Chapter 7

Strategies for Managing Complications of Osteotomies of the Lesser Metatarsals

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Introduction

Osteotomies of the lesser metatarsals are generally indicated for the management of pathologies gathered under the term metatarsalgia, which refers to pain in the forefoot. Classic central metatarsalgia is considered to be caused by excessive pressure at the plantar surface and is associated with plantar callosities and bony prominence of the second through fourth metatarsal heads.

Metatarsalgia has been classified as primary, secondary, or iatrogenic. The underlying pathology may be excessive length of one of the lesser metatarsals, increased metatarsal declination, a subluxated or dislocated metatarsophalangeal (MTP) joint, a cavus foot, hypermobility of the first ray, posttraumatic malalignment, hallux rigidus, or failed forefoot surgical treatment resulting in malunion or nonunion.

The goal of treatment is to improve the distribution of pressure in the forefoot. In all patients, the first-line treatment is nonsurgical. When surgical treatment is indicated, the surgeon can choose from several lesser metatarsal osteotomies to perform on the distal, middle, or proximal metatarsal. Distal osteotomies are more often indicated for intra-articular deformities. Proximal osteotomies typically are more effective than distal osteotomies because a small correction at the proximal end of the bone results in considerable correction at the distal end. Optimal surgical management of central metatarsalgia remains controversial, and numerous procedures have been described in the literature.

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Techniques

Distal Metatarsal Osteotomies

HELAL OSTEOTOMY

The Helal osteotomy is located at the distal third of the metatarsal. If a single osteotomy is planned, a longitudinal 3-cm incision is made over the metatarsal. For a double osteotomy, this incision is made over the web space. For a triple Helal osteotomy, a longer incision is made over the central metatarsal. After the metatarsal is exposed, the osteotomy is done with a narrow-gauge oscillating saw starting proximally on the dorsum of the metatarsal and proceeding distally and plantarly at a 45° angle. With the use of an osteotome, the head is then freed from the plantar soft tissue, allowing the head to displace proximally and dorsally. No fixation is used after the osteotomy.

WEIL OSTEOTOMY

The Weil osteotomy may be performed in one of two ways. For the management of instability in the transverse plane, an extra-articular shortening osteotomy is indicated in combination with a capsular release. The intra-articular (classic) Weil osteotomy is indicated for the management of instability in the sagittal and transverse planes.

For the Weil osteotomy, if a single osteotomy is planned, a longitudinal 3-cm incision is made over the metatarsal. For a double osteotomy, this incision is made over the web space. For a triple osteotomy, a longer incision is made over the central metatarsal. After the metatarsal head and neck are identified and released, the joint capsule is incised. The collateral ligaments of the MTP joint are cut, after which the dislocation of the MTP joint is partly reduced and the toe is flexed to ensure optimal exposure of the metatarsal head. The plane of the osteotomy is parallel to the ground as if the foot is bearing weight. A slice of bone is resected to gain greater elevation of the metatarsal head. A pointed clamp is then used to grasp the mobile plantar fragment and shift it proximally to achieve the desired shortening. After the positioning is checked with the image intensifier, a screw is used to secure the two fragments. The resulting dorsal protuberance on the metatarsal head is resected.

DISTAL METATARSAL V-SHAPED (CLOSING WEDGE) OSTEOTOMY

The MTP joint is approached in the usual manner, after which a V-shaped trough is made in the dorsal three fourths of the metatarsal neck with a rongeur. This trough is 5 mm at its widest point. The osteotomy is closed using manual pressure. No fixation is used. Patients are encouraged to begin weight bearing to keep the osteotomy closed 24 hours after the procedure.

DISTAL CHEVRON OSTEOTOMY

The apex of the cut of the distal chevron osteotomy (which was described in a 1998 study for the treatment of metatarsalgia) is centered at the metadiaphyseal junction of the metatarsal. The limbs of the osteotomy are at a 45° angle and directed proximally. The distal fragment is displaced dorsally approximately 2 to 3 mm. The osteotomy itself was suggested to be stable, but the authors of the 1998 study used internal fixation with a Kirschner wire.

