

# Iatrogenic transfer metatarsalgia after hallux valgus surgery: a comprehensive treatment algorithm

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- Current literature has described many of the complications following hallux valgus surgery and their treatment options.
- Iatrogenic transfer metatarsalgia is a distinctive and challenging complication that has not been addressed in a comprehensive fashion yet.
- Iatrogenic transfer metatarsalgia may result from poor preoperative assessment, planning and/or surgical technique.
- We have classified the causes of iatrogenic transfer metatarsalgia based on a multiplanar assessment of the malalignment(s) and are recommending a comprehensive treatment algorithm to guide surgeons in addressing this complication.
- With this knowledge, surgeons may avoid potential pitfalls in the primary surgery that can result in iatrogenic transfer metatarsalgia and find the appropriate treatment option to correct them.

## Keywords

- ▶ transfer metatarsalgia
- ▶ hallux valgus
- ▶ iatrogenic
- ▶ failed
- ▶ revision surgery

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## Introduction

The incidence of complications of hallux valgus surgeries ranges from 10 to 55% (1, 2). Current literature has described the complications of hallux valgus surgery and their treatment options (3, 4). Iatrogenic transfer metatarsalgia is one of the complications with an average incidence of 6.3% as found in a systematic review by Barg *et al.* (5). With the evolution of new surgical techniques to treat hallux valgus, such as mini-open or percutaneous, this issue has become even more challenging and more frequent. Various procedures have been described in the literature to address selected causes leading to this complication. However, to date, no comprehensive and extensive treatment algorithm has been published to help surgeons solve this challenging and recurrent issue.

We have classified the causes of iatrogenic transfer metatarsalgia based on a multiplanar assessment of the alignment of the operated first ray. According to the type of malalignment, we present a comprehensive and complete algorithm for surgical treatment based on this biomechanical understanding.

### Definition of iatrogenic transfer metatarsalgia

We define iatrogenic transfer metatarsalgia as a result of hallux valgus surgeries in patients who developed pain at the lesser metatarsal head(s) after isolated surgery of the first ray (6). The lesser rays were asymptomatic prior to the index hallux valgus surgery.

### Biomechanics of transfer metatarsalgia

Transfer metatarsalgia occurs when excessive loading is transferred from the first ray to the lesser metatarsal heads and pain is experienced under one or several lesser rays. There are a few theories proposed to explain the biomechanics of transfer metatarsalgia. Classifications have also been developed to divide them based on primary and secondary or static and dynamic such as in Besse *et al.* (7).

Maceira *et al.* described how metatarsalgia manifests, based on the gait rockers (3). During the second rocker, the foot is plantigrade and ground reaction forces are distributed in a dorso-plantar direction. A dysfunctional first ray such as in pre-existing hallux valgus, an unstable medial column or a first ray that has been iatrogenically elevated during surgery, would have the load transferred to the lesser rays instead. During the third rocker phase of gait, when the forefoot is oriented vertically towards the floor, ground reaction forces are transmitted directly through the longitudinal axis of the metatarsals. Any discrepancies in the length of rays, such as a short first ray or relatively longer lesser metatarsal, can result in transfer metatarsalgia to the lesser rays, hence showing the importance of alignment in the sagittal plane.

Morton described in several of his studies the association of the hypermobility of the first tarsometatarsal joint (TMTJ1) with foot disorders (8, 9, 10, 11). As a result of this instability of the first ray, the adjacent metatarsals as well

as the longitudinal arch are affected. However, patients are frequently more symptomatic in the metatarsals rather than in the longitudinal arch. This has also been shown by Dietze *et al.* (12) in a pedographic study that increased TMTJ1 instability is positively correlated with greater forces under the adjacent metatarsal heads.

Lapidus went on to expand further on the association of first ray hypermobility and hallux valgus deformity (13, 14, 15). A hypermobile TMTJ in the sagittal plane gives rise to coronal deviation in hallux valgus deformity, and he recommended arthrodesis of this joint to treat hallux valgus. Therefore, restoration of a stable medial column is one of the key factors in addressing transfer metatarsalgia (16).

