

Silicone Hinge Replacement Arthroplasty

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The concept of prosthetic implantation is excellent, since early restoration of motion with stability has obvious advantages over simple resection arthroplasty. This has led to a significant gain in popularity regarding total joint replacement arthroplasty. It is the authors' purpose to discuss specific indications of the hinge implant, compare it to the hemi-implant, and to compare different types of hinge prostheses and consider the advantages and disadvantages. A technique is discussed and possible design improvements are suggested.

Silastic®¹ Hinge Implant

As with all implants, the selection of the proper patient must fulfill certain requirements. The patient must be cooperative and in good general health. Skin coverage must be adequate, and there must be appropriate neurovascular status. The elements necessary to produce a functional musculotendinous system must be available, along with adequate bone stock to receive and support the implant. As always, implants are contraindicated in the presence of sepsis, anemia, osteoporosis, history of previous implant rejection, or osteomyelitis.^{1, 2}

The authors feel the specific indications of the hinge prosthesis are:

1. When there is destruction of the articular surface of the first metatarsal head, with or without destruction of the proximal phalangeal base cartilage. This commonly occurs in severe hallux abducto valgus, hallux limitus, and hallux rigidus.³ It also occurs following McKeever-type bunionectomies, poorly healed intra-articular fractures, or nar-

rowing joint space with degeneration following soft tissue bunion corrections.

2. Iatrogenic hallux adductus (varus).
3. Flail toes following Keller, Mayo, and Stone procedures.

Discussion

The authors believe there is a common misconception regarding this implant. Unlike Swanson, the authors feel it is not necessary to remove weight-bearing portions of the first metatarsal head proximal to the articular surface. Swanson suggests this in his technique in order to get to the widest portion of bone so that the largest possible implant can be used. As with the hemi-implant, Swanson feels the larger the implant, the greater the stress it can tolerate. The authors disagree with these concepts for the following reasons:

1. It has been found that using the largest possible hemi-implant may inhibit sagittal motion by causing a dorsal impingement on the metatarsal, while it has been shown that using smaller sizes can increase this motion.⁴

2. Close examination of the metatarsal head fails to show a significant increase in width proximal to the proximal portion of the articular surface (Fig. 1).

It should be pointed out, however, that the im-

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^{®1} Dow Corning Corporation, Midland, MI.

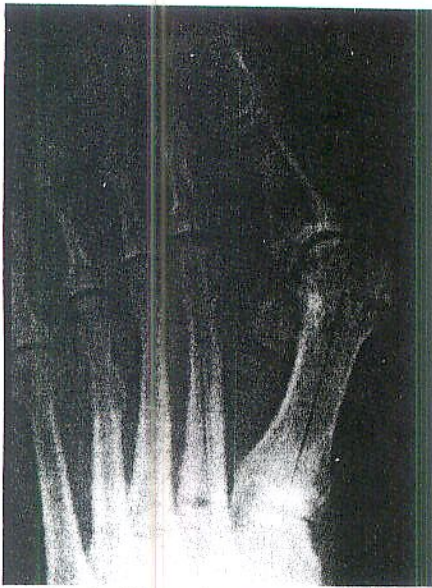


Figure 1. No significant increase in width proximal to the proximal portion of the articular cartilage.

plant must accept some weight during toe-off. This is exhibited by grooves in the plantar and distal surface of the metatarsal head which articulate with the sesamoids, allowing the metatarsal head to glide into plantarflexion during closed kinetic chain motion.

