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Clinical and radiological outcomes after Weil osteotomy compared to distal metatarsal metaphyseal osteotomy in the treatment of metatarsalgia—A prospective study

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ABSTRACT

Background: The distal metatarsal metaphyseal osteotomy (DMMO) may have lower complication rates than the Weil osteotomy (WO) due to its extraarticular location and its minimal invasive nature. This study compares the clinical and radiological outcomes and complications after DMMO and WO.
Methods: We compared 30 patients with WO (Group A) to 30 patients with DMMO (Group B). Ten males and 50 females with a mean age of 57.7 were included. 45 WOs and 73 DMMOs were evaluated in 60 patients.
Allocation to Group A or B were random, indications comparable.
The outcome was measured clinically using the Visual Analogue Scale Foot and Ankle and radiologically with an average follow up period of 13 months.
Results: Clinical examination six weeks postoperatively showed swelling of the forefoot in 66.7% for Group A and in 73.3% for Group B. Swelling subsided in the course of time, but postoperative stiffness, lack of toe purchase and range of motion deficits did not change in the course of time. All osteotomies healed. The VAS-FA improved for both groups. Tourniquet time and operating time were lower and radiation doses higher in Group B.
Conclusions: The DMMO resulted in a comparable patient satisfaction and comparable radiological healing compared to WO and appears to be a valid alternative to the WO.

1. Introduction

Static metatarsalgia of the forefoot is a frequent condition and is in many cases a sequelae to first ray deficiency. Metatarsalgia means pain and tenderness in the forefoot and below the metatarsal heads. There are many causes of metatarsalgia, and it can be difficult to treat adequately. Prevalence of metatarsalgia is approximately 10% in a population, with a female preponderance [1]. First line treatment of metatarsalgia is non-operative with orthotics or cushioning, but when non-operative management fails, surgery may be indicated [2]. Surgery aims at shortening and raising the metatarsal head in order to relieve pressure under the metatarsal heads and restoring ideal forefoot morphology [3,4].

The Weil osteotomy (WO) is an intra-articular osteotomy widely used in surgical treatment of metatarsalgia, but also resulting in stiffness of the metatarsophalangeal joint (MTPJ) in up to 30% of the patients. Elevation of the toe postoperatively was found in 25–33% of the patients after the Weil procedure [4–6]. Highlander et al. [7] reported floating toe in 36%, recurrence of metatarsalgia in 15% and transfer metatarsalgia in 7% of the patients operated with the WO. The WO has for many years been the most popular distal lesser metatarsal osteotomy for treating imbalance of the forefoot and static metatarsalgia [8].

The distal metatarsal metaphyseal osteotomy (DMMO) is an extraarticular osteotomy performed using minimally invasive technique which theorectically results in less postoperative stiffness and may therefore represent a viable alternative to the WO in treating metatarsalgia operatively [1,8–11]. Henry et al. [4] found no differences in outcome when comparing the two methods regarding joint stiffness, but longer recovery time in the DMMO group. Dhukaran et al. [12] found a minimal risk of neurovascular and tendon injury associated with minimally invasive techniques in the forefoot.

The DMMO is gaining popularity, but clinical studies are scarce.

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2. Aims

The aim of this study is to compare the outcome of the WO and the DMMO regarding function, complications and patient satisfaction at six weeks postoperatively, and at a final follow-up minimum six months after index surgery, at an average 13 months follow-up postoperatively.

The aim of this article is to provide data in order to allow surgeons a better base for decision making when choosing between open surgery and minimally invasive surgery in the forefoot.

3. Material and methods

A manual search through all surgical reports for WOs performed between 1/8/2009 and 5/8/2011 were carried out ().

The first 30 patients who had the WO performed and had at least six months clinical follow-up and radiologic assessment at six months post-op were included (Group A).

A manual search through all surgical reports between 1/1/2014 and 17/9/2014 for DMMOs was performed.

The first 30 patients who had the DMMO performed and had at least 6 months clinical follow-up and radiologic assessment at 6 months were included (Group B).

Allocation to Group A or B were random, indications for surgery comparable.

All included patients were evaluated using the VAS-FA score preoperatively and in November 2016. Phone interviews were conducted with all included patients in November 2016 reevaluating the patients using the VAS-FA score [13]. In the Group A 86.7% of the patients were reached and in Group B 76.7% of the patients were reached.

All included patients were operated by the second and third author in Hessingpark Clinic, Augsburg, Germany.

The study was approved by the internal clinical committee in the Hessing Parc Clinic.

Photo 2. Intraoperative photo showing incisions for DMMO.

