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Prospective evaluation of an action protocol for metatarsalgia due to failure of the first radius: results of conservative and surgical treatment

Evaluación prospectiva de un protocolo de actuación para la metatarsalgia por insuficiencia de primer radio: resultados de tratamiento conservador y quirúrgico

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Keywords:

Corticosteroids, metatarsalgia, risk factors, first ray insufficency, Weil osteotomy, protocol, insoles conservative treatment, surgical treatment, intralesional infiltrations.

Abstract

Introduction: Metatarsalgia for first ray insufficiency is one of the most common pathologies of the foot, whose treatment protocol is not well established. The objective of this prospective study is to assess a protocol of treatment, and to consider different factors that influence the pathology and treatment results.

Patients and method: Patients diagnosed with metatarsalgia for first ray insufficiency diagnosed through simple radiology and biomechanical study were prospectively assessed, evaluating plantar pressures and pain, function and alignment using the American Orthopedic Foot and Ankle Surgery (AOFAS) scale at the beginning and after each treatment; first applying the treatment with personalized plantar supports with metatarsal bar, at 3 months according to effectiveness, infiltration with corticosteroids, evaluating the patient at 6 months and, in case of failure of the previous two, the treatment was indicated using Weil's osteotomy. Follow-up of each patient to one year, observing that variables can influence the pathology.

Results: The final sample was of 56 patients, of whom 46 remained asymptomatic by plantar supports, 10 patients needed plantar supports and infiltration with corticosteroids, of which 4 ceased to have pain and 6 patients the previous treatments were ineffective, they underwent surgery.

Discussion: Three variables were significant associated with metatarsalgia before applying any treatment (Body Mass Index, associated pathologies, affected metatarsal-phalagic joint instability) and the 2 prevalent variables after applying the infiltration and surgery treatment were previous surgery and insufficiency of first iatrogenic ray.

Palabras clave:

Corticoides, metatarsalgia, factores de riesgo, insuficiencia del primer radio, osteotomía de Weil, protocolo, soportes plantares, tratamiento conservador, tratamiento quirúrgico, infiltraciones perilesionales.

Resumen

Introducción: La metatarsalgia por insuficiencia de primer radio es una de las patologías más frecuentes del pie, cuyo protocolo de tratamiento no está bien establecido. El objetivo de este estudio prospectivo es valorar un protocolo de actuación, y considerar diferentes factores etiológicos que influyen en la patología y los resultados del tratamiento.

Pacientes y método: Se valoraron pacientes diagnosticados de metatarsalgia por insuficiencia del primer radio, diagnosticados por radiología simple y estudio biomecánico, evaluando las presiones plantares y el dolor, función y alineación mediante la escala American Orthopedic Foot and Ankle Surgery (AOFAS) al inicio y después de cada tratamiento; aplicando el tratamiento con soportes plantares personalizados con barra metatarsal y extensión de Morton, a los 3 meses según la efectividad, infiltración con corticoides, evaluando al paciente a los 6 meses y, en caso de fracaso de los dos anteriores, se indicó el tratamiento quirúrgico utilizando la osteotomía de Weil. Seguimiento de cada a paciente a un año, observando qué variables pueden influir en la patología.

Resultados: La muestra final fue de 56 pacientes: 46 permanecieron asintomáticos mediante soportes plantares, 10 precisaron soportes plantares e infiltración con corticoides, de los cuales 4 dejaron de tener dolor y 6, al ser inefectivos los anteriores tratamientos, fueron sometidos a la cirugía.

Discusión: Tres variables fueron significativas asociadas a la metatarsalgia antes de aplicar cualquier tratamiento (índice de masa corporal, patologías asociadas, inestabilidad de la articulación metatarsofalángica afectada) y la variable prevalente después del tratamiento de infiltración y cirugía fue cirugía previa.

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INTRODUCTION

Middle ray metatarsalgia is defined as pain in the area of the central metatarsal heads. It is characterized by the presence of pain in the forefoot, mechanical overload, producing an overuse injury with the second, third and fourth metatarsals getting affected[1]. Metatarsalgia can have multiple etiologies, produced by an excess of mechanical overload in the central area of the metatarsus in the forefoot. The distribution of forces may vary with physical activity, age, footwear, retraction of the posterior musculature and morphology of the forefoot[2]. Biomechanical factors explain the 90 % of the causes of metatarsalgia. The causes of metatarsalgia are classified into 3 groups: primary, secondary and iatrogenic after forefoot surgery[3]. The development of forefoot surgery could also contribute to a higher incidence of metatarsalgia due to iatrogenic causes, especially hallux valgus surgery, as it may cause excessive shortening or elevation of the first metatarsal[4,5].

