

Forefoot Function after Hallux Valgus Surgery

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The load integrals (impulse) over the central metatarsal region significantly increased, indicating that surgeries increased the risk of transfer metatarsalgia. There is no solid evidence that hallux valgus (HV) surgeries could improve forefoot functions from a biomechanical point perspective. Surgeries might reduce the plantar load over the hallux and adversely affect push-off function.

Keywords: bunion ; hallux abducto valgus ; metatarsus primus varus ; pedobarography

1. Introduction

Hallux valgus (HV) is one of the most prevalent foot problems, affecting nearly one-third of the female population and exacerbating with increasing age ^[1]. It is characterized by medial deviation of the first metatarsal, lateral deviation of the hallux, and a swollen medial eminence (bunion). HV not only causes pain and difficulty in fitting shoes ^{[2][3]}, but also attenuates muscle activity and gait stability, which foists risks of falls, knee injuries, and ankle sprains ^{[4][5]}. In severe cases, subluxation of the metatarsophalangeal joint and dislocation of sesamoids may happen. In addition, HV could be associated with secondary deformities of the lesser toes ^[6]. Corrective surgeries are often recommended to patients with severe angular deformity (HV angle > 40° and intermetatarsal angle > 20°), particularly those with serious incongruent and hypermobile joint conditions ^[7]. The correction methods could be broadly classified as osteotomy, arthrodesis, arthroplasty, and soft tissue procedures. Though osteotomy is the most common option ^[8], the choice of surgical method could depend on the multiplicity of patient condition and surgeon preference ^[9]. Osteotomy could be conducted in a minimally invasive or percutaneous way ^[10]. Percutaneous surgery is carried out through the skin, while minimally incision surgery could be a procedure with an exposure level between open surgery and percutaneous surgery ^[11]. Nevertheless, these techniques are currently recommended for mild cases and require a high degree of expertise in arthroscopic and endoscopic surgery ^{[10][11]}.

Radiographic examination is the gold standard to evaluate surgical outcomes since the primary goal of surgery is to correct skeletal alignment ^[12]. However, X-ray-proven bone realignment may not reflect sufficient restoration of foot functions. Clinical assessment exploits patient-reported outcomes on the perceived pain and function postoperatively, in which the American Orthopaedic Foot and Ankle Society (AOFAS) scales are the most widely utilized instrument ^[13], especially the AOFAS hallux metatarsophalangeal-interphalangeal scale (Hx-MTP-IP). The AOFAS Hx-MTP-IP scale is a 100-point grading scale with 40 points to evaluate pain level and 15 points to evaluate hallux alignment ^[13]. The remaining 45 points are used to assess functions, including limitations in daily activity, footwear requirements, joint range of motion, and stability ^[13]. Nevertheless, it was argued that the AOFAS scales lack precision and have not been appropriately validated ^{[14][15]}.

On the other hand, biomechanical evaluations targeting foot loading and functions have emerged recently, the results of which implicate risks of complications, recurrence, and walking instability ^{[12][16][17]}. Biomechanically, the failure in medial forefoot functions induced by HV transfers the load to the central metatarsal regions, causing transfer metatarsalgia ^[18]. The assessment of postoperative forefoot function is therefore imperative. Plantar pressure measurement (pedobarography), which quantifies the biomechanics of plantar foot functions, has been proven to be a reliable clinical tool to evaluate interventions ^{[19][20][21]}. Transfer metatarsalgia (midfoot pain) is caused by the aberrant high load that is shifted from the failed medial forefoot ^[22]. Therefore, an increase in the medial forefoot pressure and a reduction in the central forefoot pressure (i.e., medialized pressure) indicate the restoration of push-off function and pain relief. There is strong evidence that HV individuals had lower medial forefoot but higher central forefoot loading ^{[22][23]}. The pathomechanism of HV and transfer metatarsalgia is illustrated in **Figure 1**.

