THE JOURNAL OF BONE & JOINT SURGERY (BR)

The Weil osteotomy

A SEVEN-YEAR FOLLOW-UP

S. G. Hofstaetter,
J. G. Hofstaetter,
J. A. Petroutsas,
F. Gruber,
P. Ritschl,
H.-J. Trnka

From Hospital Gersthof, Vienna, Austria

We prospectively evaluated the one- and seven-year results of the Weil osteotomy for the treatment of metatarsalgia with subluxed or dislocated metatarsophalangeal joints in 25 feet of 24 patients. Good to excellent results were achieved in 21 feet (84%) after one year and in 22 (88%) after seven years. The American Orthopaedic Foot and Ankle Society score significantly improved from 48 (SD 15) points before surgery to 75 (SD 24) at one year, and 83 (SD 18) at seven years. The procedure significantly reduced pain, diminished isolated plantar callus formation and increased the patient's capacity for walking. Redislocation of the metatarsophalangeal joint was seen in two feet (8%) after one year and in three (12%) after seven years. Although floating toes and restricted movement of the metatarsophalangeal joint may occur, the Weil osteotomy is safe and effective.

Metatarsalgia is a common but loosely defined pathological entity. It refers to pain in or near the metatarsal heads and the metatarsophalangeal (MTP) joints. Pain in the foot unrelated to the MTP joints (such as Morton's neuroma)[1] must be distinguished from those disorders which lead to abnormal pressure distribution, reactive calluses, and pain.

The proximal phalanx and the fibrocartilaginous plantar plate form an anatomical and functional unit at the MTP joint. The plantar plate provides a cushion and acts as a point of insertion for tendons, ligaments, and stabilising structures.[2] High functional stresses of weight-bearing and repetitive hyperextension of the MTP joint can lead to attenuation or rupture of the plantar plate followed by subluxation or dislocation of the toe.

Initial treatment options for metatarsalgia include modifications of shoe wear, metatarsal pads, and custom-made orthoses. Conservative treatment for a pre-existing dislocation is of no benefit, and surgery is indicated.[3]

Various surgical procedures have been described such as dorsal soft-tissue release with pin-fixation,[4-6] silicone implants,[7] osteotomies of the metatarsal neck[8,9] and excisional arthroplasties of the MTP joint.[10] Unfortunately, there is a high incidence of complications with these procedures. Nonunion and transfer lesions are common following the Helal osteotomy[11-13] and silicone implants often result in malalignment of the implant with secondary resorption and remodeling of the metatarsal and the phalanx.[7] The Weil osteotomy is a joint preserving osteotomy which has been recommended for the treatment of the subluxed or dislocated joint.[14,15] Short-term results have been promising.[16] A low dislocation rate with reduction of pain and the disappearance of plantar callosities has been achieved. However, the improvement in range of movement has not always been regarded as satisfactory, and post-operative extension contractures as well as floating and stiff toes have been reported.[17] To date, the longest follow-up study by Hart et al[17] was 31 months.

We present the prospective seven-year follow-up of the Weil osteotomy, for the treatment of a painful subluxed or dislocated MTP joint. Our evaluation included clinical and radiological assessment with special attention to recurrent pain, the dislocation rate of the MTP joint, toe ground contact and patient satisfaction.

Patients and Methods

Between 1995 and 1996, 31 patients underwent a Weil osteotomy for the treatment of a painful subluxation or dislocation of the MTP joint or excessive length of the second metatarsal (abnormal metatarsal parabola) with an intractable painful plantar callosity. All operations were performed by three experienced foot surgeons (HJT, FG, PR). Three patients were lost to follow-up, two died from unrelated causes and two patients did not want to participate in the study. Patients with neuro-

■ S. G. Hofstaetter, MD
■ H.-J. Trnka, MD
Foot Centre, Alserstrasse 43/8d, 1080 Vienna, Austria.

■ J. A. Petroutsas, MD
■ F. Gruber, MD
■ P. Ritschl, MD
Department of Orthopaedic Surgery
Hospital Gersthof, Wielemannsgasse 28, 1080 Vienna, Austria.

