

# 24

## First Metatarsophalangeal Implants

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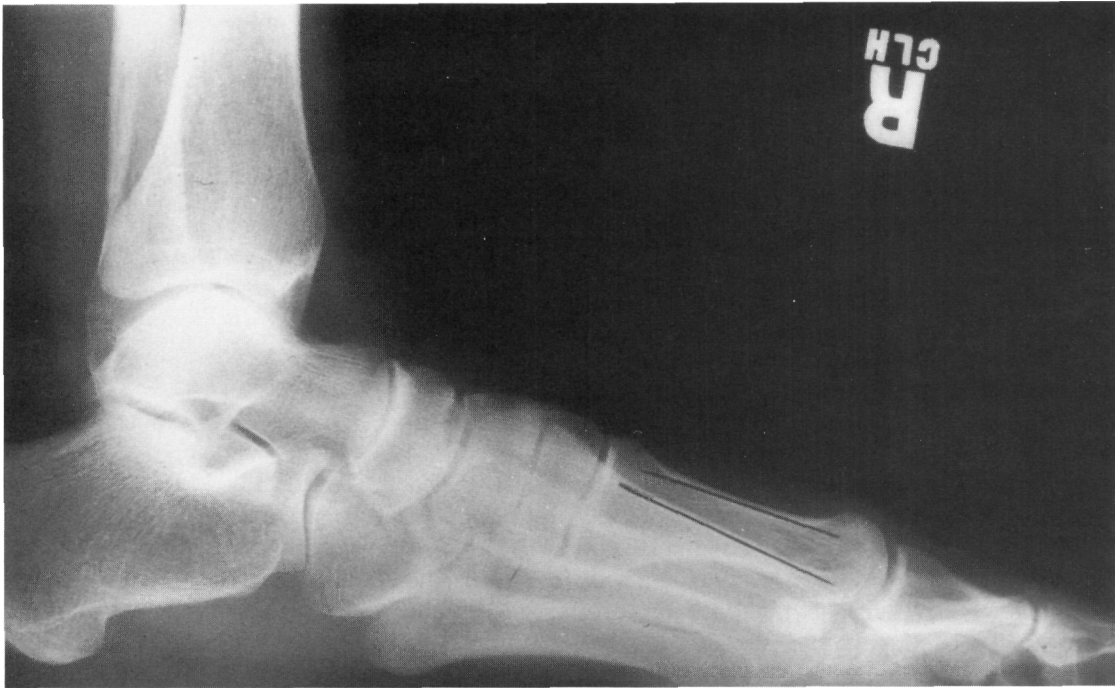
Surgical correction of hallux limitus or degenerative articular disease of the first metatarsophalangeal joint (MPJ), whether as singular conditions or in the face of concomitant hallux abducto valgus, is a dilemma with which foot surgeons have struggled with for almost a century. The ideal procedure would provide adequate pain-free motion of the first MPJ without shortening the hallux or unweighting the first metatarsal in gait, and would withstand the rigors of weight, activity, and time. The advent of the implant arthroplasty procedure utilizing silicone-based joint implants was the hopeful solution to this complex problem. After years of clinical experience, however, it has unfortunately become apparent that the silicone implant is not the panacea that many had hoped it would be. Although patient satisfaction has generally been good, complications such as material and structural failure, foreign body reaction, and short implant life span have forced many surgeons to reconsider its use. However, for a very select patient population implant arthroplasty may still be an acceptable alternative.

Before the development of the silicone implants, the only surgical alternatives available for the "unsalvageable" joint were arthroplasty and arthrodesis. Both these joint destructive procedures had their own individual inherent complications and problems. The development of the silicone implants was an effort to avoid these complications and to try to provide the patient with a functional and cosmetic alternative. The implant arthroplasty is by definition a joint destructive procedure. However, when utilizing the total joint implant, the patient is provided with a spacer to retain hallux length and functional motion for the first MPJ.

This chapter specifically addresses the implant arthroplasty as it is applied to the first MPJ. The bulk of the discussion relates to the total joint implant, although the hemi-implant is also discussed. Implant materials and designs are explained, as are the specifics of the most commonly used implants. Indications, criteria, objectives, and technical aspects of the procedure and postoperative care are also discussed, along with complications inherent to the implant arthroplasty.

### BIOMECHANICAL ASPECTS

The first MPJ is an extremely complex joint, both in its function and with regards to the multiple structures that affect it. The normal function of the first MPJ requires plantar flexion of the first metatarsal to allow dorsiflexion of the hallux. The sesamoids must also be able to glide freely to promote first metatarsal plantar flexion or dorsiflexion. First metatarsal plantar flexion is also required for the appropriate transfer of weight-bearing forces to the first metatarsal.<sup>1</sup> Simultaneously, the hallux must be stabilized by the flexor brevis and longus tendons and collateral ligaments. Transverse plane stabilization is provided by medial and lateral collateral ligaments, which limit sagittal plane motion. When functioning properly, these structures provide the joint with approximately 90° to 120° of motion, good propulsion, transverse stability, and acceptance of 50 percent of body weight. The axis remains proximal to the joint, centered in the first metatarsal head, and migrates dorsally during dorsiflexion.



**Fig. 24-1.** Radiographic example of metatarsus primus elevatus.

The fact that the axis is mobile is a key to understanding why current one-piece implant designs are unable to provide motion analogous to the original joint. The foregoing are but a few of the complexities that have frustrated attempts to reproduce normal function of the joint using modern implant designs and materials. Pathologic function of the first MPJ, or hallux limitus and rigidus, has primarily been attributed to pathomechanics in which abnormal pronatory forces act unabated in a rectus foot type. Pes planus and a long first metatarsal will result in similar pathologic function. Structural abnormalities such as metatarsus primus elevatus (Fig. 24-1) and hallux abducto valgus (also a theoretical product of pronation) are also frequently implicated.<sup>2</sup> Eccentric load of the joint eventually compromises the status of the joint and precipitates the development of premature arthritis. Regardless of cause, loss of plantar-flexory ability of the first metatarsal results in dorsal joint impingement and failure of normal dorsal phalanx gliding; tight or contracted plantar intrinsic structures ultimately occur. The excessive forces produced by the host are an effort to "buttress" the areas experiencing abnormal compres-

sion forces. Thus, the characteristic findings of dorsal phalanx osteophytes, dorsal metatarsal head osteophytes or so-called dorsal bunion, and squaring of the first metatarsal head are produced (Fig. 24-2). These structural adaptations contribute further to joint limitation and produce excessive cartilage wear and resultant osteoarthritis.

## HISTORICAL PERSPECTIVE

Attempts to reproduce joint function began with Swanson's hemi-implant design.<sup>3</sup> This procedure had hopes of improving on the weaknesses inherent in the time-honored Keller arthroplasty procedure by replacing the resected phalangeal base with a similarly shaped silicone elastomer implant. However, like the Keller procedure, resection of the base of the proximal phalanx to receive the implant resulted in destabilization of the phalanx (caused by resection of the flexor brevis/sesamoid attachment and collateral ligament), thus reducing the hallux purchase and stabilization that assist in first metatarsal plantar flexion. In addi-



**Fig. 24-2.** (A) Characteristic osteophytic lipping of the first metatarsal and proximal phalanx seen with hallux limitus. (B) Characteristic dorsal osteophytes seen with hallux limitus.

tion, excessive implant wear and eventual implant failure occurred as a result of the implant functioning opposed to irregular and abraded cartilage on the first metatarsal head. This is not unexpected as the presence of arthritis on one side of the joint would be unusual with the possible exception of the early stages following an intra-articular fracture. These factors led to dissatisfaction with hemi-implant use.<sup>4-7</sup>

Designers later attempted to reproduce function by replacing both the proximal phalanx and first metatarsal head with two separate components (e.g., Richards implant.<sup>6</sup> Unfortunately, patients frequently experienced poor transverse plane stability and hallux purchase, loosening of the first metatarsal component, and bony overgrowth of both components.<sup>7</sup> Once again, lack of hallux stability may have contributed to poor joint function, and weight-bearing on the implant (proximal portion) may have contributed to implant loosening and osteophytic production.