Surgery as a treatment for metatarsalgia is controversial, nowadays. There are many procedures that can be performed for metatarsal surgery, which will always be guided by symptoms, physical findings of the patient and radiological evaluation[6,7].

The present study focuses exclusively on primary metatarsalgia, caused by first ray insufficiency, which Viladot first described, as the syndrome of the first ray insufficiency[8,9]. This is characterized by a decrease in the amount of load that supports the head of the first metatarsal, which can cause an overload of the rest of the forefoot structures, usually the second and third metatarsals, in static and dynamic[10,11]. The etiology may be congenital, due to a first short metatarsal, due to weakness of the soft tissues in the metatarsocuneiform joint that do not fix the ray while walking, due to the suppression of the forefoot in the valgus flatfoot, or it may respond to an etiology iatrogenic due to excessive shortening of the first ray in the previous surgical treatment of Hallux Valgus[12].

Metatarsalgia treatment can be medical or conservative[11,13-28], or surgical[12-14,29–31]. The most indicated conservative treatment is the semi rigid orthotics with a retro-capital bar shaped discharge, to unload the affected metatarsal area and a sub capital piece of Morton to cause the loading of the first metatarsal[32]. Two other parameters are considered of importance since they can also contribute to the appearance of metatarsalgia: plantar arch adaptation of the patient and neutralization of the subtalar joint, to avoid flattening, valguisms and to compensate soft tissue weaknesses that may affect the forefoot[33,34]. Functional recovery, physiotherapy, massages, passive exercises, active exercises or anti-inflammatory drugs, serve as adjuvant treatments. However, these treatments are only useful in cases of painful exacerbations, or as a compulsory post-surgical rehabilitation[13]. Local infiltrations with corticosteroids is a good treatment, as long as it is associated with the use of plantar supports that discharge the metatarsal area previously, in cases where, despite the discharge, joint edema, tissue inflammation or other tissues may persist adjacent[11,19,35,36].

Surgical treatment is generally indicated for recalcitrant refractory metatarsalgias to conservative treatments[30,37], a consequence of long metatarsals with or without digital transverse plane deformities, crossed fingers and subluxations or dislocations of the phalangeal metatarsal joint. These are the indications of this procedure, although it has also been used to correct rheumatic deformities[30,37]. There are different techniques to shorten and correct the position in plantar flexion of the affected metatarsal, but currently the most used, due to its versatility and stability, is Weil's osteotomy, with its various modifications, described by the American podiatrist Lowell Weil. Weil osteotomy can be used in one or more metatarsals according to the complexity of the forefoot deformities and the total length pattern of adjacent metatarsals[29,38–40].

Although there are many studies related to metatarsalgia, the value of the different variables associated with the pathology and the prognostic factors to determine the failure or success of the treatments and the order of action is not clearly defined. The present study intends to evaluate a treatment protocol that aims to study the effectiveness of an action against metatarsal pathology due to first ray insufficiency, taking into account different risk factors that can influence metatarsalgia caused by first ray insufficiency, before and after each treatment.

PATIENTS AND METHODS

Study population

A 24-month prospective study was conducted with patients diagnosed with central metatarsal pathology due to first ray insufficiency, collected at the Institut Mèdic del Peu and the Ponent Clinic in Lleida (Catalonia, Spain). Data collection was carried out between September 2016 and September 2017. All patients were followed up for a year, ending the data collection in September 2018.

The inclusion criteria were patients of legal age who suffered from central metatarsalgia symptoms caused by first ray insufficiency. The diagnosis of central metatarsalgia for first ray insufficiency was determined by: functional insufficiency and deficit support in the baropodometric study; sedestation posture examination to examine musculoskeletal abnormalities, such as soft tissue weakness or hyper mobility of the joints of the first ray (cuneal metatarsus and phalangeal metatarsal); and simple AP x ray in charge, with the purpose of confirming and identifying the shortening of the first ray regarding to the second and the rest of the metatarsals that caused little load on the first metatarsal through loading situations.

