CHAPTER **26**

TECHNIQUES OF DIGITAL ARTHRODESIS: Revisiting The Old And Discovering the New

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Surgical correction techniques for digital deformities have been a debated subject in podiatric surgery. Multiple techniques have been described and utilized throughout the past century. Common techniques include amputation, arthroplasty, flexor tendon transfer, lesser digital implants and arthrodesis. Digital arthrodesis has been advocated as an effective and predictable method of treatment for digital deformities, including hammertoes and clawtoes. Successful digital arthrodesis provides permanent and reliable correction of deformities and is considered by the authors to be a favored technique.

Two fundamental techniques of digital arthrodesis are employed; end-to-end and peg-in-hole. End-to-end arthrodesis essentially involves resecting the cartilaginous surfaces of the head of the proximal phalanx and the corresponding base of the middle phalanx. Peg-in-hole arthrodesis involves fashioning the head of the proximal phalanx into a peg (or a spike), and creating a hole in the base to receive the peg snugly. This creates a secure, stable point of fixation. Over the years, various modifications of these two procedures have been described. We will provide a thorough historical review of the literature and introduce two new fixation devices for digital arthrodesis, the Stayfuse™ interdigital fusion device (Pioneer Surgical Technology, Marquette, MI) and the Weil-Carver™ Hammertoe Implant (Biomet, Warsaw, Indiana).

HISTORICAL REVIEW

The first documented end-to-end digital arthrodesis procedure was described by Soule in 1910.[1] He advocated a longitudinal linear plantar approach one and a quarter inches long centered over the proximal interphalangeal joint (PIPJ). Fusion of the PIPJ was then achieved with the end-to-end technique and compression was maintained at the fusion site by bandaging the digit in hyperextension. In 1917, Jones described an end-to-end technique at the PIPJ employing a dorsal longitudinal incision.[2] Jones also maintained compression via bandaging. In 1927, Lambrinudi proposed arthrodesis of both the PIPJ and the distal interphalangeal joint (DIPJ) utilizing the end-to-end technique, as a treatment for claw toes.[3]

In 1940, Taylor was the first to advocate fixation of all three phalanges with a Kirschner wire to maintain stability at the proximal interphalangeal joint.[4] The end-to-end arthrodesis was performed at the PIPJ followed by insertion of a Kirchner wire of unknown size across the DIPJ and PIPJ; the digit was bandaged in slight plantarflexion at the metatarsophalangeal joint. In 1941, Selig described Kirschner wire fixation across both the DIPJ and PIPJ to promote fusion of the PIPJ. He encouraged the utililization of a 0.035 or 0.045 inch wire and his variation involved bending the distal exposed portion of the wire to prevent proximal or inward migration.[5] Taylor recommended removing the Kirschner wire at 3 weeks, while Selig recommended maintaining the K-wire in for at least 6 weeks to obtain fusion.[4,5] In 1995, Creighton and Blustein modified the Kirschner wire fixation technique by burying the wire to eliminate the incidence of pin tract infections while maintaining proper fixation at the PIPJ.[6]

In 1990, Patton et al described the use of the Orthosorb Absorbable Pin in digital arthrodesis at the PIPJ.[7] The Orthosorb Absorbable Pin is 1.3mm in diameter and composed of poly (p-diaxanon), which dissolves via hydrolysis. Most recently, Giovinco recommended end-to-end arthrodesis utilizing an un-named absorbable pin at the PIPJ combined with vicryl suture through drill holes in the proximal and middle phalanx.[8]

The history of the peg-in-hole (or spike-in-hole) arthrodesis technique is brief in comparison to the end-to-end arthrodesis technique. In 1931, Higgs originally described a "spike-in-hole" arthrodesis at the PIPJ.[9] He felt that with firm impaction of the proximal phalanx into the middle phalanx a firm and stable arthrodesis is obtained with no need for fixation. Young modified this procedure into a peg fashion, maintaining the dorsal

cortex of the peg for stability.[10] He also felt no fixation was necessary. Alvine and Garvin, in 1980, also utilized a peg-in-hole without fixation.[11] In 1983, Schelfman et al. advocated the use of Kirschner wire fixation of the peg-in-hole arthrodesis to reinforce immobilization of the PIPJ.[12]

