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## Metatarsalgia and Lesser Metatarsal Surgery

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Metatarsalgia is defined as pain localized to the forepart of the foot. Although the definition is simple enough, it describes only a symptom: metatarsalgia can be a complex clinical problem. Pain under the metatarsals may be a reflection of systemic disease, a result of biomechanical imbalances, or local foot pathology.

### CLASSIFICATION

Several authors have attempted to classify metatarsalgia. Helal<sup>1</sup> classified metatarsalgia into primary, secondary, and unrelated to weight distribution. Primary metatarsalgia is defined as pain across the area of the metatarsophalangeal joints associated with plantar keratoses. It may be a result of functional problems such as wearing a high-heeled shoe or structural problems associated with, for example, a short first metatarsal, limb length discrepancies, or pes cavus. Also included by Helal as primary metatarsalgia were Freiberg's disease, hallux valgus, hallux rigidus, and problems of iatrogenic and traumatic origin. Secondary metatarsalgia was caused by systemic disease such as rheumatoid arthritis. Metatarsalgias attributed to tarsal tunnel and vascular insufficiency are those types of metatarsalgia unrelated to load distribution.

Regnauld<sup>2</sup> defined metatarsalgia into diffuse, localized, subcutaneous soft tissue, and cutaneous metatarsalgia. Diffuse metatarsalgia is an example of an acquired mechanical disorder, such as functional disorders, abnormalities of the ankle such as ankle equinus, overload of the metatarsals, and metatarsalgia

from high-heeled shoes. Localized metatarsalgia results from an osseous disorder such as a long metatarsal, large metatarsal, or aplasia of a metatarsal. Subcutaneous soft metatarsalgia includes pain from intermetatarsal neuroma, articular synovial cysts, and bursa. Cutaneous metatarsalgia is a result of plantar calluses, verruca, or ulcerations of the skin. Viladot<sup>3</sup> describes metatarsalgia in two categories: first, overload of anterior support as a result of high-heeled shoes, an equinus or cavus foot in which support is by the heel, and the metatarsal heads only, resulting in subluxation of the toes, a change in load, and change in cadence of gait. The second aspect of this classification is irregular distribution of mechanical load, as evidenced by the following symptoms:

First-ray insufficiency syndrome, examples of which are a short first metatarsal and hypermobility of the first ray. It may also be result iatrogenically following osteotomy of the metatarsal or Keller resection.

First-ray overload syndrome, which may be a result of chronic overload, plantar flexion of the first metatarsal, an index plus, or excessively long first metatarsal or first ray.

Central ray insufficiency syndrome, which may arise from congenital, iatrogenic, or neurogenic causes.

Central ray overload syndrome, attributed to long metatarsal or plantar-flexed metatarsals.

Scranton<sup>4</sup> described metatarsalgia as primary, secondary, and pain under the forepart of the foot. Primary metatarsalgia included hallux rigidus, a long first ray, Freiberg's disease, hallux valgus, and postsurgical

deformities. Secondary metatarsalgia was attributed to rheumatoid arthritis, neurogenic disorders, gout, limb length discrepancies, stress fractures, and sesamoiditis. Pain under the forefoot included diagnosis of Morton's neuroma, plantar fasciitis tarsal tunnel syndrome, tumors, Friberg's disease and plantar warts.

It is readily apparent that it is difficult to classify metatarsalgia; however, certain themes run through these classifications. These include evidence of systemic involvement, metatarsalgia as result of disturbances within the foot itself or of the biomechanics and function of the foot, and those unrelated to problems in weight-bearing.

## ETIOLOGY

Complaints of pain and paresthesias in the forefoot may also accompany neurologic processes such as nerve impingement syndromes, low back problems, and peripheral neuropathy. Peripheral neuropathy may be associated with diabetes and other systemic diseases. Dyck<sup>5</sup> has reported that burning in the forefoot may be one of the first signs indicating peripheral neuropathy. Rheumatoid arthritis is another form of systemic disease that results in painful disturbances of the forefoot. Metatarsalgia may also occur as a result of vascular insufficiency.

Metatarsalgia may be result from cutaneous soft tissue and osseous pathology. Cutaneous causes of metatarsalgia include plantar hyperkeratoses, inclusion cysts, foreign-body reactions, porokeratosis, and plantar verruca. Manifestations of inherited palmar plantar diskeratoses should also be considered in the differential diagnosis of metatarsalgia associated with plantar lesions. Plantar hyperkeratotic lesions presents with a varied clinical picture (Fig. 29-1). They may be diffuse in nature, involving an area plantar to several metatarsal heads, or they may be isolated under discrete metatarsal heads or appear as punctuate-type keratotic lesions.

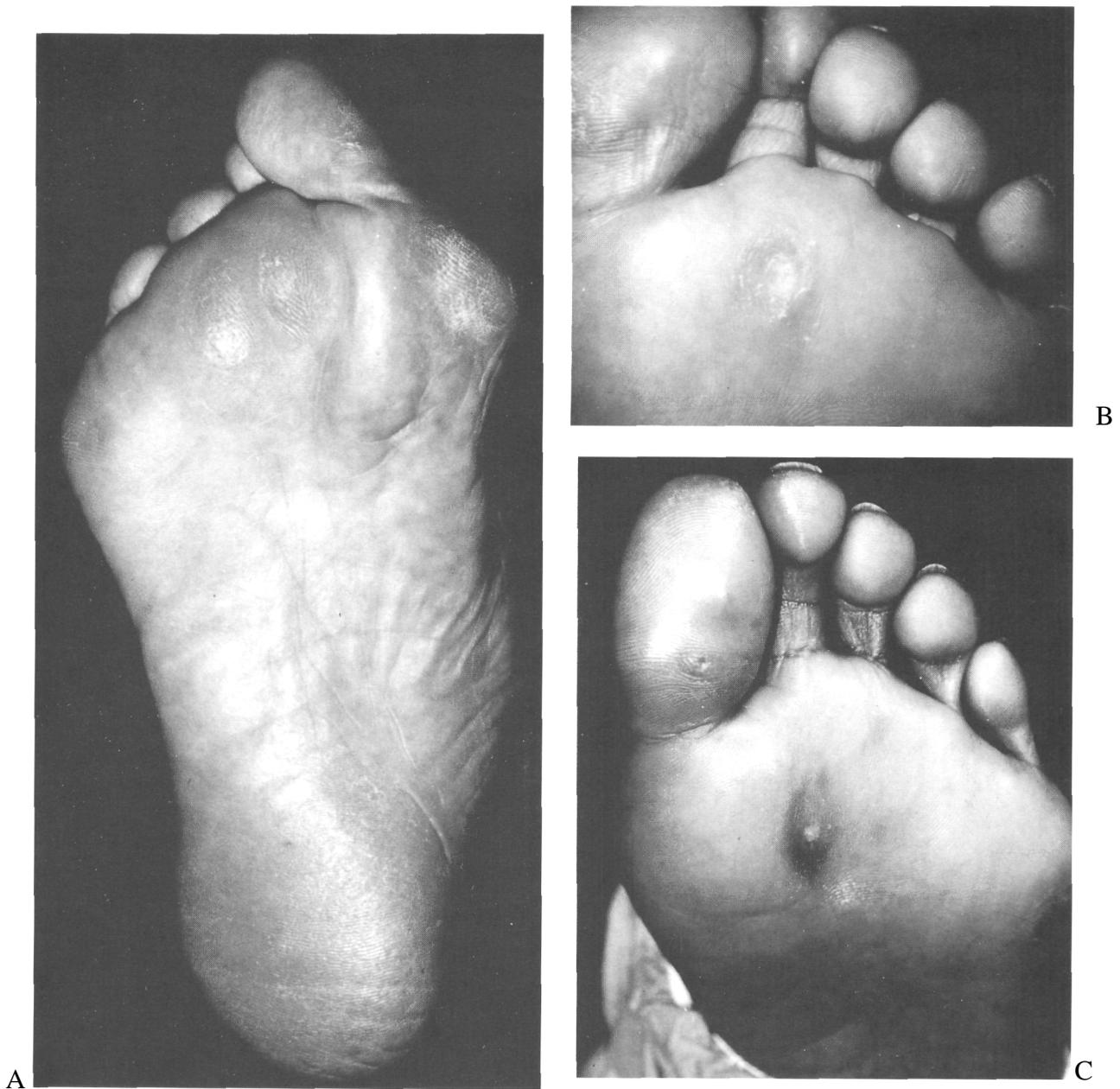
Subotnik<sup>6</sup> described two types of plantar calluses, one caused by friction and other caused by shearing forces. Frictional calluses are superficial and nonnucleated. It was theorized that they occur as a superficial portion of the skin moves along with the metatarsal heads against a resistant force. Frictional keratosis may surround the localized shearing lesion. This type

of callus may be more amenable to biomechanical or orthotic treatment. Shearing calluses on the other hand are a result of the skin being stabilized with the supporting surface and the metatarsal heads moving such that shear occurs within the soft tissues on the weight-bearing surface of the foot. Shearing results in fibrosis and scarring of the soft tissues and causes more symptoms than the frictional callus. These types of lesions are believed to result from a structural component to the deformity and may benefit from surgical intervention. Several types of shearing calluses were identified, including the following<sup>6</sup>:

- Superficial shearing callus
- Superficial fibrous shearing callus
- Nucleated shearing callus
- Fibrous nucleated callus
- Multinucleated fibrous shearing callus
- Neurovascular fiber shearing callus.

