CHAPTER **22**

TREATMENT OF CHRONIC CONTAMINATED DEEP WOUNDS WITH INFECTED TENDON AND BONE

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Severe deep space infections can be difficult to eradicate, especially in those wounds with underlying bone or tendon infection. Chronic osteomyelitis is a surgical disease that can pose a difficult problem for the treating surgeon. It is important to understand the etiology of the infection, as well as the pathophysiology of its chronicity to avoid delayed healing and poor outcomes. Surgeons must individualize treatment for each patient, because host morbitities often play an important role in the propagation of infection. Persistence of infection is the result of a variety of etiologies, including lack of skin coverage, abundant scar tissue, impaired vascularity and residual nidus of infection. Treatment requires isolation of the pathogens, aggressive debridement and removal of all infectious and necrotic material, management of resected dead space and then bone and soft tissue reconstruction. These patients require a team approach involving general medicine, infectious disease and surgery.

Chronic osteomyelitis and infected tenosynovitis are difficult to treat because of the avascular nature of tendon and sequestra (dead pockets of bone). Once bacteria bind to bone, acute inflammation occurs. Local edema and oxidative enzymes released by immune cells can cause bone infarction and resorption. Infection then tracks along the Haversian and Volkman canals eventually disrupting the blood supply and, leading to a sequestrum. Treatment goals are to resolve the infection and maximize patient function. Historically, extensive debridement of infected bone and tissue with lengthy antibiotic regimens were the gold standard.[1,2] Outcomes can be further improved with osseous stability,[3] instillation-suction drains,[4-12] management of the dead spaces with antibiotic beads,[13-25] and vascularized free flaps.[26] The use of muscle flaps and vascularized bone transfers are less available to the foot and ankle surgeon in the treatment of these complex infections. Therefore, other modalities such as debridement (with attention to function), external fixation, amputation and intravenous antibiotics are more commonly used. The author has found increased success with the use of instillation-suction drains and antibiotic beads in chronic deep infections involving tendon and bone. Multiple surgical strategies are available for managing septic feet at risk for leg amputation. This manuscript presents the author's experience and discusses the use of biodegradable antibiotic beads, as well as instillation-suction devices particularly the new VAC Instill (KCI, San Antonio, TX) in the treatment of these difficult chronic wounds.

ANTIBIOTIC BEADS

The benefit of antibiotic beads is the ability to deliver high local tissue concentration of an antibiotic to an area that has relatively poor blood supply. The antibiotic diffuses into the cavity and aids in the eradication of infection. There are two available mediums routinely used as a carrier of antibiotic's in foot and ankle surgery; Polymethylmethacrylate (PMMA) and calcium sulfate (OsteoSet, Wright Medical)

Septopal (Merck, Darmstadt, Germany) is a prefabricated chain of gentamicin-impregnated PMMA 7mm beads. Commercially prepared antibiotic-impregnated PMMA beads are not available in the US because of a lack of trials, but many surgeons make their own antibiotic impregnated beads by adding antibiotic powder or liquid into PMMA cement pellets. Vancomycin and aminoglycosides are the best choices for antibiotic beads because of their broad spectrum, extensive use, and low incidence of complications and heat stability.

The antibiotic is released into the wound by diffusion with local antibiotic levels remaining high while systemic serum levels are low. The highest concentration of antibiotic occurs within the first 48 hours followed by a gradual decline over the next one to two weeks.[13,18] Smaller PMMA beads have been found to release a higher percentage of antibiotic at a quicker rate than larger beads due to increased surface area.[17] Antibiotic beads are able

to give higher antibiotic levels to the affected area than intravenous antibiotics in these types of pedal bone infections. This is secondary to the lack of bone penetration of many antibiotics as well as the relative avascular nature of osteomyelitic bone and the possible coexisting peripheral vascular disease that may exist in patients with foot infections. Seabrook et al demonstrated the limitation of systemic antibiotics in the treatment of diabetic feet even with adequate peripheral circulation (toe pressures greater than 30 mm hg).[19]

Routinely, a combination of Vancomycin and Gentamicin PMMA antibiotic beads can be made and placed either on double strand 28G wire or nonabsorbable nylon suture. The Vancomycin powder (1G) is added to the PMMA powder and then is mixed with the liquid monomer to form the beads. The Gentamicin beads require a more tedious process to fabricate. Gentamicin (ten, 80mg/2 ml vials of Gentamicin) are mixed with the PMMA cement as it is becomes homogenous after the liquid monomer and powder polymer are mixed. Figure 1 demonstrates successful treatment of a chronic osteomyelitis case of the calcaneus with the use of both Vancomycin and Gentamicin PMMA beads in conjunction with a partial calcanectomy and systemic antibiotics.

Despite historical success, and no known reports of antibiotic resistance to antibiotic beads, PMMA antibiotic beads do have disadvantages when compared with calcium sulfate. The first and most obvious disadvantage is the need for secondary surgery to remove them since they are not absorbable. Many times granulation will form around the beads and the secondary surgery will disrupt the internal healing process. PMMA beads theoretically may also harbor bacteria themselves if they are left in for a prolonged period. Klemm described a reinfection of Pseudomonas aeuriginosa without resistance in a tibia after 8 years of antibiotic beads being in place.[25] PMMA beads also have a poor elution property (less than 50% of antibiotic at four weeks).[20] For these reasons, the author prefers biodegradable beads.