KIRSCHNER WIRE FIXATION

Kirschner wires are the most common type of fixation device advocated in digital arthrodesis. However, use of K-wires is not without complication. Compression across the fusion site is often difficult to achieve and single K-wires alone cannot prevent frontal plane rotation of the digit.[13] Migration, bending and breakage have also been reported.[13-15] Typically, the tip of the Kirschner wire is left external, increasing the potential for skin irritation and pin tract complications. The incidence of pin tract infection is variable and has been reported in 1.8% to 18% of cases.[14,15] In part, because of these complications, alternative fixation devices for digital arthrodesis have recently been described.[16,17,18]

ZIMMER® STAYFUSE™ INTER-DIGITAL FUSION DEVICE

One recently FDA approved device for digital arthrodesis is the Stayfuse™ inter-digital fusion device. This is a two component titanium device compatible with both the proximal and middle phalanges. This device is indicated as a replacement for the 1.1mm (0.045 inch) Kirschner wire used during arthrodesis, or fracture fixation of fingers, toes and small bones.

The Stayfuse™ device comes in several sizes with a "PROX" component for the proximal phalanx and a "MID" component for the middle phalanx. The components come in two different colors, blue and gray. The color coding system facilitates matching the "PROX" component with the appropriate size "MID" component. The "PROX" components come in 3.3mm and 3.8mm (gray) and 2.8mm (blue). The "MID" components range from 3.8mm to 5.0mm (gray) and 3.8mm to 4.3mm (blue) (Figure 1).

The design of the device allows for a simple insertional technique. Utilizing the patient's pre-operative radiographs, templates are used to determine the appropriate size of the device. These templates are provided in the packaging. Following anatomical dissection of the digit and preparation of the fusion surfaces, a pilot hole is drilled perpendicular to the resected portions of the proximal phalanx and middle phalanx. When drilling the middle phalanx, it is important to drill slightly dorsal to the center point to accommodate for the shape of the middle phalanx and avoid disruption of the plantar cortex (Figure 2).

The PROX component is then inserted into the proximal phalanx (Figure 3). The proximal phalanx should be manually stabilized to prevent rotation of the phalanx during screw insertion. Insertion is complete when the Hex Driver spins off of the implant hex, indicating the hex of the implant is flush with the bone surface. The same technique is then used to insert the MID component into the middle phalanx, however, the

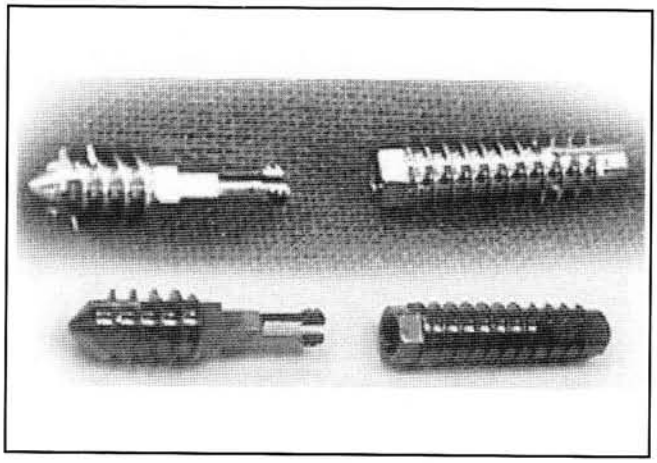

Figure 1. Shown are the two different sizes of the Stayfuse System which are color coded; blue and gray Prox and Mid components are shown.

