# Incidence of Floating Toe After Distal Minimally Invasive Metatarsal Osteotomy with Pin Osteosynthesis for the Treatment of Metatarsalgia and Rigid Hammertoe

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## ABSTRACT

**Introduction:** Central metatarsalgia is a common cause of forefoot pain. The most common surgical treatment is Weil osteotomy and the most popular percutaneous technique is distal minimally invasive metatarsal osteotomy (DMMO). However, the main disadvantage of these techniques is the appearance of floating toes, which is even greater when associated with proximal interphalangeal arthrodesis. In this series of cases, DMMO was combined with a pin to elevate the center of rotation of the metatarsal head with the aim of reducing the presence of floating toes. Our main hypothesis was that this technique would result in a lower presence of floating toes in patients diagnosed with mechanical metatarsalgia and rigid hammertoe, compared to Weil osteotomies. **Materials and Methods:** A retrospective observational study was carried out on consecutive adult patients diagnosed with mechanical metatarsalgia and rigid hammertoe. DMMO was performed with pin fixation in combination with proximal interphalangeal (PIP) arthrodesis. Finally, the presence of floating toes was compared with a group of patients operated on with the Weil technique and PIP arthrodesis. **Results:** A total of 39 DMMOs with PIP arthrodesis were performed. The percentage of floating toes was 31% . There was no statistically significant difference compared to the Weil technique (36%, p = 0.634). **Conclusion:** DMMO for elevation of the center of rotation associated with PIP arthrodesis fixed with a pin did not provide a lower incidence of floating toes compared to Weil osteotomy.

**Keywords:** Metatarsalgia; hammertoe; distal metatarsal metaphyseal osteotomy; proximal interphalangeal arthrodesis; floating toe.
**Level of Evidence:** IV

## Incidencia de dedo flotante en la osteotomía metatarsiana distal percutánea con osteosíntesis para el tratamiento de la metatarsalgia con dedo en martillo rígido

## RESUMEN

**Introducción:** La metatarsalgia central es una causa frecuente de dolor de antepié. La osteotomía de Weil es el tratamiento quirúrgico más popular y la osteotomía metatarsiana distal percutánea (OMDP) es la técnica percutánea más utilizada. La principal desventaja de estas técnicas es la aparición de dedo flotante que es aún mayor cuando se la asocia a artrodesis interfalángica proximal (AIFP). En esta serie de casos, se combinó la OMDP y la osteosínetsis con clavija de Kirschner para elevar el centro de rotación de la cabeza del metatarsiano con el objetivo de disminuir la presencia de dedos flotantes. Nuestra principal hipótesis fue que esta técnica generará menos dedos flotantes en los pacientes con diagnóstico de metatarsalgia mecánica y dedo en martillo rígido, comparada con la osteotomía de Weil. **Materiales y Métodos:** Se realizó un estudio retrospectivo en pacientes adultos con diagnóstico de metatarsalgia mecánica y dedo en martillo rígido. Se los sometió a una OMDP más fijación con clavija de Kirschner en combinación con AIFP. Finalmente, se comparó la presencia de dedos flotantes con un grupo de pacientes operados con la técnica de Weil y AIFP. **Resultados:** Se realizaron 39 OMDP más AIFP. La tasa de dedos flotantes fue del 31%. No hubo una diferencia estadísticamente significativa comparada con la técnica de Weil (36%, p = 0,634). **Conclusión:** La ODMP con elevación del centro de rotación asociada con AIFP no proporcionó una menor incidencia de dedos flotantes en comparación con la osteotomía de Weil.

**Palabras clave:** Metatarsalgia; dedo en martillo; osteotomía metatarsiana distal percutánea; artrodesis interfalángica proximal; dedo flotante.
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## INTRODUCTION

