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Distal Minimally Invasive Metatarsal Osteotomy ("DMMO") Procedure

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ABSTRACT
Metatarsalgia, a common cause of forefoot pain, often necessitates surgical correction when conservative measures fail. The distal minimally invasive metatarsal osteotomy (DMMO) has emerged as a preferred technique due to its soft tissue-sparing approach and capacity for multiplanar correction without fixation. This article evaluates the surgical principles, technical modifications and clinical outcomes associated with the DMMO procedure in the treatment of central metatarsalgia, with emphasis on its biomechanical rationale, evolving applications and comparison with traditional osteotomies. A detailed account of surgical technique, anatomical considerations and operative outcomes was developed, including procedural variations such as distal intracapsular (DICMO) and distal oblique (DOMMO) osteotomies. Observations regarding healing, complications and patient-reported functionality were integrated to inform technique selection and postoperative management. The DMMO allows precise, extraarticular osteotomy with dynamic correction under physiological load. It avoids fixation, supports early weight bearing and enables self-adjustment of metatarsal alignment. Healing rates are consistently high, with low incidence of stiffness, nonunion, or transfer lesions. Comparative outcomes with Weil osteotomy favor DMMO in terms of joint motion and complication profile. The DMMO represents a safe, effective, and biomechanically sound approach to managing metatarsalgia, particularly in patients requiring multiplanar correction with joint preservation. Its minimally invasive philosophy supports functional recovery and broadens the scope of forefoot reconstruction strategies.

INTRODUCTION

Metatarsalgia, characterized by pain beneath the metatarsal heads, is a prevalent cause of forefoot discomfort and functional impairment. It arises due to mechanical overload of one or more lesser metatarsals, commonly associated with anatomical anomalies such as elongated metatarsals, claw toe deformities, or biomechanical disturbances across the forefoot[1]. While conservative management with orthotic devices, shoe modifications and physiotherapy is often the initial strategy, a significant proportion of patients do not experience adequate or lasting relief, warranting surgical intervention. Surgical correction of metatarsalgia seeks to redistribute plantar pressure by modifying the length, alignment, or elevation of the affected metatarsals. Historically, various osteotomies have been described for this purpose, with the Weil osteotomy becoming a mainstay due to its reproducibility, intraarticular control and internal fixation[2]. However, complications such as floating toe, joint stiffness, scarring and prolonged recovery have highlighted the limitations of traditional open approaches. Furthermore, the invasive nature of intraarticular dissection has raised concerns regarding long-term joint preservation and postoperative function. Against this backdrop, minimally invasive surgical (MIS) techniques have garnered increasing interest for their potential to achieve comparable radiological and functional outcomes with reduced soft tissue trauma[3]. The distal minimally invasive metatarsal osteotomy (DMMO) is one such evolution, conceptualized and refined through the work of De Prado and later standardized by the GRECMIP (Groupe de Recherche et d'Étude en Chirurgie Mini-Invasive du Pied) collective. DMMO involves performing an extraarticular osteotomy in the metatarsal neck using a percutaneous burr under fluoroscopic guidance, allowing multiplanar correction without fixation. Unlike traditional procedures, the DMMO leverages postoperative weight-bearing to enable functional "self-adjustment" of the metatarsal heads, aligning them in response to physiological ground reaction forces[4]. The advantages of the DMMO technique extend beyond its minimal invasiveness. The absence of osteosynthesis permits dynamic realignment and minimizes hardware-related complications, while the small incisions and preservation of surrounding soft tissues reduce postoperative morbidity. However, concerns regarding the lack of fixation, potential for malunion or transfer metatarsalgia and a perceived learning curve have limited its widespread adoption, especially in comparison to more established techniques like the Weil osteotomy[5]. Over time, the scope of percutaneous metatarsal surgery has expanded through the development of advanced modifications such as the distal intracapsular minimally invasive osteotomy (DICMO) and the distal oblique metatarsal minimally invasive osteotomy (DOMMO). These variants aim to address specific surgical needs, including increased shortening, enhanced stability and correction in cases of instability or severe anatomical deviation[6]. This article aims to provide a comprehensive appraisal of the DMMO technique, detailing its surgical principles, operative nuances, and biomechanical rationale. Additionally, it explores its clinical applications, outcome data, complication profile and comparisons with conventional approaches. By critically examining the evolution and implementation of DMMO and its derivatives, this review seeks to define their role in the contemporary surgical management of metatarsalgia.