The advent of the double-stemmed hinge-type implant provided the transverse plane stability that had previously been lacking in other designs. However, by fixing the axis of motion to the implant, designers inadvertently extended the lever arm for dorsiflexion of the first metatarsal and this produced poor mechanical advantage to the hallux and excess stress at the stem-hinge interface. Continued demands for dorsiflexion at the hinge during dorsiflexion causes flexion and distraction of the stems from their respective stem holes.<sup>1</sup> Thus, a portion of the hinged implant motion is a result of stem pistoning and stem flexion. Efforts to fixate the stems to the proximal phalanx and first metatarsal by use of Dacron mesh resulted in excessive stem-implant interface stress and early implant fracture and failure.<sup>8</sup> Failure of the first metatarsal to plantar-flex also results in excessive transfer of body weight to the second and often third metatarsal. Thus, metatarsalgia and second and third submetatarsal tylo-

mas may result or continue similar to those occurring following Keller arthroplasties. On occasion, second metatarsal stress fractures can even result. In a study specifically addressing second metatarsalgia by Beverly et al.<sup>9</sup> a 33 percent incidence of postimplant second metatarsalgia was found. They also found a 65 percent increase of peak load to the second metatarsal in gait, with a 43 percent decrease in load to the hallux.

It is our opinion and that of other authors writing on this subject<sup>1-4</sup>, that the normal function of the first MPJ is not and cannot be reproduced by any of the implant designs currently available. Current designs function only as a flexible spacer that maintains the cosmetic length of the hallux and transverse phalanx stability. We also think that the outlook for a truly functional implant design in the future is promising but that a nonconstrained design is necessary.

## IMPLANT MATERIALS AND DESIGNS

One of the greatest challenges in the development of joint implants has been finding materials that could meet the extensive demands imposed on them by the human body. Ideal characteristics of implantable biomaterials include durability, resistance to deformity and tearing, nontoxicity, and biologic nonreactivity.<sup>3,10</sup> The ideal biomaterial should closely replicate the physical properties of the tissues that it is meant to replace. Initial endeavors involved the use of glass, ivory, metal alloys, and high molecular weight polyethylene, which were promising, given their biologically nonreactive qualities, but their extreme rigidity led to multiple complications.<sup>11</sup> Later, medical-grade silicon elastomer, often praised for its biocompatibility, and an elastic modulus similar to cartilage (Table 24-1) was used by Swanson for first MPJ implantation.

**Table 24-1. Comparison of Elastic Modulus (N/m<sup>2</sup>)**

Silastic HP <sup>a</sup>	2.1	x 10 <sup>6</sup>
Artic cart	2.3	x 10 <sup>6</sup>
Cancellous bone	1,800	x 10 <sup>6</sup>
Cortical bone	17,700	x 10 <sup>6</sup>
Titanium	120,000	x 10 <sup>6</sup>

<sup>a</sup> Dow Corning

Although the material provided the flexibility necessary for a hinged implant, its relative softness provided poor resistance to tear propagation and abrasion. Later, Dow Corning Wright developed its Silastic HP (high performance silicone elastomer), which had a higher durometer reading and elastic modulus. This increased durability reduced related complications, and Silastic is the current acceptable grade of first MPJ implantable silicon.

Silicon elastomers are the most acceptable biomaterials to date available for implantation. Early studies suggested that silicon was extremely nonreactive and that elastomers were simply encapsulated in fibrous tissue. This phenomenon does in fact seem to occur with intact blocks of elastomer. However, clinical experiences with rigid elastomers have shown that microshards are produced from abrasion and wear, and these by-products of implant wear do in fact produce host reactions. Giant cell foreign body reactions, silicon dendritic synovitis, and lymphadenopathy (ranging from 0.01 to as high as 13 percent) have all been reported in the literature.<sup>12-17</sup> Although accentuated immune reactions such as those seen in rheumatoid arthritis have been implicated in the multiple cases of foreign body reactions<sup>5</sup> they cannot account for all the immune-related complications that are reported in the literature.

Mounting concern about the use of silicon biomaterials has led to several studies that have implicated silicon in the alteration of human fibroblast cell metabolism,<sup>18</sup> direct type I and IV immunogenicity,<sup>19</sup> and T-cell activation.<sup>20</sup> Nevertheless, silicon elastomers are still the most acceptable biomaterials available for first MPJ implants and when utilized properly have an "acceptable" level of complications.

## Implant Designs

The hemi-implant, although originally a very popular design (it was introduced in 1967), is rarely used today because of limited indications. The original design (Dow Corning Wright Swanson Great Toe Hemi-implant) has a phalanx base portion that is perpendicular to the square tapered stem. Dow Corning later produced a second design (Weil modification) with a 15° wedged base portion (base of wedge lateral), which is indicated for abnormally angled proximal ar-

**Table 24-2. Implants Most Commonly Used**

Type	Material	Intrinsic ROM	Sagittal Angulation	Transverse Angulation	Makeup
* Hemi (Swanson)	Silastic/Siliflex	NLBD	NA	0°	DC
Angled hemi (Well)	Silastic/Siliflex	NLBD	NA	10°	Sutter DC
Lawrence	Siliflex	85°	15°	0°	Sutter Sutter
La Porta	Siliflex	60°	15°	10°	Sutter
+ Swanson	Silastic	45°	0°	0°	DC

*Abbreviations and symbols:* \*, Now available made of titanium; + also available with Gromet; NLBD, not limited by design; DC, Dow Corning Wright; Sutter, Sutter Biomedical, Inc.; NA, not available.

ticular set angles such as are often seen with more severe cases of hallux abducto valgus (Table 24-2).

Dow Corning Wright and Sutter Biomedical, Inc. both produce hemi-implants. The Dow Corning model is constructed of Silastic HP in five sizes (0 through 4),<sup>10</sup> with short-stemmed models designated as OS through 4S. The Weil modification hemi-implant (also Silastic HP) is available in sizes 1 through 3. Sutter Biomedical, Inc. produces hemi-implants utilizing Siliflex (a medical-grade silicone elastomer) and similar size options are available. Dow Corning Wright has also begun distributing titanium hemi-implants (five sizes). Because research and long-term follow-up studies are not available, we cannot recommend them.

At present, the primary indication for the hemi-implant is arthritis of the base of the proximal phalanx, without concomitant arthritis of the first metatarsal head or limited range of motion. In addition, the phalanx should be stable and without deforming soft tissue or bony structural stresses. Proximal and distal osseous segments must be properly aligned to prevent excessive stresses to the implant and contiguous bone.

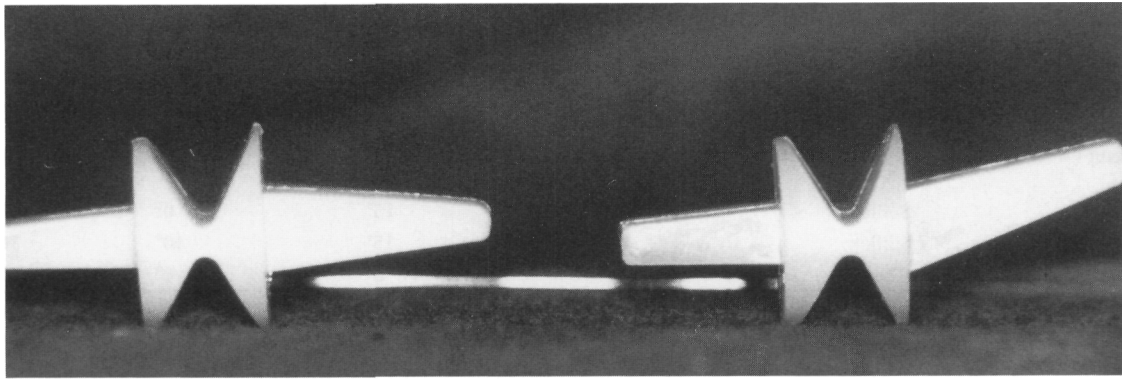
Years of experience have shown that, although patient acceptance is generally good, the implant life span can be relatively short and that a significant number of complications have arisen. Problems with implant wear and fragmentation, bony overgrowth, metatarsal cartilage wear, subchondral cysts, and poor phalanx stability have all been reported.<sup>4,6,13,21</sup> Because indications for its use are rather limited and it has a propensity for complications, the hemi-implant is rarely used in podiatry today.