Central metatarsalgia is a common cause of forefoot pain that is often associated with deformity of the hallux or lesser toes. This could be related to a variety of factors, including anatomical abnormalities of the foot, systemic diseases, iatrogenesis, etc.[1] Rocker[2] is a term used in gait cycle analysis to refer to the fulcrum used by the foot during gait progression. During gait, the foot functions as a *three-rocker* mechanism. Depending on the moment in the gait cycle at which the overload occurs, mechanical metatarsalgia can be classified as first-, second- or third-rocker metatarsalgia. The heel is the first rocker while resting on the ground during the first 10% of the gait cycle; in this case, metatarsalgia is caused by a congenital deformity, pes cavus, or calf shortening. The ankle is the second rocker, the entire foot is in contact with the ground. In this instance, metatarsalgia occurs with limited ankle motion or increased plantar flexion of the lesser metatarsals that overloads the forefoot. Mechanical metatarsalgia of the propulsive third rocker or forefoot develops when the heel is lifted and overload is transferred to the lesser metatarsal heads due to an insufficient first ray. Metatarsal head elevation is effective for second-rocker metatarsalgia, while metatarsal shortening is effective for third-rocker metatarsalgia.[2,3] When conservative treatment fails, surgical resolution is required. Radical techniques have been described, such as resection of the metatarsal head, as well as conservative techniques, such as open or percutaneous osteotomies, with preservation of the metatarsophalangeal joint.[1,4,5]

Among osteotomies, the one described by Weil[6] for the treatment of central metatarsalgia is the most popular. It is an open intra-articular technique for controlled metatarsal shortening. Its main disadvantage is the appearance of floating toe, that is, toes that do not make contact with the floor when standing.[7-9] The etiology of this complication has not yet been clarified.[10] In terms of percutaneous osteotomies, one of the most commonly used is the distal metatarsal minimally invasive osteotomy (DMMO). These minimally invasive techniques are on the rise because they cause less soft tissue damage, which has led to the use of this approach for mild to severe forefoot deformities.[11,12] However, floating toe also appears to be a common complication following this osteotomy. The presence of floating toe is even greater when associated with proximal interphalangeal joint (PIPJ) arthrodesis.[6] Some authors suggest that this is due to a lowering of the center of rotation that leads the intrinsic flexor muscles to pass over it, leading to extension of the metatarsophalangeal joint.[13]

Considering the latter, DMMO and Kirschner pin osteosynthesis were combined to elevate the metatarsal head in order to reduce the presence of floating toes. Our main hypothesis was that DMMO with a pin will cause fewer floating toes in those patients diagnosed with mechanical metatarsalgia and rigid hammertoe compared to Weil osteotomy.

## MATERIALS AND METHODS

A retrospective observational study was performed on consecutive adult patients with a diagnosis of mechanical metatarsalgia and rigid hammertoe who underwent DMMO plus Kirschner pin fixation in combination with PIPJ arthrodesis at our institution, between August 2012 and February 2015.

Inclusion criteria were: adults who underwent surgery using the technique described below for mechanical metatarsalgia of the third rocker with metatarsophalangeal dislocation or subluxation with rigid hammertoes.

Exclusion criteria included neurological disease, post-traumatic sequelae, previous metatarsal surgeries, osteoarthritis of the involved metatarsophalangeal joint, Freiberg's disease, pes cavus, and incomplete medical records.

### Surgical technique

The patient is placed in the dorsal decubitus position, with regional anesthetic block and hemostatic cuff at ankle level. Extensor tenotomy and proximal interphalangeal capsulotomy are performed via a dorsal longitudinal approach to the toe, followed by peg-and-socket arthrodesis of this joint with a 1.5 mm diameter Kirschner pin under image intensification.

We proceed with a minimally invasive approach to the metatarsal neck, followed by a percutaneous tenotomy of the extensor digitorum longus and extensor digitorum brevis, a dorsal capsulotomy, and percutaneous excision of both collateral ligaments. Once the metatarsophalangeal joint is reduced, the Kirschner pin is advanced towards the distal metatarsal metaphysis maintaining the reduction, all under fluoroscopic control.

DMMO is then performed on the distal metaphysis at an angle of approximately 45° to the floor. This is performed from distal dorsal to proximal plantar to achieve the ascent and shortening of the metatarsal head, finally the pin is advanced towards the diaphysis of the metatarsal (Figure 1). Thus, the aim is to reduce the pressure exerted by the metatarsal heads against the floor (Figure 2). On the other hand, the center of rotation is raised so that the intrinsic muscles act again as flexors of the metatarsophalangeal joint, trying to reduce the incidence of floating toe. Finally, percutaneous tenotomy of the flexor digitorum longus of the treated toe is performed to prevent further progression to mallet toe.

