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REVIEW ARTICLE

Hallux rigidus: aetiology, diagnosis, classification and treatment

J. Asunción Márquez [a,*] **and X. Martín Oliva** [b]

[a] *Foot and Ankle Unit, Hospital Clínic, Universidad de Barcelona, Spain*
[b] *Foot and Ankle Unit, Clínica del Remei, Barcelona, Spain*

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KEYWORDS
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Abstract
Hallux rigidus is a degenerative and progressive disease of the metatarsal phalangeal joint of the hallux, with its main symptoms being pain and loss of joint movement. Different aetiological mechanisms are involved in its development, and clinical anamnesis and radiological examinations are essential for an accurate diagnosis and to be able to establish the correct stage of progression, with the aim of giving suitable treatment in each case. Surgical treatment is indicated in most cases and is necessary to know all the surgical techniques to make the right treatment for each patient.

PALABRAS CLAVE
Pie;
Hallux rígidus;
Metatarsiano;
Antepié

Hallux rígidus: etiología, diagnóstico, clasificación y tratamiento

Resumen
El hallux rígidus es una patología degenerativa y progresiva de la articulación metatarsofalángica del hallux, cuyo principal síntoma es el dolor y la pérdida de la movilidad articular. Existen distintos mecanismos etiológicos que se han involucrado en su desarrollo y la anamnesis clínica y los exámenes radiológicos son indispensables para llegar a su preciso diagnóstico y poder concretar el correcto estadio evolutivo, con la finalidad de efectuar un adecuado tratamiento en cada caso.
El tratamiento quirúrgico está indicado en la mayoría de casos y es indispensable tener un amplio conocimiento de las diversas técnicas quirúrgicas para realizar el tratamiento correcto a cada paciente.

* Corresponding author.
E-mail address: asuncion@clinic.ub.es (J. Asunción Márquez).

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Introduction

Hallux rigidus is the second most common cause of pain in the first metatarsophalangeal (MTP) joint after hallux valgus. It is an arthritic and progressive degeneration of the joint which causes pain, decreased mobility and the appearance of osteophytes. In 1887, Davies-Colley[1] described it as a flexed plantar position of the proximal phalanx of the hallux relative to the metatarsal head, calling it "hallux flexus" and, a few months later, Cotterill[2] gave it the name "hallux rigidus", since it presented a painful limitation of mobility of the first MTP joint. Over time it has been given other names such as "hallux limitus", "dorsal bunion", "hallux dolorosus" and "hallux malleus". Currently, the decrease in joint dorsiflexion is known as "hallux limitus" and the loss of mobility as "hallux rigidus".

It is suspected to stem from an affectation during adolescence by a primary deformity, and in adults from a secondary degenerative arthritis. Although no evidence has been found to confirm a difference based on age[3] it is true that women present a higher incidence.[3,4]

There may be cases of unilateral presentation, especially when correlated with a previous trauma, but most patients present bilateral involvement. Coughlin and Shurnas[3] indicate that, when patients with hallux rigidus are monitored over a prolonged period of time, over 80% develop bilateral symptoms. In addition, about 95%of cases with a family history of hallux pathology present bilateral hallux rigidus and 80%of patients with hallux rigidus have a positive family history.

Although the exact cause of hallux rigidus has not yet been established,[5-7] several aetiologies have been proposed and many predisposing factors have been described. The most frequent cause is a trauma[3] which causes articular cartilage damage and destroys the joint. In many circumstances it is not possible to detect an injury but microtrauma cannot be ruled out. This would be caused by repeated hyperextension or hyperflexion mechanisms which would cause strong joint compression forces. Inflammatory diseases such as rheumatoid arthritis and seronegative arthritis, as well as metabolic diseases, especially gouty arthritis, can cause a joint involvement which develops secondary hallux rigidus. Infectious arthritis of the first MTP can cause ankylosis by osteochondral destruction of the joint.

Osteochondritis dissecans has also been mentioned as a cause of hallux rígidus.[8] This occurs on the convex surface of the MTP joint by the convergence of impaction forces and causes joint damage in the first metatarsal head.