MATERIALS AND METHODS

The present article is based on a detailed technical and conceptual exposition of distal minimally invasive metatarsal osteotomy (DMMO) for the management of central metatarsalgia. The methodology includes an integrated synthesis of surgical technique, anatomical considerations and operative principles related to percutaneous metatarsal osteotomies, including evolved variants such as distal intracapsular minimally invasive osteotomy (DICMO) and distal oblique minimally invasive metatarsal osteotomy (DOMMO). The DMMO procedure involves a percutaneous, extraarticular osteotomy of the lesser metatarsals, performed using a high-speed burr through a small lateral or dorsolateral incision. The osteotomy is initiated at the metatarsal neck approximately 2-3 mm proximal to the articular surface and oriented obliquely at an angle of 45° to the metatarsal axis. The burr is advanced under fluoroscopic control or tactile guidance to ensure accurate positioning, while preserving surrounding soft tissues through subperiosteal dissection. Osteotomy completion is achieved through rotational wrist movement to create an arc-shaped cut, which promotes dorsal elevation and shortening of the distal fragment. No internal fixation is employed. Instead, immediate postoperative full weight bearing is permitted in a rigid-soled flat shoe to allow for natural redistribution of plantar forces, leading to progressive self-adjustment of the metatarsal heads. Dressing techniques are used postoperatively to guide alignment and limit undesirable drift. Range of motion at the metatarsophalangeal joints is encouraged from the early postoperative period to prevent stiffness and promote functional recovery. The DICMO variant is indicated in cases requiring enhanced stability or where isolated osteotomy is preferred. This intraarticular approach is performed via a medial incision with capsular penetration and permits controlled shortening with minimal elevation. The DOMMO variant is used when greater shortening is required, involving an oblique metaphyseal cut directed from dorsal-distal to plantar-proximal, enabling displacements exceeding 10 mm without fixation. The methodology presented reflects current surgical standards and clinical reasoning for technique selection, osteotomy planning and postoperative management in patients undergoing minimally invasive correction of metatarsalgia.

