

ORTHOPAEDICS

FOREFOOT ADDUCTION IN CHILDREN

Management and Treatment

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ABSTRACT • Forefoot adduction is a common condition between metatarsus adductus, Z-shaped foot and residual clubfoot. This deformity is located in a pure transverse plane at Lisfranc's joint. Isolated metatarsus adductus is corrected spontaneously for the majority of newborns. In rare uncorrected cases, it could result in Z-shaped foot with a functional hindfoot valgus to equilibrate the resistant metatarsus adductus. As well, in residual clubfoot, recurrent metatarsus adductus varus is observed, usually in children over three years.

In flexible metatarsus adductus the treatment is conservative. The surgery is proposed in toddlers and after failure of conservative treatment. Procedures carried out on metatarsals gave good results on short term, but showed a high rate of recurrence and growth disturbance. Osteotomies proximal to the Lisfranc's joint: calcaneo-cuboid fusion, anterior resection of calcaneus, and opening wedge osteotomy of medial cuneiform, gave permanent correction but they act only on one of the sides of deformity. Therefore, the theory of elongated lateral column associated with a shortened medial column is crucial in dealing with this deformity: combining opening wedge osteotomy of cuneiform with closing wedge osteotomy of cuboid described by Jawish *et al.* in children over 4 years allows – in all causes of metatarsus adductus stiffness – a lateral shifting of forefoot. Concerning the associated heel's valgus, it is corrected in Z-shaped foot after the double osteotomy cuneiform/cuboid. However, in complicated treated clubfoot a particular treatment for the posterior tarsal is necessary.

Keywords: metatarsus adductus varus, skew foot, Z-shaped, clubfoot, cuneiform osteotomy, cuboid osteotomy

INTRODUCTION

Metatarsus adductus is a positional deformity in which the metatarsals are deviated in the transverse plane when compared with the longitudinal axis of the lesser tarsus; this deformity is located at Lisfranc's joint in a pure transverse plane [1], where the metatarsals are regularly adducted, with a normal position of the hindfoot under the ankle joint. In literature the incidence of metatarsus

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RÉSUMÉ • L'adduction de l'avant-pied est une déformation qui existe dans le métatarsus varus, le pied en Z et le pied bot varus résiduel. Elle est dans un plan transversal au niveau de l'articulation de Lisfranc. Dans le métatarsus adductus ou varus la déformation est corrigée spontanément pour la majorité des nouveau-nés. Dans les cas non corrigés, elle conduit à un pied en Z avec valgus fonctionnel de l'arrière-pied pour équilibrer le métatarsus adductus résistant. Dans le pied bot résiduel, le métatarsus adductus varus apparaît habituellement chez les enfants ayant plus de trois ans.

Dans le métatarsus adductus flexible, le traitement est conservateur. La chirurgie est indiquée après échec du traitement orthopédique. Les procédures appliquées aux métatarses ont donné de bons résultats à court terme, mais avec un taux élevé de récurrences et des troubles de croissance à long terme. Les ostéotomies faites en amont de l'articulation de Lisfranc – fusion calcanéo-cuboïde, résection antérieure du calcaneum et ostéotomie d'ouverture du cunéiforme – ont donné une correction incomplète en agissant sur une des deux colonnes de la déformation. L'ostéotomie d'ouverture du premier cunéiforme associée à l'ostéotomie de fermeture du cuboïde, décrite par Jawish *et al.*, chez les enfants de plus de 4 ans, a permis une correction anatomique de l'avant-pied. Après cette double ostéotomie cunéiforme /cuboïde, le valgus fonctionnel du talon est corrigé spontanément dans le pied en Z. Cependant, dans le pied bot compliqué de valgus, un traitement particulier est nécessaire pour l'arrière-pied.

adductus in the population varies from 8.8% to 15% of as reported by Cornwall *et al.* [2], while others suggested much higher levels [3, 4].

Heredity accounts for only 2 to 4% of all cases of metatarsus adductus [5]; the theory of abnormal intra-uterine position is mostly accepted as etiology of metatarsus adductus [6, 7], supported by several studies showing a disproportionate number of affected infants in primigravida mothers [8]. Male preponderance is approximately 1.3:1 ratio as reported by most authors.