The degree of fibrous scarring, as well as the prognosis, worsens as one moves from the superficial shearing callus to the fibrous nucleated callus. In the superficial shearing callus there may be a small shallow hyperkeratotic nucleus with a surrounding frictional-type callus. As the condition worsens with the fibrous nucleated shearing callus, a deep fibrous base is present that is easily and well differentiated from the surrounding margins. The multinucleated fibrous shearing callus and the neurovascular shearing callus are uncommon. The neurovascular shearing callus with its extended neurovascular filaments may be confused with a plantar verruca. However, the lesion is extremely painful, which helps distinguish it from that of the plantar verruca.

In evaluations of patients with plantar hyperkeratosis, the existence of an inherited palmar and plantar diskeratosis should be kept in mind. Examples of such conditions are keratosis punctata<sup>7</sup> and Unna-Thost<sup>8</sup>-type palmar plantar keratoderma. Mechanically induced plantar hyperkeratotic lesions can be distinguished histologically from nonmechanical keratoses. As pointed out by Lemont,<sup>9</sup> pressure-induced histologic changes are not limited to the epidermis but involve the dermis and fatty tissue as well. In contrast, nonmechanical keratoses, even if located on weight-bearing surfaces, usually do not exhibit epidermal, dermal, or fat changes seen in those with mechanical



**Fig. 29-1.** Examples of plantar keratotic lesions. (A) Frictional hyperkeratosis in a patient with multiple digital contractions and hallux valgus plantar and dorsal view (flat triangular forefoot syndrome). (B) Nucleated plantar keratosis. (C) Porokeratosis plantaris discreta diagnosis (confirmed by biopsy). (*Figure continues.*)



D



E

**Fig. 29-1** (*Continued*). (D) Plantar lesions in a patient with an inherited palmar-plantar dyskeratosis. (E) An atypical presentation of a plantar wart (confirmed by biopsy) in an older patient with neglected general health and foot care.

causes. The characteristic features in nonmechanically induced keratosis of the sole include a thick stratum corneum with a normal underlying stratum malpighii. The dermis also remains normal.

Foreign-body reactions may also demonstrate small hyperkeratotic lesions as part of the clinical reaction. Inclusion cysts or epidermal inclusion cysts<sup>10</sup> may also be a cause of metatarsalgia. They can usually be palpated as cystic lesions and may have an overlying hyperkeratosis dependent on the location of the lesion itself. Another keratotic lesion, originally described by Taub and Steinberg,<sup>11,12</sup> is the porokeratosis plantaris discreta, which has come under some challenge as to whether it exists as a lesion discrete from other mechanically induced keratoses.<sup>13</sup> The term porokeratosis plantaris discreta was originally used to describe a plugged sweat duct. The lesion is clinically described as a sharply marginated, cone-shaped, wide-based callus surface of a rubbery consistency. The keratotic plug is easily separated by blunt dissection, and an opaque material may be obtained.<sup>12</sup>

The verruca plantaris or plantar wart is a viral-induced lesion that has a tendency to occur in the non-mechanical portions or areas of the foot. The lesion is caused by the human papova virus. Single or multiple lesions may appear on the plantar surface of the foot as well-delineated, circumscribed lesions that are most painful on palpation by lateral pressure. The overlying hyperkeratotic tissue may be hard; it gives way to the softer verrucous tissue. The lesions are characterized by pinpoint bleeding. A plantar verruca on an area of the foot other than the plantar surface may not be associated with an overlying keratosis. As mentioned previously, verruca may occur singly, in small groups, or in a mosaic lesion pattern.

There is a wide variety of treatment for warts, including applications of liquid nitrogen, electrodesiccation and curettage, topical acid preparations, and the carbon dioxide laser.<sup>14</sup> Surgical excision may also be performed. The depth of the excision has been reported to be to the level of the dermoepidermal junction or as recommended by Lemont and Parekh<sup>15</sup> to the level of the superficial fascia.

Other soft tissue lesions contributing to the development of the metatarsalgia may include the intermetatarsal neuroma, intermetatarsal bursitis,<sup>16</sup> and degeneration of the accessory plantar ligament.<sup>17</sup> Displacement of the plantar fat pad, as reported by

Hlavac and Schoenhaus,<sup>18</sup> is associated with digital deformities. Atrophy of the plantar fat pad, which may result after trauma, surgical intervention, or with the natural aging process, may also result in a painful metatarsalgia. Wasting or atrophy of the plantar fat pad interferes with the ability of the foot to absorb shock and dissipate heat, resulting in these energies being transferred to the underlying osseous structures. Treatment of this type of metatarsalgia is best handled by the use of an orthotic device to augment and replace the loss of the dysfunctional area of the skin.

Plantar calluses, especially those of the shearing type, may occur with either structural or mechanical problems in foot functions. Structural considerations for isolated plantar lesions have been divided into stance-phase and propulsive-phase lesions. These for the most part have been described as follows: stance-phase lesions are related to patient history as being lesions more painful with prolonged standing, as opposed to the propulsive-phase lesions, which the patient may complain cause more pain with active ambulation.

The stance-phase lesion is believed to be caused by a structurally plantar-flexed metatarsal. These may be detected on clinical examination by palpation of the relative position of one metatarsal head to the other while the foot is held in neutral position, and may be identified in axial radiography of the forefoot. The lesion is palpated and observed to be present directly beneath the head of the metatarsal. An elevating osteotomy is the treatment of choice for this type of lesion. The propulsive-phase lesions are clinically located distal to the metatarsal head, and an abnormality in the length of one or more metatarsals may be seen in the dorsoplantar view. This is essentially a focal abnormality of the metatarsal parabola. Other causes of isolated plantar lesions may be an (a) enlarged metatarsal heads, as a result of trauma or degenerative changes, or (b) as secondary to the retrograde instability of the metatarsophalangeal joint associated with a hammer toe or other digital deformity (Figs. 29-2 and 29-3). Variation and alteration in the location and severity of clinical lesions may result from differences in the relative motion of the lesser metatarsals. The degree of mobility available to the second and third metatarsals is limited and increases for the fourth, fifth, and first metatarsals. The degree of mobility may allow the more mobile elements to avoid participation in load-



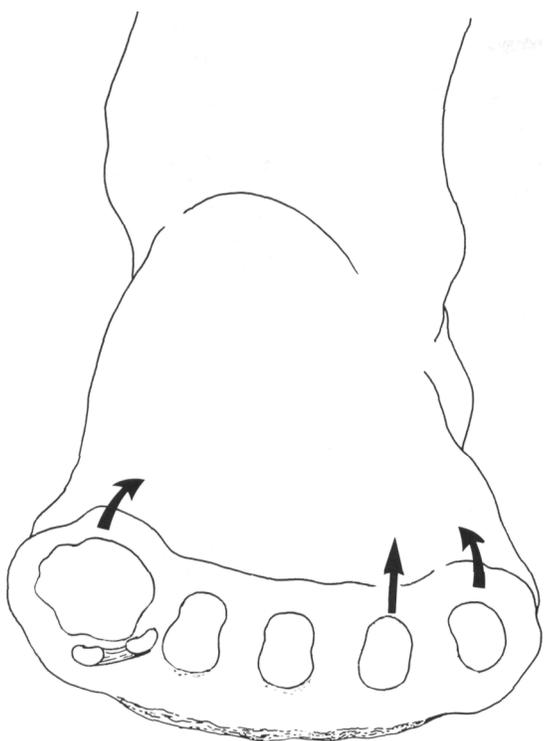
**Fig. 29-2.** A patient with multiple painful plantar lesion resulting from pes planus, hypermobility of the first ray, and multiple digital deformities.

bearing, increasing the load on the less mobile metatarsal. Pressure over time (duration) may be as important as direct vertical load in the development and clinical symptomatology of plantar lesions.

Metatarsalgia may be associated with localized arthritic problems such as degenerative joint disease and Freiberg's disease (Fig. 29-4), which is discussed in a separate chapter. The sesamoids of the forefoot may also be actively involved in a patient with metatarsalgia and this is also addressed separately. Metatarsal stress fractures are a cause of metatarsalgia; pain can be repetitively elicited by a palpation of the metatarsal shaft. Initially no radiographic changes may be found; however, radiographic follow-up will reveal the development of a periosteal callus.