Different structural or biomechanical factors may predispose towards the development of hallux rigidus; the incongruity of joint surfaces with a congenitally flat, square or chevron-shaped morphology of the first metatarsal head, may produce stiffness of the first MTP,[6,9] although it is also thought that this inconsistency may be the result of biomechanical alterations which lead to a chevron shape due to repetitive articular erosions caused by the retraction of the plantar fascia medial band.[10] A longer first metatarsal may increase pressure on the MTP joint,[4,11-13] although a short first metatarsal has also been linked with hallux rígidus.[9] A longer first toe, in an Egyptian foot, may overload the first segment and lead to the development of a hallux limitus.[11] Interphalangeal hallux valgus has also been associated with hallux rigidus[3] although it may not be a causative factor, but rather a consequence of excessive rigidity of the middle column of the foot which develops both joints affectations simultaneously.

One of the most controversial has been metatarsus primus elevatus, an excessive elevation of the first metatarsal with respect to the minor metatarsals, resulting in excessive plantar flexion of the phalanx and causing stiffness in flexion of the first MTP joint or hallux flexus.[14] With respect to terminology, metatarsus primus elevatus is considered as a different pathology from hallux rigidus and the elevation of the first metatarsal in hallux rigidus as a secondary phenomenon, caused by the functional impairment and restricted mobility of the first MTP joint,[3] given that, after performing an MTP arthrodesis, the elevation of the first metatarsal is corrected spontaneously. Meyer et al[15] reported that this metatarsal elevation in hallux rigidus was caused by an increase in the diameter of the metatarsal head, a retraction of the plantar soft tissues and the sesamoid bones, finding that a metatarsal elevation greater than 5mm occurred in 2/3 of normal feet and that, therefore, it was not a pathological entity, nor was it correlated with joint involvement.

Plantar soft tissues have also been involved in the causal mechanism of hallux rigidus. Durrant and Slepert[16] referred that the retraction of the intrinsic muscles affected dorsal flexion in hallux. Harton et al,[17] in cadavers, have shown that excessive tension of the plantar fascia causes a mobility limitation of the first MTP, developing a functional hallux limitus which progresses to hallux rigidus, and that its section causes an increase of about 10° in dorsiflexion. Kiran et al[18] demonstrated that a progressive fibrosis of the flexor hallucis longus tendon (FHL) at its myotendinous junction increased the stress on the first MTP joint and caused hallux rigidus, since it limited the normal movement of the phalanx on the metatarsal head, increasing the compression forces on the dorsal side of the joint during dorsiflexion. Flavin et al[10] postulated that a 30%increase in the tension of the medial band of the plantar fascia causes an increase in the abnormal tensions of the MTP joint, which focus on the dorsal side of the metatarsal head, and an increase in the tension of the plantar fascia. In hallux rigidus, FHL tension and flexor hallucis brevis (FHB) increase and reduce hallux dorsiflexion.

In our experience, we have observed that a simple release of the glenoid base plate from the proximal phalanx produces, by itself, a re-centering of the phalanx on the metatarsal head and an increase in dorsiflexion of the first MTP.

Iatrogenic causes can also originate secondary hallux rigidus.[13] Any surgery on the first MTP which destroys the joint may result in the development of a secondary arthropathy of this joint, as occurs, for example, in resection arthroplasty in hallux valgus surgery and in surgical cases of the first metatarsal where the patient does not follow appropriate rehabilitation and joint stiffness is originated which overloads the first segment.

Biomechanics and Physiopathology

The normal range of motion of the first MTP joint is 110°, with a plantar flexion of 35° and dorsiflexion of 75°.[19] The consistency and three-dimensional geometry of the articular surfaces establish the inherent stability of the centre of rotation of this joint which, in addition, is stabilized by static structures, that is, the articular capsule, the plantar fascia and the lateral ligaments, and dynamic structures, formed by the extensor hallucis longus tendon (EHL), FHL, FHB, hallucis abductor and hallucis adductor.[10] In hallux rigidus the total range of motion decreases, with a relatively normal plantar flexion and decreased dorsiflexion, caused by both dorsal osteophytes and retraction of the plantar soft tissues.

In a normal foot, the centres of rotation are constant throughout the range of motion and are located on the metatarsal head, whereas in hallux rigidus they are located outside or eccentrically to the metatarsal head.[10,19] This can cause the appearance of dorsal exostosis, joint degeneration and retraction of the juxta-articular soft tissues which increasingly limit joint mobility.