Those patients with metatarsalgia caused by other causes were excluded: length of the second or third metatarsals, congenital deformities of the metatarsal heads, shortening of the gastrocnemius muscles or the sural triceps, an equine foot, a

cavus foot, as well as abnormalities of the hindfoot that may affect the forefoot position. Minor patients, allergic to corticosteroids or patients with rheumatoid arthritis, gout or psoriasis, neurological disorders such as Charcot-Marie-Tooth, Freiberg disease, diabetics with poor metabolic control or all those who voluntarily decided to refuse to enter the study were also excluded. The study went through the ethics committee of the Faculty of Medicine of the University of Lleida, with CEIm number CEIC-2156, of the University Hospital Arnau de Vilanova of Lleida.

Variable Measurement

The following measurements were made:

a. Biomechanical study of gait using baropodometric pressure platform to observe the plantar pressures in order to identify the coincidence of the painful area in the central metatarsals with the one with more pressure in static and dynamic, and the functional insufficiency of support of the first metatarsal.
b. Physical examination of the patient in sitting, static and dynamic: The type of foot was examined by the Foot Posture Index (FPI) to achieve an easy quantification of the static posture of the foot. The Lunge test was also performed to measure the dorsal flexion of the foot under load conditions. A sitting posture examination was performed to examine musculoskeletal abnormalities such as soft tissue weakness, that is, ligamentous hyperlaxity or hyper mobility of the joints of the first ray, which produce a hypermobility of the metatarsocuneiform or cuneonavicular joint in the medial spine causing first metatarsal receives less charge. The Silverfskiold test was also performed to assess the shortening of gastrocnemius and the Lachman test in the minor metatarsophalangeal joints to measure the instability of these joints. A dermatological and deformity examination was performed to detect associated pathologies such as hallux valgus, hallux rigidus or plantar calluses.
c. In a complementary way, a radiological study of the foot was performed with a simple AP x ray in charge to confirm and identify the first short ray with respect to the second or the rest of the central metatarsals, taking into account the metatarsal parabola. That is, the first ray insufficiency that was suspected by the exploration in the biomechanical study and the length of the first ray with respect to the second was identified visually by the principal examiner of the study without using any concrete measurement. In the case of all patients, the angles of the hallux valgus and intermetatarsal were measured, determining if they were greater than 9 and 15 degrees which are their normal values; defining the HV angle as the angle created by the axis length of the proximal phalanx of the Hallux and that of the first metatarsal and the IM angle , which was defined as the angle created by the length of the axis of the first and second metatarsals.
d. The AOFAS scale to assess pain, function (activity, maximum walking distance, walking surface, abnormality of the passage, sagittal mobility, mobility of the hindfoot and stability of the ankle) and alignment, was used to measure the results of the Study and the treatments used.

Interventions performed and study protocol

After evaluating the patient and determining all the etiological factors, the treatment started using customized orthotics with metatarsal discharge, reassessing patients after a month, after 3 months, after 6 months and after a year, and considering the effectiveness of the treatment depending on the value of the AOFAS score, also repeating it after 1, 3, 6 and 12 months.

If, after 3 months of treatment with plantar supports, the patient continued with the symptomatology, that is, if the AOFAS scale score was the same or lower, the infiltration with corticosteroids was recommended by the physician, and according to the subjective decision of the patient, we proceeded to perform it, with review of the patients after 3 months. If given this time, this symptomatology persisted; surgery was carried out using simple Weil osteotomy.

Treatment with plantar supports

According to the previous diagnostic criteria, the patients were treated with customized orthotics with metatarsal bar shaped discharge and Morton´s extension in the first metatarsal, in order to provide an equitable distribution of the loads in the metatarsal area and unload the conflict zone in the affected central metatarsals, since there are studies that have shown that these sub capital parts, such as the Morton´s extension, work properly[41]. Two other parameters that may also contribute to the appearance of metatarsalgia are considered: the custom adaptation of the patient's plantar arch and the neutralization of the subtalar joint.

Orthopedic materials were used for the elaboration of the orthotics: the 1'2 mm resin base, covered with a micro perforated foam lining between 1.5-3 mm. Two essential elements were also used for load compensation and symptom relief: the metatarsal bar and the Morton´s extension. The retro capital metatarsal bar was complete with 5-6 mm of roval foam to unload the heads of the metatarsals and to extend the fingers from the inner edge to the forefoot. The anterior retro capital border to the 5 metatarsals, ended in the first metatarsal behind the sesamoids and the posterior border in front of the base of the 5 metatarsals. Morton's extension was EVA between 3-4 mm and 40 shore A density of the first ray to establish a normal magnitude of the reactive force of the soil on the first metatarsal head, the first metatarsal assuming its normal load, and avoiding the transfer of excessive loads to the second metatarsal.