There is a lot of research in biodegradable beads. Polyglycolic acid and polylactic acid (same material as absorbable suture) have been tested.[16] Fatty acid dimer and sebacic acid also has been developed as a biodegradable substance for antibiotic beads.[13] However, the author's preferred material is calcium sulfate despite its off-label use. Calcium sulfate is biodegradable, radio opaque and has a predictable linear antibiotic elution rate and absorption rate.[20-22] Early research regarding the use

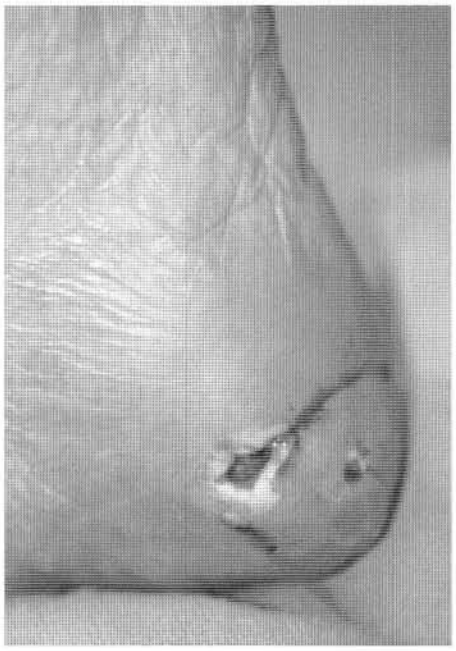

Figure 1A. Preoperative clinical picture of a 83-year-old diabetic male with a two year history of a draining sinus with cellulitis/ osteomyelitis in the heel status post heel spur surgery. (Note the cloacae as well as the non-healing surgical wound.)

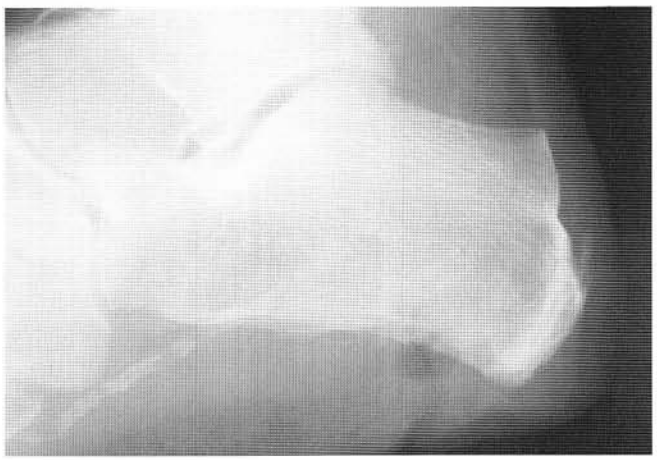

Figure 1B. Preoperative lateral radiograph showing cortical destruction of the inferior plantar calcaneal cortex.

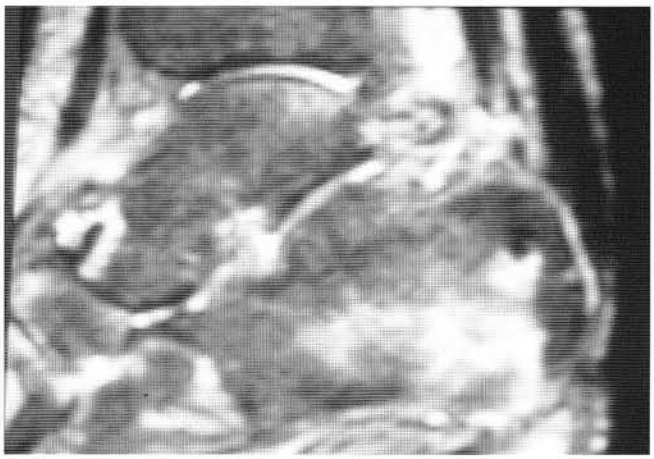

Figure 1C. Preoperative MRI showing marrow edema consistent with osteomyelitis.

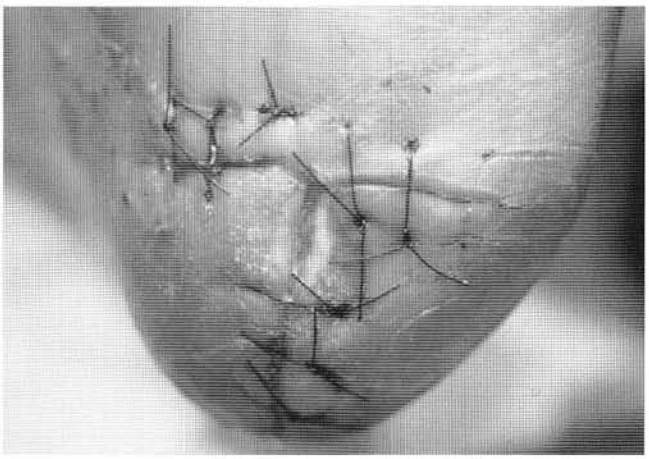

Figure 1D. Postoperative appearance after insertion of PMMA beads.

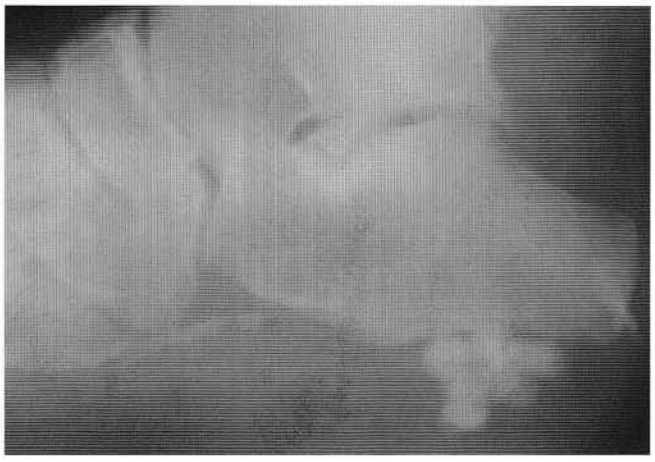

Figure 1E. Postoperative x-rays with PMMA beads in place.

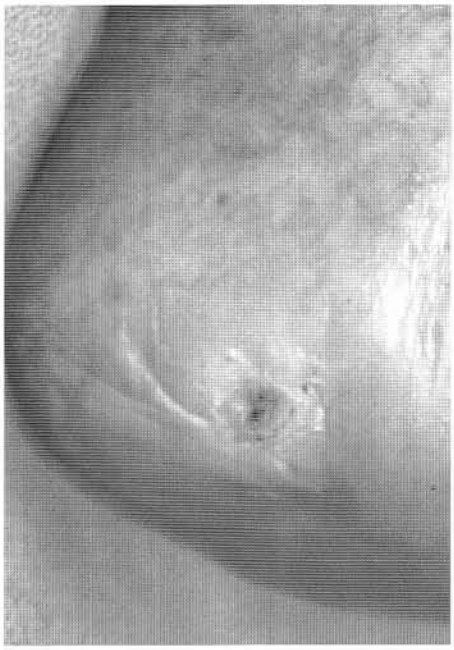

Figure 1F. Final clinical picture of complete healing.