Proximal and Diaphyseal Metatarsal Osteotomies

STEP-CUT OSTEOTOMY

The original technique for the diaphyseal shortening osteotomy, described in 1954 and 1958, involved fixation with only a catgut suture. This technique was technically demanding. Because small power saws were not available, the osteotomy was created by making numerous drill holes that were then connected with an osteotome. Postoperative care included 4 weeks of cast fixation. Good to excellent results were reported in the first patients treated with this technique.

OBLIQUE SHORTENING OSTEOTOMY

Mann and Coughlin modified the step-cut osteotomy and described a diaphyseal sliding osteotomy. In this technique, an oscillating saw is used to perform an oblique osteotomy in the diaphysis of the metatarsal. By applying pressure at the distal end, the shortening is achieved by displacing the distal fragment proximally. Internal fixation is usually achieved with two small fragment screws. In a series published in 2006, 97% of patients treated with this method had pain relief and radiographic union by an average of 10 weeks postoperatively.

SEGMENTAL OSTEOTOMY

Segmental resection is the most precise method of shortening. Segmental osteotomy without internal fixation was reported in 1990, with good to excellent results in 89% of patients. The osteotomy is performed over a dorsal longitudinal incision. After exposing the metatarsal, a metatarsal segment is resected. Anecdotal reports did not reflect results similar to those of the 1990 study, and high numbers of nonunions occurred. The authors of a study published in 2007 reported their early results of segmental resection and internal fixation with a four-hole plate. In these patients, autogenous bone graft was packed around the osteotomy. Union occurred in 125 of the 126 osteotomies.

PROXIMAL METATARSAL V-SHAPED OSTEOTOMY

A proximal central metatarsal osteotomy without fixation was described in 1983. This dorsal proximal vertical V-shaped osteotomy is performed with the apex facing proximally. With the plantar cortex left intact, a three-dimensional V-shaped fragment is resected, resulting in elevation of the metatarsal head but not essential shortening of the metatarsal. In the study published in 1983, all 41 patients treated experienced relief of symptoms and had no significant complications.

BRT OSTEOTOMY

In the year 2000, Barouk, Rippstein, and Toullec popularized another elevating osteotomy without shortening. This BRT osteotomy consists of proximal closing metatarsal osteotomy with horizontal wedge resection. The plantar cortex is left intact, and a horizontal bony wedge is resected, after which the osteotomy is secured with a compression screw.

Results

Results of osteotomy of the lesser metatarsals are reported in **Table 1**.

Distal Osteotomies

The author of a study published in 1975 reported few complications following the Helal sliding osteotomy without fixation. The complications consisted of wound healing problems, nonunion, and stiffness of the MTP joints. In a later study of 310 patients, transfer metatarsalgia was reported in 4.8%, fibrous nonunion in 15.5%, and malposition in 8.7%.

Several studies have been published on the results of dorsal V-shaped and chevron osteotomies as well as asymmetric V-shaped osteotomy. In a study published in 1998, 40 V-shaped osteotomies were performed—25 with fixation and 15 without. The consolidation time was significantly ($P < 0.05$) less in the patients treated with fixation. A high incidence of transfer metatarsalgia was reported; this outcome was higher in the group that underwent fixation than in the one that did not (52% and 26.7%, respectively). Floating toe deformity was reported in both groups. In a study published in 2014, 33 V-shaped osteotomies with T-plate fixation were performed in 30 patients. Complications consisted of two cases of nonunion, one floating toe, and five cases of hardware failure.

A literature review of complications after Weil osteotomies included 17 articles with a total number of 1,131 Weil osteotomies. The most common complication noted was the floating toe, followed by transfer metatarsalgia, malunion, and nonunion.

The senior author of this chapter (H.-J.T.) presented results in studies published in 1999, 2002, and 2005. The studies published in 1999 and 2005 included the same patient population with 1- and 7-year follow-up, respectively. The most significant complication was the floating toe, which was present in 60% of patients at 1-year follow-up; this incidence increased to 68% at 7-year follow-up. The senior author of this chapter has not observed nonunion, osteonecrosis of the metatarsal head, or malunion in any of the patients in that cohort.

