surgeries

MDPI

Review

Hindfoot Valgus and First Ray Insufficiency: Is There Correlation?

Gabriele Colò [1,2,*,†], Federico Fusini [3,†], Daniele Marcolli [4], Massimiliano Leigheb [5] and Michele Francesco Surace [1,2]

[1] Department of Orthopaedics and Traumatology, Sant'Anna Hospital, Via Ravona 20, San Fermo Della Battaglia, 22042 Como, Italy
[2] Multidisciplinary Research Center for Pathology and Surgery of the Musculoskeletal System, Department of Biotechnology and Life Sciences (DBSV), Insubria University, 21100 Varese, Italy
[3] Department of Orthopaedic and Traumatology, Orthopaedic and Trauma Centre, University of Turin, via Zuretti 29, 10124 Turin, Italy
[4] UOC Week Surgery, Azienda Socio-Sanitaria Territoriale, Centro Specialistico Ortopedico Traumatologico Gaetano Pini-CTO, 20122 Milan, Italy
[5] Orthopaedics and Traumatology Unit, San Gaudenzio Clinic (Monza Polyclinic Group), Via Enrico Bottini 3, 28100 Novara, Italy
* Correspondence: gabriele.colo@yahoo.it
† These authors contributed equally to this work and share first authorship.

Abstract: The first metatarsal has the greatest inclination of all metatarsals and carries about 40% of body weight during the static stance. The rearfoot and the first ray (FR) are two distinct structures, but they are strongly related to the latest studies in the literature; however, their mutual involvement in the foot biomechanics appears not to be fully explored. Understanding their interdependence is essential to approaching the patient in his totality. This overview aims to analyze the current evidence from the latest studies that examine the correlation between FR insufficiency (FRI) and hindfoot valgus (HV), focusing on their biomechanical interaction, clinical implications, and treatment approaches. All analyzed studies showed that plantarflexion of the first metatarsophalangeal (MTP1) joint in correct alignment increased by 26% compared to a deviated articulation. In FRI, the "windlass" mechanism appears compromised, and FR lacks the necessary stability and plantarflexion; consequently, the medial arch collapses, and the foot moves into excessive pronation. On the other hand, in HV condition, the pulley system is significantly diminished, and peroneus longus contraction cannot stabilize the FR with resultant FRI and dorsal migration. A significant correlation was found between hindfoot alignment and first metatarsal rotation (86% of patients) and between HV and hallux valgus. Foot orthoses, physical therapy, and exercise programs, especially in the initial stages of symptomatic HV, provide satisfactory results in 67% to 90% of cases, improving foot alignment and pain relief in FRI patients. In more severe cases, surgical intervention to realign the hindfoot is indicated with a very low complication rate (1–4%), which can vary from 24% to 55% in stage 4 flatfoot. No study in the literature has been found to address both pathologies simultaneously from a treatment point of view, and, although not all HV patients are affected by FRI, most patients seem to benefit from surgical stabilization of the FR in 80% of individuals with symptomatic HV. However, despite a predominance of FRI among HV individuals, not all clinical studies have confirmed this correlation.

Keywords: first ray; flatfoot; hypermobility; medial arch; hindfoot valgus

check for updates

Academic Editor: Gaetano Isola

Received: 22 January 2025
Revised: 12 March 2025
Accepted: 25 March 2025
Published: 27 March 2025

Citation: Colò, G.; Fusini, F.; Marcolli, D.; Leigheb, M.; Surace, M.F. Hindfoot Valgus and First Ray Insufficiency: Is There Correlation? *Surgeries* **2025**, *6*, 26. https://doi.org/10.3390/surgeries6020026

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The structural integrity and function of the human foot rely on the proper alignment and interplay of its anatomical components. Dysfunction in any part of the foot can have widespread effects on biomechanics, leading to compensatory changes, pain, and functional limitations. Two such anatomical components, the first ray (FR) and hindfoot, are frequently seen together in scientific literature and appear to be functionally related (Figures 1 and 2) [1,2].

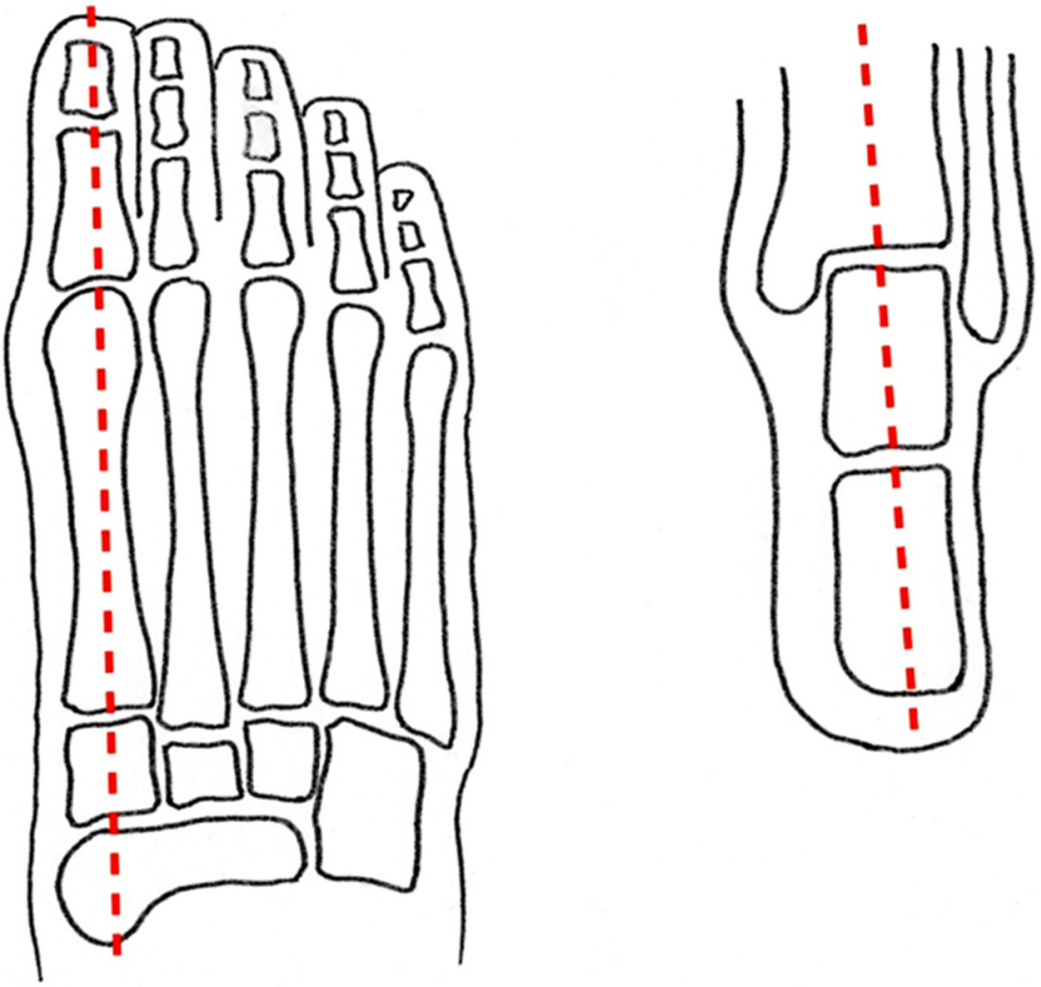


Figure 1. Drawing representing a correct hindfoot alignment connected to a regular alignment of the first ray.

FR is formed by the first metatarsal and medial cuneiform bone [3,4]. It is probably the most essential forefoot mechanical structure. The first metatarsal has the most extraordinary inclination of all metatarsals, ranging from 15 to 25 degrees [5], and during the static stance of the gait, it carries about 40% of body weight [6]. Since hallux valgus deformity is often observed with the first metatarsocuneiform instability or FR hypermobility, this three-dimensional condition usually has an associated hindfoot valgus (HV) [7,8].

In recent decades, some authors have suggested a strong correlation between FRI and HV [9–12], but others have not confirmed [13]; the factors leading to the development of the conditions and a possible correction are not yet fully understood in the literature [14].