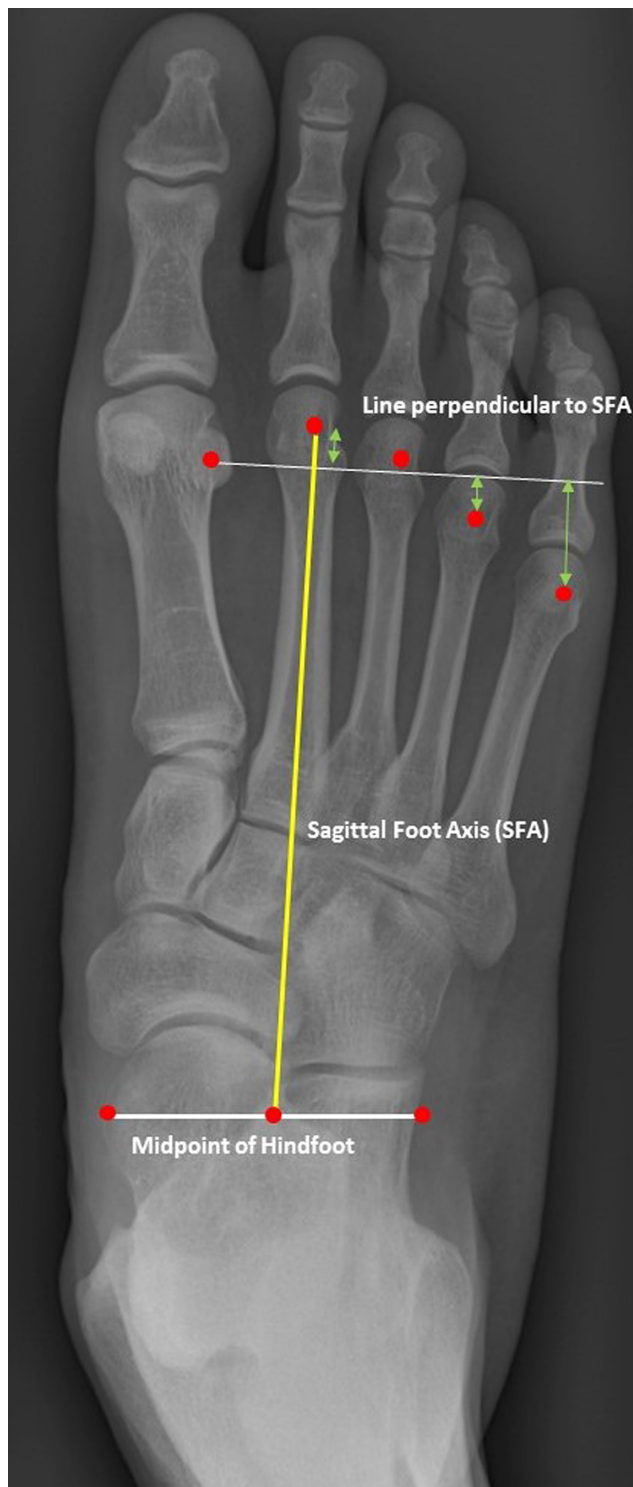
Maestro *et al.* introduced the importance of maintaining a harmonious curve with a geometrical progression of factor 2 and any shortening excessive of 2 mm can result in transfer metatarsalgia (17). Surgical planning starts with drawing architectural landmarks on a dorso-plantar radiograph of the foot (Fig. 1). A sagittal foot axis is drawn from the centre of the second metatarsal head to the midpoint of the hindfoot. A second axis is drawn perpendicular to the sagittal foot axis and passes through the centre of the lateral sesamoid. It is called the SM4 axis when this line is extended laterally passing through the middle third of the fourth metatarsal head. When the lateral sesamoid is absent, a surrogate level can be found on the projection area of the lateral condyle of the first metatarsal head. Distance is measured from the tip of the metatarsal heads to the SM4 axis. In order to minimize the risk of transfer metatarsalgia according to Maestro, surgical correction of the forefoot should aim to achieve three characteristics:

- (i) Restoration of the relationship between lateral sesamoid centre and the centre of the fourth metatarsal head;
- (ii) Progression of the lesser metatarsal length by a factor of 2;
- (iii) Restoration of similar length between first and second metatarsal or preferably a minus index of which the difference should be 1–3 mm.