In hallux rigidus there is also involvement of the sesamoid bones, due to a retraction of the plantar structures, with a displacement of the centres of rotation which causes compression of the articular surfaces throughout the range of motion and causes a decrease in mobility.[10] This causes a sesamoid hypertrophy by bone proliferation, due to an excessive continuous traction with extension in the sagittal plane.[20] There is also an inverse relationship between the length of the sesamoids and hallux dorsiflexion. It is also possible to find a proximal displacement of the sesamoids, due to a retraction of the FHB which is inserted in them, and they are relocated in a more proximal position with respect to the metatarsal head,[7] restricting dorsal mobility of the first MTP.

In short, hallux rigidus is caused by an imbalance of the soft tissues which alter the normal biomechanics of the first MTP joint. The proximal phalanx is progressively moved towards a plantar position with respect to the metatarsal head, causing a gradual displacement of the joint rotation center[10] which dorsally clamps the joint during dorsal flexion movement. The repeated concentration of high stresses under compression in the dorsal portion of the first metatarsal head causes the appearance of cartilage lesions and the progressive development of dorsal osteophytes which evolve into gradual joint degeneration and may reach total ankylosis.

Clinic

Clinically, hallux rigidus is characterized by pain, joint swelling and decreased dorsiflexion of the first MTP, with a feeling of creaking joints when mobilizing the first toe. In the early stages, pain occurs in the last degrees of dorsal and plantar flexion and there is a loss of passive dorsiflexion of the hallux, generally preserving plantar flexion. This pain worsens with walking, especially during the lifting movement of the first toe and when standing on tiptoe, which may cause the patient to overload the lateral edge of the foot in order to compensate for the lack of mobility of the first MTP.[5,13]

As joint degeneration advances so does the proliferation of dorsal and dorso-lateral osteophytes of the first metatarsal head. Over time, they increase their size and force the proximal phalanx to be placed in flexion, with a greater loss of dorsiflexion and a progressive increase of the symptoms at lower levels of joint mobility. Dorsal osteophytes also appear in the proximal phalanx and limit joint mobility, thus imposing an antalgic gait with increased overload of the lateral edge of the foot as well as appearance of plantar keratosis and development of transfer metatarsalgia.[21] The hallux interphalangeal joint may go into hyperextension to compensate for the limitation in dorsiflexion of the MTP[6,7] and plantar calluses may appear in this joint, in response to a recurring drive of the foot on this area.[21]

Forced plantar flexion may cause pain due to the stretching of the extensor hallucis longus tendon and the dorsal and synovial capsule inflammation caused by the osteophyte.[6] Dorsal osteophytes (fig. 1) cause an inconsistency with footwear and produce skin lesions and

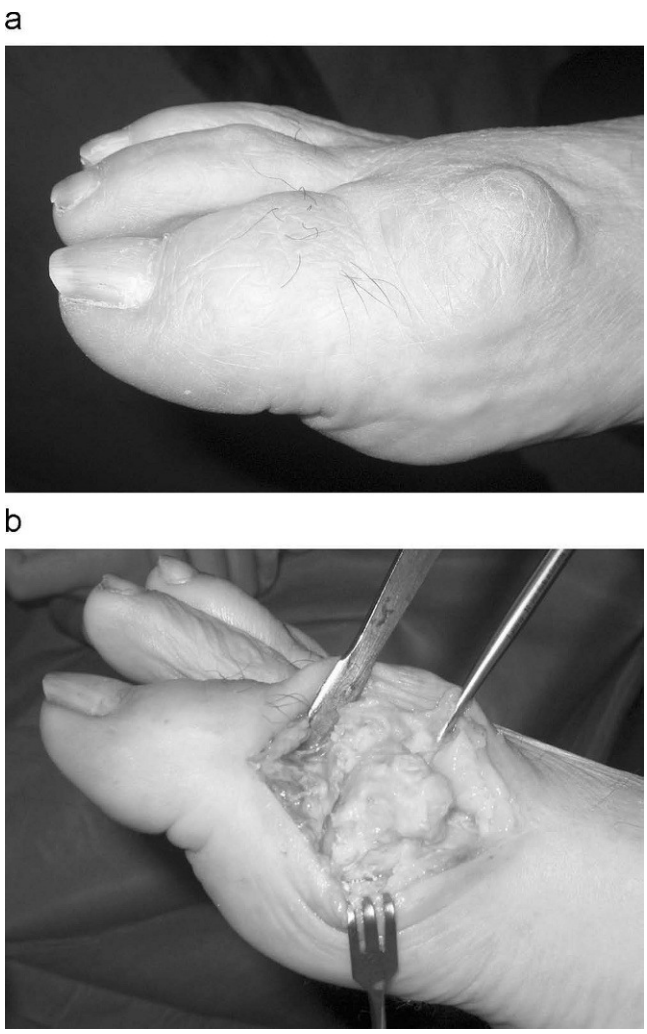

Figure 1 Characteristic dorsal bony prominence of hallux rigidus. a) Clinical appearance of the foot. b) During surgery.