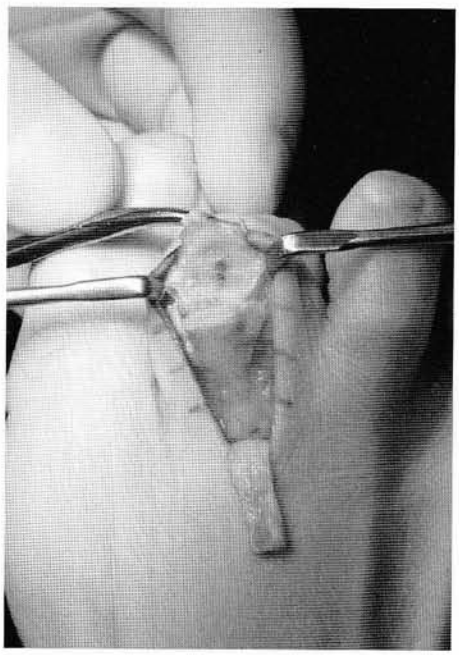

Figure 2. The appropriate size pilot hole is made in the middle phalanx. The pilot hole is slightly dorsal to the center point of the phalanx to avoid disruption of the plantar cortex which is concave in configuration. In addition, placement of the pilot hole slightly dorsal to midline should improve toe purchase postoperatively.

hex driver will not spin off the implant hex. Therefore, care is taken to insert the MID component flush with the base of the middle phalanx to allow for a solid fusion site.

The two components are aligned to ensure in-line insertion; any interposed soft tissue is removed and the MID component is inserted into the PROX component (Figure 4). While applying moderate pressure, the implant halves are rotated slightly in opposite directions until the hexes engage. Finally, compression is applied and the two components lock together. The surgeon should feel or hear three snaps to assure approximation of the two components. If the surgeon fails to achieve adequate approximation of the two components, the Stayfuse™ system will not lock and may cause diastasis at the fusion site (Figures 5A, 5B). The fusion site is inspected carefully to verify locking prior to wound closure. Intra-operative radiographs are helpful and recommended to ensure approximation (Figures 6, 7A, 7B).

There are some situations or scenarios necessitating implant removal. They include, but are not limited to, infection, failure, delayed or non-union, over or under correction, pain and excessive edema. In these cases a cortical window must be created over the dorsal aspect of the middle phalanx; the implant may then be removed by elevating the tip of the device utilizing a small elevator or curette. The tip of the device may then be grasped and turned counterclockwise allowing both ends of the implant to be removed as one unit. The authors have no experience with removal; it would seemingly be difficult and is likely the main disadvantage of this type of fixation.

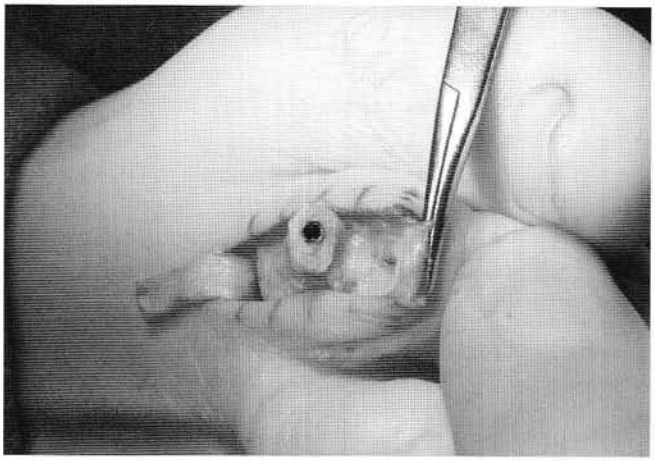

Figure 3. The Prox component of the implant is inserted in the proximal phalanx after creation of the appropriate size pilot hole. It is important to ensure the hub of the implant is flush with the distal surface of the proximal phalanx.

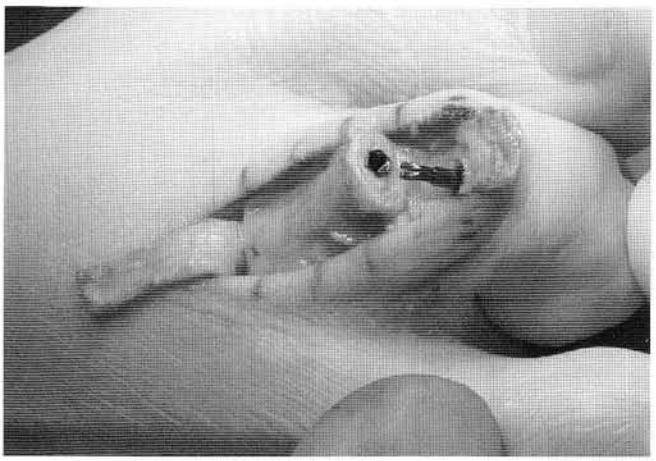

Figure 4. After both components are properly seated within their respective bones, they are joined together by insertion of the Mid component into the Prox component. This step can be somewhat difficult depending on the amount of bone resection performed and the resultant shortening. Care must be taken to avoid fracturing the device itself.

