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RESEARCH ARTICLE

Hallux Valgus Surgery: Radiographic and Biomechanical Outcomes

Halluks Valgus Cerrahisi: Radyografik ve Biyomekanik Sonuçlar

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ABSTRACT

Objective: This study aimed to evaluate the effects of hallux valgus surgery on radiographic deformity correction, pain reduction, and long-term foot biomechanical outcomes.

Material and Method: A total of 60 participants (30 HV patients and 30 healthy controls) aged 30-60 years were included in this study. HV patients were subdivided based on the surgical approach used: distal, proximal, or combined proximal and distal surgery. Foot angular measurements, including the hallux valgus (MTP) angle, intermetatarsal (IMT) angle, calcaneal inclination (CAI) angle, talo-calcaneal (TC) angle, and talo-metatarsal (TM) angle, were taken one week before surgery and one-year post-surgery. Pain was assessed using the Visual Analog Scale (VAS).

Results: Preoperative foot angular measurements (MTP, IMT, and CAI angles) were significantly different in HV patients compared to the control group ($p < 0.05$), indicating altered biomechanics before surgery. Postoperatively, the MTP and IMT angles differed significantly from the control group, suggesting that full anatomical correction may require longer-term follow-up. The CAI angle showed improvement postoperatively, reflecting recovery in foot alignment and stability. The IMT angle and VAS pain scores were significantly reduced after surgery ($p < 0.05$). There were no significant differences in outcomes between distal, proximal, or combined surgical methods.

Conclusion: Hallux valgus surgery significantly improves radiographic deformities and reduces pain. Improvement in the CAI angle indicates early recovery in foot alignment. Both distal and proximal techniques yield comparable outcomes, highlighting the importance of long-term follow-up to optimize functional results.

Keywords: Hallux Valgus, Foot Biomechanics, Surgery, Pain, Angular Measurements.

ÖZET

Amaç: Bu çalışmada halluks valgus cerrahisinin radyografik deformite düzeltme, ağrı azaltma ve uzun dönem ayak biyomekanik sonuçlarına olan etkilerinin değerlendirilmesi amaçlandı.

Gereç ve Yöntem: Çalışmaya yaşları 30-60 arasında değişen toplam 60 katılımcı (30 HV hastası ve 30 sağlıklı kontrol) dahil edilmiştir. HV hastaları, uygulanan cerrahi tekniğe göre distal, proksimal veya kombine (distal ve proksimal) cerrahi olmak üzere alt gruplara ayrılmıştır. Halluks valgus (MTP) açısı, intermetatarsal (IMT) açısı, kalkaneal inklinasyon (CAI) açısı, talo-kalkaneal (TC) açısı ve talo-metatarsal (TM) açısı dahil olmak üzere ayak açısal ölçümleri, ameliyattan bir hafta önce ve ameliyattan bir yıl sonra alınmıştır. Ağrı düzeyi Görsel Analog Skala (VAS) kullanılarak değerlendirilmiştir.

Bulgular: Ameliyat öncesi ayak açısal ölçümleri (MTP, IMT ve CAI açıları), HV hastalarında kontrol grubuna kıyasla anlamlı şekilde farklıydı ($p < 0.05$); bu durum, cerrahi öncesi biyomekanik değişiklikleri ortaya koymaktadır. Ameliyat sonrası MTP ve IMT açıları kontrol grubuna kıyasla hâlâ farklılık göstermekteydi; bu durum, tam anatomik düzeltme için daha uzun süreli takip gerekebileceğini göstermektedir. CAI açısında ameliyat sonrası anlamlı bir iyileşme gözlenmiş olup, bu durum ayak hizalanması ve stabilitesinde iyileşmeyi yansıtmaktadır. IMT açısı ve VAS ağrı skorları ameliyat sonrası anlamlı düzeyde azalmıştır ($p < 0.05$). Distal, proksimal ve kombine cerrahi yöntemler arasında sonuçlar açısından anlamlı bir fark bulunmamıştır.

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Sonuç: Halluks valgus cerrahisi radyografik deformiteleri ve ağrıyı anlamlı düzeyde düzeltmektedir. CAI açısındaki düzelme, ayak hizalanmasında erken iyileşmeyi göstermektedir. Distal ve proksimal teknikler benzer sonuçlar vermekte olup, uzun dönem takip fonksiyonel sonuçların en üst düzeye çıkarılması açısından önemlidir.

Anahtar Sözcükler: Halluks Valgus, Ayak Biyomekaniği, Cerrahi, Ağrı, Açısal Ölçümler.

