

25

Review of First Metatarsophalangeal Joint Implants

VINCENT J. HETHERINGTON
PAUL S. CWIKLA
MARIA MALONE

Interest in the development of a functional first metatarsophalangeal joint prosthesis has gradually developed during the past several decades. The motivation for this interest is the recognition of the importance of first metatarsophalangeal joint in foot function and the significance of its proper functioning in achieving normal gait. Recent studies have focused on the shape, motion, and load-bearing characteristics of this joint. These efforts have been directed toward defining the range of motion required for normal function and the center of rotation and characteristics of motion.¹⁻⁴ An improved understanding concerning the osseous architecture of the joint will help to delineate joint shape and configuration and thereby define the osseous parameters to be replaced.⁵⁻⁹ In addition, loading characteristics will clarify material and fixation needs.¹⁰⁻¹³

A classification of first metatarsophalangeal joint implants is presented in Table 25-1. This classification separates the implants into hemi-joints and total joints. The hemi-joints are further categorized by materials, either metal or polymer. Total implants are classified as hinged, bipolar, or interpositional. The hinged implants are composed of a polymer, alone or as a composite; the total bipolar implants are constructed of a metal/polymer or ceramic.

This chapter presents a historical and contemporary view of implant arthroplasty designs of the first metatarsophalangeal joint. An effort has been made to be as

thorough as possible; however, other first metatarsophalangeal joint designs may have been inadvertently omitted. All dates are approximate and are based on available literature sources.

ENDLER (1951)

Endler¹⁴ designed this custom implant using bone cement, acrylic methacrylate, to recreate the base of the proximal phalanx. This is the first reference in the literature specifically concerned with the first metatarsophalangeal joint.

SWANSON HEMI-IMPLANT (1952)

The first Swanson-designed implant for the first metatarsophalangeal joint was a metal hemispherical cap with a tapered stem as a replacement of the first metatarsal head. Bone cement was not used. Swanson¹⁵ stated that the implant was not successful because of the rigidity of the material.

SEEBURGER (1964)

Seeburger¹⁶ used Durallium to make a first metatarsal head prosthesis. His design had three modifications.

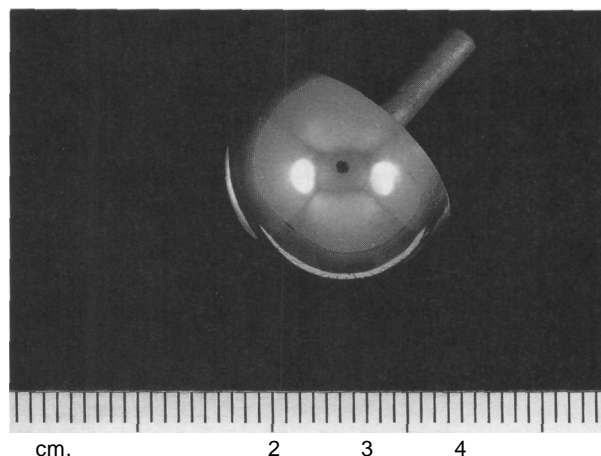
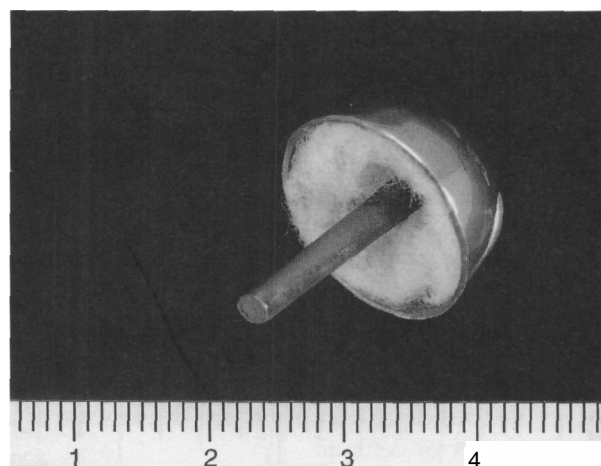
Table 25-1. Classification of Common and Some Experimental First Metatarsophalangeal Implants

Hemi-Joint implants
Polymer
Silastic great toe implant (Swanson design) ^a
Silastic angled great toe implant (Swanson design), Weil modification ^a
Metal
Seeburger durallium ^b
Swanson titanium great toe implant ^a
Total implants
Hinge
Polymer
Silastic Swanson flexible hinge toe implant ^a
Sutler hinged great toe metatarsophalangeal joint implant (Lawrence design) ^c
Sutler hinged great toe metatarsophalangeal joint implant (Laporta design) ^c
ZMR toe prosthesis ^d
GAIT ^e
Composite
Cutter metatarsophalangeal prosthesis ^f
Helal universal joint spacer ^g
Bipolar
Metal/polymer
Richards total first metatarsophalangeal joint ^b
Depuy first metatarsal phalangeal joint surface replacement ⁱ
Biomet total toe system ^j
Lubinus ^k
Bio Action great toe implant ^l
Wyss ^m
Merkle
Ceramics
Pyrolytic carbon
Alumina (Giannina and Moroni)
Interpositional (metals)
Regnauld
Barouk Spacer ⁿ

^a Down Coming Wright, 5677 Airline Rd., Arkubgtibm TN 38002.^b Austen Co., New York, NY.^c Sutler Corp., 9425 Chesapeake Dr., San Diego, CA 92123.^d Zimmer, Warsaw, IN 46580.^e Sgarlato Lab. Inc., 100 O'Connor Dr., Suite 18, San Jose, CA 95128.^f Cutter Biomedical, San Diego, CA.^g Corin Medical LTD, Chesierlon Lane, Cirencesler, Gloucestershire, England GL7 1Y7.^h Richards Manufacturing Co. Inc., 1450 Brooks Rd., Memphis, TN 38116.ⁱ Depuy, Warsaw, IN 46580.^j Biomet Ind., Warsaw, IN 46580.^k Waldemar Link GmbH & Co., Hamburg, Germany.^l Orthopaedic Biosystems LTD, 7725 E. Redfield Rd., #102, Scottsdale, AZ 85260.^m Questor Clinical Mechanics Group, Kingston, Ontario.ⁿ ISI Manufacturing Inc., 1947 Ivahoe Dr., Irwin, PA 15642.