A previous mold was taken with phenolic foam in semi-load, drawing the preferred elements and the thicknesses, mate-

rials were specified and sent to the workshop Aixalá Sabater Artesá SL, Lleida, Spain, for its preparation and adaptation to the patient.

All prescriptions of the plantar supports and discharge materials, as well as mold making works, were made by the same researcher who is the principal investigator of the study (B.C.D.).

Infiltration treatment: corticosteroids

Patients who did not respond to treatment with orthotics because the AOFAS value was low and continued reporting pain and symptoms persisted after three months, received a corticosteroid infiltration with Celestone Cronodose® (Betamethasone, sodium phosphate / betamethasone, acetate , Merck Sharp & Dohme, from Spain, SA). Injections with 2 ml corticosteroids were injected mixed with anesthetic (2 ml Mepivacaína 2 %). A single peri articular infiltration was performed, due to the side effects that it could cause following the recommendations of the laboratory that produces it[42]. Patients also signed a specific informed consent. All infiltrations were performed by the same researcher who is the principal investigator of the study (B.C.D.).

Surgical treatment

If after 6 months conservative treatments (orthotics and infiltration) were inefficient, since the value of AOFAS was low and the patient continued to report pain, and the symptoms persisted, the patients were surgically operated by Weil osteotomy for central metatarsals by open surgery and osteosynthesis. Following the usual protocol of ambulatory surgery, patients signed an official informed consent and received the antibiotic prophylaxis, Cefazolin 2 grams, IV. All patients were visited by an anesthesiologist to determine the technique of anesthesia, sedation and popliteal or ankle block, and complementary tests were requested: basic analytical with vitamin D, thorax plaque and ECG. Ischemia tourniquet was used above the ankle at 250 mm hg, with pre-swept hemostasis. The surgical intervention was planned according to the study of the radiography and the pre surgical physical assessment of the patient by measuring the HV and IM angles if there was HAV associated and revising again the shortening of the first metatarsal with respect to the second metatarsal and the rest of the parabola to assess whether it was convenient to make corrections of the rest of the metatarsals. Sometimes Weil osteotomies of several metatarsals were performed, in cases of HAV associated surgical technique was also performed, as well as realignment of the fingers through inter phalangeal arthrodesis and tendon lengthening or tenotomy.

Weil osteotomy was performed with the purpose of shortening as planned and decompressing the relevant metatarsals, on the distal end of one of the central metatarsals[29,43]. A postoperative bandage was performed on the patient without allowing prolonged deambulation for 7 days and after with a Walker boot for 3 more weeks. All surgical interventions were performed by the same researcher, who is the principal investigator of the study (B.C.D.).

Analysis of data

The follow-up time was one year for all patients since they entered the study and the diagnostic tests and the first treatment with orthotics were performed, reviewing them at the 1st, 3rd, 6th and 12th month. The patients we infiltrated after 3 months were followed until the end of the study one year, that is, 9 months more, with revisions at 15 days after the infiltration and after 3 and 6 months following the infiltration. In the case of patients who underwent surgery after 6 months, the follow-up was 6 months, until the end of the study. Although they were reviewed weekly for 2 months and monthly until 6 months after surgery.

The dependent variables were obtained from the physical, demographic, radiological and pathological data of the patients, including the explanatory variables of treatment with plantar supports, infiltrations and surgery.

Variables: sex, age, body mass index (divided into two categories: normal or overweight), physical activity (work of more than 5 hours, sports physical activity, both or none) and associated pathologies were analyzed.

Patient examination provided physical data and foot variables that directly influence metatarsalgia: The morphology variables of the foot were analyzed (according to the FPI (Foot Posture Index) in A "FPI from -12 to -6, B" FPI from -5 to +5 and C "FPI from +6 to +12), previous surgical procedures of the foot and ankle (if the patient had been previously operated or not), IM angle (A" IM angle <9 "and B "IM angle> = 9"), and hallux valgus angle (A "HV angle <15" and B "HV angle> = 15"), gastrocnemius retraction according to Lunge Test to measure dorsal foot flexion under load conditions and Silverfkiold test, regarding posterior musculature and joint limitation (YES "has retraction" and NO "does not have retraction".), instability of the affected metatarsophalangeal joint (according to the Lachman test to measure instability of the metatarsophalangeal joint pain zone related to plantar flexor plate (normal or instability.), Hallux Valgus (presence or absence of HAV), use of heels (heels "or" not heels), type of first ray insufficiency (according to the 4 types of First ray insufficiency described in the literature: congenital, iatrogenic, soft tissues, flat feet).