Proximal Metatarsal Osteotomies

Other than four cases of transfer metatarsalgia, no complications were reported in the original study on step-cut osteotomy. Floating toes and slower healing rates were reported in a 2006 study on oblique diaphyseal osteotomy, but no nonunions were noted. In a 1990 study on segmental osteotomies without fixation, transfer lesions were reported in 18% of feet. In a 2007 study on this technique modified to include internal fixation, one nonunion and two cases of superficial wound infection were noted. No other clinical results were reported. The authors of a study published in 1983 reported relief of symptoms and no complications in all patients treated with dorsal wedge V-shaped osteotomy. No published data are available on the BRT osteotomy. The results of distal metatarsal osteotomies are well documented, but that is not the case for proximal metatarsal osteotomies.

Complications

Although metatarsal osteotomies generally carry a low risk of complications, as with any surgical procedure the risk of complications is present. Complications of lesser metatarsal osteotomies that should be discussed in the informed consent process include general surgical complications such as local nerve irritation, implant failure, nonunion, and malalignment. Each of the osteotomies also entails unique complications, including osteonecrosis of the lesser metatarsal heads, malunion, nonunion, transfer metatarsalgia, and floating toe deformity.

Because of the anatomy of the dorsum of the forefoot, the risk of wound healing problems is greater after lesser metatarsal osteotomies than after hallux valgus surgery. The lack of subcutaneous tissue with tendons close to the incision site leads to reduced blood flow close to the incision. In a study published in 1998, the reported rate of wound dehiscence after lesser metatarsal V-shaped osteotomy was 12.5%. In the group of patients treated with osteotomy without fixation, the rate of wound dehiscence was 20% (**Figure 1**).

Osteonecrosis of the Lesser Metatarsal Heads

Osteonecrosis of the lesser metatarsal heads is a rare complication of distal metatarsal osteotomy (**Figure 2**). The senior author (H.-J.T.) has not reported this complication in published studies on the Weil and Helal osteotomies. In the past 10 years, this author has seen two patients with osteonecrosis of the metatarsal head after Weil osteotomy. One patient was treated for Freiberg disease, and the other had a revision Weil osteotomy. Both patients had impaired blood supply preoperatively. The authors of a 2002 study reported one instance of osteonecrosis among 14 osteotomies. Other publications of the results of distal lesser metatarsal osteotomies have reported no osteonecrosis.

Postoperative osteonecrosis of the metatarsal head is difficult to diagnose, but it should be treated as soon as possible after it is noted. Subchondral bone resorption can lead to collapse of the subchondral bone plate and the articular cartilage. Off-loading is the first step to avoid further structural damage and collapse. Early osteonecrosis often goes undiagnosed, but patients often heal without major destruction nonetheless.

Surgical options follow the principles published for management of osteonecrosis of the femoral head. Core decompression should be used to reduce intraosseous pressure and promote revascularization. In patients with more advanced osteonecrosis resulting in a large defect, débridement of synovitic tissue such as loose bodies or osteophytes is necessary. Biomechanically, a closing wedge osteotomy may shift healthy cartilage into the articulating region. Total osteonecrosis of the metatarsal head with nonunion of the osteotomy can only be resolved by resection of the remaining metatarsal head. This resection leads to permanent functional impairment of the toe; the outcome in terms of pain relief has not been studied.

Malunion

Malunion may occur after any metatarsal osteotomy. The first step in planning correction of a malunion is to obtain a weight-bearing radiograph (**Figure 3**). Further investigations needed to determine the amount of malposition are a tangential radiograph of the plantar forefoot (skyline view), pedobarography, and a CT scan.

The malposition may be in either the horizontal or the vertical plane. A revision osteotomy should be done to realign the metatarsal. Depending on previous surgical treatment and local bony conditions, the site of the revision osteotomy is typically at the metadiaphyseal

Table 1 Results of Osteotomy of the Lesser Metatarsals

Authors (Year)	No. of Patients (Feet)	No. of Osteotomies	Mean Patient Age in Years (Range)
Helal and Greiss (1984)	310 (508)	1,524	55
Winkler and Kelaridis (1989)	114 (161)	336	61.5
Kitaoka and Patzer (1998)	19	24	59 (32–85)
Pontious et al (1998)	29	40	NR (21–78)
Mühlbauer et al (1999)	30 (30)	69	60 (25–78)
Vandeputte et al (2000)	32	59	NR
Trnka et al (2002)	31	60	60 (25–78)
Hofstaetter et al (2005)	24 (25)	53	63 (51–78)
Galluch et al (2007)	95 (102)	126	Women, 56.8; men, 56.1 (NR)
Garg et al (2008)	48	71	58 (19–83)
Herzog et al (2014)	30	33	53 (37–75)

Figure 1 Photograph shows wound dehiscence of the dorsal aspect of the foot after Weil osteotomy in a 63-year-old patient with diabetes.