The first type was a complete metatarsal head prosthesis with a double flange, fabricated in 1962. This implant was designed to correct severe hallux valgus. The two flanges were used to fasten the implant onto the stump of the first metatarsal using two self-tapping screws.

The second type (Fig. 25-1) was a metatarsal cap of Durallium to replace the articular surface of the metatarsal head. The third type was a slight modification of the second (Fig. 25-2). Dacron was inserted into the

**Fig. 25-1.** Seeburger design, first metatarsal head cup.**Fig. 25-2.** Seeburger design, first metatarsal head cup with Dacron modification.

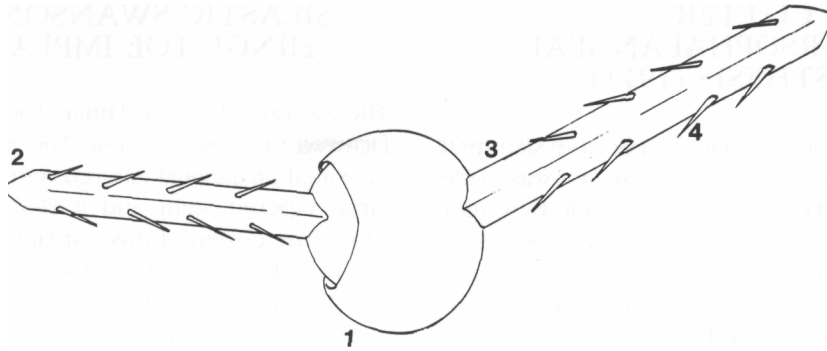


Fig. 25-3. Downey's proposed articulated ball-and-socket implant.

cap head in the hope that fibrous tissue would be deposited into the Dacron and secure the implant.

JOPLIN (1964)

Joplin¹⁷ discussed using noncemented Vitallium implants for the first metatarsophalangeal joint. One design was a single-stemmed prosthesis for the base of the proximal phalanx and the second a single-stemmed prosthesis for the metatarsal head.

DOWNEY (1965)

Downey¹⁸ proposed, but never constructed, a chromium alloy implant of a ball-and-socket design. Figure 25-3 illustrates this ball-and-socket implant with barbs on the medullary stems to secure the implant.

SWANSON (1965)

This implant is similar to the implant designed by Swanson in 1952 with the exception that the implant was constructed using silicone.¹⁵ The intramedullary stemmed implant was intended to replace the first metatarsal head.

SILASTIC GREAT TOE IMPLANT (SWANSON DESIGN) (1967)

Swanson, with Dow Corning,¹⁹ introduced a Silastic single-stemmed intramedullary prosthesis to replace the base of the proximal phalanx. The implant was designed to augment the Keller procedure by acting as a spacer and to preserve its weight-bearing function of the first metatarsophalangeal joint (Figure 25-4). The implant comes in five sizes (0 through 4), and each size has a smaller stem version.

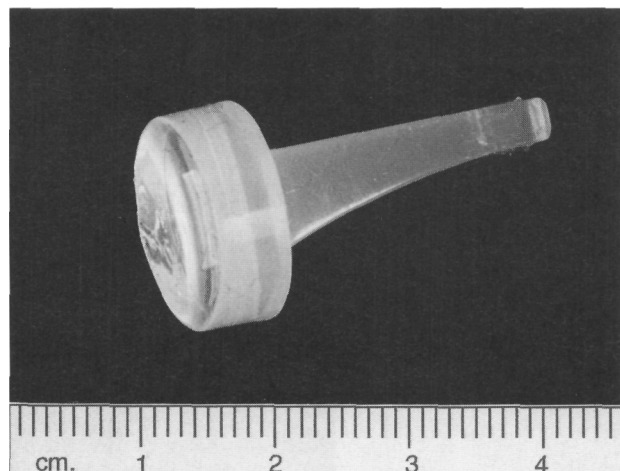


Fig. 25-4. Swanson design, silicon single-stemmed hemi-implant.

CUTTER METATARSOPHALANGEAL PROSTHESIS (1971)

The Kampner-designed implant is a double-stemmed prosthesis with a central hinge. The implant was made from a silicone-polyester composite made by Cutter Biomedical. The first design contained polyester sleeves attached to the stems. It was hoped that the sleeves would allow for better fixation. One design had suture material to be used to increase initial stabilization of the implant (Fig. 25-5). The polyester sleeves were later dropped from the implant because Kampner²⁰ believed the sleeves caused the implant to be too rigid and constrained, thus causing too much stress across the joint hinge.

SILASTIC SWANSON FLEXIBLE HINGE TOE IMPLANT (1974)

The Swanson Flexible Hinge Toe Implant was manufactured by Dow Corning. The implant consists of a proximal phalangeal tapered stem with a longer metatarsal tapered stem and a U-shaped crossbar (Fig. 25-6). The design of this implant is similar to a Swanson double-stemmed flexible finger implant from the mid-1960s. A discussion of this implant can be found in Swanson et al.²¹ In 1985, Dow Corning introduced a titanium grommet (Fig. 25-7) to shield the Swanson hinged implant from bone damage.²² The implant comes in 20 sizes that include two stem styles. A standard stem style is available along with a smaller style that requires less reaming of the intramedullary canal.