Historically, several names were given to this forefoot deformity such as metatarsus adductus, metatarsus varus [9, 5], metatarsus adductovarus [10], pes adductus [11], metatarsus supinatus [12], forefoot adductus [13], and hooked forefoot [14], all these names are given to medial

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FIGURE 1. Clinical metatarsus adductus varus (a). Radiological aspect with adduction at tarsal-metatarsal joints (b).

deviation of the forefoot. However, simple metatarsus adductus is considered as the third deformity in clubfoot, it could be presented with a valgus of the hindfoot for many reasons and display the aspect of Z-shaped foot. Berg [15] differentiated between the simple metatarsus adductus and complex metatarsus adductus where the midfoot is translated laterally. He also distinguished between the simple skew foot (presence of hindfoot valgus) and the complex skew foot (presence of lateral translation of midfoot and hindfoot valgus).

In resistant metatarsus varus and Z-shaped foot, the metatarsal heads are supinated in relation to the hindfoot. During foot stance, this position increases the pronation of sub-talar and mid-tarsal joints, in order to allow the medial metatarsals to contact the floor resulting in an increase of the talo-calcaneal angle [16]. During push-off, instead of a rigid lever, the forefoot may become a mobile structure and induces a larger compressive and shear force which is transmitted to the surrounding soft tissues [17-20]. All these changes may have negative effects on the rest of the foot, the more proximal joints of the lower limb and the spine, which will all have to adapt to these modifications. Thus, problems at the foot, ankle, knee, pelvis and the spine, have been reported in resistant metatarsus adductus [19, 21, 22]. Common problems derived from this deformity may include pain, swelling, tiredness as well as problems of balance and coordination [23].

FOREFOOT ADDUCTION

Metatarsus adductus/varus (Figure 1)

The metatarsus varus was described for the first time by Kite in 1950s, he noted that the foot was supinated and

adducted in a non-weight bearing position [24], while it was only adducted in a pure transverse plane during weight bearing position. For this reason the term of metatarsus adductus was confused with metatarsus varus and metatarsus adductus varus. In metatarsus varus there is an inversion of the forefoot in relation to the rearfoot associated with adduction at Lisfranc's joint which is usually a severe component of this deformity. Several theories of muscle imbalance as a cause of metatarsus varus were proposed by authors, such as tibialis anterior and tibialis posterior overpowering the weaker peroneal muscles [5, 25]. However, Reimann and Werner concluded that metatarsus varus was the result of primary subluxation of Lisfranc's joint with soft tissue adaptation occurring secondarily; they showed that metatarsus varus could only be reproduced in the normal infant foot by extensive capsulotomy even with extreme tension placed on the tibialis anterior tendon [26]. Other theories of abnormal tendon insertion [11, 27-29], osseous malformations [11], and combinations of both factors were mentioned also [30].

Skew foot/Z-shaped foot (Figure 2)

This deformity was described in 1863 by Henke [31]. The first review of literature was done by Peabody and Muro [32] in 1933 where they labeled the deformity "*congenital metatarsus varus*" aiming to differentiate it from the common metatarsus adductus. McCormick and Blount proposed the term of skew foot [33] which was used as a generic term to resume all following deformities: metatarsus varus, metatarsus adductus, metatarsus adductovarus, and metatarsus adductocavovarus. Other investigators have had a share in adding the confusion



FIGURE 2

Skew foot or Z-shaped foot, adduction of the forefoot and valgus of the hind foot, secondary to resistant metatarsus adductus varus.

a. In childhood b. In adult age.