The independent variable AOFAS scale to assess pain, function (activity, maximum walking distance, walking surface, abnormality of the passage, sagittal mobility, mobility of the hindfoot and stability of the ankle) and alignment, was used to measure the results of the study and the treatments used.

The Wilcoxon signed rank test was used to compare the results of patients who improved, due to treatments, with those who did not improve according to AOFAS values.

Differences of the AOFAS scale were compared between the first visit and visits at 3, 6 and 12 months (See table 2). Significant results were considered from a p value less than or equal to 0.05.

The 't-test' was applied to contrast the incidence of the variables in pain, function and alignment (AOFAS) of the patients before being treated and after applying each treatment. To evaluate the effect of these variables and their influence on the treatment, an analysis was used using the "proportions test" to identify the factors that were potentially associated.

Tests were applied to compare each variable with the treatment. After 3 months comparing patients who have improved pain with plantar supports with those who have not and who were consequently treated with infiltration. After 6 months, tests were done again, this time to compare patients who improved pain either with plantar supports or with infiltration with those who did not heal and underwent surgery. Thus, the variables that are significant at both 3 and 6 months are the ones that have the greatest influence on the treatment.

All statistical analyzes have been performed using the R [R, Developmental, Core, Team package. A: A Language and Environment for Statistical Computing 2017; available at: http://www.R-project.org)[44].

Table I. Demographic data and variables collected from the study sample.

	MEN			WOMEN		
	Average	Desviation	IC (95%)	Average	Desviation	IC (95%)
Age	47.1	14.4	39.1 – 55.1	53.9	10.7	50.5 – 57.3
BMI	27.0	5.1	24.2 -29.8	25.0	4.0	23.8 – 26.3
FPI	-1.5	4.4	-3.9 - 1.0	-0.2	4.1	-1.5 - 1.0
IM Angle	9.2	1.2	8.6 – 9.9	9.4	1.2	9.1 – 9.8
HV Angle	13.9	2.4	12.6 – 15.2	14.3	2.4	13.6 – 15.1

Table II. Demographic data and variables collected from the study sample.

		Men		Women	
		Pacients	% Pacients	Pacients	% Pacients
Activity	A	3	5,36	4	7,14
	AB	4	7,14	17	30,36
	B	6	10,71	17	30,36
	C	2	3,57	4	5,36
Alterations	NO	8	14,29	18	32,14
	Yes-A	2	3,57	7	12,50
	Yes-B	1	1,79	1	1,79
	Yes-C	4	7,14	15	26,79
Previous IQ	No	13	23,21	31	55,36
	Yes	2	3,57	10	17,86
Stability joint	Unstable	2	3,57	8	14,29
	Stable	13	23,21	33	58,93
Retraction	No	9	16,07	27	48,21
	Yes	6	10,71	14	25,00
Shoe	No heel	15	26,79	26	46,43
	Heel	0	0,00	15	26,79
1ʳ. Ray in.	Congenital	15	26,79	27	48,21
	Iatrogenic	0	0,00	8	14,29
	Soft tissues	0	0,00	3	5,36
	Flat feet	0	0,00	3	5,36
HAV	No	10	17,86	22	39,29
	Yes	5	8,93	19	33,93
HR	No	14	25,00	41	73,21
	Yes	1	1,79	0	0,00

Table III. Results of the comparison of the difference in the AOFAS value of the 56 patients between the first visit and the visits at 3, 6 and 12 months.

Visits	Pre		Post		Difference			
Pre – Post	Average	Desviation	Average	Desviation	Average	Desviation	IC 95%	P-value
1 – 3	53,5	16,8	78,3	14,5	24,8	12,0	20,5 – 28,0	<0.001
1 – 6	53,5	16,8	84,7	15,3	31,3	14,9	27,5 – 35,5	<0.001
1 – 12	53,5	16,8	89,0	13,8	35,5	17,6	31,5 – 40,5	<0.001

RESULTS

A total of 56 patients diagnosed with metatarsalgia due to first ray insufficiency that met the inclusion criteria were included in the study and analyzed. 41 patients (73'2 %) were women and 15 patients (26'7 %) were men. The average age of the group was 51'25 years; in the case of women, the average age was 55 (between 35-81) and in the case of the group of men it was 47.5 (26-75). Tables I and II collect the demographic data and the variables collected in the study sample.

From the 56 initial patients in the study, after 3 months, 46 (82.14 %) patients had improved and obtained a higher score on the AOFAS scale with customized orthotics with metatarsal bar. The 10 (18'85 %) patients who did not improve with orthotics were periarticularly infiltrated with corticosteroids.