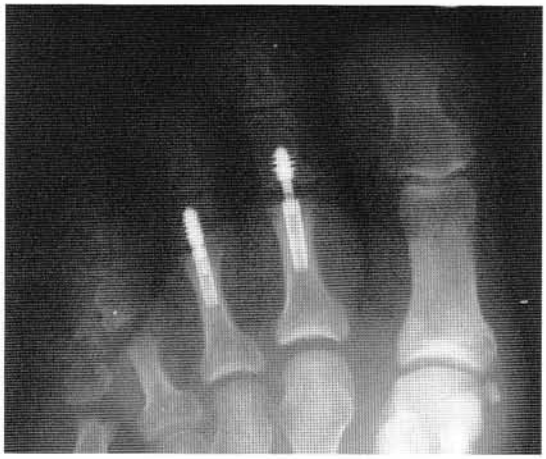

Figure 5A. A complication of diastasis, or separation of the two components has occurred due to failure to achieve proper locking of the two components of the Stayfuse system. Particular care must be taken to feel the series of clicks that ensure that the two components are secure and locked.

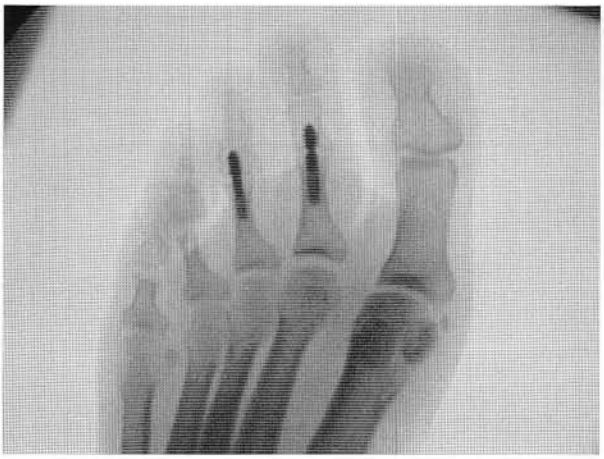

Figure 5B. Reseating of the implant performed under local anesthesia and fluoroscopic visualization without the need to reopen the surgical site. Proper seating and locking was successfully achieved.

BIOMET WEIL-CARVER™ HAMMERTOE IMPLANT

The second device recently introduced as an adjunct in digital fusions is the Biomet Weil-Carver™ Hammertoe Implant. This implant is designed from an amorphous (non-crystalline) copolymer, Lactosorb® (Biomet®, Inc. Warsaw, Indiana), which is synthesized from 82% L-Lactic acid and 18% Glycolic acid. Lactosorb retains most of its strength for approximately 6-8 weeks, which is an adequate time frame for biological consolidation to occur at the arthrodesis site. Lactosorb completely loses its strength and degrades in approximately 12 months. The Biomet Weil-Carver™ Hammertoe Implant is manufactured in one size only and measures approximately 25 mm in length and is characterized by a 2.5mm dia. threaded proximal segment (13 mm in length) with a 2.0 mm dia. (12 mm in length) barbed distal segment to prevent pistoning. The Biomet Weil-Carver™ Hammertoe Implant is FDA approved for proximal interphalangeal joint arthodesis (Figure 8).

A dorsal longitudinal incision is placed centrally over the proximal interphalangeal joint. The incision may extend proximally to the level of the metatarsophalangeal joint in cases where soft tissue release is required.