3.1. Surgical technique

All patients were operated in the supine position under full or regional anaestesia with the use of a tourniquet 300 mmHg on the ipsilateral thigh or calf. All patients had an intravenous single shot Cefuroxime pre-operatively. A fluoroscope was used in all cases in both groups intra-operatively.

Standard technique for the WO and the DMMO were used [2–4,8,14,15].

All but one patient had the WOs fixed with the Twist-off screw from Wright Medical, Memphis, Tennessee, USA. In one patient the WO was fixed with a bioabsorbable screw from Arthrex, Naples, Florida, USA. No internal fixation was used for the minimally invasive osteotomy of lesser metatarsal osteotomies. Surgery on the first ray was done by open technique ().

3.2. Postoperative protocol

The postoperative treatment in both groups was dependent on the surgery performed on the first ray. Most patients had

Photo 1. Hallux valgus and overriding 2nd toe with hyperkeratosis over proximal interphalangeal joint.

Photo 3. Two weeks postoperative after correction of 1th toe with double osteotomy and Akin osteotomi. DMMO of 2nd-4th metatarsal (8/4 2014).

additional surgery on the first ray in order to correct the forefoot malalignment and additional hallux valgus deformity.

Patients with isolated Weil procedure were allowed partial weight-bearing with 20 kg for six weeks in stiff soled postoperative shoe. Patients with isolated DMMO were allowed full weight-bearing in the same type of stiff soled postoperative shoe for six weeks.

WO or DMMO in combination with 1st ray procedures were allowed partial weight-bearing with 20 kg in the postoperative shoe for six weeks.

The patients were required to wear an elasto-cohesive dressing around the forefoot excluding the toes providing mild compression to the osteotomy area, i.e. Coban® 3M, 3M Center St. Paul, MN 55144, USA, for six weeks postoperatively to reduce swelling.

3.3. Inclusion and exclusion criteria

Inclusion criteria were metatarsalgia with or without MTPJ subluxation or claw toe deformity and static metatarsalgia overload.

Exclusion criteria were previous surgery on the same metatarsal or toe, rheumatoid arthritis, metatarsal head necrosis or head destruction, dislocation of MTPJ II–IV, less than 6 months post-op follow-up or lack of X-rays at 6 months post-op.

3.4. Radiologic assessment

Standard weight-bearing X-rays, Anterior-Posterior, Lateral and Medial Oblique views were used. All X-rays performed six weeks postoperatively were evaluated by the first author regarding displacement of the osteotomies compared to the primary postoperative X-ray.

At final follow-up X-rays were evaluated by the first author regarding bony healing at the osteotomy sites and secondary displacement of metatarsal heads.

3.5. Statistical analysis

Distribution of continuous data was assessed using Shapiro–Wilkins test. Welch t-test was used for approximately normal distributed data, while Wilcoxon Rank Sum test was used for non-normal distributed data. For paired data, the Wilcoxon Signed Rank test was used. Pearson's chi squared test of independence was used for categorical data, but Fisher's exact test was used when expected frequency was below five for more than 20% of the compared categories.

$P < 0.05$ was considered statistically significant. All calculations were performed using R, version 3.3.2, R Core Team, 2016, Vienna, Austria or http://statpages.info/ctab2x2.html, accessed 30 November, 2016.

4. Results

4.1. Demography and patient characteristics

Group A, WO Group, consisted of 30 patients with a total of 45 WOs.

Group B, DMMO Group, consisted of 30 patients with a total of 73 DMMOs.

General information regarding Group A and Group B is displayed in Table 1.

Group A and B were comparable regarding age, gender, follow-up period and surgery performed on the first ray. The average surgery time was 36 min, 95% CI: 17–54, $P < 0.001$ shorter and the

Photo 4. Six weeks postoperative after correction of 1th toe with double osteotomy and Akin osteotomi. DMMO of 2nd–4th metatarsal. DMMOs still visible (6/5 2014).

average tourniquet time was 27 min, 95% CI: 12–42, $P < 0.001$ shorter for the DMMO procedure in Group B, see Table 1.

There were no significant difference between Group A and Group B regarding VAS-FA scores. Postoperative Total score: $P = 0.689$, Pain: $P = 0.399$, Function: $P = 1.00$, Other complaints: $P = 0.463$.

4.2. Clinical outcome

The clinical result at the final follow-up, on average 13.8 months for Group A and 12.3 months for Group B, did not yield any change in outcome of surgery compared to the clinical examination at six weeks postoperatively. Information on clinical data at the final follow-up, at an average of 13 months postoperatively, is displayed in Table 2.

Clinical examination at six weeks postoperatively showed swelling of the forefoot and toes in 20 of 30 patients, 66.7% for Group A and in 22 of 30 patients, 73.3% for Group B.