bursitis by rubbing. This constant friction can irritate the dorso-medial cutaneous nerve and lead to the appearance of paresthesias, hyperesthesia or hypoesthesia in the medial edge of the first toe, and even to a positive Tinel sign.[5,6]

Osteophytes proliferate in the final stages (fig. 1) with significant deformity and swelling, even leading to the total loss of active and passive movement. Joint ankylosis can be found in the first toe, in an irreducible plantar flexed position which prevents normal gait.

Imaging Study

Although the diagnosis of hallux rigidus is predominantly clinical, the radiographic study can assess the extent of joint involvement in order to establish the most appropriate surgical treatment. It is advisable to carry out standing, PA and sideways radiographs, oblique and axial of the sesamoid bones. CT and MRI are not usually necessary.

In PA radiographs (fig. 2) it is possible to notice an uneven narrowing of the joint interline with a large and flattened metatarsal head. The joint space usually disappears in PA radiographs, due to the interposition of osteophytes, with only oblique radiographs (fig. 2) showing the true joint space. Moreover, subchondral bone cysts and articular sclerosis can be visualized, both in the metatarsal head and in the base of the proximal phalanx. It is also possible to observe a proliferation of marginal osteophytes, especially in the lateral edge but also in the medial section of first metatarsal head.

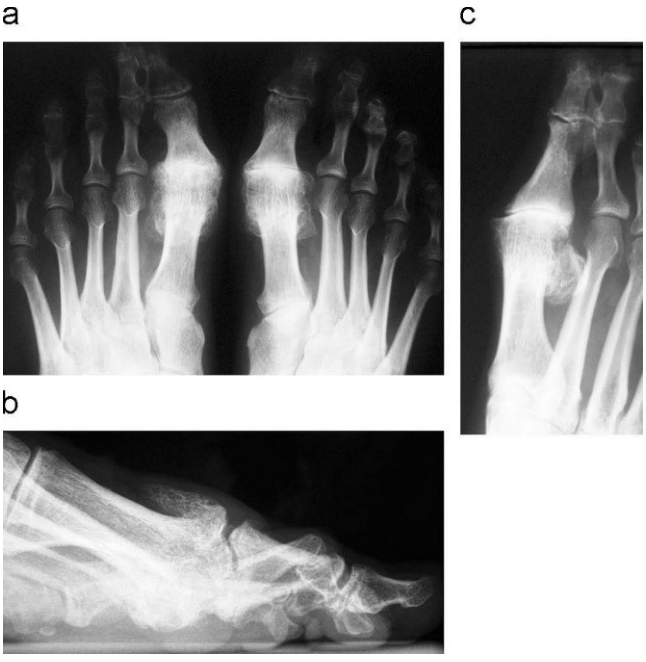

Figure 2 X-ray of hallux rigidus. a) Standing, posteroanterior radiograph of the feet, with complete loss of joint space of the first metatarsal-phalanges of both feet. b) Standing, lateral radiograph showing the dorsal, tear-shaped osteophyte characteristic of hallux rigidus. c) Oblique radiograph showing the actual joint space, by absence of interposition of osteophytes.

The lateral radiograph (fig. 2) shows a dorsal metatarsal osteophyte which projects proximally as a "drop of wax", parallel to the dorsal surface of the metatarsal head and which, in very advanced cases, is very large. The base of the proximal phalanx may also appear larger and present a dorsal osteophyte parallel to the metatarsal head. Another point to observe is the elevation of the first metatarsal in relation to the minor metatarsals. The sesamoids are longer and the distance to the base of the proximal phalanx decreases as joint involvement progresses.