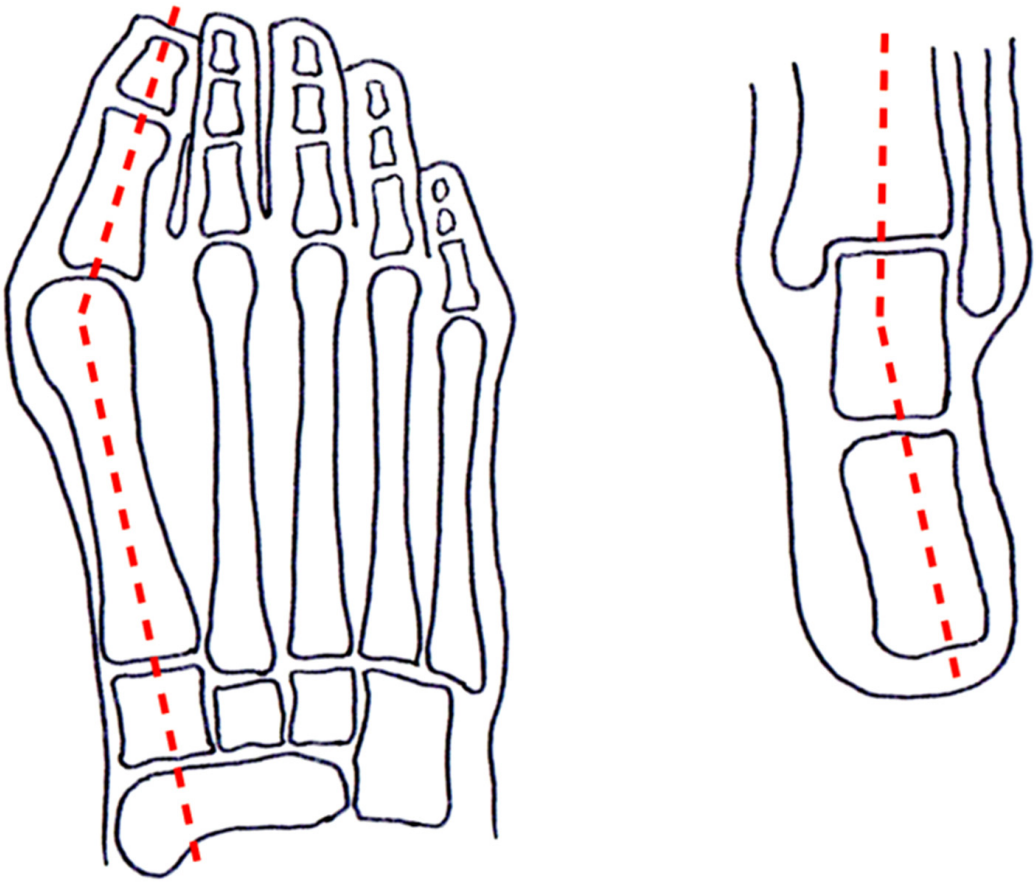


Figure 2. The drawings represent a hindfoot valgus related to a first ray insufficiency (a consequent hallux valgus).

Understanding the interdependence between FRI and HV should be essential to approach the patient; otherwise, management that restores a single defect may lead to an incomplete outcome. Interventions such as custom orthotics and surgical procedures can restore alignment and stability, preventing further deterioration and improving patient outcomes [15,16]. This overview aims to synthesize current evidence from the latest studies that explore the correlation between FRI and HV, focusing on their biomechanical interaction, clinical implications, and treatment approaches.

2. First Ray Insufficiency or First Ray Hypermobility?

The FRI and FR hypermobility are terms often used synonymously but refer to distinct conditions [17]. The FRI refers to the inability of the first metatarsal to provide adequate support during the stance phase of the gait [18]. It is often associated with conditions like posterior tibial tendon dysfunction (PTTD), where the collapse of the medial arch occurs due to inadequate plantarflexion of the FR. It results in overpronation and weight transfer to the lesser metatarsals, leading to transfer metatarsalgia [17,19–22].

On the other hand, FR hypermobility describes an excessive range of motion in the tarsometatarsal (TMT) joint of the FR, often without immediate symptoms. While hypermobility allows the first metatarsal to move more than usual, it may not lead to issues unless compounded by structural problems like flatfoot. Hypermobility can, however, exacerbate insufficiency by allowing the further collapse of the medial column; however, some other mechanisms are involved (e.g., the windlass mechanism) [1] that can contribute to FR stability during gait. FR hypermobility does not influence the FR to perform its normal function of load transmission in the correct setting [23,24].

Another additional condition is FR instability, typically associated with hallux valgus. It involves pathological motion, particularly dorsiflexion of the FR, where the first metatarsal loses its ability to maintain alignment during gait. All these features lead to deformities and uneven load distribution. According to studies by Myerson et al. [25] and Root et al. [26], instability often results from ligamentous laxity. It can cause progressive deformities like hallux valgus, worsening the biomechanical inefficiency of the foot.

While all three conditions affect foot mechanics, insufficiency primarily relates to support failure, hypermobility to excessive motion, and instability to abnormal joint displacement, requiring targeted interventions based on the specific pathology [1].

3. Anatomy

The first metatarsal is the strongest and most crucial weight-bearing point in the forefoot, even if the shortest metatarsal, as described by Otto F. Schuster. Being the shortest metatarsal, it is forced to plantar flex during propulsion to maintain contact with the support surface [18].

The ligaments stabilize the first metatarsal-cuneiform joint. The posterior and anterior tibial tendons improve and enhance ligamentous stability, but the peroneus longus tendon plays a central role [3,5]. The French neurologist Duchenne recognized functional stability and noted that it depended on the agonist and antagonist muscular balance [18].

The peroneus longus, along its course, runs obliquely through the cuboid canal from posterior and lateral to anterior and medial aspects. The distal insertion is located in the lateral aspect of the base of the first metatarsal bone and the plantar aspect of the medial cuneiform. Its activation causes the eversion of the first metatarsal base, blocking the medial cuneiform in the medial column [10,15]. Johnson and Christensen found that peroneus longus activity resulted in 8.06 $\pm$ 3.07 degrees of first metatarsal eversion and 7.44 $\pm$ 2.64 degrees of internal cuneiform eversion [18].

The role of the peroneus longus tendon on FR stability is influenced by the application and direction of force, which in turn is determined by the position of the midtarsal and subtalar joints. Physiologically, peroneus longus contraction pulls laterally and plantarward the FR. During supination, this application of force is increased and restricts the dorsal excursion of the FR, providing a mechanical advantage [5,7].

4. Biomechanics

Biomechanically, the FR stability directly influences the medial longitudinal arch. The Windlass Mechanism, first described by Hicks in 1954 [27], begins when the hallux dorsiflexes during the push-off phase. This movement creates tension in the plantar fascia, acting like a "windlass", pulling the heel and the metatarsals closer together. It elevates the medial longitudinal arch and increases foot rigidity, generating an efficient push-off phase in walking and running [1].

During the stance phase, the peroneus longus exerts a plantarflexion and eversion force on the FR, which helps counteract excessive first metatarsal dorsiflexion. By maintaining the plantar flexion of the FR, the peroneus longus tendon assists in keeping the medial longitudinal arch intact and preventing excessive pronation [28,29].

The Achilles tendon is the other factor increasing stable gait propulsion, with a long lever arm on the forefoot through the medial longitudinal plantar arch. According to Rush et al., the windlass mechanism is more efficient when the first metatarsal, sesamoid apparatus, and hallux are correctly aligned. If the first metatarsophalangeal (MTP1) joint is correctly aligned, there is a 26% increase in first metatarsal plantarflexion [30].

In the case of FRI, the windlass mechanism is compromised, therefore the hallux and first metatarsal lack the necessary stability and plantarflexion during this phase. Conse-

quently, the medial arch collapses, and the foot moves into excessive pronation. Conversely, in a pronated foot, the pulley system is significantly diminished due to an altered cuboid position, and peroneus longus contraction cannot stabilize the FR with resultant FRI and dorsal migration [31].

5. Clinical Findings

Clinically, subjects may complain of metatarsalgia, first metatarsocuneiform joint pain, central painful hyperkeratoses of second or third metatarsal heads, hallux interphalangeal joint pain associated with compensatory hyperextension or medial hyperkeratoses, MTP1 joint pain with or without accompanying shoe irritation, and increased dorsal mobility of the FR [10].

Several instruments have been designed to measure first-ray motion over the years; however, the accurate value of FR motion has yet to be determined [18].