Therefore, this Maestro study illustrates the importance of coronal plane alignment of metatarsal length during loading of the forefoot.

### Causes of iatrogenic transfer metatarsalgia

The biomechanics of transfer metatarsalgia, as described earlier, can be understood more easily if we classify its causes based on the planes that they have failed in. As we are discussing specifically the iatrogenic subtype of transfer metatarsalgia, it would refer to a failed first ray surgery and its various planar malalignments.



**Figure 1**  
Pre-op planning on radiograph.

#### Sagittal plane

This group includes first ray insufficiency in the dorso-plantar direction. There are four possible scenarios:

- (i) Unrecognised and thus untreated instability of the TMTJ1;
- (ii) Unaddressed intercuneiform instability during a modified Lapidus procedure;
- (iii) Extension malunion of the first ray in a Lapidus procedure;
- (iv) Extension malunion of the metatarsal in a shaft or distal metatarsal procedure.

### Frontal plane

This refers to the first metatarsal length that has not been balanced well with the lesser metatarsals in the anteroposterior plane. Reasons include iatrogenic shortening on various levels of the medial column from TMTJ1 to the head of the first metatarsal. Failure to recognise and address the length discrepancy between the first and lesser metatarsals will disrupt the Maestro parabola.

Iatrogenic shortening of the first metatarsal is one of the more common underlying causes of transfer metatarsalgia after hallux valgus surgery in the frontal plane (18, 19). Studies have shown that shortening up to 2–5 mm (20, 21, 22) can result in transfer metatarsalgia.

The amount of length discrepancy is measured on the anteroposterior radiograph and classified as severe, moderate, mild and none:

- (i) Severe: Iatrogenic shortening of first ray >7 mm. It can occur either in TMTJ1 in a Lapidus procedure or first metatarsal in a shaft procedure.
- (ii) Moderate: Length difference between first and lesser metatarsals 5–7 mm.
- (iii) Mild: Length difference between first and lesser metatarsals <5 mm.
- (iv) No length discrepancy (normal Maestro parabola).

This classification is important as this is what we based our treatment algorithm on and will determine the site of correction. We use a cut-off value of 7 mm to define it as severe shortening which in our experience is best treated with a lengthening revision on the first ray; while for discrepancies below 7 mm, we privilege corrections at the level of the metatarsals themselves.

### Transverse plane

This group describes a first ray that is malaligned in a mediolateral direction. There is an undercorrection of the intermetatarsal angle (IMA) leading to transfer metatarsalgia. Undercorrection of the IMA during index surgery will lead to failure and is addressed differently depending on whether the initial procedure was well chosen but badly performed or the performed osteotomy

was inadequate from the start (i.e. the selected osteotomy was not powerful enough to address the magnitude of the IMA). Finally, a third group includes patients presenting with recurrence of the deformity in the transverse plane due to TMTJ1 instability that had not been identified and addressed during index surgery.

- (i) Correct osteotomy but technically inadequate correction of the IMA;
- (ii) Wrong osteotomy with respect to the IMA;
- (iii) Unaddressed instability of TMTJ1.