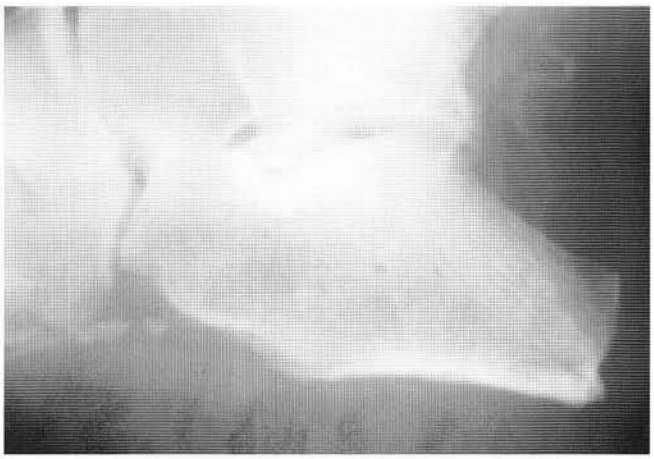

Figure 1G. Final x-rays showing resolution of bony involvement.

of calcium sulfate beads is promising.[20,23,24] Nelson et al noted in an animal study a 35% cure with systemic antibiotics, 41.7% cure with debridement alone and a 84.6% cure with calcium sulfate antibiotic beads.[23] McKee et al reported a 92 percent resolution of infection in 25 patients with culture confirmed osteomyelitis at a mean follow up of 28 months. Tobramycin calcium sulfate beads were used in addition to local debridement and systemic oral antibiotics. However, in eight cases they did note sterile draining sinuses.[24] It is important to achieve a balance between the number of beads needed to fill a void with the desired antibiotic effect. Care must be taken to avoid over packing the closed wound to avoid a dehiscence secondary to the breakdown of the calcium sulfate leading to a seroma/exudate problem. If drainage does occur it must be differentiated from potential residual infection. Wounds that drain after implantation of biodegradable antibiotic beads usually represent the breakdown product of the calcium sulfate. This breakdown product usually is sterile. The beads may be seen on plain radiographs for up to three months. In small wounds the author usually uses approximately 5-10 beads. Typically 10 beads fit well into a foot. Large wounds can handle a larger number of beads depending on the space. The author has used as many as twenty beads without a postoperative draining sinus. Figure 2 and 3 demonstrate the absorbable bead kit with successful use of the beads in different clinical situations.

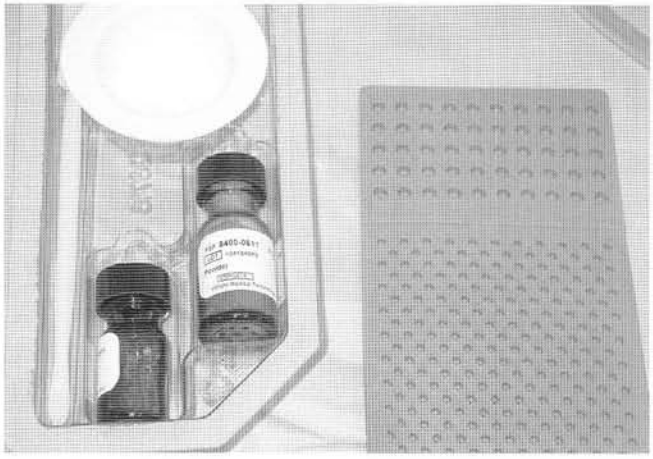

Figure 2A. OsteoSet bead kit (Wright Medical) - plastic tray to formulate the beads after mixing the liquid monomer and powder polymer.

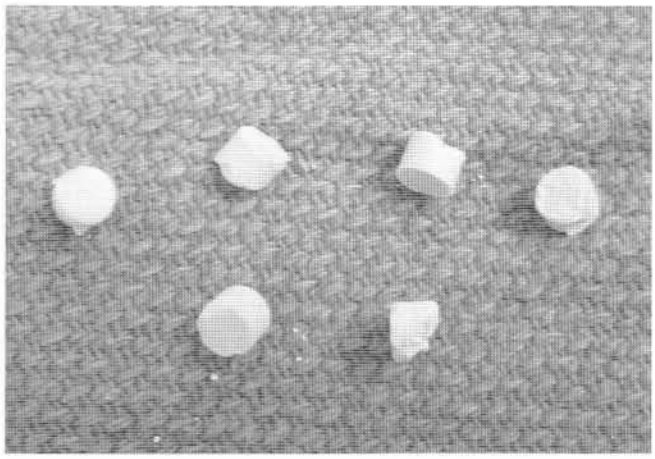

Figure 2B. Calcium sulfate beads.

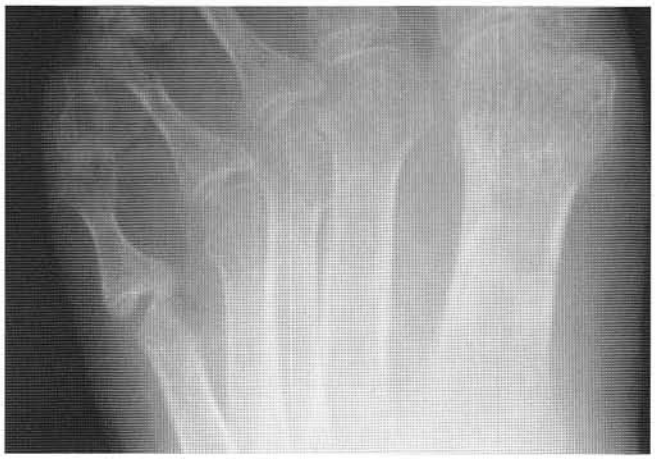

Figure 2C. Preoperative radiograph of chronic osteomyelitis of the fifth metatarsal.