As evaluated by Morton in 1928 and Root in 1971, the FR clinical mobility test (Root's test) assesses the hypermobility of the FR in the sagittal plane. The maneuver requires placing the right-hand thumb and index finger on the head of the first metatarsal bone, then putting the left-hand thumb and index finger on the second, third, and fourth metatarsal heads, and then moving only the first metatarsal head to the maximum dorsal and plantar excursion. A value of 10 mm (5 mm dorsal, 5 mm plantar) is generally considered normal; if the excursion is greater than 10 mm, it is considered hypermobile (Figure 3). ROM evaluation should be extended to the contralateral side to be compared [10].

Bednarz and Manoli suggested that one full thumb breadth of movement in a dorsalward direction indicates hypermobility [18].

The Coleman block test can assess the FR sagittal plane motion on weight-bearing. The subject stands on a 1.5 mm wooden block supporting the central and lateral metatarsals, allowing free FR plantarflexion. The wooden block is then shifted to support the FR, making the lateral metatarsal free to plantarflex while the FR dorsiflexion can be evaluated.

It is essential to underline that all tests should be performed with the ankle in the neutral position since dorsiflexing the ankle reduces FR mobility, and plantarflexion increases it [18].

In mild HV, FR should endure increased ground reactive pressure with the compromise of windlass function. This process can provoke a progressive alteration of the medial column and the onset of symptoms [1]. In a pathologically pronated foot, the forefoot abducts on the rearfoot while the rearfoot everts. Pain initially started along the course of the PTT, and the pain severity is activity- and standing-dependent. The pain at rest worsens with increased disease severity [2,4].

It is crucial to evaluate patients' feet when they are bearing weight. The "too many toes" sign is coherent with excessive forefoot abduction. Palpation along the course of the PTT could show tenderness or swelling. Another critical step is evaluating muscle strength, ankle and hindfoot movement, and alignment. Therefore, the patient is asked to invert the foot passively to assess PT weakness [11,12].

The Silfverskiold test evaluates the gastrocnemius-soleus complex tightness after passively correcting the heel valgus to eliminate motion through the transverse tarsal joint.

Fixed deformities may be present in the subtalar zone and can have treatment implications.

The heel-rise test evaluates the strength of the PTT; in case of tendon dysfunction, it will manifest as the inability to invert the hindfoot or perform the test. Finally, gait is valued to estimate heel inversion during toe-off [14,31].

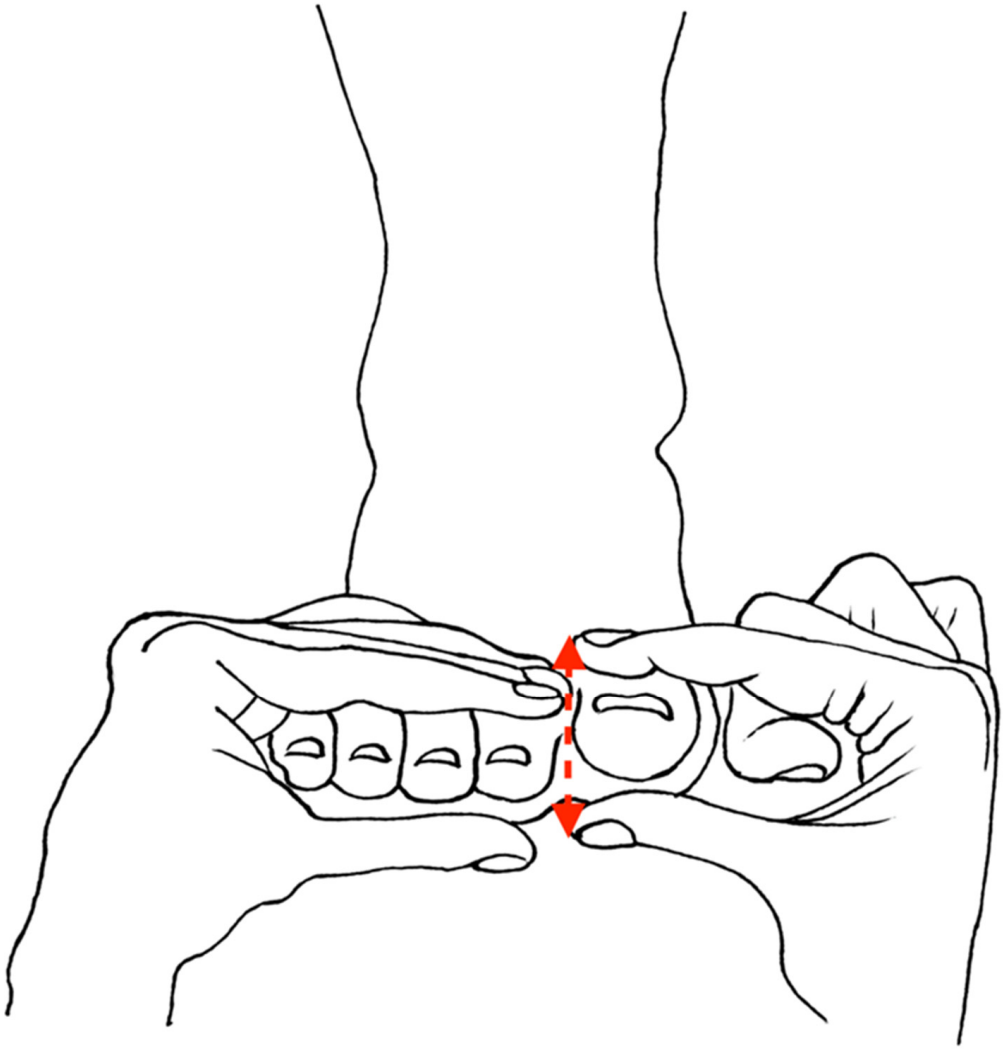


Figure 3. Root's test: The maneuver requires placing the right-hand thumb and index finger on the head of the first metatarsal bone, then putting the left-hand thumb and index finger on the second, third, and fourth metatarsal heads, and then moving only the first metatarsal head to the maximum dorsal and plantar excursion. If the total excursion is greater than 10 mm, it is considered a first ray hypermobility.

6. First Ray Insufficiency and Its Impact on Hindfoot Valgus

Morton already proposed that hypermobility of the FR was a crucial factor for the biomechanics of the foot 70 years ago [32]. He revealed that excessive dorsal flexion of the first metatarsal pushed the foot inward, which overloaded the second metatarsal, which carried most of the weight. This FRI [33,34] has been reported as a related factor in hallux valgus genesis [35–37]. The FR elevates, diverges medially, and rotates [38], with the valgus deformity considered compensatory to the malalignment of the FR [39–41].

Over the years, several authors have identified essential correlations between the FR and the hindfoot [4,42–46]. Kirby [47,48] was the first to report that the subtalar joint axis is connected to the forefoot axis and noticed its extension between the first and second metatarsals. Since then, several studies have documented the association between forefoot and hindfoot [49]. Root et al. [4,26] attributed excessive subtalar joint pronation to the resulting grades of rearfoot eversion, the cause of FR hypermobility. The severity of medial longitudinal arch collapse is directly related to the FR rises. This feature agrees with Durrant's research, where he noted that low declinations of the FR accompanying excessive

pronation cause the FR to recruit an everted position relative to the ground. In contrast, at higher declination angles, the FR assumes an inverted position [50].

In patients with adult-acquired flatfoot deformity (AAFD), often secondary to PTTD [51], FRI is frequently observed alongside HV, with these conditions working in a vicious cycle: hypermobility or instability of the FR leads to medial column collapse, which in turn promotes HV [52,53].

Kohls [54] noted that the patients affected by AAFD seek medical attention primarily for signs of FRI, such as unsteady, limping, limited walking distance, hallux valgus, or rigidus. Similarly, a study by Yokozuka et al. [9] emphasized that it is desirable to appropriately utilize footwear and insoles that simultaneously suppress the inclination of the calcaneus and support the plantar arch.

Morgan [55] reported 14 subjects with FR hypermobility defined as $\geq$8 mm; 12 of them (86%) exhibited a planus foot type. An interaction between the translation and rotational mechanism of the FR was demonstrated in connection with weight-bearing ray mobility and MTP1 joint laxity. They were also associated with the partial weight-bearing FR mobility, accounting for 38% of the model variance.