## Three-plane approach for surgical treatment of iatrogenic transfer metatarsalgia

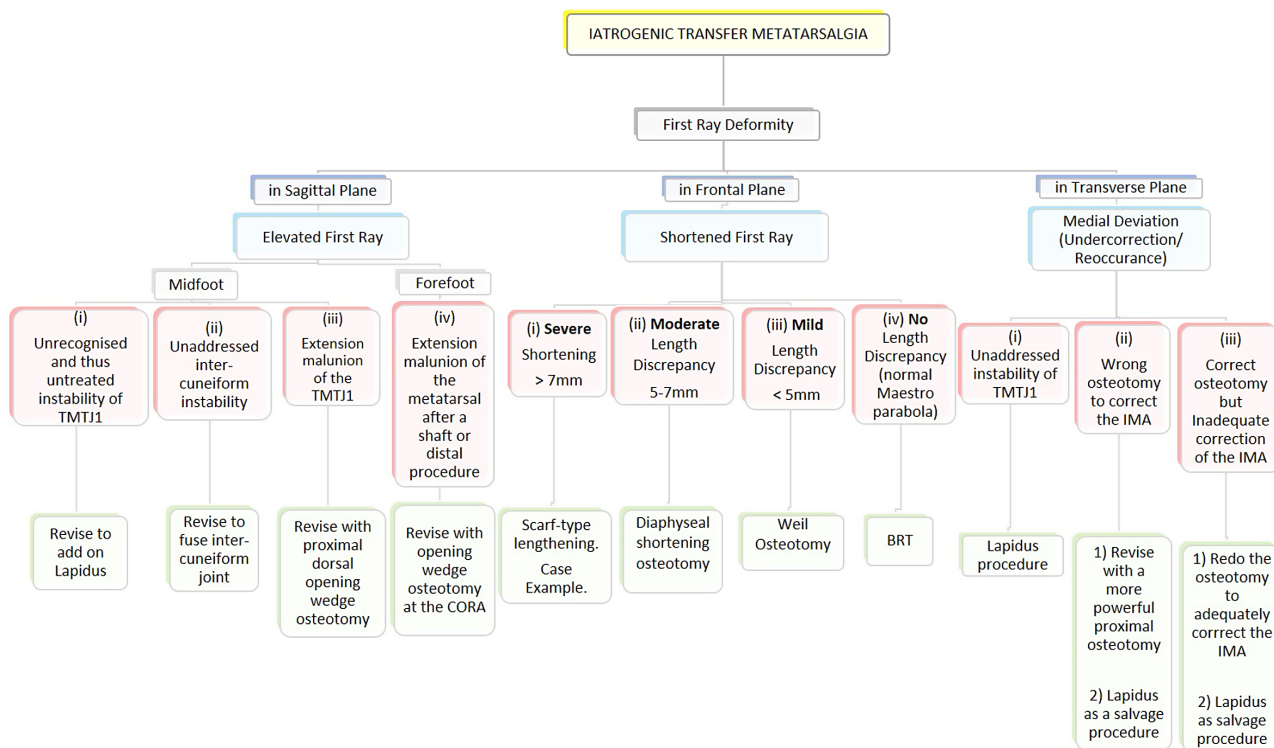
Many authors have introduced procedures over the years to address the more common causes of iatrogenic transfer metatarsalgia (3, 23). However, we should be cognizant that every hallux valgus is different and with each failed surgery, lies slight variations in deformities that have not been addressed. Therefore, it is useful to develop a concept to evaluate that specific complication and use a comprehensive treatment algorithm (Fig. 2) that allows surgeons to address the underlying biomechanical misunderstanding. To the best of our knowledge, current literature has not addressed yet iatrogenic transfer metatarsalgia with a comprehensive approach based on a multiplanar viewpoint.

Technically, one of the first questions arising in the clinical setting of a patient presenting with iatrogenic transfer metatarsalgia following hallux valgus surgery is whether the problem should be corrected at the level of the first ray or at the level of the lesser metatarsals.

Our treatment principles would start with solving the problem at the level of the first ray if any of the four findings is present:

- (i) Sagittal plane issue where the TMTJ1 instability has not been addressed during index surgery;
- (ii) Sagittal plane malpositioning where the surgery has resulted in an elevated first metatarsal ray;
- (iii) Transverse plane issue with undercorrection of IMA;
- (iv) Frontal plane issue with length discrepancy greater than 7 mm between first and second rays.

If the above four problems are not present, we would restore balance in forefoot loading by performing surgery on the lesser metatarsals only. In fact, our current experience at our institution has found that with lesser metatarsal osteotomies alone, the recovery period is shorter and more predictable.