Following anatomic dissection of the digit, the bone is prepared for fusion by removal of the articular surface of the head of the proximal phalanx and the corresponding middle phalangeal base. Utilizing a 2.0mm Steinman pin, the central medullary canals of both the proximal and middle phalanx are drilled making sure the holes are equidistant from the corresponding dorsal cortex (Figure 9). It is the senior authors' preference to align the digit with a 0.045-0.062 Kirchner wire before drilling with a 2.0mm Steinman pin to visualize proper positioning of the pilot holes and proper apposition of the fusion site.

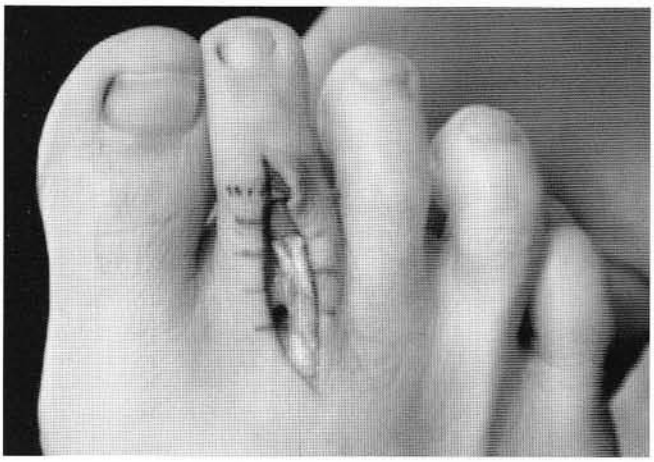

Figure 6. Inspection of the arthrodesis site intra-operatively, prior to closure, to ensure proper apposition, seating and locking. Intraoperative radiographic confirmation is strongly recommended.

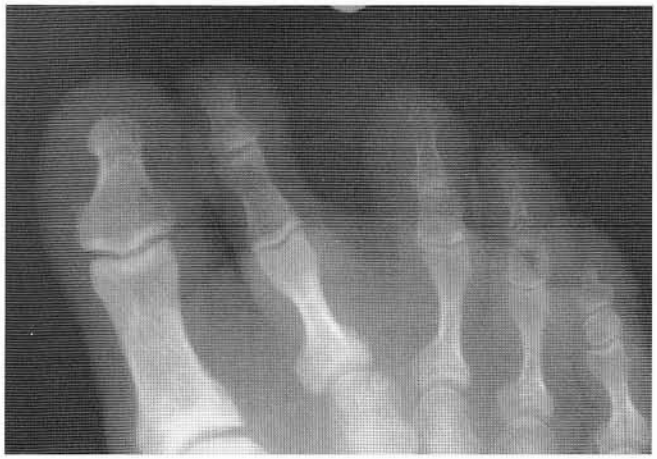

Figure 7A. Preoperative radiograph of a patient with a hammertoe deformity of the 2nd digit of the right foot.

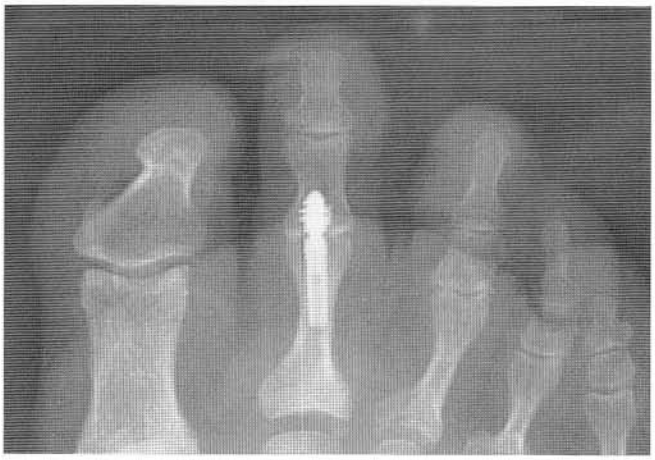

Figure 7B. Postoperative radiograph 2 months later showing excellent alignment and radiographic fusion of the PIPJ site. The implant is well seated and secure.