These conclusions, however, were not confirmed by Heng [13], who stated that no significant differences were found between asymptomatic controls and PTTD patients in FR displacement [median (IQR), PTTD: 6.00 (1.75) mm; control: 6.00 (1.00) mm; P = 0.31].

Findings of Avino [56] suggest that the Lapidus arthrodesis, a fusion procedure of the first metatarsocuneiform joint, may influence the medial longitudinal arch, giving a stabilizing effect. These results were confirmed by Chi et al. [57], who found that 80% of individuals with PTTD who underwent lateral column lengthening and medial column stabilization obtained with the fusion of the naviculocuneiform and first metatarsocuneiform joints were pain-free.

7. Radiological Evidence

Radiological studies further support the correlation between FR and hindfoot pronation. Weight-bearing radiographs of patients with flatfoot deformity often reveal a collapsed medial arch with medial column instability alongside a valgus alignment of the calcaneus [58,59]. Meary's angle, which measures the alignment between the talus and the first metatarsal, is frequently abnormal in these patients, illustrating the relationship between FR dysfunction, first metatarsal rotation, and hindfoot malalignment [60].

Coughlin and Jones [61] provided radiological evidence linking HV and FRI; in 15% of patients of the present series, there was a moderate or severe pes planus. Patients with hallux valgus are more inclined to report increased FR mobility and plantar gapping of the first metatarsocuneiform joint.

Eustace et al. analyzed weight-bearing X-rays of 100 feet. They demonstrated a significant relationship between first metatarsal pronation, i.e., eversion, and the height of the medial longitudinal arch ($r = 0.93$, $p < 0.0001$). Multivariate analysis of patient age, sex, intermetatarsal angle, and medial longitudinal arch angle against metatarsal pronation showed that the medial longitudinal arch height was the most dominant variable affecting metatarsal pronation [62].

Flores et al. highlighted TMT misalignment in subjects with AAFD using weight-bearing X-rays analyzing the correlation between HV and forefoot abduction [63]. Metrics such as the Kite angle (talocalcaneal angle), talonavicular angle, and talus bone–first metatarsal axis [64] were altered in the pronated foot. Although Computed Tomography (CT) scans and Magnetic Resonance Imaging (MRI) are commonly used to describe alignment, these techniques revealed some limitations due to the lack of weight-bearing

when performing the exam and the low sensitivity until the deformity becomes advanced and inflexible [63].

Greisberg [65] examined simulated weight-bearing CT scans and plain radiographs of 37 symptomatic flat feet. The medial column of the arch collapsed through the talonavicular joint, and the subluxation of the first TMT joint was also a frequent finding.

Bakshi [11,60] found a substantial correlation between first metatarsal rotation and HV alignment, as assessed by weight-bearing CT, that increased in severity as the HV deformity worsened.

Deland [66] analyzed 31 consecutive patients diagnosed with PTTI compared to an age-matched control group without PTTI to identify the pattern of ligament involvement using standardized, high-resolution MRI. The spring ligament complex was the most frequently affected. Still, a statistically significant difference was found in the PTTI group for plantar metatarsal ligaments (p = 0.0002) and plantar naviculocuneiform ligament involvement (p = 0.0006).

8. Treatment Approaches

8.1. Conservative Management

One of the primary conservative treatments involves custom orthotics or bracing. These devices are designed to realign the foot, support the medial longitudinal arch, and reduce the stress on the FR [67–69].

The last studies investigated the existence of different foot orthoses, such as custom-made, uniformly manufactured, and semi-rigid foot orthoses. Unfortunately, no consistent evidence was reported on the effect of foot orthoses on patients suffering from HV [70–72].

A recent systematic review focused on the efficacy of plantar orthoses in pediatric flexible flatfoot (FFF) deformity. Of the 237 studies considered, seven randomized controlled trials and controlled clinical trials were published between 2017 and 2022, representing 679 participants aged 3–14. The studies differ in diagnostic criteria, types of foot orthoses, and duration of treatment. All studies reported a beneficial effect of orthotics, although some bias could affect the results. There is evidence of foot orthoses' efficacy as a treatment for symptomatic pediatric FFF. There is no treatment algorithm or ideal type of foot orthosis, although all have in common the incorporation of a large internal longitudinal arch [73].

Nonsurgical management, as in other pathologies, is always related to the degree of injury. In the case of AAFD, conservative treatment is considered the gold standard of treatment for stage I disease. Although failure to achieve substantial improvement may occur in advanced stages of deformities, a first conservative approach is often justified before indicating a patient for a surgical procedure in more advanced stages. An initial stage of conservative treatment with immobilization can provide satisfactory results in symptomatic patients in 67% to 90% of cases [74].

In severe instability cases, an anterior ankle–foot orthosis (AFO) can provide more rigid support to the entire foot and ankle complex [75]. Lin et al. evaluated 32 patients with stage II PTTD treated conservatively with a double upright AFO. The average VAS pain scale score was 1.9. At a mean follow-up of 8.6 years, 69.7% of subjects had symptom relief and were free from braces [76].

Alvarez et al. reported a success rate of 89% in 47 patients with low-stage PTTD treated conservatively with physical therapy and orthosis for a median of 4 months. Just five patients (11%) required surgery after failure of conservative treatments [74].

Conservative treatment of FRI depends on the underlying pathology. In the case of hallux rigidus, shoes should be sufficiently long and comfortable, with a high toe box and

broad toe box, to prevent or delay their development. They also should bear an allowed space for the orthotic device. A 3 mm thickness with a correct stiffness should be used to avoid or delay its development. The increase and extension of the medial metatarsal arch just proximal to the metatarsal head allow the raise of the first metatarsal and the proximal phalanx to rest in a more plantarflexed position, removing the load from the dorsal aspect of the joint. The increased foot pronation moment with medial column overload should be corrected [10,15].

Personalized 3D-printed customized toe spreaders may be used in patients suffering from hallux valgus, improving pain relief and other symptoms. Data obtained from the latest literature suggest that dynamic foot orthoses prefer a biomechanical type with 3/4-length, which is less likely to negatively affect the medial or dorsal pressures, which were noted to increase with the sulcus- and full-length orthoses [68].

As in other pathologies [77–81], activity modification and physical therapy may also play a role in conservative management [82], focusing on strengthening the muscles that support the medial arc and resistance exercise [83]. In 2023, a randomized trial proved a comprehensive exercise program to improve foot alignment in patients with FFF. Randomization allocated 26 participants to each group. After 6 weeks, the patients in the experimental group improved the navicular drop height by 0.4 cm (95% CI 0.4 to 0.5) compared to those in the control group. These participants also improved their longitudinal arch angle by 16 degrees (95% CI 13 to 19) more than those in the control group [84].

8.2. Surgical Management

When conservative treatments fail, surgical intervention may be necessary, and the correct procedure depends on the severity of the deformity and the specific pathophysiology of the structures involved. Unfortunately, no study in the literature was found that reflects the central theme of this review and simultaneously addresses HV and FRI. However, the two conditions will be treated separately in light of the latest studies.

In symptomatic FFF surgical procedures, calcaneal stop has proved significant improvements in pain relief (93.5%), radiological measures including reductions in Kite (7.32°), Meary (11.65°), and Costa-Bertani angles (17.11°), heel alignment (95.21%), talar declination (12.63°), and an increase in Calcaneal Pitch Angle (5.92°). The American Orthopaedic Foot and Ankle Society (AOFAS) score increased, or an average of 22.32 points, in addition to a very high satisfaction and low complication rate (7.8%) [85].

Subtalar arthroereisis with endorthesis may be a good alternative to the calcaneal-stop procedure.

However, data from a recent literature review (2010–2020) show that among the 691 feet that underwent subtalar arthroereisis with the endorthesis, the average age at surgery was 11.40 years. In the 1856 feet that underwent the calcaneal-stop procedure, the mean age was 11.69 years. The complication rates were 9.00% and 6.38%, respectively. These results highlight that the calcaneal-stop procedure may be an advantage over endorthesis since the screw is placed into the calcaneus and not across the subtalar joint [86].

