

COMPARATIVE EVALUATION OF METATARSAL BAR AND PAD ON PAIN, FUNCTION AND PLANTAR PRESSURE IN PATIENTS WITH PRIMARY METATARSALGIA

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Abstract

Background: Primary metatarsalgia is a common forefoot condition associated with pain, functional limitation, and excessive plantar loading. Metatarsal bars and pads are frequently used as conservative orthotic interventions to redistribute plantar pressure and reduce symptoms. However, their comparative effectiveness remains unclear.

Objective: To compare the effects of a metatarsal bar and metatarsal pad on pain, foot function, and plantar pressure in patients with primary metatarsalgia.

Methodology: A randomized controlled trial was conducted among 24 patients aged 20–60 years with clinically diagnosed primary metatarsalgia. Participants were randomly allocated into two equal groups. Group A received a metatarsal bar attached to the outer sole of the footwear, while Group B received a metatarsal pad placed proximal to the metatarsal heads inside the shoe. Pain was assessed using the Visual Analog Scale (VAS), foot function using the Foot Function Index (FFI), and plantar pressure using a foot-scanner plantar-pressure test. Pre- and post-intervention outcomes were analyzed using paired and independent sample t-tests.

Results: Both groups demonstrated substantial improvements in pain, foot function, and plantar pressure following intervention. The metatarsal-bar group showed greater improvement, with VAS decreasing from 6.79 to 2.45, FFI from 61.83 to 24.00, and plantar pressure from 420.00 to 282.08. In the metatarsal-pad group, VAS decreased from 6.75 to 3.53, FFI from 62.25 to 34.91, and plantar pressure from 419.53 to 322.19. Overall, the metatarsal bar produced superior clinical and biomechanical outcomes.

Conclusion: Both metatarsal interventions were beneficial; however, the metatarsal bar demonstrated greater improvements in pain, functional ability,

and plantar-pressure distribution and may therefore be considered the more effective conservative orthotic intervention for primary metatarsalgia.

INTRODUCTION

Metatarsalgia is a frequent clinical problem and a condition that presents with pain located in the plantar surface of the forefoot and especially in the metatarsal heads. The term refers not just to one single pathological condition, but to a group of symptoms linked to mechanical overload, altered forefoot biomechanics or metatarsophalangeal structural abnormalities. Patients often complain about a dull, burning, or stabbing sensation under the ball of the foot, this can be worse when standing for long periods of time, walking, running, or other weight bearing activities. Given the critical role that the metatarsal region has during the terminal stance and propulsion phases of gait, it can significantly affect mobility and everyday function (1).

Primary metatarsalgia is typically a reaction to intrinsic anatomical and/or biomechanical problems of the forefoot, and not the result of systemic inflammatory disease, neurological disorders, trauma or postoperative complications. Multifactorial, such as abnormal length relationships of the metatarsals, excessive plantarflexion of one or more metatarsals, decreased mobility of the first ray, hallux deformity, pes cavus and changes in plantar loading. Biomechanical studies in recent years have focused attention on the dynamic loading variables during walking, which do not always correlate with static alignment of the foot, and the link between foot structure and development of metatarsalgia is therefore complex. Hence, structural and functional loading patterns must be taken into account when clinically evaluating (2). The most common symptom of primary metatarsalgia is pain under one or more metatarsal heads. This repetitive loading of the forefoot may lead to an increase in mechanical stress on the plantar soft tissues such as the plantar plate, plantar joint capsule and plantar soft tissues. If a person has a changed forefoot morphology, the

distribution of the load across the metatarsal heads may be disrupted causing focal areas of increased load. This mechanical overload can be a part of continued pain and tenderness with weight-bearing activities (3). Plantar-pressure assessment has also recently been shown to be clinically relevant in the evaluation of patients with forefoot symptoms, as there is an association between forefoot pressure and metatarsal pain (4).

Symptoms of metatarsalgia can be different in each person. In some patients the pain may only occur when they are doing high impact activities, while in others they may develop symptoms when they walk normally or stand for long periods of time. Patients can also report a feeling of “walking on a pebble” or having a foreign body under the front foot. Certain shoes can worsen symptoms and lead to hyperloading of the metatarsal area or decreased forefoot space. The characteristics of the footwear, such as lack of space in the forefoot and poor sole stiffness, can thus play a role in the persistence of symptoms. Running and other sporting activities that involve repetitive loading and unloading of the forefoot in physically active people can also increase mechanical stresses on the metatarsal heads (5).

Primary metatarsalgia is significant and related to structural foot characteristics. The load through the metatarsophalangeal joint of the second or central metatarsal may be greater if it is relatively long. Recent studies looking at the relationship between relative second metatarsal length and metatarsalgia have shown a possibility for the role that metatarsal morphology plays in symptom onset (6). Likewise, a high arched foot is often correlated with a forefoot loading pattern that leads to pes cavus. Finite-element research has shown that stiffness of the plantar fascia and foot architecture changes can affect the internal mechanics of the forefoot, and offer a biomechanical explanation of the relationships between foot cavity and metatarsalgia (7).

The diagnosis of primary metatarsalgia is mainly clinical, based on a thorough history and physical examination. Typical assessment techniques are palpation of metatarsal heads, observation of foot posture and deformity, examination of joint mobility and observation of gait, and identification of location and nature of pain. Radiographic or other imaging tests can be ordered to detect structural abnormalities or rule out other causes of forefoot pain if clinically warranted. Most importantly, differential diagnosis is required, as a number of entities can cause similar symptoms such as Morton's neuroma, stress fracture, plantar plate pathology, inflammatory arthropathy, sesamoid problems and forefoot disorders (8).

Metatarsalgia is a significant rehabilitation issue owing to its functional implications. Walk-related pain can lead to decreased physical activity and occupational or recreational activity, and impact quality of life. Conservative treatment therefore is usually aimed at minimizing the excess forefoot loading whilst maintaining or enhancing functional mobility. Mechanical contributors to symptoms can be treated with footwear modification, activity modification, therapeutic exercise, or accommodative/corrective foot orthoses. There are still recent publications that highlight the importance of orthotic intervention in the modification of the forefoot load, but there is a big variation in the level of influence and its consistency (9).

The clinical features of primary metatarsalgia are of special interest in the context of assessing interventions for the redistribution of forefoot load. Metatarsal pads and bars are frequently used in conservative therapy and are used to try to modify the mechanics of the metatarsal heads. Modern data suggests that orthotics may affect distribution of plantar pressures, which can be influenced by the type of orthotics used, orthotic location, foot shape, and biomechanics of the individual. These factors should be taken into account when assessing interventions not only by pain reduction but also by functional

improvements and objective plantar pressure changes (10).