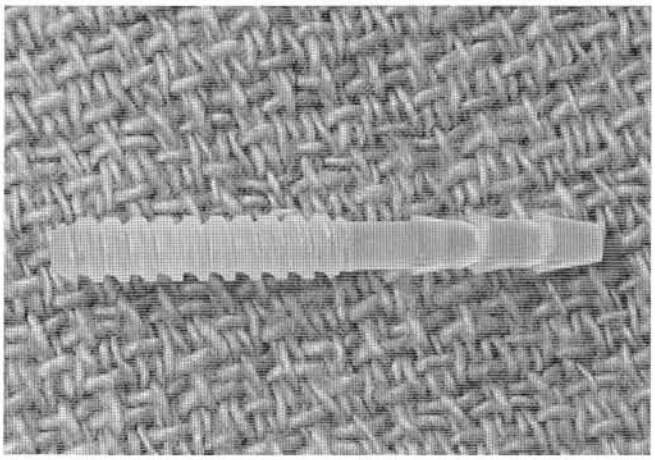

Figure 8. The Biomet Weil Carver Implant for digital arthrodesis. This absorbable implant is a one component device which seats in both the proximal and middle phalanges and is available in only one size.

A 2.5mm tap, which is provided in the package, is introduced into the proximal phalanx (Figure 10). The implant is loaded onto the manual driver provided in the package and threaded into the proximal phalanx leaving the barbed distal portion of the implant accessible for the middle phalanx (Figure 11). If pistoning of the implant occurs in the proximal phalanx the authors' recommend inserting a 0.045 Kirchner wire perpendicular to the shaft of the proximal phalanx just proximal to the implant tip to help avoid the proximal migration of the implant (Figure 12). At this time the digit is manipulated to initiate proper seating of the barbed distal portion into the middle phalanx and counter pressure is applied to both proximal and middle phalanx to achieve fixation. If a Kirschner wire was utilized, it may be removed after adequate apposition is achieved. In certain instances, the distal barbed end may be too long. Therefore, it may be necessary to reduce the length of the distal barbed portion of the implant by the use of a power saw, burr or bone cutter (Figure 13). After achieving fixation and confirming seating and apposition of the fusion surface, the extensor tendon is re-approximated and sutured to the periosteum (Figures 14, 15A, 15B). Standard closure is then performed.

These two devices offer several advantages over conventional fixation in digital arthrodesis. There is no healthy joint disruption, no external postoperative implant exposure and "pin tract" infections are

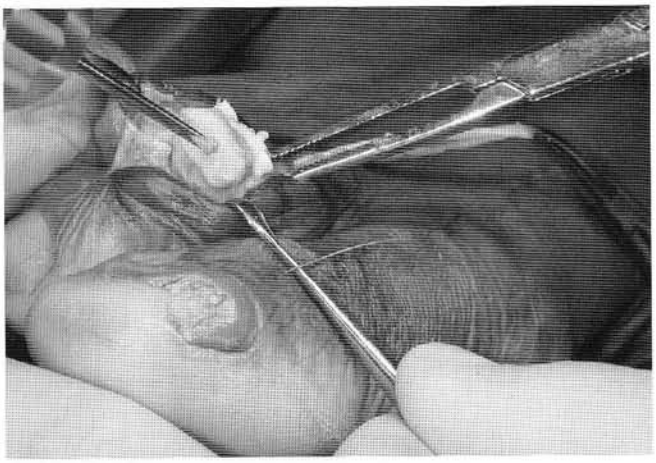

Figure 9. A 2.0 mm (5/64") Steinmann pin is utilized to drill the central medullary canal of both the proximal and middle phalanx prior to insertion of the implant. The hole is usually made equidistant from the dorsal cortex of the bone, although offsetting the middle phalanx hole would certain be acceptable and perhaps desirable.

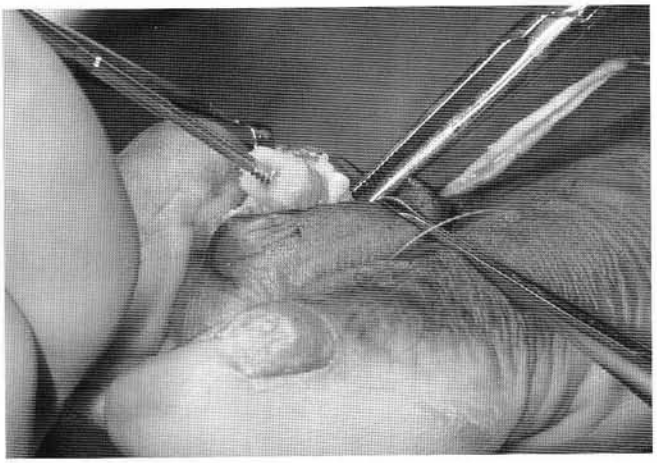

Figure 10. A 2.5 mm tap is provided to partially tap the proximal phalanx. The quality of the bone based on preoperative radiographs and intraoperative examination may alter the extent of tapping before insertion of the implant device.