The foot plays a critical role in proprioception, serving as the point of contact with the ground to facilitate walking. It supports body weight and acts as a lever during walking and running, propelling the body forward. The big toe, a highly specialized and mobile foot part, can bear up to 90% of the force exerted on the ground. During the push-off phase of walking, approximately 40% of body weight is transferred to the toes, with most of this load falling on the big toe. The big toe carries twice the load that all the other toes combined (1). Any pathology affecting the big toe significantly impacts the quality of life. Hallux valgus (HV) is one of the most common foot deformities, with a higher prevalence in women (2). In HV, the first MTP joint progressively subluxated due to lateral deviation of the first phalanx and medial deviation of the first metatarsal. This lateral deviation of the Hallux causes metatarsal rotation and valgus torque at the MTP joint, further displacing the Hallux from the joint surface. The resulting decrease in joint congruency and articular cartilage degradation leads to a reduced range of motion and pain in the MTP joint. In HV, the big toe deviates laterally and typically pronates relative to the metatarsal head. The plantar cushion and sesamoids are displaced in relation to the big toe, and the ligaments on the medial side of the joint become tense (3). The articulation between the metatarsal head and the phalanx shifts laterally and is marked by a sagittal groove where cartilage thinning occurs, beginning from a medial protrusion over which the tense ligaments pass. While the groove accommodating the lateral sesamoid appears normal, the groove for the medial sesamoid shows signs of erosion. Small osteophytes along the joint margin give the metatarsal head a square appearance in cross-section, deviating from its normally rounded shape. As the MTP joint becomes unstable and HV develops, deforming forces push the first toe laterally. This results in the proximal phalanx base pressing the metatarsal head medially, disrupting the muscle balance of the first toe. Consequently, HV becomes either permanent or progressive. There is no complete consensus on treating hallux valgus, and numerous surgical techniques have been proposed. While exercise therapies for HV may alleviate pain, they do not correct the deformity. Therefore, various surgical methods have been attempted (1-3).

Hallux valgus is classified into three groups based on radiographic measurements: mild, moderate, and severe. In mild hallux valgus, the hallux valgus angle is less than 20º, the IMT angle is less than 11º, and the lateral sesamoid bone subluxation is less than 50%. In moderate hallux valgus, the hallux valgus angle ranges from 20º to 40º, the IMT angle is less than 16º, and the lateral sesamoid bone subluxation is between 50% and 75%. In severe hallux valgus, the hallux valgus angle exceeds 40º, the IMT angle is more significant than 16º, and the lateral sesamoid bone subluxation is over 75%. Studies have shown that HV leads to foot pain and functional disability, negatively impacting balance, mobility, and ambulation. It disrupts walking patterns, reduces postural stability, and increases the risk of falls (3). These pathomechanical effects on foot function in HV patients have been linked to the disease's impact on foot kinematics. Additionally, changes in the sagittal plane kinematics of the foot have been observed in individuals with HV, including increased dorsiflexion/adduction at the tarsometatarsal joint due to an earlier onset of dorsiflexion. Electromyography studies have also demonstrated an imbalance in muscle force between the muscles affected by HV and the foot's intrinsic muscles (4). Based on this information, this study aimed to evaluate the degree of radiographic correction achieved following the surgical treatment of HV deformity and to examine the relationship between this correction, patients' pain levels, and foot radiographic measurements.

MATERIAL AND METHOD

Ethical approval for this study was obtained from the Ethics Committee of University (decision number; 2024/13-17 date: 10.10.2024). The Declaration of Helsinki's ethical rules and principles were carried out in all procedures. This study is a retrospective analysis of medical records/archived samples. Before accessing the data, all documents were fully anonymized to ensure confidentiality and compliance with ethical standards. Additionally, the Institutional Review Board (IRB)/ethics committee waived the requirement for informed consent, as the study involved only de-identified retrospective data (5, 6).

Participants

This study determined the required sample size using G*Power software (version 3.9.7.1). The effect size (Cohen's d =0.9) was derived from a survey of Hallux Valgus Deformity in women (7). However, a smaller effect size of 0.5 was chosen for this study to enhance statistical power. The parameters used for the sample size calculation included an alpha level of 0.05, 95% statistical power, and two groups. The total sample size required was calculated to be 42 participants (7). This study included 60 participants (30 patients who underwent Hallux Valgus surgery and 30 healthy controls) to increase the statistical power.