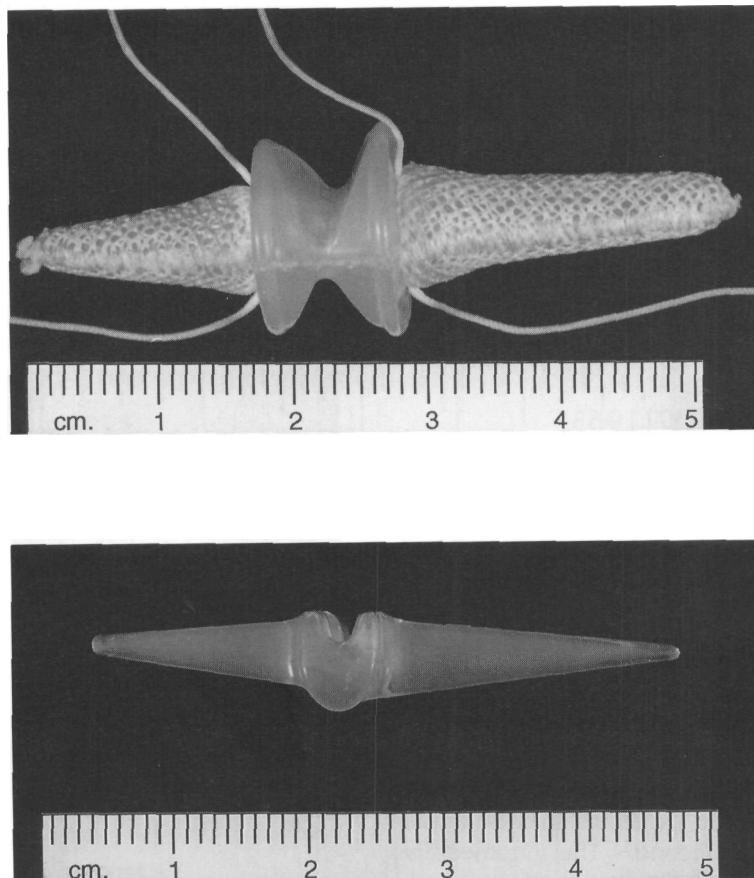


Fig. 25-6. Swanson design, silicon double-stemmed, hinged implant.

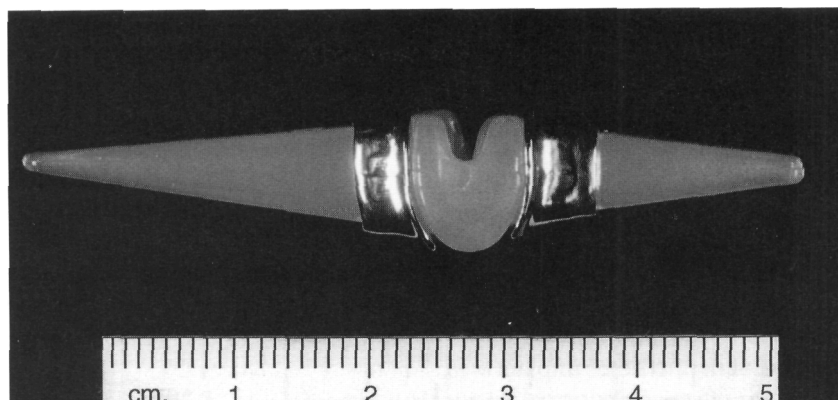


Fig. 25-7. Swanson design, hinged implant with titanium grommets.

Sizes are classified from 0 through 7 and 2-0 through 7-0. The smaller stem style is available in sizes 0 through 5. Sizes 0 through 7 and all small-stem implants are recommended for use in the great toe by Dow Corning.

RICHARDS TOTAL FIRST METATARSOPHALANGEAL JOINT (1975)

Weil and Smith designed a total first arthroplasty system produced by Richards Manufacturing.²³ This two-piece implant had a phalangeal component made of ultrahigh molecular weight polyethylene (UHMWPE) and a metatarsal component of stainless steel (Fig. 25-8). The metatarsal component was designed for

right and left components for hallux abductus valgus with an intermetatarsal angle between 12° and 16° and a neutral component for intermetatarsal angles below 12° . The implant was fixated using polymethylmethacrylate. Failure from recurrence of the abductus deformity and loosening were the main reason that use of this implant was discontinued.²³

REGNAULD (1975)

Regnault²⁴ introduced a stainless steel cap used in interpositional cup arthroplasty. The cap is designed to be sutured into place between the head of the first metatarsal and proximal phalanx after a Keller arthroplasty for 1 year and then removed (Fig. 25-9). The cup was originally designed of polyethylene in 1968; the

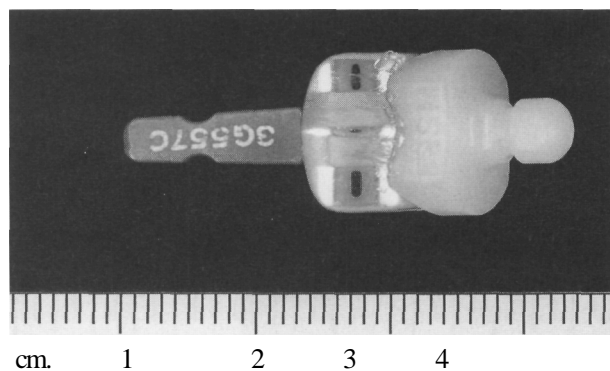


Fig. 25-8. Richards total implant.