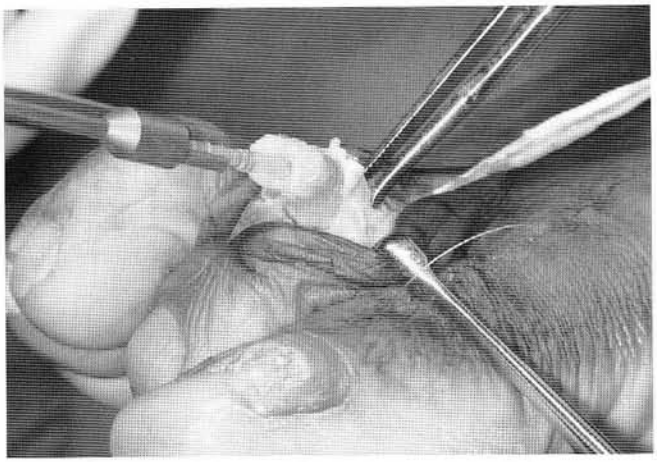

Figure 11. Insertion of the Biomet Weil Carver Hammertoe Implant into the proximal phalanx following drilling and tapping of the 2.0 mm hole. A special inserter prevents overaggressive seating of the implant in the proximal phalanx.

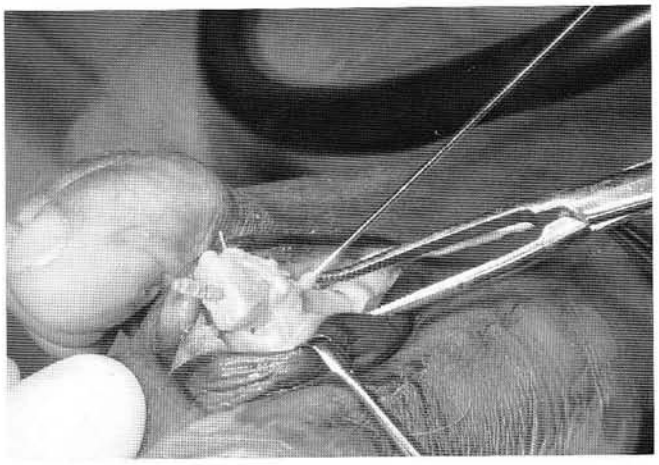

Figure 12. A 0.045" Kirschner wire has been inserted just proximal to the implant stem in the proximal phalanx to prevent proximal migration of the implant during the process of insertion and compression. In osteopenic or softer bone, we have experience loosening of the implant and proximal migration down the medullary canal necessitating the insertion of a small Kirschner wire to serve as a "doorstop" to proximal migration. This modification has worked well in our limited experience.

Figure 13. Bone cutting forceps are used to reduce the overall length of the distal barbed portion of the implant which is to be seated into the middle phalanx. Depending on the amount of shortening as a result of resection of the articular surfaces of the fusion site, it may be impossible or very difficult to seat the implant into the drill hole of the middle phalanx due to its length. Shortening of the distal end of the implant facilitates the final step.