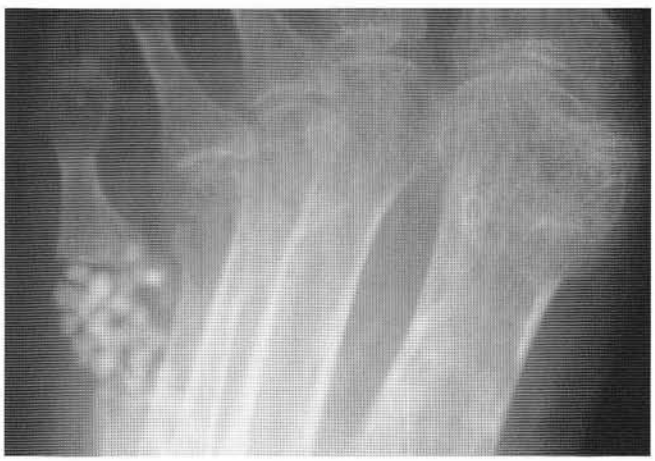

Figure 2D. Postoperative appearance with absorbable beads in place.

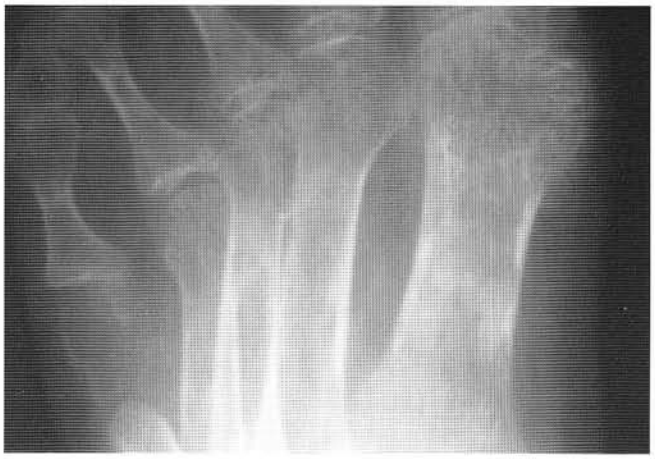

Figure 2E. Final radiographs demonstrating resorption of the beads with resolution of the osseous destruction.

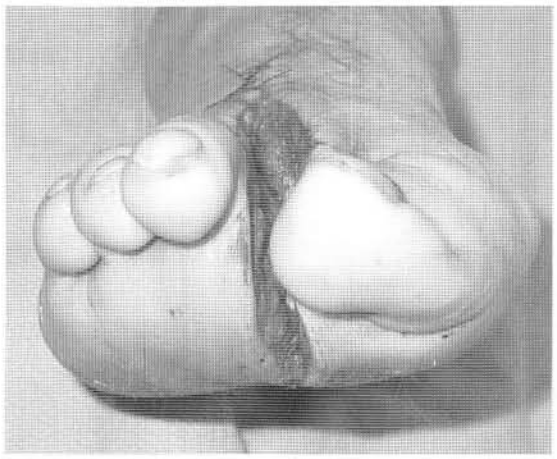

Figure 3A. A large wound status post 2nd ray amputation and I&D for a septic foot with acute osteomyelitis. (2 weeks postoperative)

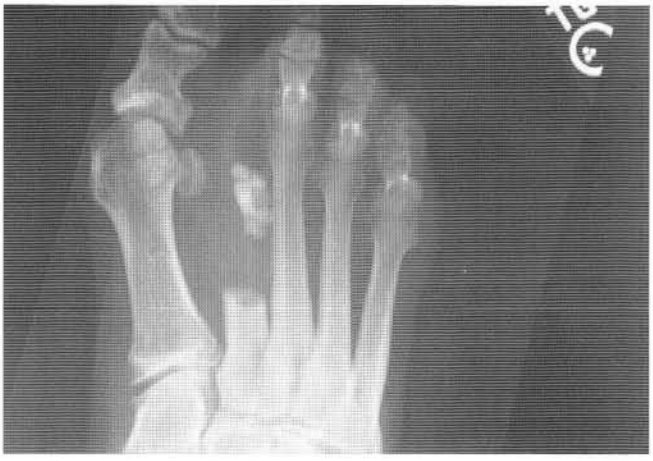

Figure 3B. Radiographic appearance after revisional closure of the large wound with implantation of antibiotic beads.

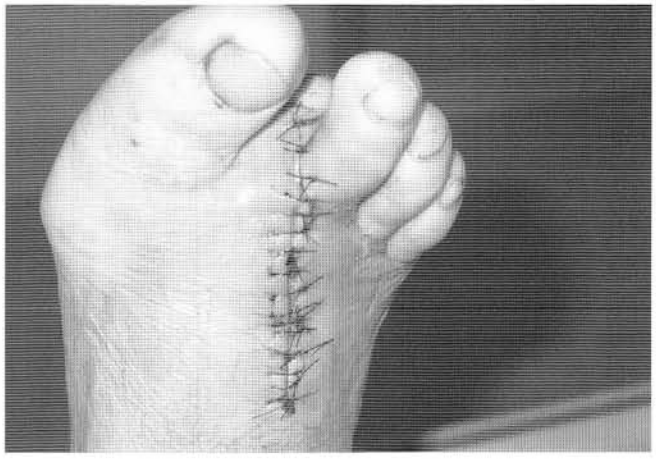

Figure 3C. Final dorsal clinical picture of complete healing only 3 weeks after original emergent amputation/I&D.

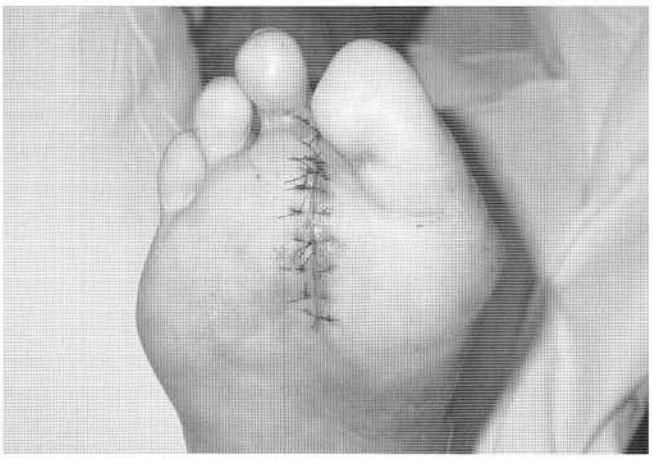

Figure 3D. Final plantar clinical picture of complete healing only 3 weeks after original emergent amputation/I&D.