Hemi-Implant Versus Hinge Implant

Articular cartilage is a structure with four zones. The outermost is acellular and contains collagen fibers that are parallel to the surface and to each other. The middle two layers differ in collagen and proteoglycan content, as well as in structure, being more three dimensional. The deepest zone lies directly on subchondral bone.⁵ In the presence of readaptation and degeneration of the metatarsal heads' articulating surface, it has been customary when using the hemi-implant to reshape the chondral portion so the implant will have a convex surface in the frontal plane for articulation. "Unlike bone, articulating cartilage is not self repairing. Defects thus created by this reshaping of the articular cartilage are filled in with fibrocartilage."⁵ Initially, this surface may be satisfactory for articulation with a hemi-implant, but after 1 to 2 years it deteriorates and becomes necrotic. This is caused by the high degree of friction produced by silicone rubber against cartilage or subchondral bone (Dr. Johnathan Black, personal communications, 1973). Through this mechanism, subchondral bone is reached and rapidly flattens. This may lead to decreased range of motion⁵ (Fig. 2).

Another disadvantage of the hemi-implant is the lack of frontal plane stability leading to mild to severe varus or valgus in 66% of the cases, as well as a lack of transverse stability which cannot be contributed to asymmetry or obliquity of the proximal phalanx in 8%⁶ (Fig. 3). By virtue of its shape, the hinge implant provides stability in the transverse and frontal planes, decreasing the incidence of abductus, adductus, varus, and valgus. In addition, the hinge implant can correct for a high proximal articular set angle, making a distal wedge osteotomy unnecessary.

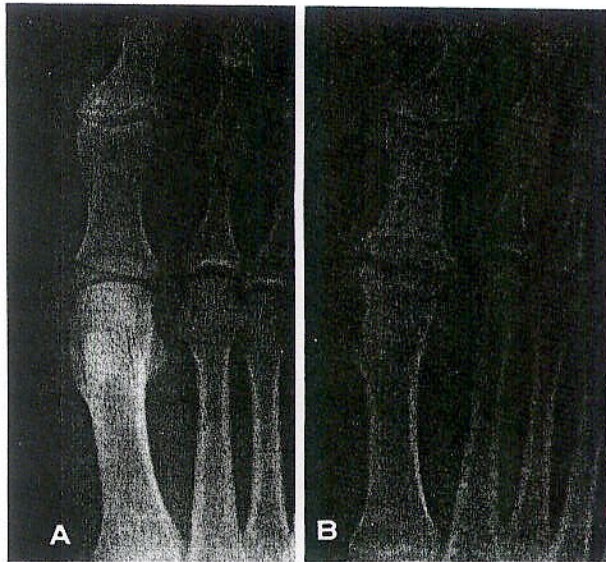


Figure 2. A, immediately postoperative. B, 2 years postoperative showing flattening of the metatarsal head.



Figure 3. Lack of frontal plane stability with hemi-implant.

Disadvantages of All Silastic Implants

Surgeons have been utilizing silicone implants successfully for many years. As mentioned by Dumbleton and Black,⁵ inherent in the physical features and properties of implants are certain disadvantages which we feel are worthy of reviewing. Among these are:

1. "Wear debris can give rise to small particles which stimulate phagocytic reaction and give rise to granulation tissue typical of that seen in long term, low level infectious processes."⁵

2. The bulk of an implant may cause problems of revascularization leading to avascular necrosis simply by occluding directions of approach to the operative site tissues by the nutrient artery and metaphyseal vessels.^{5,7}

3. Immune foreign body reactions may occur as a result of direct tissue interaction, but these tend to be of transient nature, subsiding as the implant surfaces become coated with proteins.⁵

4. The presence of an implant may interfere with the treatment of infection in a purely mechanical way.

5. There is a possible relationship between infection and implantation.^{5,7}

Since much of the mechanism of foreign body reaction to implants is the same as that combating infections, a continued sterile reaction may somewhat deplete the local sources of disease resistance. This could enhance the likelihood and severity of local infection long after implantation.⁵

Complications of the Hinge Prosthesis

In Swanson's⁸ study of 4,218 metacarpophalangeal joint implant arthroplasties (predecessor to the metatarsophalangeal joint implant), the following complications were encountered:

1. In less than 1%, the implant became dislocated. This was almost always because of incomplete surgical corrections of the deformity, using too small an implant, or an improper application of the operative dressing.