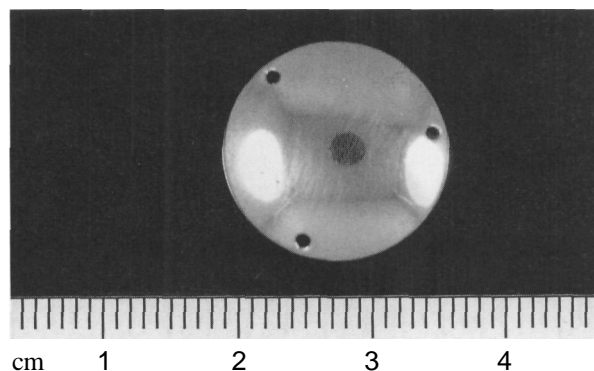


Fig. 25-9. Regnault design, stainless steel cap.

purpose was to develop fibrocartilage on either side of the cup, which after removal of the cup would provide a pain-free mobile articulation.

SILASTIC ANGLED GREAT TOE IMPLANT (SWANSON DESIGN), WEIL MODIFICATION (1977)

Weil noted an abductory drift of the hallux following resectional arthroplasty using the Swanson hemi-implant.²⁵ To correct this problem, the hemi-implant was given 15° of angulation so to offset an abnormal proximal articular facet angle. In addition, the stem was rectangular in an attempt to improve frontal plane sta-

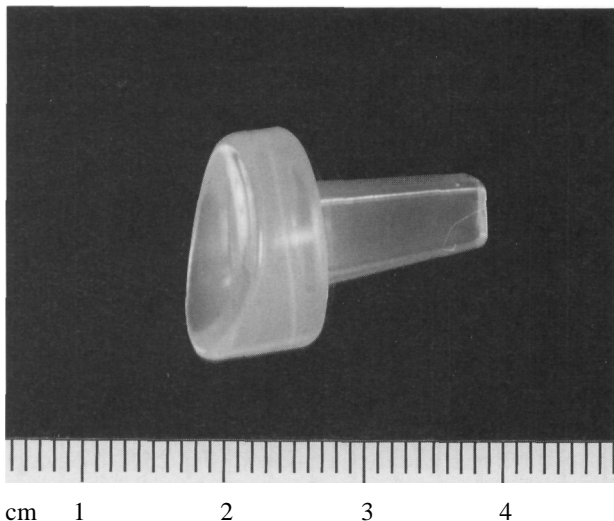


Fig. 25-10. Weil modification of Swanson hemi-implant.

bility, while the curvature of the collar was smaller to decrease the amount of articulation with the implant (Fig. 25-10).

HELAL UNIVERSAL JOINT SPACER (1977)

This silicone elastomer implant reinforced with a Dacron core is a spacer with the central portion containing a spherical ball of silicone (Fig. 25-11).²⁶

DEPUY FIRST METATARSAL PHALANGEAL JOINT SURFACE REPLACEMENT (1981)

The DePuy First Metatarsal Phalangeal Joint Surface Replacement prosthesis is a two-component prosthesis fixed with methylmethacrylate. The metatarsal

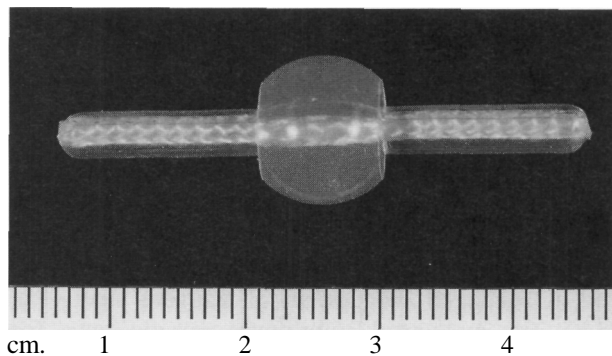


Fig. 25-11. Helal silicone spacer with Dacron core.

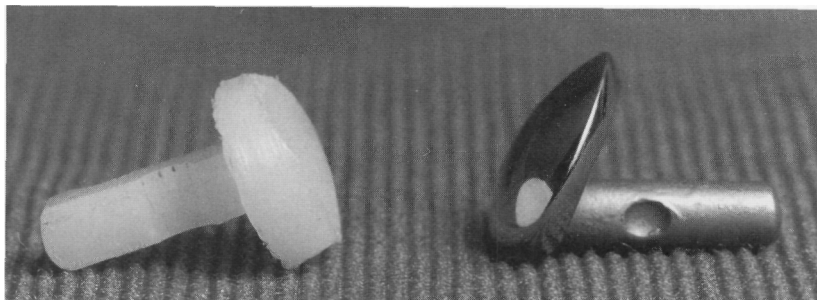


Fig. 25-12. DePuy two-component implant.

component is made from stainless steel and the phalangeal component from polyethylene (Fig. 25-12). Johnson and Buck²⁷ stated that the use of this implant should be limited to older patients with painful degenerative arthritis of the first metatarsophalangeal joint. The results reported were not better than resection arthroplasty.²⁸

SUTTER HINGED GREAT TOE METATARSOPHALANGEAL IMPLANT (LAWRENCE DESIGN) (1982)

The Lawrence-designed silicone intermedullary, double-stemmed, hinged implant is manufactured by Sutter Corporation Inc. The implant design consists of a stem angulated 15° in the sagittal plane (Fig. 25-13).

This angulation was designed to correspond with the metatarsal declination angle.²⁹ The phalangeal portion of the implant is modified to allow the flexor hallucis brevis tendon to remain attached to the base of the proximal phalanx. This preserves full flexor strength and normal sesamoid function. In addition, the implant has a broad collar for the separation of bone surfaces. The Lawrence-designed, double-stemmed implant is available in five sizes (10,20,30,40, and 50).