**Figure 2**  
Treatment algorithm.

*Comprehensive analysis based on clinical and radiological assessments – a plane-by-plane observation*

Sagittal plane

In the midfoot

(i) **Underestimated and thus untreated instability of the first TMTJ** There are cases where the index hallux valgus surgery failed because a hypermobile first ray was not recognised and addressed – in most cases at the level of the TMTJ. In this group of patients, a shaft or a distal osteotomy has been performed as index surgery. The corrective option at this stage consists of a modified Lapidus (TMTJ1 fusion) to stabilise the first ray in order to restore the biomechanical function of the foot.

We perform the modified Lapidus by a longitudinal approach over the TMTJ1. After the joint surface of TMTJ1 is prepared, we make a medial longitudinal incision over the metatarsophalangeal joint 1 (MTPJ1) to mobilise the sesamoids medially back to alignment below the first metatarsal head. We then fuse the TMTJ1 with a 3.5-mm fully threaded cortical screw from the dorsum of the medial cuneiform to the plantar aspect of the first metatarsal base. The positioning of the first metatarsal is crucial before fixation and should be sufficiently plantarflexed so that the position of the first metatarsal head lines up with the second metatarsal head in the sagittal plane. It is followed by a 3.5-mm fully threaded cortical screw from

the dorsum of first metatarsal base to the plantar aspect of the medial cuneiform.

(ii) **Unaddressed intercuneiform I-II instability after a modified Lapidus procedure (TMTJ1 fusion)** There are cases where the index hallux valgus surgery failed because of a persistent hypermobile first ray despite a correctly performed modified Lapidus procedure. In most cases, the instability takes place at the level of the intercuneiform I–II joint. Typically, these patients present with a series of radiographs depicting the loss of IMA correction over time together with clinical signs of sagittal instability with increasing transfer metatarsalgia. According to Lapidus and Morton, this scenario may occur in up to 23% of patients (intercuneiform instability) (13, 14, 15, 24). The corrective option at this stage consists in reinforcing the index-modified Lapidus procedure (TMTJ1 fusion) with the original Lapidus by fusing the intercuneiform joint in order to stabilise the first ray and restore the biomechanical function of the foot.

The intercuneiform instability is identified intraoperatively and requires fusion of the medial and middle cuneiforms with 2 medial-to-lateral compression 3.5-mm lag screws. An additional M1–M2 screw fixation at the bases of the metatarsal can be performed to rigidify the construct after preparing in a standard fashion the joint for fusion.



(iii) **Extension malunion** When a TMTJ1 has been iatrogenically fused in an extended position during a Lapidus or modified Lapidus procedure, it will require revision surgery by means of an osteotomy rather than taking down the TMTJ1 fusion. We recommend to perform a plantarflexing dorsal opening wedge osteotomy at the proximal metaphysis of the metatarsal (Figs 3 and 4). Care should be taken during the osteotomy so that the plantar hinge is preserved. The osteotomy should be as proximal as possible at the level of the metatarsal and secured with a dorsal plate 2.4 mm. The amount of opening dorsally is dictated by the magnitude of plantar flexion of the first metatarsal required so that the position of the first metatarsal head lines up with the second metatarsal head in the sagittal plane. Grafting of the opened wedge is not required.

**In the forefoot**

(iv) **Extension malunion of the metatarsal shaft after a shaft or distal procedure** First metatarsal osteotomies of any type that have been iatrogenically elevated during index surgery or united in extension due to loss of position related to lack of fixation stability (Fig. 5) will be revised with an opening wedge osteotomy at the level of the centre of rotation of angulation to plantarflex the first ray (25) (Fig. 6).



**Figure 3**  
Coronal radiograph. (A) Post-Lapidus with elevated first ray. (B) Dorsal opening wedge osteotomy to plantarflex first ray.



**Figure 4**  
Sagittal radiograph. (A) Post-Lapidus with elevated first ray. (B) Dorsal opening wedge osteotomy to plantarflex first ray.

**Frontal plane**

In frontal plane scenarios, solutions are suggested depending on the amount of length discrepancy between the first metatarsal and the lesser rays. Only severe iatrogenic shortening of the first ray is corrected by first ray lengthening. Mild, moderate or no length discrepancy should be addressed on the lesser rays.