■ J. G. Hofstaetter, MD
Department of Orthopaedic Surgery
Children's Hospital and Harvard Medical School, 300 Longwood Avenue, Boston, Massachusetts 02215, USA.

Correspondence should be sent to Dr S. G. Hofstaetter at Herderstrasse 40, A-4600 Wels, Austria; e-mail: stefanhofstaetter@gmx.at

doi:10.1302/0301-620X.87B11.16590 $2.00

J Bone Joint Surg [Br] 2005;87-B:1507-11.
Received 6 April 2005; Accepted after revision 13 July 2005

logical disorders and rheumatoid arthritis were excluded. We followed up 25 feet in 24 patients, two men and 22 women with a mean age at the time of surgery of 60 years (46 to 77) for seven years. Surgery was proposed after failure of conservative treatment which had been used for a minimum of six months.

In patients with dislocated MTP joints and a hammer toe deformity, the Weil osteotomy was combined with the removal of the distal end of the proximal phalanx. In severe, subluxed MTP joints with a hammer toe deformity, the Weil osteotomy was combined with a proximal interphalangeal joint arthrodesis and extensor tendon lengthening. All six patients who had a MTP arthrodesis of the hallux had previously undergone a Keller's operation with an unsatisfactory outcome. Their main complaints included recurrent and painful hallux valgus with a painful dislocation of a MTP joint with increased plantar pressure. Proximal osteotomies were used to achieve adequate correction of an increased intermetatarsal angle (> 15°).

Operative technique. All operations were performed under a regional ankle block with an Esmarch bandage as a tourniquet. A dorsal, 3-cm longitudinal incision was made over the metatarsal for a single osteotomy and over the web space for a double osteotomy. After identifying and releasing the metatarsal head and neck, the joint capsule was incised. The collateral ligaments of the MTP joint were cut, the dislocation of the MTP joint was partly reduced and the toe was flexed to give optimal exposure of the metatarsal head. The plane of the osteotomy was parallel to the ground as if the foot was bearing weight. It passed from the dorsal portion of the metatarsal head proximally. The plantar mobile fragment was then grasped with a pointed clamp and shifted proximally to achieve the requisite amount of shortening. This was determined pre-operatively on anteroposterior radiographs using a modified version of the method described by Davies and Saxby.[18] After checking the positioning with the image intensifier the two fragments were secured with a special 2-mm titanium twist-off screw (DePuy; Johnson & Johnson, Vienna, Austria). We recommend the twist-off screw rather than Kirschner wires for fixation of the Weil osteotomy. Most of the available mini-fragment screws need predrilling, which may dislocate the plantar fragment. The twist-off screw is used without predrilling.

The resulting dorsal protuberance on the metatarsal head was resected. Weight-bearing in a post-operative shoe was allowed immediately after surgery.

Clinical assessment. All patients were examined using a standardised questionnaire based on the American Orthopaedic Foot and Ankle Society (AOFAS) lesser metatarsophalangeal-interphalangeal scale.[19] This score includes points for clinical variables such as pain (40), restriction of footwear (10), interphalangeal range of movement (5), painful callus (5), functional restriction of the MTP joint (10), MTP range of movement (ROM) (10), stiffness of the MTP joint (5) and alignment of the toes (15); in total 100 points. The MTP range of movement was measured with a goniometer and graded as follows: normal ROM (> 75°), moderate restriction (30° to 75°), severe restriction (< 30°) and no ROM. Patients were asked to rate their result as excellent, good, fair or dissatisfied.

Radiographic assessment. Anteroposterior and lateral weight-bearing radiographs were taken pre-operatively and at one and seven years post-operatively. Radiographs were examined for alignment of the metatarsal heads and subluxation or dislocation of the MTP joint, for degenerative changes and for evidence of nonunion, malunion or pseudarthrosis.

Statistical analysis. One-way analysis of variance (ANOVA) with a Bonferroni post-test was performed. A p value < 0.05 was considered significant. All statistical calculations were performed using Graph Pad Prism 4.0 (GraphPad Software Inc., San Diego, California).