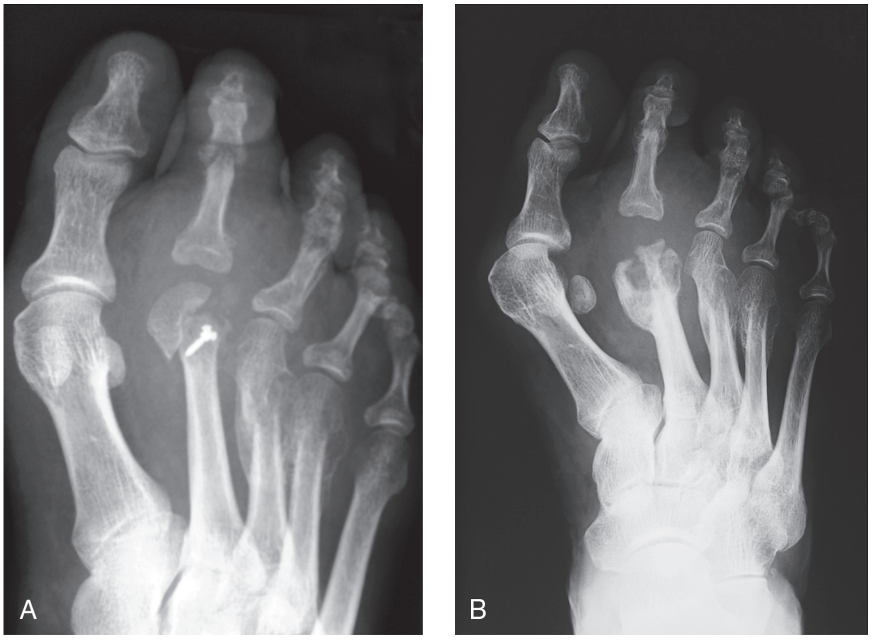

Figure 2 **A,** AP radiograph demonstrates a nonunion after Weil osteotomy in a 58-year-old woman. **B,** AP radiograph of the same patients 5 months later demonstrates osteonecrosis of the distal fragment.

Table 1 (cont.) Results of Osteotomy of the Lesser Metatarsals

Mean Follow-up (Range)	Results	Level of Evidence
4.3 yr (1–12 yr)	Malunion in 8.7%, nonunion in 15.5%, infection in 4%, wound healing problems in 12%	IV
7.2 yr (0.4–12 yr)	Transfer metatarsalgia in 24%, nonunion in 5 osteotomies, floating toes in 34.8%	IV
4 yr (2–7 yr)	Transfer metatarsalgia in 12.5%	IV
91 wk	Transfer metatarsalgia in 42.5%, floating toes in 25%, wound healing problems in 12.5%	IV
15 mo (12–26 mo)	Floating toes in 60%, wound healing problems in 10%	IV
30 mo	Transfer metatarsalgia in 11%, floating toes in 22%	—
30 mo (24–44 mo)	Wound healing problems in 10%	IV
Final follow-up, 84 mo	Floating toes in 68%	IV
8.8 mo (5–18 mo)	Nonunion in 1 osteotomy, wound healing problems in 2 osteotomies	IV
13 mo (6–26 mo)	Transfer metatarsalgia in 18.8%, floating toes in 27.1%, infection in 14.6%, wound healing problems in 10.4%	IV
9.1 mo (6–15.4 mo)	Nonunion in 2 patients, floating toes in 1	IV

NR = not reported.

junction of the metatarsal. The fixation should be rigid to guarantee good bone healing. The authors of this chapter usually perform dorsal plate fixation in a revision osteotomy.