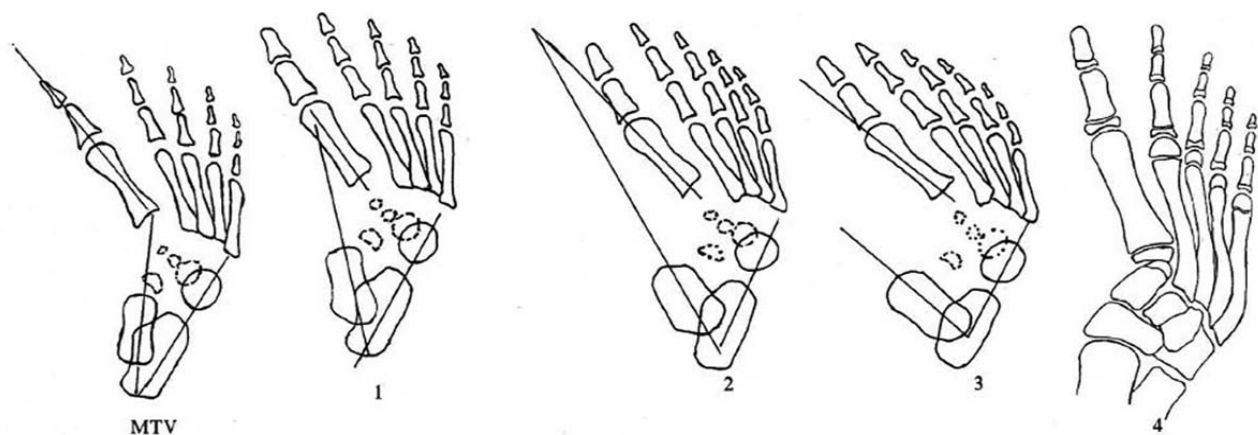


FIGURE 3. Schematic representation of the foot in charge.

MTV: an isolated metatarsus varus where the axis of the talus meets the first metatarsal at its base; the talo-calcaneal divergence is normal. **Grades 1, 2, 3:** Z-shaped foot of increasing severity in young age, where the axis of the talus crosses the shaft of first metatarsus (1), beyond the shaft of first metatarsal (2) or parallel to it (3); the talo-calcaneal divergence is even more exaggerated when the "serpentine" foot is accentuated.

Grade 4: A "serpentine" foot in elder child: an abduction of the anterior tarsal, a developmental disorders of the tarsal-metatarsal skeleton, and a normal or exaggerated talo-calcaneal divergence where added to the fixed metatarsus adductus, all giving the foot the appearance of a "Z". Jawish *et al.* [26]

between the terms metatarsus adductus, serpentine metatarsus adductus, and S-shaped foot. Jawish *et al.* [34] in 1990 defined the Z-shaped foot as varus of the forefoot and valgus of the heel, as a separate deformity from metatarsus varus. They considered metatarsus adductus as the initial deformity resistant to usual treatment, and the rear foot valgus as the opposite deformity in the weight bearing position. According to the severity of the tarsal deformity, four grades were defined, more the adduction is stiff more the valgus is important and the Z-shaped pronounced, going from normal talo-calcaneal angle to severe valgus of the heel (Figure 3). Lynn T. Staheli (1993) [35] recommended using terms such as skew foot, serpentine foot, or Z-shaped foot for the description of a foot deformity that matches the criteria for forefoot adduction and hindfoot valgus. These terms clearly discriminate this deformity from metatarsus adductus.

Residual forefoot adductus in club feet (Figure 4a)

In treated idiopathic club feet, the recurrent forefoot adduction is commonly seen in children over three years of age [36]. Under-correction at the time of the initial surgery and medial displacement of the anterior part of the calcaneus and the navicular around the talus were considered to be etiological factors as demonstrated by Tarraf and Carroll [37] in an analysis of residual deformity in a series of 159 club feet, where they found an adduction in 81.1% at the first revision and in 47.5% at the second revision. An abnormal attachment of the anterior tibialis tendon has been found in these feet. Although, in all our operative observations in hallux valgus and metatarsus adductus, the tibialis anterior was clearly inserted on the plantar aspect of the first metatarsal but not on the first cuneiform. Muscular imbalances between the abductors and adductors of the foot have been found also in these feet [5].

TREATMENT

Conservative treatment

The majority of the metatarsus adductus are corrected spontaneously in the short time after birth or it can be effectively treated conservatively with the help of parents by applying specific minor manipulation of the foot when recognized early, preferably from birth to the time the child takes his or her first steps [33] where only 5% of metatarsus adductus are stiff and persist till the walking age (Figure 5). Jawish *et al.* [34] in "*The Z-shaped or serpentine foot in children and adolescents*" insisted on early radiographic diagnosis and treatment which is orthopedic before the first year of age, then surgical when first failed or missed. Unfortunately, the treatment of resistant metatarsus adductus is often delayed because it is not evaluated seriously until the child is walking, and coordination and shoe-fitting problems occur. Also, there is a misguided notion by many physicians that metatarsus adductus will be "outgrown." In young children up to the age of 6 or 7 years, the treatment is corrective shoes and cast and soft tissue release. As the child grows and the deformity persists, conservative measures fail because osseous adaptation has already occurred. Therefore, in elder children whose conservative treatment has failed or was missed, surgery with osseous procedure become necessary. Several surgical techniques were described in the literature such as metatarsal osteotomies, lateral epiphysiodesis, and osteotomies proximal to Lisfranc's joint and external fixator.