SUTTER HINGED GREAT TOE METATARSOPHALANGEAL IMPLANT (LAPORTA DESIGN) (1983)

The LaPorta-designed silicone intramedullary double-stemmed hinged total implant is manufactured by Sut-

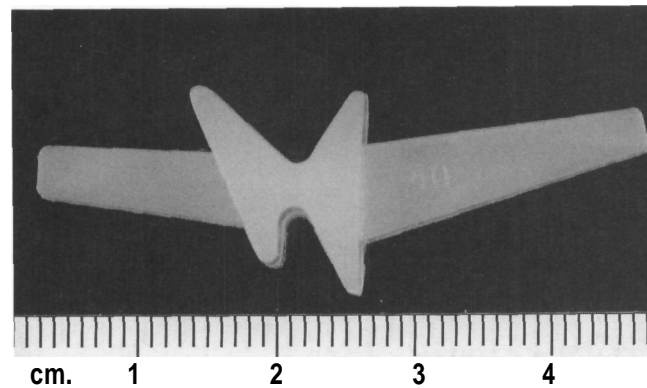


Fig. 25-13. Lawrence design, double-stemmed hinged implant.

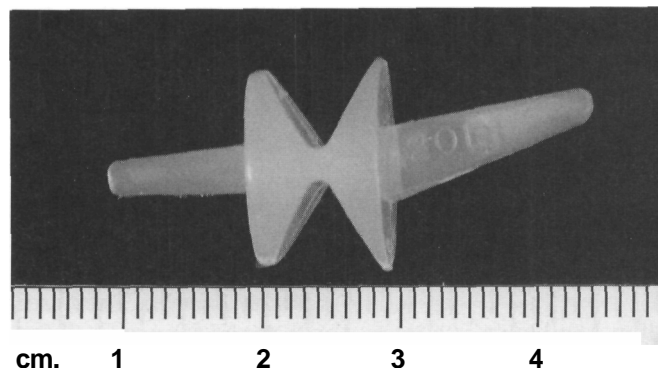


Fig. 25-14. LaPorta design, double-stemmed hinged total implant.

ter Corporation (Fig. 25-14). The metatarsal stem is angulated 15° in the sagittal plane to correspond to the normal metatarsal declination angle. In addition, the implant has broad collars to provide protection from cutting bone surfaces of the first metatarsal head and proximal phalanx. Dorsiflexion of the implant occurs in the hinge portion of the prosthesis. The Swanson implant, on the other hand,³⁰ relies on the viscoelastic properties of the silicone rubber for dorsiflexion. The LaPorta implant can have a 10° stem angulation built into the implant. Thus, the implant comes in right, left, or neutral forms. The LaPorta double-stemmed implant is available in four sizes (20, 30, 40, and 50), and each size has right, left, or straight forms.

LUBINUS (1983)

This implant was designed to transfer the concept of the double-cup arthroplasty of the hip joint to the first metatarsophalangeal joint.³¹ The implant consisted of a hemispheric metal cup made from cobalt chrome and a polyethylene socket that replaces the resected proximal phalanx. The proximal phalanx was cemented for wide osteoporotic canals. This implant was abandoned because of complications in 16 of 22 experimental cases (Hans H. Lubinus, M.D., personal communication to V.J.H.) that consisted of sclerosis and osteonecrosis of cancellous bone.

ZMR TOE PROSTHESIS (1984)

This silicone elastomer hinged implant, known as the ZMR Toe Joint Implant, is a modification of the 1971 Kamper implant. Instead of the polyester sleeves over the stems, the ZMR toe implant has ribbed stems that allow some fibrous attachment for some stability yet also allow for slight pistoning within the medullary cavities.³¹ The ZMR Toe Joint Implant was available in 48-mm, 57-mm, and 68-mm lengths.

SWANSON TITANIUM GREAT TOE IMPLANT (1986)

Swanson designed this titanium hemi-joint as a intra-medullary prosthesis for the base of the proximal pha-

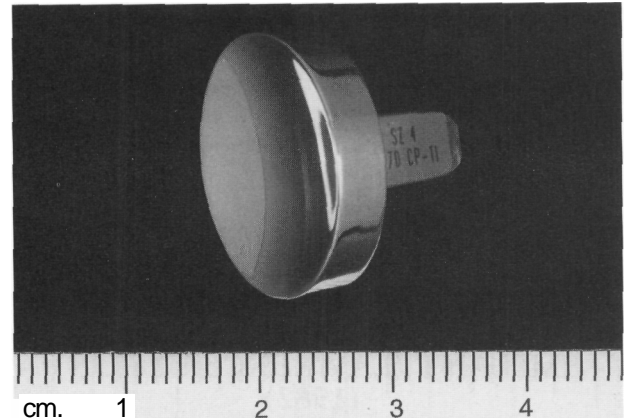


Fig. 25-15. Swanson design, titanium hemi-implant.

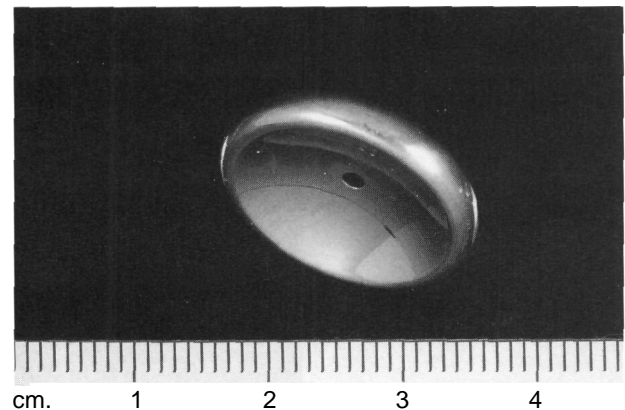


Fig. 25-16. Barouk stainless steel spacer cup.

lanx. The implant is manufactured by Dow Corning Wright (Fig. 25-15) and comes in five sizes (0, 1, 2, 3, and 4).

