	Distal Chevron Osteotomy	Proximal Dome Osteotomy	p*
Preop HVA	31.47 ±6.31 (24.73 - 48.42)	39.17 ±8.64 (29.12 - 55.31)	**0.049**
Postop HVA	16.54 ±2.31 (11.55 - 21.39)	18.54 ±2.88 (13.26 - 24.24)	**<0.001**
p**	**<0.001**	**<0.001**	
Preop IMA	11.83 ±2.87 (9.32 - 21.99)	14.10 ±3.42 (9.36 - 23.71)	**<0.001**
Postop IMA	7.52 ±1.11 (5.25 - 11.05)	8.30 ±1.22 (6.23 - 11.69)	**<0.001**
p**	**<0.001**	**<0.001**	
Preop TDA	23.49 ±2.83 (16.66 - 29.37)	22.81 ±2.49 (16.38 - 29.71)	0.201
Postop TDA	23.78 ±2.63 (16.94 - 29.25)	25.07 ±2.76 (18.34 - 31.27)	**0.017**
p**	0.092	**<0.001**	
Preop CIA	23.42 ±2.2 (18.67 - 28.01)	22.91 ±2.69 (16.57 - 27.27)	0.102
Postop CIA	23.06 ±2.19 (17.34 - 26.92)	19.83 ±2.49 (14.71 - 25.15)	**<0.001**
p**	0.067	**<0.001**	
Preop MA	1.36 ±2.21 (-3.70 - 5.11)	2.85 ±2.06 (-3.10 - 6.82)	**<0.001**
Postop MA	1.04 ±2.20 (-4.62 - 4.97)	1.39 ±2.50 (-5.76 - 4.79)	0.185
p**	0.097	**<0.001**	
Preop THU	1.09 ±0.74 (0.02 - 2.58)	1.23 ±0.78 (0.11 - 3.29)	0.369
Postop THU	1.21 ±0.77 (0.10 - 2.77)	1.86 ±0.73 (0.22 - 3.98)	**<0.001**
p**	0.379	**<0.001**	
Preop TI	7.62 ±10.83 (-24.89 - 37.12)	13.23 ±12.34 (-20.74 - 50.79)	**0.017**
Postop TI	5.52 ±11.19 (-30.85 - 36.30)	3.14 ±11.34 (-25.75 - 33.14)	0.288
p**	**<0.001**	**<0.001**	

*Student t test, **Paired t test / HVA:Hallux valgus angle , IMA: Intermetetarsal angle, TDA: Talar declination angle, CIA: Calcaneal inclination angle, MA: Meary's angle, THU: Talar head uncover, TI: Tripod index

Table 4. Correlation between mean TI and other angular parameters pre-postoperatively in both groups

r	Distal Chevron Osteotomy		Proximal Dome Osteotomy	
	Preop.	**Postop.**	**Preop.**	**Postop.**
HVA	0.324*	0.413**	0.393**	0.378**
IMA	0.491**	0.534**	0.511**	0.583**
MA	0.772**	0.789**	0.585**	0.638**
THU	0.625**	0.621**	0.661**	0.724**
TDA	0.500**	0.483**	0.464**	0.458**
CIA	-0.814**	-0.810**	-0.526**	-0.506**

Pearson correlation coefficient r values (*Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed)) / HVA:Hallux valgus angle , IMA: Intermetetarsal angle, MA: Meary's angle, THU: Talar head uncover, TDA: Talar declination angle, CIA: Calcaneal inclination angle

DISCUSSION

The most important finding obtained in this study is the strong correlation between TI and IMA, CIA, THU and MA, and moderate correlation with HVA which define midfoot and forefoot deformity in HV. In the past, many reliable and valid radiological parameters have been identified that evaluate the alignment of different parts of the foot in HV; as follows hindfoot: calcaneal pitch, tibiocalcaneal, and talocalcaneal angles; midfoot: talonavicular coverage angle; and forefoot: lateral and AP talar–1st metatarsal angles (11-13). But many studies have shown that hallux valgus is a three-dimensional complex deformity that affects the entire foot, therefore standart radiological measurements can be insufficient to define the whole deformity (5,14,15). In the literature, the relationship between HV and foot arc has been reported (8). Medial foot arc is an important structure in supporting body weight and shows structural changes under load (8,16). In the literature, it is known that HV can coexist with medial arch depression (16,17). In the study of Kim et al. (18) midfoot pronation was observed accompanying the forefoot deformity was in Juvenile HV. In patients with lapidus arthrodesis, Avino et al. (19) observed significant improvement in Meary's angle and medial cuneiform height, elevating the medial longitudinal arch and increasing the forefoot supination. Argerakis et al. (20) showed that scarf osteotomy caused a significant decrease in both IMA and Meary's angles, thus that type of osteotomy has a risk to medial arch collapse. However, they found no evidence that it affected the hindfoot (20).

It has been reported that the effect of the entire foot alignment on the subtalar joint and hindfoot can be

explained by evaluating the relationship between the foot tripod and the talar head center (21-22). Since the TI is determined by reference points on both of the forefoot and hindfoot, this measurement has the potential to evaluate the sum of the deformity within the hind foot, mid foot and forefoot in more than one plane. This index that developed by Arunakul et al. (10), showed 100% sensitivity and 93% specificity for flatfoot, 96% sensitivity and 95% specificity for pes cavus foot (10).

In the present study, it has been shown that proximal dome osteotomy significantly changed the hind foot, midfoot, and forefoot alignment parameters postoperatively. These data were found to be compatible with medial arch collapse and forefoot abduction, and are similar to many studies in the literature (18-20). Additionally, TI was strongly correlated with IMA, THU, MA, CIA and TDA, and moderately correlated with HVA in both groups undergoing proximal dome osteotomy and distal chevron osteotomy. These findings revealed that the TI can partially define the forefoot, midfoot and hindfoot deformity of the sagittal and transverse plan in patients with HV deformity, similar to the previously proven parameters. However, it is insufficient to explain the factors that may affect treatment options such as metatarsophalangeal joint incongruity, interphalangeal joint disruption, and hallux pronation. Although TI is insufficient in the evaluation of surgical options in HV deformity, it can be considered as a sensitive parameter that provides advantages such as saving time in the evaluation of the patients and preventing unnecessary radiation exposure, thanks to its ability to be performed with a single measurement in a single radiography. However, it can help to evaluate the hinfoot and midfoot deformities accompanying HV deformity and to determine additional surgical needs in the hind and midfoot.

To the best of our knowledge, this is the first study using TI to evaluate HV deformity. The limitations of this study include small size and selection bias. Patients who were operated with 2 different techniques for HV were compared in the study. Comparisons to be made with a control group without HV deformity in larger series can provide a more informative evaluation. Besides, there is a lack of clear information about frontal plane deformity, which is one of the most important components of HV deformity and defines metatarsal rotation.

TI can provide information about the transverse and sagittal deformity of the first metatarsal in HV deformity with a single measurement in a single radiograph, but it is not sufficient to evaluate the complex HV deformity alone. However, it can help to evaluate the midfoot and hindfoot deformities such as pes planovalgus and to evaluate the necessity of hindfoot surgeries such as calcaneal shift osteotomy. Further studies of modifications that may enable the definition of frontal plane deformity and hallux position may reveal an effective radiological parameter in identifying HV and guiding treatment.

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