Results

Patients rated their outcome as excellent in 15 feet (60%) at one year and in 19 (76%) at seven years. Good results were reported in six feet (24%) after one year and in three (12%) after seven years. Fair results were reported in two feet (8%) at one year as well as at seven years. After one year two feet (18%) were rated as poor and only one (4%) after seven years. The major complaint of the unsatisfied patient at one and seven years post-operatively was pain. However, no clinical or radiological cause could be found. The radiograph of the other unsatisfied patient at one year revealed a prominent screw tip that had penetrated the plantar side of the foot. The patient was comfortable after removal of the screw. Patients with fair and poor results had no radiological or clinical signs of subluxation or dislocation of the MTP joint or callosity under the joint. Their main complaint was not the painful joint, but floating, that is toes which did not touch the ground, and stiff toes. In the standing weight-bearing position only 17 (32%) of the toes had ground contact, and 36 (68%) did not.

The mean pre-operative AOFAS score 48 (SD 15), rose significantly to 75 (SD 24) at one year and further increased to 83 (SD 18) at seven years ($p < 0.0001$ with ANOVA). Bonferroni's multiple comparison test showed significant statistical differences between the pre-operative state after one year ($p < 0.001$) and between one and seven years ($p < 0.05$) (Fig. 1). Five patients had a poorer result at seven years than at one year. Three of these patients had a previous failed Keller resection arthroplasty and complained of general metatarsalgia after seven years. Inadequate shortening caused recurrent painful callus formation in the other two patients after seven years.

The mean AOFAS pain subscore rose from 21 (SD 9) pre-operatively, to 31 (SD 13) at one year, and to 36 (SD 6) at seven years. Repeated-measures ANOVA with Bonferroni's multiple comparison test revealed significant differences between all three groups. Before surgery, no patient was pain-free, but ten feet (40%) caused mild, 12 (48%) caused moderate and three (12%) caused severe pain. One year

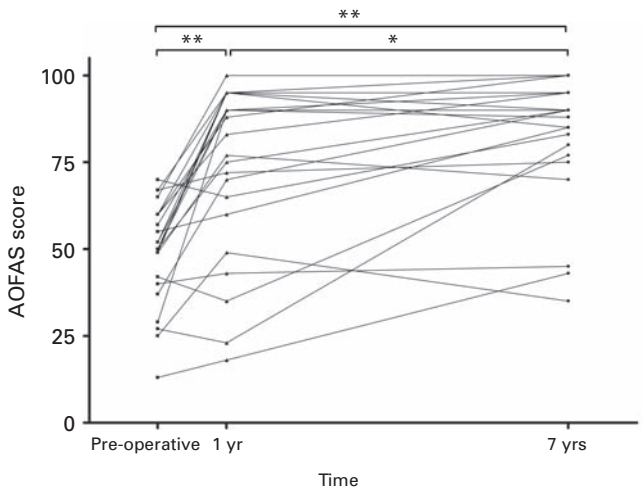

Fig. 1

The American Orthopaedic Foot and Ankle Society (AOFAS) score[19] at one and seven years follow-up. Patients achieved a higher overall score by seven years than at one year. Each individual patient is plotted on the graph. Some of the results are overlapped (*, $p < 0.05$; **, $p < 0.001$).

after surgery, 13 feet (52%) were pain-free, seven (28%) caused mild, two (8%) moderate and three (12%) severe pain. Seven years after surgery, 17 feet (68%) were pain-free, six (24%) caused mild, two (8%) caused moderate and none caused severe pain.

The function-activity limitation AOFAS subscore rose from 5.2 (SD 2.4) before surgery to 7.3 (SD 3.6) at one year and to 8.8 (SD 2.8) at seven years. Bonferroni's multiple comparison test showed significant differences between the pre-operative and one-year post-operative values ($p < 0.001$), pre-operative and seven-year post-operative values ($p < 0.001$) and between one- and seven-year post-operative values ($p < 0.05$). The AOFAS painful-callus subscore was significantly increased at one (4 (SD 2); $p < 0.001$) and seven years (4.6 (SD 1.4); $p < 0.001$) when compared with the pre-operative score (1.2 (SD 2.4)). Painful callus formation under the metatarsal head was seen in 19 feet (76%) pre-operatively, in six (24%) at one year and three (12%) at seven years. A significant change in the AOFAS alignment subscore was found at one (12 (SD 4.2); $p < 0.001$) and seven years (12.7 (SD 7.4); $p < 0.001$) when compared with the pre-operative score (5.3 (SD 4.8)). No change was seen between one and seven years. Ten feet had severe malalignment pre-operatively, but none after surgery. Seven years after surgery, 17 (32%) of the operated toes had a normal range of movement (> 75°), 25 (48%) had moderate restriction (30° to 75°), and 11 (20%) had severe restriction (< 30°) of movement of the MTP joint.