The axial radiograph of the sesamoids enables assessment of the metatarsal-sesamoid joint condition. The sesamoids are usually hypertrophied and are longer, with the possibility of articular degeneration in advanced cases.

Classification

When focusing on the treatment of hallux rigidus, it is necessary to establish the evolution stage of patients in order to determine prognosis and propose a treatment. The Coughlin and Shurnas[3] classification structures hallux rigidus into 4 stages, based primarily on the radiographic image of the forefoot:

Stage I: images which present a lateral marginal osteophyte as an element of early diagnosis, but where the interline is preserved.

Stage II: in addition to the lateral osteophyte, it is possible to appreciate a flattening of the metatarsal area, subchondral sclerosis with a dorsal metatarsal osteophyte and involvement of the joint interline.

Stage III: presents an evident dorsal and lateral osteophyte, involvement of the sesamoid bones, serious deterioration of the interline with articular clamping over one quarter of the joint.

Stage IV: the destruction of the articular surfaces is evident and is associated with severe osteophytosis.

Conservative Treatment

The treatment of hallux rigidus is eminently surgical but conservative treatment is indicated in the absence of pain, in the early stages and in patients with surgical contraindications. Rest, anti-inflammatory drugs and treatment of infected hygroma, as well as the use of an insole which produces a metatarsal head elevation, thus artificially increasing the range of dorsiflexion, may improve the symptoms. By contrast, an external, pronator wedge aggravates the pain and accelerates the formation of dorsal osteophytes.

The timely use of intra-articular corticosteroid injection can improve the symptoms. We have no experience with the injection of hyaluronic acid although some authors have reported good results in the treatment of hallux rigidus.

Surgical Treatment. Arthrolysis-Cheilectomy Remodelling Techniques

The Du Vries[22] cheilectomy is a remodelling of the articular osteophytes associated to a dorsal osteotomy of the

metatarsal and the phalanx, with the aim of improving pain and dorsiflexion; it would be indicated in stages II and III.

A release of the joint capsule is carried out through a longitudinal dorsal-lateral or dorsal incision at the level of the first metatarsophalangeal joint. This is resected laterally along with the extensor tendon of the hallux. Next, a synovectomy is performed and loose bodies are removed, with resection of osteophytes and 25%of the dorsal portion of the metatarsal head through an oblique section.[23] This can be associated with the resection of a small wedge from the phalanx base (fig. 3), in order to increase dorsiflexion. Possible adhesion between the sesamoid bones and the metatarsal head in its plantar side should also be reviewed. A dorsiflexion of approximately 60° should be achieved, since this always tends to decrease in the postoperative period. The onset of active and passive mobility should be immediate and ambulation should start on the day after surgery.

Metatarsal Osteotomies

The aim of metatarsal osteotomies is to decompress the metatarsal joint and achieve a lowering of the metatarsal head. Excessive shortenings of the first metatarsal should be avoided; these are indicated in stage II. One possible complication is transfer metatarsalgia. Various osteotomies have been described in the treatment of hallux rigidus, including modified chevron osteotomy,[24] Watermann osteotomy[25] and Weil-Barouk osteotomy,[26] which may be associated with an osteotomy of the phalanx.

Chevron osteotomy is performed through a medial approach to the metatarsophalangeal joint and enables, after conducting a thorough cleaning of the articular osteophytes, an osteotomy in "V" of the anterior apex to be made at an angle of approximately 60° (fig. 4). A second cut is made at 5 mm, parallel to the dorsal of the "V", resecting a dorsal segment of the metatarsal head. This double osteotomy enables the metatarsal head to be lowered and shortened, thus correcting the hallux flexus and increasing the articular space. The intervention is completed by stabilizing the osteotomy with a cannulated screw.

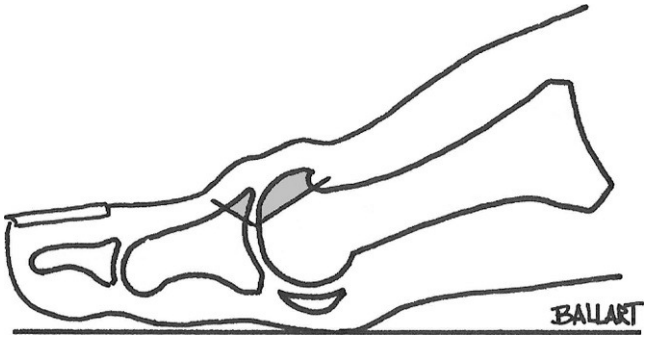

Figure 3 Outline of dorsal cheilectomy in hallux rigidus.