**Figure 5**  
Sagittal radiograph: elevated first metatarsal.



**Figure 6**  
Intraoperative photograph: revision osteotomy to plantarflex first ray.

(i) **Shortening of more than 7 mm** For frontal plane malalignment where the first ray is severely shortened by more than 7 mm, we suggest a revision scarf-type diaphyseal lengthening osteotomy with bone grafting if needed (26, 27, 28) (Figs 7, 8 and 9). A medial approach to the first metatarsal allows to perform a scarf osteotomy with the vertical limb parallel to the metatarsal shaft axis (Fig. 8A). The osteotomy is gently distracted using a small laminar spreader placed into the proximal vertical cut to obtain the desired degree of lengthening. A low-profile locking plate (LCP Compact Foot 2.0, DePuy Synthes, New Brunswick, NJ, USA) is provisionally placed on the dorsal aspect and stabilized with K-wires. The position of the first ray is evaluated both clinically by simulating weight-bearing on a board as well as under fluoroscopy. The dorsal plate is then fixed with locking screws (Figs 8B and 9).

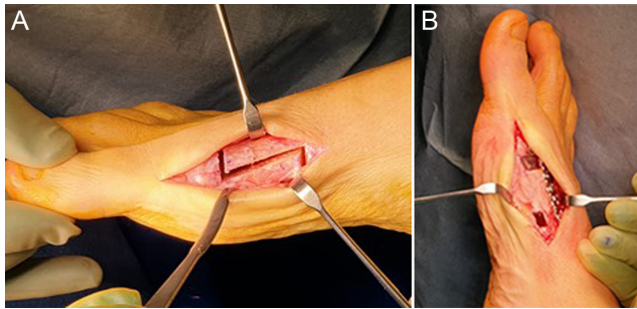
(ii) **Length discrepancy of 5–7 mm Lesser metatarsal diaphyseal osteotomy** Diaphyseal shortening osteotomy of the lesser metatarsals is the current workhorse in our institution to address transfer metatarsalgia following hallux valgus surgery in which the first metatarsal has been shortened. The number of lesser metatarsals which have to be shortened and the required amount of shortening are calculated as per Maestro Index. Diaphyseal osteotomies avoid the frequent problem of stiffness and floating toes commonly associated with Weil’s osteotomies when such magnitude of shortening is required. Five, six or seven millimetres of shortening are typically performed. If the fourth metatarsal requires a shortening of less than 5 mm, we select a Weil osteotomy (see later). A dorsal longitudinal incision is made with careful retraction and protection of the extensor tendon and neurovascular structures. A distal transverse cut is first made so stability can be retained proximally by the midfoot joints. The proximal



**Figure 7**  
Dorso-plantar radiograph of the foot: frontal failure with a shortened first ray.

transverse osteotomy is then made (Fig. 10). The osteotomy is fixed with a 2-mm plate in compression mode (Figs 11 and 12). The patient will receive a cast and be allowed weight-bearing as tolerated on the heel for 6 weeks.

(iii) **Length discrepancy of less than 5 mm Lesser metatarsal weil osteotomy** When the length discrepancy between the first and the second metatarsal is less than



**Figure 8**  
Intraoperative photograph: (A) Modified scarf osteotomy cut. (B) Modified scarf osteotomy fixation.

5 mm, we perform Weil osteotomies on the lesser metatarsal(s). This intra-articular distal shortening osteotomy was first described by Weil (29) in 1985 and has been further published by Barouk in 1996 to treat metatarsalgia (30, 31). The advantages are that it produces a predictable shortening and is a stable osteotomy that allows for immediate weight-bearing post-operatively. Studies have shown that it is able to achieve shortening from a range of 3.5–5.6 mm (32, 33, 34, 35). A longitudinal dorsal incision is made over MTPJ1 with the extensor tendon and neurovascular structures retracted laterally and protected. The osteotomy is started 2 mm plantar to the dorsal border of the cartilage of the metatarsal head. The blade and direction of the osteotomy is made parallel to the floor. The problem with the original Weil osteotomy is that it can result in the lowering of the metatarsal after the osteotomy. Therefore, we use the procedure modified by Barouk to create a parallel osteotomy and hence remove a 2 mm slice of bone to avoid that complication (Fig. 13). It is then fixed with a single 2.5-mm headless compression screw (HCS) (Fig. 14). It has also been known to be associated with stiffness (36). Weight-bearing is allowed as tolerated and the patient is encouraged to perform active movement of the metatarsophalangeal joint to avoid stiffness.