In AAFD, procedures such as calcaneal osteotomy [2,43,51] or subtalar fusion are often utilized to correct HV [87]. In a recent systematic review, authors reported a total of 501 cases treated with minimally invasive surgery (MIS) in medial displacement calcaneus osteotomy (MDCO) were reported with a mean of 11.9 $\pm$ 5.1 months of follow-up. The sural neuropathy was reported in about 1% of cases, while the rate of wound infection was about 3%. In only 4% of the patients, the removal of the screw for pain was necessary. In the comparative studies (MIS versus Open MDCO), clinical results were comparable but with significant differences ($p < 0.001$) in infection rates (1% versus 14%) and sural neuropathy (2% versus 1%) [51].

Calcaneal osteotomy seems to provide less correction but a lower incidence of degenerative change in the hindfoot than lateral column lengthening over time [88]. In more severe cases, subtalar fusion can be used in a very strict cohort of patients without clinical or radiological compromise to correct the HV, the talonavicular uncoverage (TNU), and the corresponding medial arch collapse [89].

In more severe cases, with a rigid hindfoot, with valgus angulation of the talus and early degeneration of the ankle joint (stage 4 flatfoot) [90], retrograde intramedullary nailing may be required. Overall complications ranged from 24% to 55% and include malunion rates of up to 8% (typically increased HV), metal fatigue failure of up to 5%, and a combined superficial and deep infection rated between 5% and 9%, amputation rate was reported between 2% and 4.7%, the iatrogenic perioperative fracture and tibial stress fracture rate ranged from 5% to 18% [91].

When FRI is significant, surgical procedures to stabilize the first metatarsal and medial column are often required in conjunction with hindfoot surgery. The first TMT (Lapidus) fusion [92,93] or Cotton (medial cuneiform opening wedge) osteotomy [94] may be used to stabilize or lower the FR, respectively.

Metatarsalgia related to Lapidus surgery is known to be associated with persistent FR elevation after realignment. Busch et al. analyzed thirty feet (28 patients) after the first TMT fusion with a follow-up at 42.5 ± 21.0 months in their series. Metatarsalgia was associated with a poorer outcome in the Foot and Ankle Disability Index (FADI) and AOFAS scores ($p < 0.005$). The procedure caused a lateral shift in plantar pressure distribution to the third metatarsal head. However, no correlation to the occurrence of metatarsalgia was related to the shortening of the first metatarsal after the Lapidus procedure. On the other hand, there was a high correlation between the elevation of the first ray and related metatarsalgia ($p = 0.007$) [95].

In the series of Boffeli [96], Meary's angle improved by an average of 17.75°, from −17.24° ± 8.00° to 0.51° ± 3.81°, in a statistically significant manner ($p < 0.01$), highlighting the role of Cotton osteotomy as an ancillary procedure for flatfoot corrective surgery.

Deformities such as hallux valgus or hallux rigidus should be corrected when symptomatic but must always be related to the realignment of the hindfoot to maintain the correction over time [10,68].

Although not all PTTD patients are affected by FRI [13], most patients seem to benefit from surgical stabilization of the FR in HV [57].

Tendon transfers or soft tissue procedures may be required, combined with bone fixations. In the series of Hintermann et al., patients had significantly increased their scores from an average preoperative value of 49.1 to a mean postoperative value of 91.1 after a mean follow-up of 24.6 months [97].

9. Limitations of the Study

This study has several limitations, mainly related to the narrative typology of the review. Although an accurate analysis has been made of all the studies regarding the correlation between FRI and HV, the nature of the method has inherent limitations in terms of objectivity, completeness of literature search, and interpretation of findings.

Selection bias in the studies chosen for the review, the impossibility of inserting inclusion criteria, and failure to consider relationships between study characteristics and study outcomes may have led to misleading and inaccurate conclusions.

The review reported mainly studies of III–IV level of evidence, primarily observational and anatomical-biomechanical studies, often without a comparative or control group.

Furthermore, in most analyzed studies, the absence of statistical analysis may have led to an over/underestimation of the results obtained. Higher-powered, prospective, or

randomized controlled trials are necessary to evaluate further the correlation between FRI and HV, especially in clinical-therapeutic value.

10. Conclusions

The correlation between HV and FRI appears well-established in all anatomical and biomechanical studies. A significant correlation was found between hindfoot alignment and first metatarsal rotation (86% of patients) and between HV and hallux valgus. Radiological evidence has further supported this interconnection.

A conservative approach, especially in the initial stages of symptomatic HV, seems to provide satisfactory results in 67% to 90% of cases. Foot orthoses, physical therapy, and an exercise program may improve foot alignment and pain relief in FRI patients.

In more severe cases, surgical intervention to realign the hindfoot is indicated with a very low complication rate (1–4%), which can vary from 24% to 55% in stage 4 flatfoot.

Although no study in the literature addresses both pathologies simultaneously from a treatment point of view, all studies agree that although not all HV patients are affected by FRI, most patients seem to benefit from surgical stabilization of the FR in 80% of individuals with symptomatic HV.

However, despite a predominance of FRI among HV individuals, not all clinical studies have confirmed this correlation. The factors leading to the development of the conditions and a possible correction appear not yet fully understood in the literature.

Author Contributions: G.C.: writing—review and editing, conceptualization, methodology, project administration; F.F.: writing—review and editing, data curation, methodology, investigation; D.M.: software—visualization, investigation; M.L.: software—visualization, investigation; M.F.S.: supervision and validation. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Acknowledgments: I thank my parents for their constant loving support.

Conflicts of Interest: The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

Abbreviations

FR	first ray
FRI	first ray insufficiency
HV	hindfoot valgus
MTP1	first metatarsophalangeal
PTTD	posterior tibial tendon dysfunction
TMT	tarsometatarsal
AAFD	adult-acquired flatfoot deformity
CT	Computed Tomography
MRI	Magnetic Resonance Imaging
FFF	flexible flatfoot
AFO	ankle–foot orthosis
AOFAS	American Orthopaedic Foot & Ankle Society
MIS	minimally invasive surgery
MDCO	medial displacement calcaneus osteotomy
TNU	talonavicular uncoverage
FADI	Foot and Ankle Disability Index