The Swanson double-stem implant (total implant) was first introduced in 1974 and was the first silicone-based double-stem implant.<sup>7</sup> As currently produced,

the implant is composed of Silastic HP 100 and has long rectangular stems (proximal stem longer than distal stem) and a U shaped hinge. Eight sizes are available with the standard stem (0 through 7) and six with small stems (OS through 5S). A titanium grommet set is now also available for each size Swanson total implant. These are thin titanium shields that are press-fitted into the stem hole openings and were developed to reduce abrasion and shear forces at the stem—hinge interface; no long-term follow-up studies are available regarding the success of this innovation. The implant has no transverse or sagittal plane angulation. Although most reports in the literature suggest that the open portion of the hinge should be dorsal when placed, several authors have suggested that inverting the hinge will provide greater dorsiflexion to the hallux.<sup>22</sup>

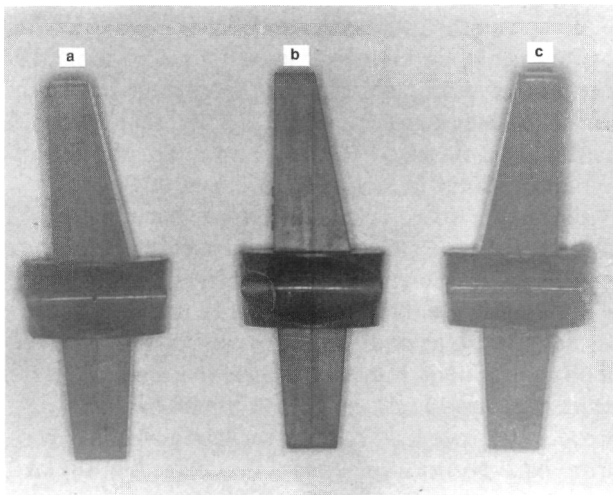
Along with the indications previously mentioned for total implants, we believe that the Swanson implant is the preferred implant for the correction of hallux varus because of its long stems and inherent rigid and stable hinge. As with other implant usage, deforming soft tissues must be removed concurrently.

Alternative total implant designs have appeared over the years. Produced by Sutter Biomedical Inc., the LaPorta and Lawrence total implants were released in 1982 and were the first centrally hinged implants to enjoy wide use in podiatry. They are both constructed of Silastic, a medical-grade silicone elastomer, and offer design modifications whose intent has been improved function. The LaPorta total implant has cylindrical base portions connected by a central horizontal flexible hinge with 60° of intrinsic motion. The stems are rectangular and tapered with the proximal stem angled 15° in the sagittal plane, which duplicates the



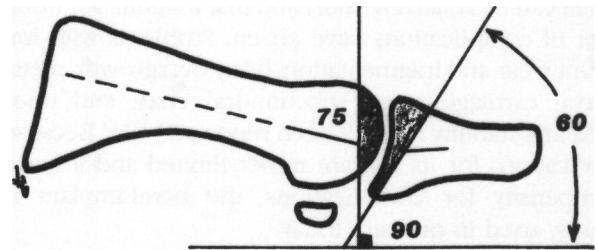
**Fig. 24-3.** LaPorta neutral (left) and standard (right with 15° sagittal plane angulation) total implants.

first metatarsal declination angle. A neutral model is also available with 0° sagittal plane angulation and is indicated for the abnormally low metatarsal declination angle seen with the pes planus foot (Fig. 24-3). A 15° transverse plane angulation is also provided that duplicates the normal anatomic hallux abductus angle (Fig. 24-4). The implant is supplied in four sizes (20, 30, 40, 50) in right left, and reversible neutral configurations. Studies have shown that approximately 40° to 50° of MPJ range of motion can be expected postoperatively,<sup>23,24</sup> and similar results can be expected with the Lawrence implant.<sup>25</sup>



**Fig. 24-4.** LaPorta total implants (a. left; b. sizer; c. right) with 15° transverse plane angulation.

The Lawrence implant is unique in its attempt to preserve the anatomic insertion of the sesamoid apparatus. It does this by angling the proximal phalanx osteotomy from dorsal distal to plantar proximal by 30° from the perpendicular (Fig. 24-5). A guide is available to accurately angle the osteotomy. The implant, like the LaPorta, has tapered square stems with a 15° sagittal plane angulation. The bases are cylindrical with a central horizontal flexible hinge boasting 85° of intrinsic motion. Unlike the LaPorta, the Lawrence has no transverse plane angulation. The implant comes in five sizes (10, 20, 30, 40, 50) and can be used on either foot. Although more technically difficult to place properly, the implant leaves the plantar intrinsics intact and has shown to maintain hallux purchase.<sup>25</sup>



**Fig. 24-5.** Proper osteotomy orientations for the Lawrence total implant.

**Table 24-3. Indications for Implant Arthroplasty<sup>a</sup>**

Structural hallux limitus/rigidus
Hallux abducto valgus with degenerative arthritis
Painful osteoarthritis
Inflammatory arthritides
Posttraumatic arthritis
Hallux varus with degenerative arthritis
Unstable hallux (flail toe)

<sup>a</sup> The indications listed assume that the joint is not amenable to primary correction (i.e., unsalvageable).

## INDICATIONS AND CRITERIA FOR IMPLANT USE

Dysfunctions of the first MPJ, such as hallux limitus/rigidus, severe degenerative joint processes, or destabilization of the hallux are the primary indications for implant arthroplasty procedures (Tables 24-3 and 24-4).<sup>26</sup> These conditions may present alone or, more commonly, in conjunction with other pathologies of the first MPJ.

Hallux limitus (and hallux rigidus), for the purpose of this discussion, will refer to structural hallux limitus as opposed to functional hallux limitus. Functional hallux limitus is not an indication for implant arthro-

plasty, because the articular cartilage is still intact and joint preservation procedures are thus preferred. Great attention should therefore be placed on discerning functional from structural limitations. Structural hallux limitus and hallux rigidus can be caused by several pathologic conditions (see Table 24-4). Most commonly, osteophytes at the base of the hallux and on the dorsum of the first metatarsal head limit motion by bony abutment during dorsiflexion. Concomitant osteoarthritis is frequently seen in these areas of excessive stress. Structural metatarsus primus elevatus (or a long first metatarsal) can also limit first MPJ motion, as discussed in the biomechanics section. Adhesions of the sesamoid apparatus to the plantar aspect of the first metatarsal head, often caused by chondral erosions, can also limit motion. Iatrogenic hallux limitus following procedures addressing the first MPJ is not uncommon and is frequently the result of fibrous adhesions, tissue contractures, and malunion of osteotomies.

The multitude of procedures available to address hallux limitus/rigidus (Table 24-5) can be divided into two categories: salvage procedures and joint destructive procedures. Determination of joint salvageability is based on the severity of the symptoms experienced by the patient, the physical and radiographic findings, and the actual intraoperative findings. In general, severely painful joints with significant chondral wear and osteophytes are candidates for implantation. However, the etiology of the limitus should be identified and correctable if implant use is to be considered. Ultimately, the surgeon is the one to decide when implantation is warranted.

Osteoarthritis and rheumatoid arthritis are the most common arthritic conditions for which the implant arthroplasty may be indicated (Fig. 24-6). Gout and other inflammatory arthritides on rare occasions may also warrant implantation, but to a far lesser degree than osteoarthritis or rheumatoid arthritis.