BAROUK SPACER (1987)

Barouk designed a removable, stainless steel, Spacer cup used with a metatarsophalangeal resection (Fig. 25-16). The cups are to be used with K-wires for temporary fixation. They are made in six sizes and were designed for use in all five digits. This implant, known only from the promotional literature, is similar in

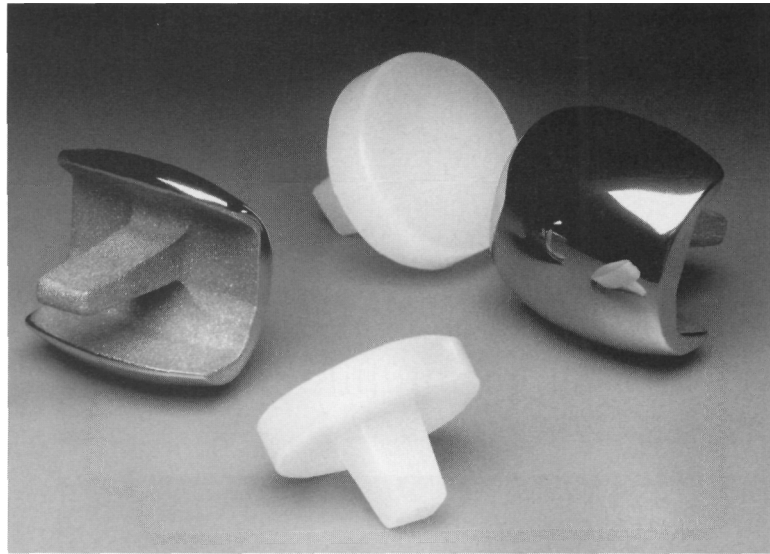


Fig. 25-17. Koenig total two-component implant.

function to the Regnauld implant. The implant was later designed using a ceramic material.

BIOMET TOTAL TOE SYSTEM (1988)

The Koenig total great toe implant, manufactured by Biomet Inc., is a two-component, press-fitted implant that is not cemented.³³ The metatarsal component was initially made from a titanium alloy, while the phalangeal base component is made of UHMWPE or UHMWPE with a metal base (Fig. 25-17). Subsequent designs have resulted in a modification of the metatarsal component. The new component is constructed of cobalt-chrome with a titanium plasma sprayed coating of the stem and back of the articular surface. This design combines the superior wear properties of cobalt-chrome for articulation with the polyethylene material of the proximal phalanx and provides a surface of titanium to enhance fixation of implant. Future designs may consist of a metatarsal component manufactured of cobalt-chrome only (Richard Koenig, D.P.M., personal communication to V.J.A.) This implant, which has had limited clinical use, is available in small, medium, or large sizes.

MERKLE (1989)

Merkle and Sculco³⁴ described a custom two-component, noncemented implant. The metal component was made from titanium alloy and the phalangeal component from titanium and UHMWPE. Implant loosening was observed in half of the implanted toes.

WYSS (1989)

The proposed Wyss implant (Tray/Questor Clinical Mechanics Group, Kingston, Ontario, Canada) is a two-component, noncemented implant. The metatarsal component is titanium, and the phalangeal component is UHMWPE in a titanium tray.

LU (1990)

Dr. Lu of the Arthritic Clinic and Research Center, People's Hospital, Beijing Medical University, Beijing, China, designed two types of implants (Fig. 25-18). The first design consists of a titanium cup for the metatarsal component and UHMWPE for the phalangeal component. The second design resembled the first with notches on the stem for better fixation. In addi-