Surgical treatment

The indications for surgery are the same as they would be for traditional metatarsus adductus correction: failure to respond to conservative therapy with residual pain and



Figure 4. Residual forefoot adductus in clubfoot after failed surgery (a). Clinical result after opening wedge osteotomy of the first cuneiform and closing wedge osteotomy of the cuboid (b).

difficulty in wearing shoes comfortably. Ponseti and Becker (1966) found that when congenital metatarsus varus occurred as an isolated deformity only 11.6% needed definitive treatment. Contraindications include infection, extremely small cuneiforms, and an architectural configuration of the midfoot preventing the geometry of the step-down osteotomies.

Many different surgical procedures have been described for the treatment of metatarsus adductus. Lichtblau [29] found that a transverse sectioning of the abductor hallucis tendon near its insertion was effective early on in those cases in which a tight abductor hallucis is found. Thompson *et al.* [38] excised the abductor hallucis muscle, relieving the medial soft tissue contracture. Heyman

et al. [39] and Kendrick *et al.* [40] described a transaction of the dorsal, plantar and inter-osseous ligaments and joint capsules of Lisfranc's joint to mobilize the soft tissues, allowing manual correction of the forefoot deformity. In residual forefoot adductus in club feet, capsulotomies of the tarso-metatarsal joints have been advocated after failed conservative treatment but an incidence of degenerative joint disease of 68% has been reported [41]. Soft-tissue revision surgery is more difficult because of scarring from previous operations and does not take into account deformation of the tarsal bones which occurs with time [5].

Although the previously described soft tissue releases can be helpful procedures early on in the recognition of



FIGURE 5. Conservative treatment for resistant metatarsus adductus, shifting the metatarsals Lisfranc joint laterally.
a. Before walking age. b. Walking age

metatarsus adductus deformities, osseous procedures become necessary in resistant cases and those that go untreated into adolescence. Peabody and Muro [32] described an osseous procedure in which an abductory osteotomy was performed on the fifth metatarsal base with an excision of the central three metatarsal bases and a medial mobilization with reduction of the first metatarsal cuneiform articulation. Steytler and Van der Walt [42] described a V-shaped metatarsal osteotomy of metatarsals 1 through 5 in which the "V" was made obliquely with the apex toward the hindfoot. By making the medial arm almost vertical and the lateral arm more horizontal, they felt they could translate the osteotomy with more stability because no fixation was used. A lateral epiphysiodesis of the metatarsal base was proposed by Ellis [43]. Berman and Gartland [44] described a crescendo metatarsal osteotomy of metatarsals 1 through 5 with lateral translation and fixation of metatarsals 1 and 5 only, with risk of impact on the metatarsal's bone growth. These different osteotomies give a good result in short term, but they cannot prevent the recurrence of the deformity, since the varus deviation of the tarso-metatarsal joint was not corrected.

In skew foot the treatment has known many procedures, all focused on the anterior metatarsal deformity and posterior valgus deviation. The different results demonstrated that osteotomy of the metatarsals has created growth disturbance and the intervention on the posterior foot was useless, creating instability of the tarsal bone, because the valgus is functional and related to the stiffness of the forefoot adduction. Surgical procedures proximal to Lisfranc's joint have rarely been described. Fowler *et al.* [45] described an opening wedge osteotomy of the medial cuneiform with the insertion of bone graft into the medial wedge. In 1958, Johanning [46] described wedge resection and enucleation of the cuboid to shorten the lateral column, followed by manipulation and casting as treatment of resistant clubfoot. In 1961, Evans [47] posed that an elongated lateral column associated with a shortened medial column is crucial in dealing with forefoot adduction, but he proposed a calcaneo-cuboid fusion for re-establishing the balance between the two columns. In 1973, Lichtblau [48] suggested a resection of the anterior end of the calcaneus. However, this acts on only one of the sides of the deformity, as happens with procedures that lengthen the medial column, such as the one described by Hoffman *et al.* [39] in 1984, but the medial column lengthening does not easily address the supination deformity, and has an additional problem because it requires harvesting a bone graft from another site. Napiontek *et al.* [49] in their series on opening wedge osteotomy of the medial cuneiform in the treatment of forefoot adduction reported 14% overcorrection (forefoot abduction), and in 24% of the operated feet, the ceramic porous graft had to be removed.