The primary objective when considering implantation for arthritic conditions or hallux limitus is the return of function and the relief of chronic pain (Table 24-6). Relief of pain is the objective most easily obtained. However, when considering implant arthroplasty for the correction of hallux varus, severe subluxation secondary to hallux abducto valgus (HAV), or flail hallux (following Keller arthroplasty), the objective becomes stabilization of the hallux. Correction of

**Table 24-4. Cause of First Metatarsophalangeal Joint Dysfunction**

Hallux limitus/rigidus
Functional
Functional met primus elevatus (MPE)
Pes planus
Structural
Structural MPE
Sesmoid abnormalities
Osteophytes
Previous MPJ surgery
Long first metatarsal
Arthritides
Inflammatory
RA
SLE
Psoriatic
Gout
Degenerative
Osteochondritis
Posttraumatic
Neurotrophic
Stabilizing influence
Hallux varus
Flail toe following Keller
Hallux extensus
Subluxed hallux with severe hallux abducto valgus

**Table 24-5. Alternatives to Implant Arthroplasty for Treatment of Hallux Limitis/Rigidus**

Type	Advantages	Disadvantages
Salvage procedures		
Osteotomy procedures	Salvage procedure	Recurrence Technically difficult
Enclavement (Renault)	Salvage procedure	Recurrence Avascular necrosis NWB postoperatively
Cheilectomy	Salvage procedure Technical ease	May recur
Joint destructive procedures		
Arthroplasty (Keller)	Less complications Technical ease	Shortens phalanx Second Metatarsalgia No motion
Arthrodesis	Technical ease	Potential for nonunion/malunions Transfer weight/motion

Abbreviation: NWB, non-weight-bearing.



hallux varus using the total implant should only be considered if degenerative articular processes have developed or if soft tissue corrections would result in a severely unstable hallux. All efforts should be made to salvage the first MPJ if at all possible. Soft tissue corrections must be able to fully balance musculotendinous and capsular influences before implant insertion. Improvement of the flail hallux can be achieved using the total implant as a stabilizing force and as a spacer. However, the surgeon should proceed cautiously, because lengthening of neurovascular structures by implant placement might cause a vascular compromise and ultimately threaten the viability of the hallux.

Use of the implant to stabilize the hallux following correction of a subluxed hallux (usually secondary to HAV) should only be considered if articular surfaces have been irreparably damaged. As with hallux varus, all efforts should be made to salvage the joint when possible. If implantation is necessary, then the surgeon must be able to neutralize all deforming soft tissue and structural influences. In particular, an abnormally high intermetatarsal angle (usually seen with severe HAV) must be corrected if an implant is to be used. If the patient is not a candidate for the appropriate base procedure, the implant should not be used.

Fig. 24-6. Preoperative radiograph. Note subchondral sclerosis and osteophytes indicative of osteoarthritis.



**Table 24-6. Functional Objectives**

Functional/pain-free motion
Stability
Cosmetic length
Durability

Because the hemi-implant replaces only the base of the proximal phalanx and provides no inherent stability, the authors believe that it is only indicated for posttraumatic arthritides affecting only the base of the hallux. Use for degenerative arthritis is rarely indicated because these processes usually involve wear to both chondral surfaces. Use in the treatment of hallux limitus is not usually indicated, given that surgical remodeling of the first metatarsal head is frequently required, resulting in rough osseous surfaces would rapidly abrade a hemi-implant and likely provide poor motion. Use of the angled (Weil) hemi-implant to correct severe HAV with a subluxed hallux is not advisable if the angled portion is to be used to "buttress" the hallux into the correct position. If the joint is arthritic, then a total implant would be advisable. If the joint is not arthritic, the appropriate osteotomies and soft tissue procedures should be performed to properly correct the HAV deformity.

Once it has been determined that an implant is indicated, then the surgeon must determine if the patient meets the criteria required for implant use (Table 24-7). Evaluation of the bone stock and musculotendinous balance is of particular importance. Soft bone stock or cystic subchondral spaces lack the mechanical support necessary to stabilize the implant, an area of particular importance with the rheumatoid or sedentary elderly patient. When a musculotendinous imbalance is present it must be correctable; if it is left

**Table 24-7. Criteria for First Metatarsophalangeal**

**Joint Implant Use**

Adequate bone stock
Adequate soft tissue strength
Adequate neurovascular status
Adequate skin coverage
No allergy to implant material
Intermetatarsal angle <12-14 (or correctable deformity)
Correctable musculotendinous capsular imbalance
No active infection for 6 months
Adequate immune function

**Table 24-8. Ideal Patient**

Not overly obese or large
Sedentary life-style
Older
Realistic expectation
Intact immune system
Apropulsive gait

uncorrected, the abnormal forces could lead to permanent plastic deformation, poor implant function, or even early implant demise.

In addition to the physical criteria required for implant use, the surgeon must also consider the patient population for which implants are acceptable (Table 24-8). The total implants currently available, although durable and reliable, will not withstand the demands of overly obese, large, very active, or athletic patients nor should an implant be expected to last more than 10 to 15 years. Therefore, when considering implantation, the ideal patient should be moderate in weight and size, have an apropulsive gait, and have a relatively sedate life-style. Patient expectations should be realistic with regards to function and expected life span for the implant. The prospect of additional surgery in the future to replace or remove a failed implant should also be clearly explained to the patient, as well as the possibility of requiring orthotic devices to promote proper foot function.

Special consideration should be given to the use of implants in rheumatoid patients because of the increased incidence of complications.<sup>27</sup> Findings of dendritic synovitis, infection, giant cell reactions, and poor bone stock secondary to chronic steroid use have all been reported. Therefore, patients should be very well informed as to possible complications before considering implantation.

**TECHNICAL CONSIDERATIONS OF IMPLANT SURGERY**

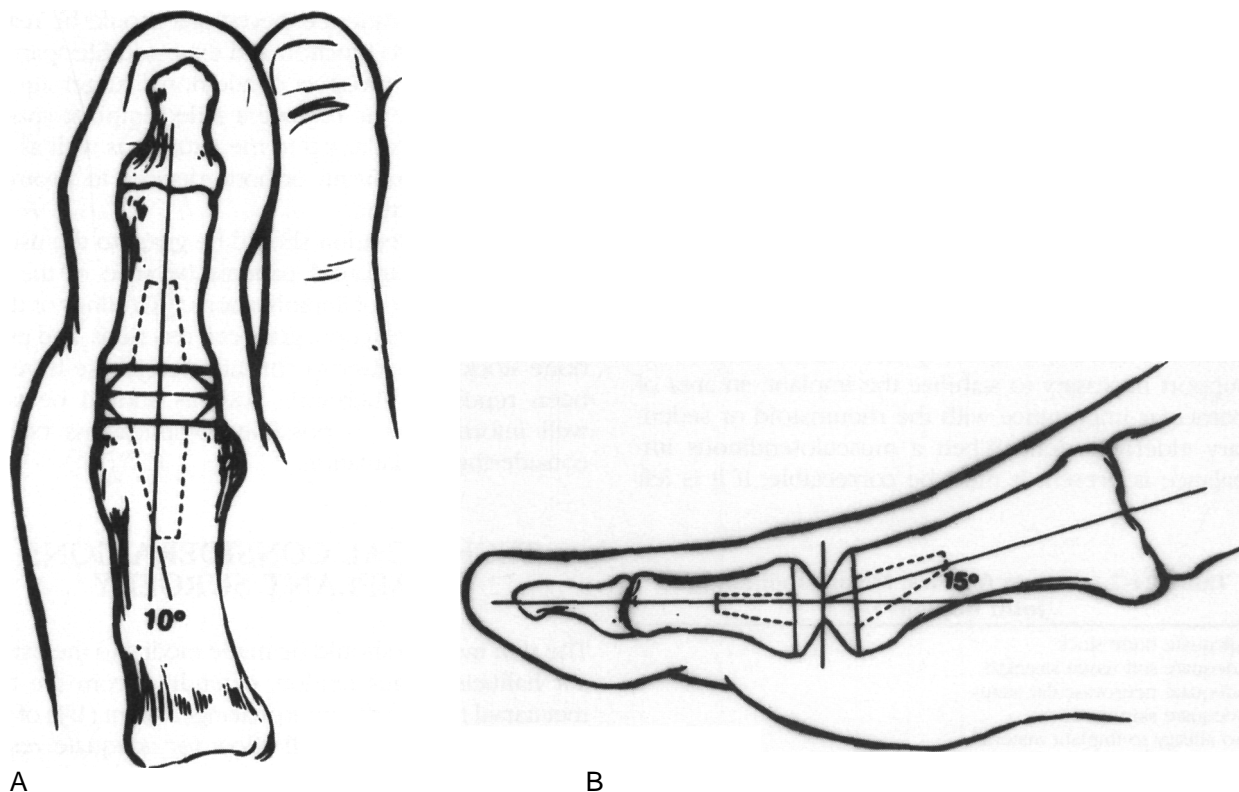
The skin incision should be made medial to the extensor hallucis longus tendon, extending from the first metatarsal neck to the interphalangeal joint (IPJ) of the hallux. This exposure will allow for adequate resection of the proximal phalanx base and remodeling of all portions of the first metatarsal head. At this point, correction of any HAV, metatarsal primus adductus, or