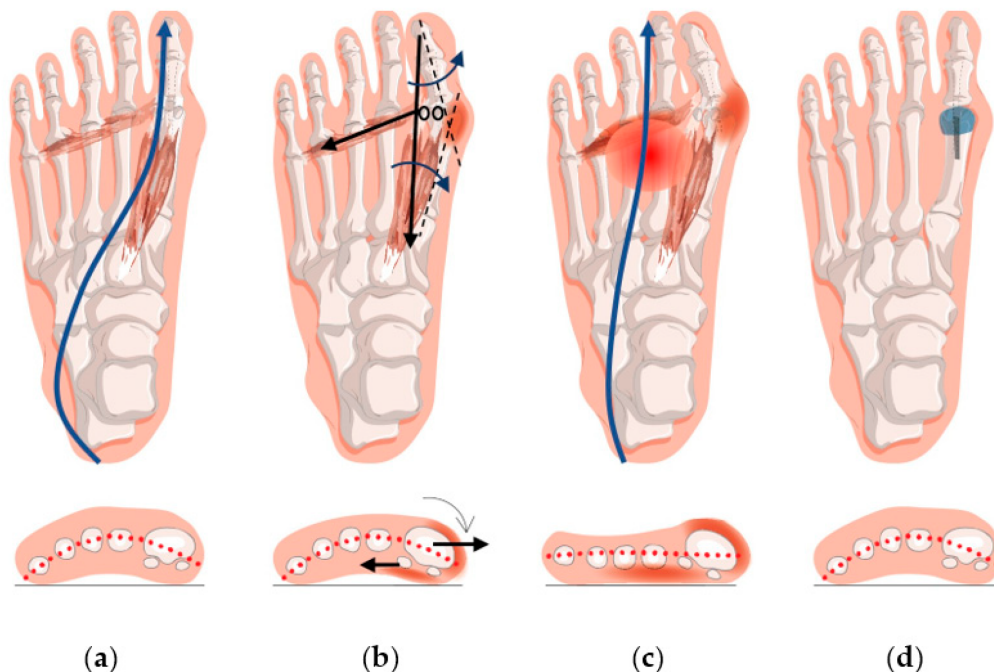


Figure 1. Pathomechanism of HV and transfer metatarsalgia: (a) The first ray plays an important role in push-off functions. The blue line illustrates the center of pressure trajectory during gait; (b) since the first metatarsal is less stable without any muscle insertions, it might deviate medially, conforming with the direction of the push-off load. The black arrows represent the directions of muscle force. The blue arrows represent the deformity directions of the bones [2]. The hallux and the sesamoids are hold in position by the muscle and plantar aponeurosis. Therefore, the hallux looks laterally deviated relative to the first metatarsal, while the sesamoids beneath the first metatarsal head are gradually exposed and disanchored. Plantarflexors, abductors, and stabilizing muscles of the first ray would become lateral to the longitudinal axis of the first ray and distribute deforming forces [2]. The problem aggravates with higher exposure and loading of the forefoot, such as wearing high-heeled shoes [24]; (c) when the muscles and the sesamoids that served as the fulcrum are deranged, the load-carrying capability and push-off functions are compromised and compensated by other forefoot regions, resulting in transfer metatarsalgia. The blue line represents the lateralized center of pressure trajectory; (d) the bone alignment and sesamoid positions shall be corrected after HV surgeries, but whether the center or pressure trajectory and thus load-carrying capability of the first ray could be restored is in doubt.

2. Forefoot Function after Hallux Valgus Surgery

A meta-analysis showed that there was a reduction in hallux and medial forefoot load/impulse that implicated the failure of surgeries to restore forefoot functions [25]. Besides, the pain-causing load at the central forefoot was not lessened. The pathomechanics that manifested transfer metatarsalgia was thus not resolved.