After 6 months from the 56 patients, 46 had improved with orthotics, 4 (7.14 %) with infiltration, and 6 (10.71 %) patients where the infiltration did not work nor previously the orthotics, were surgically intervened by Weil osteotomy.

Table 3 shows the results of the comparison of patients who improved and those who did not improve according to the values of AOFAS in the first visit, with the values of AOFAS in visits at 3, 6 and 12 months subtracting the difference and giving a p-value that in all cases was significant. 3 treatments showed to improve the AOFAS score. The difference between each visit is bigger and therefore treatments improve the symptoms in the longer term.

Statistical analysis[45] showed the presence of significant statistically associations between the analyzed variables and the presence of metatarsalgia due to first ray insufficiency before beginning the study. The presence of BMI greater than 25, the presence of associated systemic pathologies and the presence of metatarsophalangeal instability were the only variables associated with the presence of metatarsalgia in the pre treatment period.

Table 4 shows the comparative analysis of the variables that showed significant association with the presence of no improvement at 3 months (after treatment with orthotics) and at 6 months (after treatment with orthotics and infiltration).

The presence of previous surgery on the foot and ankle was the only variable that was associated with the absence of improvement and, therefore, prevalence of metatarsalgia at 3 months and at 6 months.

Table 5 shows the logistic regression model that identified a single predictive variable of no improvement after treatment with plantar supports at 3 months and after treatment with orthotics and infiltrations at 6 months.

DISCUSSION

In this work, once diagnosed by biomechanical study and simple x-rays, three treatments were applied in chronological order from conservative to surgical: customized orthotics with metatarsal bar, infiltration with corticosteroids at 3 months if the patients did not improve and finally with Weil osteotomy surgery if, at 6 months of study, none of the previous treatments worked. Measuring its improvement with the AOFAS score by assessing pain, function and alignment at each visit before and after each treatment. Likewise, different etiological factors that could be associated and therefore influence the appearance of metatarsalgia due to first ray insufficiency and the result of the treatments have been evaluated and considered, being able to be predictive.

The concept of the syndrome of the first ray insufficiency was introduced by Viladot A in 1996 in Barcelona, describing it as the decrease in the load that the head of the first metatarsal carried, causing an overload of the rest of the metatarsals. In recent decades, knowledge about the mechanics of the forefoot and the methods of diagnosis and treatment have been advanced, in the concept of supportive and propulsion metatarsalgia, of transfer metatarsalgia, of its congenital etiology, iatrogenic, soft tissue weakness and flatfoot. More solid foundations have been established in terms of forefoot anatomy, metatarsal formula, its conservative or surgical treatments and its different etiological factors and associated variables.

The results obtained in the present study demonstrate that the treatment protocol applied is effective from the point of view of improving the AOFAS score after 3, 6 and 12 months, due to the reduction in the value of this. It showed a decrease in pain, improved function and alignment. The value of AOFAS focuses more on pain compared to other scales such as SF36[46].

Besse et al.[3], performed a work determining differents etiologies of metatarsalgia, including metatarsalgia due to first ray insufficiency. The study provides very useful data since they

Table IV .Compare the percentage of patients who improve with orthotics at 3 months and those who do not improve and metatarsalgia prevails, and at 6 months patients who improve with plantar supports and infiltration with those who do not.

	Visit 3 month			Visit 6 month		
	Prevalence Metatarsalgia			Prevalence Metatarsalgia		
	n	%	P-value	n	%	P-value
Sex						
W (41)	7	17,1	1,000	5	12,2	0,917
M (15)	2	13,3		1	6,7	
BMI						
A (27)	5	18,5	0,907	5	18,5	0,165
B (29)	4	13,8		1	3,4	
Activity						
A (7)	2	28,6	0,408	2	28,6	0,231
AB (21)	2	9,5		1	4,8	
B (23)	5	21,7		3	13,0	
Alterations						
No (26)	4	15,4	0,597	3	11,5	1,000
SIC (19)	5	26,3		3	15,8	
Foot type						
A (10)	2	20,0	1,000	2	20,0	0,509
B (43)	7	16,3		4	9,3	
Previous surgery						
No (44)	4	9,1	0,023	2	4,5	0,020
YES (12)	5	41,7		4	33,3	
IM Angle						
<9 (32)	4	12,5	0,636	2	6,2	0,418
>9 (24)	5	20,8		4	16,7	
HV Angle						
<15 (32)	4	12,5	0,636	2	6,2	0,418
>15 (24)	5	20,8		4	16,7	
BiHAV						
NO (32)	4	12,5	0,636	2	6,2	0,418
YES (24)	5	20,8		4	16,7	
Retraction						
No (36)	6	16,7	1,000	4	11,1	1,000
Yes (20)	3	15,0		2	10,0	
Joint instability						
Unstable (10)	3	30,0	0,396	2	20,0	0,629
Stable (46)	6	13,0		4	8,7	
Shoe heel						
No (41)	6	14,6	0,942	5	12,2	0,917
Yes (15)	3	20,0		1	6,7	
Insuf-1r						
Congenital (42)	6	14,3	0,287	3	7,1	0,034
Iatrogenic (8)	3	37,5		3	37,5	