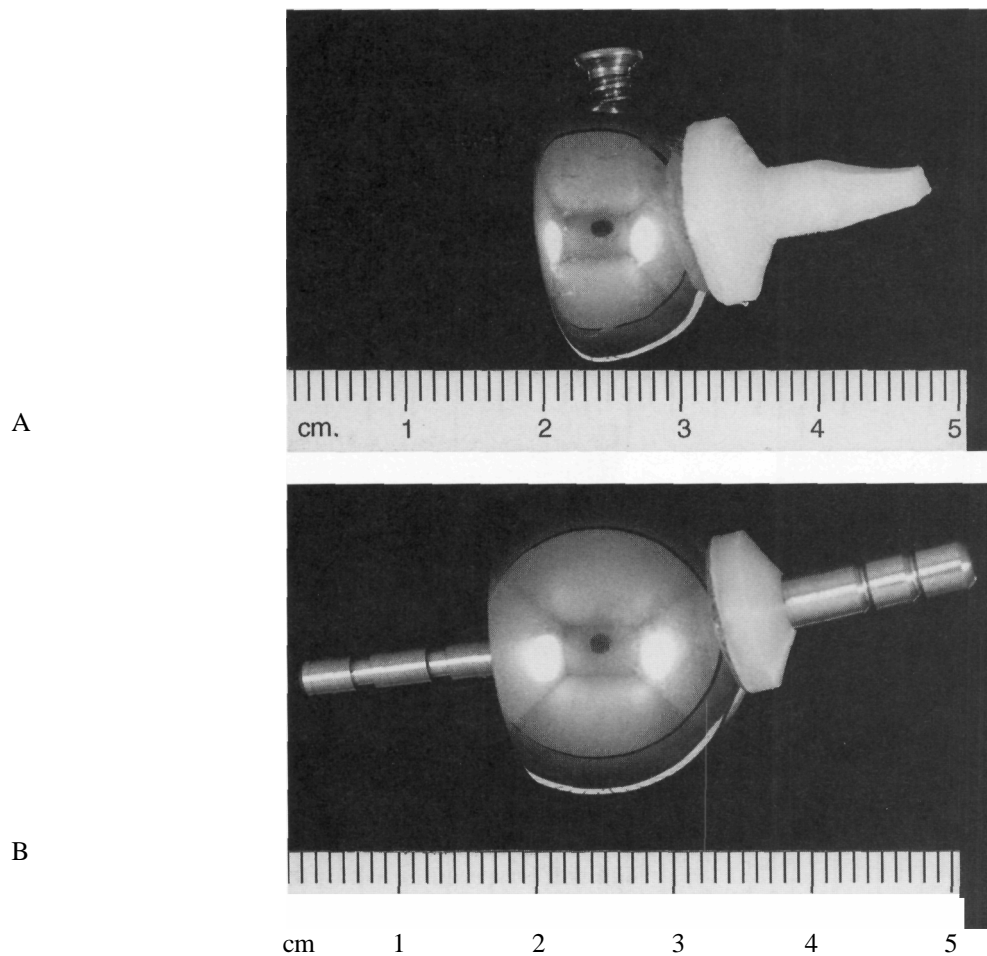


Fig. 25-18. Lu design, total two-component implant. (A) Type A; (B) type B.

tion, the second design used titanium for the stem of the phalangeal component.³⁵

BIO ACTION GREAT TOE IMPLANT (1990)

This two-piece, total joint system is inserted into the medullary canals. The metatarsal component is constructed from cobalt-chrome, while the phalangeal component is constructed from titanium, and polypropylene. This implant is purportedly available in small and large sizes and in right, left, and neutral forms.

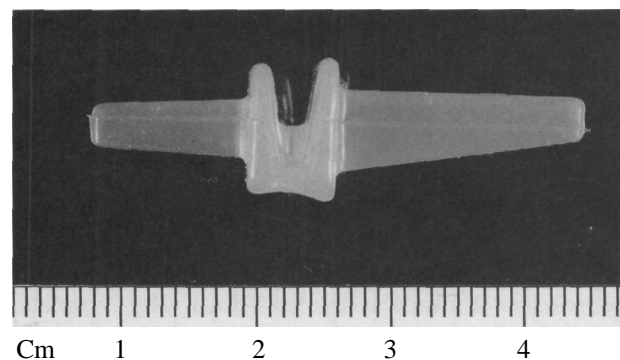


Fig. 25-19- GAIT double-stemmed silicone implant.

PYROLYTIC CARBON (1991)

The proposed use of pyrolytic carbon as a joint replacement biomaterial for use in the foot was discussed by Hetherington et al.³⁶ in 1982. Kampner³² in 1991 described short-term clinical results using a two-component pyrolytic carbon implant for the first metatarsophalangeal joint.

GAIT (1991)

Sgarlato Labs, Inc. makes the GAIT (great toe arthroplasty implant technique) implant. The implant is a silicone, double-stemmed implant similar in design to the Swanson hinged implant and is stained to act as a spacer to augment a Keller arthroplasty (Fig. 25-19). The implant was designed to have a thicker hinge and to allow better toe purchase.

GIANNINA AND MORONI (1991)

This implant was first described by Giannini and Moroni in 1991.³⁷ The prosthesis consists of a phalangeal and metatarsal component, both of which are composed of an inert biocompatible ceramic material called alumina. The implant design is based on an anatomic study of 20 cadaver first metatarsal phalangeal joints, resulting in three available sizes. Fixation is uncemented. Its only recorded use is in clinical trials. A report in 1993³⁸ documented poor performance of this implant with failure due to loosening and breakage of the implant.

SUMMARY

Of the implants described, few have enjoyed the wide usage of the silicone implants. Recent concern regarding the longevity of the silicone implant and biocompatibility of panicle silicone has led to reassessment of their role in implant arthroplasty of the first metatarsophalangeal joint. The concept of temporary interpositional cup arthroplasty is primarily a European phenomena.

The recent designs have been predominantly non-constrained bipolar designs with an articulation established between a metal metatarsal component of titanium or chromium and ultrahigh molecular weight polyethylene. To enhance its compatibility in bone, the polyethylene articulation is being secured to a titanium tray. Few data are currently available on the long-term performance of these implants. Ceramic material such as pyrolytic carbon may hold promise for future replacement designs of the first metatarsophalangeal joint.

nium or chromium and ultrahigh molecular weight polyethylene. To enhance its compatibility in bone, the polyethylene articulation is being secured to a titanium tray. Few data are currently available on the long-term performance of these implants. Ceramic material such as pyrolytic carbon may hold promise for future replacement designs of the first metatarsophalangeal joint.