Calcium Sulfate (OsteoSet, Wright Medical) can be mixed with Vancomycin 500mg powder or Tobramycin/Gentamicin 1G liquids. The mixture is then placed into a pellet template that comes with the kit and in two minutes the beads are hard enough to be implanted into the wound.

The author believes antibiotic beads should be a mainstay in the treatment of osteomyelitis cases, particularly now with the increasing use of absorbable beads. The overall advantages compared with traditional PMMA beads include higher sustained antibiotic concentrations during the entire resorption process, rather than no residual levels after surgical removal usually two weeks postoperatively with PMMA. Obviously, it also eliminates the need for a second surgery to remove PMMA beads. Finally, because calcium sulfate beads gradually dissolve, the soft tissue or bone defect will slowly fill with tissue avoiding a dead space after removal leading to a decreased need for further reconstruction.

INGRESS-EGRESSS DRAINS

Antibiotic beads do not provide high enough concentrations unless closure is accomplished. Bead pouches have been described with the use of a bio-occlusive film.[27] However, the author believes wounds without skin available for closure are better treated with the V.A.C. Instill. (KCI, SanAntonio, TX) The V.A.C. Instill is a type of ingress-egress drain that is coupled with the proven success of traditional wound VAC therapy. The wound VAC therapy is the application of controlled, localized negative pressure to help uniformly contract wound margins, assist with granulation and to help remove interstitial fluid to help promote wound healing. The device has been used on all types of wounds with success.[28,29] Elimination of nonviable tissue is paramount in the success of this device. Nonviable tissue can become a focus of bacterial proliferation, which impedes wound healing. The V.A.C. Instill System extends the already proven treatment of the wound VAC to assist with wound cleansing, irrigation and removal of infectious materials. The instillation therapy is designed to control the delivery of topical solutions such as antibiotics, antiseptics, antifungals, cleansers and analgesics to the wound site. The addition of instillation therapy adds a new way to further decrease the bacterial burden in complex wounds.

Instillation-suction drainage systems have been described in the literature for the treatment of infected joints, bones and soft tissues on multiple occasions.[4-12] However, the use of these devices have subsided over the last several years due to the labor intensive issues associated with making and maintaining these devices, as well as potential post-operative problems. Postoperative bleeding, obstruction of the tubing and maceration have been described.[8] Many physicians have utilized antibiotic beads to avoid these downfalls.[10] Schmidt et al showed prolonged hospitalization with instillation and drainage compared with PMMA beads despite similar results in treating these difficult infections.[10] The majority of articles published regarding ingress-egress antibiotic solution through an infected surgical wound were published years ago.[5-9,11,12] This is most likely secondary to the extra care necessary in formulating and maintaining the instillation and drainage system. Improvements in the ingress-egress drain have been described.[8,9] A crisscross flow reversal system using a double tube can prevent obstruction.[8]

Incomplete resolution or recurrence of infection has been traditionally thought to be a problem after primarily closing infected wounds, although Connolly et al found a 90% success rate in 30 patients treated with an antibiotic ingress-egress system. Chronic open wounds, surgical or not, increase the potential risk for desiccation and colonization of the tissues. Debridement is critical in any treatment of infection. It is critical to debride any potential nidus of infection to well vascularized bleeding tissue. Once this is performed the potential exists for primary or secondary closure of these wounds. Connolly et al described a modification of Kritter's closed instillation system in the treatment of diabetic foot infections to facilitate primary closure.[4,7] Kritter's original work described the use of Neomycin sulfate which is no longer available secondary to toxicity.[7] They utilized 80 mg Gentamicin/1L normal saline. This dose is approximately 1mg/kg compared with the usual intravenous 5-7mg/kg dosage with Gentamicin. This dose will allow high local concentrations with less significant systemic absorption. Systemic levels of Gentamicin are detectable with local irrigation, but elevated serum creatinine or other drug side effects do not seem to occur.[30] Gentamicin is ideal because it is water soluble and is bactericidal at high concentrations. Also, persistent suppression of

bacterial growth after exposure to aminoglycosides occurs and is described as the post antibiotic effect.[4]

Connolly et al loosely coapted the skin edges to allow drainage from the incision line. Significant maceration secondary to instillation systems has been well described but are self-limiting once the instillation is discontinued. However, the addition of egress suction decreases this problem. Oguachuba showed clinical resolution of chronic osteomyelitis in 26 of 28 patients utilizing an instillation-suction device. Two perforated drainage tubes are inserted approximately 3-4 cm from the wound and are laid close to the region of infection. An antibiotic solution is then dripped in via the tubing and the continuous suction pump removes debris, exudate and the antibiotic solution.[12] Tong et al described superior results in the treatment of chronic hematogenous osteomyelitis with closed intermittent irrigation and suction compared to secondary intention and primary closure with or without muscle pedicle transfer when similar debridement and systemic antibiotics were utilized.[5]

A review of the treatment of infected wounds with the instillation-suction devices shows promising results that may be further improved when combined with the benefits of negative pressure, intermittent therapy and an excellent closed suction system. These factors will avoid some of the reported complications in the past. The new release of the V.A.C. Instill System is expected to cause a resurgence of ingress-egress treatment of infections of the lower extremity.

The author utilizes the VAC instill when there is inadequate skin coverage for closure. The treatment is geared toward resolution of infection without reinfection or amputation at a higher level while maintaining optimal function of the patient's extremity. The goals are to reduce infection, reduce edema, remove exudate, and enhance granulation in preparation for split thickness skin grafting and final closure. The delivery of a solution into a wound irrigates and helps remove exudate and decrease bacterial contamination. The use of mechanical debridement with saline has been shown to be an effective means of decreasing bacterial load.[31] Bansal et al compared antibiotic instillation versus Betadine in 50 patients with chronic osteomyelitis (25 in each group) irrespective of culture and no notable difference was identified between the two groups. Their overall success rate was 80%.[6]

Most commonly the agent used in the instillation with the VAC instill is AgNO3 (Silver nitrate, 0.5%). It is utilized to decrease the bacterial colonization via dilution and for its antiseptic properties. The usual settings include three seconds of infusion followed by a 1-3 minute hold (dwell) followed by 15-30 minutes of negative pressure therapy at 125 mm Hg. Other instillation products can be considered and need to be researched. Aminoglycosides seem to be the most obvious antibiotic that could be utilized in this system although concern for systemic absorption has kept it from being allowed to be implemented in the author's hospital. Saline, bacitracin, polymixin B, 0.25% acetic acid have also been considered as viable adjuncts to instillation therapy. Figures 4, 5, and 6 show examples of difficult infections with inadequate skin for closure that responded beautifully to the instillation therapy.