metatarsal primus elevatus should be completed. Once HAV correction is completed, and hallux should be able to sit in the corrected position without undue deforming stress from lateral capsular structures, tendons, or skin. Excessive abductory force from soft tissue structures will subject the implant to transverse plane stress, which could inhibit pistoning (and thus limit motion) and lead to permanent deformation or fracture of the implant.

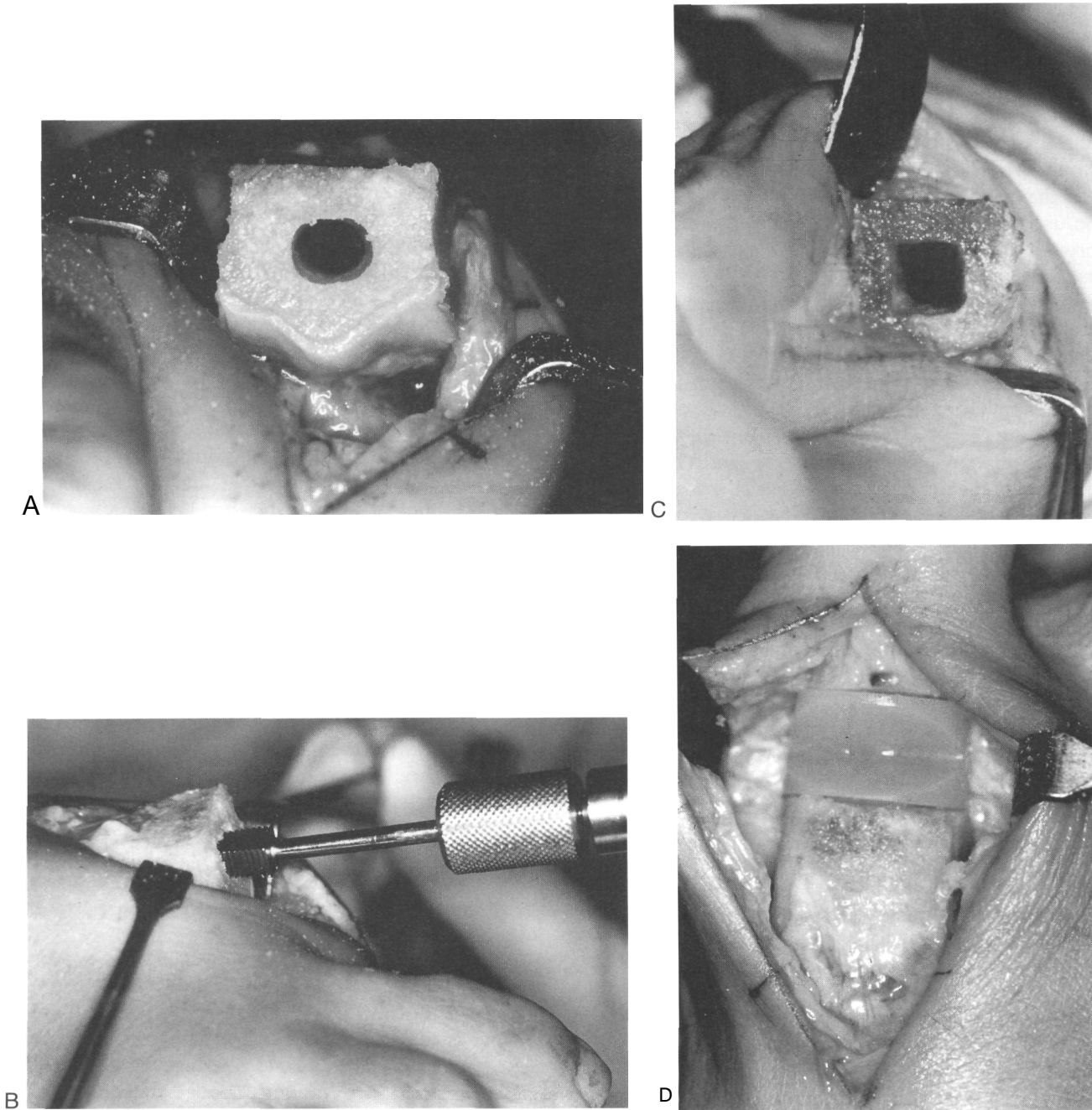
While the hallux is held in the corrected position, the base of the proximal phalanx is then resected so that the osteotomy will provide appropriate transverse and sagittal plane orientation for the given implant. If using the Lawrence total implant, the osteotomy angulation guide should be used to properly orient the osteotomy in the sagittal plane. In general, the amount of base being resected should be slightly greater than the base portion of the implant. The excess resection

distance allows for pistoning of the implant and slacking of soft tissue structures. The base is then dissected free, taking care to preserve the plantar intrinsic structures and flexor longus tendon. Bone quality of the proximal phalanx can now be assessed, and if necessitated by excessively soft or cystic medullary bone the procedure can be converted to a Keller procedure. A portion of the distal first metatarsal head is next resected. The osteotomy should be distal to the sesamoid articulation, but it should be proximal enough to provide a flat stable surface for the implant to rest upon. Bone quality should again be evaluated to ensure adequate stock for implant placement (see Figs. 24-5 and 24-7).

The sesamoids should now be investigated to ensure that they articulate properly with the first metatarsal head and are not overly arthritic or adherent to the metatarsal head. If the sesamoids are overly



**Fig. 24-7.** (A & B) Proper placement of LaPorta total implant. Osteotomies are perpendicular to weight-bearing surface.



**Fig. 24-8.** (A) First metatarsal head after osteophyte resection (dorsal, medial, and lateral) and initial stem hole. (B) Medullar reaming with manual broach squares corners of stem hole. (C) Stem hole after medullar reaming with broach. (D) Proper placement of LaPorta implant and appropriate remodeling of surrounding bone. (Note that no bone extends past the edge of implant.)

arthritic, the surgeon may elect to resect them, but he should be conscious of the potential ramifications on short flexor function and ultimately joint stability.

Stem holes can now be fashioned in the proximal phalanx and first metatarsal using a side-cutting burr (four corners). Once the hole is the appropriate depth and diameter, a square broach (manual or power) can be used to square the corners of the hole; this will provide a more exacting stem hole that will assist with rotational stability of the implant.<sup>28</sup> The broach is intended to enlarge and square previously drilled holes and should not be used to deepen a shallow stem hole (Fig. 24-8).