References

1. Christensen, J.C.; Jennings, M.M. Normal and abnormal function of the first ray. *Clin. Podiatr. Med. Surg.* **2009**, *26*, 355–371. [CrossRef] [PubMed]
2. Greenfield, S.; Cohen, B. Calcaneal Osteotomies: Pearls and Pitfalls. *Foot Ankle Clin.* **2017**, *22*, 563–571. [CrossRef] [PubMed]
3. Hicks, J.H. The mechanics of the foot: I. The joints. *J. Anat.* **1953**, *87*, 345–357. [PubMed]
4. Root, M.L. Planovalgus foot deformity revisited. *J. Am. Podiatr. Med. Assoc.* **1999**, *89*, 268–269. [CrossRef]
5. Davis, B.; Crow, M.; Berki, V.; Ciltea, D. Shear and pressure under the first ray in neuropathic diabetic patients: Implications for support of the longitudinal arch. *J. Biomech.* **2017**, *52*, 176–178. [CrossRef]
6. Brockett, C.L.; Chapman, G.J. Biomechanics of the ankle. *Orthop. Trauma* **2016**, *30*, 232–238. [CrossRef]
7. Greisberg, J. Foot and ankle anatomy and biomechanics. In *Core Knowledge in Orthopedics Foot and Ankle*; DiGiovanni, C., Greisberg, J., Eds.; Elsevier: Amsterdam, The Netherlands, 2007; pp. 6, 7, 12, 15.
8. Hensl, H.; Sands, A.K. Hallux valgus in Core Knowledge. In *Orthopedics Foot and Ankle*; DiGiovanni, C., Greisberg, J., Eds.; Elsevier: Amsterdam, The Netherlands, 2007; pp. 106–107.
9. Yokozuka, M.; Okazaki, K. Characteristics of hindfoot morphology and ankle range of motion in young women with Hallux valgus. *J. Foot Ankle Res.* **2023**, *16*, 64. [CrossRef]
10. Colò, G.; Fusini, F.; Zoccola, K.; Samaila, E.M.; Magnan, B. The influence of first ray instability and hindfoot valgus in developing hallux rigidus: State of art. *Acta Biomed.* **2023**, *94* (Suppl. S2), e2023116. [CrossRef]
11. Bakshi, N.; Steadman, J.; Philippi, M.; Arena, C.; Leake, R.; Saltzman, C.L.; Barg, A. Association Between Hindfoot Alignment and First Metatarsal Rotation. *Foot Ankle Int.* **2022**, *43*, 105–112. [CrossRef]
12. Kohls-Gatzoulis, J.; Angel, J.; Singh, D. Tibialis posterior dysfunction as a cause of flatfeet in elderly patients. *Foot* **2004**, *14*, 207–209. [CrossRef]
13. Heng, M.L.; Krishnasamy, P.; Kong, P.W. First ray mobility and posterior tibial tendon dysfunction (PTTD) in persons with flatfoot: A case control study. *Foot* **2018**, *37*, 57–60. [CrossRef] [PubMed]
14. Matsumoto, T.; Takeda, R.; Uchio, A.; Mizuhara, H.; Omata, Y.; Juji, T.; Tanaka, S. Associated correction of forefoot alignment with hindfoot fusion for pes planovalgus deformity. *Foot Ankle Surg.* **2023**, *29*, 280–287. [CrossRef]
15. Colò, G.; Fusini, F.; Zoccola, K.; Rava, A.; Samaila, E.M.; Magnan, B. May footwear be a predisposing factor for the development of hallux rigidus? A review of recent findings. *Acta Biomed.* **2021**, *92* (Suppl. S3), e2021010. [CrossRef]
16. Biz, C.; Maso, G.; Malgarini, E.; Tagliapietra, J.; Ruggieri, P. Hypermobility of the First Ray: The Cinderella of the measurements conventionally assessed for correction of Hallux Valgus. *Acta Biomed.* **2020**, *91*, 47–59. [CrossRef]
17. Walker, A.K.; Harris, T.G. The Role of First Ray Insufficiency in the Development of Metatarsalgia. *Foot Ankle Clin.* **2019**, *24*, 641–648. [CrossRef]
18. D'Amico, J. Understanding the First Ray. *Orthot. Biomech.* **2016**, 109–120. Available online: https://www.podiatrym.com/cme/CME1_916.pdf (accessed on 11 March 2025).
19. Wang, C.S.; Tzeng, Y.H.; Yang, T.C.; Lin, C.C.; Chang, M.C.; Chiang, C.C. First-Ray Radiographic Changes After Flexible Adult Acquired Flatfoot Deformity Correction. *Foot Ankle Int.* **2022**, *43*, 55–65. [CrossRef]
20. Colò, G.; Bignotti, B.; Costa, G.; Signori, A.; Tagliafico, A.S. Ultrasound or MRI in Evaluating Anterior Talofibular Ligament (ATFL) Injuries: Systematic Review and Meta-Analysis. *Diagnostics* **2023**, *13*, 2324. [CrossRef]
21. Colò, G.; Fusini, F.; Alessio-Mazzola, M.; Samaila, E.M.; Formica, M.; Magnan, B. Interposition arthroplasty with bovine collagenous membrane for hallux rigidus: A long-term results retrospective study. *Foot Ankle Surg.* **2022**, *28*, 1473–1478. [CrossRef] [PubMed]
22. Kimura, T.; Kubota, M.; Kihara, T.; Suzuki, N.; Hattori, A.; Saito, M. First ray mobility in hallux rigidus, Hallux valgus, and normal feet based on weightbearing computed tomography and three-dimensional analysis: A case-control study. *J. Orthop. Sci.* **2024**, *30*, 320–324. [CrossRef]
23. Wong, D.W.; Zhang, M.; Yu, J.; Leung, A.K. Corrigendum to 'Biomechanics of first ray hypermobility: An investigation on joint force during walking using finite element analysis'. *Med. Eng. Phys.* **2014**, *36*, 1388–1393. [CrossRef] [PubMed]
24. Glasoe, W.M. An Operational Definition of First Ray Hypermobility. *Foot Ankle Spec.* **2022**, *15*, 494–496. [CrossRef] [PubMed]
25. Myerson, M.S.; Badekas, A. Hypermobility of the first ray. *Foot Ankle Clin.* **2000**, *5*, 469–484.
26. Root, M.L.; Orien, W.P.; Weed, J.H. *Motion of the Joints of the Foot: The First Ray*; Clinical Biomechanics Corporation: Los Angeles, CA, USA, 1977.
27. Hicks, J.H. The mechanics of the foot. II. The plantar aponeurosis and the arch. *J. Anat.* **1954**, *88*, 25–30. [PubMed]
28. Koutsogiannis, P.; Frane, N.; Aliyev, T.; Regala, P.; Tarazi, J.M.; Bitterman, A.D. Peroneus Longus and Peroneus Brevis: A Review on Pathology and Updated Treatments. *JBJS Rev.* **2022**, *10*, e21. [CrossRef]
29. Delcogliano, M.; Marin, R.; Deabate, L.; Previtali, D.; Filardo, G.; Surace, M.F.; Candrian, C.; Gaffurini, P. Arthroscopically assisted and three-dimensionally modeled minimally invasive rim plate osteosynthesis via modified anterolateral approach for posterolateral tibial plateau fractures. *Knee* **2020**, *27*, 1093–1100. [CrossRef]