2. Postoperative infections occurred 29 times (0.5%). It should be noted that they were controlled by the usual measures of wound drainage and antibiotics in 23 cases. Six implants were removed because of persistence of infection. The infection then cleared and, because of the capsular formation that had occurred, *the joints continued to function adequately* as simple resection arthroplasties. Ankylosis was not reported to occur.

3. Fracture of the implant occurred in 48 joints although almost none were symptomatic nor did

they alter function significantly. This is believed to be caused by the presence of the capsuloligamentous framework which develops around the implant. Most of these implant fractures were related to inadequate release of joint deformity during surgery or to lacerations or tears inflicted on the surface of the implant by sharp bone edges or traumatic handling of the implant with sharp instruments.

The following complications have been specifically encountered or believed to be possible complications with the first metatarsophalangeal joint implant arthroplasty:

1. Difficulty in active dorsiflexion. The authors believe this may be caused by atrophy of the extensor hallucis longus from the presurgical deformity. Active dorsiflexion, however, is not necessary except to an extremely small degree during the early swing and stance phases of gait. More important is passive dorsiflexion in the third period of the stance phase: foot flat to toe-off.

2. If too small an implant is used, the hinge can get displaced into the proximal phalanx or the metatarsal, causing a "telescoping effect."⁸ As previously mentioned, this may also lead to dislocation of the implant.

3. Since subcapital amputation (ie, Hueter bunionectomy) has been known to destroy the blood supply to the distal half of the shaft of the first metatarsal leading to avascular necrosis, it is possible that a similar problem could be encountered with the hinge prosthesis. This is unlikely since significant amounts of blood are derived from periosteal vessels, and the principal nutrient artery is located 2.7 cm proximally from the articular cartilage and 0.4 cm from the dorsal aspect on the *lateral* border of the first metatarsal.¹⁰ (The significance of the lateral approach will be discussed later).

4. Lack of toe purchase has been reported with both type implants (Dr. Robert Turf, personal communication, 1978), although the hinge tends to decrease the incidence of this since the stems of the implant are 180 degrees to each other, while the normal metatarsophalangeal joint angle in the sagittal plane is approximately 155 degrees. On the contrary, it would seem that the implant would try to (and it does) force the proximal phalanx down. We believe this problem may be caused by failure to lengthen a severely contracted extensor hallucis longus tendon, inserting the stem incorrectly in the sagittal plane, or failure to cut the metatarsal or proximal phalanx perpendicular to the distal metaphysis in the sagittal plane.

5. Inherent in its design, the implant does not accommodate for inversion and adduction of the

metatarsal above the transverse plane, nor for eversion and abduction below the transverse plane. Root points out, however, that transverse plane motion of the metatarsal is clinically insignificant.¹¹

6. If infection develops and the implant must be removed, you are left with two raw bone surfaces. As mentioned previously in Swanson's⁸ study, this has not led to ankylosis in the hand. Seeburger¹² states this does occur in the foot, but Root¹¹ claims it occurs only if pronation is not controlled postoperatively. It must also be mentioned that two raw bone surfaces also exist following removal of the hemi-implant, if the articular cartilage has been removed to reshape the head in order to provide a convex surface for smooth articulation.

Pistoning: Silicone Versus Dacron^{®2}-Reinforced Silicone

Although Dacron reinforcement on the external stem surface does seem to increase surface wear qualities, the authors feel its negative features far outweigh the advantages. It has been found that Dacron in a synovium-lined cavity causes severe inflammatory reactions which, in turn, cause enlargement of the joint capsule, resulting in instability.⁸ In an attempt to increase strength, internal reinforcements of Dacron result in separation at the interface of the two materials and an actual decrease in the flex life of the implant. More important, it is found that fixation with glues, pins, or Dacron over the intramedullary stems has led to early breakage of the implant at the junction of the stem and the central portion because it allows movement only at the center of the hinge.⁷ This places intolerable stress on the implant and increases the reaction at its juncture with bone because this is not the normal mechanism of the first metatarsophalangeal joint. The joint does not dorsiflex or plantarflex on an axis (hinge) but rather, the proximal phalangeal base glides dorsally on the plantarflexing, abducting, and everting metatarsal head.¹³