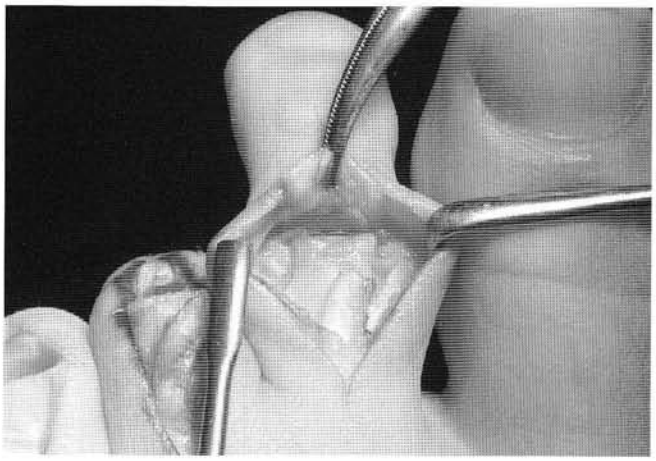

Figure 14. Intraoperative confirmation of proper seating of the implant to ensure proper alignment and apposition of opposing fusion surfaces.

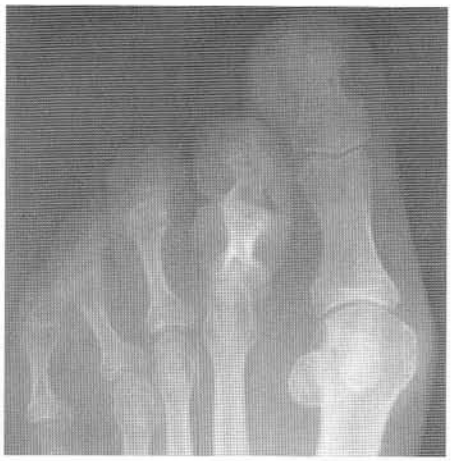

Figure 15A. Preoperative radiograph of a rigid deformity of the second digit in an active elderly patient; a transverse plane abduction deformity is noted as well. The HAV was asymptomatic and the patient did not wish to have surgical correction of the bunion deformity.

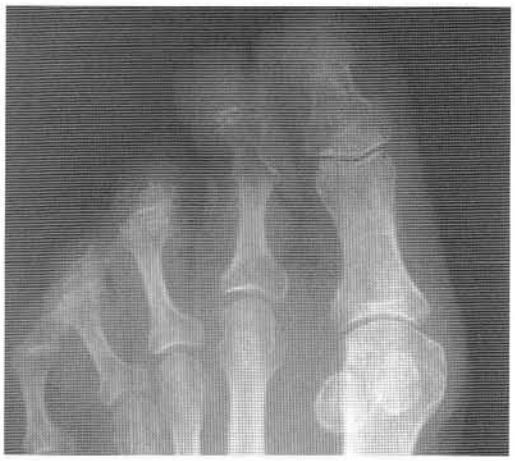

Figure 15B. Postoperative radiograph 8 weeks following surgery. Excellent consolidation is seen at the fusion site. The digit was fused in slight abduction to accommodate the deviation of the hallux and prevent creation of an interdigital lesion.

eliminated. In addition, they are relatively easy to use, constructed of biocompatible materials and have high patient acceptance. One distinct advantage of the Biomet Weil-Carver implant is its biodegradability. A distinct advantage of the Stayfuse device is that it comes in different sizes to accommodate different anatomic sizes of the phalanges.

They also possess similar disadvantages. There is the potential for excessive swelling postoperatively due to increased manipulation, fracture of the proximal or middle phalanges during execution of the surgery, mechanical failure, rejection potential or other foreign body reaction, as well as significantly increased cost. They cannot be used to stabilize the metatarsophalangeal joint, which is not uncommonly necessary. When stabilization of the metatarsophalangeal joint is important for correction of the deformity, a conventional Kirschner wire for stabilization of the fusion site and metatarsophalangeal joint is recommended. The Biomet Weil Carver™ implant is only available in one size and may not be suitable for all patients.

Throughout the past century, there have been many variations of digital arthrodesis techniques advocated. The physician must assess the overall advantages and disadvantages of each, and choose the method that best meets the needs of the patient as well as the physician's skill level. With the introduction and success of the Stayfuse and Biomet Weil-Carver™ hammertoe implants,

it is possible that we are at the beginning of another century of new and innovative techniques in digital arthrodesis. The true advantages and efficacy remain to be seen but show great promise. Certainly the improving design and concept of the newer devices is exciting and intriguing and has captured the attention of foot and ankle surgeons for correction of digital deformities of varying severity.

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