RESULTS AND DISCUSSIONS

The clinical and surgical applications of the DMMO technique reveal favourable outcomes in the correction of metatarsalgia, with advantages in functional mobility, reduction in postoperative complications and preservation of joint integrity. Comparative observations across reported case series indicate consistent union rates, low incidence of transfer lesions and satisfactory patient-reported functional scores. The results also demonstrate meaningful differentiation between the classical DMMO and its procedural variants DICMO and DOMMO based on the degree of shortening, correction stability and postoperative realignment. The results also highlight specific procedural adaptations and their relevance in varied clinical contexts. Among these, the selection of the osteotomy technique is determined primarily by the metatarsal index, degree of metatarsal overload, associated toe deformities and the presence or absence of instability. The availability of multiple minimally invasive options allows tailored correction with reduced surgical trauma. **(Table 1)** highlights the core procedural features and indications of the DMMO, DICMO and DOMMO techniques, emphasizing the anatomic level of osteotomy, burr orientation, correction type and requirement for fixation. **(Table 2)** presents the range of clinical outcomes observed with DMMO procedures, including postoperative union, resolution of symptoms, incidence of transfer metatarsalgia and complication rates. These data reflect consistent results across diverse patient populations and varying levels of preoperative deformity. **(Table 3)** highlights comparative findings between DMMO and the traditional Weil osteotomy, focusing on radiographic correction, patient-reported outcomes and complication profile. DMMO shows equivalent or superior results in preserving joint motion and reducing stiffness. **(Table 4)** outlines observed complications in DMMO procedures and recommended strategies for prevention and management. The most common technical error is incorrect osteotomy placement too proximally, which may lead to suboptimal shortening or unintentional dorsiflexion. **(Table 5)** illustrates the recommended indications for each DMMO variant based on clinical presentation, allowing for standardized procedural planning. Additionally, postoperative management protocols influence both early function and long-term outcomes. Immediate full weight bearing in a flat postoperative shoe is uniformly recommended to initiate self-adjustment and avoid stiffness. Dressing techniques and elastic taping contribute to maintenance of toe alignment, particularly when multiple rays are addressed. **(Table 6)** summarizes the key elements of postoperative care that enhance outcomes following DMMO and its variants. The evolution of minimally invasive techniques in forefoot surgery has transformed the management of central metatarsalgia, with the DMMO procedure emerging as a pivotal intervention. The present synthesis demonstrates that DMMO and its procedural variants offer a reliable, tissue-sparing and biomechanically intelligent alternative to traditional open osteotomies, particularly the Weil procedure. Central to the DMMO philosophy is its extraarticular nature, elimination of fixation and reliance on physiological loading for real-time metatarsal head alignment. These principles are a marked departure from conventional fixed osteotomies and underpin the dynamic correction strategy intrinsic to the minimally invasive approach[7]. The findings across multiple case series reveal consistently high rates of symptom resolution and bone healing with DMMO. Union rates exceeding 95% and symptom relief in over 85% of cases affirm the procedure's efficacy[8]. Moreover, the lack of internal fixation reduces the risk of hardware-related complications, while early weight-bearing and active mobilization preserve joint motion. This is particularly evident in comparative studies where DMMO demonstrated lower rates of stiffness and floating toe than the Weil osteotomy. Although the incidence of swelling is greater in the early postoperative phase due to the absence of osteosynthesis, this typically resolves with load adaptation and does not compromise long-term outcomes[9]. A significant technical merit of DMMO is its ability to address multiplanar deformities through a single, percutaneous access point. The oblique orientation of the osteotomy enables controlled shortening and dorsal translation of the metatarsal head, thereby redistributing plantar pressure. Importantly, the preservation of the soft tissue envelope, including the extensor mechanism and joint capsule, contributes to postoperative stability and functional restitution[10]. One of the major criticisms directed at minimally invasive osteotomies is the lack of intraoperative fixation, raising theoretical concerns regarding alignment control and stability. However, results indicate that proper osteotomy placement within the metaphyseal zone, along with postoperative load modulation, achieves stable and predictable correction. Malunion and nonunion remain rare and are generally linked to technical errors, such as osteotomy placement too proximally or excessive dorsal translation. When such issues occur, revision strategies including additional DMMOs or stabilization with temporary wiring have shown favorable

Table 1: Comparison of DMMO, DICMO and DOMMO Techniques in Terms of Surgical Characteristics and Indications

Parameter	DMMO	DICMO	DOMMO
Osteotomy Location	Extraarticular, neck region	Intracapsular, subchondral zone	Distal metaphysis
Burr Orientation	45° oblique to metatarsal axis	45° to plantar cortex	Dorsal-distal to plantar-proximal
Fixation Required	No	No	No
Degree of Shortening	Mild (≤5 mm)	Minimal (1-2 mm)	Moderate to large (up to >10 mm)
Correction Stability	Dynamic/self-adjusting	Higher due to capsular support	Directional, depends on angulation
Indication	Central metatarsalgia (static/propulsive)	Painful ray instability	Severe overload or long metatarsals
Additional Notes	Allows real-time load-based alignment	Can be performed in isolation	Used in hybrid or multi-level corrections

Table 2: Reported Clinical Outcomes in Patients Undergoing DMMO-Based Procedures

Outcome Parameter	Observation Range
Radiographic Union Rate	95-100%
Symptom Resolution (Metatarsalgia)	85-90%
Transfer Metatarsalgia	<5%
Postoperative Joint Stiffness	<10%
Nonunion (isolated cases)	Rare., <1%
Secondary Procedure Requirement	<5% (mostly in fourth/fifth rays)
Infection Rate	Very low (<1%)
Time to Comfortable Shoe Use	Median 3-6 weeks
Return to Full Activity	Within 2-3 months

Table 3: Comparative Observations Between DMMO and Weil Osteotomy

Parameter	DMMO	Weil Osteotomy
Postoperative Joint Motion	Preserved in majority (60-70%)	Reduced in ~40% cases
Floating Toe Incidence	Very low	More frequent (up to 20%)
Fixation Requirement	None	Yes (typically screw fixation)
Return to Activity	Faster due to minimal dissection	Slower due to soft tissue trauma
Transfer Lesions	Rare	Occasional
Surgical Access	Percutaneous (1-3 mm incision)	Open dorsal approach
Osteotomy Type	Extraarticular	Intraarticular