Compensation for functional or biomechanical disorders of the foot may also lead to the development of

plantar lesions. These plantar lesions result from alterations in the mechanical function of the foot and interfere with its ability to distribute the loads placed on it by the mechanics of walking. These are illustrated by the development of the sub-second-metatarsal lesions seen with hypermobility of the first metatarsal that result in hallux valgus, hallux rigidus and digital deformity. Digital deformity such as hammer and claw toe deformities are a principal cause of painful plantar lesions. These dynamically produced deformities cause retrograde instability of the metatarsophalangeal joint, which results in an inability to distribute the forces in gait effectively, producing areas of overload culminating in a painful plantar lesion. The role that digital deformities play in the etiology of painful plantar lesions should not be underestimated. The assessment and management of digital deformity is discussed in Chapter 26.



**Fig. 29-3.** Diagram illustrating the potential for overload of the second and third metatarsals resulting from excessive pronation, causing hypermobility of the first ray and, as a result of increased mobility at the metatarsal-cuboid articulation, loss of participation by the fourth and fifth metatarsals in distribution of forefoot load.

Another osseous problem in metatarsalgia is abnormalities of the metatarsal parabola, which may be reflected as a long first metatarsal, short first metatarsal, and insufficiency of the central metatarsals or brachymetatarsia. These types of deformity may have a congenital, acquired, or iatrogenic basis. A normal metatarsal parabola has been defined by the formula of  $1 < 2 > 3 > 4 > 5$ ; various abnormalities in the length pattern of the metatarsals can be described according to Whitney<sup>19</sup> (Fig. 29-5) as follows.

A short first metatarsal segment, at times referred to as Morton's syndrome, by itself, as reported by Whitney,<sup>19</sup> may not represent a potential first-ray insufficiency but when combined with other defects and pronatory stresses must be regarded as significant (Fig. 29-5B). The short great toe mentioned previously as part of insufficiency of the first ray results in an

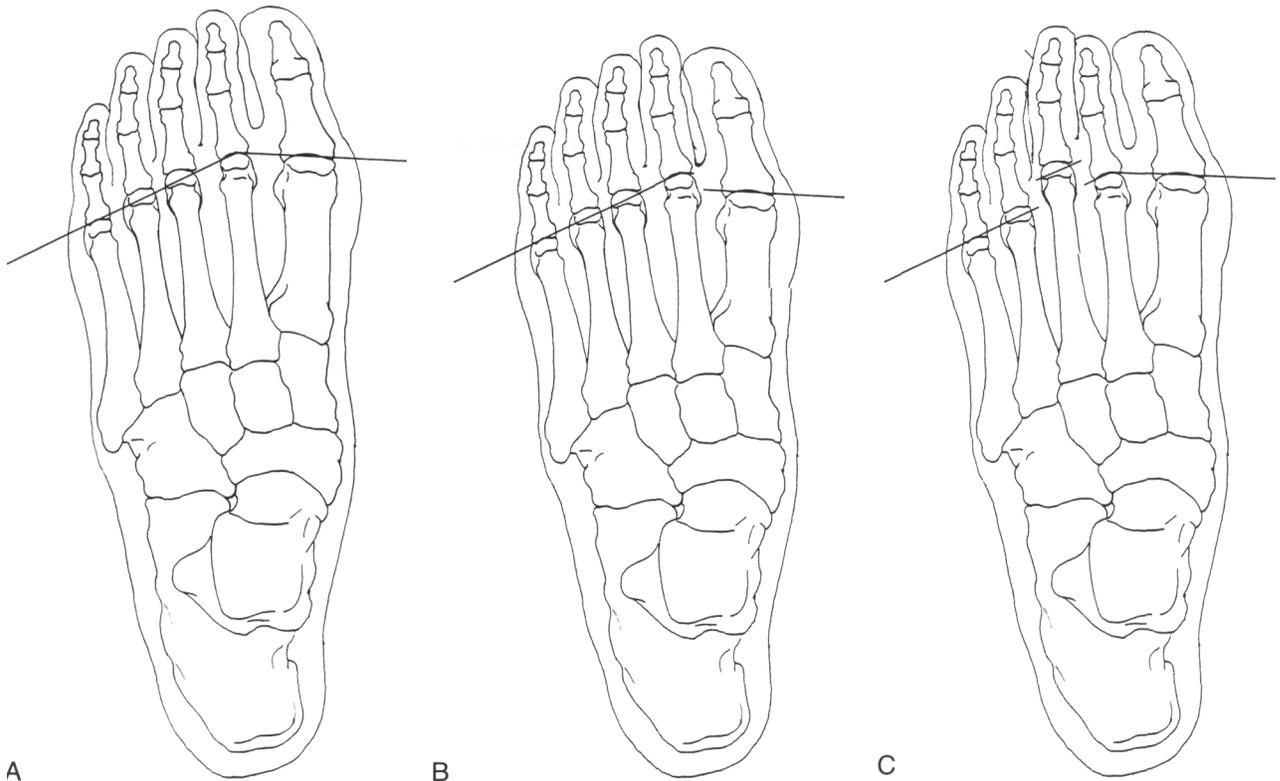


**Fig. 29-4.** Freiberg's disease of the second metatarsal.

improper distribution of the weight load of the first ray, allowing a displacement of the vertical component of force more laterally and causing greater load to be borne underneath the lesser metatarsals. It is important to note that insufficiency of the first ray may be acquired as in an iatrogenically short first metatarsal or from procedures involving resection of the base of the proximal phalanx. In high-heeled shoes, the abnormally short first metatarsal leads to an adjacent metatarsal overload.

A long third ray may lead to overload of that metatarsal (Fig. 29-5C). A long first segment or a long first ray (Fig. 29-5D) leads to direct trauma of the hallux, dynamic functional overload of the first metatarsophalangeal joint leading into hallux rigidus. Brachymetatarsia, more commonly of the fourth metatarsal, may involve any of the central metatarsals. Brachymetatarsia (Fig. 29-5 E and F) may have either a congenital, acquired, or iatrogenic basis.

A recent concept in the function and alignment of the forefoot and their relationship to metatarsalgia is that of the forefoot syndromes. Regnaud<sup>2</sup> describes the central metatarsals as a functional unit. He further



**Fig. 29-5.** (A) Normal metatarsal alignment (parabola). (B) Short first segment. (C) Long third metatarsal. (*Figure continues.*)

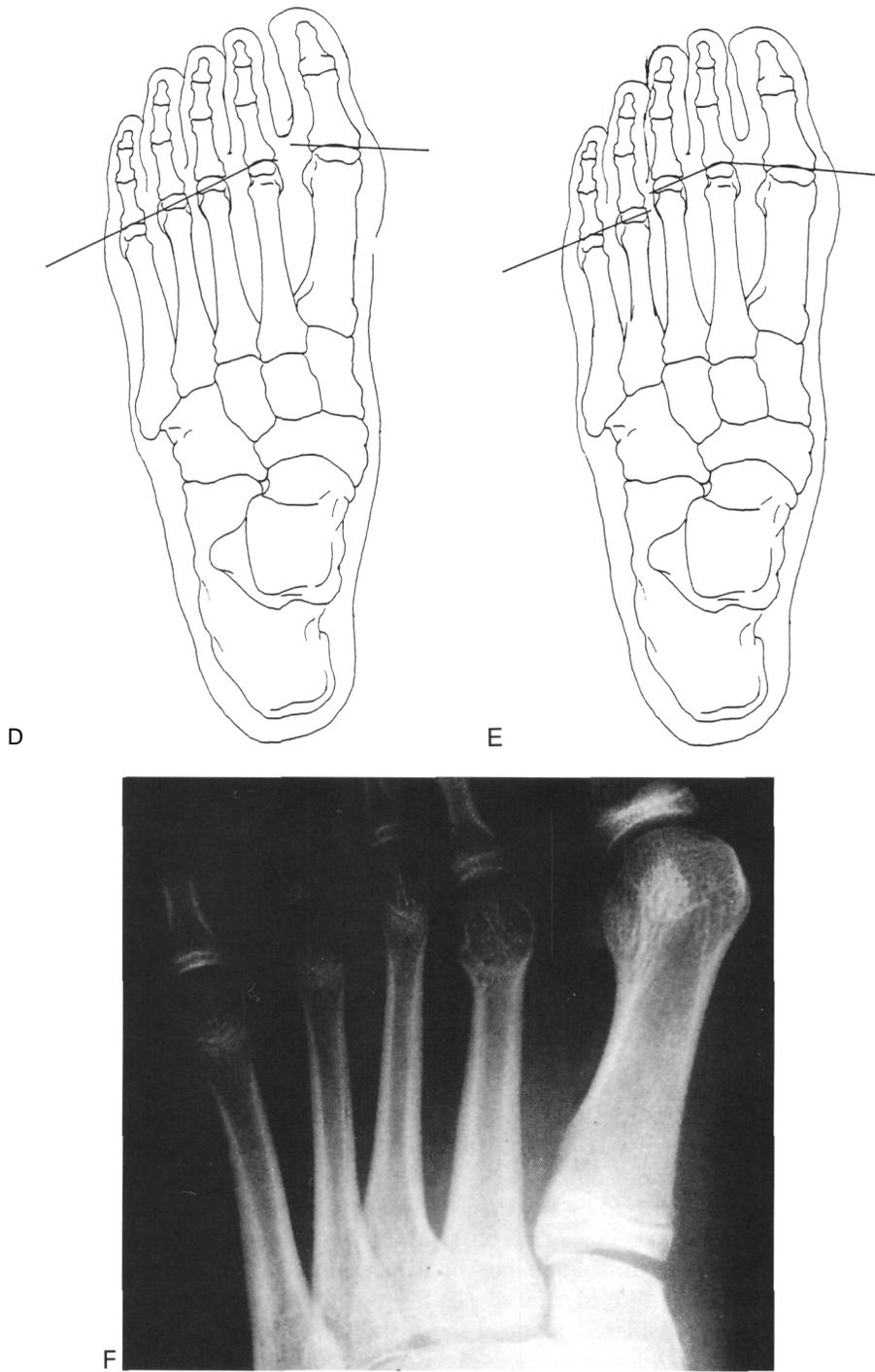
states that any "disadvantageous configuration" in the alignment of the metatarsal heads cannot be compensated for by an intrinsic or extrinsic muscular control. Conversely, however, activity of plantar flexors especially of the first and fifth rays result in a cavus foot and weakness of these plantar flexors causes central metatarsal overload. Inability of the first and fifth rays to compensate for forefoot loading, may be regarded as the main influence in protecting the weight-bearing function of the ball of the foot.<sup>2</sup> Failure of this mechanism is an important cause of painful syndromes of the forefoot (Fig. 29-6). The anterior or frontal plane configuration of the Lisfranc's joint is influenced by the load generated by body weight acting through the talus. This is reflected by a change in the convexity of Lisfranc's joint that controls the relative position of the metatarsals and results in four forefoot syndromes:

1. The flat triangular forefoot with frontal protrusion of the second, third, and fourth metatarsals without

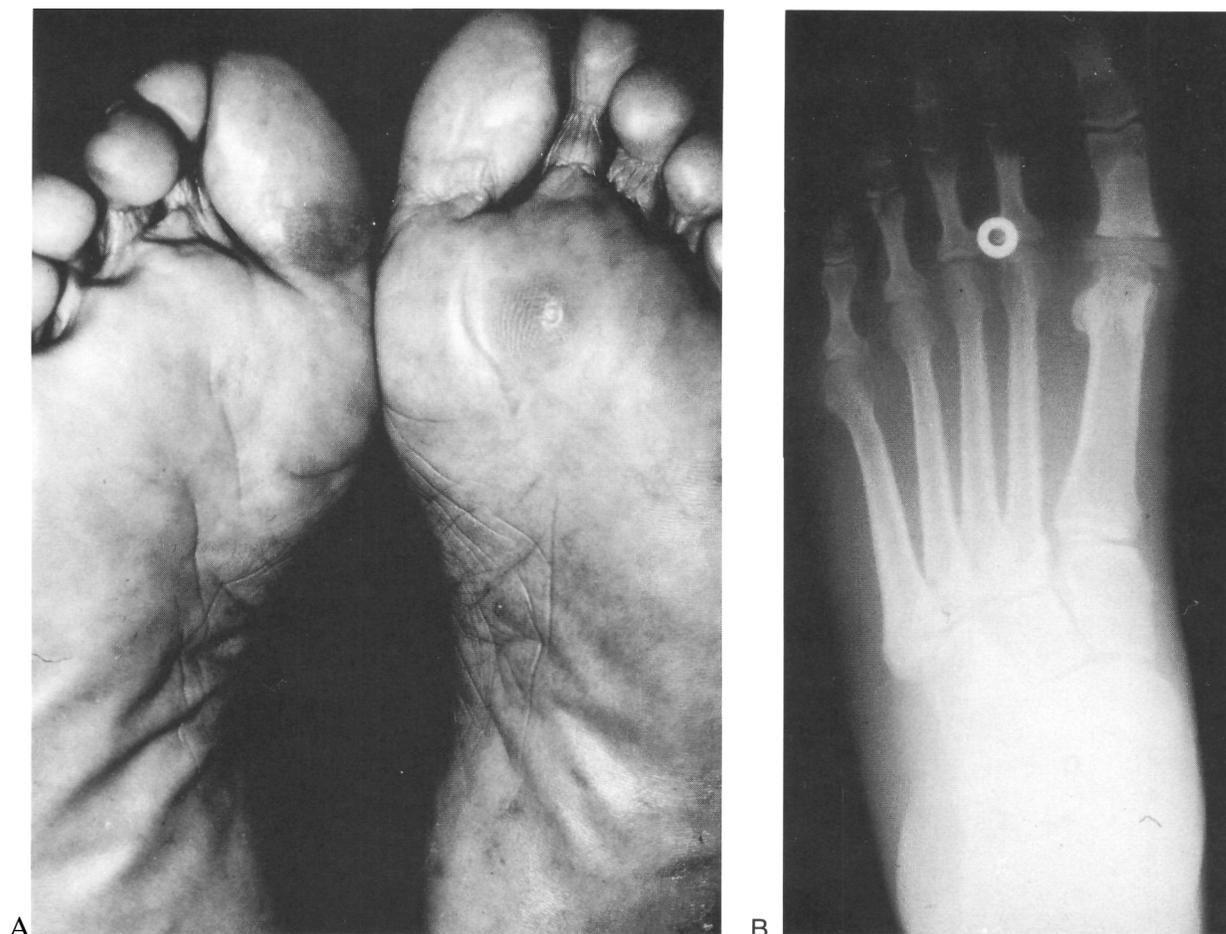
equinus of the metatarsals with all metatarsals on the same plane (see Fig. 29-1A);

2. Simple convex forefoot with frontal protrusion of the second, third, and fourth metatarsals associated with the equinus of those metatarsals. The horizontal position of the first and fifth metatarsals is normal. One of the more difficult of these forefoot conditions to manage is convex forefoot with insufficiency of the first ray;
3. The convex triangular forefoot, in which the augmentation of the frontal convexity of Lisfranc's joint occurs with equinus of the second, third, and fourth metatarsals and divergence of the first and fifth metatarsals;
4. The cavus forefoot, in which metatarsals one or five are lower or relatively shortened in relationship to the central metatarsals.

Regnault<sup>2</sup> recommends management of these disorders address realignment of the metatarsal formula to



**Fig. 29-5 (Continued).** (D) Long first ray. (E) Brachymetatarsia. (F) Brachymetatarsia, second metatarsal.



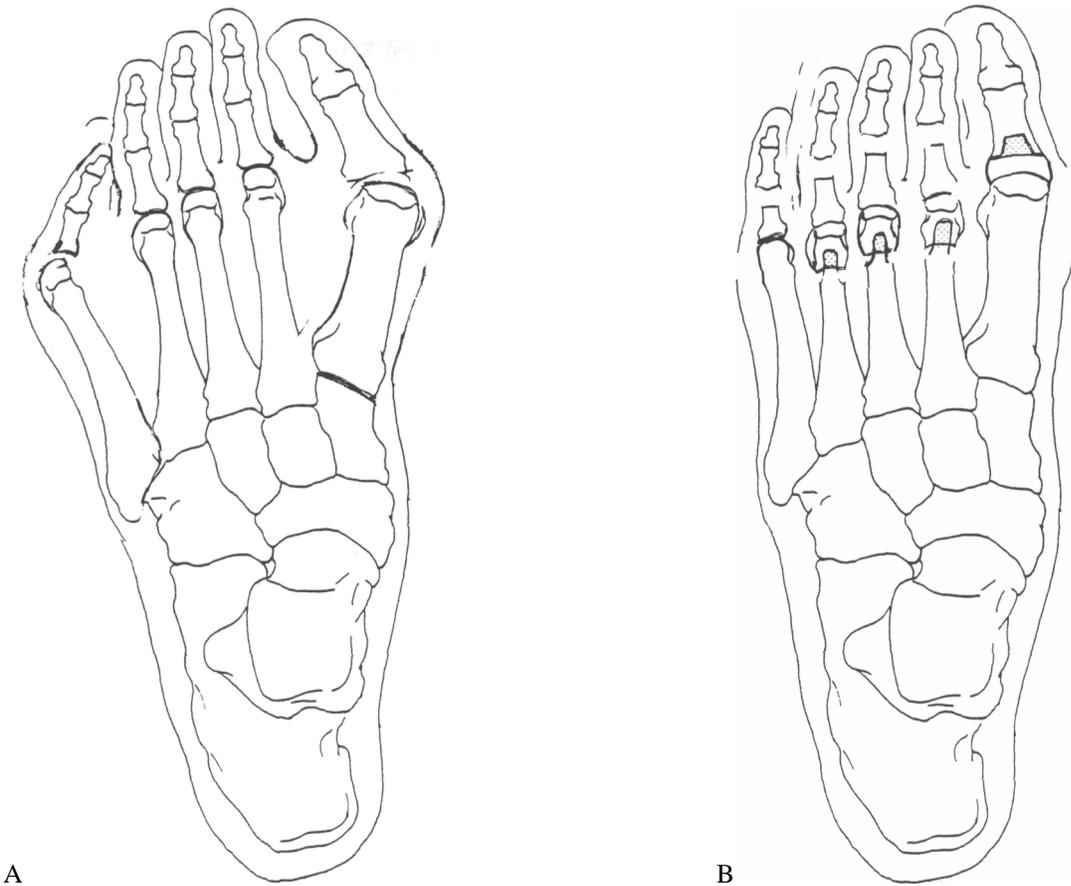
**Fig. 29-6.** (A & B) Example of insufficiency of the great toe. The patient underwent implant arthroplasty of the left first metatarsophalangeal joint with a silicone hemi-implant. The right foot was not operated. Postoperatively, a plantar keratosis developed beneath the second metatarsal as a result of the inability of the hallux to participate in weight-bearing because of loss of intrinsic muscle stability of the great toe.

a correct position and preservation of the metatarsophalangeal joint (Fig. 29-7).