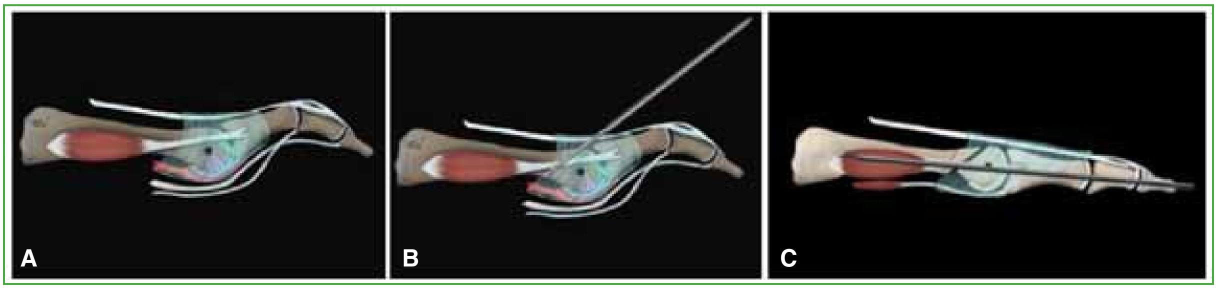


**Figure 1.** Percutaneous distal metatarsal osteotomy. **A.** Diagram of hammertoe with center of rotation of the metatarsal head. **B.** Percutaneous osteotomy with Shannon reamer. **C.** The Kirschner pin advances toward the diaphysis of the metatarsal, raising the center of rotation.

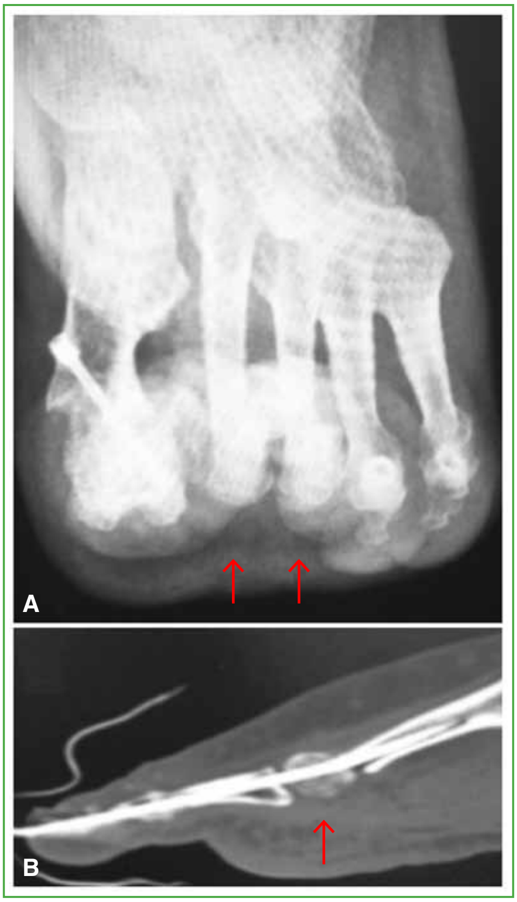


**Figure 2.** Elevation of the metatarsal heads. **A.** Sesamoid radiograph, axial view. **B.** Computed tomography of the forefoot, sagittal section. The red arrows indicate the elevation of the metatarsal heads.

## Postoperative care

The first 24 hours are spent without weight-bearing until the anesthetic block effect fades. After 20 days, home ambulation is permitted with full weight bearing in the post-surgical neutral shoe, and the osteosynthesis is removed at 21 days.

Patients were evaluated clinically and radiologically before surgery, after 3 weeks, after 3 months, or until consolidation was established (Figures 3 and 4).

## Radiographic evaluation

Anteroposterior and lateral weight-bearing radiographs were taken before surgery and at different subsequent instances. Preoperatively and postoperatively, metatarsophalangeal joint congruence was analyzed and recorded as reduced, subluxated or luxated. The osteotomy (DMMO) was also evaluated for the presence of malunion or pseudarthrosis. The variation of the metatarsal formula, especially the length of the first metatarsal (*Index Plus/Index Plus Minus/Index Minus*), was recorded.[14,15]

## Clinical evaluation

The main evaluation was the presence or absence of floating toes, defined as toes that do not make contact with the floor when the patient is standing.[7-9] At the end of the follow-up period, function was assessed with the *American Orthopaedic Foot and Ankle Society* (AOFAS) scale,[16] which takes into account the following variables: pain, functional impairment, footwear restriction, plantar callus, alignment, stability, and metatarsophalangeal joint stiffness. As all patients had proximal interphalangeal joint arthrodesis, the maximum score considered was 95.