Jawish *et al.* [34, 50] have recommended in 1990 the correction of the resistant forefoot adduction carrying out an opening wedge osteotomy of the first cuneiform

and closing wedge osteotomy of the cuboid, and what is removed from the cuboid is filled in the opening wedge of first cuneiform, resulting in a complete lateral shift of the forefoot and thus avoiding recurrence (Figure 6). The study was addressed to the correction of the Z-shaped foot in resistant metatarsus adductus, after failure of the conservative treatment in children over 4 years old. Therefore, the simple bean-shaped foot, which is isolated metatarsus adductus, or complicated with Z-shaped foot, is thoroughly corrected with the double cuneiform/cuboid osteotomy. Similarly, McHale and Lenhart [51] in 1991 talked about combination of a shortening osteotomy of the cuboid and lengthening osteotomy of the cuneiform. A semicircular tarsal osteotomy has been described by Gupta and Kumar [52] in 1993; they didn't address the imbalance between the long lateral and short medial columns characteristic of the deformed foot. In 1994, Jawish [53], in a next study, reported the application of the double osteotomy of cuneiform/cuboid in a series of children with multiple causes of forefoot deformities, resistant metatarsus adductus, Z-shaped foot, and resistant clubfoot. Many authors, Schaefer *et al.* [54], Lourenco AF [55], Pohl M *et al.* [56] and Gordon *et al.* [57] have published about the results of this technique and advocated that surgery should be reserved for children over 4 years of age, when the medial cuneiform ossification nucleus is well developed. In 2009, for children younger than 5 years old, Mahadev *et al.* [58] described a corrective procedure for treatment of the residual forefoot adduction combining a closing wedge cuboidal osteotomy and trans-midfoot rotation procedure without a medial opening wedge osteotomy. They believed the medial cuneiform osteotomy should be performed once the ossific nucleus has become well defined.

However, a significant difference should be considered between the causes of valgus of the heel. The valgus deformity could be corrected spontaneously after the double osteotomy of the medial and lateral columns, but in other cases it requests a particular treatment. The first condition corresponds to resistant metatarsus adductus with Z-shaped foot. The second is observed in complicated clubfoot, when a posterior subtalar imbalance is created after operative correction of the varus of the heel (Figure 4b). Therefore, we have to distinguish the Z-shaped foot equilibrating resistant metatarsus adductus from that complicating a surgery for clubfoot. The first aspect necessitates a correction on the forefoot only, the latter advocates a correction at the forefoot and hindfoot.

Ilizarov technique is very interesting, it has been recommended for difficult club foot. Grill and Fanke [59] advocated this method in 1987 for neglected club feet, but the only arthrogryptic foot in their series had a complete relapse of the deformity. Brunner, Hefti and Tgetgel [60] treated 16 arthrogryptic feet with a circular frame, between them 11 had a severe adductus deformity. In six patients, who had an osteotomy of the first metatarsal, correction was maintained, whereas in five without an osteotomy a significant loss of correction was observed.