Both instillation-drainage systems and antibiotic beads have been shown to be a valuable adjunct in the treatment of these difficult infections. The author believes that the newer advances (calcium sulfate absorbable beads and the instillation-suction VAC instill therapy) have improved patient outcomes and tolerance to many limb threatening infections.

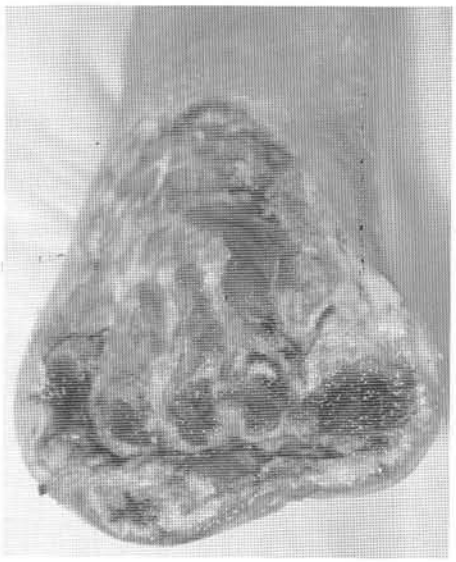

Figure 4A. A post radical debridement picture of a 66-year-old diabetic female with Serratia sepsis secondary to a deep space foot infection. Vascular surgery performed a guillotine amputation in conjunction with a fem-pop by-pass.

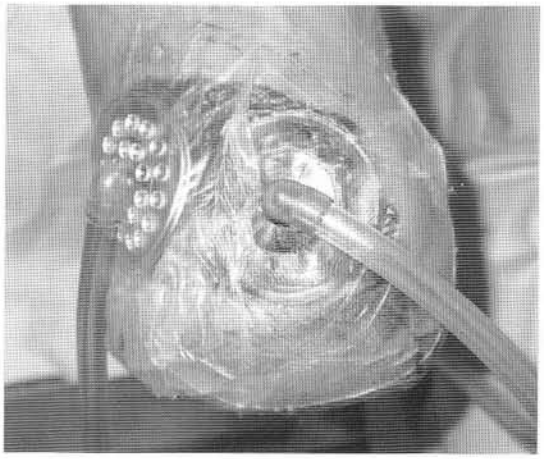

Figure 4B. Postoperative appearance of revisional transmetatarsal amputation with the VAC instill in place.

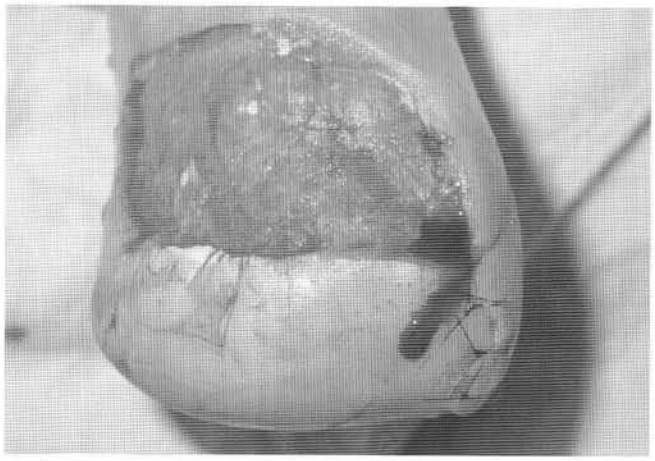

Figure 4C. Clinical appearance of the amputation one week after the initiation of the VAC instill.

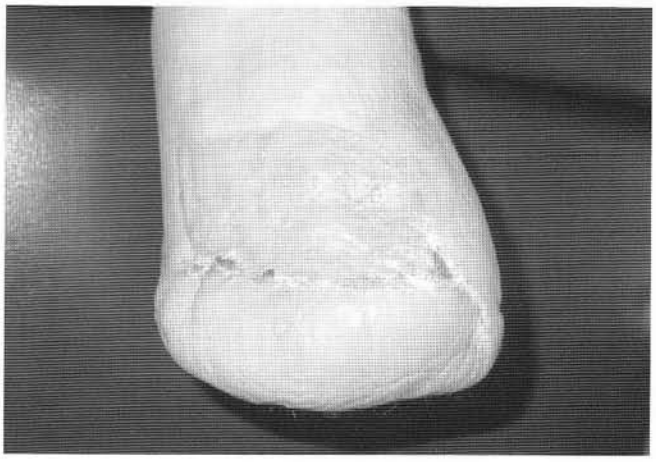

Figure 4D. Final appearance after STSG.

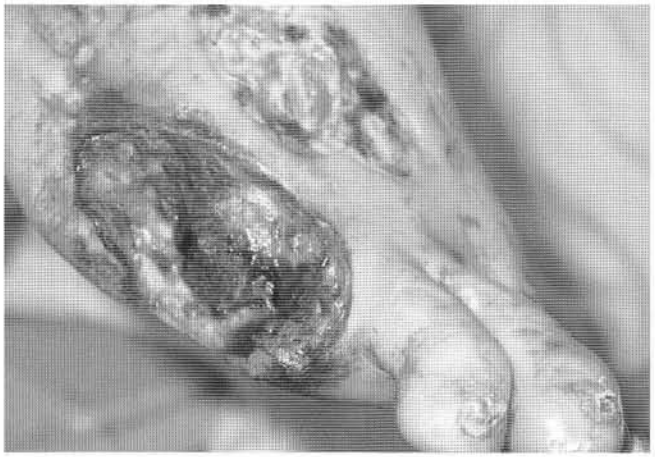

Figure 5A. Wet gangrenous changes of the foot secondary to MRSA and Pseudomonas aeuriginosa in a patient with atherosclerotic peripheral vascular disease.