Finally, these variables were compared to those of the first 26 consecutive patients with metatarsalgia and rigid hammertoes who underwent Weil and PIPJ arthrodesis at our Center. This approach involves conducting an open osteotomy parallel to the floor surface, from the dorsal region of the metatarsal head to the proximal, to accomplish shortening, which is then fixated with a 2.7 mm screw.


**Figure 3.** Preoperative weight-bearing foot radiographs. **A.** Anteroposterior **B.** Lateral.


**Figure 4.** Anteroposterior and lateral radiographs of the foot. **A and B.** Two weeks later. **C and D.** Three months later. **E and F.** Six months later.

## RESULTS

Between August 2012 and February 2015, 28 patients diagnosed with metatarsalgia with rigid hammertoe underwent surgery with the previously described surgical technique. Five of them were excluded because they failed to attend the indicated clinical controls. Seven of the remaining 23 patients underwent bilateral surgeries (30 feet, 39 osteotomies).

The rate of floating toes was 31% (12 of 39 osteotomies). In the postoperative radiographic evaluation of the metatarsal formula, although 28 of the 30 feet had undergone hallux surgery, only four showed postoperative index minus.

There were no cases of pseudarthrosis or transfer metatarsalgia. Metatarsophalangeal reduction was achieved in 34 cases (88%) and dislocation recurrence occurred in five joints (12.8%). In most cases, recurrence was asymptomatic. The only symptomatic case, a patient with varus deviation of the second toe, was resolved with a percutaneous osteotomy of the first phalanx (Figures 5 and 6).


**Figure 5.** Postoperative complication. Weight-bearing foot radiographs, AP view. **A. B.** Immediate postoperative period. **C.** Varus misalignment of the second toe. **D.** Percutaneous osteotomy of the first phalanx. **E.** Radiographic control with consolidated osteotomy.


**Figure 6.** Clinical images of postoperative complication. **A.** Preoperative image. **B.** Advanced postoperative period after percutaneous distal metatarsal osteotomy plus osteosynthesis. **C.** Postoperative period after percutaneous osteotomy of the first phalanx for correction of varus deviation of the second toe.

Tables 1 and 2 show the demographic characteristics and postoperative outcomes of the patients treated with the surgical technique described in this case series, compared with those of the first 26 consecutive patients in the series treated with Weil osteotomy plus PIPJ arthrodesis at our institution.

There was no statistically significant difference in the presence of floating toes comparing both techniques ($p = 0.634$); however, the postoperative reduction of the metatarsophalangeal joint was significant and was more successful with the Weil technique ($p < 0.001$). Functional outcomes were satisfactory in both groups, with a mean AOFAS scale score of 86 (range 63-90) for the DMMO with Kirschner pin group and 81.2 (range 19-95) for the Weil osteotomy plus PIPJ arthrodesis group.

**Table 1.** Demographic characteristics of patients treated with percutaneous distal metatarsal osteotomy (DMMO) plus Kirschner pin and Weil osteotomies.

| | DMMO + pin | Weil Osteotomy |
|---|---|---|
| Number of patients | 23 | 26 |
| Age (years) | 72 (69-85) | 62 (23-78) |
| Gender (Female/Male) | 23/0 | 24/2 |
| Follow-up (months) | 22 (18-30) | 18 (6-36) |
| Distribution | | |
| Second metatarsal | 30 | 31 |
| Third metatarsal | 7 | 6 |
| Fourth metatarsal | 2 | 1 |

**Table 2.** Clinical and radiographic outcomes of patients treated with percutaneous distal metatarsal osteotomy (DMMO) plus Kirschner pin and Weil osteotomies.

| | DMMO + pin | Weil Osteotomy | p |
|---|---|---|---|
| Number of osteotomies | 39 | 38 | |
| Floating toes, n (%) | 12 (31) | 14 (36) | 0.634 |
| Dislocated/subluxated joint, preoperative, n (%) | 39 (100) | 19 (50) | 0.5 |
| Reduced joint, postoperative, n (%) | 34 (87) | 38 (100) | **<0.001** |