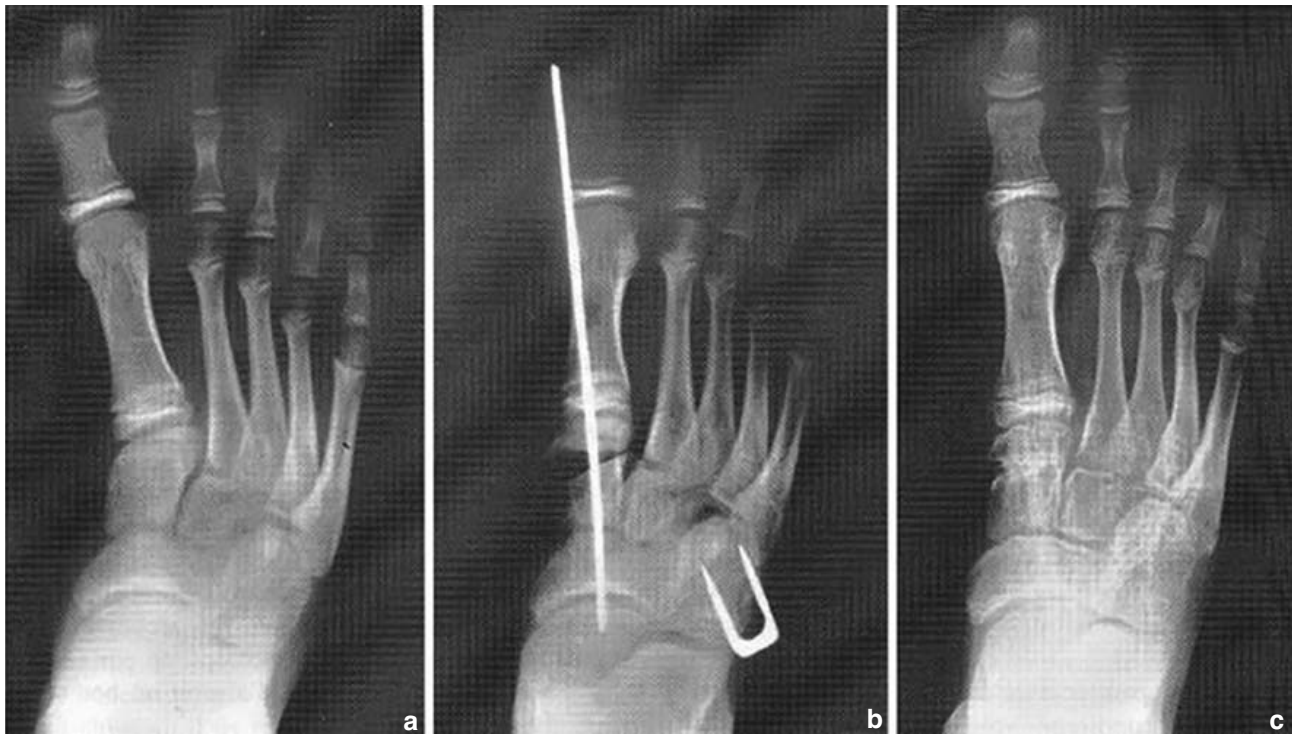


FIGURE 6. (Boy Del... Stéphane). **a:** At 12 years old, the patient had a Z-shaped foot grade 4 with no initial treatment. He had metatarsus adductus and lateral deviation of the anterior tarse, with deformities of the first cuneiform and the cuboid. **b:** We performed a closing wedge osteotomy of the cuboid and an opening wedge osteotomy of the first cuneiform allowing good alignment of the first ray. The pins were removed after 2 months, the cast after 3 months. **c:** After one-year follow-up, the clinical correction and radiological aspect remained excellent. This procedure is recommended for the treatment of the Z-shaped foot after the age of 4-6 years. Jawish *et al.* [26]

This suggests that the combination of an osteotomy with continuous soft-tissue distraction may be necessary to maintain the correction. The Ilizarov technique seems to give the best results in severe deformities, but the treatment is complex and request particular experience, it also involves fixation of the lower leg for several months [61].

CONCLUSION

Forefoot adduction is a common condition in the isolated metatarsus adductus, Z-shaped foot, simple residual clubfoot and complicated residual clubfoot. Therefore, these deformities are differentiated by the hindfoot positioning. In isolated metatarsus adductus and simple residual clubfoot, the hindfoot has a normal position and the main deformity is located at Lisfranc's joint. In case of hindfoot deformity, it is essential to differentiate if it is functional hindfoot valgus as in Z-shaped foot or it is constitutional hindfoot valgus as in complicated residual clubfoot.

However, the theory of elongated lateral column associated with a shortened medial column by combining opening wedge osteotomy of cuneiform with closing wedge osteotomy of cuboid is crucial in dealing with all these types. This technique when applied to children after 4 years of age allows a correction of forefoot adduc-

tion without any growth disturbance in all causes of metatarsus adductus stiffness. Concerning the associated hindfoot valgus, after the double osteotomy cuneiform/cuboid, it is thoroughly corrected in Z-shaped foot where the hindfoot valgus is due to the stiffness of metatarsal adductus when the foot is in weight bearing and is considered as a transient deformity. But in complicated residual clubfoot, the hindfoot valgus resulted from overcorrection in previous surgeries is considered a constitutional deformity and related to imbalance at the rearfoot. Therefore a particular treatment for the posterior tarsal is necessary.

CONFLICT OF INTEREST: The authors declare that they have no conflict of interest.

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