If one considers the alignment of the metatarsals, two axes of function have been described by Bojsen-Moller.<sup>20</sup> He described a transverse axis consisting of the first and second metatarsals and an oblique axis consisting of the second through the fifth metatarsals (Fig. 29-8). The transverse was considered to be a high-speed axis and the oblique axis a low-speed axis. These are similar to the axis of propulsion and axis of balance as described by Whitney.<sup>19</sup> The second metatarsal participates in both axes and represents the key or fulcrum of the forefoot.

Painful conditions of the first-ray, for example, hallux valgus and hallux rigidus, will force the patient to use the low-speed or oblique axis. The foot of the patient with hallux valgus is prevented by the deformity of the toe and the hypermobility of the first ray from using the long lever arm or transverse axis. The fourth and fifth metatarsals with their greater freedom of mobility than the second or third and can yield dorsally so that the brunt of pressure may be then carried by the second or third metatarsals. Abnormalities of metatarsal length may aggravate the situation.

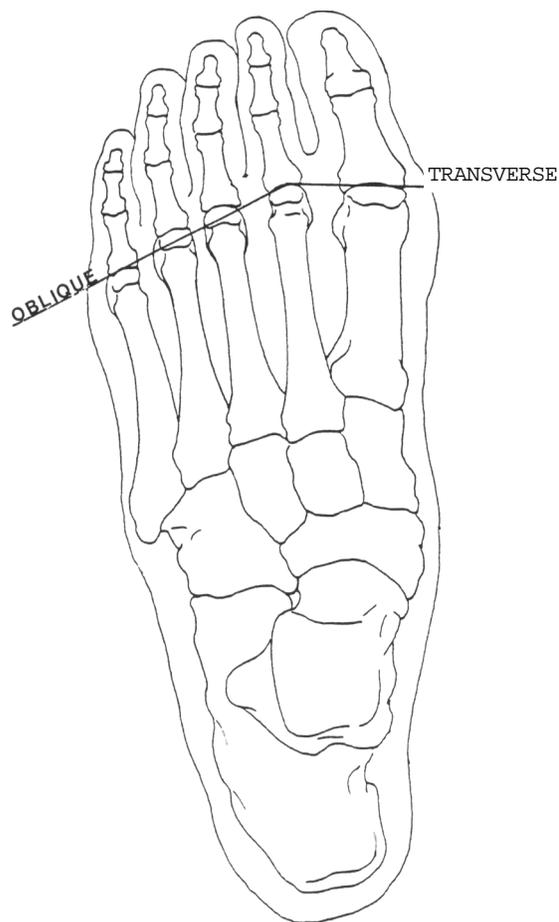
Radiographic assessment of plantar lesions should include dorsoplantar, oblique, forefoot, axial, and lat-



**Fig. 29-7.** (A & B) Pronated or pes planus foot type, which will develop, depending on the severity and composition of the rearfoot deformity, a flat triangular or convex triangular forefoot. In this instance, a flat triangular forefoot is demonstrated. As a result of the change in the decrease in height of the longitudinal arch, as well as the transverse height of the foot, Lisfranc's joint projects distally, increasing its frontal convexity and resulting in splaying of the forefoot and protrusion and prominence of the central metatarsals. This will be accompanied by digital deformity, hallux valgus, and possibly a tailor's bunion. Treatment may include correction of the first-ray pathology and central metatarsal shaft-head enclavement to restore the metatarsal alignment. At the other end of the spectrum, supination reflected by an increase in the longitudinal arch and transverse height of the foot may result in a simple convex forefoot or cavus forefoot. This foot type is described as frontal protrusion the central metatarsals with equinus of those metatarsals as a result of upward displacement of the cuneiforms, causing overload. This overload will be associated by insufficiency of the first and fifth rays. The cavus forefoot results from continued displacement of the cuneiforms and relative equines of the first and fifth metatarsals. Treatment may include enclavement, osteotomy, or a combination to restore metatarsal alignment with other procedures of the first ray as indicated.<sup>2</sup>

eral views of the foot. The dorsoplantar or anteroposterior view allows assessment of metatarsophalangeal joint pathology as well as assessment of metatarsal length patterns. The axial view of the forefoot may identify plantar-flexed metatarsals and plantar prominences, and is especially useful in the evaluation of

patients following metatarsal osteotomy or those with transfer lesions. This view has limited value in preoperative patient assessment for it rarely demonstrates that a plantar-flexed metatarsal. The reason for this is probably that the presence of a true structurally plantar-flexed metatarsal is uncommon and most lesions



**Fig. 29-8.** The transverse and oblique axes of the metatarsals as described by Bojsen-Möller.

result from biomechanical imbalances often associated with hallux valgus, hallux rigidus, digital deformity or other dynamic imbalances. Oblique views can reveal abnormalities in the relationship of lesser metatarsals by loss of the normal colinear relationship of the lesser metatarsals. Lateral views may serve as a baseline for future comparisons (Fig. 29-9).

## MANAGEMENT

Several procedures have been described for the management of lesser metatarsal lesions (Fig. 29-10). These include the following:

Metatarsal head resection, including both total and partial head resection

Condylectomy  
 Osteoclasts  
 Distal metaphaseal osteotomy  
 Tilt-up osteotomy  
 Distal V osteotomy  
 Proximal wedge osteotomy  
 Proximal V osteotomy  
 Collectomy-type procedures  
 Metatarsal head recession or enclavement.

## Metatarsal Head Resection

Metatarsal head resection for the management of plantar lesions has been advocated by several authors.<sup>21-23</sup> Rutledge and Green<sup>21</sup> in 1957 reported on the removal of the metatarsal head and one-third of the shaft of the metatarsal. They described their results as excellent in a study involving 30 plantar "corns." They described recession of the toe as a complication and did not observe transfer lesions; 18 months was the longest follow-up in their series. Perhaps the most aggressive form of resection is that of Dickson,<sup>24</sup> who advocated total ray resection for the management of intractable plantar warts. He reported as results as uniformly successful in 25 cases.

Metatarsal head resection is not a commonly indicated procedure in the management of isolated plantar lesions. It is primarily associated with complications of dorsal and posterior retraction of the digit, as well as developments of transfer lesions. Metatarsal head resection is reserved for those cases associated with advanced degenerative disease of the metatarsophalangeal joint, including prolonged subluxation of the digit, and in certain cases for the management of plantar ulcerations. Metatarsal head resection is indicated in the management of tumors of the metatarsal heads. Multiple metatarsal head resections or panmetatarsal head resections play an important role in the management of the rheumatoid patient, as well as other patients with chronic disabling arthritic processes involving all the metatarsophalangeal joints. Isolated metatarsal head resections have less application.