Nonunion

Nonunion has not been reported after distal metatarsal osteotomies with internal fixation (Weil osteotomies) (**Figure 4**). Studies investigating the distal V-shaped or chevron osteotomy also have not revealed any nonunions. In one study, the authors compared distal V-shaped osteotomies with and without internal fixation and found a significant difference in consolidation time (10 to 12 weeks and 22 weeks, respectively). After Helal osteotomies, nonunions are more common (**Figure 5, A**). [AU: Please cite Figure 5, B and C. Or shall we delete those panels?] In most patients, nonunions after Helal osteotomies are asymptomatic and no revision surgery is necessary. Symptomatic nonunions require revision. Usually, débridement

Figure 3 AP weight-bearing radiograph demonstrates the foot of a 66-year-old woman with malunion after a Helal osteotomy that was done too proximally.

Figure 4 AP radiograph demonstrates nonunion of the second and third metatarsal after Weil osteotomy without fixation.

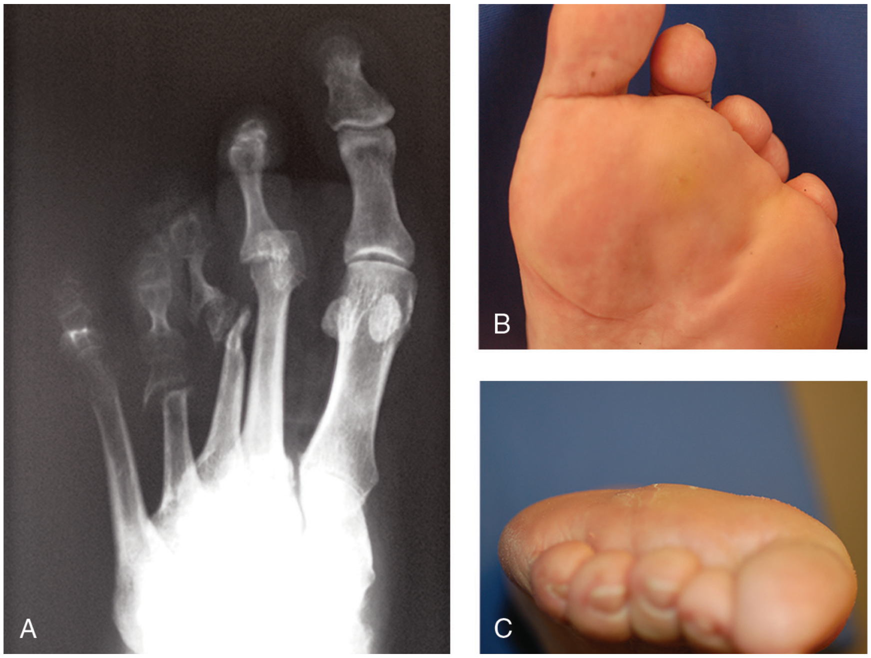

Figure 5 **A,** AP radiograph demonstrates nonunion after Helal osteotomy of the third and fourth metatarsals to address transfer lesion and dislocation of the second metatarsal head. **B** and **C,** Photographs of the sole of the foot demonstrate localized callosity under the second metatarsal head.

Figure 6 AP radiograph demonstrates nonunion after diaphyseal osteotomy.

of the nonunion and drilling of the metatarsal with dorsal plate fixation and bone grafting resolves this complication.

Diaphyseal and proximal lesser metatarsal osteotomies are biomechanically more prone to nonunion than are distal lesser metatarsal osteotomies, but only a few studies mention nonunions; however, time to bony union can be extended. Although a nonunion rate of up to 76% after segmental osteotomy without internal fixation has been reported anecdotally, the authors of a study published in 1990 reported a union rate of 99.2% in patients in whom internal fixation was used (**Figure 6**).

The authors' preferred proximal metatarsal osteotomy is the BRT osteotomy. No results have been published in the English-language literature, but in the authors' patient cohort, no nonunions have occurred.

The authors of this chapter have noted nonunions after the step-cut osteotomy and the sliding osteotomy. In these patients, the nonunions were resected, multiple drillings of both ends of the osteotomy were performed, and rigid dorsal plate fixation was applied. Cast immobilization was used for 6 weeks in the postoperative period. Internal fixation is important for avoiding nonunion. The findings of the aforementioned study on distal metatarsal osteotomies and a comparison of the results of the aforementioned segmental osteotomy studies with and without fixation suggest that internal fixation of metatarsal osteotomies is necessary.