Although substantial heterogeneity was observed in the meta-analysis [25], most of the individual studies did not favor surgeries, and some did admit that surgical interventions failed to restore normative plantar functions or produced no significant biomechanical improvement [26][27][28][29][30][31]. One possible explanation for the finding is that some of the included studies were old, and the surgical technique or plantar pressure instrument might have been flawed at that time. Nevertheless, subgroup analyses by year of publication indicated that this lack of effectiveness was unlikely due to whether the surgical methods were old or relatively new. Another reason for the failure could be premature ambulation with pain, stiffness, and weakened intrinsic muscles [28][31]. Indeed, a significantly worse load distribution on the hallux and central metatarsal region was observed in the studies with a shorter follow-up period (<12 months). A third reason could be related to the elevation of first metatarsal head in the surgical procedure in some studies, which might produce negative impact on the plantar pressure. Elevated or a more dorsal position of the first metatarsal head might reduce the load-carrying capacity of the first ray, which was recognized as the cause of metatarsalgia and poor surgical outcomes [32]. Some osteotomy techniques, such as Crescentic [26], closing wedge [33], and Weil [34] are vulnerable to the elevation of the first metatarsal. Nevertheless, the analysis did not support this fact as the source of heterogeneity. A fourth reason is that the surgeries may not correct or ameliorate hypermobility or instability of the forefoot, which is the etiology of HV [35]. Besides, mainstream surgical techniques may fail to repair the stabilizing soft tissue structures and the underlying soft tissue deficiency or imbalance, which adversely affect the load-carrying capacity [36].

The “negative” biomechanical effects of HV surgeries demonstrated seem to contradict the positive clinical improvement after surgeries. It hypothesizes that immediate pain relief and restoration of daily functions might not necessarily complement the resumption of normal foot kinematics and walking capability, which is a secondary measure to contemplate potential deformity recurrence, complications, compensatory foot problems, and falling risks. Surgeries treat the bone misalignment of HV but might not be treating the root cause of the problem.

In fact, HV surgeries could remedy bunion (swollen joint) problems, shoe-fitting issues, and facilitate immediate pain relief. Moreover, the restoration of bone alignment ameliorates push-off functions by correcting the position of the sesamoid bones and muscle directions. Radiographic assessment and patient-reported outcomes are undoubtedly the primary outcomes, reflecting deformity correction and immediate pain relief. Yet, these evaluation measures are insufficient, and perceived pain relief may not necessarily be associated with restoration of biomechanical functions [37]. Plantar load measurements examine whether the corrected foot could resume normal foot kinematics and walking capability and could serve as a secondary measure to contemplate potential deformity recurrence, complications, compensatory foot problems, and falling risks. Thus, it would be desirable to have surgeries that are effective in improving plantar load distribution. Some surgeons endeavor to develop alternative surgical methods, including metatarsal suturing techniques (e.g., mini-tightrope) that could reinforce the site stability and minimize the risk of traumatizing osseous procedures [38]. However, the effectiveness of these methods warrants further investigation.

Postoperative rehabilitation, such as orthosis and muscle training, plays an important role in load redistribution and regaining foot functions. Postoperative muscle retraining could strengthen hallux functions, restore joint mobility and thus physiological gait patterns [39][40]. Schuh et al. [39] commented that the strengthening of peroneus longus muscle can facilitate a better midfoot pronation control and therefore direct load to the first ray correctly. Foot orthosis with arch support could also help control pronation [41], while a metatarsal pad could relieve pain and maintain the integrity of the transverse arch, in cases of first ray insufficiency [42][43][44]. Besides, despite that an increase (or a restoration) of first ray load indicated the restoration of biomechanical functions, it should be noted that unloading the first ray by immobilization or partial weight bearing in the early postoperative stage is essential to facilitate pain management and mitigate risks of non-union [45][46][47].

Besides the variations of surgical techniques, the intrinsic features of HV, such as spring ligament insufficiency [48], first ray hypermobility [49], hypermobility due to malpractice in amateur ballet dancers [50], generalized ligament laxity [51], medial column instability, and posterior tibial tendon dysfunction [52], may have contributed to clinical heterogeneity as well. Moreover, HV was often compounded with other foot problems that were infeasible to isolate [35][53], such as flatfoot [54], plantar fasciitis [55], transfer metatarsalgia [18], and claw toes [56]. There is limited research on the impact of plantar pressure under such circumstances. Those additional foot problems may contribute to variations in plantar loading pattern or postoperative compensatory gait [18][57]. For example, individuals with flat feet might not have sufficient load under the medial forefoot during push-off [58], while those with valgus hindfoot deformities might have higher medial forefoot pressures [59].

3. Conclusions

While HV surgeries had previously demonstrated improvement in shoe fitting, pain relief on the bunion, and quality of living, there was no solid evidence that HV surgeries could improve forefoot functions from a biomechanical point perspective. Currently available evidence even suggests that surgeries might reduce the plantar load over the hallux and adversely affect push-off function.

References

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