30. Rush, S.M.; Christensen, J.C.; Johnson, C.H. Biomechanics of the first ray. Part II: Metatarsus primus varus as a cause of hypermobility. A three-dimensional kinematic analysis in a cadaver model. *J. Foot Ankle Surg.* **2000**, *39*, 68–77. [CrossRef]
31. Grebing, B.R.; Coughlin, M.J. The effect of ankle position on the exam for first ray mobility. *Foot Ankle Int.* **2004**, *25*, 467–475. [CrossRef]
32. Morton, D.J. Structural factors in static disorders of the foot. *Am. J. Surg.* **1930**, *9*, 315–326.
33. Donatelli, R.A. Abnormal biomechanics. In *The Biomechanics of the Foot and Ankle*, 2nd ed.; Donatelli, R.A., Ed.; FA Davis Co: Philadelphia, PA, USA, 1996; pp. 34–72.
34. Viladot, A. The metatarsals. In *Disorders of the Foot and Ankle*, 2nd ed.; Wickland, E., Ed.; WB Saunders Co: Philadelphia, PA, USA, 1991; pp. 1229–1254.
35. Klaue, K.; Hansen, S.T.; Masquelet, A.C. Clinical, quantitative assessment of first tarsometatarsal mobility in the sagittal plane and its relation to Hallux valgus deformity. *Foot Ankle Int.* **1994**, *15*, 9–13. [CrossRef]
36. Jahss, M.H. Disorders of the Hallux and the first ray. In *Disorders of the Foot and Ankle*, 2nd ed.; Wickland, E., Ed.; WB Saunders Co.: Philadelphia, PA, USA, 1991; pp. 943–946.
37. Shereff, M.J. Pathophysiology, anatomy, and biomechanics of Hallux valgus. *Orthopedic* **1990**, *13*, 939–945. [CrossRef] [PubMed]
38. Kay, D.B.; Njus, G.; Parrish, W.; Theken, R. Basilar crescentic osteotomy. A three-dimensional computer simulation. *Orthop. Clin. North. Am.* **1989**, *20*, 571–582. [PubMed]
39. Wanivenhaus, A.; Pretterklieber, M. First tarsometatarsal joint: Anatomical biomechanical study. *Foot Ankle* **1989**, *9*, 153–157. [CrossRef]
40. Usuelli, F.G.; Maccario, C.; D'Ambrosi, R.; Surace, M.F.; Vulcano, E. Age-Related Outcome of Mobile-Bearing Total Ankle Replacement. *Orthopedics* **2017**, *40*, e567–e573. [CrossRef]
41. Monestier, L.; Riva, G.; Zabetta, L.C.; Surace, M.F. Outcomes After Unstable Fractures of the Ankle: What's New? A Systematic Review. *Orthop. Rev.* **2022**, *14*, 35688. [CrossRef]
42. Kawakami, W.; Takahashi, M.; Iwamoto, Y.; Shinkoda, K. Coordination Among Shank, Rearfoot, Midfoot and Forefoot Kinematic Movement During Gait in Individuals with Hallux Valgus. *J. Appl. Biomech.* **2019**, *35*, 44–51. [CrossRef]
43. Colo', G.; Mazzola, M.A.; Pilone, G.; Dagnino, G.; Felli, L. Lateral open wedge calcaneus osteotomy with bony allograft augmentation in adult acquired flatfoot deformity. Clinical and radiological results. *Eur. J. Orthop. Surg. Traumatol.* **2021**, *31*, 1395–1402. [CrossRef]
44. Morton, D.J. *The Human Foot: Its Evolution, Physiology and Functional Disorders*; Columbia University Press: New York, NY, USA, 1935.
45. Rao, S.; Song, J.; Kraszewski, A.; Backus, S.; Ellis, S.J.; Deland, J.T.; Hillstrom, H.J. The effect of foot structure on 1st metatarsophalangeal joint flexibility and hallucal loading. *Gait Posture* **2011**, *34*, 131–137. [CrossRef]
46. Ledoux, W.R.; Shofer, J.B.; Ahroni, J.H.; Smith, D.G.; Sangeorzan, B.J.; Boyko, E.J. Biomechanical differences among pes cavus, neutrally aligned, and pes planus feet in subjects with diabetes. *Foot Ankle Int.* **2003**, *24*, 845–850. [CrossRef]
47. Kirby, K.A. Methods for determination of positional variations in the subtalar joint axis. *J. Am. Podiatr. Med. Assoc.* **1987**, *77*, 228–234. [CrossRef]
48. Kirby, K.A. Rotational equilibrium across the subtalar joint axis. *J. Am. Podiatr. Med. Assoc.* **1989**, *79*, 1–14. [CrossRef] [PubMed]
49. Riva, G.; Monestier, L.; Colombo, M.; D'angelo, F.; Surace, M.F. Subtalar arthroeresis with peek endorthesis in juvanile flexible flafoot: Short-term results. *Pediatr. Medica Chir.* **2022**, *44*. [CrossRef] [PubMed]
50. Durrant, M.N.; McElroy, T.; Durrant, L. First metatarsophalangeal joint motion in Homo sapiens: Theoretical association of two-axis kinematics and specific morphometrics. *J. Am. Podiatr. Med. Assoc.* **2012**, *102*, 374–389. [CrossRef] [PubMed]
51. Vaggi, S.; Vitali, F.; Zanirato, A.; Quarto, E.; Colò, G.; Formica, M. Minimally invasive surgery in medial displacement calcaneal osteotomy for acquired flatfoot deformity: A systematic review of the literature. *Arch. Orthop. Trauma Surg.* **2024**, *144*, 1139–1147. [CrossRef]
52. Aquino, A.; Payne, C. Function of the windlass mechanism in excessively pronated feet. *J. Am. Podiatr. Med. Assoc.* **2001**, *91*, 245–250. [CrossRef]
53. Bierman, R.A.; Christensen, J.C.; Johnson, C.H. Biomechanics of the first ray. Part III. Consequences of Lapidus arthrodesis on peroneus longus function: A three-dimensional kinematic analysis in a cadaver model. *J. Foot Ankle Surg.* **2001**, *40*, 125–131. [CrossRef]
54. Kohls-Gatzoulis, J.; Angel, J.C.; Singh, D.; Haddad, F.; Livingstone, J.; Berry, G. Tibialis posterior dysfunction: A common and treatable cause of adult acquired flatfoot. *BMJ* **2004**, *329*, 1328–1333. [CrossRef]
55. Morgan, O.J.; Hillstrom, R.; Turner, R.; Day, J.; Thaqi, I.; Caolo, K.; Ellis, S.; Deland, J.T.; Hillstrom, H.J. Is the Planus Foot Type Associated with First Ray Hypermobility? *Foot Ankle Orthop.* **2022**, *7*, 24730114221081545. [CrossRef]
56. Avino, A.; Patel, S.; Hamilton, G.A.; Ford, L.A. The effect of the Lapidus arthrodesis on the medial longitudinal arch: A radiographic review. *J. Foot Ankle Surg.* **2008**, *47*, 510–514. [CrossRef]

57. Chi, T.D.; Toolan, B.C.; Sangeorzan, B.J.; Hansen, S.T., Jr. The lateral column lengthening and medial column stabilization procedures. *Clin. Orthop. Relat. Res.* **1999**, *365*, 81–90. [CrossRef]
58. Mazzotti, A.; Langone, L.; Zielli, S.O.; Artioli, E.; Arceri, A.; Brognara, L.; Traina, F.; Faldini, C. Do First Ray-Related Angles Change following Subtalar Arthroereisis in Pediatric Patients? A Radiographic Study. *Children* **2024**, *11*, 760. [CrossRef] [PubMed]
59. Fusini, F.; Massè, A.; Rava, A.; Zoccola, K.; Felli, L.; Colò, G. Correction to: Aetiology, diagnosis, and treatment of brachymetatarsia: A narrative review. *Musculoskelet. Surg.* **2022**, *106*, 475. [CrossRef]
60. Steadman, J.; Bakshi, N.; Philippi, M.; Arena, C.; Leake, R.; Barg, A.; Saltzman, C.L. Association of Normal vs Abnormal Meary Angle with Hindfoot Malalignment and First Metatarsal Rotation: A Short Report. *Foot Ankle Int.* **2022**, *43*, 706–709. [CrossRef] [PubMed]
61. Coughlin, M.J.; Jones, C.P. Hallux valgus: Demographics, etiology, and radiographic assessment. *Foot Ankle Int.* **2007**, *28*, 759–777. [CrossRef] [PubMed]
62. Eustace, S.; Byrne, J.O.; Beausang, O.; Codd, M.; Stack, J.; Stephens, M.M. Hallux valgus, first metatarsal pronation and collapse of the medial longitudinal arch--a radiological correlation. *Skelet. Radiol.* **1994**, *23*, 191–194. [CrossRef]
63. Flores, D.V.; Mejía Gómez, C.; Fernández Hernando, M.; Davis, M.A.; Pathria, M.N. Adult Acquired Flatfoot Deformity: Anatomy, Biomechanics, Staging, and Imaging Findings. *Radiographics* **2019**, *39*, 1437–1460. [CrossRef]
64. Tay, A.Y.W.; Goh, G.S.; Thever, Y.; Yeo, N.E.M.; Koo, K. Impact of pes planus on clinical outcomes of Hallux valgus surgery. *Foot Ankle Surg.* **2022**, *28*, 331–337. [CrossRef]
65. Greisberg, J.; Hansen, S.T., Jr.; Sangeorzan, B. Deformity and degeneration in the hindfoot and midfoot joints of the adult acquired flatfoot. *Foot Ankle Int.* **2003**, *24*, 530–534. [CrossRef]
66. Deland, J.T.; de Asla, R.J.; Sung, I.H.; Ernberg, L.A.; Potter, H.G. Posterior tibial tendon insufficiency: Which ligaments are involved? *Foot Ankle Int.* **2005**, *26*, 427–435. [CrossRef]
67. Kogler, G.F.; Veer, F.B.; Solomonidis, S.E.; Paul, J.P. The influence of medial and lateral placement of orthotic wedges on loading of the plantar aponeurosis. *J. Bone Jt. Surg. Am.* **1999**, *81*, 1403–1413. [CrossRef]
68. Colò, G.; Leigheb, M.; Surace, M.F.; Fusini, F. The efficacy of shoes modification and orthotics in Hallux valgus deformity: A comprehensive review of literature. *Musculoskelet. Surg.* **2024**, *108*, 395–402. [CrossRef] [PubMed]
69. Colò, G.; Fusini, F.; Melato, M.; De Tullio, V.; Logrieco, G.; Leigheb, M.; Surace, M.F. The effectiveness of shoe modifications and foot orthoses in conservative treatment of lesser toe deformities: A review of literature. *Musculoskelet. Surg.* **2024**, 1–8. [CrossRef]
70. Xu, R.; Wang, Z.; Ren, Z.; Ma, T.; Jia, Z.; Fang, S.; Jin, H. Comparative Study of the Effects of Customized 3D printed insole and Prefabricated Insole on Plantar Pressure and Comfort in Patients with Symptomatic Flatfoot. *Med. Sci. Monit.* **2019**, *25*, 3510–3519. [CrossRef] [PubMed]
71. Aminian, G.; Safaeepour, Z.; Farhoodi, M.; Pezeshk, A.F.; Saeedi, H.; Majddoleslam, B. The effect of prefabricated and proprioceptive foot orthoses on plantar pressure distribution in patients with flexible flatfoot during walking. *Prosthet. Orthot. Int.* **2013**, *37*, 227–232. [CrossRef]
72. Miller, C.D.; Laskowski, E.R.; Suman, V.J. Effect of corrective rearfoot orthotic devices on ground reaction forces during ambulation. *Mayo Clin. Proc.* **1996**, *71*, 757–762. [CrossRef]
73. Molina-García, C.; Banwell, G.; Rodríguez-Blanque, R.; Sánchez-García, J.C.; Reinoso-Cobo, A.; Cortés-Martín, J.; Ramos-Petersen, L. Efficacy of Plantar Orthoses in Paediatric Flexible Flatfoot: A Five-Year Systematic Review. *Children* **2023**, *10*, 371. [CrossRef]
74. Alvarez, R.G.; Marini, A.; Schmitt, C.; Saltzman, C.L. Stage I and II posterior tibial tendon dysfunction treated by a structured nonoperative management protocol: An orthosis and exercise program. *Foot Ankle Int.* **2006**, *27*, 2–8. [CrossRef]
75. Cikajlo, I.; Osrečki, K.; Burger, H. The effects of different types of ankle-foot orthoses on postural responses in individuals with walking impairments. *Int. J. Rehabil. Res.* **2016**, *39*, 313–319. [CrossRef]
76. Lin, J.L.; Balbas, J.; Richardson, E.G. Results of nonsurgical treatment of stage II posterior tibial tendon dysfunction: A 7- to 10-year follow-up. *Foot Ankle Int.* **2008**, *29*, 781–786. [CrossRef]
77. Fusini, F.; Girardo, M.; Aprato, A.; Massè, A.; Lorenzi, A.; Messina, D.; Colò, G. Percutaneous Cement Discoplasty in Degenerative Spinal Disease: Systematic Review of Indications, Clinical Outcomes, and Complications. *World Neurosurg.* **2022**, *168*, 219–226. [CrossRef]
78. Fusini, F.; Massè, A.; Risitano, S.; Ferrera, A.; Enrietti, E.; Zoccola, K.; Bianco, G.; Zanchini, F.; Colò, G. Should we operate on all patients with COVID-19 and proximal femoral fractures? An analysis of thirty, sixty, and ninety day mortality rates based on patients' clinical presentation and comorbidity: A multicentric study in Northern Italy. *Int. Orthop.* **2021**, *45*, 2499–2505. [CrossRef] [PubMed]
79. Ratti, C.; Murena, L.; Surace, M.F.; Rolla, P.R. Clinical and ultrasound results after arthroscopic repair of the rotator cuff. *Chir. Organi Mov.* **2005**, *90*, 95–104, (In English, Italian). [PubMed]