Forefoot biomechanics is linked to development and maintenance of metatarsalgia. When walking normally, the body weight is transferred gradually from the heel to the midfoot and forefoot and significant loading occurs under the metatarsal heads in the terminal stance and push-off phases. This load transfer is necessary for effective propulsion but overloading or unbalanced loading of the metatarsal area can lead to mechanical strain of the plantar soft tissue and pain. Mechanical properties of the symptomatic foot can thus be objectively assessed by plantar-pressure data, and abnormal loading patterns of the forefoot can be determined (11).

The force exerted between the plantar surface of the foot and the supporting surface relative to the area over which the force is distributed is called plantar pressure. Peak plantar pressure, mean pressure, contact area, force-time characteristics and pressure-time integral are several parameters which can be determined when plantar pressures are measured. Peak plantar pressure is the peak pressure that is applied at one point during a step, while the pressure-time integral is the total loading over the contact time. These parameters give additional information on the intensity and duration of mechanical loading during gait. In metatarsalgia patients, the measurements can be useful to determine if the symptoms relate to abnormal or increased forefoot loading (12).

The metatarsal heads are not subjected to the same load during gait. The four factors that affect the magnitude and timing of the pressure under individual metatarsals are metatarsal length, forefoot alignment, first-ray function, foot posture, body mass, gait velocity, footwear and mechanical properties of plantar tissues. Any change in any of these factors may change the normal movement of the center of pressure over the foot. Thus, an individual with primary metatarsalgia might exhibit a differential load distribution between the medial and lateral forefoot or too much load under certain metatarsal heads (13).

The distribution of plantar pressure may be additionally affected by foot posture. With a high arched foot, individuals may exhibit increased pressure on the heel and forefoot due to less contact area and abnormal load transfer. It has been shown by finite-element modelling that plantar fascia stiffness variations can affect the internal plantar foot mechanics, and metatarsal loading, so giving a biomechanical explanation for the occurrence of symptoms in the forefoot for persons with cavus-type foot morphology. Other foot postures can cause medial or lateral shifts in loading depending on the amount of pronation/supination and/or the structural deformity (14).

Forefoot disorders are increasingly being evaluated by measurement of plantar pressure, with the conservative treatment of these conditions gaining increasing significance. New pressure-measurement systems enable clinicians and researchers to measure regional loading during walking and to study how an intervention affects the distribution of loading. The in-shoe pressure systems are especially advantageous because they can be used in an environment that is similar to normal footwear and activity. This objective assessment is useful to determine if an intervention is actually mechanical offloading the symptomatic areas of the metatarsus (15).

Orthotic interventions have the ability to alter forefoot biomechanics by altering the point and amount of contact of the foot and the supporting surface. Systematic evidence in recent years suggest that forefoot modifications in foot orthoses can decrease plantar pressure and affect cumulative forefoot loading but the amount differs depending on the foot orthoses design and foot type. In the same way, biomechanical analysis of orthoses in chronic metatarsalgia patients has shown that plantar pressure will change during functional tasks such as stairs as well, but that this plantar response will be influenced by individual gait adaptations (16).

There is no direct link between pain and plantar pressure. Additionally, increased plantar pressure may help cause tissue irritation and pain, but

tissue sensitivity and the amount of time the tissue is loaded on, type of footwear, activity level, and individual adaptation also play a role in the perception of pain. Therefore, if the peak pressure drops, it does not necessarily mean that the symptoms will drop by the same amount. Thus, modern approaches to assessment of metatarsalgia should include objective biomechanical assessment and patient-reported outcomes including pain and functional outcomes (17).

Conservative management is generally thought to be an important first treatment for cases of primary metatarsalgia because symptoms are often secondary to the mechanical stress and overload rather than due to a single lesion that needs to be corrected by immediate surgery. The main goals of conservative care are to decrease undue stress on the metatarsal heads, redistribute plantar loading of the foot, alleviate pain, and restore a foot to a functional position. Management is often personalized based on symptoms, foot shape, activity level, shoes and underlying biomechanical traits (18).

One of the most basic approaches for managing forefoot pain is to modify the footwear. Well-fitting shoes that have a sufficiently wide toe box can help to eliminate compression of the forefoot and soft materials may help to minimize mechanical impact caused by repetitive weight bearing. In addition, by avoiding narrow or restrictive shoes as well as high heels, excessive forefoot loading may also be minimized. If symptoms are worsened by long periods standing or walking, then temporary modification of activities may also be recommended to decrease repetitive mechanical stress while symptoms are being treated (19).

Different types of orthotic interventions can be used according to the individual's clinical presentation. Both prefabricated insoles and custom foot orthoses, metatarsal pads and bars, cushioning materials, and combinations of these have been studied for their potential effects on forefoot loading. The type of intervention is crucial as the orthotic elements do not always have a similar biomechanical effect. The location,

thickness and properties of these as well as their relationship to the metatarsal heads may affect the amount and distribution of pressure (20).

The treatment of metatarsalgia with conservative (non-surgical) methods is especially relevant to metatarsal accommodations. The metatarsal pad is usually found at the base of the metatarsal heads, and is intended to spread the load over the forefoot and lessen the pressure at the metatarsal heads. The purpose of the pad is to spread out the forces it transmits, which could decrease peak pressures at problem areas. But if something is positioned incorrectly or too thick, it can also cause pain or cause pressure to be redistributed to other areas. Placement and adjustment are thus critical elements in the treatment of orthotics (21). Clinical outcomes (including pain and functional ability) are important when assessing conservative interventions, in addition to modification of plantar-pressure. The biomechanical change is only clinically significant if it helps improve symptoms or functional performance. The last research examining orthotic effect on persons with chronic metatarsalgia has therefore studied the orthotic effect during functional tasks, instead of only weighing the static pressure. These methods understand that the metatarsalgia is most commonly caused by activities like walking, standing, going up and down stairs, and exercising (22).

Corrective exercises and rehabilitation can also be used in combination with orthotic treatment. Treatment options can focus on the factors that contribute to the condition, including decreased ankle flexibility, a weak foot, altered gait mechanics, and inadequate control of the lower limbs. While the type of exercise program would need to be tailored to the individual, mechanical offloading coupled with rehabilitation could offer a more holistic approach to regaining functional movement and minimizing the risk of re-injury in the forefoot (23).