(iv) **When Maestro parabola is normal Proximal osteotomy** In rare cases when the first ray has not been substantially shortened during the index procedure and the



**Figure 9**  
Post-operative radiograph of the foot: (A) Dorso-plantar view. (B) Lateral view.



**Figure 10**  
Intraoperative photograph: diaphyseal osteotomy.

Maestro parabola is normal, we employ the Barouk–Rippstein–Toullec (BRT) proximal dorsal closing wedge osteotomy (37) to the lesser metatarsals. BRT proposed this technique in 2003 to treat metatarsalgia with sagittal plane deformities. It offers great correction of sagittal malalignment; hence, caution is needed to avoid the common pit-fall of causing excessive elevation of the metatarsal.

A longitudinal dorsal incision is made to approach the base of the metatarsal. Starting 20 mm distal to the Lisfranc joint line, an incomplete, oblique (60°) osteotomy is performed with a small oscillating saw (Fig. 15A); care must be given not to end up in the Lisfranc joint. A dorsal wedge is removed by performing a second cut further distally. Removal of 1 mm of dorsal cortex will lead to 3 mm of elevation of the metatarsal head. It is crucial for stability that the plantar cortical remains intact while the osteotomy is closed manually by applying pressure to the metatarsal head. A cannulated 3.0 mm screw is then used to fix the osteotomy (Fig. 15B). It is introduced starting on the dorsal rim of the metatarsal base adjacent to the Lisfranc joint and its position is controlled by fluoroscopy. The weight-bearing distribution of the metatarsal heads is checked by simulating weight-bearing on a transparent, flat sterile board.



**Figure 11**  
Preoperative radiograph: (A) Dorso-plantar view. (B) Lateral view.





**Figure 12**  
Post-operative radiograph: (A) Dorso-plantar view. (B) Lateral view.

Transverse plane

**(i) Unaddressed instability of TMTJ1** This group includes patients with reoccurrence of the transverse plane deformity following a hallux valgus procedure for which TMTJ1 instability has not been diagnosed nor addressed. Joint instability at this level may be multiplanar; therefore, reoccurrence of the deformity in the transverse plane will often involve some excessive motion in the sagittal plane as well. The Lapidus procedure is the recommended treatment of choice.

**(ii) Wrong osteotomy in respect to the IMA (intermetatarsal angle)** There are multiple surgical procedures to correct hallux valgus. They are not equal and have their specific indications. One of the key elements in determining which technique should be used for index surgery is the magnitude of the IMA. Some techniques are less powerful at correcting the IMA than others and should therefore be used appropriately.

This group includes patients who were treated with the wrong technique (type of osteotomy not powerful enough) resulting in undercorrection of the IMA during index surgery. These patients require revision surgery with a more powerful metatarsal osteotomy at the level of the shaft or the diaphysis.



**Figure 13**  
Intraoperative photograph: Weil osteotomy.

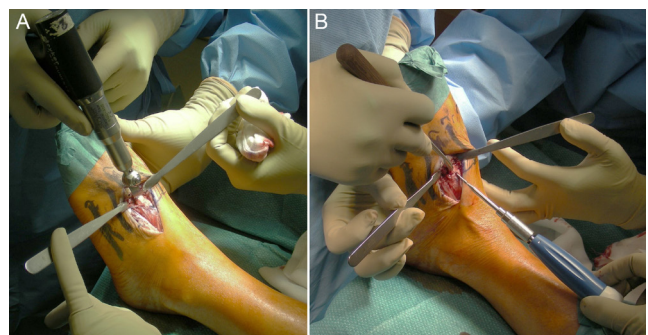


**Figure 14**  
Intraoperative photograph: fixation of Weil osteotomy with HCS.

Salvage procedure with the use of a Lapidus procedure has been shown to be a sound option as it confers a predictable outcome as published by Coetzee *et al.* (38).