Patients who presented to the orthopedic outpatient clinic of the University Research Hospital with foot pain between June 2019 and June 2024 were included in this study. Our study included 60 participants (30 HV patients, 30 controls) aged 30-60. Radiographs of all hallux valgus patients were routinely taken and measured one week before surgery and one year after surgery. The radiological parameters of these patients were retrospectively reviewed using the PACS system. HV patients were divided into three groups according to whether they underwent proximal or distal surgery or both distal and proximal surgery. For all HV patients, the following measurements were taken pre-and post-operatively: HV angle, 1st and 2nd IMT angles, CAI angle, TC angle, and the angle between the talus and 1st metatarsal. Additionally, in the control group, which was retrospectively created from individuals who presented to the orthopedic clinic without any foot pathology and matched the HV group in terms of age and gender, the following measurements were also taken: HV angle, IMT angles between the 1st and 2nd toes, CAI angle, TC angle, and the angle between the talus and 1st metatarsal (Figure 1, 2).

Figure 1. Measurement of MTP and IMT angles in hallux valgus.

Figure 2. Measurement of CAI, TM and TC angles in hallux valgus.

Surgical Method

In mild to moderate hallux valgus cases, distal metatarsal osteotomies (Chevron osteotomy) combined with soft tissue procedures were performed. For severe deformities, proximal osteotomy techniques (open wedge, Ludloff) and tarsometatarsal arthrodesis (Lapidus procedure) were used. The choice of surgical technique was based on the severity of deformity and associated foot pathologies (8, 9). Pain was assessed using the Visual Analog Scale (VAS)(10, 11).

Angular meaurements

1- HV Angle (MTP angle): The MTP angle was measured as the supplementary angle between the longitudinal axes of the first metatarsal and the proximal phalanx. The conventional hallux valgus angle (HVA) can therefore be calculated as HVA = 180° − MTP angle (Figure 1).
2- 1st and 2nd IMT Angles: The IMT angle is defined as the angle between the longitudinal axes of the first and second metatarsals, which is normally less than 9º. Subluxation of the lateral sesamoid bone can be identified on anteroposterior radiographs (Figure 1), (13).
3- CAI Angle: The CAI angle is the angle formed between the CAI axis and the supporting surface. Typically, this angle ranges between 20º and 30º (Figure 2), (14, 15).
4- TC Angle: The TC angle is defined as the angle between the mid-talar axis and the CAI axis. It is generally expected to fall within the range of 25º to 50º (Figure 2), (15).
5- TM Angle: The TM angle is formed between the long axis of the talus and a line drawn along the shaft of the first metatarsal. Typically, this angle ranges from -4º to +4º. When the angle exceeds 4º with a convex downward curvature, it indicates pes planus. Pes planus is further classified as mild when the angle falls between 4º and 15º, moderate between 15º and 40º, and

severe when greater than 40º. Conversely, an angle greater than 4º with a convex upward curvature suggests the presence of pes cavus (Figure 2), (15, 16).

Statistical Analysis

Statistical analyses for the study were performed using the Statistical Package for Social Sciences (SPSS), Version IBM Statistics 25. Based on the Skewness and Kurtosis values (ranging between -2 and +2), it was determined that our data followed a normal distribution. Demographic data were presented as mean ± SD. Continuous variables were analyzed using the Student's t-test, while paired sample t-tests will be applied for within-group data analysis. The Chi-square test was used for percentage comparisons. A p-value of <0.05 was considered statistically significant.

RESULTS

This study included 19 female (63.3%) and 11 male (36.7%) patients with HV. In the control group, there were 17 females (56.7%) and 13 males (43.3%). No statistically significant difference was observed in gender distribution between the groups (p >0.05). The mean age of the HV group was 47.17±16.82 years, compared to 45.39±15.34 years in the control group (p =0.676). Among the HV patients, 6 (20%) underwent proximal surgery, 22 (73.3%) had distal surgery, and 2 (6.7%) received a combined proximal and distal procedure.

The majority of patients presented with mild and moderate hallux valgus. Gender-based comparisons and detailed subgroup analyses of surgical procedures did not reveal significant differences and are therefore provided in the Supplementary Material for brevity.

Across the HV cohort, the IMT angle, TC angle, and VAS values were significantly higher preoperatively compared to postoperatively. The MTP angle increased after surgery, while the IMT angle and VAS decreased (Table 1).

Table 1. Comparison of foot angular measurements within the HV patients before and after surgery.