Metatarsal pads and metatarsal bars are commonly used orthotic modifications intended to alter forefoot loading and reduce mechanical stress beneath the metatarsal heads. Although both

interventions are designed to redistribute plantar pressure, their construction, location, and mechanical interaction with the foot differ. These differences may result in distinct patterns of pressure redistribution and may therefore produce different effects on pain and functional performance in patients with primary metatarsalgia (24).

A metatarsal pad is generally a localized cushioning or dome-shaped component positioned proximal to the metatarsal heads. Its primary purpose is to increase the contact area of the forefoot and encourage redistribution of load away from the painful metatarsal heads. Correct placement is particularly important because a pad positioned directly beneath a symptomatic metatarsal head may increase rather than reduce local pressure. Recent evidence indicates that forefoot modifications, including metatarsal pads, can reduce peak plantar pressure in some individuals, although responses vary according to orthotic design and individual foot characteristics (25).

A metatarsal bar, in contrast, is a broader and relatively rigid transverse modification incorporated into the sole or orthosis. Rather than concentrating the intervention at a localized point, the bar can influence the rollover characteristics of the forefoot and redistribute loading across a wider region. Metatarsal bars have also been incorporated into rocker-type footwear, where they may reduce the amount of motion and loading required at the metatarsophalangeal joints during propulsion. Biomechanical studies of rocker footwear with metatarsal bars have investigated changes in plantar pressure and lower-limb muscle activity, supporting their potential role in modifying forefoot mechanics (26).

The mechanical differences between these two interventions provide an important rationale for direct comparison. A metatarsal pad primarily modifies local contact and pressure distribution, whereas a metatarsal bar may influence the overall progression of the center of pressure and the rollover mechanism of the forefoot. Consequently, reductions in plantar pressure may

occur at different locations and through different biomechanical mechanisms. The clinical response may also depend on the patient's foot morphology, severity and location of pain, gait characteristics, and tolerance of the orthotic modification (27).

LITERATURE REVIEW

Schalkens et al. (2026) investigated the effect of a foot orthose with a medial wedge and metatarsal pad compared to a regular foot orthose in lowering the plantar pressure under the metatarsal heads during stair descent in people with chronic metatarsalgia. There were 22 participants (16 female and 6 male) in the study. Participants walked up and down stairs in 3 conditions: shoe-only, standard foot orthoses, and medial-wedge foot orthoses + metatarsal pads. Peak plantar pressure was evaluated using repeated measures analysis, along with three-dimensional lower-limb joint angles and moments. The plantar pressures under the metatarsal heads and under the heel were reduced in both orthotic conditions when compared to shoes alone. The medial-wedge orthoses with metatarsal pads resulted in a larger decrease in peak pressure under the first metatarsal head than the standard orthoses alone and modified midfoot and lower-limb mechanics. After conducting the analysis, the authors drew the following conclusions: Foot orthoses, especially the ones containing metatarsal pads, are effective at altering plantar loading during difficult functional tasks (28).

Thiaspras et al. (2026) undertook a systematic review examination the effectiveness of foot orthoses for the reduction of forefoot plantar pressure. A search was performed in five databases and papers were analysed that compared various types of orthotics and forefoot types. The aim was to establish if there was a role for orthoses in lowering peak plantar pressure and to highlight lack of evidence. Several orthotic interventions including soft contoured orthoses and metatarsal pads were found to be able to reduce forefoot plantar pressure in the review. There was, however, significant differences between studies in terms of the orthotic design, the location of the

orthotics, the participants, the measurement methods and the outcome measures. The authors noted that the evidence present is still quite diverse and the mechanisms driving the pressure reduction are still not fully understood. They found that foot orthoses have the potential to reduce the forefoot pressure, but adequate comparative studies of orthotic modifications are needed (29).

Lin et al. (2025) studied the effects of the stiffness of the insole material on biomechanics of the human foot using finite element analysis. The aim was to assess the effects of various material characteristics on plantar-pressure distribution and internal mechanical loading. Using the weight-bearing conditions the researchers modelled various insole stiffness conditions to examine changes in pressure and foot mechanics. The findings showed that insole stiffness affected the mechanical response of the foot, affecting also the characteristics of the plantar-pressure. The results revealed that the effectiveness of orthotics is not just dependent on their shape and place, but also the material properties. This is especially important when comparing metatarsal pads and bars as they can have varying structural stiffness. The authors found that the stiffness of the material is a key factor to consider in designing orthotics and can affect the plantar force distribution (30).

Wang et al. (2025) studied the mechanical reaction of the foot to a custom-made insole during static standing and walking. The aim of this study was to elucidate the effect of individual orthotic design on plantar mechanics for various weight bearing conditions. Assessment of participants was conducted while standing and walking with a custom-made insole, while plantar-pressure characteristics were assessed. Results showed that the custom-made insole changed the characteristics of plantar pressure and mechanical responses in both static and dynamic situations. During walking, changes showed that orthotic intervention might be able to affect plantar loading distribution and timing during functional activity. The authors highlighted the need to

consider dynamic assessment, as walking places different mechanical demands on the body than standing. They found that custom-made insoles alter foot mechanics and that plantar-pressure during walking can give helpful information in the assessment of orthotic effectivity (31).

To evaluate the effects of personalized orthopedic insoles on plantar pressure during running in subtle cavus foot, a study by Ma et al. (2024) was conducted. The aim was to assess if individual orthoses will alter excessive plantar loading in relation to cavus foot morphology. Participants who had subtle cavus foot were evaluated at their running gait with and without customized orthopedic insoles. Dynamic plantar-pressure measurements were taken to assess changes in regional loading. The findings showed that the insoles for orthopedic use with individual inserts were effective in changing the plantar-pressure distribution during running. The intervention changed the loading patterns of a foot type that is often related to higher forefoot loading. It was found that one shoe type could be designed to redistribute mechanical loading depending upon foot type. The authors found that dynamic activity may be modified by personalized orthopedic insoles, and that they could be utilized for biomechanical abnormalities caused by excessive forefoot loading (32).

The study by Kyung et al. (2024) aimed to examine the differences in plantar-pressure distribution between the affected and unaffected foot of patients with unilateral plantar fasciitis. This was to find abnormal loading patterns that would help with the clinical evaluation and orthotic prescription. The participants were recruited from July 2021 to December 2022 when the patients had unilateral plantar fasciitis. Parameters of plantar pressure such as pressure-time integral (PTI) and peak pressure (PP) were compared between symptomatic and asymptomatic feet. The results showed that plantar-pressure distribution between the right and left foot was different, so that foot pain may be linked to changes in weight bearing. They found that the plantar-pressure-based approach is capable of discriminating

between the differences in regional loading for symptomatic feet and that could prove to be useful information for prescribing orthotics. The study participants were patients with plantar fasciitis and not metatarsalgia, however, the methodology used in this study would allow for objective plantar-pressure assessment to be used when studying painful foot conditions (33).