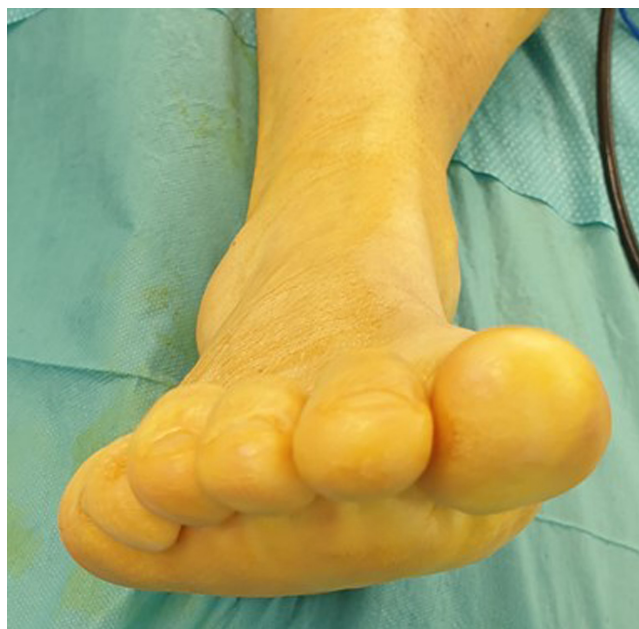
MTP1J fusion is also an option if there are signs of MTPJ arthritis since this procedure will take care of both issues in one sequence.

**(iii) Correct osteotomy but inadequate correction of the IMA** In this group of failures, the appropriate osteotomy was selected for index surgery, but clearly poorly executed. There are several technical issues or pitfalls with each technique that need to be trained and mastered by surgeons. The failure is usually visible on the immediate post-operative radiographs of the patients which show insufficient IMA correction and/or sesamoid reduction. In this scenario, the salvage option is either to revise the osteotomy to achieve the desired IMA or to select a Lapidus procedure as definitive salvage as published by Coetzee *et al.* (38).



**Figure 15**  
Intraoperative photograph of the BRT technique. (A) An incomplete, oblique (60°) osteotomy is performed with a small oscillating saw. (B) A cannulated 3.0 mm screw is then used to fix the osteotomy.





**Figure 16**

Clinical photo: loss of transverse parabola arch with first ray elevated.

### Case example in revision surgery

*A shortened and elevated hallux: revision by a lengthening and lowering scarf-type osteotomy*

A 67-year-old male patient underwent hallux valgus osteotomy surgery many years ago and has reported transfer metatarsalgia. Clinical examination showed a loss of normal transverse parabola arch (Fig. 16). On evaluation with a radiograph (Fig. 7), the first ray was found to be shortened and dorsiflexed. With failure in both coronal and sagittal planes, respectively, we decided to lengthen the ray using a scarf osteotomy and modified the longitudinal limb of the scarf osteotomy to be more oblique in a dorso-proximal to plantar-distal manner (Fig. 8A). Hence, as we lengthened the scarf, the resultant fixation also lowers the ray. We fixed the osteotomy with a 2.0 mm plate (LCP Compact Foot 2.0, DePuy Synthes) (Figs 8B and 9).

### Conclusion

Failed hallux valgus surgery complicated by transfer metatarsalgia is a biomechanically challenging issue that is getting more frequent with the increasing types of techniques used to correct hallux valgus and the volumes of patients treated. We are proposing a detailed algorithm to break down the causes of iatrogenic metatarsalgia as a consequence of hallux valgus surgery into their various planar deformities. This algorithm challenges

the preoperative planning for revision surgery with a multiplanar reflexion. The surgeon should be encouraged therefore to select an appropriate procedure for the revision surgery based on biomechanical evidence.

#### ICMJE Conflict of Interest Statement

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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