Great care should be taken in the orientation of the proximal phalanx stem hole. The shaft should be parallel to the dorsal cortex of the phalanx and biased to the dorsal aspect of the osteotomy site. The natural plantar concavity of the phalanx and first metatarsal neck place the plantar cortex at risk of being violated if the surgeon orients the stem hole too plantarly. Violation of the plantar cortex may cause inadequate distal stem stability, increased stem abrasion and wear (secondary to pistoning abrasion), fracture of the plantar proximal phalanx cortex, and irritation of surrounding soft tissues. Careful attention must also be given to the coronal plane orientation of both stem holes. Medial and lateral walls should be perpendicular to weightbearing surfaces to place the hinge horizontal and to prevent torsional forces between the hallux and the first metatarsal.

The surgical site should then be copiously lavaged with a physiologic solution to remove debris created by surgery. Antibiotics may be added to the solution at the discretion of the surgeon, based on host risk factors and any previous breaks in sterile field. As with any joint replacement procedure, prophylactic antibiotics seem best advised. Topical antibiotics remain at the discretion of the operating surgeon.

Acetate implant template sheets can be used preoperatively to estimate which implant size is likely to be required.<sup>10</sup> This is also an excellent illustration for informed consent. Implant sizers can now be used to determine the appropriate size for the arthroplasty site. More accurate sizing lessens the chance for implant size-related complications.

Once placed, the implant should flex and extend freely, and stems should glide freely within the stem holes and should not bind within the hole. The bases

of the implant should bridge both cortices, and no bone should be lipping the implant edge. If the implant is too small, it may telescope into cancellous bone. Hallux position should also be evaluated at this time to ensure that both the transverse and frontal plane orientations are appropriate. Larger sized implants are less likely to be compromised by bone overgrowth. However, larger sized implants require greater bone resection, and if adequate bone resection is not achieved, the motion may be compromised. If stem holes are too tight or if excess bone overlaps the implant base, these conditions should now be modified. Continue to try implant sizers until appropriate motion, position, and bone modeling are achieved. The surgical site should again be copiously lavaged and cleansed of debris.

The appropriate sized implant can now be opened and rinsed in sterile solution (antibiotics are optional) to eliminate any static charge that the implant may carry. The implant should be handled only with atraumatic, toothless forceps to avoid any damage to the implant. All contact with gloves, paper, or linen should be carefully avoided so that no foreign material is carried into the implant site; foreign material such as glove powder, paper fiber, or lint could cause a foreign body reaction. Foreign body reactions often attributed to the implant are in reality reactions to some material that has inadvertently made its way onto the implant during the handling process. Contact with skin edges should also be avoided as this is a potential source of bacterial contamination. If grommets are to be used, they should now be press-fitted into their respective stem holes. Placement of a double-stem implant is easiest if the proximal stem is placed first and the distal stem is then plantar-flexed into the hallux stem hole.

Once placed, the implant should again be tested for proper function. The foot should be loaded in the position of function and again tested for motion. If the implant is functioning properly, the capsule can be closed. Again, function should be evaluated to ensure that capsular closure has not impeded function. Skin closure can then be accomplished and the surgical site dressed. Emphasis should be placed on bandaging of the phalanx in the proper transverse position with compressive dressings to reduce postoperative edema. Postoperative radiographs should be taken on the day of surgery to ensure correct implant placement (Fig. 24-9).



Fig. 24-9. (A) Radiograph of properly placed Swanson implant. (B) Radiograph at first postoperative visit. Note that base procedure was required to fully correct metatarsal primus varus and hallux abducto valgus.

### TECHNICAL ASPECTS OF FIRST METATARSOPHALANGEAL JOINT IMPLANT ARTHROPLASTY

The surgical objectives of the implant arthroplasty should be consistently implemented to reduce avoidable complications. These objectives (Tables 24-9 and

**Table 24-9. Technical Objectives of Procedure**

1. Appropriate skin and capsular incisions
2. Complete correction of deforming soft tissue structures
3. Adequate resection of bone with proper orientation
4. Complete correction of structural abnormalities (i.e., IM angle)
5. Proper orientation of stem holes
6. Atraumatic sterile handling of implant
7. Evaluation of function before and during closure

24-10) cannot prevent all potential complications, but they will help avoid correctable problems that consistently lead to implant failures and complications.

### Intraoperative Complications

Complications may arise intraoperatively that would require modification of the procedure or even contraindicate the use of an implant.

The finding of cystic or excessively soft medullary bone is a contraindication to any implant use. Inadequate cancellous strength will lead to failure of the stem holes and result in poor implant stability, failure to maintain proper phalanx position, and potential implant dislocation. The use of bone grafts to pack cystic areas has been suggested. However, we believe this is not advisable because the immobilization required for

**Table 24-10. Key Points of Procedure**


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Proper skin incision placement
Careful capsular reflection from first metatarsal head and proximal phalanx base
Complete release of deforming forces
Adequate resection of articular surfaces with careful attention to orientation of cuts
Remodeling first metatarsal head as required
Fashion stem holes; careful attention for orientation
Evaluate implant function and size with sizer; flush copiously
Place implant atraumatically; correct as necessary
Evaluate, modify, and close capsule
Close skin

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proper graft incorporation would seriously compromise rehabilitation of the surgical site.

During resection of the phalanx base, the inadvertent laceration of the flexor longus or flexor brevis tendon may occur. Should this happen, it is imperative that the tendon be sutured to its distal end to prevent total loss of hallux purchase and an eventual hallux valgus. A nonabsorbable suture should be used.

Improper orientation of the stem holes or osteotomies may be corrected by reorientation of the inappropriate osteotomy(ies) of stem hole(s). However, if this would result in overresection of bone or overly large stem holes (and thus an unstable implant site), the surgeon may wish to abandon the attempt at implantation. In some cases, switching to a larger implant may correct the instability. However, this option also carries potential complications and has limitations.

If the proximal phalanx is too short to accommodate a given implant stem length, then the surgeon may alter the implant by cutting the stem to the appropriate length. This is the only alteration that may be made on the implant by a surgeon, and even this may cause increased silicone fragmentation and microfractures. Excessive shortening of the stem should be avoided in that it could produce poor implant stability and potential implant dislocation.

If lapses in sterile technique occur, the authors recommend that the surgical site be lavaged with antibiotic solutions, and the patient should be given prophylactic antibiotics if not given previously. In the case of suspected contamination, antibiotics should be continued for 24 to 48 hours after surgery. This is in contrast to the perioperatively administered one dose of antibiotics recommended for prophylaxis. If the surgical site is grossly contaminated, the surgeon may wish to de-

lay implantation for a minimum of 6 months, or until such time that further documentation as to the sterility of the implantation site can be assessed and assured.

Finally, if the implant fails to function properly once placed, then the surgeon must determine the cause. Failure to resect adequate bone or an implant that is too large often causes difficult or inadequate motion.

Failure of the implant to piston, which can limit joint motion, has several causes. Stem holes that are too small will bind the stems once pressed into the cancellous bone and prevent pistoning. Overzealous medial capsulorrhaphy and closure during the course of HAV correction also can limit pistoning and should be avoided. As mentioned earlier, adequate soft tissue releases and structural correction must be completed before implantation. Otherwise, excessive stresses placed on the implant will limit function and lead to increased complications and decreased implant life span. The presence of structural metatarsus primus elevatus can also limit implant/toe dorsiflexion.

Once capsular closure is completed, it is imperative that the foot be loaded in a position where the foot is likely to function, in that functional metatarsus primus elevatus may also occur and impeded function.

Recognition of complications intraoperatively and immediate correction of these problems will provide the patient with a more functional foot and the surgeon with a more consistent and reliable result.

### Postoperative Management

In general, postoperative management of an implant arthroplasty site should consist of weight-bearing for 3 to 6 weeks in a postoperative shoe, with the first dressing change at 3 to 7 days and suture removal at 14 days. Both passive and active motion should be started as early as possible. Return to normal shoe gear can begin as soon as patient tolerance will allow.