80. Guindani, N.; Eberhardt, O.; Wirth, T.; Surace, M.F.; Fernandez, F.F. Surgical dislocation for pediatric and adolescent hip deformity: Clinical and radiographical results at 3 years follow-up. *Arch. Orthop. Trauma Surg.* **2017**, *137*, 471–479. [CrossRef] [PubMed]
81. Surace, M.F.; Monestier, L.; D'Angelo, F.; Bertagnon, A. Factors Predisposing to Dislocation After Primary Total Hip Arthroplasty: A Multivariate Analysis of Risk Factors at 7 to 10 Years Follow-up. *Surg. Technol. Int.* **2016**, *30*, 274–278.
82. Colò, G.; Massarini, M.; Cavagnaro, L.; Felli, L.; Ferracini, R. Exercise therapy indications in metastatic bone patients. *Minerva Ortop. E Traumatol.* **2020**, *71*, 8–22. [CrossRef]
83. Kulig, K.; Reischl, S.F.; Pomrantz, A.B.; Burnfield, J.M.; Mais-Requejo, S.; Thordarson, D.B.; Smith, R.W. Nonsurgical management of posterior tibial tendon dysfunction with orthoses and resistive exercise: A randomized controlled trial. *Phys. Ther.* **2009**, *89*, 26–37. [CrossRef]
84. Brijwasi, T.; Borkar, P. A comprehensive exercise program improves foot alignment in people with flexible flat foot: A randomised trial. *J. Physiother.* **2023**, *69*, 42–46. [CrossRef]
85. Galán-Olleros, M.; Del Baño Barragán, L.; Figueroa, M.J.; Prato de Lima, C.H.; Fraga-Collarte, M.; Torres-Izquierdo, B.; Hosseinzadeh, P.; Martínez-Caballero, I. Outcomes of the "Calcaneo-stop" procedure for treating symptomatic flexible flatfoot in children: A systematic review and meta-analysis of 2394 feet. *Foot Ankle Surg.* **2024**, *30*, 535–545. [CrossRef]
86. De Pellegrin, M.; Moharamzadeh, D. Subtalar Arthroereisis for Surgical Treatment of Flexible Flatfoot. *Foot Ankle Clin.* **2021**, *26*, 765–805. [CrossRef]
87. Cates, N.K.; Mayer, A.; Tenley, J.; Wynes, J.; Tefera, E.; Steinberg, J.S.; Kim, P.J.; Weinraub, G.M. Double Versus Triple Arthrodesis Fusion Rates: A Systematic Review. *J. Foot Ankle Surg.* **2022**, *61*, 907–913. [CrossRef]
88. Osman, A.E.; El-Gafary, K.A.; Khalifa, A.A.; El-Adly, W.; Fadle, A.A.; Abubeih, H. Medial displacement calcaneal osteotomy versus lateral column lengthening to treat stage II tibialis posterior tendon dysfunction, a prospective randomized controlled study. *Foot* **2021**, *47*, 101798. [CrossRef] [PubMed]
89. Davies, J.P.; Ma, X.; Garfinkel, J.; Roberts, M.; Drakos, M.; Deland, J.; Ellis, S. Subtalar Fusion for Correction of Forefoot Abduction in Stage II Adult-Acquired Flatfoot Deformity. *Foot Ankle Spec.* **2022**, *15*, 221–235. [CrossRef] [PubMed]
90. Myerson, M.S. Adult acquired flatfoot deformity: Treatment of dysfunction of the posterior tibial tendon. *Instr. Course Lect.* **1997**, *46*, 393–405. [PubMed]
91. Heyes, G.; Molloy, A. Treatment of Stage 4 Flatfoot. *Foot Ankle Clin.* **2020**, *25*, 269–280. [CrossRef]
92. Coetzee, J.C.; Wickum, D. The Lapidus procedure: A prospective cohort outcome study. *Foot Ankle Int.* **2004**, *25*, 526–531. [CrossRef]
93. Dujela, M.D.; Langan, T.; Cottom, J.M.; DeCarbo, W.T.; McAlister, J.E.; Hyer, C.F. Lapidus Arthrodesis. *Clin. Podiatr. Med. Surg.* **2022**, *39*, 187–206. [CrossRef]
94. Johnson, J.E.; Sangeorzan, B.J.; de Cesar Netto, C.; Deland, J.T.; Ellis, S.J.; Hintermann, B.; Schon, L.C.; Thordarson, D.B.; Myerson, M.S. Consensus on Indications for Medial Cuneiform Opening Wedge (Cotton) Osteotomy in the Treatment of Progressive Collapsing Foot Deformity. *Foot Ankle Int.* **2020**, *41*, 1289–1291. [CrossRef]
95. Busch, A.; Wegner, A.; Haversath, M.; Brandenburger, D.; Jäger, M.; Beck, S. First ray alignment in Lapidus arthrodesis-Effect on plantar pressure distribution and the occurrence of metatarsalgia. *Foot* **2020**, *45*, 101686. [CrossRef]
96. Boffeli, T.J.; Schnell, K.R. Cotton Osteotomy in Flatfoot Reconstruction: A Review of Consecutive Cases. *J. Foot Ankle Surg.* **2017**, *56*, 990–995. [CrossRef]
97. Hintermann, B.; Valderrabano, V.; Kundert, H.P. Anteriore Kalkaneus-verlängerungsosteotomie und mediale Weichteilrekonstruktion zur Behandlung der schweren Tibialis posterior-Sehnendysfunktion. Technik und präliminäre Resultate [Lateral column lengthening by calcaneal osteotomy combined with soft tissue reconstruction for treatment of severe posterior tibial tendon dysfunction. Methods and preliminary results]. *Orthopade* **1999**, *28*, 760–769. (In German)

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.