Radiological Measurements	Before 1 Week	After 1 Year	p
Metatarsophalangeal Angle	143.93±9.58	158.81±7.24	0.001
Intermetatarsal Angle	13.59±2.95	11.53±1.77	0.001
Calcaneal Inclination Angle	24.13±4.21	25.20±3.77	0.180
Talometatarsal Angle	51.36±11.91	51.56±5.45	0.925
Talocalcaneal Angle	4.72±3.34	4.03±3.38	0.341
Visual Analogue Scale	8.63±0.85	2.23±0.85	0.001

When comparing HV patients with the control group, preoperative MTP, IMT, and CAI angles differed significantly (p <0.05). At one-year follow-up, postoperative MTP and IMT angles remained significantly different from controls, while CAI showed improvement, reflecting the beginning of foot structure recovery (Table 2).

Table 2. Comparison of radiological foot angle measurements between hallux valgus patients and healthy controls.

Radiological Measurements	Group	PRE-OP X±SD	p	POST-OP X±SD	p
MTP	**HV**	143.93±9.58	0.001	158.81±7.22	0.001
	C	168.24±4.81		168.24±4.81	
IMT	**HV**	13.59±2.95	0.001	11.53±1.77	0.001
	C	8.95±2.88		8.95±2.88	
CAI	**HV**	24.13±4.21	0.009	25.20±3.77	0.054
	C	27.82±6.19		27.82±6.19	
TM	**HV**	51.36±11.91	0.589	51.56±5.45	0.331
	C	50.01±6.81		50.01±6.81	
TC	**HV**	4.72±3.34	0.421	4.03±3.38	0.106
	C	5.38±2.98		5.38±2.98	

MTP: Metatarsophalangeal, IMT: Intermetatarsal, CAI: Calcaneal Inclination, TM: Talometatarsal, TC: Talocalcaneal, HV: Hallux Valgus, C: Control.

DISCUSSION

The primary objective of this study was to evaluate the degree of radiographic correction achieved following surgical treatment of HV deformity and to examine the relationship between this correction, pain levels, and foot radiographic measurements in HV patients. Our findings demonstrated that surgery significantly improved the MTP angle, IMT angle, and CAI angle, supporting structural recovery of the foot. These results align with previous studies that have shown that surgical intervention can successfully correct the radiographic deformities associated with HV while improving function and reducing pain (17, 18).

In this study, most patients presented with mild and moderate HV, which aligns with previous epidemiological data indicating that most individuals with HV exhibit mild to moderate deformity (19). The absence of significant gender differences in preoperative and postoperative radiological angular measurements suggests that the progression and severity of HV and the outcomes of surgical correction are not strongly influenced by gender. This finding contrasts with the higher prevalence of HV in women, often attributed to biomechanical and footwear-related factors (20). However, the lack of gender-based differences in radiological outcomes supports the notion that once HV has developed, the degree of angular deformity and response to surgical intervention are similar between males and females (21). This emphasizes the importance of individualized treatment strategies based on deformity severity rather than patient gender, and it reinforces the efficacy of the surgical procedures used in this study for addressing HV regardless of gender.

In this study, when comparing foot angular measurements according to the surgical procedures performed, we observed that the preoperative MTP angle was significantly lower in patients who underwent proximal and distal surgery than those who had distal surgery alone. This finding suggests that preoperatively, patients requiring proximal and distal interventions may present with more severe or complex deformities, as reflected in the lower MTP angles. Proximal procedures are typically reserved for more advanced cases of HV where deformities extend beyond the first metatarsal head and require a more extensive realignment (22). Combining proximal and distal procedures is necessary to address the angular deformity at the MTP joint, and the increased IMT angle explains the more significant preoperative abnormalities in this group. This underscores the importance of tailoring surgical techniques to the severity of the deformity to achieve optimal correction.

In this study, the pain assessment of hallux valgus patients using the VAS revealed that preoperative pain levels were significantly higher in patients who underwent the proximal surgical method compared to those who underwent the distal method. This finding likely reflects the more severe deformities and more significant functional impairment present in patients requiring proximal surgical intervention. Proximal surgeries, typically reserved for cases with more significant metatarsal deviation or more advanced stages of hallux valgus, may correlate with increased joint instability, soft tissue strain, and altered biomechanics, all of which contribute to heightened pain levels preoperatively (23). The distal surgical method often applied in less severe cases, may result in lower preoperative pain due to a more localized deformity confined to the metatarsophalangeal joint (18). These differences in preoperative pain underscore the necessity of individualized surgical approaches based on the severity of the deformity and the associated symptoms to achieve better functional and symptomatic outcomes.