The radiographic results showed no malunion or pseudarthroses after seven years. There were 25 feet with pre-operative, dorsal MTP dislocations, but two (8%) which were dislocated after one year and three (12%) after seven years. One patient with a dislocated, painful MTP joint underwent a revision Weil osteotomy, but the remaining two were treated with a metatarsal pad. Both were satisfied with this conservative treatment. The mean metatarsal shortening was 4.3 mm (2.9 to 5.0).

Discussion

We evaluated the results of the Weil osteotomy and patients rated them as good to excellent in 21 feet (84%) at one year and in 22 feet (88%) at seven years. The AOFAS score increased significantly at one year and even more so by seven years. This increase was mainly because of the marked decrease in pain, which also led to an increase in the patient's capacity to walk. The patients who did not improve with time and who complained of general metatarsalgia, had a previous failed Keller's operation which may have limited the success of the procedure. We found that adequate shortening was critical for the long-term success of a Weil osteotomy. Two patients with inadequate shortening had inferior results at seven years but not at one year.

We found a reduction of callus beneath the metatarsal heads despite the fact that the toes did not touch the ground in 68% of the toes. A recent biomechanical study in cadaver feet showed that load in the forefoot was not significantly affected by the Weil osteotomy, but a significant increase in load was produced in the first metatarsal region.[20] We suggest that the same load is transmitted through thicker and more compliant soft tissue under the metatarsal head, following a proximal shift of the plantar fragment, and therefore reduces callus formation.[21]

In 1975, Helal[11] described the oblique distal metatarsal osteotomy. However, other authors have not reproduced the 88%[9,22] good-to-excellent results he reported. Trnka et al[14] reported on 15 patients who had undergone a Helal osteotomy with a mean follow-up of 26.4 months. They reported excellent results in 26%, good results in 26%, 14% fair results and 34% were dissatisfied with the outcome.[14] Radiographic results showed malunion in 33% and 14% with pseudarthroses. Of 22 MTP dislocations, 59% (13 of 22) remained dislocated. Short-term results for the Weil osteotomy have been very promising.[16] Hart et al[17] reported 83% (29 of 35) excellent and 17% (6 of 35) good results at 31 months after the procedure. Trnka et al[14,23] reported 68% (21 of 31) excellent and 13% (4 of 31) good results after 30 months of follow-up. The mean overall AOFAS score was 81 points at the time of follow-up; 68% had no pain, 16% mild, 10% moderate and 6% had persistent pain because of the Kirschner wire, or the screw had penetrated the soft tissue on the plantar side. There were no malunions or pseudarthroses seen radiologically. O'Kane and Kilmartin[24] reported about 85% completely satisfied patients 18 months post-operatively in 20 feet. In their series, the mean AOFAS score improved 45 points, from 44 to 89. At a mean follow-up of 30 months, Vandeputte et al[25] reported excellent or good results for 32 of 37 feet (86%); with a mean pre-operative AOFAS score of 59,

Fig. 2a

Fig. 2b

Fig. 2c

Fig. 2d

Figure 2a – Pre-operative radiographs of a 68-year-old woman with hallux valgus and metatarsophalangeal (MTP) subluxation of the second and third ray. Painful callus formation was localised to the second to fourth metatarsal heads (American Orthopedic Foot and Ankle Society score[19] (AOFAS) of 57). Figure 2b – A Chevron osteotomy with pin fixation with a Weil osteotomy of the second, third and fourth rays. Figure 2c – Radiograph at one year showing successful correction of the hallux valgus as well as of the second, third and fourth joints (AOFAS score of 95). Figure 2d – Radiograph at seven years showing maintenance of corrected lesser MTP joints. Plantar keratosis was not seen at this follow-up (AOFAS score of 95).

which improved to 81 post-operatively. The AOFAS score of our series significantly improved from 48 (SD 15) points before surgery to 75 (SD 24) at one year, mostly because of the marked decrease in pain, and to 83 (SD 18) at seven years' follow-up.