## Condylectomy

Condylectomy, originally described by DuVries,<sup>25</sup> involves the resection of the plantar condyles of the metatarsal head and is usually reserved for those pa-



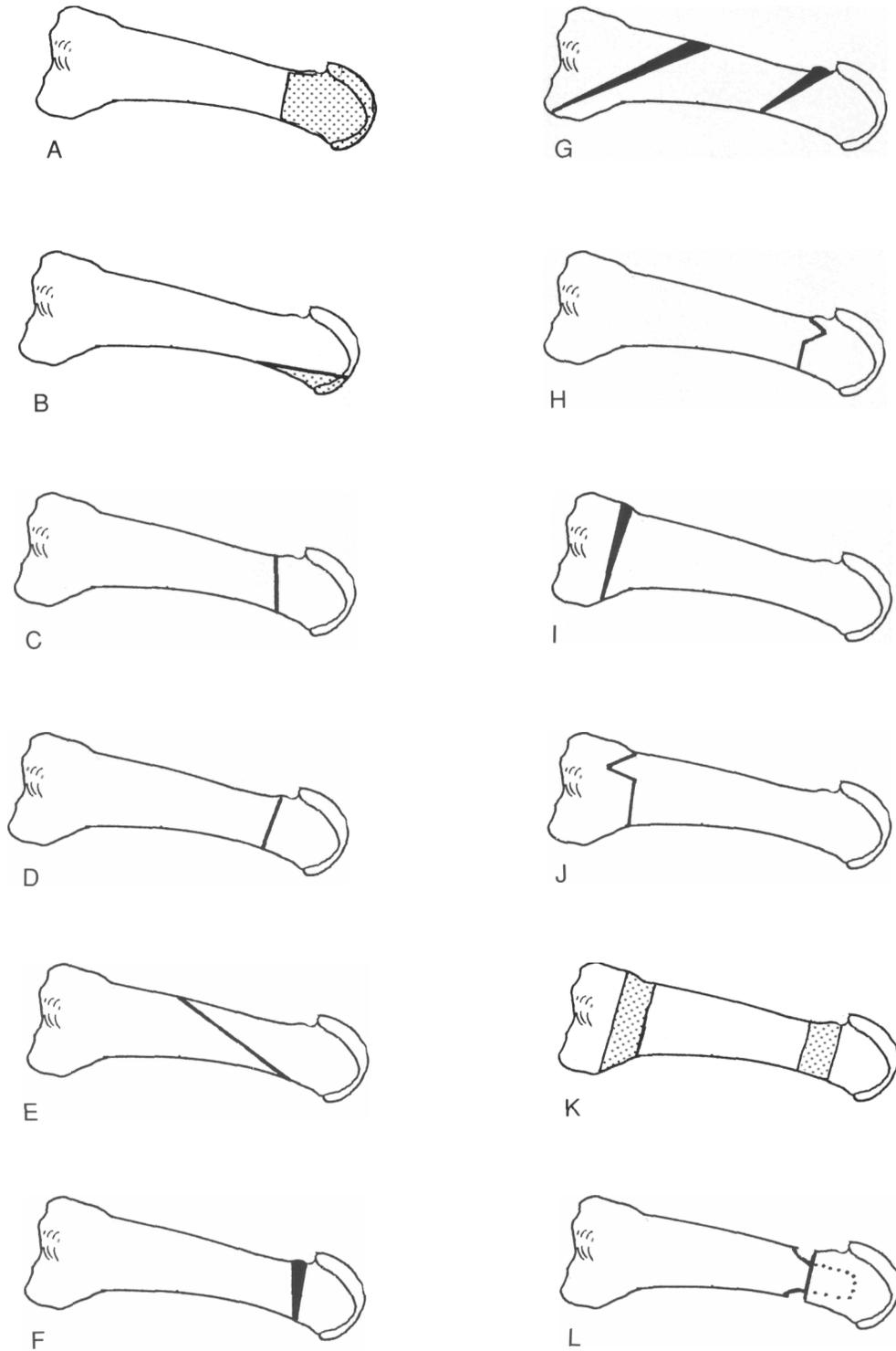
**Fig. 29-9.** Radiographs of a patient who underwent several lesser metatarsal osteotomies. (A) The dorsoplantar view reveals the osteotomies with the metatarsal parabola intact; (B) the axial view, however, demonstrates the reasons for the patient's continued complaints of metatarsalgia.

tients in whom prominent condyles can be ascertained preoperatively. DuVries<sup>25</sup> and Mann and DuVries<sup>26</sup> have reported success in the management of intractable plantar keratosis by this technique. In the study by Mann and DuVries, a 93 percent patient satisfaction rate was reported. Complications reported by them with this procedure were fracture of the metatarsal head, avascular necrosis of the metatarsal head, cocked-up deformity of the toe, and occasionally medial or laterally drifting in the position of the toe. They also reported recurrent and transfer lesions and that a number of patients required a second procedure because a lesion occurred adjacent to the original site. Anderson<sup>27</sup> described the use of condylectomy in association with a plantar rotational flap for the management of "intractable plantar warts." The modification of the plantar condylectomy using a min-

imal incision approach, called plantar metatarsal head reduction, was also reported by Brown.<sup>28</sup>

### Osteoclasia

Osteoclasia is a procedure attributed to Dr. Joseph Addante<sup>29,30</sup> in which a bone-cutting forceps or rongeur is utilized to create an osteotomy in the neck of a lesser metatarsal for the management of plantar keratosis. Addante reported an 85 percent success rate in his experiences in more than 1,000 cases. A transfer lesion incidence of 15 percent occurred, but there was no report of delayed union or nonunion. Osteoclasia is a simple technique that is usually managed immediately postoperatively by weight-bearing; it is however a rather unstable osteotomy and may cause shortening of the metatarsal.



**Fig. 29-10.** Types of lesser metatarsal osteotomies. (A) Metatarsal head resection. (B) Condylectomy. (C) Osteoclasis. (D) Distal metaphyseal osteotomy. (E) Helal. (F & G) Tilt-up osteotomy. (H) Distal V osteotomy. (I) Proximal dorsiflexory wedge osteotomy. (J) Proximal V osteotomy. (K) Collectomy procedure. (L) Metatarsal head recession (enclavement).

### Distal Metaphyseal Osteotomies

Distal metaphyseal osteotomies have been reported by several authors. The procedure is usually a transverse or oblique osteotomy performed in the distal metaphaseal area of the metatarsal. Variations in technique relate to the angle of orientation of the osteotomy to the bone itself. Sullivan and O'Donnell<sup>31</sup> performed the osteotomy in an oblique fashion and reported on a study of 75 patients and 150 procedures. The follow-up range was 4 months to 2.5 years. They reported uniform resolution of the chief complaint and minimal evidence of transfer lesions. The osteotomy was performed in an oblique fashion from distal-dorsal to plantar-proximal to limit the amount of dorsal excursion of the metatarsal head. Pedowitz<sup>32</sup> performed an osteotomy in the distal metaphaseal area with the osteotomy perpendicular to the supporting surface. He reported on 69 distal osteotomies with an average follow-up time from 8 months to 8 years (average, 16 months). The overall results were reported as 83 percent good, with a good rating consisting of no complaints of pain, unrestricted shoe wear, no limitation of activity, and no transfer or asymptomatic calluses. Six patients had loss of the weight-bearing function of the toe on the involved rays and three patients developed transfer lesions. Use of a postoperative shoe and immediate weight-bearing was encouraged.

A modification of the distal metaphaseal osteotomy called the percutaneous metaphyseal osteotomy was described by Smith<sup>33</sup>; in this technique the metatarsal neck was cut perpendicular to the long axis 2 to 4 mm proximal to the capsular attachments through a percutaneous approach without visualization.

A modification of the distal metaphaseal reported by Helal<sup>34</sup> was initially described to include both distal diaphaseal and metaphaseal bone. The technique as described by Helal is a distal oblique osteotomy in the distal one-half of the metatarsal shaft. The osteotomy is angled 45 degrees plantar and distally. In this procedure it is important that the distal fragment slide upward but that it is not angled. The prominent dorsal tip of the distal fragment is remodeled. The purpose of the osteotomy was to allow for soft tissue relaxation to realign deformed toes and reposition the metatarsal fat pad. In long-term follow-up, Helal and Greiss<sup>35</sup> have reported an overall 88.4 percent success rate.

Primary indication for the procedure is for the management of "pressure metatarsalgia." The procedure is also indicated for the management of patients with rheumatoid arthritis, and it is not uncommon for the procedure to be performed simultaneously on all three metatarsals. Postoperatively the patients are managed by immediate postoperative weight-bearing. Other authors have also reported uniformly successful results. Reikeras,<sup>36</sup> in a comparison between a proximal wedge resection dorsiflexed osteotomy and a distal oblique osteotomy, reported the distal oblique to be preferred over the more proximal osteotomy.

An osteotomy similar to that of Helal was performed by Turan and Lindgren<sup>37</sup> using a distal oblique osteotomy with internal screw fixation. They thought that the internal fixation in this instance ensured metatarsal head symmetry and provided for more predictable results. Winson<sup>38</sup> and others reported that better results were obtained in the Helal procedure when plaster and immobilization was not used postoperatively. Further details of the Helal osteotomy are described by a subsequent chapter by Steinbock.

### Tilt-Up Osteotomy

One of the more common osteotomies in recent years is the tilt-up osteotomy, which has been described several authors. Although it is more commonly performed in the area of the distal metaphysis of the metatarsal, Meisenbach<sup>39</sup> in 1916 described this type of osteotomy to be performed 3 cm. from the metatarsal phalangeal joint. Other authors have referred to the tilt-up osteotomy as a V-type osteotomy (not to be confused with the distal metaphaseal V osteotomy, which is discussed later). This reference is to a wedge osteotomy with a dorsal base and a plantar apex. Wolf<sup>40</sup> described this as a V-shaped notch made in the metatarsal down to but not including the plantar cortex of the metatarsal shaft. He reported 35 of 42 osteotomies were completed with excellent results. Four were fair, because of the remaining callous tissue, and 3 were poor because the callus recurred.