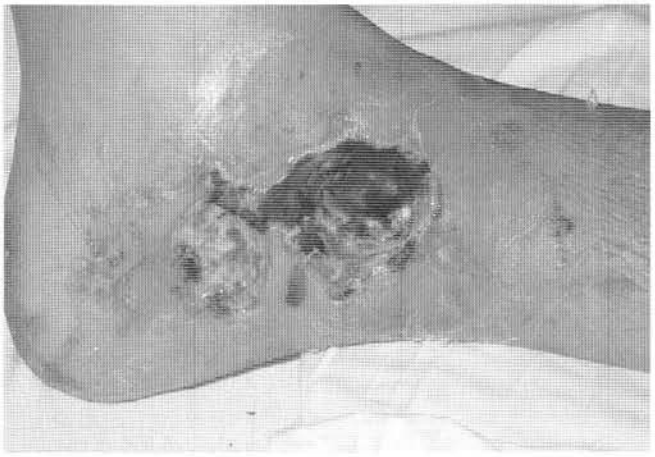

Figure 5B. Similar appearance over the medial malleolus with exposed bone.

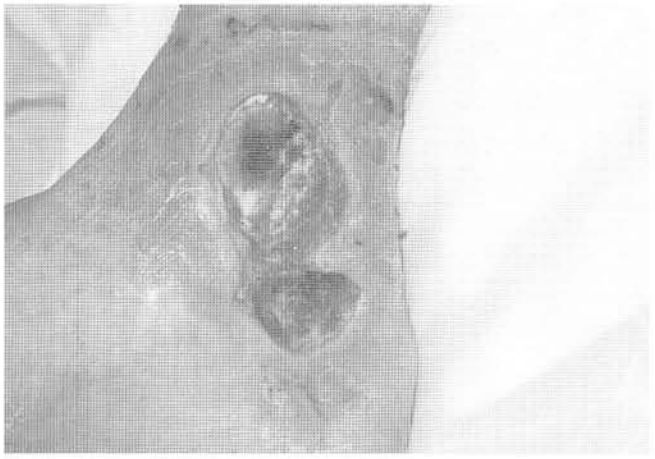

Figure 5C. Status post revasclarization and radical debridement of the ankle with the initiation the the VAC instill (one week postoperative).

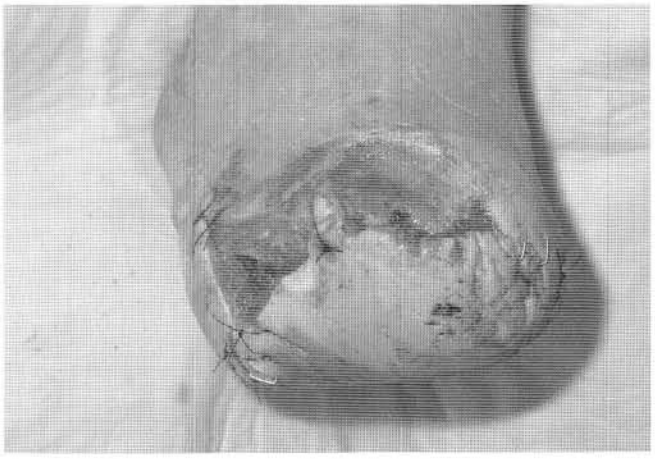

Figure 5D. Status post revasclarization and aggressive transmetatarsal amputation the foot with the initiation the the VAC instill (one week postoperative).

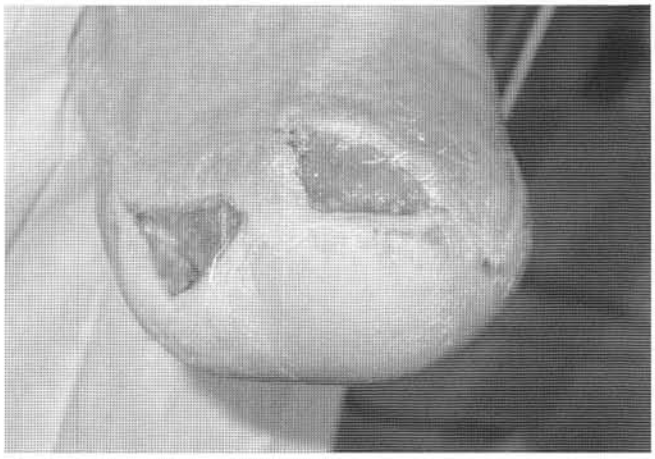

Figure 5E. 1 month postoperative foot appearance now with traditional VAC therapy.

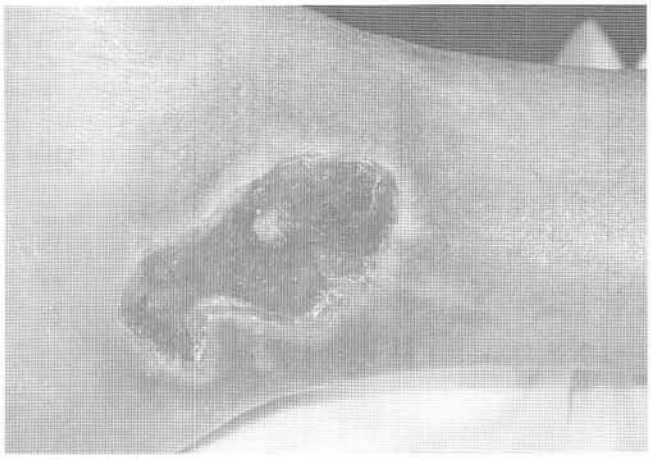

Figure 5F. 1 month postoperative ankle appearance now with traditional VAC therapy.