The swelling subsided in the course of time in both groups, but postoperative stiffness, lack of toe purchase and range of motion deficits did not change in the course of time. Hypertrophic scarring, assessed by clinical observation in Group A was significantly higher than in Group B, $p = 0.019$.

The surgical groups were comparable according to demographic information; however, the average surgery duration was 36 min, 95% CI: 17–54, $p < 0.001$, shorter and the average tourniquet time was 27 min, 95% CI: 12–42, $P < 0.001$, shorter for the DMMO procedure, see Table 1.

Other than a higher rate of hypertrophic scarring in the Weil group, 9% vs. 0%, no significant differences in complication rates were detected, see Table 2.

One patient from each group developed a deep venous thrombosis in the postoperative period.

One patient in Group B developed a second metatarsal head necrosis 15 months after index surgery, which healed uneventfully with non-operative treatment. None of the patients in Group A or Group B had unwanted secondary displacement of the metatarsal heads. There were no avascular head necrosis found in Group B. One patient in Group B underwent closed arthrolysis of the MTPJs operated at index surgery, due to stiffness of the toes.

4.3. Subjective score

VAS-FA scores increased significantly between pre- and postoperative assessments and the increases were similar between surgical groups, see Table 3.

No significant differences were detected for VAS-FA scores preoperatively or at final follow-up between both surgical groups.

4.4. Radiology

All osteotomies showed bony healing at final follow-up. The use of X-rays intraoperatively lasted median 13.3 s in Group A and 23.6 s in Group B, $P = 0.01$. The median X-ray dose in Group A was 1.2 cGy and 7.5 cGy in Group B, $P = 0.01$.

Photo 5. Weightbearing X-ray left foot 14 months postoperative after double osteotomy and Akin osteotomi 1th toe. DMMO of 2nd–4th metatarsal. All osteotomies healed. No callus is seen on the lesser metatarsals (16/6 2016).

No secondary displacement of osteotomies were observed at final follow-up.

5. Discussion

The WO is an intra-articular, non-dynamic, open distal osteotomy requiring internal fixation. The aim is to shorten and elevate the metatarsal head [16]. The shortening and elevation of the metatarsal head aim at off-loading the forefoot and relieving metatarsalgia. Vandeputte et al. [17] found a significantly decreased load under the metatarsal heads after the WO. Other studies have shown no decrease or even increase in load under the metatarsal head after the WO [18].

The DMMO is an extra-articular, dynamic osteotomy that does not require fixation. It shortens and elevates the metatarsal head slightly. The dynamic concept of the DMMO relies on the tension of the soft-tissues surrounding the metatarsal head. The soft tissues dictate the optimal postoperative position of the metatarsal head. Full weight-bearing is part of the dynamic concept since on weight-bearing the heads shift into an optimal position for weight distribution in the ball of the foot.

The literature is still sparse on the post-operative results of the DMMO and there is a lack of long term follow-up studies. Most authors report prolonged swelling in patients who undergo DMMO and a higher incidence of non-union, compared to the WO [4,8–11]. Meticulous surgical technique is important to avoid displacement medially or laterally of the metatarsal heads when performing DMMO. If the surgical technique is faulty the translation medially or laterally will occur immediately, and not as a secondary displacement of the metatarsal heads later.

The threshold for DMMOs is lower aiming for a complex solution in the forefoot with a physiological load distribution over the forefoot. This is a way of avoiding transfer metatarsalgia which is a realistic complication after WO.

Our data does not support the hypothesis that the lower threshold for DMMOs results in more patients with transfer metatarsalgia. The rate of transfer metatarsalgia in Group A and B should be looked for in a follow-up study.

This study has a mean postoperative follow-up of 13 months. Group A and B were comparable regarding age, gender, follow-up period and surgery performed on the first ray. The use of minimally invasive surgery technique clearly diminished both tourniquet time and operating time.

We did not find significantly prolonged swelling in Group B compared to Group A in this study.

There were no non-unions in the DMMO group. The clinical findings at six weeks after surgery, apart from the swelling, are likely to be permanent, i.e. extension/flexion deficits, lack of toe purchase,

Photo 6. Postoperative bandage after minimally invasive surgery.

diminished range of motion and stiffness of lesser MTPJs do no alter at final follow-up compared to the findings six weeks postoperatively.

The overall complication rate in the DMMO group B was comparable to the WO group A.

The minimally invasive technique does not require more frequent post-operative follow-up compared to the WO. The patients were required to wear an elasto-cohesive dressing around the forefoot, excluding the toes, providing mild compression to the osteotomy area, i.e. Coban® (3 M, 3 M Center St. Paul, MN 55144, USA) for six weeks postoperatively to reduce swelling.