Guo et al. (2023) examined the biomechanical changes in children with flatfoot caused by a custom-made insoles that reduce plantar pain. The aim was to assess the effect of an individually fabricated insole for altering abnormal plantar loading. A biomechanical examination of the foot was performed to assess foot mechanics with and without the custom-made insole. The plantar loading and mechanical characteristics were evaluated in the weight-bearing state. The results indicated that the plantar mechanical loading was altered and the forces were redistributed over the plantar surface using the custom-made insole. The authors concluded that insoles fitted to an individual may alter plantar biomechanics and have the potential to reduce mechanically-induced plantar pain. In this study, the participants were not experiencing metatarsalgia, but the results support the concept that changes in orthotics may alter plantar forces and decrease the plantar mechanical stress [7] in the affected area (34).

Jiménez-Cano et al. (2022) evaluated the ability of socks with a U-shaped, 3D discharge element to decrease dynamic plantar pressure under the central forefoot. Thirty-eight people (25 women and 13 men) participated in the study. Dynamic plantar pressure was recorded in three different conditions: barefoot, control sock condition, and sock condition with the discharge element in the shape of a U. Pressure was measured under the hallux, lesser toes and metatarsal heads. The third metatarsal head had the greatest pressure. The experimental socks significantly decreased the pressure under the second metatarsal head when compared to barefoot and control-sock status and decreased the pressure under the third metatarsal head as well. The authors found that the U-shaped discharge element was effective in decreasing

dynamic pressure in the center forefoot area and could have some potential to decrease mechanical stress when associated with forefoot disease (35). Molines-Barroso et al. (2022) explored the effectiveness of the Fixtoe Device® for altering the plantar-pressure distribution in patients with propulsive metatarsalgia. The aim was to assess if the device would decrease forefoot loading, and to make some comparisons with the use of traditional metatarsophalangeal (MTP) stabilizing taping. Twenty four subjects participated in the preliminary study and were evaluated in different experimental conditions with the use of dynamic plantar-pressure assessments. The Fixtoe Device® with a metatarsal-dome component was able to measure changes in plantar-pressure distribution. The results gave preliminary indications that the device was able to influence excessive forefoot loading which is linked to propulsive metatarsalgia. The authors suggest that the Fixtoe Device® could be a beneficial conservative treatment for plantar pressure modification but larger clinical trials are required to prove its efficacy in pain and function (36).

Partovifar et al. (2021) studied how the use of prefabricated insoles affects plantar-pressure distribution in patients with RA. While the study population was not people with primary metatarsalgia, many people with rheumatoid arthritis experience pain in the forefoot and abnormal loading of the plantar surface. The participants were evaluated before and after wearing prefabricated insoles, through plantar-pressure measurements. The researchers looked at the distribution of pressure under the feet in the region to see if the intervention could shift excess mechanical load. The results revealed that the modified prefabricated insoles affected the plantar-pressure distribution of the participants. The study thus validates a biomechanical argument for the use of orthoses for decreasing plantar load concentration. The authors suggested prefabricated insoles might be beneficial in the management of abnormal foot loading, but the usefulness of these findings cannot be directly

extrapolated to the primary metatarsalgia due to the differences in pathologies (37).

Naranjo-Ruiz et al. (2021) have looked at how the foot type affects clinical results after minimally invasive surgery for primary central metatarsalgia. The data presented here is from a prospective pilot study of 28 patients – 6 males and 22 females. Minimally invasive distal metaphyseal metatarsal osteotomy was performed on participants and functional results were evaluated preoperatively and at 6 and 12 months postoperatively using the American Orthopaedic Foot and Ankle Society scale. Mean functional scores improved from 42.82 ± 15.60 preoperatively to 86.50 ± 8.6 at 6 months and 92.93 ± 8.6 at 12 months. There was significant functional improvement but no significant differences between the foot types. The authors found that the surgery was successful in all patients, with regard to foot posture, and highlighted the need to assess each patient's foot shape when treating patients with metatarsalgia (38).

OBJETIVE

To compare the clinical and biomechanical effectiveness of metatarsal bars and metatarsal pads in patients with primary metatarsalgia.

HYPOTHESIS

Null Hypothesis (H₀): There is no statistically significant difference between metatarsal bars and metatarsal pads in reducing pain, improving function, or redistributing plantar pressure in individuals with primary metatarsalgia.

Alternative Hypothesis (H₁): A statistically significant difference exists between metatarsal bars and metatarsal pads regarding pain reduction, functional improvement, and plantar pressure redistribution in individuals with primary metatarsalgia.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study Design

The study was Randomized Control Trial.

3.2 Study Setting

The study was conducted at Rehabilitation and Orthotics Department, RTEH Indus Hospital Muzaffargarh and Pakistan Institute of Prosthetics and Orthotics Sciences (PIPOS), Peshawar.

3.3 Study Duration

The study was conducted over a period of 6 months after the approval of synopsis.

3.4 Study Population

Patients aged 20-60 years with clinically diagnosed primary metatarsalgia.

3.5 Sample Size

Sample size is calculated using OpenEpi tool on the basis of mean and standard deviation values. Outcome variable "pain". The required sample after adding 10% attrition rate is 24 (39).

Sample Size For Comparing Two Means

Input Data			
Confidence Interval (2-sided)	95%		
Power	80%		
Ratio of sample size (Group 2/Group 1)	1		
	Group 1	Group 2	Difference*
Mean	5.21	6.32	-1.11
Standard deviation	0.95	0.87	
Variance	0.9025	0.7569	
Sample size of Group 1	11		
Sample size of Group 2	11		
Total sample size	22		

3.6 Sampling Technique

A non-probability convenience sampling technique was used.

3.7 Sample Selection Criteria

3.7.1 Inclusion Criteria

- Both male and female age 20-60 years
- Clinically diagnosed primary metatarsalgia
- Foot pain persisting for more than 4 week

3.7.2 Exclusion Criteria

- Individuals diagnosed with diabetic neuropathy, as altered sensation and nerve dysfunction may influence plantar pressure distribution and pain perception.
- Individuals with rheumatoid arthritis or other systemic inflammatory conditions affecting the foot.

- Individuals with a history of foot surgery, which may alter normal foot biomechanics and plantar pressure patterns.