Abbreviations: BMI, body mass index; Hav, hallux valgus angle; IM, intermetatarsal angle.

Table V. Logistic regression model of predictive variables of no improvement in patients with metatarsalgia due to first ray insufficiency.

	Visit 3 months			Visit 6 months		
	Odds Ratio	95% Inter. Confidence	P-value	Odds Ratio	95% Inter. Confidence	P-value
Previous surgery	0,14	0,03 – 0,6	0,012	0,095	0,01 – 0,57	0,013

mention the diagnostic methods and all conservatives treatments talking about plantar supports and surgical. Emphasis is placed on the reliability of Weil's osteotomy compared to DMMO and considering the resection of gastrocnemius or plantar plate repair in an associated manner. Although these authors do not consider the order of treatment and they did not do a prospective study, we agree on the treatments performed in this study except the corticosteroid infiltration, and the importance of weighing the associated biomechanical factors.

This prospective and observational study is just focused on the etiology of metatarsalgia due to first ray insufficiency, and the three treatments that have been considered most valid from conservative to surgical are applied and the AOFAS score is monitored in the different visits. Orthotics with metatarsal discharge and Morton's extension is considered to be the most effective conservative treatment[41], finding in the literature different studies that support it. Postema et al.[17] analyzes the influence of custom orthotics in terms of plantar pressures, obtaining that they produce a decrease in pressure peak and impulse force. Holmes and Timmerman[14] reach the same conclusion, analyzing the effect of discharges on baropodometric plantar pressures. Williams[15] considering, like Burns et al.[16] in the caved feet, the orthotics can correct the biomechanics of metatarsalgia, obtaining that patients with customized orthotics with metatarsal discharge improve the plantar pressures more than the standard supports.

Different studies have shown the greater efficacy of custom plantar orthotics to reduce plantar pressures and clinical symptoms on placebo or standard orthotics or other types of treatment[26,27],. Other studies show that Morton's extension works better than retro capital parts in reducing plantar pressures while walking[41]. These authors give value to the importance of the use of plantar supports in metatarsalgia caused by first ray insufficiency, as it´s shown in our study. Results show that in the beginning there is a significant clinical improvement with respect to the reduction of the symptoms of the pathology in 46 patients who improved with orthotics.

Regarding to corticosteroid infiltrations, several authors[18,19] consider them a valid treatment in inflamed soft tissues after an overload, as well as static metatarsalgia in the instability of metatarsophalangeal joints, especially in cases of intense local inflammatory reactions. Results in this study, using corticosteroid infiltrations in a complementary way if orthotics was not therapeutic success, were also significant. Results show that, from the 10 patients who infiltrated at 3 months, 4 of them improved their symptoms regarding the reduction of the value of the AOFAS score. Thus, we consider it as a valid treatment associated with plantar supports when after using these, edema and soft tissue inflammation remain.

Surgical treatment is more frequent in the literature, despite its controversies and comparisons between techniques, generally indicated for recalcitrant metatarsalgia refractory to conservative treatments. Currently, Weil's osteotomy is the most commonly used for its stability and simplicity in metatarsalgia due to first metatatarsal insufficiency.

Barouk[5], in his study on the recurrence of metatarsalgia, points out that in the recurrence of middle ray metatarsalgia, hallux valgus surgery can be a problem for two reasons: for the position of the first metatarsal after an inappropriate correction, or for not recognizing a shortening of gastrocnemius prior to surgery. The author recommends that the best treatment is to restore the normality of the anatomy and that surgery on the affected ray may be the solution. It basically focuses on the fact that the recurrence of metatarsalgia has a multifactorial origin and can be considered as an iatrogenic or a failure of a previous surgery. As we significantly observed in our study, where we found as the only variable associated with the recurrence of metatarsalgia due to first ray insufficiency, the patients who underwent surgery prior to 3 months of treatment. It was also significant at 6 months together with first ray insufficiency due to iatrogenic with respect to patients who had congenital or flat foot insufficiency, meaning that they were associated with the recurrence of metatarsalgia and therefore the patients had to undergo surgery.