The silicone implant partially allows this vectorial change by converting the up and down gliding (arthroidial) motion of the metatarsophalangeal joint to in and out motion of the stems. In open kinetic chain dorsiflexion of the hallux on the metatarsal, the distal stem of the implant withdraws from the proximal phalanx. In closed kinetic chain motion, the proximal stem withdraws from the metatarsal while it is plantarflexing, abducting, and everting. This is the so-called intramedullary "pis-

ton effect."¹⁴ This distributes forces over a broader area, allowing the device to absorb more stress, deferring structural fatigue, and virtually eliminating osseous absorption. It also allows an increase in joint motion by permitting the implant to position itself with respect to the true axis of motion of the first metatarsophalangeal joint.¹⁴ We must remember that neither type implant accommodates for inversion or eversion of the metatarsal.

One local effect of this motion is increased formation of a fibrous capsule around the implant in soft tissue sites. In hard tissue sites, such as the medullary space of the first metatarsal, the reaction is generally a mixed fibrocartilage and bone formation.⁵

Thus, intramedullary placement of the stem, pressures applied to it by adjoining bone, and the development of a capsuloligamentous system around the implant provide adequate stabilization for proper function. However, it should be pointed out that unusual extrinsic forces created by soft tissue contractures, joint subluxation, and tendon imbalances will compromise the stability of the new implant. Therefore, it is essential to release all contractures, resect the proper amount of bone, and correct all tendon imbalances to obtain a permanent reduction of the joint and achieve a full range of motion while at the same time respecting the joint space requirements.

Technique

At Las Olas General Hospital, a midhigh tourniquet is used whenever possible. Adequate length of exposure is achieved by utilizing an incision running from the distal third of the first metatarsal to a point just proximal to the head of the proximal phalanx, medial to the extensor hallucis longus tendon. Strict hemostasis is imperative and vital structures are retracted and/or ligated. When it is present, and it usually is, extensor hallucis capsularis is preserved as its purpose is to lift the capsule out of the way during dorsiflexion.¹⁵

A longitudinal or lenticular capsular incision is made medially. Since most capsular stress in the postoperative period will be at the joint, an inverted L-type capsulotomy is not utilized. Transverse plane stability is gained with the hinge implant and it is unlikely that the toe will return to pathologic abductus. In time, redundant medial capsule will contract. As previously mentioned, capsular integrity is essential in the event of implant fracture. After resecting the collateral ligaments, the metatarsal head is delivered into the surgical site and the articular surface is examined.

^{®2} DuPont Corporation, Wilmington, DE.

Although preoperative radiographs and clinical examination provide many facts, *now is the time to decide if the hinge prosthesis is necessary.* Assuming it is, the authors do not feel it is necessary to remove apparent hypertrophy medially. A normal metatarsal head is not flush with the shaft. If you remove cortical bone medially, you will get bleeding bone, resulting in a capsulodesis and decreased motion postoperatively. The authors also have found that resection of the medial cortical bone may lead to pressure necrosis of remaining cancellous bone and displacement of the implant medially.

In hallux abducto valgus deformity, the fibular sesamoid is removed if it has become dystrophic, ankylosed to the medial sesamoid, or, if there is degeneration of the metatarsal, sesamoidal articulation.¹³ It is also essential to do a closing abductory wedge osteotomy of the metatarsal base if the intermetatarsal angle is greater than 12 degrees.³

Before removing the base of the phalanx or the distal aspect of the metatarsal, place the sizer on the joint while holding the hallux in the corrected position, then determine what percentage of the phalangeal base and metatarsal needs to be resected. Remember, the anteroposterior length of the largest implant is only 0.4 inch.