Postoperative radiographic control will in many cases present a large bone callus at the DMMO site, not to be confused with hypertrophic non-union. The observed callus will subside within months.

The DMMO technique exposes the surgeon and the patients to more radiation than the WO in the operating room.

Prolonged swelling may be due to bone debris after the DMMO, and as a result meticulous flushing of the wounds with saline at the end of the procedure is mandatory in order to lower the risk of prolonged swelling. The prolonged swelling in the DMMO group is likely due to secondary bone healing process with callus formation. With improved surgical technique in order to eliminate or reduce the translational shift of the metatarsal head there is less swelling.

To our knowledge no study on metatarsal head necrosis following DMMOs has been published yet. Therefore we cannot compare DMMO metatarsal head necrosis to WO related metatarsal head necrosis. Further studies are needed with radiological long-term follow-up in order to detect metatarsal head necrosis.

This study has some shortcomings. No standardized objective method was used in the clinical evaluation pre- and postoperatively, although the authors were performing their examination with the same steps and objectives on each patients. The average follow-up period was only a little over one year in this study, but a

Table 2
Complications at final follow-up.

	Weil	DMMO	
	n = 45	n = 73	P-value[b]
Stiffness/dimished range of motion	4 (9%)	5 (7%)	0.730
Extension—flexion deformity MTPJ	6 (13%)	4 (6%)	0.178
Lack of toe purchase	2 (5%)	0 (0%)	0.145
Hypertrophic scarring	4 (9%)	0 (0%)	0.019
Swelling	6 (13%)	6 (8%)	0.532
DVT[a]	1 (2%)	1 (2%)	1.00

[a] n = 30 feet in each group; MTPJ = metatarsalphalangeal joint; DMMO = distal metatarsal metaphyseal osteotomy.
[b] Test for differences using Fisher's exact test.

Table 1
Basic patient demographics and procedure details.

	Weil Group A	DMMO Group B	
	n = 30	n = 30	P-value
Median age [IQR] (range)	59.0 [52.8, 63.0] [36.0, 75.0]	58.0 [51.2, 65.0] [22.0, 75.0]	0.952
Sex, n (%)			
Female	24 (80.0)	26 (86.7)	
Male	6 (20.0)	4 (13.3)	0.729
Foot, n (%)			
Left	16 (53.3)	19 (63.3)	
Right	14 (46.7)	11 (36.7)	0.600
Mean OP time in min (SD) [range]	109.4 (41.4) [32.0, 216.0]	73.7 (30.2) [5.0, 150.0]	<0.001
Median Torniquet time in min [IQR] [range]	116.5 [87.2, 129.0] [54.0, 144.0]	82.5 [69.5, 91.0] [0.0, 138.0]	<0.001
Median X-ray duration in s [IQR] [range]	13.3 [9.7, 19.8] [0.1, 52.5]	23.4 [19.7, 27.6] [10.9, 51.2]	<0.001
Median X-ray dose in cGy [IQR] [range]	7.5 [5.3, 10.3] [1.0, 29.0]	1.2 [1.0, 2.5] [0.6, 19.8]	<0.001
Procedures on first ray			
Chevron	5	3	
Scarf	4	4	
TMT fusion	9	6	
MTP1 fusion	3	2	
Proximal osteotomy	4	11	
Akin osteotomy	17	21	
None	5	4	0.260
Median months of follow-up in (IQR) [range]	12.5 [6.5, 18.8] [6.0, 42.0]	10.2 [7.5, 15.6] [6.0, 24.0]	0.672

DMMO = distal metatarsal metaphyseal osteotomy; TMT = tarsometatarsal; MTP1 = metatarsophalangeal 1; IQR = interquartile range.

Table 3
VAS-FA scores.

	Preoperative	Postoperative	Median diff. (95% CI)	P-value[a]
Weil				
Total	73.4 [56.6, 79.6]	96.6 [94.6, 98.2]	26.0 (20.0–33.4)	<0.001
Pain	56.3 [50.0, 74.3]	100 [95.5, 100]	41.4 (31.2–47.5)	<0.001
Function	77.6 [58.6, 83.4]	97.2 [94.4, 99.1]	24.1 (16.2–33.3)	<0.001
Other complaints	68.4 [61.8, 77.8]	94.6 [91.4, 97.8]	22.2 (15.2–28.3)	<0.001
DMMO				
Total	66.8 [61.9, 76.6]	96.7 [95.3, 98.0]	25.1 (18.2–32.4)	<0.001
Pain	61.0 [47.2, 78.2]	100 [98.2, 100]	35.1 (23.9–47.7)	<0.001
Function	73.7 [60.8, 80.0]	98.0 [94.7, 99.0]	24.0 (16.9–31.1)	<0.001
Other complaints	71.2 [64.0, 84.8]	92.0 [88.5, 96.8]	19.7 (14.4–26.1)	<0.001

Median [IQR] scores.
[a] Wilcoxon Signed Rank test was used to test for differences; DMMO = distal metatarsal metaphyseal osteotomy.

continuous follow-up on these patients is planned for the next years in order to provide longer mid-term data and possible long term follow-up data at some point.