Immediately following surgery, there are three general areas of concern. First, range of motion should be instituted as early as possible to retain the motion increase achieved at the time of surgery. The patient should be instructed preoperatively in passive range-of-motion therapy and can then begin at home as soon as pain tolerance allows. Eventually, continuous passive motion (CPM) devices will assist with this process. If patient compliance is in doubt, the surgeon may wish to begin a formal physical therapy regimen soon

after surgery. The patient should return to flexible weight-bearing shoe gear to promote joint mobilization as early as possible. The vital role of postoperative physical therapy is appreciated with most implant arthroplasty techniques. It is especially important in those patients whose medical conditions predispose them to excessive fibrosis postoperatively, such as in the psoriatic arthritis patient.

Second, aggressive management of potential edema should include compressive dressings (e.g., Coban, Tubigrip), emphasis on postoperative limb elevation, and avoidance of prolonged dependent periods; the use of cryotherapy and nonsteroidal anti-inflammatory medications may even be indicated. Failure to control immediate postoperative edema may lead to prolonged edema, increased fibrosis, and slower joint rehabilitation. A high index of suspicion for early complications, including hematoma, infection, and dislocation, should be maintained.

During the immediate postoperative period, if there are clinical signs and symptoms indicative of a hematoma (Table 24-11), immediate action should be taken. The presence of a hematoma greatly increases the chance of infection and wound complications. In the early postoperative period, the hematoma can be extravasated through the closed wound with gentle manual pressure. A syringe with a large-bore needle can also be used to aspirate focal hematomas, following strict adherence to sterile technique and with consideration for antibiotic prophylaxis. If the blood has clotted, however, extravasation and aspiration are of limited value. If the hematoma is discovered after clotting has occurred, then conservative measures such as heat compression and physical therapy may be used to accelerate the body's normal enzymatic and regenerative processes. If the hematoma is severe or slow to resolve, the surgeon may wish to reenter the surgical site and perform an aggressive sterile wound evacuation.

The best way to handle hematomas obviously is to prevent their occurrence. This can be accomplished

by use of meticulous hemostasis intraoperatively, release of pneumatic cuffs before wound closure, and even the use of wound drainage systems. The use of gravity or capillary action drains is not recommended because retrograde flow could contaminate the surgical site. Use of closed pressurized systems has been advocated by several authors,<sup>29,30</sup> although we would caution the surgeon to use careful sterile management of such drains, as they provide potential bacterial portals directly to the implant site.

Infection is probably the most dreaded complication of implant surgery, and as such deserves a high index of suspicion, especially during the early postoperative period. Follow-up visits should always include oral temperature and examination of the surgical site for drainage or pus, elevated skin temperature, cellulitis, lymphangitis, or lymphadenopathy. If in doubt, the surgeon should obtain a complete blood count (CBC), sedimentation rate, and radiographs. Diagnosis and management of postoperative infections are discussed in the complications section below.

If dislocation occurs, it will likely happen in the early postoperative period. Whether caused by trauma, improper implant size, or the failure of soft tissue or bone to adequately contain the implant, dislocation is always a potential complication. When suspected, dislocation can usually be diagnosed with both physical examination and radiographs. The physical examination will usually show poor or no implant motion, deformity, and possibly pain; the radiograph will likely show displaced implant stems or malposition of the hallux. To correct dislocation, the surgeon may try closed manual reduction under anesthesia. However, this is unlikely to be successful. Open surgical relocation or replacement or removal of implant is usually required after dislocation and should be performed as soon as possible after diagnosis of the dislocation.

Implant Compications

As any other surgery, the implant arthroplasty procedure is subject to potential complications. The implant procedure may be subject to a greater variety of complications because it involves introduction of a foreign body and intrinsic complex demands.

In an effort to logically organize these complications, classification systems have been devised. Vanore

Table 24-11. Hematoma Signs and Symptoms

- Edema
- Tense or fluctuant surgical site
- Ecchymosis (plus or minus)
- Disproportionate pain

et al.<sup>31</sup> have devised the most widely used system, which separates the complications into four basic areas: problems with the implant itself, alignment problems, tissue problems (soft tissue and bone), and functional problems.

Intrinsic implant failures are those resulting from failure of the implant structure because of environmental stresses. Although silicone is designed to resist permanent deformation and fracture, long-term stresses can surpass the capability of the material. Deformation of the stem or articular surfaces of hemi-implants can result from long-term compressive or torsional forces.

Fatigue fractures of implants are also caused by long-term stresses. Hemi-implants tend to fracture at the base portion or at the stem-base interface, and total implants tend to fracture at the stem-base interface or at a central hinge. Implant fractures such as these have sometimes been difficult to determine from plain radiographs. However, recent studies of fractured MPJ implants have shown that magnetic resonance imaging (MRI) can be very valuable in evaluating implant conditions.<sup>32</sup> The most common intrinsic failure of implants is that of microfragmentation. Even with the advent of the tougher silicone elastomers, it has become apparent that microfragmentation is unavoidable.<sup>33</sup> Given that almost all implants experience some stem pistoning with the stem and base in contact with bone, abrasion of silicone into microfragments can be expected. While in the "solid block" state, silicone is a very nonreactive material that is uneventfully encapsulated<sup>21,33,34</sup> by fibroblasts and collagen. However, microfragments of silicone (10-100  $\mu$ m) do produce multinucleated giant cell and inflammatory reactions. The effects of these silicone microshards are discussed in the section on tissues. Extrinsic implant failures or structural failures from intraoperative physical insults are almost always iatrogenic. Whether accidental or intentional, any alteration to the implant can lead to microtears that propagate and result in gross fracture or failure.

Alignment problems with implants can be caused by muscle imbalances or improper surgical orientation. Muscle imbalance usually manifests itself in the sagittal plane in the form of hallux extensus. When the extensor hallucis longus overpowers the flexor tendon(s), an extensus results. Evaluation of extensor contractions should be accomplished at the time of implanta-

tion and corrected as necessary. However, because intrinsic flexor ability can be disrupted in the process of implantation, hallux extensus may not present until postoperative ambulation has begun. In these cases, a second surgery to balance the tendon or arthrodesis of the hallux IPJ may be required. Extensus deformities can also result from improper osteotomy orientations. Plantar contractures or plantar-flexed orientation of the hallux are relatively rare and usually result from iatrogenic malpositioning of the proximal implant stem.

Transverse plane malorientation is a problem primarily associated with hemi-implants and is usually caused by imbalance of tendinous or capsular structures. Recurrent hallux abductus is typically caused by inadequate correction of metatarsus primus varus or tight lateral capsular structures. Hallux adductus (varus) is usually caused by overzealous medial capsulorrhaphy. Transverse malorientation is infrequently seen with the total implants, and when it occurs usually results from improper stem hole or osteotomy orientation.

Frontal plane deformities are not a frequent problem, especially when a total implant is used and the stem holes are squared and properly oriented with a manual or power broach. However, oversized stem holes can allow stems to rotate, even in square holes. Therefore, careful attention must be given to proper implant and stem hole sizes intraoperatively.

Tissue problems, both soft tissue and osseous, can be divided into three subjects: infection, host reactions to silicone, and sequelae of the stress of implantation or implant function. Although the incidence of implant infection is similar to that of other lower extremity surgeries (0.38-2percent),<sup>6,30,35,36</sup> its occurrence can seriously affect the final surgical outcome. Because the body has a drastically reduced tolerance to infection when a foreign body is present (reduced from  $10^5$  to  $10^2$  bacteria/mm<sup>3</sup>), the presence of infection may necessitate implant removal.<sup>22</sup>

Infection presentation and its diagnostic picture are best divided into two timeframes, early infection and delayed infection.<sup>36</sup> Early infection, which presents in the first postoperative month, must be differentiated from hematoma and wound dehiscence, which may exhibit similar signs and symptoms. However, the presence of cellulitis, lymphangitis, increased pain, elevated sedimentation rate, and white blood cells



(WBCs) with left shift are all suggestive of infection. Radiographs and radionucleotide studies are generally of little value in this immediate postoperative stage, although some authors have reported increased ability to differentiate infection from surgical sites that are not infected by more specific bone scanning techniques. This is discussed at greater length below. Wound dehiscence, if it occurs, must be differentiated from infection, and deep wound and tissue cultures are a must. Careful investigation of dehiscence sites must be undertaken to determine if sinus tracts or portals to the implant exist. Any exposure of an implant to air in a dehiscent or infected wound would mandate removal. If soft tissue infection exists, but is not suspected of extending to the deeper planes, it may be treated with appropriate antibiotics, local wound care, and debridement. Antibiotics should address *Staphylococcus aureus* and *S. epidermidis*, and if prophylactic antibiotics were given, it must be assumed that the offending organisms are resistant to the original antibiotic.