The distal cut on the base of the phalanx should be perpendicular to the shaft. This will correct a high distal articular set angle if any exists. The proximal cut on the distal aspect of the metatarsal should be in approximately 10 degrees of abductus. This will allow the toe to dorsiflex and plantarflex in the sagittal plane when the intermetatarsal angle is 10 degrees. To allow this sagittal motion and proper seating of the hinge, it is necessary to drill into the metatarsal perpendicular to the metatarsal cut for insertion of the stem. Drilling thus will be from distal lateral to proximal medial. This has the added advantage of not interfering with the principal nutrient artery, thereby decreasing the possibility of avascular necrosis. One should be cautious not to drill through the medial cortex of the diaphysis so judgment is exercised, depending on the diameter of the shaft. We usually drill 5 to 10 degrees off the longitudinal axis and attempt to ream a rectangular hole by using a narrow side-cutting burr (Figs. 4 and 5).

In general foot surgery, the routine use of antibiotic flush damages polymorphonuclear leukocytes, macrophages, and lymphocytes.¹⁶ It is well known that good tissue handling is the best defense against infection. However, antibiotic flush has been shown to reduce significantly postoperative edema and infection with implants.⁴ Perhaps it is the effect on these cells which causes the decreased



Figure 4. A, preoperative. B, postoperative. Note cut on metatarsal in 5 to 10 degrees abductus.

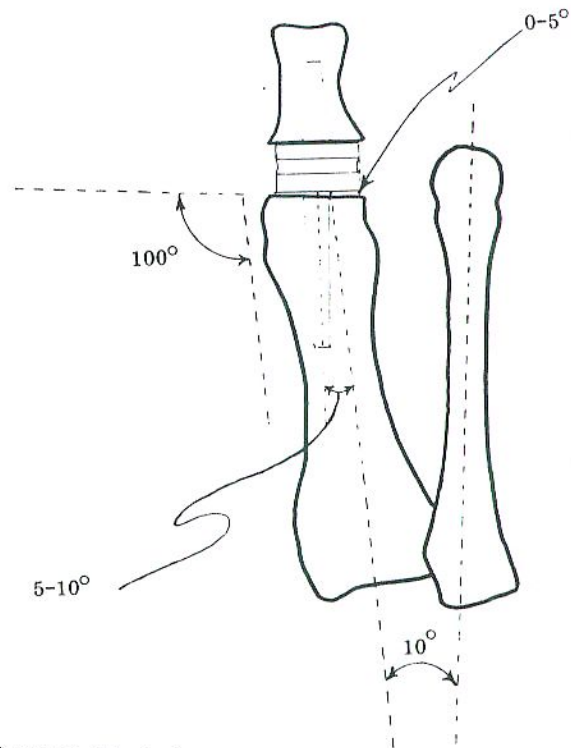


Figure 5. Illustrating cuts required and angular relationships.

inflammation and congestion (normally intense with implants) and therefore inhibits infection. Thus, in the instance of implant surgery, we use Neosporin GU^{®3} or 1 ml of Kantrex^{®4}/liter sterile

^{®3} Burroughs Wellcome Company, Research Triangle Park, NC.

^{®4} Bristol Laboratories, Syracuse, NY.

water.¹⁷ In addition, the solution should be used for immersion of the implant since the implant produces an electric charge and attracts dust. Povidone iodine should not come in contact with the implant since the implant can attract metallic ions.¹⁸ Prior to implant insertion, we place several drops of dexamethasone (4 mg/ml) in the metaphysis and at the osteotomy sites to aid also in decreasing postoperative edema. The postoperative dressing should give support, control motion, and provide adequate compression without constriction.

Postoperative Therapy

The immediate postoperative positioning and control of joint movement during the first 6 to 8 weeks after reconstruction by dynamic bracing and physiotherapy is extremely important. Early active motion at the metatarsophalangeal joint during the second phase of wound healing (fourth to fifth day) with intensive physical therapy during the third phase (remodeling) to ensure longitudinal orientation of capsular fibers is encouraged.⁴ Reconstructed joints start tightening up during the second postoperative week and can be quite tight by the end of 3 weeks.⁸ If the desired range of motion in plantarflexion has not been obtained after 3 weeks, it will be difficult to gain further improvement in motion. On the other hand, active and passive dorsiflexion exercises can continue for 3 months.⁸

Design Improvements

Since the normal metatarsophalangeal joint angle in the sagittal plane is approximately 155 degrees, we feel the implant should be the same, rather than the current 180 degree design. This will decrease the amount of pistoning necessary during open and closed kinetic chain motion (Fig. 6).