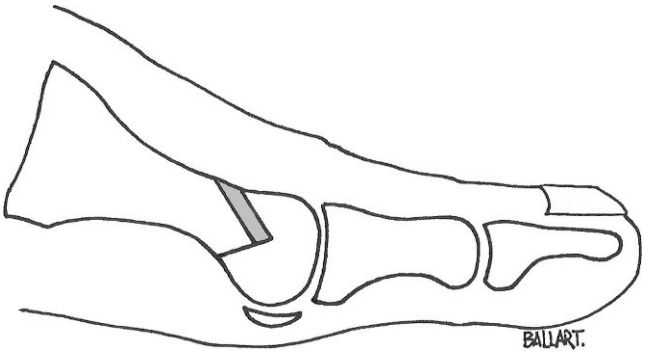

Figure 4 Outline of the chevron osteotomy carried out on the metatarsal head in order to shorten and lower it.

Phalanx Osteotomies

Osteotomies at the level of the phalanx are indicated in stage II. In shortening diaphyseal osteotomy we use a medial approach, excising a portion of the diaphysis of the phalanx. This is especially suitable in Egyptian feet with a long proximal phalanx. Another technique is Moberg wedge osteotomy,[27] which is indicated in hallux rigidus flexus. A wedge is resected from the dorsal base at the level of the metaphyseal-diaphyseal union through a dorsal approach. An osteosynthesis is always made, in order to stabilize the osteotomy. Both osteotomies can be associated when there is a long and flexible first toe.

Phalanx osteotomies, by producing its shortening and dorsal displacement, improve the conditions which facilitate the development of hallux rigidus, in which a loss of elasticity or excessive traction of the plantar fascia tends to displace the phalanx downwards and increase the pressure on the metatarsal articular surface, leading to joint degeneration.

Keller Resection Arthroplasty

A few years ago, this was the technique of choice in hallux rigidus and also in hallux valgus surgery. It is currently indicated for stages III and IV, as an alternative to arthroplasty or arthrodesis,[28] in elderly or diabetic patients and in those patients with major vascular abnormalities. The technique involves the resection of the proximal 2/3 of the first phalanx base. It is, therefore, a broader resection than that used in the surgery of hallux valgus.[29] This detail is important because an insufficient resection causes the risk of producing a painful stiffness of the metatarsophalangeal joint, always associated with a release of the sesamoids and articular cleaning. Negative points include recurrence, transfer metatarsalgias and loss of the first toe flexor power.

Valenti Method

Valenti[30] developed this technique for the treatment of hallux rigidus. It consists in a hinge arthrectomy, in "V" with respect to the sagittal plane. The 2 lines of the metatarsal and phalangeal osteotomies meet in the

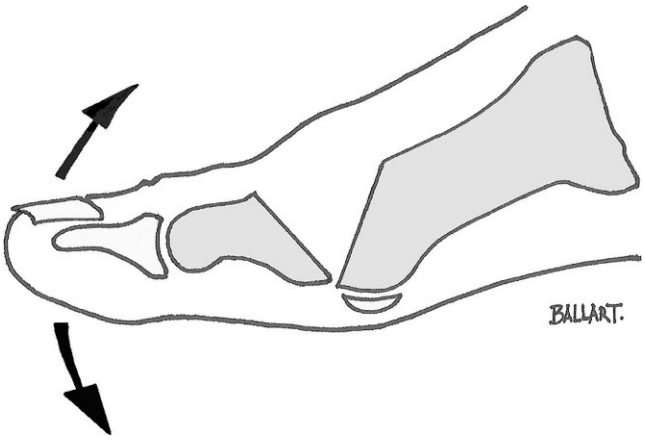

Figure 5 Schematic of the Valente Valenti technique, a hinge arthrectomy in "V".

metatarsophalangeal joint at the plantar level (fig. 5), respecting the plantar area of the first metatarsal head and the first phalanx, and thus maintaining the insertion of the short flexor and the function of the sesamoid bones.[31]

Phalanx osteotomy is initiated through a medial approach, from dorsal-distal to plantar proximal, at an angle of 40°. Next, the dorsal metatarsal osteotomy is carried out, about 12mm from the articular interline, at an angle of 55° from the dorsal-proximal to the distal-plantar. It is important to start mobility and ambulation as soon as possible.