REFERENCES

1. Shereff MJ, Bejjani FJ, Kummer FJ: Kinematics of the first metatarsophalangeal joint range of motion. *J Am Podiatr Med Assoc* 78:439, 1988
2. Buel T, Green DR, Risser J: Measurement of the first metatarsophalangeal joint range of motion. *J Am Podiatr Med Assoc* 78:439, 1988
3. Hetherington VJ, Carnett J, Patterson BA: Motion of the first metatarsophalangeal joint. *J Bone Joint Surg* 68A:397, 1986
4. Hetherington VJ, Johnson RE, Albritton JS: Necessary dorsiflexion of the first metatarsophalangeal joint during gait. *J Foot Surg* 29:218, 1990
5. Yoshioka Y, Siu DW, Cooke DV, et al: Geometry of the first metatarsophalangeal joint. *J Orthop Res* 6:878, 1988
6. Wyss UP, Cooke TDV, Yoshioka Y, et al: Alignment of the first metatarsophalangeal joint: important criteria for a new joint replacement. *J Biomed Eng* 11:19, 1988
7. Christman RA, Ly P: Radiographic anatomy of the first metatarsal. *J Am Podiatr Med Assoc* 80:177, 1990
8. Cwikla PS, Hetherington VJ, Petek JM: Morphological considerations of the first metatarsophalangeal joint. *J Foot Surg* 31:3, 1992
9. Hetherington VJ, Cwikla PS, Malone M, et al: Sectional morphology of the first metatarsophalangeal joint. *J Foot Ankle Surg* 33:77, 1994
10. Stokes IAF, Hutton WC, Scott JRR: Forces acting on the metatarsals during normal walking. *J Anat* 9:579, 1979
11. Wyss UP, McBride I, Murphy L, Cooke TDV, Olhey ST: Joint reaction forces at the first MTP joint in a normal elderly population. *J Biomech* 23:977, 1990
12. McBride ID, Wyss UP, Cooke TDV et al: First metatarsophalangeal joint reaction forces during high heel gait. *Foot Ankle*, 11:282, 1991
13. Hetherington VJ, Chessman GW, Steuben C: Forces on the first metatarsophalangeal joint: a pilot study. *J Foot Surg* 31:450, 1992
14. Endler F: Zur entwicklung einer kuenstilichen arthroskopik des grosszehengruegel enke unde ihre bisheride indekation. *Z Orthop* 80:480, 1951

15. Swanson AB: Flexible Implant Resection Arthroplasty in the Hand and Extremities. CV Mosby, St. Louis, 1973
16. Seeburger RH: Surgical implants of alloyed metal in joints of the feet. *J Am Podiatry Assoc* 54:391, 1964
17. Joplin RJ: The proper digital nerve, vitallium stem arthroplasty, and some thoughts about foot surgery in general. *Clin Orthop Relat Res* 76:199, 1971
18. Downey MA: A ball and socket metal prosthetic joint replacement, as applied to the foot. *J Am Podiatry Assoc* 55:343, 1965
19. Kaplan EG, Kaplan GS, Kaplan DM, Kaplan RK: History of implants. *Clin Podiatry* 1:3, 1984
20. Kampner SL: Total joint prosthetic arthroplasty of the great toe—a twelve year experience. *Foot Ankle* 4:249, 1984
21. Swanson AB, Lumsden RM II, Swanson GD: Silicone implant arthroplasty of the great toe. *Clin Orthop Relat Res* 142:30, 1979
22. Swanson AB, Swanson G de G, Maupin BK, et al: The use of a grommet bone linear for flexible hinge implant arthroplasty of the great toe. *Foot Ankle* 12:149, 1991
23. Weil LS, Pollak RA, Goller WL: Total first joint replacement in hallux valgus and hallux rigidus, longterm results in 484 cases. *Clin Podiatry* 1:103, 1984
24. Regnauld B: *The Foot, Pathology, Aetiology, Semiology, Clinical Investigation and Therapy*. Springer-Verlag, New York, 1986
25. Arenson DJ: The angled great toe implant (Swanson design/Weil modification) in the surgical reconstruction of the first metatarsophalangeal joint. *Clin Podiatry* 1:89, 1984
26. Helal B, Chen SC: Arthroplastik des grosszehengrundgelenks mit einer neuen silastik—endoprothese. *Orthopäde* 11:220, 1982
27. Johnson KA, Buck PG: Total replacement arthroplasty of the first metatarsophalangeal joint. *Foot Ankle* 1:307, 1981
28. Johnson KA: Dissatisfaction following hallux valgus surgery, p. 63. In *Surgery of the Foot and Ankle*, Raven, New York, 1989
29. Jarvis BD, Moats DB, Burns A, Gerbert J: Lawrence design first metatarsophalangeal joint prosthesis. *J Am Podiatr Med Assoc* 76:617, 1986
30. Hetherington VJ, Cuesta AL: Implant arthroplasty of the first metatarsophalangeal joint and alternatives, p. 1005. In Levy LA, Hetherington VJ (eds): *Principles and Practice of Podiatric Medicine*. Churchill Livingstone, New York, 1990
31. Lubinus H: Endoprothetischer ersatz des robzehengrundgelenkes. *Arch Orthop Trauma Surg* 121:89, 1983
32. Kampner SL: Implants and Biomaterials in the foot, p. 2688. In Jahss MH (ed): *Disorder of the Foot and Ankle, Medical and Surgical Management*. WB Saunders, Philadelphia, 1991
33. Koenig RD: Koenig total great toe implant, preliminary report. *J Am Podiatr Med Assoc* 80:462, 1990
34. Merkle PF, Sculco TP: Prosthetic replacement of the first metatarsophalangeal joint. *Foot Ankle* 9:267, 1989
35. Lu HS: Follow-up result in 14 cases of the 1st metatarsophalangeal joint arthroplasty with titanium total joint prostheses—introduction to two designs of titanium total MTP prosthesis (in Chinese). *Chin J Orthop* (submitted for publication)
36. Hetherington VJ, Kavros SJ, Conway F, et al: Pyrolytic carbon as a joint replacement in the foot, a preliminary report. *J Foot Surg* 21:160, 1982
37. Giannini S, Moroni A: Alumina total joint replacement of the first metatarsophalangeal joint, p. 39. In Bonfield W, Hastings GW, Tanner KE (eds): *Bioceramics*. Vol. 4. Butterworth-Heinemann, London, 1991
38. Giannini S: First metatarsal joint implant. Presented at the American College of Foot and Ankle Surgeons World Foot and Ankle Congress. October 21-23, 1993