This has also been reflected in the result of this study, since 6 of the 56 patients, at 6 months, did not improve with either plantar supports or infiltration. They underwent surgically, observing in the review at 12 months a significant improvement in the value of AOFAS between patients at the beginning and at the end of the study.

Regarding the etiological factors, before treating the patients and the variables associated with metatarsalgia due to first ray insufficiency that could influence the therapeutic outcome of the different treatments, it was found that three

variables were significant: the presence of major BMI of 25, the presence of associated systemic pathologies and the presence of metatarsophalangeal instability (see table 2).

In this study the influence of BMI has been a significant variable in patients before being treated. It has been obtained that overweight or obese patients have lower AOFAS value and consequently a high BMI affects metatarsalgia due to first ray insufficiency. This is also contrasted in other studies consulted such as Butterworth, et al.[47] and Dufour et al.[48] which highlight the evidence of a strong association between elevated BMI and foot pain. Hsu, Chih Chin et al.[49] compare type 2 diabetic patients with healthy patients, determining that the plantar tissues below the metatarsal heads are usually altered while receiving load.

The instability of the affected phalangeal metatarsal joint was also a significant associated factor compared to those that were stable before applying the treatments, since we found that patients with metatarsophalangeal instability had a lower AOFAS score. Other prospective studies, such as Nery et al.[50], deal in a very specific manner, similar to this study, with the evaluation of a protocol for the surgical treatment of central ray metatarsophalangeal joint injuries and lesions of the plantar plate. Their findings, as in the present study, demonstrate that instability of the minor phalangeal metatarsal joints is a common cause of pain and deformity. The results of the study by Nery et al.[50] present that patients with less or no alteration of the plantar plate, looking at the instability of the respective joint, had less pain with a higher AOFAS score.

The only significant variable of the study at 3 months was that patients had previously undergone surgery on the foot or ankle. Patients who had improved with orthotics were compared with those who had not improved and it was observed that a previous surgery influences the effectiveness of the treatment. Specifically, it is a factor associated with the fact that plantar supports do not work, repeating itself as a significant variable also in the 6 month visits.

This finding agrees with Maceira and Monteagudo´s[51] and with Barouk´s[5] findings, which indicate that in the management of metatarsalgia transfer after hallux valgus surgery, a deep understanding of anatomical disorders is important to plan the right treatment. A detailed history and a clinical examination along with imaging studies will determine what went wrong and why.

As a limitation of the study, it must be indicated that a low number of patients were available. The total number of patients was 56 and the number of patients on each treatment, as a result, was low. There were 46 patients treated with orthotics where we can obtain and compare more data, but only 10 patients were infiltrated and only 6 patients underwent surgery. The fact of having a low number of patients influences the significance of the variables throughout the study. Another limitation attributable to the present study was to have just one follow-up in patients within a year from the beginning of the first treatment and, therefore, only 6 months in patients who have undergone surgery. It is interpreted that studying and observing patients longer could change the results and give us more data. Finally, although a considerable number of variables have been studied, it is believed that by investigating other variables not studied, more significance could be achieved and we could have the answer the question of why treatments work or do not.

In conclusion, the present study shows that it is necessary to perform the treatments sequentially from conservative to surgical and in chronological order. Most cases of metatarsalgia due to first ray insufficiency are resolved with conservative treatment, by personalized plantar supports with metatarsal bars. Infiltration is effective in 40 % of cases where treatment with orthotics has failed, being surgery the only corrective route in case of failure of the two previous treatments. After applying the treatments, at 3 and 6 months, it is extremely important to consider whether the patients have previously been operated on the foot and ankle. The prevalence of metatarsalgia in patients with first ray insufficiency may depend on this variable when treatment with orthotics is not effective and therefore it is necessary to infiltrate them. In the same way, in patients who will be intervened with Weil's osteotomy because previous conservative treatments have not worked. To treat the pathology of central metatarsalgia due to first ray insufficiency, physicians are advised to focus on the three treatments: plantar supports, infiltration or surgery with Weil osteotomy in chronological order and from conservative to surgical. Likewise, it is advisable to examine taking into account the significant variables before treating patients, and after each treatment.

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