With respect to the Keller[28] technique, it has the advantage of respecting the hallux insertion of the short extensor tendon, since the plantar section at the base of the phalanx is not resected, and so the biomechanics of walking are not altered, the function of the sesamoids is not affected and the length of the first toe is not modified. It is indicated in grades III and IV and the main drawback of this technique is that in case of failure, the secondary arthrodesis causes an excessive shortening of the metatarsal.

Arthrodesis

Arthrodesis of the metatarsophalangeal joint of the first toe is indicated in rescue surgery of the hallux valgus or in the treatment of severe deformities of the metatarsophalangeal angle as well as in stages III and IV of hallux rigidus.[32]

Concave-convex drills are used with a medial or dorsal approach to facilitate contact between the metatarsal and the phalanx, after resecting the articular surfaces and in order to facilitate the perfect coaction of the 2 surfaces. Arthrodesis is stabilized through a plate osteosynthesis, with a dorsal flexion of 20° and a valgus deviation of between 5-10°.[33] A contraindication relative to arthrodesis would be interphalangeal joint stiffness.

Arthroplasty

Swanson[34] presented different series of his silastic implants, which today have been abandoned due to the deterioration of the prosthesis and foreign body reactions, with lymphadenitis and appearance of lytic pockets in the metatarsal and phalanx.[35]

Figure 6 Surgical implantation of a prosthetic total of 3 components.

We have used the Werner[36-38] ceramic arthroplasty with adequate functional results, but with a high rate of complications including massive destruction of the ceramic material so we have turned to other models such as 3-component arthroplasties; the metatarsal made of chrome-cobalt and hydroxyapatite to facilitate osseointegration, the phalanx made of titanium and a polyethylene spacer which is inserted into the phalangeal component (fig. 6), with encouraging initial results.

Implantation is carried out using a medial approach for joint cleaning and sesamoid release, resection of the phalanx and metatarsal and, finally, implanting the prosthesis without cement. It is indicated for stages III and IV, in patients over 55 with low functional demand, while arthrodesis is reserved for younger patients.

Hemiarthroplasty

This consists in a prosthesis made of a single chrome-cobalt component with a titanium rod which is implanted in the phalanx.[39] This arthroplasty must enable a better match between the design of the prosthetic component of the phalanx and the roundness of the metatarsal head.[40] The technique is simple and must be associated with cleaning of the metatarsal head. It is indicated for stage III cases. In our experience, functional results are favourable but lack long-term monitoring.[41] There are also hemiarthroplasties of the metatarsal head which provide a surgical solution to cases in which there is a localized osteochondral lesion of the metatarsal head.

Hemiarthroplasty Associated to Osteotomy

This technique, which was proposed by Ronconi,[42] is indicated in stage III. It consists in the implantation of a hemiprosthesis in the phalanx, associated to a shortening and lowering osteotomy of the first metatarsal. The technique is based on the importance of the first metatarsal, which is elevated in the aetiopathogenesis of hallux rigidus although the elevation is secondary to the occurrence of hallux rigidus[8] and Pochera et al.[43] relate it to a retraction of the fascia and plantar musculature.

Treatment Algorithm

In stage I of Coughlin and Shurnas, the treatment of choice is conservative. Stage II is the ideal indication for metatarsal osteotomies, which prevent transfer metatarsalgia and decompress the MTP joint by lowering and shortening the metatarsal. Furthermore, cheilectomy in stage II can improve metatarsophalangeal joint dorsiflexion and painful symptoms.

Cheilectomy is indicated in stage III. Hemiarthroplasty implanted in the phalanx associated with a cleaning of the joint is also indicated. Ronconi et al.[42] associated hemiarthroplasty with a shortening and lowering osteotomy of the metatarsal head. The Keller technique or metatarsophalangeal arthroplasty has been used in patients of advanced age with acceptable results.

The technique of choice in stage IV is metatarsophalangeal arthrodesis. In elderly patients with low functional demand, the indication is metatarsophalangeal arthroplasty; moreover, arthrodesis of the metatarsophalangeal joint must be avoided whenever possible in those patients with ankle joint involvement.

Conflict of interests

The authors declare no conflict of interests.

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