Thomas<sup>41</sup> also used a tilt-up osteotomy similar to that of Meisenbach and reported a 90 percent success rate as judged by relief of pain in 73 patients, of whom 39 were rheumatoid; the average follow-up was

4 years. Indications were for painful prominent metatarsals with only moderate toe deformity. He recommended in his paper that if an adjacent metatarsal feels prominent after osteotomy of the prominent metatarsal then that metatarsal should be osteotomized as well. Complications included transfer lesions in 4 patients that were treated by osteotomy of the adjacent metatarsal. Kuwada et al.<sup>42</sup> described a dorsiflexory distal tilt-up osteotomy for painful plantar lesions. The plantar cortex was left intact, and a rongeur was used to perform the bone cut; in some instances the plantar lesion was excised. They reported no incidence of painful scars, and no transfer lesions, and managed the patient non-weight-bearing for the first 3 weeks postoperative. Berkun et al.<sup>43</sup> reported on 14 patients and 25 osteotomies managed by the tilt-up osteotomy. Their overall objective rating was 65 percent excellent, 35 percent good, determined by the appearance of a transfer lesion, and 8 percent poor where there was a painful recurrence and painful transfer lesion. Subjectively, all but 1 patient had a good or excellent result; patients satisfaction was 92.5 percent. There was no reports of nonunion, and only minimal bone callous tissue formed. They also noted toe purchase remained active in 23 of 25 digits.

Leventen and Pearson<sup>44</sup> described an osteotomy, similar to that of Kuwada et al., as a simple V-shaped osteotomy cut transverse to the shaft with a small longer cut close to the metatarsal head and reported an overall success rate of 86 percent. They noticed that the key to the procedure is early weight-bearing to maintain adequate elevation of the metatarsal head. Dannels<sup>45</sup> advocated the use of distal fixated tilt-up osteotomy in the management of preulcers in a diabetic population. Another osteotomy described by Schwartz et al.,<sup>46</sup> is a double oblique lesser metatarsal osteotomy. This osteotomy in the metaphaseal diaphaseal area of the distal metatarsal is performed in an oblique manner and fixated by a simple Kirschner wire (K-wire). For a long metatarsal, the plantar cortex may be osteotomized and shortened. This osteotomy is also readily fixated by screw fixation (interfragmentary compression). Jimenez et al.<sup>47</sup> described a similar osteotomy called a transverse V-osteotomy, an oblique wedge resection osteotomy that again is amenable to screw fixation and may be performed at the distal metaphysis or as a base osteotomy in the proximal metaphysis.

### Distal V Osteotomy

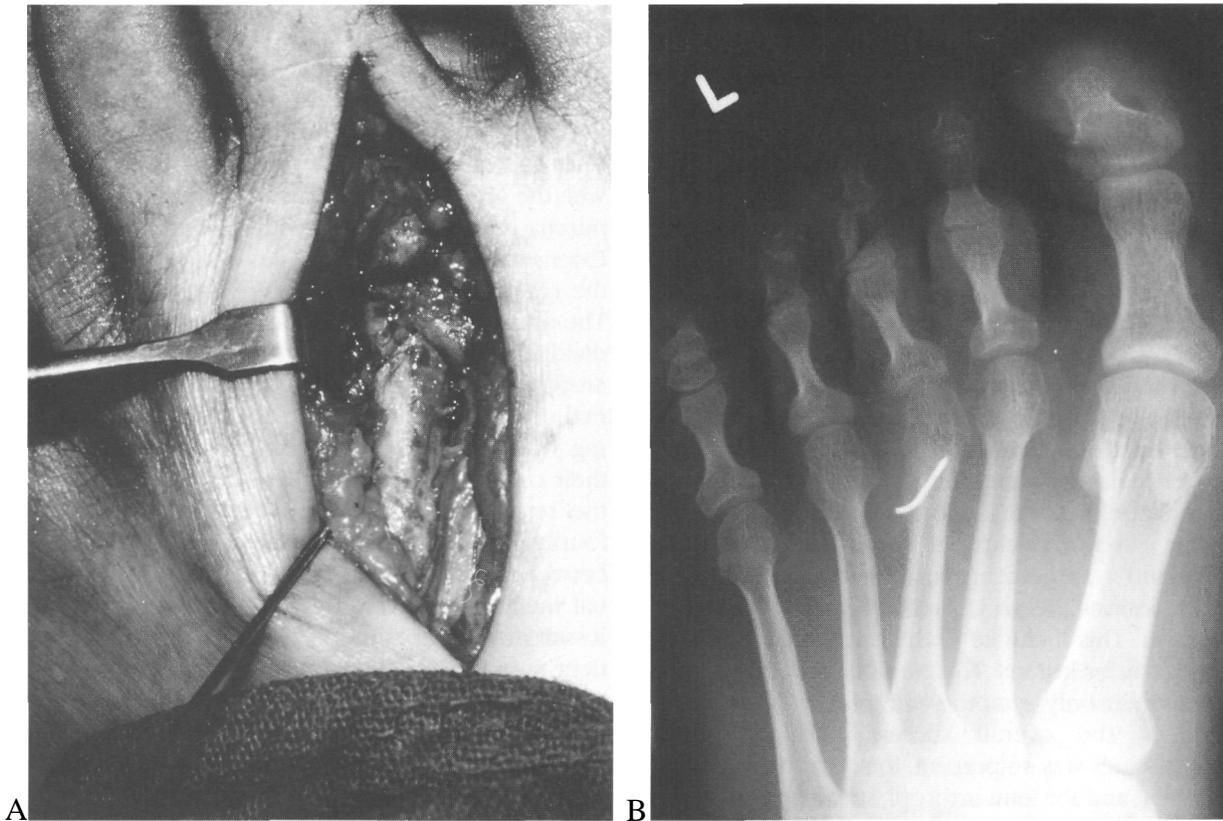
The distal V osteotomy in the podiatric profession has been attributed to Jacoby.<sup>48</sup> In the initial report, a V osteotomy was performed in the distal metaphaseal area of the metatarsal neck. The osteotomy did not extend through the plantar cortex. Two dorsal cuts were made and the bone impacted. The osteotomy was further elaborated on by Reese,<sup>49</sup> who also described the use of the osteotomy for shortening by performing a chevron resection including plantar cortical bone. Young and Hugar<sup>50</sup> reported on their study of the distal V osteotomy of lesser metatarsals in 66 patients. The procedures were uniformly performed with osteotomy completed through the plantar cortex. They reported excellent results to be obtained in 87.5 percent of 56 patients during a 2-year period. The osteotomy was performed at a 45° angle with impaction of the fragments onto the shaft. Graver<sup>51</sup> also reported on a distal V osteotomy that is oriented with the apex proximal, opposite of that described by Jacoby (Fig. 29-11).

### PROXIMAL DORSIFLEXORY OSTEOTOMY

Proximal dorsiflexory wedge osteotomy has been described by Sgarlato,<sup>52</sup> and consists of a dorsal wedge resection in the proximal metaphysis of a lesser metatarsal. Proximal metatarsal osteotomy, because of the nature and location of the osteotomy, makes a correction possible with minimal bone resection. The osteotomy usually requires internal fixation and cast mobilization postoperatively. A similar osteotomy was described by Thomas.<sup>53</sup>

### Proximal V Osteotomy

A proximal V osteotomy performed with the apex proximally has also been described by Aiello<sup>54</sup> and by Sciamberg and Lorenz.<sup>55</sup> They reported that the advantages of this osteotomy is that the V-shape osteotomy provides an excellent fit of the fragments and affords good postoperative stability. They reported a 89.4 percent rate of satisfaction. Sciamberg and Lorenz<sup>55</sup> reported the procedure to be effective with no transfer



**Fig. 29-11.** Distal V osteotomy. (A) Intraoperative view. (B) Postoperative radiographic appearance.

lesions and no subjective complaints voiced by the patients at a 6-month follow-up.

### COLLECTOMY

A resection of part of the metatarsal was described by Allen Whitney from the Pennsylvania College of Podiatric Medicine. Levine<sup>56</sup> reported on the use of collectomy or cylindrical resection of bone of the metatarsal neck in three cases. The cylindrical resection of proximal metatarsal bone 0.5 cm. in length was described by Spence et al.<sup>57</sup> The osteotomy or resection was performed by 54 patients (70 metatarsals) with a 6-year follow-up; the results were 89 percent good. Transfers developed in 18 percent; transfers were 23 percent associated with patients undergoing concurrent hallux valgus correction and 12 percent in isolated proce-

dures. The rate of recurrence was reported as 7 percent.