The Weil osteotomy provides controlled shortening of the metatarsal using rigid internal fixation.[26] The metatarsal head is moved proximal to the callus, which achieves axial decompression. This resolves the hammer toe deformity or MTP subluxations, which may cause metatarsalgia[14] (Fig. 2). Previously published articles mention a high rate of post-operative dorsiflexion contracture along with floating and stiff toes.[17,24] Once the MTP joint is dislocated and the plantar plate is elongated and ruptured, the dorsal capsule is already contracted in the chronically dislocated MTP joint. By using the Weil osteotomy and making the procedure as parallel as possible to the ground, shortening of the metatarsal helps to reduce the pre-operatively contracted MTP joint by releasing the dorsal contracture, the collateral ligaments and intrinsic muscles.[14] Trnka et al[27] demonstrated that depression of the plantar fragment with the Weil osteotomy changes the centre of rotation of the MTP joint so that the interosseous muscles act more as dorsiflexors than plantar flexors. An important modification is the excision of a 2-mm bony slice, which elevates the centre of rotation. In our series no bony slice was removed and five (20%) of the feet with a severely subluxed MTP joint had an extensor tendon lengthening.

Boyer and DeOrio[28] described single-pin fixation for a combined metatarsal neck osteotomy with proximal interphalangeal joint resection arthroplasty and flexor digitorum longus transfer in severely dislocated MTP joints and severe hammer toe deformities. In their series, 10 of 13 patients had a flexor digitorum longus transfer and none showed floating toes. In contrast, Migues et al[29] observed a high incidence of floating-toe deformity in 38 of 70 (54%) of his patients who had undergone a Weil osteotomy and a combined PIP joint arthrodesis, but without flexor digitorum longus transfer. In our series, four PIP joint resection-arthroplasties were performed without flexor digitorum longus transfer.

Our results demonstrate that the Weil osteotomy with additional soft-tissue procedures, is suitable for the treatment of metatarsalgia resulting from subluxation or dislocation of the MTP joint. We achieved a significant reduction in pain and plantar callus formation with a low dislocation rate and an increase in the patient's walking capacity. The patients continued to improve even a year after surgery. Floating and stiff toes may occur, but have little effect on patient comfort.

Supplementary Material

A further opinion by Professsor Leslie Klenerman is available with the electronic version of this article on our website at www.jbjs.org.uk

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

1. **Scranton PE Jr.** Metatarsalgia: a clinical review of diagnosis and management. *Foot Ankle* 1981;1:229-34.
2. **Johnston R-B 3rd, Smith J, Daniels T.** The plantar plate of the lesser toes: an anatomical study in human cadavers. *Foot Ankle Int* 1994;15:276-82.
3. **Mann RA.** Metatarsalgia: common causes and conservative treatment. *Postgrad Med* 1984;75:150-3,156-8,163-7.
4. **Coughlin MJ.** Subluxation and dislocation of the second metatarsophalangeal joint. *Orthop Clin North Am* 1989;20:535-51.
5. **Scheck M.** Degenerative changes in the metatarsophalangeal joints after surgical correction of severe hammer-toe deformities: a complications associated with avascular necrosis in three cases. *J Bone Joint Surg [Am]* 1968;50-A:727-37.
6. **Thompson FM, Hamilton WG.** Problems of the second metatarsophalangeal joint. *Orthopedics* 1987;10:83-9.