- Individuals who have sustained a foot fracture within the last six months, as recent fractures may affect gait, weight-bearing ability, and plantar pressure measurements.

3.8 Group Allocation

After baseline assessment, eligible participants were randomly assigned to one of two intervention groups using a computer-generated randomization sequence.

- Group A: Patients using metatarsal bar.
- Group B: Patients using metatarsal pad.

3.9 Outcome Measurement tools

Pain Rating - Visual Analog Scale (VAS):

The intensity of pain was measured by the Visual Analog Scale (VAS), which was a simple subjective tool used to measure pain intensity in both clinical and research settings. The VAS consisted of a horizontal 10 cm line with two endpoints, one marked as “no pain” and the other as “worst imaginable pain.” The participants were asked to place a mark on the line that best described their current level of pain. The score was calculated by measuring the distance between the “no pain” endpoint and the point marked by the participant, resulting in a score ranging from 0 to 10. Higher scores indicated greater pain intensity. The VAS had demonstrated good test-retest reliability and validity for assessing pain (40).

Functional Assessment -Foot Function Index (FFI):

The functional ability was assessed using the Foot Function Index (FFI), a self-reported and validated questionnaire designed to assess the effects of foot disorders on pain, disability, and activity restriction. The FFI consisted of 23 items categorized into three subscales: pain, disability, and activity limitation. Each item was scored on a scale from 0 to 10, with 0 representing no pain or difficulty and 10 representing the highest level of pain or maximum difficulty in performing activities. The scores were calculated by averaging the scores within each subscale, with higher scores indicating greater impairment and functional limitation. The FFI had demonstrated good reliability and validity for assessing functional limitations in individuals with various foot-related conditions (41).

Biomechanical Evaluation -Foot Scanner Plantar Pressure Test:

The distribution of plantar pressure was measured using a foot-scanner plantar-pressure analysis system, which provided objective information regarding pressure distribution across different regions of the foot during standing and walking. The equipment measured parameters including

peak plantar pressure, pressure distribution, and contact area beneath the metatarsal heads and other regions of the foot. The collected data were used to identify areas of excessive plantar loading, which were associated with forefoot pain and metatarsalgia. Biomechanical changes were determined by comparing plantar-pressure values obtained before and after the intervention. Plantar-pressure analysis systems had been demonstrated to have good reliability and validity for assessing foot biomechanics and plantar-loading patterns (25).

3.10 Data Collection Procedure

Recruitment:

Participants were recruited from the outpatient departments of physiotherapy and orthopaedic clinics based on the predefined inclusion and exclusion criteria. Eligible patients diagnosed with primary metatarsalgia were informed about the purpose and procedures of the study. Participants who agreed to take part provided written informed consent before being enrolled in the study.

Enrollment:

Based on the pre-intervention assessment, participants were randomly assigned into the two groups.

Randomization:

The randomization process employed a computer-generated randomizer, and allocation concealment ensured through the sealed envelope method.

Blinding:

This study was a single blinded.

Treatment:

The participants in study were divided into two group.

Treatment Procedure

Group A (Metatarsal Bar Group):

Participants in this group were provided with a metatarsal bar attached to the outer sole of the footwear, positioned just proximal to the metatarsal heads. The metatarsal bar was positioned to redistribute plantar pressure away from the forefoot and facilitate smoother rollover

during gait. Participants were instructed to wear the modified footwear during their daily activities for the prescribed duration of the study.

Group B (Metatarsal Pad Group):

Participants in this group were provided with a metatarsal pad placed inside the shoe insole, proximal to the metatarsal heads. The pad was positioned to elevate and spread the metatarsal heads, thereby reducing plantar pressure beneath the forefoot. Participants were advised to use the orthotic support during regular walking and daily activities throughout the study period.

3.11 Ethical Consideration

Ethical approval for the study was obtained from the Research Review Board (RRB), Department of Physical Therapy and Rehabilitation Sciences, Faculty of Allied Health Sciences, The Superior University, Lahore, before the commencement of data collection. All research procedures were conducted in accordance with the ethical principles outlined in the Declaration of Helsinki for research involving human participants.

Participants were informed about the purpose, objectives, study procedures, expected duration, potential benefits, and possible risks associated with the research before enrollment. Written informed consent was obtained from each

participant prior to participation. Participants were informed that their participation was entirely voluntary and that they had the right to refuse participation or withdraw from the study at any stage without providing any reason and without any negative consequences.

The findings of the study were used solely for academic and scientific purposes and could be published in scientific journals or presented at conferences without revealing the identity of any participant.

3.12 Data Analysis Procedure

The collected data were entered into IBM SPSS Statistics Version 27.0 for analysis. The level of statistical significance was set at $p < 0.05$.

Descriptive statistics: Frequency tables, pie charts, and bar charts were used to present summaries of group measurements over time.

The distribution of continuous data was assessed using the Shapiro-Wilk test because of the relatively small sample size.

Parametric tests: Independent t-tests for between group analysis and paired sample t-tests for within group analysis were employed for comparing variables with non-significant normality test results.

CHAPTER FOUR**RESULTS****Table 4.1 Statistics of age**

Statistics of age	
N	24
Mean	42.2083
Std. Deviation	11.00584
Minimum	20.00
Maximum	60.00

In Table 4.1 the age statistics indicate that the study included 24 participants, with a mean age of

42.21 years (SD = 11.01). The participants' ages ranged from 20 to 60 years, showing a relatively

broad age distribution within the sample. Overall, the findings suggest that the participants were, on

average, in their early forties, with moderate variation in age.