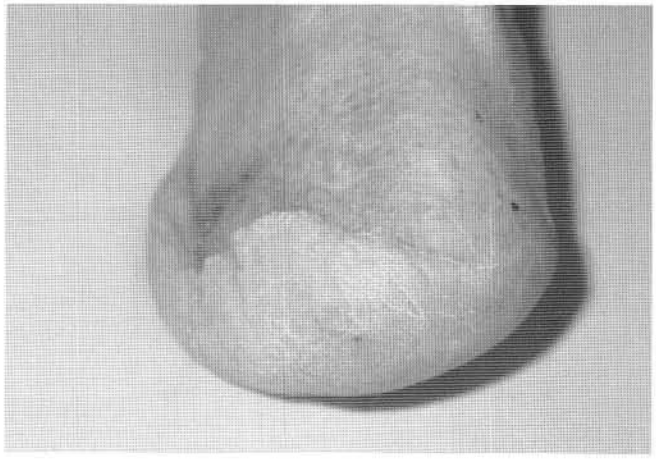

Figure 5G. Final appearance of the foot after STSG (6 months after original presentation).

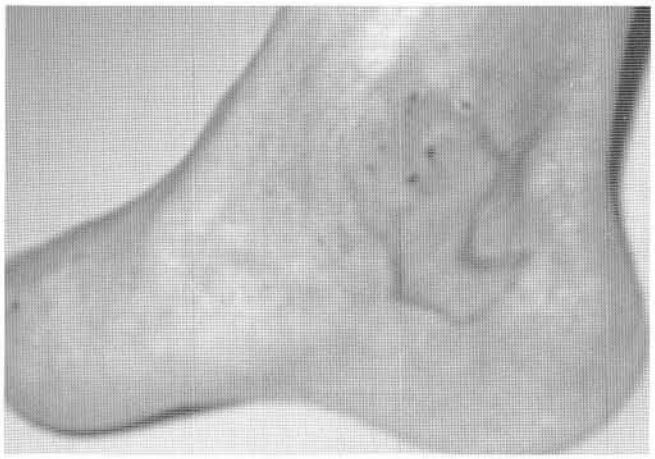

Figure 5H. Final appearance of the ankle after STSG (6 months after original presentation).

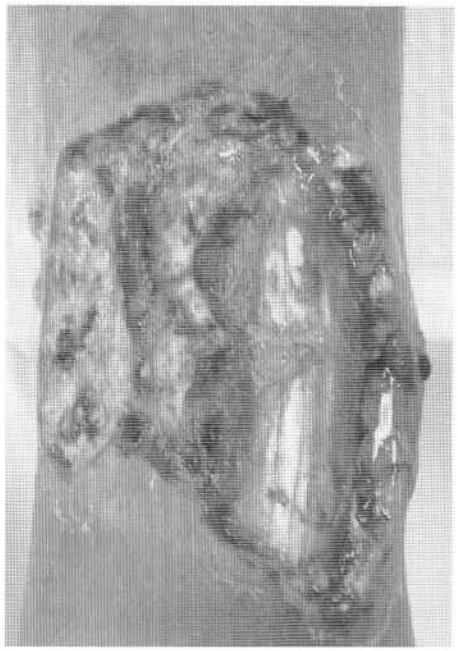

Figure 6A. 65-year-old female with MRSA necrotizing cellulitis secondary to venous ulcerations after first debridement (POD =1 - still with purulence).

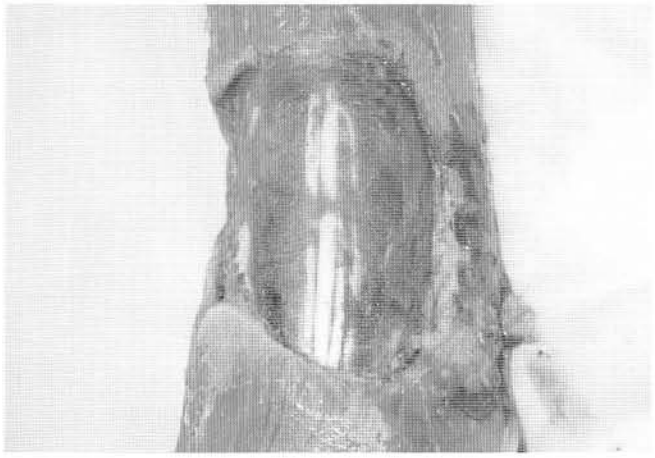

Figure 6B. Clinical appearance after second debridement. (VAC instill initiated).

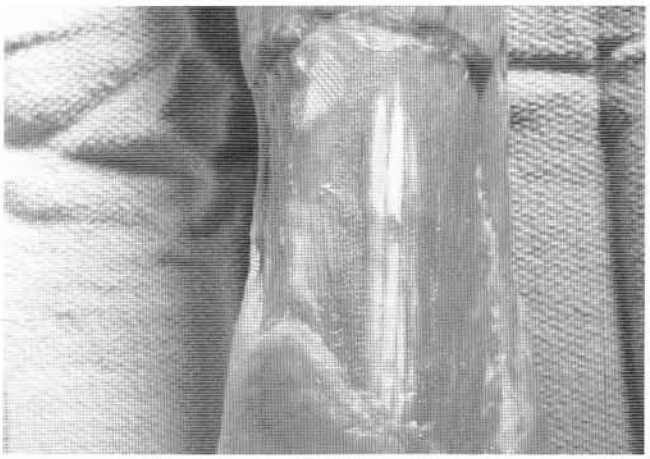

Figure 6C. Clinical appearance after repeated debridements and 10 days of ingress-egress treatment.

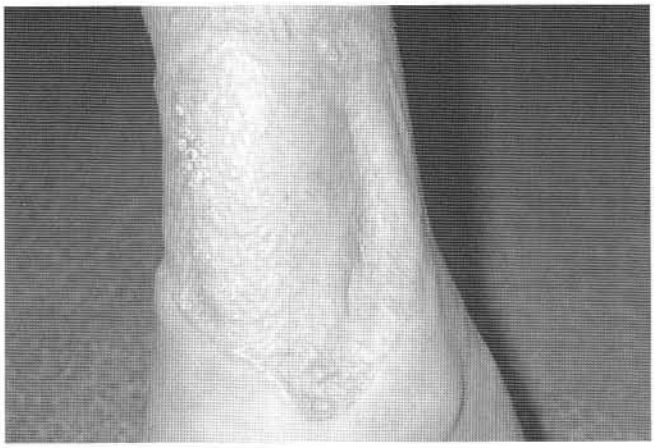

Figure 6D. Final appearance after STSG. (3 months after first surgery)

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