# DISCUSSION

Central metatarsalgia is a common cause of forefoot pain that is often associated with toe deformities.[2] Different surgical techniques have been proposed, but none have yielded optimal results.[8] Weil's osteotomy is an effective and safe procedure for the treatment of central metatarsalgia, although it may be associated with some complications, such as floating toe deformity.[8] As published by Trnka et al.,[13] this is due to the lowering of the center of rotation leading to extension of the metatarsophalangeal joint, because the interosseous muscles become dorsiflexors. However, in this series, the metatarsal head elevation achieved with DMMO plus Kirschner pin fixation failed to reduce the rate of postoperative floating toes compared with Weil osteotomy.

The rate of floating toes in our series is 31%, considering that 30 of the 39 osteotomies were performed on the second metatarsal, 10 of the floating toes were on the second toe. This may be because the second metatarsophalangeal joint has only dorsal interossei, which would explain a less effective active plantar flexion compared to the other lesser toes.[17]

In a recent review of 1131 Weil osteotomies, Highlander et al.[10] reported an overall incidence of floating toes of 36%. O'Kane and Kilmartin[1] published a 20% incidence of floating toe in 40 open Weil osteotomies without PIPJ arthrodesis, in a relatively short follow-up period of 8.6 months.[1] On the other hand, Migues et al.[8] reported an overall incidence of floating toe of 28.5% in 70 Weil osteotomies, 14 of the 20 floating toes had undergone PIPJ arthrodesis. The authors attribute this difference to PIPJ arthrodesis making the metatarsophalangeal contracture more evident in dorsiflexion. The reduction of the tension of the plantar flexor mechanism associated with the retraction of the dorsal structures during healing would be responsible for this evolution.[17]

Modifications of the Weil osteotomy, such as the Maceira osteotomy,[2,18] have been proposed to avoid the descent of the head and the incidence of floating toe. It consists of a triple cut adapted from the Weil osteotomy that allows shortening the diaphysis without head descent, however studies are still needed to confirm its advantages over the Weil osteotomy.[17]

Weil osteotomy has also been described along with suturing of the plantar plate and lengthening of the extensor tendon, in order to realign and decompress an unstable metatarsophalangeal joint.[19] Repair of the plantar plate restores the end part of the windlass mechanism favoring plantar flexion over dorsiflexion.[18,19] Gregg et al.[19] reported good functional outcomes and the lowest incidence (6%) of floating toe, with only two patients.

We can say that the incidence of floating toe in our patients (31%) is similar to that published in other articles.[8,10] The incidence of postoperative dislocation in this series was 13%. This figure is comparable with other published series (12-15%).[7,20] In most cases, the dislocations were asymptomatic. The only symptomatic case was resolved with a percutaneous osteotomy of the first phalanx (Figures 4 and 5). Postoperative functional outcomes were satisfactory with a mean AOFAS scale score of 86 points (range 63-90).

One of the limitations of this study was that the AOFAS scale was not used before surgery, but it should be taken into account that none of the patients included had responded to conservative treatment. On the other hand, this is a retrospective study and the number of patients is small. In addition, other associated surgical procedures were performed on the lesser toes and hallux.

It is important to note that all were treated by the same surgeon and under the same surgical protocol. This procedure would cause less soft-tissue damage because it is percutaneous and, in addition, it would have a lower cost in osteosynthesis material since only one Kirschner pin would be used.

Although several studies have compared the results of the Weil technique with DMMO without differences in range of motion and satisfaction,[21-23] we found no articles comparing the two techniques for the treatment of metatarsalgia associated with rigid hammertoe. Studies should be carried out with the same technique and in a randomized comparative fashion to obtain better evidence compared to open Weil osteotomy.

## CONCLUSIONS

DMMO with elevation of the center of rotation associated with PIPJ arthrodesis fixed with a Kirschner pin did not provide a lower incidence of floating toes compared to Weil osteotomy. However, it is a valid alternative for the treatment of mechanical metatarsalgia associated with rigid hammertoes.

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Conflict of interest: The authors declare no conflicts of interest.

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