Table 4: Common Complications in DMMO and their Management Strategies

Complication	Description	Preventive/Management Approach
Malunion	Excessive dorsiflexion or shortening	Accurate burr placement in metaphysis
Nonunion	Rare., usually due to instability	Re-osteotomy or stabilization (Diebold method)
Transfer Metatarsalgia	Overload of adjacent ray	Consider prophylactic adjacent osteotomy
Toe Drift (Valgus)	Lateral deviation of toe axis	Controlled dressing and elastic taping
Swelling and Edema	Common in early phase	Elevation, footwear modifications, analgesia
Delayed Weight Tolerance	Due to pain or overload	Gait training, orthoses

Table 5: Indications for DMMO, DICMO and DOMMO Based on Clinical Presentation

Clinical Presentation	Preferred Technique	Rationale
Isolated second or third ray overload	DMMO	Allows dynamic alignment with low risk of stiffness
Multi-ray metatarsalgia (rays 2-3-4)	DMMO + DOMMO	DOMMO offers greater shortening where needed
Instability of MTP joint (e.g., hammertoe)	DICMO	Intracapsular access with controlled correction
Prior surgical scars or limited soft tissue	DMMO	Minimally invasive access preserves local vascularity
Severe metatarsal length discrepancy	DOMMO	Permits >10 mm shortening with directional control
Revision cases after failed Weil osteotomy	DOMMO or hybrid	Avoids repeat intraarticular intervention
Risk of floating toe or stiffness	DMMO or DICMO	Preserves joint capsule and extensor mechanism

Table 6: Postoperative Management Components and Functional Impact

Component	Protocol Description	Functional Impact
Weight Bearing	Immediate, full weight bearing in flat shoe	Facilitates dynamic alignment
Dressing	Gauze and crepe bandaging to prevent valgus drift	Maintains toe alignment
Toe Mobilization	Initiated from day 1 postoperatively	Prevents joint stiffness
Shoe Use Duration	3-6 weeks depending on swelling	Allows return to standard footwear
Physical Therapy	Generally, not required routinely	Reserved for persistent stiffness
Imaging	Radiographs for union assessment at 6-12 weeks	Confirms correction and healing

results[11,12]. The introduction of DICMO and DOMMO has further extended the versatility of the percutaneous approach. DICMO provides enhanced control in cases of isolated ray instability or painful hypermobility, where intraarticular elevation is necessary without significant shortening. DOMMO, on the other hand, allows for greater shortening and directional correction in cases with severe metatarsal length discrepancy or residual overload. These modifications broaden the scope of indications, enabling tailored treatment without compromising the foundational principles of minimally invasive surgery[13,14]. Despite the overall safety profile, the surgeon's experience plays a critical role in avoiding complications. Precise burr handling, familiarity with fluoroscopic anatomy and disciplined postoperative dressing protocols are key determinants of successful outcomes. The learning curve for DMMO, while manageable, warrants structured training and adherence to technique-specific landmarks to prevent iatrogenic instability or metatarsal drift[15]. The existing comparative literature supports the equivalence of DMMO with the Weil osteotomy in terms of pain relief and functional scores. Importantly, the DMMO group consistently shows lower rates of joint stiffness and surgical morbidity, making it a valuable option in patients where soft tissue preservation and joint motion are prioritized. However, the absence of high-level randomized trials remains a limitation and further prospective research is needed to quantify long-term durability, cost-effectiveness and patient-reported outcomes across broader populations.

CONCLUSION

Distal minimally invasive metatarsal osteotomy (DMMO) offers a precise, low-morbidity and function-preserving solution for the surgical management of central metatarsalgia. Its extraarticular approach, minimal soft tissue disruption and dynamic postoperative realignment enable effective correction with reduced complications compared to traditional open techniques. The availability of DMMO variants such as DICMO and DOMMO further enhances procedural versatility across a spectrum of forefoot deformities. With consistently high union rates, low revision rates and preservation of joint motion, the DMMO technique represents a valuable addition to the modern forefoot surgeon's armamentarium. Future prospective trials are warranted to establish long-term outcomes and optimize patient selection protocols.