Transfer Metatarsalgia

The incidence of transfer metatarsalgia ranges from 4.8% to 42.5%. Radiography with the patient in the dorsoplantar standing position and pedobarography are important tools to determine the correct treatment plan. Nonsurgical management should be the initial approach. Many patients continue to unload the surgically treated area of the forefoot and transfer more pressure to the adjacent metatarsal heads. Gait training to facilitate better pressure distribution to the forefoot is the first nonsurgical option to manage transfer metatarsalgia. The second option is to unload the affected area with custom orthoses. The downside of this second option is that the orthoses do not fit in all types of shoes.

If nonsurgical management is unsuccessful, surgical treatment is performed. The surgeon must first determine whether the transfer metatarsalgia is caused by a dorsiflexion malposition of the treated metatarsal or is solely the result of a domino effect. If the dorsiflexion malposition is present, a plantarflexion osteotomy with dorsal plate fixation is needed (**Figure 6**).

After a single Weil osteotomy, transfer metatarsalgia may occur as a result of overlength of the adjacent metatarsal. In this situation, shortening of the symptomatic metatarsal is the treatment of choice.

Floating Toe

The floating toe deformity is a common complication following distal lesser metatarsal osteotomies (**Figure 7**). In one published series, the floating toe

Figure 7 Photograph shows floating toes that developed after Weil osteotomy.

deformity occurred in 10% of patients after proximal metatarsal osteotomy. After distal metatarsal osteotomies, the reported incidence is as high as 36%. In the literature review encompassing 1,131 Weil osteotomies, floating toe was the most commonly reported complication, occurring in 233 patients (20.6%).

Generally, distal metatarsal osteotomy is indicated in patients with metatarsalgia associated with intra-articular MTP pathology such as subluxation, dislocation, or crossover toe deformity in addition to a hammer toe deformity. The Weil osteotomy is the technique that has received the most attention in the literature. The floating toe deformity is a serious complication associated with the Weil osteotomy.

No floating toe deformities have been reported in association with either the distal chevron osteotomy or the dorsal wedge V-shaped osteotomy. However, an incidence of 25% was reported in a series of 40 Helal osteotomies. For the Helal osteotomy, only one study has analyzed the incidence of floating toe deformity, which was reported in 6 of 49 patients.

Multiple causes of the postoperative floating toe have been suggested. In a cadaver study that included three-dimensional analysis, the Weil osteotomy was shown to change the center of rotation of the MTP joint axis. This change also alters the function of the intrinsic muscles from stabilization of the MTP joint to dorsiflexion. The shortening of the metatarsal may change the physiologic tension of the flexor and extensor tendons. Another cause may be contracture of the scar and the subcutaneous tissue.

Techniques to reduce the likelihood of postoperative floating toes include resection of a slice of bone to avoid depression, appropriate skin incisions that are made in a curvilinear fashion over the MTP joints, and lengthening of the extensor tendons in the case of dislocated MTP joints with preoperative contracture of the extensor tendons.

Several treatment options are available to manage floating toe deformity. First, lengthening of the dorsal contracture is necessary, including the extensor tendons and the dorsal joint capsule. Next, a McGlamry elevator is used to mobilize the plantar capsule. If at this point the toe still does not touch the ground, a flexor pro extensor tendon transfer is recommended. Alternatively, proximal interphalangeal joint fusion can be done. After proximal interphalangeal joint fusion, the force of the long flexor tendon is used to plantar flex the toe.

Summary

Lesser metatarsal osteotomies are well-accepted methods of surgically managing central metatarsalgia. Certain distal and proximal osteotomies are associated with specific complications. The most commonly performed metatarsal osteotomy is the distal oblique sliding osteotomy (Weil osteotomy), whether the classic or modified technique. Complications of metatarsal osteotomies are rare and include osteonecrosis of the metatarsal head, nonunion, malunion, transfer metatarsalgia, and floating toe deformity. Salvage of failed metatarsal osteotomies depends on the type of complication and has to be considered for each individual patient. No widely accepted treatment algorithm exists to address these pathologic conditions. Nonsurgical methods should generally be considered the first-line treatment option.

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