In this author's opinion, the two osteotomies more commonly used today are the distal V osteotomy as described by Jacoby and a variation of the tilt-up osteotomy. The distal V osteotomy is usually performed with an angulation of the arms of the V at 45 to 60 degrees. Minimal dorsal displacement is allowed, and fixation with a K-wire or other simple fixation may be utilized. Weight-bearing in the immediate postoperative phase is usually in a postoperative wooden shoe. The advantages of this osteotomy are the ease of performance and the frontal and transverse plane stability afforded by the configuration of the osteotomy. Because it is a dorsal displacement osteotomy, if unfixated it may exhibit varying degrees of instability in the sagittal plane and result in a floating toe syndrome. Minimal periarticular dissection will reduce the

amount of postoperative limitation of motion of the metatarsal phalangeal joint. The transverse V or tilt-up osteotomy allows one to use interfragment compression and in most cases no wedge of bone is removed.

Studies on the outcomes of surgical correction of intractable plantar keratosis have been reported. Hatcher et al.<sup>58</sup> reported on 238 surgical procedures of the central metatarsals with an average follow-up of 2 years and 2 months. The types of procedures evaluated in this study were the percutaneous metaphyseal osteotomy, distal V osteotomy, partial metatarsal head resection, total metatarsal head resection, osteoclasts, extension osteotomy, and extension osteoarthrotomy. One hundred patients representing a total of 238 lesser metatarsal osteotomies were studied. Although the paper did not support one procedure over another, certain conclusions were drawn. The authors reported a 18 percent rate of recurrence of symptomatic lesions and an instance of transfer lesions in 39 percent. This included both symptomatic and asymptomatic transfer lesions. That number dropped to 27 percent when only symptomatic transfer lesions are included. The overall success rate for proximal osteotomies was 46 percent, for distal osteotomies, 61 percent, and for joint arthroplastic procedures, partial head or total head resection, it was 53 percent. They did report, however, that based on the studies' criteria for an acceptable result that patients' satisfaction levels were considerably higher than the clinically observed satisfaction level. These authors recommended, in light of the low success rate of proximal osteotomies, that these osteotomies not be recommended as a primary procedure. The authors also believed that the arthroplastic procedure should not be performed unless pathology at the metatarsophalangeal joint such as arthritic changes is distinctly present. They concluded that distal osteotomies are the preferred procedure based on their findings.

The authors<sup>58</sup> reported an increasing number of acceptable results with multiple osteotomies. They indicated that consideration should be given to osteotomizing adjacent metatarsal heads if there is evidence of a lesion beginning adjacent to the primary lesion. The authors also reported better results were obtained for patients of older age and attributed this to the possibility of decreased physical activity in the older age patients.

Hatcher et al. also reported that there was a lack of toe purchase in those cases in which the metatarsophalangeal joint demonstrated limited plantar flexion postoperatively; however, this problem was not believed to affect the overall outcome of the surgery. They reported the distal V osteotomy to be associated with the greatest lack of plantar flexion and lack of toe purchase when compared with the other osteotomies. Extensor tendon tenotomy did not seem to improve the results or enhance toe purchase postoperatively. The overall decrease in metatarsal length for each individual procedure was also reported. The least amount of shortening was associated with the proximal osteotomies and the greatest amount of shortening with total metatarsal head resection. Almost half their osteotomies were of the second metatarsal, and the remainder was divided between the third and fourth metatarsals. There was no reported difference between the success rates when evaluating the individual metatarsals. Overall the average success rate for lesser metatarsal surgery was 56.5 percent, with patient satisfaction being considerably higher.

In another study by Goforth et al.<sup>59</sup> an overall success rate of 78 percent was reported for 119 osteotomies in 94 patients; 74 osteotomies were performed on the second, third, and fourth metatarsals. The distal osteotomies on these metatarsals were nonfixated distal V osteotomies or simple transverse metaphyseal osteotomies. Follow-up time in this study for the patients averaged 16.9 months. The overall results for osteotomies of the second, third, and fourth metatarsals were approximately 67 percent success. Recurrent or transfer lesions were reported as complications.

Young and Hugar<sup>50</sup> discussed the evaluation of the V osteotomy for the intractable plantar keratosis. They reported on 56 patients over a 2-year period, and on the basis of their clinical observations and patient satisfaction, 75 percent excellent results were obtained. This was defined as resolution of the original lesion with no transfer lesion. Seven patients were reported as good. Three symptomatic transfer lesions and four asymptomatic transfer lesions occurred, and 7 patients were described as having an unacceptable result. Complications included transfer lesions, lack of toe plantar flexion and purchase, and dorsal bone callus associated with the nonfixated osteotomy. They also reported that the diminished range of motion in the



**Fig. 29-12.** Complications of lesser metatarsal osteotomy. (A) Excessive shortening. (B) Excessive shortening with atrophic nonunion. (C) Poor osteotomy placement. (*Figure continues.*)



**Fig. 29-12** (Continued). (D) Poor osteotomy placement. (E) Osseous coalition of adjacent metatarsals.

digit was proportional to the amount of elevation of the distal fragment.

Reinherz and Toren<sup>60</sup> reviewed 32 patients with simultaneous adjacent metatarsal osteotomies to determine the effect of surgical location on postoperative healing. They concluded that the placement of simultaneous adjacent metatarsal osteotomies does indeed influence postoperative healing. A significant high incidence of bone callus was found when adjacent osteotomies were performed in the metatarsal neck as compared to those performed in the neck and adjacent metatarsal base. They also suggested that greater prolonged postoperative edema occurs when adjacent osteotomies are performed at the metatarsal base. It was their conclusion and recommendation that, when two adjacent osteotomies are to be performed, one should be performed in the surgical neck and the other in the metaphyseal area of the base to reduce

the possibility and consequences of the prolonged postoperative healing. Hart and Hart<sup>61</sup> reported on a case of an iatrogenic osseous coalition between two adjacent metatarsals having undergone simultaneous osteotomy; this is an unusual occurrence.

Schweitzer et al.<sup>62</sup> reported on metatarsal shortening following osteotomy and its clinical significance. Some degree of shortening may accompany different metatarsal osteotomies. Comparing the dorsoflexory wedge, osteoclasts, V distal metaphyseal, crescentic, and percutaneous metaphyseal osteotomies, the authors demonstrated that the osteotomies which produced the least amount of shortening were the crescentic followed by the percutaneous metaphyseal osteotomy and distal metaphyseal osteotomy. The greatest amount of shortening resulted with the osteoclasts procedure. The amount of shortening for the distal V osteotomy and the proximal base osteotomy

were found to be similar, falling between that of the osteoclasts and the crescentic osteotomies. The percutaneous metaphyseal, distal metaphyseal, and crescentic osteotomies revealed less than 0.2 cm. of shortening; the proximal base osteotomy and V osteotomy more than about 0.2 cm. of shortening, and the osteoclasts had slightly more than 0.3 cm. McGlamry<sup>63</sup> reported that the most common cause of the floating toe in a lesser ray is overcorrection following metatarsal osteotomy.

## COMPLICATIONS

Complications of lesser metatarsal surgery (Fig. 29-12) include the following<sup>64</sup>:

1. Recurrence of lesion and symptoms
2. Development of transfer lesions to a adjacent metatarsals because of too much elevation or shortening of the metatarsal
3. Loss of digital function as evidenced by lack of toe purchase and floating toe syndrome seen clinically
4. Loss of metatarsophalangeal joint range of motion as a result of excessive elevation of the metatarsal and of secondary degenerative changes occurring as a result of osteotomy placement or osteonecrosis<sup>65</sup>
5. Disordered bone healing resulting in the development of malunion (abnormal alignment of a metatarsal head), delayed union, and nonunion
6. Contraction of the metatarsophalangeal joint.

Fixation of osteotomies has always been left to the surgeon's preference. Fixation of lesser metatarsal osteotomies is readily achieved by a variety of simple fixation techniques including K-wire and absorbable fixation. In cases where a nonfixated osteotomy is anticipated, consideration need be given to the type of osteotomy and the compliance of the patient in the immediate postoperative period. Complications are best avoided by careful preoperative planning and assessment. Isolated metatarsal and multiple osteotomies should be performed only in the presence of the demonstrative criteria.

Prophylactic osteotomies and the management of plantar lesions associated with biomechanical problems such as hallux valgus and hallux rigidus should

be avoided because it does not address the primary etiology and thus only in the most recalcitrant lesions should this be considered as a option. With regards to the surgical management of postoperative transfer lesions, the goal is to establish normal weight-bearing relationship function and of the metatarsal heads. Management of transfer lesions may require plantarflexory or lengthening osteotomies with or without bone grafting and, in some instances, osteotomy of the adjacent metatarsals. Panmetatarsal head resection may be indicated as a end-stage salvage procedure. The cause and treatment of metatarsalgia associated with mechanical as well as structural deformities of the foot and leg is an area ripe for continuing study and research as evidenced by the diversity in classifications and treatment methods. Advances in the use of force plate analysis for the distribution of plantar pressures combined with biomechanical assessment hold promise for a better understanding of forefoot pathology in the future.

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