REFERENCES

1. Laffenêtre O. and A. Perera., 2019. Distal Minimally Invasive Metatarsal Osteotomy ("DMMO" Procedure). Foot Ankle Clin., 24: 165-625.
2. Slullitel G., V. López, V. Álvarez, L. Gaitán and J.P. Calvi., 2022. A Refined Minimally Invasive Distal First Metatarsal Osteotomy for Moderate Hallux Valgus Treatment: The BC Procedure. The J. Foot Ankle Surg., 61: 1052-1055.
3. Magnan, B., S. Negri, T. Maluta, C. Dall'Oca and E. Samaila., 2019. Minimally invasive distal first metatarsal osteotomy can be an option for recurrent hallux valgus. Foot Ankle Surg., 25: 332-339.
4. Singh M.S., A. Khurana, D. Kapoor, S. Katekar, A. Kumar and G. Vishwakarma., 2020. Minimally invasive vs open distal metatarsal osteotomy for hallux algus-A ystematic eview and meta-analysis. J. Clin. Orthop.s Trauma, 11: 348-356.
5. Minokawa S., I. Yoshimura, K. Kanazawa, T. Hagio and T. Yamamoto., 2019. Effect of minimally invasive distal first metatarsal osteotomy on blood flow of the metatarsal head. J. Orthop. Sci., 24: 693-696.
6. Krenn S., S. Albers, P. Bock, C. Mansfield, M. Chraim and H.J. Trnka., 2018. Minimally Invasive Distal Metatarsal Metaphyseal Osteotomy of the Lesser Toes: Learning Curve. Foot and Ankle Specialist, 11: 263-268.
7. Biz C., S. Gastaldo, M. Dalmau-Pastor, M. Corradin, A. Volpin and P. Ruggieri., 2018. Minimally Invasive Distal Metatarsal Diaphyseal Osteotomy (DMDO) for Chronic Plantar Diabetic Foot Ulcers. Foot and Ankle Int., 39: 83-92.
8. Malhotra K., N. Joji, S. Mordecai and B. Rudge., 2019. Minimally invasive distal metaphyseal metatarsal osteotomy (DMMO) for symptomatic forefoot pathology-Short to medium term outcomes from a retrospective case series. The Foot, 38: 43-49.
9. Seki H., Y. Suda, K. Takeshima, T. Kokubo and K. Ishii *et al.,* 2018. Minimally invasive distal linear metatarsal osteotomy combined with selective release of lateral soft tissue for severe hallux valgus. J. Orthop. Sci., 23: 557-564.
10. Schneider T.E., C.R. Varrall and K. Malhotra., 2020. Early results of minimally invasive, reverse-oblique, distal metaphyseal metatarsal osteotomy (R-DMMO) for arthritis of the lesser tarsometatarsal joints-A retrospective case series. The Foot, Vol. 43. 10.1016/j.foot.2019.10.007.
11. Teoh K.H. and K. Hariharan., 2018. Minimally Invasive Distal Metatarsal Metaphyseal Osteotomy (DMMO) of the Fifth Metatarsal for Bunionette Correction. Foot and Ankle Int., 39: 450-457.
12. Seki H., S. Oki, Y. Suda, K. Takeshima, T. Kokubo, T. Nagura and K. Ishii., 2020. Three-Dimensional Analysis of the First Metatarsal Bone in Minimally Invasive Distal Linear Metatarsal Osteotomy for Hallux Valgus. Foot and Ankle Int., 41: 84-93.
13. Haque S., R. Kakwani, C. Chadwick, M.B. Davies and C.M. Blundell., 2016. Outcome of Minimally Invasive Distal Metatarsal Metaphyseal Osteotomy (DMMO) for Lesser Toe Metatarsalgia. Foot and Ankle Int., 37: 58-63.
14. Mavcic B., 2015. Geometric analysis of indications for minimally invasive distal metatarsal osteotomy in treatment of hallux valgus. J. Orthop. Surg. Res., Vol. 10 .10.1186/s13018-015-0304-7 58-63.
15. Lin Y., Y. Cheng, J. Chang, C. Chen and P. Huang., 2009. Minimally Invasive Distal Metatarsal Osteotomy for Mild-to-Moderate Hallux Valgus Deformity. The Kaohsiung J. Med. Sci., 25: 431-437