7. **Cracchiolo A 3rd, Kitaoka HB, Leventen EO.** Silicone implant arthroplasty for second metatarsophalangeal joint disorders with and without hallux valgus deformities. *Foot Ankle* 1988;9:10-18.
8. **Helal B, Greiss M.** Telescoping osteotomy for pressure metatarsalgia. *J Bone Joint Surg [Br]* 1984;66-B:213-17.
9. **Trnka HJ, Kabon B, Zettl R, et al.** Helal metatarsal osteotomy for the treatment of metatarsalgia: a critical analysis of results. *Orthopedics* 1996;19:457-61.
10. **DuVries.** Dislocation of the toe [letter]. *JAMA* 1956;160:728.
11. **Helal B.** Metatarsal osteotomy for metatarsalgia. *J Bone Joint Surg [Br]* 1975;57: 187-92.
12. **Winson IG, Rawlinson J, Broughton NS.** Treatment of metatarsalgia by sliding distal metatarsal osteotomy. *Foot Ankle* 1988;9:2-6.
13. **Mulier, Dereymaeker G, Victor J, Stuer P, Fabry G.** Long-term functional results after the Helal osteotomy. *Foot Diseases* 1994;1:69-77.
14. **Trnka HJ, Mühlbauer M, Zettl R, Myerson MS, Ritschl P.** Comparison of the results of the Weil and Helal osteotomies for the treatment of metatarsalgia secondary to dislocation of the lesser metatarsophalangeal joints. *Foot Ankle Int* 1999;20: 72-9.
15. **Barouk LS.** Weil's metatarsal osteotomy in the treatment of metatarsalgia. *Orthopade* 1996;25:338-44 (in German).
16. **Muhlbauer M, Trnka HJ, Zembsch A, Ritschl P.** Short-term outcome of Weil osteotomy in treatment of metatarsalgia. *Z Orthop Ihre Grenzgeb* 1999;137:452-6 (in German).
17. **Hart R, Janecek M, Bucek P.** The Weil osteotomy in metatarsalgia. *Z Orthop Ihre Grenzgeb* 2003;141:590-4 (in German).
18. **Davies MS, Saxby TS.** Metatarsal neck osteotomy with rigid internal fixation for the treatment of lesser toe metatarsophalangeal joint pathology. *Foot Ankle Int* 1999; 20:630-5.
19. **Kitaoka HB, Alexander IJ, Adelaar RS, et al.** Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. *Foot Ankle Int* 1994;15:349-53.
20. **Snyder J, Owen J, Wayne J, Adelaar R.** Plantar pressure and load in cadaver feet after a Weil or chevron osteotomy. *Foot Ankle Int* 2005;26:158-65.
21. **Weijers RE, Walenkamp GH, van Mameren H, Kessels AG.** The relationship of the position of the metatarsal heads and peak plantar pressure. *Foot Ankle Int* 2003; 24:349-53.
22. **Winkler IT, Kelaridis T.** Helal's metatarsal osteotomy: indication and technic with reference to shape and function of the foot. *Z Orthop Ihre Grenzgeb* 1989;127:556-60 (in German).
23. **Trnka HJ, Gebhard C, Muhlbauer M, Ivanic G, Ritschl P.** The Weil osteotomy for treatment of dislocated lesser metatarsophalangeal joints: good outcome in 21 patients with 42 osteotomies. *Acta Orthop Scand* 2002;73:190-4.
24. **O'Kane C, Kilmartin TE.** The surgical management of central metatarsalgia. *Foot Ankle Int* 2002;23:415-19.
25. **Vandeputte G, Dereymaeker G, Steenwerckx A, Peeraer L.** The Weil osteotomy of the lesser metatarsals: a clinical and pedobarographic follow-up study. *Foot Ankle Int* 2000;21:370-4.
26. **Barouk.** Die Metatarsalosteotomie nach Weil zur Behandlung der Metatarsalgie. *Orthopäde* 1996;25:388-44.
27. **Trnka HJ, Nyska M, Parks BG, Myerson MS.** Dorsiflexion contracture after the Weil osteotomy: results of cadaver study and three-dimensional analysis. *Foot Ankle Int* 2001;22:47-50.
28. **Boyer ML, DeOrio JK.** Metatarsal neck osteotomy with proximal interphalangeal joint resection fixed with a single temporary pin. *Foot Ankle Int* 2004;25:144-8.
29. **Migues A, Slullitel G, Bilbao F, Carrasco M, Solari G.** Floating-toe deformity as a complication of the Weil osteotomy. *Foot Ankle Int* 2004;25:609-13.