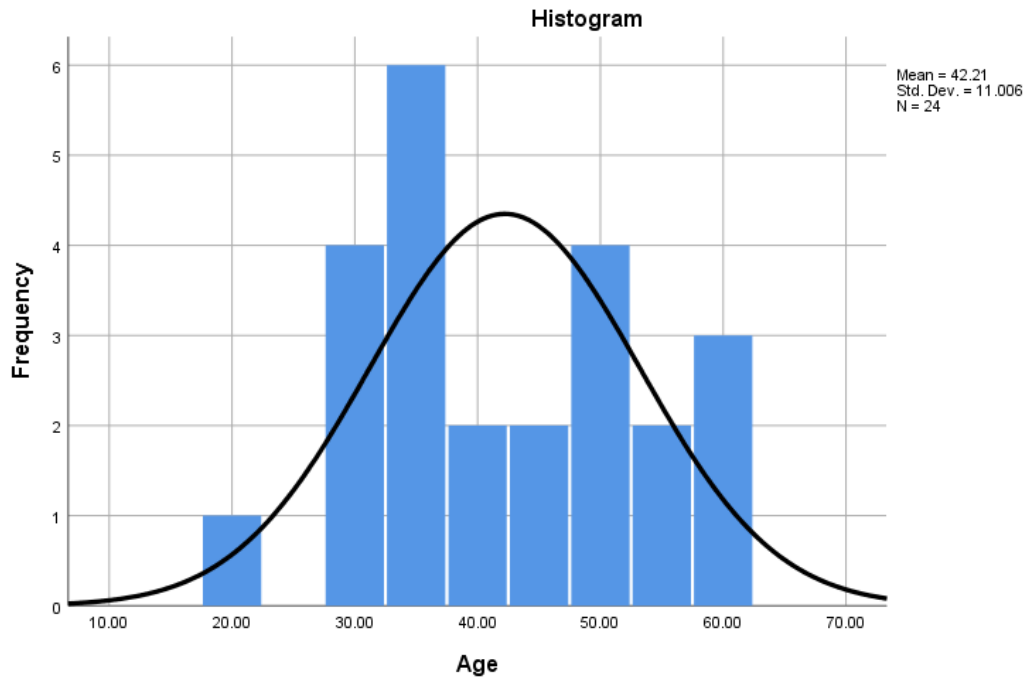


Figure 4. 1 Histogram of Age

Table 4.2 Gender

Gender		
	Frequency	Percent
Male	17	70.8
Female	7	29.2
Total	24	100.0

In Table 4.2 The gender distribution shows that out of the 24 participants, 17 (70.8%) were male and 7 (29.2%) were female. This indicates that the

study sample consisted predominantly of male participants, while females represented a smaller proportion of the total sample.

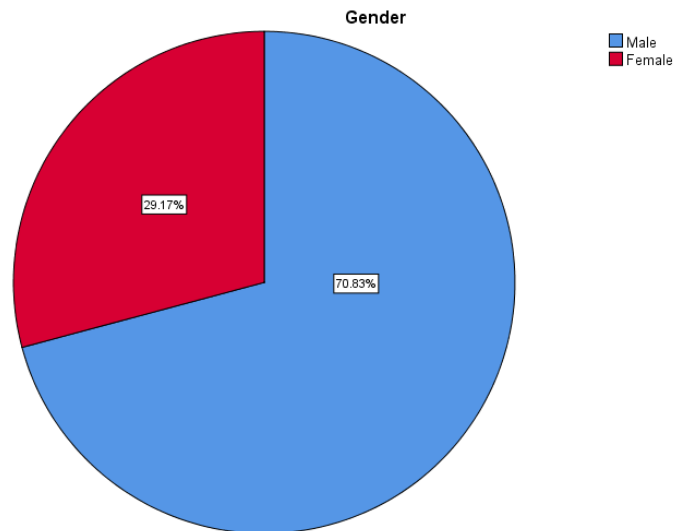


Figure 4. 2 Pie chart of Gender

Table 4.3 Study groups

Study groups		
	Frequency	Percent
Group A: Patients using metatarsal bar	12	50.0
Group B: Patients using metatarsal pad	12	50.0
Total	24	100.0

The Table 4.3 shows that the 24 participants were equally divided between the two groups. Group A, consisting of patients using a metatarsal bar, included 12 participants (50.0%), while Group B,

consisting of patients using a metatarsal pad, also included 12 participants (50.0%). Thus, both study groups were equally represented in the sample

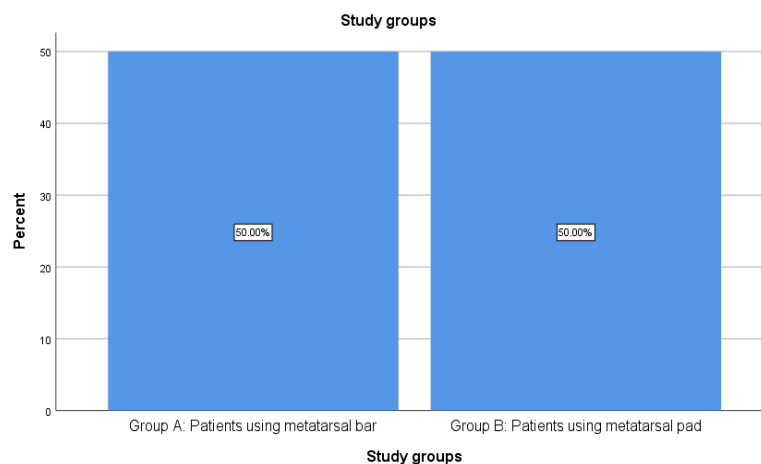


Figure 4. 3 Bar chart of Study groups

Table 4. 4 Tests of Normality

Tests of Normality			
	Shapiro-Wilk		
	Statistic	df	Sig.
Pre: Visual analogue scale (VAS)	.946	24	.218
Pre: Foot function index (FFI)	.976	24	.816
Pre: Foot Scanner Plantar Pressure Test	.967	24	.591

The Table 4.4 Shapiro-Wilk test was used to assess the normality of the data for the three pre-intervention outcome measures. The results showed that the Visual Analogue Scale (VAS) scores were normally distributed ($W = 0.946$, $p = 0.218$), as were the Foot Function Index (FFI)

scores ($W = 0.976$, $p = 0.816$) and Foot Scanner Plantar Pressure Test scores ($W = 0.967$, $p = 0.591$). Since all p-values were greater than 0.05, the assumption of normality was satisfied for all three variables, indicating that parametric statistical tests could be appropriately applied.

Table 4. 5 Independent sample T test between groups analysis of VAS

	Group A	Group B	Mean difference	p-value
Pre VAS	6.79±.72	6.75±.72	.0416	.889
Post VAS	2.45±.65	3.53±.82	-1.125	.001

In Table 4.5 the independent samples t-test showed that there was no statistically significant difference in pre-intervention VAS scores between Group A (6.79 ± 0.72) and Group B (6.75 ± 0.72), with a mean difference of 0.0416 and a p-value of 0.889. However, a statistically significant difference was observed in post-intervention VAS

scores, with Group A recording a lower mean score (2.45 ± 0.65) compared with Group B (3.53 ± 0.82). The mean difference was -1.125, with a p-value of 0.001, indicating that Group A demonstrated significantly greater reduction in pain compared with Group B.