Consistent with studies in the literature (24), in this study, we observed that the IMT angle, TC angle, and VAS pain scores were significantly higher before surgery than after surgery, indicating the positive impact of surgical intervention on both foot alignment and pain relief in HV patients. The significant decrease in the IMT angle postoperatively highlights the effectiveness of surgical correction in realigning the first and second metatarsals, a key goal in HV surgery. Similarly, the reduction in VAS scores post-surgery suggests improved pain management and patient comfort, further demonstrating the clinical success of the procedures performed. Notably the MTP angle significantly increased after surgery, indicating improved positioning and stabilization of the hallux following the deformity correction. These findings are consistent with previous research showing that surgical intervention for HV improves radiographic alignment, alleviates pain, and restores foot function. The postoperative reduction in the IMT angle and pain and the increase in the MTP angle reflects the comprehensive benefits of hallux valgus surgery in addressing structural and symptomatic issues. we found that the choice of surgical method-whether distal, proximal, or a combination of both-had no statistically significant effect on the foot angular measurements in HV patients. This suggests that regardless of the surgical approach used, similar outcomes can be achieved regarding correcting foot angles such as MTP, IMT, and CAI. These findings align with previous studies that report comparable success rates across different surgical techniques for HV, emphasizing that the surgeon's expertise and patient-specific factors might play a more significant role in surgical outcomes than the specific method used. Additionally, the lack of substantial differences across surgical methods suggests that each technique can effectively restore foot alignment without significantly varying radiographic results. This supports the notion that surgical decision-making should be individualized based on patient needs, severity of deformity, and associated conditions rather than believing one method is superior to another in achieving angular correction (25).

Studies have reported improvements in the IMT and MTP angles following surgery in patients with HV (26). However, research on foot biomechanics after HV surgery remains limited, and the literature has no consensus (24, 26, 27). As a result, long-term follow-up studies are essential to understand the biomechanical outcomes of HV surgery better. In our study, we conducted angular evaluations of foot biomechanics in patients who underwent HV surgery, focusing on long-term outcomes. The comparison of foot angular measurements between HV patients and a control group revealed significant differences both pre-and postoperatively, underscoring the profound impact of HV on foot structure. Preoperatively, the MTP, IMT, and CAI angles significantly differed in HV patients compared to the control group, highlighting the substantial deformity and altered biomechanics associated with HV. This finding suggests that foot structure in HV patients had deteriorated considerably before surgery. Despite surgical intervention, the postoperative MTP and IMT angles remained significantly different from those in the control group after one year. This indicates that while surgery may partially correct the deformity, complete restoration of foot anatomy may not be achieved in the short term or may require longer-term follow-up. However, the improvement observed in the CAI angle postoperatively suggests that foot structure recovery had begun, reflecting positive changes in foot alignment and stability.

These findings suggest that surgical correction initiates a gradual recovery process in foot structure, particularly calcaneal alignment. Certain deformities, particularly in the MTP and IMT angles, may persist or require further correction. This highlights the importance of surgical intervention and long-term postoperative care to optimize functional outcomes in HV patients.

This study highlights the importance of surgical intervention in correcting foot deformities and reducing pain in HV patients. The significant improvement in radiographic measures post-surgery supports surgical correction as a viable option for patients with moderate to severe HV. The lack of differences in outcomes based on surgical technique suggests that both distal and proximal procedures are effective, and the choice of technique should be individualized based on the patient's foot structure and deformity severity. The findings also underscore the importance of long-term follow-up in assessing the success of HV surgery. While significant improvements were observed one year postoperatively, the persistence of some differences compared to the control group suggests that further monitoring is necessary to determine whether foot angles continue normalizing over time or if additional interventions are needed.

This study has some limitations. The sample size was relatively small, which may limit the generalizability of the findings. Additionally, the study's retrospective design could introduce bias, as the selection of patients and surgical techniques was not randomized. Future studies with more extensive, prospective cohorts are needed to confirm these findings and further investigate the long-term outcomes of different surgical methods for HV correction.

Hallux valgus surgery effectively corrects deformity and reduces pain, with both distal and proximal techniques yielding comparable outcomes. Improvement in CAI indicates early recovery in foot alignment, highlighting the importance of long-term follow-up.

Declarations

*** Ethics approval and consent to participate:** Ethical approval for this study was obtained from the Ethics Committee of University (decision number; 2024/13-17 date: 10.10.2024). The Declaration of Helsinki's ethical rules and principles were carried out in all procedures. This study is a retrospective analysis of medical records/archived samples. Before accessing the data, all documents were fully anonymized to ensure confidentiality and compliance with ethical standards. Additionally, the Institutional Review Board (IRB)/ethics committee waived the requirement for informed consent, as the study involved only de-identified retrospective data.

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