6. Conclusion

Compared to the Weil procedure the duration of surgery and tourniquet times were significantly shorter and hypertrophic scarring was less prevalent for the DMMO procedure. The radiation time was significantly longer in the DMMO group. VAS-FA scores increased significantly following surgery and no differences were detected between procedures.

The DMMO offers a good alternative to the WO in treating static metatarsalgia. It is a safe procedure with few complications and with good clinical outcome. We found less patients with postoperative stiffness, lack of toe purchase and less reduction in ROM in the DMMO group than in the Weil group, although not statistically significant. Proper training of surgeons in the DMMO technique is essential for obtaining good results and reducing the risk of complications.

Conflicts of interest

The authors declare no conflicts of interest associated with this publication.

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References

[1] Haque S, Kakwani R, Chadwick C, Davies MB, Blundell CM. Outcome of minimally invasive distal metatarsal metaphyseal osteotomy (DMMO) for lesser toe metatarsalgia. Foot Ankle Int 2015;37:58–63, doi:http://dx.doi.org/10.1177/1071100715598601.
[2] de Prado M, Ripoll PL, Galano P. Minivally invasive foot surgery. About Your Health Publisher; 2009.
[3] Maffulli N, Easley M. Minimally invasive surgery of the foot and ankle. Springer-Verlag; 2011.
[4] Henry J, Besse JL, Fessy MH. Distal osteotomy of the lateral metatarsals: a series of 72 cases comparing the Weil osteotomy and the DMMO percutaneous osteotomy. Orthop Traumatol Surg Res 201197:, doi:http://dx.doi.org/10.1016/j.otsr.2011.07.003.
[5] Beech I, Rees S, Tagoe M. A retrospective review of the Weil metatarsal osteotomy for lesser metatarsal deformities: an intermediate follow-up analysis. J Foot Ankle Surg 2005;44:358–64, doi:http://dx.doi.org/10.1053/j.jfas.2005.07.002.
[6] Trnka H-J, Gebhard C, Mühlbauer 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, doi:http://dx.doi.org/10.1080/000164702753671795.
[7] Highlander P, VonHerbulis E, Gonzalez A, Britt J, Buchman J. Complications of the Weil osteotomy. Foot Ankle Spec 2011;4:165–70, doi:http://dx.doi.org/10.1177/1938640011402822.
[8] Redfern DJ, Vernois J. Percutaneous surgery for metatarsalgia and the lesser toes. Foot Ankle Clin 2016;21:527–50, doi:http://dx.doi.org/10.1016/j.fcl.2016.04.003.
[9] Botezatu I, Marinescu R, Laptoiu D. Minimally invasive-percutaneous surgery—recent developments of the foot surgery techniques. J Med Life 2015;8(Spec Iss):87–93.
[10] Bauer T. Percutaneous forefoot surgery. Orthop Traumatol Surg Res 2014100:, doi:http://dx.doi.org/10.1016/j.otsr.2013.06.017.
[11] Darcel V, Villet L, Chauveaux D, Laffenetre O. Treatment of static metatarsalgia using distal percutaneus metatarsal osteotomy: a prospective study of 222 feet. Rev Chir Orthop 2009;5:229–42.
[12] Dhukaram V, Chapman AP, Upadhyay PK. Minimally invasive forefoot surgery: a cadaveric study. Foot Ankle Int 2012;33:1139–44, doi:http://dx.doi.org/10.3113/FAI.2012.1139.
[13] Stüber J, Zech S, Bay R, Qazzaz A, Richter M. Normative data of the visual analogue scale foot and ankle (VAS FA) for pathological conditions. Foot Ankle Surg 2011;17:166–72, doi:http://dx.doi.org/10.1016/j.fas.2010.05.005.
[14] Barouk LS. Forefoot reconstruction. Springer; 2003.
[15] www.my-medibook.de.
[16] Barouk LS. Weil's metatarsal osteotomy in the treatment of metatarsalgia. Orthopade 1996;25:338–44.
[17] 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.
[18] 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.