Table 4. 6 Independent sample T test between groups analysis of FFI

	Group A	Group B	Mean difference	p-value
Pre FFI	61.83±5.70	62.25±5.81	-.4167	.861
Post FFI	24.00±5.53	34.91±7.35	-10.916	.000

In Table 4.6 The independent samples t-test showed that there was no statistically significant difference in pre-intervention FFI scores between Group A (61.83 ± 5.70) and Group B (62.25 ± 5.81), with a mean difference of -0.4167 and a p-value of 0.861. However, a statistically significant difference was observed in post-intervention FFI

scores, with Group A showing a lower mean score (24.00 ± 5.53) compared with Group B (34.91 ± 7.35). The mean difference was -10.916, with a p-value of 0.000, indicating that Group A demonstrated significantly greater improvement in foot function compared with Group B.

Table 4.7 Independent sample T test between groups analysis of foot scanner plantar pressure test

	Group A	Group B	Mean difference	p-value
Pre foot scanner plantar pressure test	420.00±20.78	419.53±21.04	.4167	.962
Post foot scanner plantar pressure test	282.08±22.69	322.19±27.67	-40.83	.001

In Table 4.7 the independent samples t-test showed that there was no statistically significant difference in pre-intervention foot scanner plantar pressure test scores between Group A (420.00 ± 20.78) and Group B (419.53 ± 21.04), with a mean difference of 0.4167 and a p-value of 0.962. However, a statistically significant difference was

observed in post-intervention plantar pressure scores, with Group A recording a lower mean score (282.08 ± 22.69) compared with Group B (322.19 ± 27.67). The mean difference was -40.83, with a p-value of 0.001, indicating that Group A demonstrated a significantly greater reduction in plantar pressure compared with Group B.

Table 4.8 Paired sample T test within group A analysis of VAS

Study group		Paired difference	
		Mean± Std. Deviation	P value
Group A	Pre VAS	6.79±.721	<0.05
	Post VAS	2.45±.655	

In Table 4.8 the paired samples t-test showed a statistically significant difference in VAS scores within Group A between the pre- and post-intervention measurements. The mean VAS score decreased from 6.79 ± 0.72 before the

intervention to 2.45 ± 0.66 after the intervention, with a p-value of <0.05. This indicates a significant reduction in pain intensity among participants in Group A following the intervention.

Table 4.9 Paired sample T test within group A analysis of FFI

Study group		Paired difference	
		Mean± Std. Deviation	P value
Group A	Pre FFI	61.83±5.70	<0.05
	Post FFI	24.00±5.57	

In Table 4.9 The paired samples t-test showed a statistically significant difference in FFI scores within Group A between the pre- and post-intervention measurements. The mean FFI score decreased from 61.83 ± 5.70 before the

intervention to 24.00 ± 5.57 after the intervention, with a p-value of <0.05. This indicates a significant improvement in foot function among participants in Group A following the intervention.

Table 4.10 Paired sample T test within group A analysis of foot scanner plantar pressure test

Study group		Paired difference	
		Mean± Std. Deviation	P value
Group A	Pre foot scanner plantar pressure test	420.00±20.78	<0.05
	Post foot scanner plantar pressure test	282.08±22.60	

Table 4.10 shows the results of the paired samples t-test for the foot scanner plantar pressure test within Group A. The mean plantar pressure score decreased from 420.00 ± 20.78 before the intervention to 282.08 ± 22.60 after the

intervention. The difference was statistically significant, with a p-value of <0.05 , indicating a significant reduction in plantar pressure among participants in Group A following the intervention.

Table 4. 11 Paired sample T test within group B analysis of VAS

Study group		Paired difference	
		Mean $\pm$ Std. Deviation	P value
Group B	Pre VAS	6.75 $\pm$.72	<0.05
	Post VAS	3.53 $\pm$.821	

Table 4.11 shows the results of the paired samples t-test for VAS scores within Group B. The mean VAS score decreased from 6.75 ± 0.72 before the intervention to 3.53 ± 0.82 after the intervention.

The difference was statistically significant, with a p-value of <0.05 , indicating a significant reduction in pain intensity among participants in Group B following the intervention.

Table 4. 12 Paired sample T test within group B analysis of FFI

Study group		Paired difference	
		Mean $\pm$ Std. Deviation	P value
Group B	Pre FFI	62.25 $\pm$ 5.81	<0.05
	Post FFI	34.91 $\pm$ 7.35	

Table 4.12 shows the results of the paired samples t-test for FFI scores within Group B. The mean FFI score decreased from 62.25 ± 5.81 before the intervention to 34.91 ± 7.35 after the intervention. The difference was statistically

significant, with a p-value of <0.05 , indicating a significant improvement in foot function among participants in Group B following the intervention.

Table 4. 13 Paired sample T test within group B analysis of foot scanner plantar pressure test

Study group		Paired difference	
		Mean $\pm$ Std. Deviation	P value
Group A	Pre foot scanner plantar pressure test	419.58 $\pm$ 21.04	<0.05
	Post foot scanner plantar pressure test	322.91 $\pm$ 27.67	

Table 4.13 shows the results of the paired samples t-test for the foot scanner plantar pressure test within Group B. The mean plantar pressure score decreased from 419.58 ± 21.04 before the intervention to 322.91 ± 27.67 after the intervention. The difference was statistically significant, with a p-value of <0.05 , indicating a significant reduction in plantar pressure among

participants in Group B following the intervention.

CHAPTER FIVE

DISCUSSION AND CONCLUSION

To compare the effects of a metatarsal bar and metatarsal pad on pain, foot function, and plantar pressure in patients with primary metatarsalgia. The study included 24 participants, equally

allocated to metatarsal bar and metatarsal pad groups. Baseline comparisons showed no significant differences between groups for pain, foot function, or plantar pressure, indicating comparable starting conditions. Following intervention, both groups demonstrated significant improvements in pain, foot function, and plantar pressure ($p < 0.005$). However, between-group analysis demonstrated that the metatarsal bar produced significantly greater improvements than the metatarsal pad in pain reduction, functional improvement ($p < 0.005$), and plantar-pressure reduction. Overall, both interventions were effective in improving clinical and biomechanical outcomes in patients with primary metatarsalgia, but the metatarsal bar demonstrated superior effects across all three measured outcomes compared with the metatarsal pad.

Schalkens et al. (2026) investigated the effects of foot orthoses on plantar pressure and lower-limb biomechanics in patients with chronic metatarsalgia during stair ascent and descent. Their findings showed that both standard foot orthoses and orthoses incorporating a medial wedge with a metatarsal pad reduced plantar pressure under the metatarsal heads and heel compared with shoes alone. The medial-wedge orthosis combined with a metatarsal pad produced a greater reduction in peak pressure under the first metatarsal head and also modified midfoot and lower-limb mechanics. The study therefore supported the ability of orthotic interventions, particularly those containing metatarsal pads, to modify forefoot loading during demanding functional activities. These findings are consistent with the current study because the metatarsal pad group also demonstrated a significant reduction in plantar pressure ($p < 0.001$) (28). However, the current study contrasts with Schalkens et al. because it directly compared a metatarsal bar with a metatarsal pad and found the bar produced significantly greater plantar-pressure reduction.