Delayed infections, which can present at any time after the first postoperative month, can be diagnostically challenging. Recent potential causes for bacteremia, such as occurs with certain dental procedures, need to be ascertained. Infection must be differentiated from allergic reactions (i.e., dendritic synovitis or bone inflammation), osseous fracture, osseous proliferation and impingement, and implant malfunction or failure.

Soft tissue infections generally present with new pain, edema, erythema, and possibly lymphangitis. The laboratory tests mentioned earlier may be helpful in differentiating infection from synovitis and implant malfunction. Any presenting sinus tracts or ulcers must be carefully evaluated and differentiated from other pathologies that can produce draining tracts such as rheumatoid nodules or tophaceous gout. Cultures from sinus tracts are notoriously inaccurate in representing actual pathogens, and therefore they should be treated as dubious laboratory information. The use of the radionucleotide indium-111, which has been recommended by multiple studies, has the advantage of being both very sensitive and specific for infection.<sup>37,38</sup> Gallium, which binds nonspecifically to plasma proteins and WBCs,<sup>39,40</sup> can produce a positive scan with many inflammatory situations and thus is falling into disfavor for diagnosis of infections.

If soft tissue infection is suspected, then attempts to obtain cultures should be undertaken. Tissue cultures are likely to provide the most accurate picture of the pathogens involved. If these are not obtainable, aspirations from the site or even blood cultures may be attempted. However, these have very poor yields of pathogens. As for any soft tissue infection, appropriate antibiotic and local wound care should be begun immediately, and surgical debridement and implant removal may be required.

Diagnosis of osteomyelitis, acute or chronic, following prosthetic implants is a difficult task. Because evidence of frank osteolysis or cortical erosions can be difficult to discern around nonfixated implants, plain radiographs are often of little help. Until recently, accurate evaluation of bone around an implant usually required a bone biopsy. Increased experience with radionucleotides and MRI have provided the surgeon with relatively accurate noninvasive diagnostic information. Accuracy of diagnostic ability when combining indium-111 with technetium-99 has been reported as 93 percent (versus 70-75 percent for technetium/gallium, 58 percent for aspiration, and 48 percent for plain radiographs),<sup>37,38</sup> with 100% sensitivity for indium alone (25 percent for gallium).<sup>40</sup> These studies were conducted on large fixated orthopedic prostheses, however. It is foreseeable that similar results could be expected for first MPJ prostheses. Use of MRI to diagnose osteomyelitis is becoming more popular and, with increased experience and research, should be a valuable diagnostic tool. If osteomyelitis is diagnosed, then implant removal and appropriate debridement are mandated.

Use of prophylactic antibiotics with implants is an area of considerable controversy. Research specifically addressing first MPJ implants has shown that infection rates necessitating implant removal are reduced with intravenous prophylactic antibiotic use. However, it is arguable that the low rate of infection seen for this procedure would not justify indiscriminate antibiotic use for all patients. It is advisable to use prophylactic antibiotics in patients at high risk for infection, and these would include patients with rheumatoid arthritis, diabetes,<sup>27,36</sup> chronic steroid use, obesity, or advanced age. The authors recommend a 2-g dose of first-generation cephalosporin (e.g., Cephazolin) given intravenously 10 minutes to 1 hour before tourniquet inflation and every 6 to 8 hours thereafter for

24 to 48 hours. For low-risk patients, we believe that surgeons should rely on community standards and their own judgment as to when to use prophylactic antibiotics.

Tissue reaction to silicone microfragments has been attracting more attention as experience with implants has grown. Reactions to silicone can manifest as dendritic synovitis, intraosseous inflammation,<sup>31</sup> cystic bone reactions,<sup>13</sup> and even regional lymphadenopathy with silicone present in the nodes.<sup>12,15,17,41</sup> Although Swanson<sup>15</sup> reported silicone lymphadenopathy as only 0.01 percent, a recent study specifically addressing this problem regardless of symptoms found a 23 percent incidence. Malignant lymphoma has also been found in conjunction with silicone lymphadenopathy, more frequently with rheumatoid arthritis. However, this is a very rare occurrence and neither statistical significance nor causation has been proven.<sup>17,42</sup>

Evidence of intraosseous giant cell and inflammatory reactions to silicone shards has been found (incidence was 57 percent in one study<sup>13</sup>). Radiographic erosive arthritis secondary to silicone-related synovial hypertrophy has also been reported.<sup>14</sup> All these conditions may remain asymptomatic, but symptoms of pain and swelling may necessitate removal of the implant in a few patients.

Bone is the tissue most likely to exhibit complications secondary to the stresses of surgery or implant function. Avascular necrosis, primarily of the proximal phalanx, has been reported<sup>31</sup> and attributed to overzealous medullary reaming and excessive periosteal dissection. Osteophyte production around implants is a very common problem and one that frequently limits motion, produces pain, and may require implant revision. Osteophyte production is likely a response of bone to abnormal forces, but it has also been attributed to osseous generation by remaining periosteum. Incidence of osteophyte production has been reported to be as high as 100 percent by several authors.<sup>6,23</sup> Finally, bone can fail to tolerate or support an implant mechanically.<sup>6</sup> Grooving of the first metatarsal head by hemi-implants is not uncommon<sup>13,31</sup> and can even be seen radiographically. If the implant does not bridge the cortices of the supporting bone, it is also possible for the implant to "telescope" into the softer medullary bone. Osteolysis at the bone implant interface has also been reported (average of 3.4 mm over 7 years),<sup>34</sup> which resulted in shortening of the hallux.



**Fig. 24-10.** Radiograph of LaPorta implant at 1.5 years post-operative. Note sclerotic bone around implant sesamoid retraction.

Fracture of bone around implants is relatively rare, but it may occur if cortices are burred through or if extreme forces are present at the joint. Sclerosis of bone surrounding the implant and sesamoid retraction are common radiographic findings, but are not considered complications because these are expected findings (Fig. 24-10).

Although many implant complications are not avoidable, many others are. For this reason careful adherence to criteria, indications, and technical recommendations should be practiced.

## NEW TECHNOLOGY

Recent efforts to improve implant life span and function have resulted in several new products. Titanium grommets to protect Swanson total implants at the implant bone interface, released in 1987, were developed to reduce implant abrasion and osteophytic lip-ping. They are press-fitted into the stem hole opening and should cover the osteotomy site. Current reports on their performance is only anecdotal.<sup>43</sup>

Dow Corning has also released a titanium hemi-implant with the hope that implant life span will be improved. This is not a new idea, however, as Swanson's first hemi-implants were also constructed of metal alloys and were abandoned because of numerous complications. The authors think that the titanium hemi-implant has a poor prognosis, given its extreme durometer difference from cartilage, and they cannot recommend its use without thorough long-term follow-up studies.

Several dual-component implants have also been reported,<sup>43-45</sup> but long-term studies of their performance have yet to be published. Historically, implants with these designs have had multiple complications (bony overgrowth, implant loosening, and poor transverse plane stability) and were eventually abandoned. A dual component, or so-called unconstrained device, if sound in biomaterial and design, is likely to function better than implants presently employed in cases in which the supporting periarticular soft tissues are healthy. With improved function, there is less implant stress and greater chance for implant longevity.

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