To allow the implant to seat firmly on the abductor cut in the metatarsal head and thereby preventing a lateral gap (Fig. 5), the implant should be angulated in the transverse plane to coincide with 10 degrees of intermetatarsal angle. This necessitates creating right and left implants (Fig. 7).

The sesamoids articulate with the distal plantar aspect of the metatarsal head at heel-off. However, this portion of bone is removed for proper seating of the implant, and there is no provision for this articulation in the implants present design. This could be accomplished if the proximal stem was rigidly fixated while the distal stem retained its pistoning ability¹⁹ (Fig. 8). Although this would increase stress on the implant, the authors feel it is a worthwhile compromise and should be investigated.

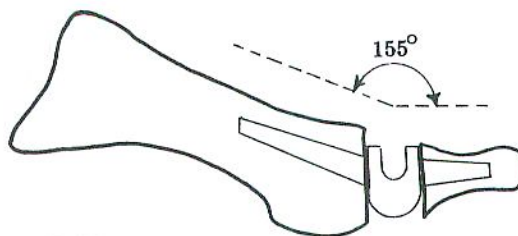
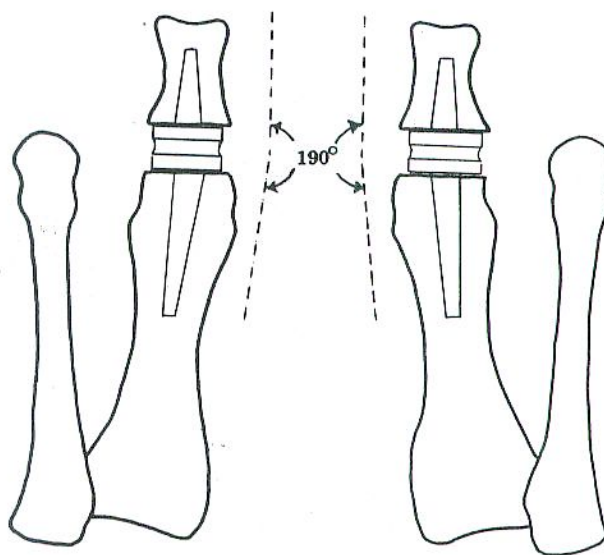


Figure 6. The implant should be 155 degrees in the sagittal plane.



Left

Right

Figure 7. Implants angulated in transverse plane creating right and left.

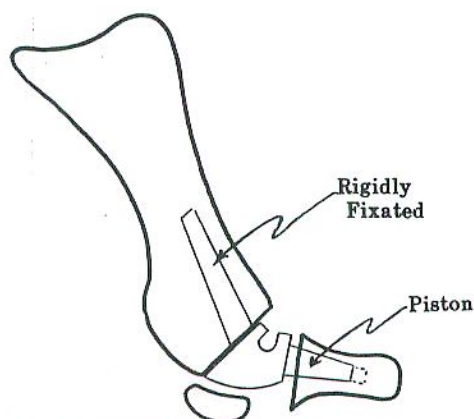


Figure 8. Allowing articulation with the sesamoids may be accomplished by rigid fixation of proximal stem.

Conclusion

In the past when we have been faced with severe joint dislocation or destruction of the types previ-

ously mentioned, our best alternative was a hemi-implant. With the hinge implant, we gain a significant step forward in better treatment and toward joint function, providing proper indications are present. It is the authors' opinion that the use of the hemi-implant will greatly decrease because, in a significant number of cases, the hinge prosthesis is more applicable.

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