Thiaspras et al. (2026) conducted a systematic review examining the effectiveness of foot orthoses in reducing forefoot plantar pressure. Their review

found that several orthotic interventions, including soft contoured orthoses and metatarsal pads, had the potential to reduce forefoot plantar pressure. However, the authors identified considerable variation among studies regarding orthotic design, placement, participant characteristics, pressure-measurement methods, and outcome measures. They therefore concluded that although orthoses may reduce forefoot pressure, the available evidence remains heterogeneous and further comparative research is required to establish which orthotic modifications are most effective. These findings agree with the current study because both interventions produced significant reductions in plantar pressure, with the metatarsal bar group showing a significant reduction ($p < 0.001$) and the metatarsal pad group also showing a significant reduction ($p < 0.001$). However, the current study extends the previous evidence by directly comparing two specific orthotic modifications (29).

Lin et al. (2025) investigated the biomechanical effects of different insole-material stiffnesses on the human foot using finite-element analysis. Their findings demonstrated that material stiffness influenced the mechanical response of the foot and altered plantar-pressure distribution under weight-bearing conditions. The study emphasized that orthotic effectiveness depends not only on the shape and position of an orthotic component but also on its material characteristics and structural stiffness. The findings are relevant to the current study because the metatarsal bar and metatarsal pad differ in their structural characteristics and mechanical interaction with the foot. Both interventions in the current study significantly reduced plantar pressure ($p < 0.001$), indicating that modification of foot mechanics can produce measurable biomechanical effects. However, the current study provides clinical evidence that goes beyond the finite-element approach used by Lin et al. While Lin et al. focused on mechanical modelling, the current study assessed actual patients with primary metatarsalgia and additionally evaluated pain and function (30).

Wang et al. (2025) examined the effects of custom-made insoles on foot mechanical responses during static standing and walking. Their results demonstrated that custom-made insoles altered plantar-pressure characteristics and mechanical responses during both static and dynamic weight-bearing conditions. The authors particularly emphasized the importance of assessing orthotic effects during walking because dynamic activity produces different mechanical demands compared with static standing. The findings are consistent with the current study because the metatarsal bar and metatarsal pad were used during participants' routine walking and daily activities, and both interventions produced significant reductions in plantar pressure ($p < 0.001$). The current study also demonstrated significant improvements in pain and foot function, indicating that biomechanical changes were accompanied by clinically relevant outcomes. In contrast to Wang et al., who evaluated custom-made insoles generally, the current study specifically compared two commonly used metatarsal modifications (31).

Ma et al. (2024) evaluated the effect of personalized orthopedic insoles on plantar-pressure distribution during running in individuals with subtle cavus foot. Their findings indicated that individualized orthopedic insoles effectively modified dynamic plantar-pressure distribution and altered excessive loading patterns associated with cavus foot morphology. The study suggested that personalized orthotic designs may redistribute mechanical loading according to individual foot characteristics and may be useful for managing excessive forefoot loading during dynamic activities. These findings support the current study because both investigations demonstrate that orthotic modifications can alter plantar loading. In the current study, plantar pressure significantly decreased following both metatarsal-bar and metatarsal-pad interventions ($p < 0.001$). However, the studies differ in population and intervention: Ma et al. studied individuals with subtle cavus foot during running, whereas the current study included patients with

clinically diagnosed primary metatarsalgia. Furthermore, the current study directly compared two interventions and found significantly greater plantar-pressure reduction with the metatarsal bar than the pad ($p = 0.001$). Thus, the current findings extend the evidence by linking plantar-pressure modification with improvements in pain and foot function (32).

Jiménez-Cano et al. (2022) investigated whether socks containing a U-shaped three-dimensional discharge element could reduce dynamic plantar pressure under the central forefoot. Thirty-eight participants were assessed under barefoot, control-sock, and experimental-sock conditions. Their findings showed that the experimental socks significantly reduced pressure beneath the second metatarsal head compared with barefoot and control conditions and also reduced pressure beneath the third metatarsal head. The authors concluded that the U-shaped discharge element could effectively reduce central forefoot loading and potentially decrease mechanical stress associated with forefoot disorders. These findings are consistent with the current study because both demonstrate that mechanical modification of the forefoot can reduce plantar pressure. In the current study, both the metatarsal bar and pad significantly reduced plantar pressure ($p < 0.001$). However, the current study differs because it evaluated patients with primary metatarsalgia and assessed pain and functional outcomes in addition to plantar pressure (35).

CONCLUSION

The study concluded that both metatarsal bar and metatarsal pad interventions were effective in reducing pain, improving foot function, and decreasing plantar pressure in patients with primary metatarsalgia. However, the metatarsal bar demonstrated greater overall improvement across all measured outcomes compared with the metatarsal pad. These findings indicate that both orthotic interventions can be useful conservative treatment options for managing primary metatarsalgia. Nevertheless, the metatarsal bar may provide superior mechanical offloading and

greater clinical benefits by redistributing plantar pressure more effectively. Therefore, based on the findings of this study, the metatarsal bar can be considered a more effective orthotic intervention for improving pain, functional ability, and plantar-pressure distribution in patients with primary metatarsalgia.

LIMITATIONS

- The effectiveness of a metatarsal pad can depend on its exact position relative to the metatarsal heads. Differences in placement may have influenced the response of individual participants.
- Participants may have differed in foot morphology, pain location, gait characteristics, and tolerance to the orthotic intervention. These factors can influence plantar-pressure redistribution and clinical response.
- The study measured plantar pressure but did not assess other biomechanical factors such as gait characteristics, center-of-pressure progression, or lower-limb mechanics, which could have provided a more comprehensive understanding of how the two interventions produced their effects.

RECOMMENDATIONS

- Clinicians may consider metatarsal bars as a preferred orthotic option for patients with primary metatarsalgia because they showed greater improvements in pain, foot function, and plantar-pressure distribution.
- Metatarsal bars and pads should be appropriately positioned according to the patient's foot morphology, pain location, and plantar-pressure pattern to optimize treatment effectiveness.
- Future studies should compare different designs, materials, and placements of metatarsal bars and pads while including additional biomechanical and functional outcomes to determine the most effective orthotic approach.

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